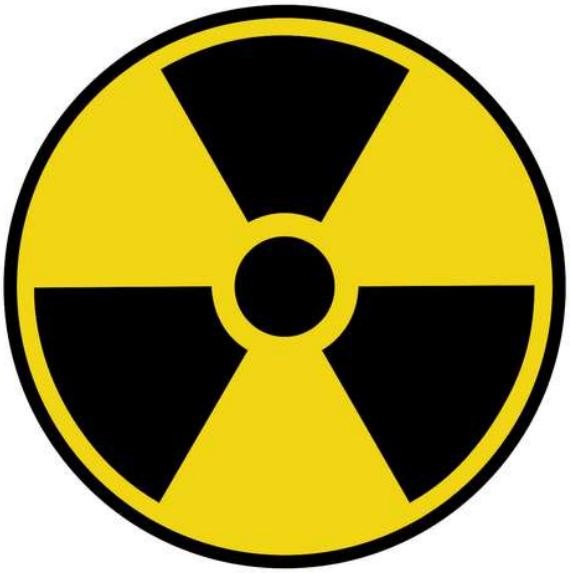


"Radiation, unlike smoking, drinking, and overeating, gives no pleasure, so the possible victims object." ~Isaac Asimov

1

Radioactive Radon in Maine

Spiders in the Basement

Prepared for the

MBOIA Code Conference

by

Jonathan Dyer, BS, ESIII Maine Radon Coordinator

Andrew Hunt, BS, ESII Assistant

May 21, 2024

2

Who We Are

The Maine Department of Health and Human Services

Maine Center for Disease Control and Prevention

Radiation Control Program

Radiation Program Manager

Office Associate

State Nuclear Safety Power Inspector

Two X-ray Inspectors

Two Radioactive Materials Inspectors

Two Radon Specialists [Radon Program]

3

Who We Are and What We Do

1. We license over 240 Radon Service Providers (RSP)
   - Radon Testers
   - Radon Mitigators
   - Laboratories
   - Consultants
2. We inspect mitigation systems when we receive a customer complaint
3. We review all quality assurance plans (QAPs) of all radon testers
4. We approve CEUs for all radon service providers
5. We offer training classes and give presentations to associations
6. We act as a “clearinghouse” for all calls or e-mails concerning radon
7. Every month, we process all data received from the RSP and enter the data into a data base
8. We work with organizations like the Maine Indoor Quality Council to share data
9. We write radon rules for legislative approval

4

We Can't Escape Radiation Exposure

Radioactive Foods






5

We Can't Escape Radiation Exposure (cont.)

Radioactive Products





6

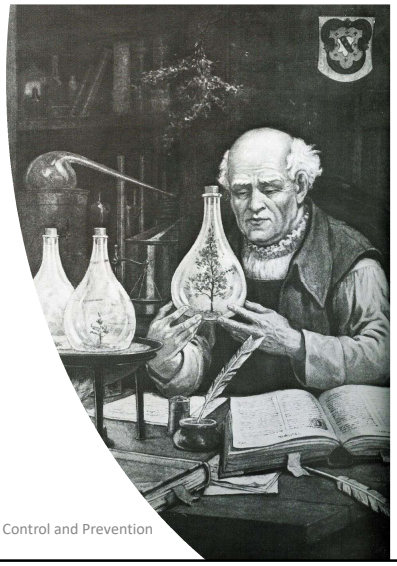
Mining in Eastern Europe

- Tin was an essential metal to make bronze
- Started ~ 3,000 B.C. [start of the Bronze Age]

7

Mining in Eastern Europe (cont.)
Discovering the Roots of Lung Cancer

- Paracelsus (1493-1541)
- Connection between mining and lung disease
- He called it "mountain-sickness"
- "***Von der Bergsucht***" is the first handbook of occupational disease



8

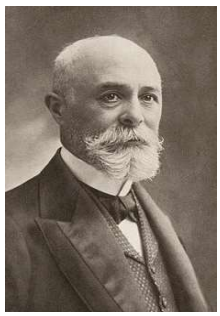
Mining in Eastern Europe (cont.)

- Uranium mining – 1556
- Called "Pitchblende"
- Extracted to use as coloring agent
- Gives glass a yellowish-green color

9

Scientist of Radiation

Martin Klapoth
Discovered Uranium
1789



Henri Becquerel
Studied the Properties
X-rays 1896

Marie Curie
Discovered Radium
1898

Friedrich Dorne
Discovered Radon
1900

10

Radon Gas
Radium in Every Product

The Revigator

These products ranged from additives in toothpaste to "Revigator," which was water with radium dissolved into it. Patients would drink from the container throughout the day to cure their ailments. By the 1940s and 50s, however, the practice of using radium as a medical treatment had been reduced to very few applications due to its high price, small quantity, and the dangers of handling radium

Maine Center for Disease Control and Prevention

11

Radon Gas
Radium Infused Products

Radioactive Toothpaste

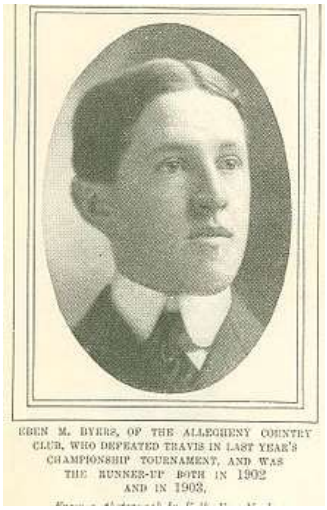
Radioactive Suppositories

Maine Center for Disease Control and Prevention

12

Radon Gas
Eben Beyers Incident

- **Wealthy American Socialite**
- **Accomplished athlete and industrialist**
- **Won the 1906 U.S. Amateur Golfers Tournament**
- **A "ladies man"**



EBEN M. BYERS, OF THE ALLEGHENY COUNTRY CLUB, WHO DEFEATED TRAVIS IN LAST YEAR'S CHAMPIONSHIP TOURNAMENT, AND WAS THE RUNNER-UP BOTH IN 1902 AND IN 1903.

Radon Gas
Eben Beyers Incident (cont.)

- In three years, Mr. Byers consumed 1,400 bottles of Radithor. He believed this greatly improved his health.
- **Radithor - $30/bottle with 1.0 µCi/½ ounce of Ra228 and 226.** The drinking water limit for Ra is 5.0 pCi/L. He was consuming approximately 15,000 times the safe dosage in water in every bottle.
- One morning he wakes up and doesn't feel well.
- He has abscesses in his brain, and holes forming in his skull
- He dies in 1932 and is buried in a lead-lined casket

Radon Gas
The Stanley Watras Incident

Maine Center for Disease Control and Prevention

15

A Brief History of Radon in Maine

1879 - The existence of lethal pulmonary disease among metal miners in Central Europe had been known since the 1500s. This disease was not recognized as cancer until 1879.

1932 – Radon's role in lung cancer found in the miners in Central Europe was not suspected until 1932 and not accepted until the 1960's

1949 – The AEC (Atomic Energy Commission) obtains data in several U.S. mines.

1950 - It was decided that the lung cancer hazard was a result of the alpha dose delivered through lung deposition of the short-lived alpha-emitting progeny of radon and not radon itself.

1958 - Maine's Dept. of Human Services (DHS) was notified of the presence of a high level of radioactivity in a private well in Western Maine. An engineer was sent to investigate the problem and confirmed the presence of high levels of Radium 226 and radon.

1964 – The USPHS Water Analyses Branch sent a team to Maine. The team reported that the major problem in Maine was not Radium 226 but radon.

1978 – The Maine DHS, through the Safe Drinking Water Act, funds the University of Maine to analyze 2,000 groundwater samples, produce a map, and develop an inexpensive method of analyzing radon in groundwater.

Maine Center for Disease Control and Prevention 16

16

A Brief History of Radon in Maine (cont.)

1979 - Maine DHS designed and built a prototype radon removal unit. The unit used the concept of spraying water several times to allow the radon gas to be released from water and exhausted outdoors.

1981 - Dr. C. T. Hess at the University of Maine found that tightly insulated homes have one pCi/L of radon per liter of air for each 10,000 pCi/L of water.

Dr. Jerry D. Lowry at the University of Maine developed a second method for removing radon gas from water by utilizing granular activated carbon.

1984 – The Stanley Watras discovery.

1988 – The Maine Radon Registration Act is introduced.

1993 – The Maine Registration Act is implemented – **Title 22, Chapter 165**

17

Title 22: HEALTH AND WELFARE
Subtitle 2: HEALTH
Part 2: STATE AND LOCAL HEALTH AGENCIES
Chapter 165: RADON REGISTRATION ACT

- **§774. Radon testing; registration required**
- A person may not perform, evaluate or advertise to perform or evaluate tests for the presence of radon in buildings or on building lots unless registered with the division. This registration requirement includes without limitation a person whose place of business is located in the State, or in another state, who offers radon testing services to residents of the State either directly or through the mail. [PL 1989, c. 657, §1 (NEW).]

18

Title 22: HEALTH AND WELFARE
Subtitle 2: HEALTH
Part 2: STATE AND LOCAL HEALTH AGENCIES
Chapter 165: RADON REGISTRATION ACT

- **§776. Exemptions**
- The requirements of sections 774 and 775 do not apply to any of the following: [PL 1989, c. 657, §1 (NEW).]
- **1. Personal use.** A person performing testing or mitigation on a building owned or inhabited by that person but not for sale at the time that person performs testing or mitigation on that building;
- [PL 2001, c. 574, §9 (AMD).]
- **2. New construction.** A builder utilizing preventive or safeguarding measures in new construction as specified in the Maine Uniform Building and Energy Code, adopted pursuant to Title 10, chapter 1103;
- [PL 2011, c. 144, §3 (AMD).]
- **3. Department employees.** Employees of the department in the course of their assigned duties; or
- [PL 1989, c. 657, §1 (NEW).]
- **4. Authorized personnel.** A person performing testing with the written approval of the department. Registration under section 774 or 775 does not constitute written approval for the purposes of this subsection.
- [PL 1989, c. 657, §1 (NEW).]

19

What is Radon?

1. A naturally-occurring radioactive gas.
2. It is odorless, colorless, and inert.
3. It is the most studied carcinogen of our time,
4. Number 1 cause of lung cancer in non-smokers.
5. Second leading cause of lung cancer in the U.S.
6. It is estimated that as many as 21,000 lung cancer deaths are caused each year by radon.

20

Radon Guidelines

- **If Radon Levels are equal to or above 4.0 pCi/L**
- Recommend taking action to reduce radon levels

- **If Radon Levels are between 2.0 pCi/L and 4.0 pCi/L**
- Consider taking action to reduce levels

- **If Radon Levels are less than 2.0 pCi/L**
- Reducing radon levels below 2.0 pCi/L mas be difficult

21

Radon Guidelines (cont.)

- If health standards applied to lead and arsenic were applied to radon:
  - indoor air radon levels would have to be less than outdoor radon levels (0.4 pCi/L)
  - drinking water levels would have to be less than 100 pCi/L

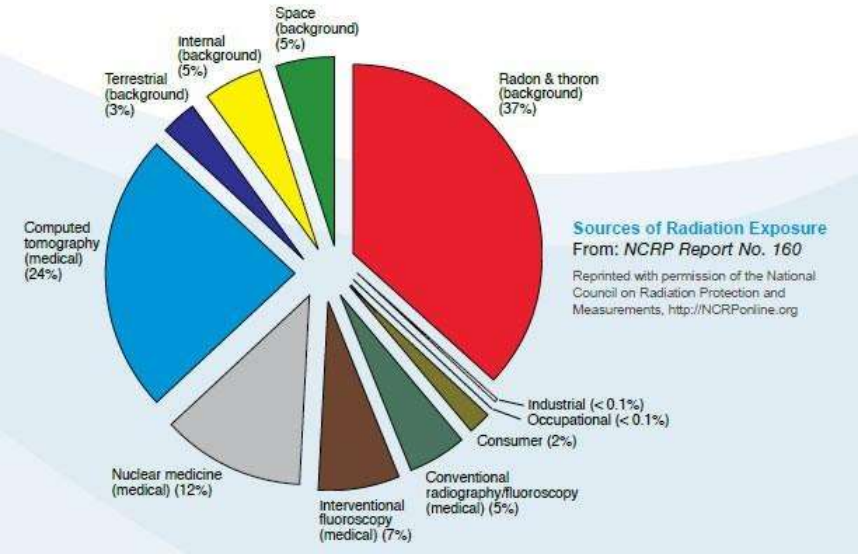
AND…….

- If normal radiation regulations were applied to radon:
  - all homes in Maine would be posted as radiation exposure areas
  - water from Maine wells would be illegal to drink

That's why Maine has adopted Radon laws

22

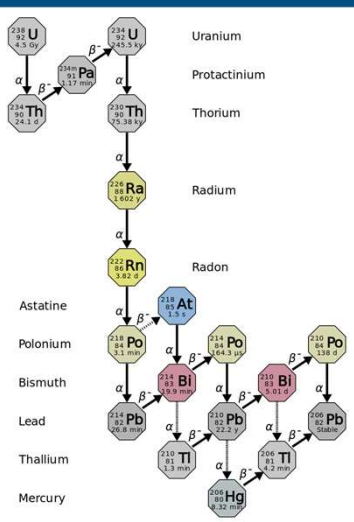
What is Radon?



Radon Gas Is Everywhere

Uranium-238 Decay Chain

- **Radon-222 ½ life = 3.84 days**
- **Polonium–218 ½ life = 3.1 min**
- **Lead-214 ½ life = 27 min**
- **Bismuth-214 ½ life = 20 min**
- **Polonium-214 ½ life = 164 µsec**
- **Lead-210 ½ life = 22 yrs.**

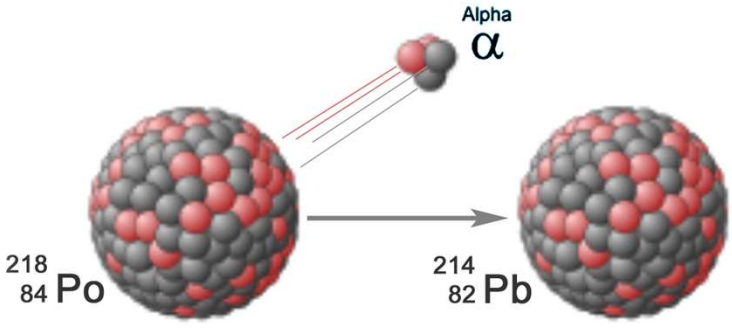


25

Unstable Atom

Decay from Po-218 to Pb-214

Isotope	Half-life	Alpha Particle Energy	Penetration into Lung Tissue
radon-222	*3.8 days*	*5.49 Mev*	*41 microns*
polonium-218	*3 minutes*	*6.00 Mev*	*48 microns*
polonium-214	*164 micro-sec*	*7.69 Mev*	*71 microns*



26

Penetration Power

Fig 1: Radioactive Penetration

27

How Do We Know that Radon Causes Cancer?

Three Major Studies

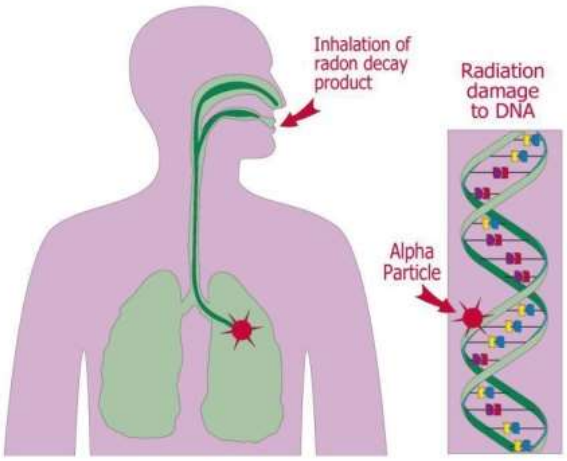
- Studies of atomic bomb survivors

- Studies of uranium mine workers

- Studies of homes

28

Radioactive Radon Gas
What Harm Can It Do?



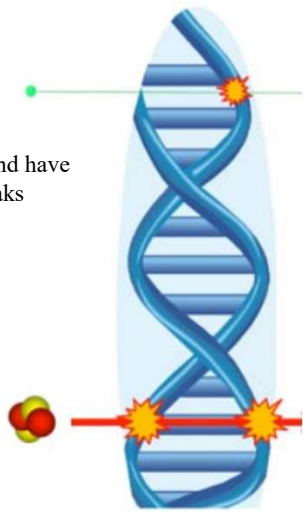
Maine Center for Disease Control and Prevention

29

How Lung Cancer Starts

Alpha particles with higher energy penetrate further and have greater probability of causing double strand DNA breaks

DNA double strand breaks are hard to repair



Maine Center for Disease Control and Prevention 30

30

Radioactive Radon Gas
What Harm Can It Do?

Maine Center for Disease Control and Prevention

31

Understanding Radon Levels

EPA recommends fixing your home if radon level is above 4 pCi/L

Radon Level 4 pCi/L	**Equals 200 chest x-ray per year or 8 cigarettes per day**
Radon Level 8 pCi/L	**Equals 400 chest x-ray per year or 16 cigarettes per day**
Radon Level 20 pCi/L	**Equals 1000 chest x-ray per year or 40 cigarettes per day**

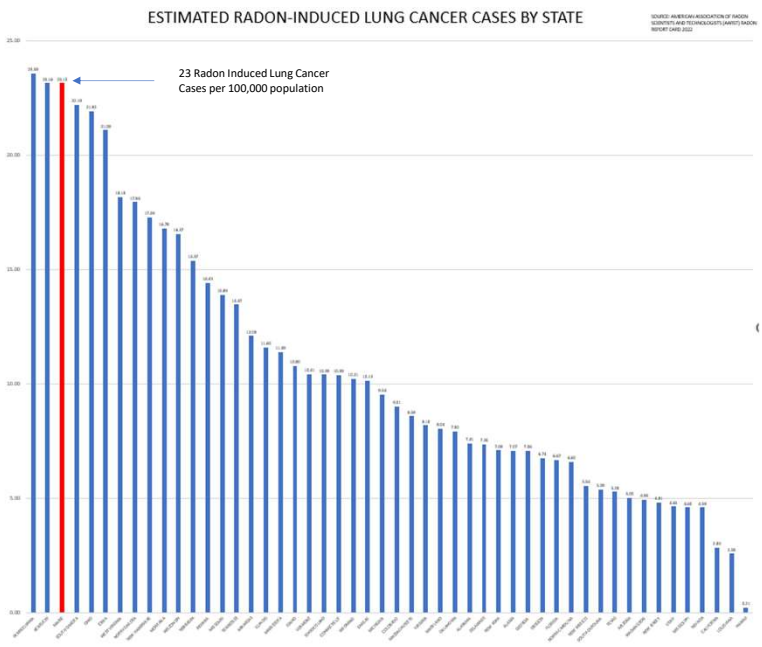
Source: U.S. Department of Health and Human Services, ABDR (1990). Toxicological Profile for Radon. Atlanta. GA.

32

Radon Level	Lifetime Risk of Lung Cancer Death (per person) from Radon Exposure in Homes		
pCi/L	Never Smokers	Current Smokers	General Population
20	36 out of 1,000	260 out of 1,000	110 out of 1000
10	18 out of 1,000	150 out of 1,000	56 out of 1,000
8	15 out of 1,000	120 out of 1,000	45 out of 1,000
4	7 out of 1,000	62 out of 1,000	23 out of 1,000
2	4 out of 1,000	32 out of 1,000	12 out of 1,000
1.25	2 out of 1,000	20 out of 1,000	7.3 out of 1,000
0.4	0.73 out of 1,000	6.4 out of 1,000	2.3 out of 1,000

Maine Center for Disease Control and Prevention

33



34

Maine in Comparison With the Rest of the Country

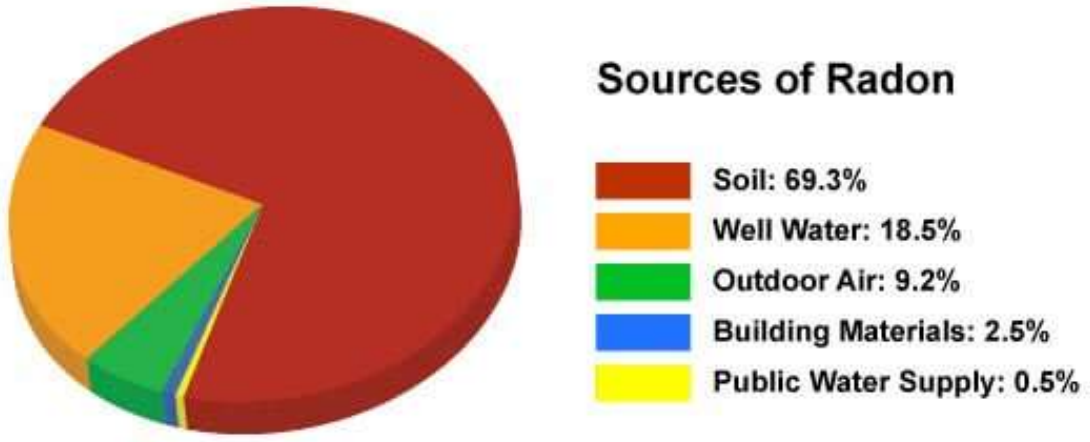
	National Stats	Maine Stats
Elevated Radon Levels	1 out of every 15 homes	1 out of every 3 homes
Avg. Radon Levels	1.6 pCi/L	*5.9 pCi/L
% of Rn-induced LC Cases	12%	**21.5%

***EPA action level is 4.0 pCi/L**

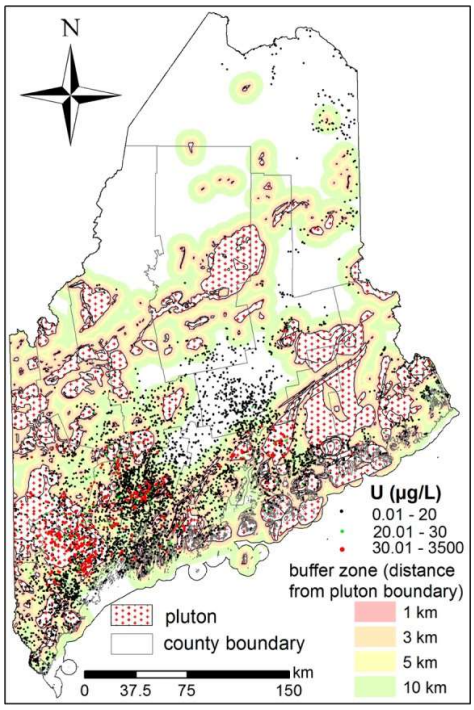
****90% above national average**

35

Sources of Radon



36



37

Maine Radon Registration Act

- 22MRS §771 et seq (1989)
- Requires regulation of anyone doing radon work.
- Exempts homeowners when house not for sale, builders installing radon systems in new construction if they are following the radon standard in MUBEC.

38

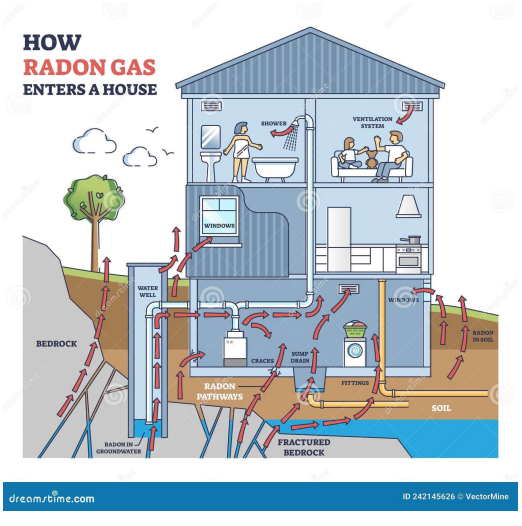
Maine Model Radon Standard for New Residential Construction

- 25 MRSA §2466 (2007)
- Requires anyone installing radon systems during new construction to comply with ASTM-E1465-08.
- Radon systems are mandatory.
- Requires any town that will adopt a RRNC code/standard to adopt ASTM –E1465-08.
- Incorporated into MUBEC 2010. Made mandatory in 2019.

39

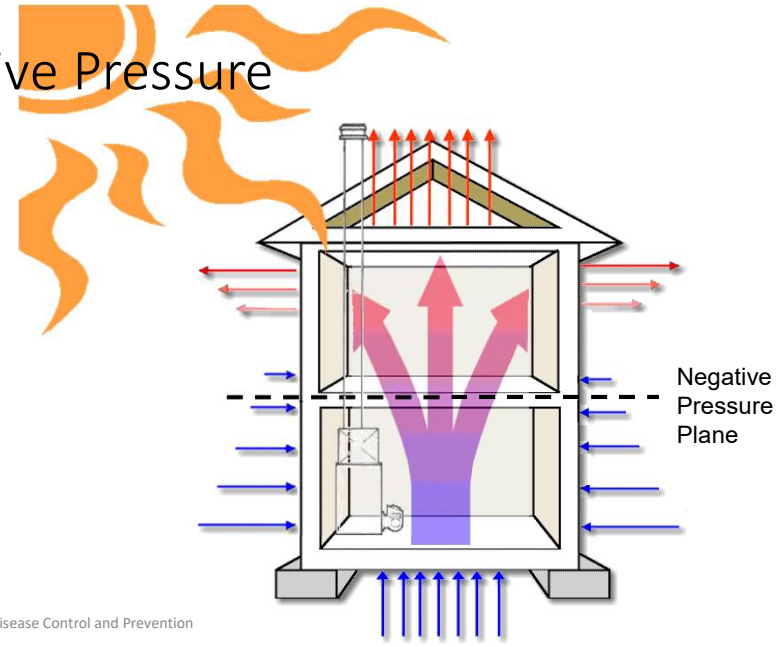
Radioactive Radon Entry

1. Radon comes from Uranium/Radium deposits beneath the home.
2. Radon is a colorless, odorless, tasteless radioactive gas.
3. Radon can enter all types of homes: old, new, homes on slab, homes with crawlspaces, homes with basements
4. Typically, the air pressure of the house is lower than surrounding areas and causes radon to be sucked into the house. The pressure difference created within the home and the surrounding soil can pull radon into the home.
5. Specifically, radon enters the home through cracks in the foundation, construction joints, cracks in the basement walls, sump holes, plumbing penetrations, and even small holes.
6. Radon can enter a home through visible and non-visible cracks in the foundation.
7. Radon can enter through unsealed sump drain areas and plumbing penetrations.
8. If the house has contact with the ground, there is a potential for radon entry.
9. Radon dissolves and builds up in the water from underground sources, such as wells and enter the home through showering, washing clothes, etc.



40

Negative Pressure

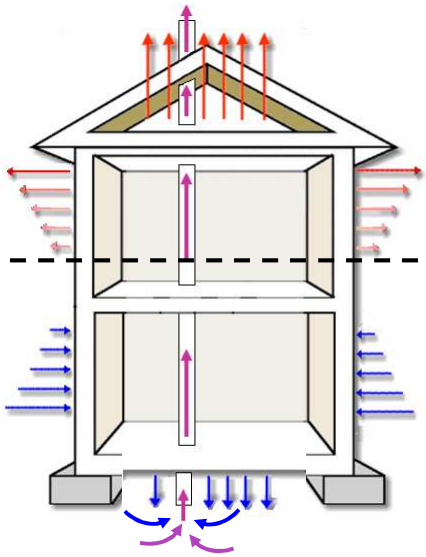


Maine Center for Disease Control and Prevention

41

Counteracting Negative Pressure

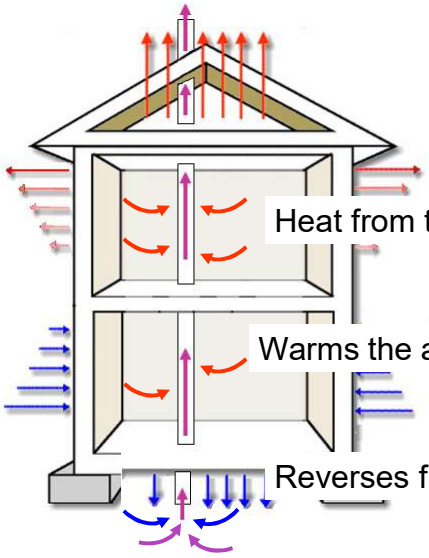
- Override house's negative pressure
- Redirect and exhaust gases



Maine Center for Disease Control and Prevention

42

Passive System

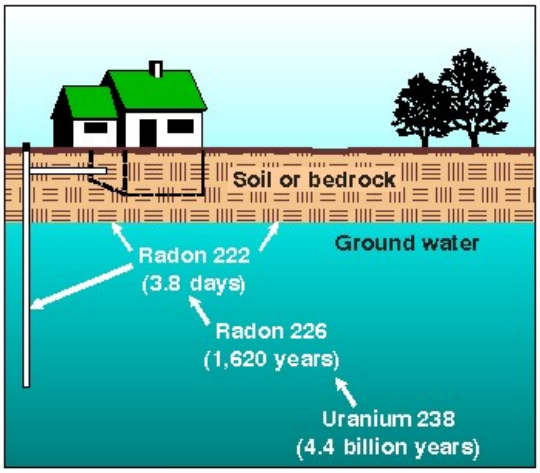


Maine Center for Disease Control and Prevention

43

Radon Entry

Maine Center for Disease Control and Prevention



Modified from Clark and Briar, 1993

44

How Radon Enters the Home Via Well Water

Maine Center for Disease Control and Prevention




45

Maine Environmental Public Health Tracking Network

- Currently there are 77,000 distinct address data points with 36,000 more data points ready to be added
- Map shows percentages greater than 2.0 pCi/L, percentages greater than 4 pCi/L and the maximum values at town levels
- Challenges:
  - Areas of Maine are low population, therefore lower real estate transactions.
  - There is also low appetite to test
- Takeaway: radon levels vary from house to house, can't avoid radon
- Message: TEST!
- https://data.mainepublichealth.gov/tracking/home

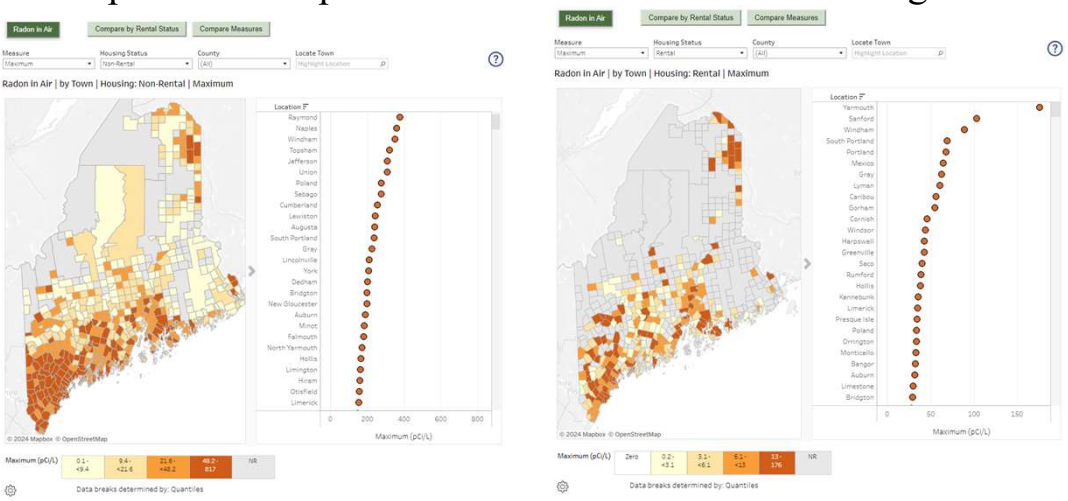
Maine Center for Disease Control and Prevention

Jon Dyer for SMH, 06-18-2019

46

Maine Environmental Public Health Tracking Network

Example of the map interface for Maine Health Tracking Network



Maine Center for Disease Control and Prevention

Ken Dyer for SWAT, Oct 16 2019

47

Maine Adopts Radon Building Code

- December 01, 2010
- ASTM E 1465-08
- To protect people from lung cancer risk
- Intended to mandate adoption of E 1465-08
- September of 2019 ASTM E 1465-08 became mandatory thru MUBEC

48

Enforcement of ASTM E 1465-08

- For the first time since its original adoption, MUBEC will be applicable State-wide regardless of the population of the community.
- Municipalities with **over 4,000** in population will be required to enforce the codes.
- Enforcement will be optional for communities **under 4,000** in population, but builder and homeowner will need to build to the same standards

49

Exemptions to ASTM E 1465-08

1. Modular and Manufactured Homes
2. Log Homes
3. Post & Beam or Timber Frame Construction
4. Seasonal Homes
   a. Occupied for not more than 180 days
   b. The max interior no more than 750 ft.² interior space
   c. No central heating
   d. No year-round sub surface wastewater system
   e. Electrical service is limited to 100amp system
   f. Water supply limited to 180 days of use per calendar year

50

ASTM E 1465-08

Part 1 - Organization

51

Organization of ASTM E 1465-08

Major Sections in the Document

1. **Scope**
2. **Referenced Documents**
3. **Terminology**
4. **Summary of Practice**
5. **Significance and Use**
6. **Construction Methods for Soil Depressurization Radon Reduction**
7. **Occupational Radon Exposure and Worker Safety**

- **Appendixes**
- **References**

52

ASTM E 1465-08
Sec. 1 "Scope"

- **There are two Options for Radon System's initial Mode of Operation:**
  1. Passive Operation (without fan)
  2. Active Operation (with fan)

Vent Stack Pipe Routes:
1. Passive (without fan)
2. Active pipe route with no fan
3. Active pipe route with fan

Selected pipe route should be appropriate for the radon system's intended mode of operation.

ASTM E 1465-08
Sec. 1 "Scope" (cont.)

Soil depressurization radon systems are effective:
- Fan-Powered Systems reduce indoor radon concentrations up to 99%.
- Passive Systems reduce indoor radon concentrations up to 50%;

Passive Systems can be converted to fan-powered operation.

ASTM E 1465-08

Sec. 4.4 is an Outline of Section 6

See Pg. 4

Section 6 is E 1465's "how-to-do-it" part.

Major parts of Section 6 are included in the outline.

Examples:

6	Construction Methods for SDRR
6.5	Radon System Piping
6.5.11	Radon System Monitoring Installation
6.10	Radon Testing for New Residential BLDGS

4.4 The outline of Section 6, *Construction Methods for Soil Depressurization Radon Reduction* follows:

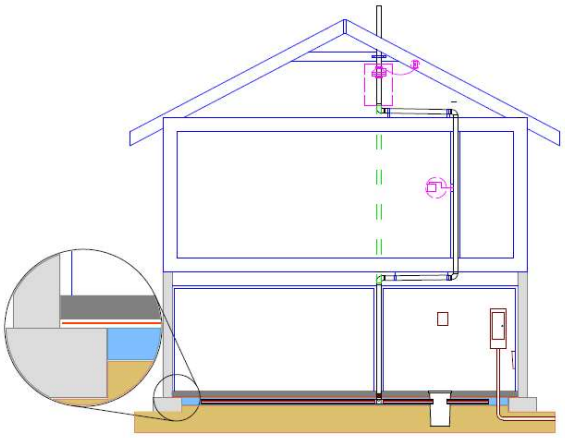
55

ASTM E 1465-08

Sec. 5.2 "Significance and Use" (cont.)

The gas-permeable layer (or the aggregate layer's sealed enclosure) is depressurized when air is pulled up the attached vent stack by a radon fan or passively (i.e., w/o using a radon fan.)

Passive Operation:
Air in a vertical vent stack will flow upward passively when it is warmer (i.e. more buoyant) than the outdoor air.



56

ASTM E 1465-08

Sec. 5.2 "Significance and Use" (cont.)

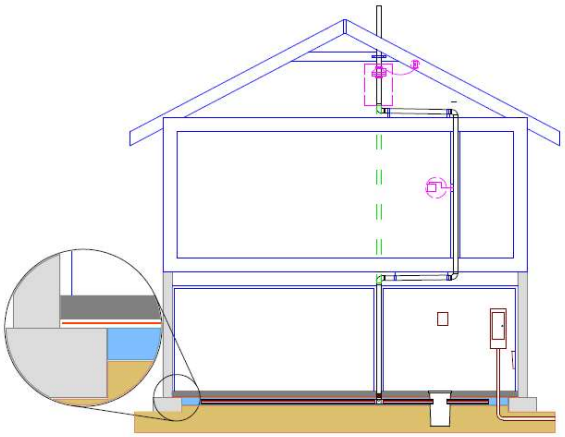
Why depressurize?

Depressurization causes air to flow out of occupiable spaces about the slab, through the slab's cracks and openings to depressurized spaces below the slab.

With depressurization: ***No radon in occupiable spaces!***

Without depressurization the opposite will happen, because of the building's stack effect.

Without depressurization radon gas gets in.



57

ASTM E 1465-08

Sec. 6.0 "Construction Methods for Soil Depressurization Radon Reduction"

Section 6 is the "How-To-Do-It" part of E 1465-08

58

ASTM E 1465-08

Part 2 - Construction

59

ASTM E 1465-08

1. Introduction to ASTM E 1465-08

1.2 “Construction Methods”

60

ASTM E 1465-08
Sec. 6.0 "Construction Methods"

Section 6, Construction Methods is logically divided into three parts:

Section	Part Description	Sections
Section 6.	Construction Methods	6.1 – 6.13
Part 1	System Construction	6.1 – 6.9
Part 2	Testing Repairing and Documenting	6.10 – 6.12
Part 3	Owner/Occupant Maintenance	6.13

61

ASTM E 1465-08
System Construction - 9 Sections

6.1 - 6.9	System Construction	
Section	Description	Page
6.1	Foundation Types	5
6.2	Ground Covers	7
6.3	Foundation Walls	8
6.4	Sub-Slab and Sub-Membrane Gas-Permeable Layers	9
6.5	Radon System Piping	22
6.6	Maintain All Fire Ratings	26
6.7	Crawlspaces	26
6.8	Electrical Installation	27
6.9	Radon Labels	27

62

E1465 Summary

1

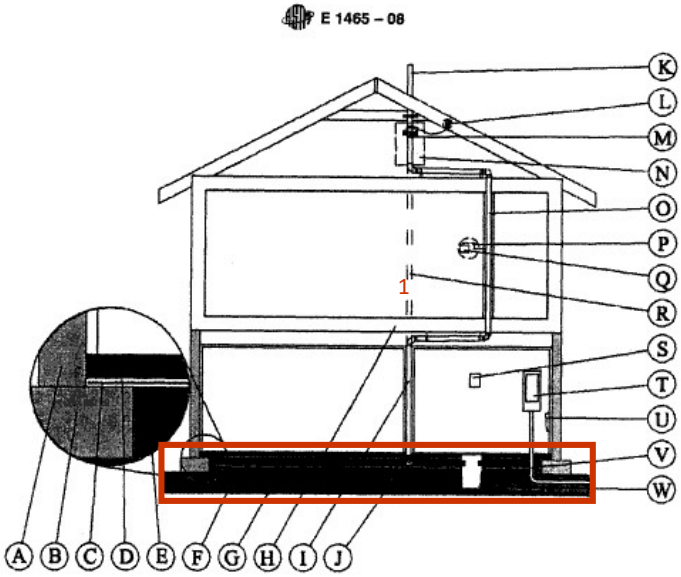


FIG. X2.1 Construction Details for Radon Control

63

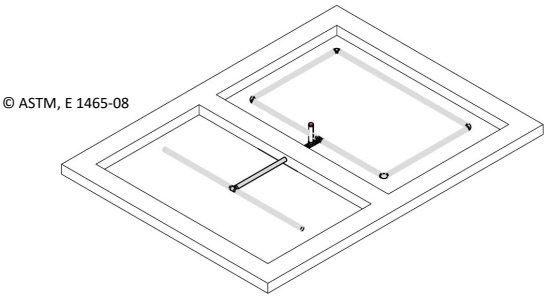
ASTM E 1465-08

Sec. 5.2 "Significance and Use (cont.)"

Soil depressurization radon systems used in new construction require a gas-permeable layer within (but not under) the footings

Ideally the gas-permeable layer is clean crushed stone that embeds the soil-gas collectors.

The objective is to make a sealed enclosure for the gas-permeable layer that prevents air from leaking into its void space.



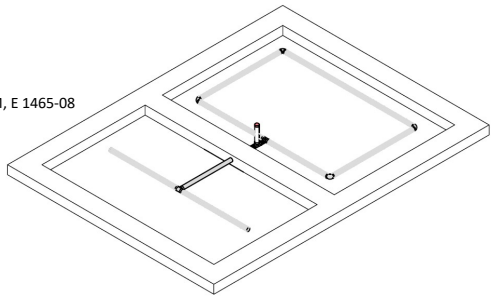
© ASTM, E 1465-08

64

ASTM E 1465-08
Sec. 5.2 "Significance and Use" (cont.)

The gas-permeable layer (i.e. the aggregate's enclosure) is sealed on all six sides

- The enclosure's top seal is made when the concrete slab is poured,
- It's four sides are sealed by the edges of the concrete footings, and
- Its bottom is usually sealed by underlying undisturbed soil.

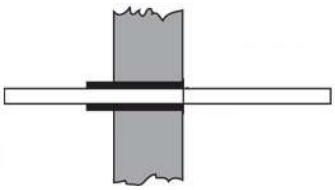


65

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.5.2 and 6.2.5.3 "Sealing Rough-ins and Slap Penetrations"

- Fill sleeved or other plumbing openings in slab
  - - airtight
  - - expanding urethane foam or comparable



66

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sub-Slab Major Feature #1

- The "air-tight" box so the radon system is not short-circuited by air coming in through ground water control systems, around utility conduits, or from porous undisturbed soils (any of these can prevent a radon system from working)

67

ASTM E 1465-08
Sec. 6.0 "System Construction" (cont.)

"Air-tight box" major components

- **Bottom:** undisturbed soils
- **Sides:** Non-porous footings & foundation walls (except for utility penetrations, ground water control pipes)
- **Top:** Soil gas retarder (vapor barrier) and sealed ground cover (slab or membrane)
- Important: Sealing around ground penetrations through footings, foundation, and slabs

68

ASTM E 1465-08
Sec. 6.0 "System Construction"

Airtight Container Scenario

If negative pressure is supposed to be created only by heat of house, need:

1. Tight sub-slab "box"
2. Easy air draw within "box"

69

ASTM E 1465-08
Sec. 6.0 "System Construction"
Sealing the Bottom of the Box

- Generally soil/bedrock
- For permeable soils or where blasting has occurred:
  - Plastic membrane
  - Engineer design

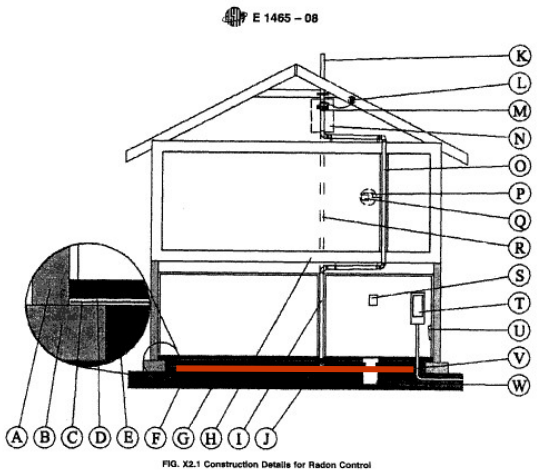


FIG. X2.1 Construction Details for Radon Control

70

ASTM E 1465-08

Sec. 6.0 "System Construction"

Sealing the Sides of the Box

- Footings
- Curtain walls
- Foundation walls

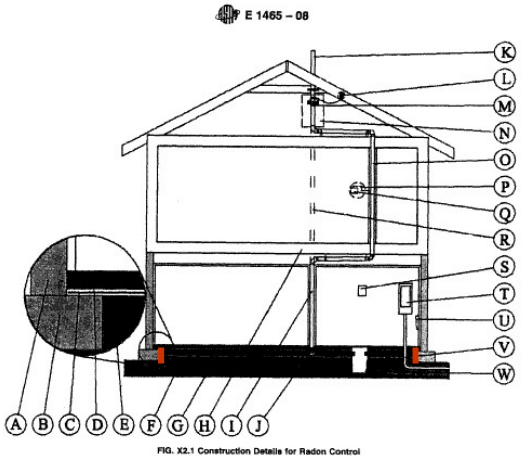


FIG. X2.1 Construction Details for Radon Control

71

ASTM E 1465-08

Sec. 6.0 "System Construction"

6.1 Foundation Types pg. 5

Four Foundation Types Cover:

- Slab-on-grade 6.2 – 6.4
- Basement 6.2 – 6.4
- Crawlspace 6.2 – 6.4
- Combination 6.2 – 6.4
- A combination foundation is used on a split level building.

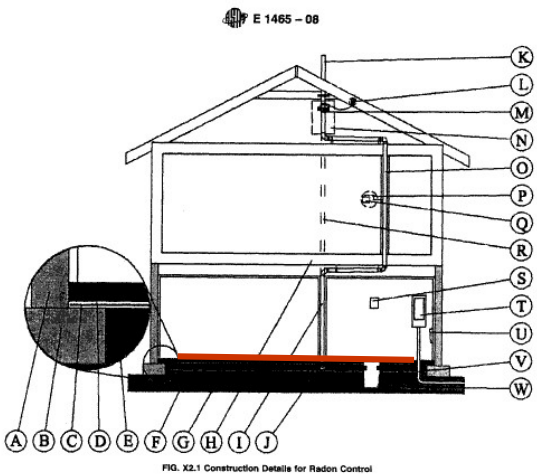


FIG. X2.1 Construction Details for Radon Control

72

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.2 Ground Covers pg. 7

Three Sealed Ground Covers:

1. Poured Concrete Floor Slabs
2. Thin Crawlspace Slabs
3. Sealed Poly Membranes permitted in Crawlspaces

Soil-Gas-Retarders (aka vapor barriers) are not considered to be radon system "ground covers" because they are not sufficiently sealed.

1. Loosely laid on soil
2. Edges overlapped 12"
3. Under slap and crawl membranes
4. To protect poly from or keep ground cover out of gas permeable layer

73

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.2 Ground Covers (cont.)

- Slabs must be sealed (6.2.1 and 6.2.5)
- Water drainage from slabs and membranes must comply with local codes and meet other requirements (6.2.4)
- Membranes must be sealed (6.2.2)

74

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.1.3.3 Membrane Protection

- Barriers routing traffic around
- Durable walkways
- For storage:
  - Durable plastic or rubber sheeting
  - Storage racks
  - Combination to prevent items from resting on plastic

75

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.1 "Poured Concrete Floor Slabs and Thin Crawlspace Slabs"

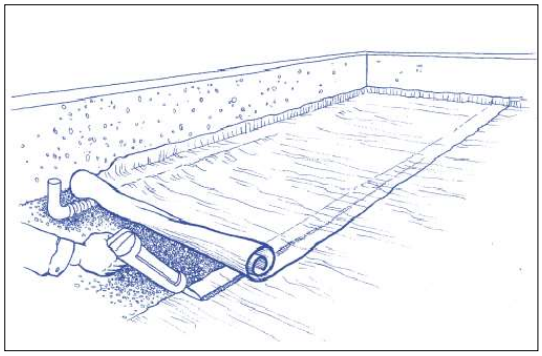
- Poured tight to walls and penetrations
- Expansion joints sealed with polyurethane caulk or equivalent
- Thickness set by code. Full slab (min. 3 ½" thick) to support:
  - Heavy equipment
  - Frequent maintenance
  - Active storage, etc
- Minimum 2" thick to
  - Reduce critters
  - Lightweight storage

76

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.2 "Sealed Polyethylene Membranes in Crawlspaces"

- Pre-installation
  - Remove all construction debris
  - Grade soil or fill for drainage
- Polyethylene
  - 6 mil
  - 3 mil cross-laminated
  - Equivalent
- Sealed
  - Seams that overlap minimum of 12"
  - Edges extend minimum of 12" up wall
  - All openings for penetrations



Maine Center for Disease Control and Prevention

77

ASTM E 1465-08
Sec. 6.2 "Ground Covers" (cont.) Permitted Use of Rn Ground Covers

Ground Covers vs. Foundation Type	Concrete Floor Slab	Thin Concrete Slab	Protected Sealed Membrane	Soil-Gas-Retarder
Basement	Required	Not Permitted	Not Permitted	Required
Slab-on-Grade	Required	Not Permitted	Not Permitted	Required
Crawlspace:				
Equipment Installed or Heavy Storage and Traffic (6.1.3.1)	Recommended	Optional	Minimum Requirement	Required
Light Storage or Light Traffic (6.1.3.2)	Optional	Recommended	Minimum Requirement	Required
No Storage No Traffic (6.1.3.3)	Optional	Optional	Minimum Requirement	Required

78

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.4 "Water Drainage From Floor Slabs and Membranes"

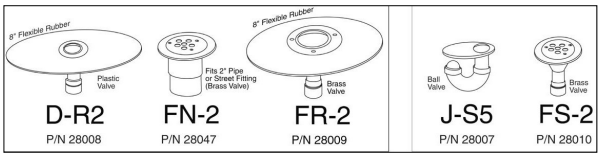
- Floor and Membrane Drains 6.2.4.1
- Sump Pits and Plastic Sump Tub 6.2.4.2
- Sealing Gaps & Joints in Slabs 6.2.5.1
- Sealing Plumbing Rough-in and Slab Penetrations 6.2.5.2 & 6.2.5.3
- Sealing Slab Openings Intentionally Provided for Future Use 6.2.5.4

79

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.4.1 "Floor and Membrane Drains"

Drain to:
- Ground water drainage
- To soil



- Slabs and membranes pitched to drains
- Prevent air leaks
  - Accessible mechanical check valve--preferred
  - Traps

80

ASTM E 1465-08

Sec. 6.0 "System Construction"

Sec. 6.2.4.1 "Floor and Membrane Drains" (cont.)

- Capable of holding 6" water
- Permanent label directing occupant to keep filled
- Condensate drains routed to:
  - trapped floor to drain
  - to daylight through non-perforated pipe
  - Exception; *water trap required when routed to storm or sanitary sewer with sufficient water for non-use periods*

81

ASTM E 1465-08

Sec. 6.0 "System Construction"

Sec. 6.2.4.2 "Sump Pits and Plastic Sump Tubs"

- Pits and tubs sealed to slab or membrane
- Removable sealed cover:
  - bolted to slab or tub
  - sealed with silicone caulk
  - plastic or rot resistant material
  - strong enough to hold adult
  - in place when tub is installed

82

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.3 Foundation Walls pg. 8

Foundation Walls are usually concrete:

- Poured concrete, or solid foundation walls, are recommended (6.3.1).
- Hollow concrete masonry are permitted provided that certain soil-gas entry barriers are built into the walls (6.3.2).

83

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.3 Foundation Walls (cont.)

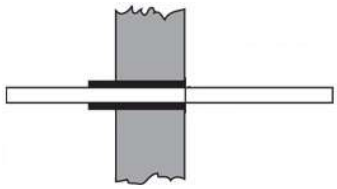
- Damp-proofing of foundation walls is recommended to help seal below grade portion of wall (6.3.5).
- Sealing foundation walls below grade is required (6.3.6).
- Certain special cases apply for Mobile Home foundations and Post-Tensioned Slab foundations (6.3.3).

84

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.2.5.2 and 6.2.5.3 "Sealing Rough-ins and Slab Penetrations"

- Fill sleeved or other plumbing openings in slab
  - airtight
  - expanding urethane foam or comparable



Maine Center for Disease Control and Prevention

85

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4 Gas-Permeable Layer pg. 9

A gas-permeable layer has three components:

1. Gas-permeable material that is placed under the slab or membrane (Table 2).

2. The soil-gas collector perforated pipe or geo-textile mat (Table 4).

3. The connection of the vent stack (radon system piping) to the soil-gas collector (Table 5).

Maine Center for Disease Control and Prevention 86

86

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4 Gas-Permeable Layer (cont.)

In addition to the necessary gas-permeable layer's three components:

1. Gas-permeable materials (6.4.1)
2. Soil-gas collectors (6.4.2)
3. Vent stack connections (6.4.3)

Add-on components needed to provide water control, when required, are provided:

4. Water control (6.4.4)
5. Finally, gas-permeable layers must be contained and sealed (6.4.5)

87

ASTM E 1465-08
Sec. 6.0 "System Construction"
Middle of the Box

- Gas permeable layer
- Soil-gas collector
- Piping/collector connection

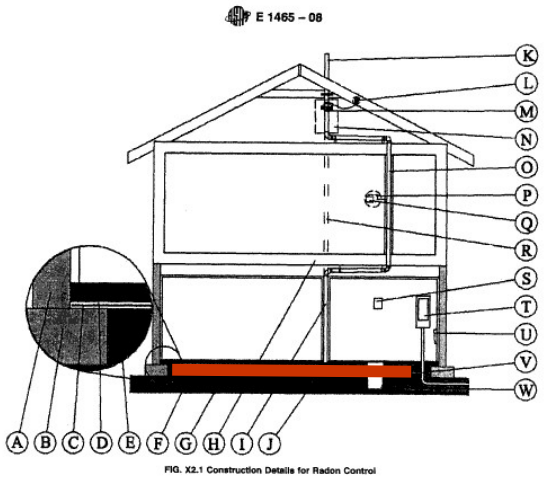


FIG. X2.1 Construction Details for Radon Control

88

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1 Gas-Permeable Layers

1. Gas-permeable material (Table 2) pg. 9

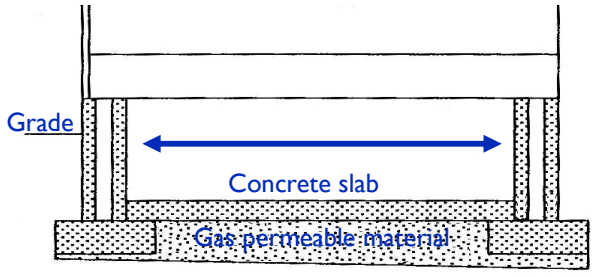
	Sect.	Page	Description
Table 2	6.4.1	9	Gas-Permeable Layer
Type 1	-	-	Large Aggregate
Type 2	-	-	Medium Aggregate
Type 3	-	-	Trench Filled with Large Aggregate
Type 4	-	-	Proprietary Mat Strips
Type 5	-	-	Flexible Corrugated Perforated Pipe under Membrane

89

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1 Gas-Permeable Layers

- Under slab
- Within building footprint including garages, etc.
- Avoid barriers in layer (pipes, conduits, etc.)

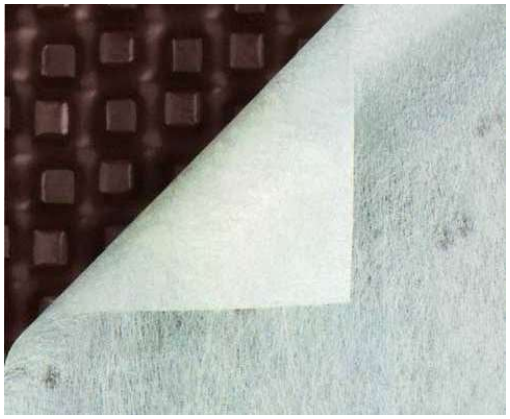


90

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1.1 Sub-Slab Layer pg. 10

- 4" clean, crushed stone
  - 1-1 ½"; covering 100% of soil
  - ½ - ¾"; covering 100% of soil
  - 1-1 ½"; foot-wide band at perimeter
- 1 ft. strips of 1" proprietary mat at perimeter



91

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1.1 Sub-Slab Layer (Geotextile) pg., 10 Table 4

Maine Center for Disease Control and Prevention

92

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1.1 Sub-Slab Layer (Geotextile) pg. 10, Table 4

Maine Center for Disease Control and Prevention

93

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.1.2 Sub-Membrane Layer pg. 10

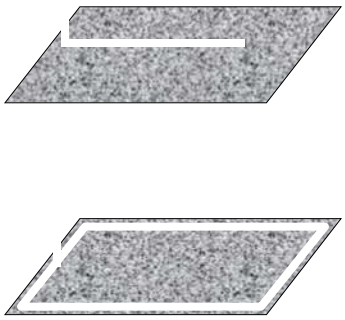
- Same as sub-slab, plus
- 4" flex pipe around perimeter
  - No aggregate
- 4" perf pipe buried in aggregate in perimeter trench

94

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.2 Soil-Gas Collector pg. 11

- Built into all/each gas-permeable layers
- 4" rigid or flex perf pipe
  - 20' anywhere
    - In 1-1 ½ " aggregate
    - Uncapped ends
    - Tee assembly
  - Loop around interior perimeter
    - In ½ - ¾ " aggregate
    - Ends attached to tee
  - Loop in perimeter trench
    - 1 ft. wide
    - Filled with 1-1 ½ " aggregate
    - Ends attached to tee
- Tee capped temporarily during pour



95

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.2 Gas-Permeable Layers

2. Gas-permeable material (Table 2) pg. 9

	Sect.	Page	Description
Table 4	6.4.2	10	Soil-Gas Collectors (SGC)
Type 1	6.4.2.1	11	Length of Perforated Pipe Buried in Aggregate
Type 2	6.4.2.2	11	Loop of Perforated Pipe Buried in Aggregate
Type 3	6.4.2.3	11	Loop of Perforated Pipe Buried in a Trench filled with Aggregate
Type 4	6.4.2.4	11	Strips of Geo-textile Mat on Soil
Type 5	6.4.2.5	13	Loop of Perforated Pipe on Soil under Membrane

96

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.3 Gas-Permeable Layers

3. Connection: radon system piping to the soil-gas collector (Tables 5 and 6.)

	Sect.	Page	Description
	Table 5	11	Methods for Connecting to the Soil-Gas Collector
	Table 6	12	Quantity of Pipe Parts Required for Connecting Suction Point Pipe to Soil-Gas Collector
Method			Suction Point Pipe Orientation:
Method 1	6.4.3.1	13	Vertical
Method 2	6.4.3.2	13	Off-Set Vertical
Method 3	6.4.3.3	13	Horizontal
Method 4	6.4.3.4	14	Vertical or Horizontal from Manifold
Method 5	6.4.3.5	14	Vertical through Membrane
Method 6	6.4.3.6	15	Vertical from Mat

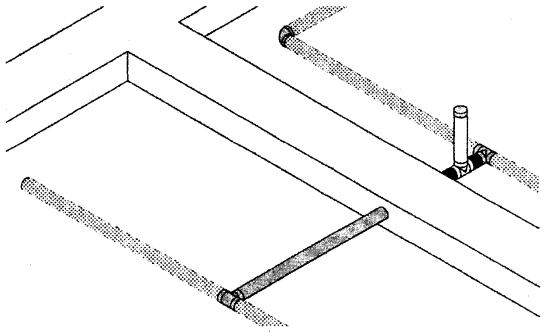
97

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sub-Slab/Membrane Manifold Design

Sec. 6.4.2.6 Soil-Gas Collector in Each Gas-Permeable Layer

Prevent soil-gas of one gas-permeable layer from being drawn through another



98

ASTM E 1465-08
Sec. 6.0 "System Construction"

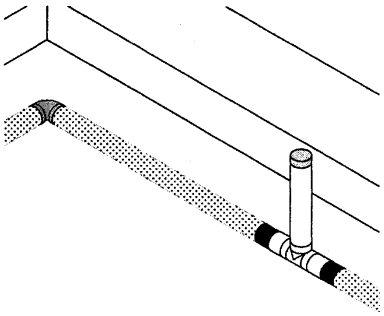
Sec. 6.4.3.1 Method 1 Vertical Suction Point Pipe Directly Over Soil-Gas Collector Pipe

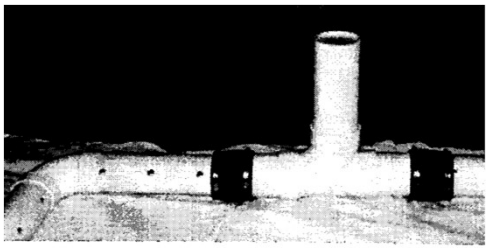
Vertical

Directly over soil-gas collector pipe

Through membrane

From mat





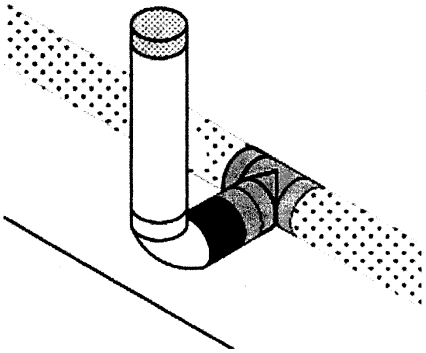
Maine Center for Disease Control and Prevention

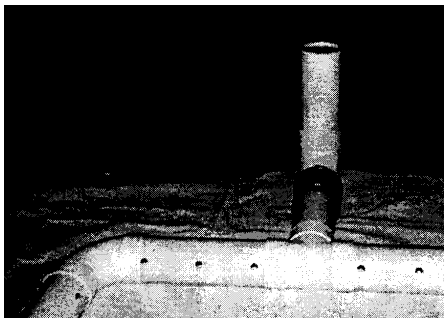
99

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.3.2 Method 2 Vertical Suction Point Pipe Offset From Soil-Gas Collector Pipe

Vertical offset from soil-gas collector pipe





Maine Center for Disease Control and Prevention

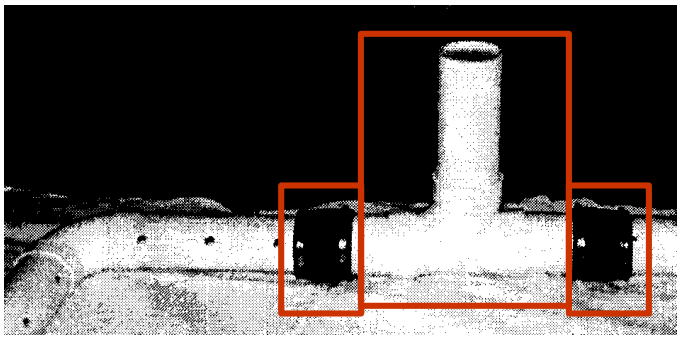
100

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.3.7 Suction Point Pipe Connection Assemblies

Basically tee + stub

Tee connected to perf pipe with rubber couplings



Maine Center for Disease Control and Prevention

101

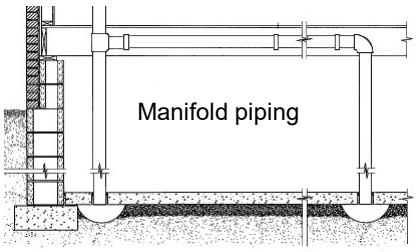
ASTM E 1465-08
Sec. 6.0 "System Construction"

Table 5 "Methods for Connecting to the Soil-Gas Collector"

Piping that collects the air flow from 2 or more suction points

Above or below slab or membrane

Above ground piping



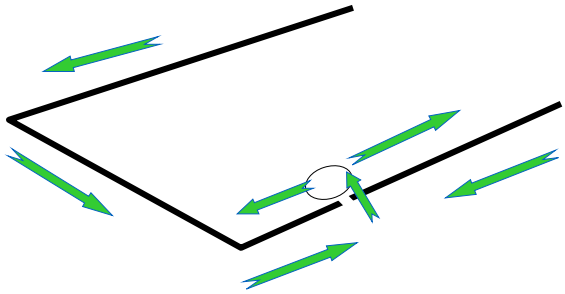
Maine Center for Disease Control and Prevention

102

ASTM E 1465-08
Sec. 6.0 "System Construction"

The Point of Table 9 Permitted Perimeter Drain Configuration

Isolation of sub-slab/membrane area can be compromised by air leakage through exterior drain tile



103

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.2.4.2 Sump Pits and Sump Tubs

- Seal tub to slab or membrane
- Use removable, gasketed bolt-on covers
- Rubber bushing seals for cover penetrations or air-tight plugs
- Larger tub for multiple pumps

Maine Center for Disease Control and Prevention

104

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.4 Water Control pg. 15

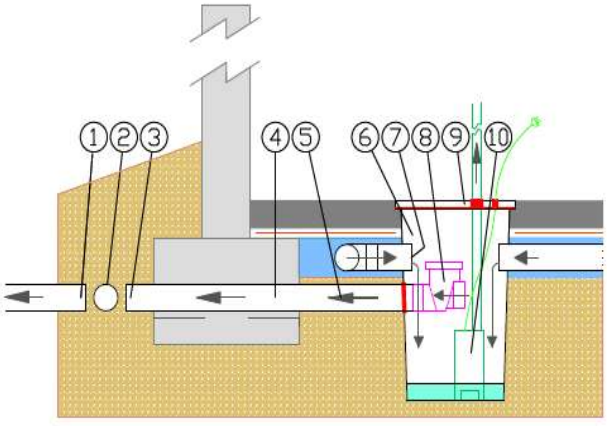
- Perimeter drains are not required for radon control.
- Water control shouldn't interfere with radon control or the other way around.
- Integrated (non-interfering) water control requirements are in section 6.4.4 (pg. 15) and Table 9 (pg. 20).

105

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.4 If Water Control is Required, it is Integrated

Fig. 9 Interior Perimeter Drain with Sump Pump and Gravity Dewatering



106

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.4 Water Control (cont.)

- The three basic configurations of integrated water control provided are:
  1. Interior perimeter drains
  2. Exterior perimeter drains
  3. Both Interior and exterior drains

- Dewatering of each configuration by:
  1. Gravity
  2. Pump
  3. Gravity and Pump.

107

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.3 Gas-Permeable Layers

3. Connection: radon system piping to the soil-gas collector (Tables 5 and 6.)

	Sect.	Page	Description
	Table 5	11	Methods for Connecting to the Soil-Gas Collector
	Table 6	12	Quantity of Pipe Parts Required for Connecting Suction Point Pipe to Soil-Gas Collector
Method			Suction Point Pipe Orientation:
Method 1	6.4.3.1	13	Vertical
Method 2	6.4.3.2	13	Off-Set Vertical
Method 3	6.4.3.3	13	Horizontal
Method 4	6.4.3.4	14	Vertical or Horizontal from Manifold
Method 5	6.4.3.5	14	Vertical through Membrane
Method 6	6.4.3.6	15	Vertical from Mat

108

ASTM E 1465-08
Sec. 6.0 "System Construction"
Maine Center for Disease Control and Prevention

Config. No.	Perimeter Drain Location	Sump Tub No.	Drainage	Applicable Figure (See p. 19)	Applicable Sections
1	Interior	1	Gravity (Grav.)	9	Table 9 (p. 20) 6.4.4.1 (p. 15) 6.4.4.2 (p. 18)
2	Interior	1	Pump	9	
3	Interior	1	Grav. & Pump	9	
4a	Exterior	1	Gravity	10	Table 9 (p. 20) 6.4.4.1 (p. 15) 6.4.4.3 (p. 21)
4b	Exterior	-	Gravity	10	
5	Exterior	1	Pump	10	
6	Exterior	1	Grav. & Pump	10	
7	Int. & Ext.	1	Gravity	9	Table 9 (p. 20) 6.4.4.1 (p. 15) 6.4.4.2 (p. 18) 6.4.4.3 (p. 21)
8a	Interior	1	Pump	9	
8b	Exterior	2	Pump	10	
9a	Interior	1	Grav. & Pump	9	
	Exterior		Gravity		
9b	Exterior	2	Pump	10	

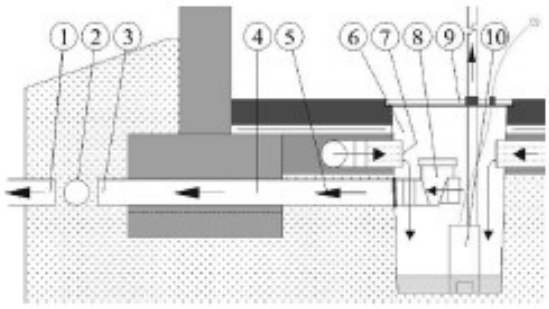
109

109

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.4 Water Control (cont.)

Sump Tub Assembly for Interior Drain Figure 9 (p. 19)



Maine Center for Disease Control and Prevention

110

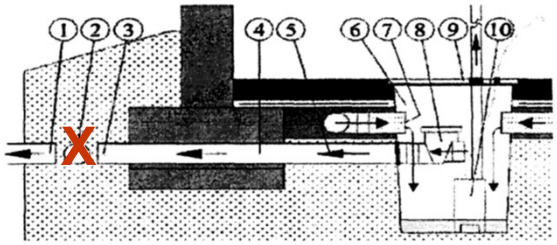
110

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.4.2 Interior Perimeter Drain Requirements

- **Gravity:**

1—Run-off pipe drains to daylight, etc. with dedicated interior drain
2—Not tied into exterior perimeter drain
3—Thru-footing pipe connected to run-off pipe
4—Thru-footing pipe required
5—Water flow out of building
6—Sump Tub require
7—Drain shall penetrate sides of tub
8—Backwater valve required for thru-footing pipe
9—Sump tub cover blank
10—No submersible pump



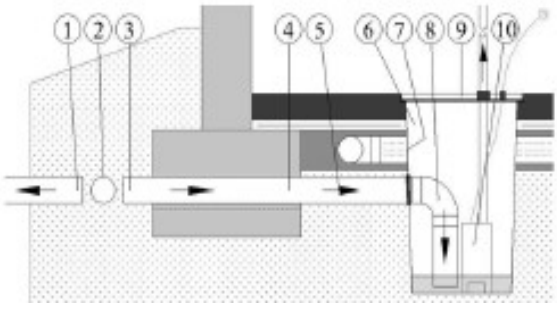
Maine Center for Disease Control and Prevention

111

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.4.4 Water Control (cont.)

Sump Tub Assembly for Exterior Drain Figure 10 (p. 19)



Maine Center for Disease Control and Prevention

112

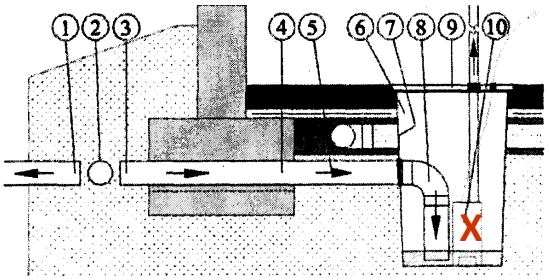
112

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.4.4.3 Exterior Perimeter Drain Requirements

- **With sump; gravity:**

1—Run-off pipe dedicated exterior drain
2—Drain connected to gravity run-off & thru-footing pipe
3—Thru-footing pipe connected to exterior drain tile
4—Thru-footing pipe required
5—Water flow direction in
6—Sump Tub require
7—Soil-gas collector shall not penetrate tub sides
8—Thru-footing pipe connected to water trap
9—Sump tub cover blank
10—No pump



Maine Center for Disease Control and Prevention

113

ASTM E 1465-08
Sec. 6.0 "System Construction"

2

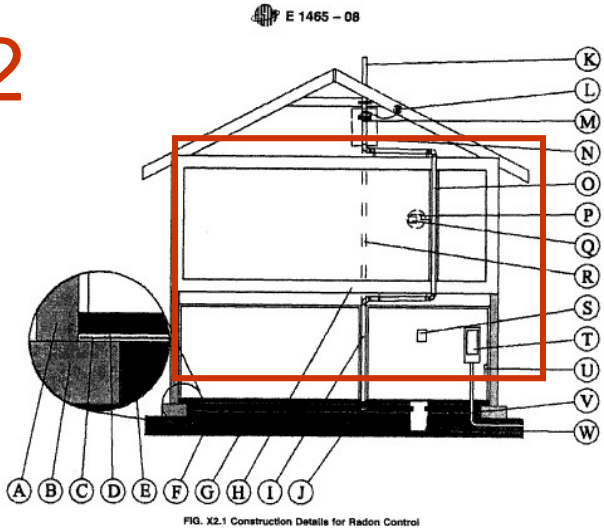


FIG. X2.1 Construction Details for Radon Control

114

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.5 Radon System Piping pg. 22

There are eleven main parts and three Tables to Section 6.5, which cover:

-Pipe used under slabs and membranes
-Pipe used in the building and above roof
-Pipe route through building to roof top discharge
-Piping drainage
-Pipe access and space for fan and radon monitor
-Pipe support
-Pipe insulation
-Pipe marking and labels
-Installing radon fan and radon monitor

115

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec 6.5.1. Physical Requirements of Pipe pg. 22

- Schedule 40 (PVC or ABS) for all above ground piping
- 4" diameter
- Especially when air leakage expected to be higher
  - Sub-membrane system
  - Large footprint
  - Joint or soil leakage
- No less than 3"
  - When low leakage expected

116

ASTM E 1465-08
Sec. 6.0 "System Construction"

117

ASTM E 1465-08
Sec. 6.0 "System Construction"

Radon Pipes
Table of Contents

Description:	Ref./ page
Pipe Specs Material: Plastic Above ground use types per 6.5.1.2 and Tables 8 or 10; 4 in. ID usually recommended per 6.5.2.1 Below ground use types per 6.5.1.3 and Table 7; 4 in. ID	Table 7 / p. 13 Table 8 / p. 16 Table 10 / p. 22 6.5.1 / p. 22 6.5.2 / p. 22
Connection to Gas-Permeable Layer All the gas-permeable layers under the building must be connected to a vent stack.	6.5.3 / p. 22
Discharge from Vent Stack Upper end vent stack must be: vertical, 12 in. min. above roof, and placement above the ridge of the highest roof is recommended; 10 ft. min. above the ground; 10 ft. min. away from openings into subject or adjacent building (including chimney flues), whenever it is not at least 2 ft. above such openings.	6.5.4 / p. 23

118

ASTM E 1465-08
Sec. 6.0 "System Construction"

Radon Pipes (cont.)
Table of Contents

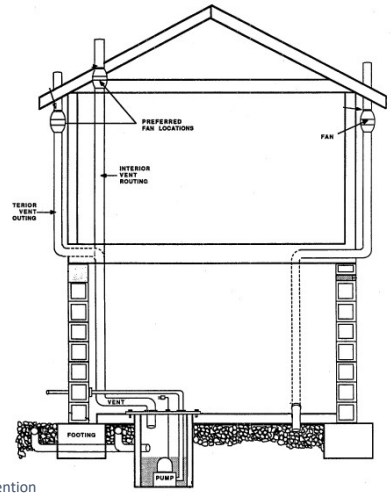
Description:	Ref./ page
Pipe Routes General: All pipe routes should be specified before construction begins; space for radon fan and monitor must be allowed for all fan-powered and passive pipe route configurations; all pipe routes must be capable of fan-powered operation. Fan-Powered System Pipe Route: Advantage of fan-powered mode of operation is its better radon reduction performance and greater flexibility for interior space utilization. Insulation of pipe is recommended inside and outside the building's thermal envelope Passive System Pipe Route: Advantage of passive mode of operation is its low operating cost. Pipe route should be vertical or nearly vertical. Insulation of pipe is recommended except where pipe can be warmed.	6.5.5 / p. 23

119

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.5.1 Fan-Powered System Pipe Route pg. 23

- More flexible pipe route
- Pipe & fan insulated in unconditioned spaces in very cold climates

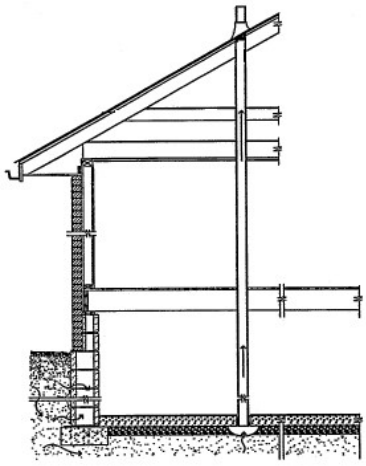


120

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.5.2 Passive System Pipe Route pg. 23

- W/in thermal envelope
- Larger pipe
- Fewer fittings
- Vertical
- Insulated in unconditioned spaces



121

ASTM E 1465-08
Sec. 6.0 "System Construction"

Radon Pipes (cont.) Table of Contents	
Description:	Ref./ page
Radon System Piping Drainage All radon system piping must be pitched so as to drain rain water and condensed water vapor back to soil through the gas-permeable layer.	6.5.6 / p. 23
Radon System Fan Mounting Space and Piping Accessibility Adequate space for a radon fan installation is prescribed.	6.5.7 / p. 24
Radon System Piping Supports, Labeling and Insulation Radon system piping must be supported like plumbing pipe of similar size and type. Radon pipe is labeled so it is not confused with plumbing. Insulation is very important for passive system performance; insulation keeps fan-powered radon pipes from sweating on the outside and freezing up on the inside.	6.5.8 / p. 24

122

ASTM E 1465-08
Sec. 6.0 "System Construction"

Radon Pipes (cont.) Table of Contents	
Description:	Ref./ page
When to Install the Radon Fan Radon fans are installed before occupancy when justified by an unacceptable radon test result; this requirement applies to passive as well as fan-powered systems. Exception: For owners who contract to have a fan installed.	1.1.1 / p. 1 6.5.9 / p. 24
Radon Fan Installation Obtain appropriate radon test results before installing radon fans enables systematic energy conservation. Only when building's radon exceeds the maximum acceptable concentration should a radon fan be installed. Inspect and repair or complete existing radon system's components before installing the radon fan. Radon fan shall be located above all occupiable space or outside above the roof.	6.5.10 / p. 25

123

ASTM E 1465-08
Sec. 6.0 "System Construction"

Radon Pipes (cont.) Table of Contents	
Description:	Ref./ page
Radon System Monitor Installation Radon system monitor is installed whenever a radon fan is installed. Radon system monitor is a pressure gage that measures the suction in the radon vent stack; it is usually connected to the radon vent stack by a length of flexible vinyl tubing. Radon system monitor also serves a visual or audible alarm; it must be located where it can be seen or heard easily, and be in a place where building occupants frequently walk by. The systems initial suction pressure along with a range of acceptable operating suction pressures must be added to the face of the gage..	6.5.11 / p. 26

124

ASTM E 1465-08
Sec. 6.0 "System Construction"

3

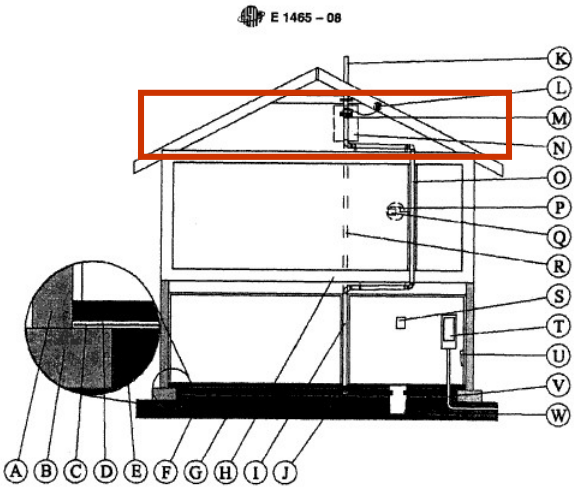


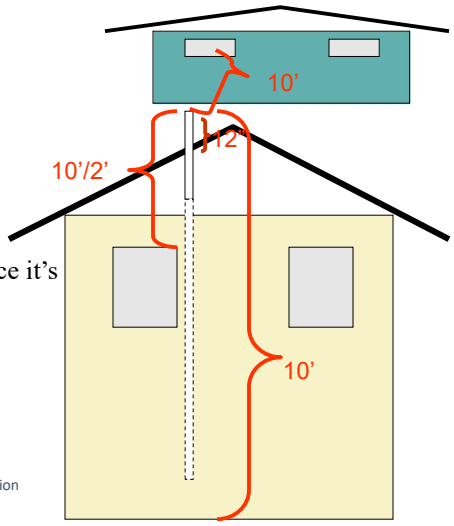
FIG. X2.1 Construction Details for Radon Control

125

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.4 Discharge from Vent Stack Pipes pg. 23

- Vertical
- Unobstructed
- Outside
- 12" above roof/edge of roof
- 10 ft.
  - Above ground
  - Away from opening in conditioned/occupiable space it's not 2 ft. above
    - Chimney flues ARE openings
    - Measure around obstructions
  - Away from adjacent building openings



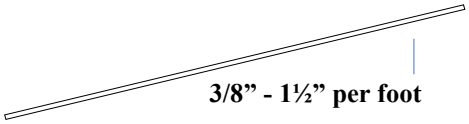
Maine Center for Disease Control and Prevention

126

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.5 Pipe Routes pg. 23

- All must be capable of fan-powering
- All routes must leave space for fan and monitor
  - Monitor visible daily with access to plastic tube
- Drainage slope per foot (suggested)
  - 3" w/high air velocity 1½" pitch
  - 4" about 3/8" pitch



127

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.9 When to Install a Radon Fan pg. 24

- When radon elevated or "unacceptable"
- Before occupancy
- When closed-house conditions can be maintained
- Cut pipe only when ready for fan installation
- Install fan only when it will be immediately, continuously operable

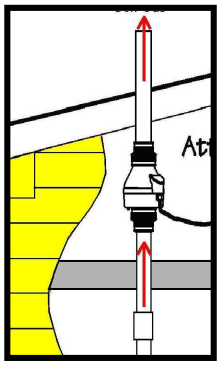
128

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.8.1 Radon System Piping Supports pg. 24

- Drain Waste Vent (DWV) above-ground piping supports
- In accordance with building codes for DWV of specific pipe size
- Vent stack braced above and below fan installation point

Maine Center for Disease Control and Prevention



129

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.9 When to Install a Radon Fan pg. 24

- When radon elevated or "unacceptable"
- Before occupancy
- When closed-house conditions can be maintained
- Cut pipe only when ready for fan installation
- Install fan only when it will be immediately, continuously operable

Maine Center for Disease Control and Prevention

130

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.10.2 Fans and Couplings pg. 25

- Resistant to temperature and moisture
- Move at least 75cfm @0.75" WC static pressure
- Connected to vent stack pipe with 2 rubber couplings

Maine Center for Disease Control and Prevention

131

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.10.4 (a) Radon Fan Location

Interior location

- Unconditioned area above occupiable space (or rooftop with electrical supply)
- Garage attic with fire-rated ceiling immediately below it
- 3 ft. X 24" diameter
- Vertical in straight length of pipe with at least 10 pipe diameters below
- Pipe supports fan

Maine Center for Disease Control and Prevention

132

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.5.10.4 (b) Radon Fan Location

- Exterior Location
- Above shingled and pitched roof
  - Securely attached to pipe by coupling
  - 8-24" pipe length secured in top coupling
  - Top pipe attached to roof with 2 horizontal weather-proofed rigid rods or equivalent
- Flat roof
  - Pipe supported by weather proof structure
  - Firmly attached to building's structure

133

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.6 Maintain All Fire Ratings pg. 26

- When a plastic pipe penetrates a fire rated assembly, appropriate use of automatic dampers, intumescent fire collars, fire rated pipe enclosures, and other means allowed by code can maintain the integrity of the required or highly recommended fire rated assembly.

134

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.7 Crawlspaces – Ventilation and Air Handling Equipment pg. 26-27

- Soil depressurization, not crawlspace depressurization, is the radon reduction strategy to be used in new construction. **6.7.1**
- Soil depressurization for radon control is compatible with the natural ventilation of crawlspaces for moisture control or other reasons, but it is not acceptable for radon control. **6.7.2**
- Air handling and HVAC equipment is not to be installed in crawlspaces, unless the crawlspace is occupiable space and maintained as such. **6.7.3**
- Radon testing of crawlspaces containing HVAC equipment is appropriate. **6.7.3**
- Sub-slab depressurization should be used for radon control in crawlspaces containing HVAC equipment. **6.7.3**

135

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.8 Radon Systems Electrical Installation pg. 27

- Electrical junction box for radon fan is required near space reserved for fan, or near the planned above roof fan location. **6.8.2**
- Electrical junction boxes required near any electrically operated radon system monitoring/alarm equipment. **6.8.3**
- The circuit list shall be posted on circuit breaker. **6.8.4**
- All wiring shall comply with applicable code, including "disconnecting means" for radon fan. **6.8.5** & **6.8.6**

136

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.9 Radon Labels pg. 27-29

Labels				
Description			Section	Page
Pipe Labels			6.5.8.3 6.9.1	24 27
Membrane Inspection Label			6.9.2	27
Radon System Label Selection Guide			Table 11	27
Radon System Labels	Pipe Route	Status	6.9.3	28
Radon System Label No. 1	Fan-Powered	Operating	6.9.3.1	28
Radon System Label No. 2	Fan-Powered	Not Operating	6.9.3.2	29
Radon System Label No. 3	Passive	Operating	6.9.3.3	29
Sump Cover Inspection Label			6.9.4	29
Radon System Maintenance and Information Label			6.9.5	29

137

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.9 Labels pg. 28 & 29

- There are Five Label Types:
  1. **Pipe Labels**
     1. **Read at a distance of 5 ft.**
     2. **Applied to accessible pipe or insulation**
  2. **Membrane Labels**
  3. **Radon System Labels**
     1. **Read from 3 ft.**
     2. **Operating Fan**
     3. **Fan-powered pipe route, no fan**
     4. **Passive system**
  4. **Sump Cover Labels**
     1. **Read from 3 ft.**
     2. **Close to or in sight of sump cover**
  5. **System Maintenance and Information Labels**
     1. **Name, address, phone of maintenance provider**
     2. **State radon agency contact information**

138

ASTM E 1465-08
Sec. 6.0 "System Construction"

Testing, Repairing, and Documenting has three sections:

6.10 - 6.12	Testing, Repairing and Documenting	
Section	Description	Page
6.10	Radon Testing for New Residential Buildings With Fan-Powered and Passive Systems	29
6.11	Requirements and Recommendations based on Initial and Post-Mitigation Radon Tests	31
6.12	Quality Assurance and Documentation for Radon Systems	33

139

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.10 Radon Testing for New Residentials Buildings with Fan-Powered and Passive Systems pg. 28-31

Section	Description	Page
Table 11	Summary of Short Term Test Requirements and Recommendations for Contractors, Owners and Occupants of Low Rise Residential Buildings	28
6.10	Radon Testing ……	29
6.10.1	Radon Test Devices and Protocols	29
6.10.2	Required Radon Testing for Buildings with Fan-Powered Pipe Routes	30
6.10.3	Required Radon Testing for Buildings with Passive Radon Systems	30
6.10.4	Radon Test Correctness	30
6.10.5	Independent Radon Tests	30
6.10.6	Documented Evidence of Acceptable Radon Concentrations	31

140

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.10.1 Radon Test Devices and Protocols pg. 29

Test Devices

- Radon Tests (48 to 72 hours)
- Device "Listed" by a recognized radon proficiency program

Protocols

- Fan-powered and passive system must have operated at least 24 hours immediately prior to starting radon test.
- "Closed House Conditions" must have been maintained for 12 hours immediately before radon test is started and must be maintained during test.

141

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.10.2 Testing Buildings with Fan-Powered Pipe Route pg. 30

1. Test using "Initial Radon Test Protocol" (i.e., without radon fan operating)
2. If Step 1's test result is greater than the maximum "acceptable radon concentration," install radon fan and monitor.
3. Test using "Post Mitigation Test Protocol" (i.e., with radon fan operating)
1. If Step 3's test result is equal to or less than the maximum "acceptable radon concentration," no further construction is required.

142

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.10.3 Testing Buildings with Passive Systems pg. 30

1. Test using "Post-Mitigation Radon Test Protocol" (i.e., with passive system operating).
2. If Step 1's test result is greater than the maximum "acceptable radon concentration," install radon fan and monitor.
3. Test using "Post Mitigation Test Protocol" (i.e., with radon fan operating).
4. If Step 3's test result is equal to or less than the maximum "acceptable radon concentration," no further construction is required.

143

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.10.5 Independent Radon Tests pg. 30

"All testing shall be done using devices that meet U.S. EPA requirements and are listed by a recognized proficiency program and performed in accordance with applicable U.S. EPA and state protocols."

The specific rules and regulations that make the radon tests independent depend on the jurisdictions in which the radon tests are performed.

A Maine Registered Radon Service Provider must do the testing. Exception, if the occupant has moved in and performed their own test; then that test result can be used.

144

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.11 Requirements and Recommendations Based On Test Results

Section	Description	Page
Table 13	Requirements and Recommendations for Radon Test Results	32
6.11	Requirements and Recommendations based on Initial and Post-mitigation Test Results	31
6.11.1	Completion Activities based on Interpretation of Test Results	31
6.11.2	Test Result Interpretation for Buildings with Fan-Powered Pipe Route	31
6.11 3	Test Result Interpretation for Buildings with Passive Pipe Route	31
6.11.4	Radon Reduction Goals	33

145

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.11.1 Completion Activities Based On Interpretations Of Test Results

After radon test shows "acceptable radon concentration" or less the radon system still needs to be completed (i.e., labeled and documented.)

If radon test shows unacceptable radon concentrations in the building, the radon system must be fixed (i.e., repaired or upgraded) and tested again until acceptable radon concentrations are achieved.

146

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.11.2 Test Results Interpretation For Buildings With Fan-Powered Pipe Route

Section 6.11.3 Test Results Interpretation For Buildings With Passive Pipe Route

For fan powered pipe route without fan, and

For passive pipe route without fan:

If test result acceptable, finish up

If test result unacceptable, install fan and monitor

For fan powered pipe route with fan and

For passive pipe route with fan

If test result acceptable, finish up

If test result unacceptable, repair system or upgrade fan

147

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.11.4 Radon Reduction Goals pg. 33

Indoor radon concentrations
as low as reasonable, i.e., **less than 2 pCi/L**
in new residential construction;

but always less than the negotiated
maximum "acceptable radon concentration"
or
4 pCi/L,
whichever is lower.

148

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.12 Quality Assurance and Documentation pg. 33

6.12.1 Check for Construction and Testing Completeness

6.12.2 Interpret Test Results

6.12.3 Install Required Labels

6.12.4 Assemble and Deliver Documentation Package

6.12.5 Deliver "Documented Evidence of Acceptable Radon Concentrations" to building's owner.

149

ASTM E 1465-08
Sec. 6.0 "System Construction"

Sec. 6.12.4 Assemble and Deliver the Documentation Package pg. 33

Delivered to owner or left in dust-proof package near electrical panel the following information:

1. Test results
2. Description of systems
3. Installer's ID
4. Radon fan warranty and documentation (if fan is installed)
5. Monitor operation
6. Principles of system operation
7. Actions to take in case of system failure
8. State radon agency information

150

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.13 Recommendations For Owner/Occupant pg. 33

Owner/Occupant Maintenance has one section:

6.13	Owner /Occupant Maintenance	
Section	Description	Page
6.13	Recommendations to Owner/Occupant	33

151

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.13.4 Operating Fan-Powered System's Suction Pressure Check pg. 34

- Visual
  - Nominal operating suction marked on display
  - Initial suction pressure at system start-up

- Audible
  - Range of normal operating pressures in monitor with adjustable set points

152

ASTM E 1465-08
Sec. 6.0 "System Construction"

Section 6.13.4 Operating Fan-Powered System's Suction Pressure Check pg. 34

- Tubing secured and protected
- Electric monitor
  - Junction box near monitor
  - Non-switched circuit not used by fan

153

ASTM E 1465-08

2. Specify a Radon System Using to ASTM E 1465-08

2.1 Collect Necessary Information

154

ASTM E 1465-08
Selecting Radon Control Options

1. **What is first choice for radon system's operating mode?**
   - ***Passive or Fan-Powered*?**
2. **What is maximum Acceptable Radon Concentration?**
   - ***Always less than 4 pCi/L, but usually an agreed to number between 2.0 and 3.9 pCi/L***
3. **Which Foundation Type will be used?**
   - ***Basement, Slab-On-Grade, Crawlspace, or Combination***
4. **Which Gas-Permeable Layer (GPL) Type will be used?**
   - ***GPL Types: 1, 2, 3, 4, or 5 (See Table 2)***
5. **Which Ground Cover will be used?**
   - ***Concrete Slab, Thin Concrete Slab, or Sealed Membrane***
6. **Which Pipe Size will be used above ground?**
   - ***3 inch ID, 4 inch ID, or other?***
7. **Which Soil-Gas Collector (SGC) Type will be used?**
   - ***SGC Types: 1, 2, 3, 4, or 5 (See Table 4)***
8. **Which Water Control System(s), if any, will be used?**
   - ***Interior Perimeter Drain, Exterior Perimeter Drain, Both, or None***

ASTM E 1465-08
Specifying a Radon System Based on E-1465-08

- Suggested Process:

1. Collect Pre-Construction Information
2. Select Radon Control Options

ASTM E 1465-08
Specify an E-1465-08 System
Collect Necessary Data

No.	Sample Questionnaire	Answer
1	Is Primary Goal "Greatest Radon Reduction" or "Lowest Operating Cost"? (Low Radon or Low Cost)	
2	Is maximum "Acceptable Radon Concentration": less than 2 pCi/L, less than 4 pCi/L, or other? (<2 or <4)	
3	Is water to be drained or pumped from Interior or exterior of foundation? (Yes or No)	
4	What is the foundation type? (Basement, Slab-on-grade, Crawlspace or Combination?)	
5	How many crawlspaces are required?	
6	Will a HVAC duct contact soil or be located in a crawlspace? (Yes or No)	
7	How big is footprint (sq. ft.)?	
8	How many stories (including lowest level) in structure?	

157

ASTM E 1465-08
Specify an E-1465-08 System
Collect Necessary Data (cont.)

No.	Sample Questionnaire	Answer
1	Is Primary Goal "Greatest Radon Reduction" or "Lowest Operating Cost"? (Low Radon or Low Cost)	
2	Is maximum "Acceptable Radon Concentration": less than 2 pCi/L, or less than 4 pCi/L? (<2 or < 4)	

Question 1:
If answer is "**Low Radon**" install a vent stack with a **fan-powered pipe route**.
If answer is "**Low [Operating] Cost**" a vent stack with a **passive pipe route**.

Question 2:
If answer is '**less than 2pCi/L**" install the **most efficient and best sealed gas-permeable layer and vent stack**.
If answer is "**less than 4pCi/L**" install the **best affordable gas-permeable layer and vent stack**.

158

ASTM E 1465-08
Specify an E-1465-08 System
Collect Necessary Data (cont.)

No.	Sample Questionnaire	Answer
3	Is water to be drained or pumped from Interior or exterior of foundation? (Yes or No)	
4	What is the foundation type? (Basement, Slab-on-grade, Crawlspace or Combination?)	

Question 3:
If answer is "**Yes**" special **water control features** that do not interfere with the radon system **must be added per 6.4.4.**
If answer is "**No**" special **water control features are not required**.
Question 4:
If the answer is "**Crawlspace**" and the answer to Q.2 was "**less than 2 pCi/L**," the **ground cover in the crawlspace should be a concrete slab**, not a plastic membrane. Membranes allow air leakage into gas-permeable layer.
If the answer is "**Combination**" the there should be **two sealed gas-permeable layers that must be attached to a vent stack or vent stacks**. Adjust building specs to reflect this condition.

159

ASTM E 1465-08
Specify an E-1465-08 System
Collect Necessary Data (cont.)

No.	Sample Questionnaire	Answer
5	How many crawlspaces are required?	
6	Will a HVAC duct contact soil or be located in a crawlspace? (Yes or No)	

Question 5:
If answer is "**2**" or **more than** "**2**", excessive air leakage into the gas-permeable layer can be expected over life of building. Such **crawlspace ground covers should probably not be plastic membranes, but instead be at least thin concrete slabs, (6.1.3.2)**.
Question 6:
If the answer is "**Yes**" **the soil is in contact with the duct**, the **duct must be rerouted** so that it is no longer in contact with (or passes through the soil.) (6.4.5)
If the answer is "**Yes**" **the duct is located in a crawlspace**, the **crawlspace must be treated as occupiable space or the duct must be rerouted** so that it does not pass through the crawlspace. (6.7.3)

160

ASTM E 1465-08
Specify an E-1465-08 System
Collect Necessary Data (cont.)

No.	Sample Questionnaire	Answer
7	How big is footprint (sq. ft.)?	
8	How many stories (including lowest level) in structure?	

Question 7
If answer is "**1,500 sq.ft. or more**," the **vent stack must have a 4 in. or larger ID per 6.5.2.1**.

Question 8:
If answer is "**4 stories or more**," **E 1465 does not apply** because it is for low-rise residential buildings. A low-rise building is usually up to three stories, however the definition of low-rise varies by jurisdiction.

161

ASTM E 1465-08
Specify an E-1465-08 System
Necessary Data Collected

No.	Sample Questionnaire with Sample Answers	Answer
1	Is Primary Goal "Greatest Radon Reduction" or "Lowest Operating Cost"? (Low Radon or Low Cost)	Low Radon
2	Is maximum "Acceptable Radon Concentration": less than 2 pCi/L, or less than 4 pCi/L? (<2 or< 4)	Less than 2 pCi/L
3	Is water to be drained or pumped from Interior or exterior of foundation? (Yes or No)	No
4	What is the foundation type? (Basement, Slab-on-grade, Crawlspace or Combination?)	Basement
5	How many crawlspaces are required?	None
6	Will a HVAC duct contact soil or be located in a crawlspace? (Yes or No)	No
7	How big is footprint (sq. ft.)?	1,200
8	How many stories (including lowest level) in structure?	3

162

ASTM E 1465-08

2. Specify a Radon System Using to ASTM E 1465-08

2.2 Select Radon Control Options

163

ASTM E 1465-08
Specify an E-1465-08 System

Radon Control Items (Example of Option Selected)	Sect.	Page	Question	Req'd.
Foundation Type (Basement)	6.1	5	4	Yes
Ground Cover (Concrete Floor Slab)	6.2	7	1 ,2, 4 & 5	Yes
Foundation Walls (Solid Concrete)	6.3.	8	1 and 2	Yes
Gas-Permeable Layer Required	6.4	9	-	Yes
Gas-Permeable Layer (Type 2)	Table 2	9	1 and 2	Yes
Soil-Gas Collector (Type 2)	Table 4	10	1 and 2	Yes
Below Ground Perforated Pipe (F 405)	Table 7	13	-	Yes
Connection to SGC Pipe (Method 2)	Table 5	11	1 and 3	Yes
Water Control (Configuration No. –)	Table 9	20	3	No
Vent Stack Pipe Route (Fan-Powered)	6.5	22	1	Yes
Vent Stack Pipe ID (4 in.)	6.5	22	1, 7 and 8	Yes
Above Ground Vent Stack Pipe (D 2665)	Table 8	16	-	Yes

164

ASTM E 1465-08
Specify an E-1465-08 System

Radon Control Items (Example of Option Selected)	Sect.	Page	Question	Req'd.
Maintain Fire Ratings	6.6	26	-	Yes
Crawlspace Ventilation and Air Handlers	6.7	26	4 and 5	No
Electrical Installation	6.8	27	-	Yes
Labels	6.9	27	-	Yes
Radon System Label (Label No. _)	Table 11	27	-	Yes
Radon Test Type (Initial Radon Test)	6.10	29	1	Yes
Documented Evidence of Acceptable Radon Concentrations	6.10.6	31	2	Yes
Interpretation of Radon Test Results	6.11	31	-	Yes
Requirements and Recommendations based on Test Results	Table 13	32	-	Yes
Quality Assurance and Documentation	6.12	33	-	Yes
Recommendations to Owner/Occupant	6.13	33	-	Yes

165

ASTM E 1465-08

3. Interpreting Radon Test Results

166

ASTM E 1465-08
Specify an E-1465-08 System
Interpreting Radon Test Results

Covered in Sub-section 6.11 and Table 13

- If test result exceeds the "acceptable radon concentration*"
  - Performance improvement required
- If test result is less than the "acceptable radon concentration**" and 2 pCi/L or greater
  - Consider improving performance

*** or equals or exceeds 4 pCi/L when an "acceptable radon concentration" has not been established**
**** or is less than 4pCi/L when an "acceptable radon concentration" has not been established**

ASTM E 1465-08
Specify an E-1465-08 System
Interpreting Radon Test Results (cont.)

When test result is above "acceptable radon concentration*"

System Description	Action Required
Fan-Powered Type Stack:	
With No Fan Installed	Install Fan and Monitor
With Fan Installed	Repair/Update System
Passive Type Stack	Install Fan and Monitor

*** or equals or exceeds 4 pCi/L when an "acceptable radon concentration" has not been established**

ASTM E 1465-08
Specify an E-1465-08 System
Interpreting Radon Test Results (cont.)

When test result is less than the "acceptable radon concentration**"
and 2 pCi/L or greater

System Description	Consider***
Fan-Powered Type Stack:	
With No Fan Installed	Install Fan and Monitor
With Fan Installed	Repair/Upgrade System
Passive Type Stack	Install Fan and Monitor

**** or is less than 4pCi/L when an "acceptable radon concentration" has not been established**
***** Section 6.11.4 "Radon Reduction Goals" provides the rationale for these considerations.**

169

ASTM E 1465-08

4. ASTM E 1465-08 User Aids

170

ASTM E 1465-08
User Aides are Built into E-1465-08 System

Six Significant Summaries in E-1465-08

1. "**Summary**" [of E-1465] pg. 4]
   Found in Sec. 4; is half page summary of E-1465

2. "**Outline of Section 6, Construction Methods for Soil Depressurization Radon Reduction"** pg.4
   Found in Sec. 4.4 "Outline of Section 6";E-1465's "How-To-Do-It"

3. "**Summary of Steps Performed Before Occupancy**" pg. 6
   Found in Sec. 6, Table 1; provides a list of job steps

171

ASTM E 1465-08
User Aides are Built into E-1465-08 System

Six Significant Summaries in E-1465-08 (cont.)

4. "**Gas Permeable Layer Comparison**" pg. 10
   Found in Sec. 6, Table 3; Provides a method for calculating and comparing the total void space in the gas-permeable membrane

5. "**Summary of Short-Term Radon Test Requirements and Recommendations for Contractors, Owners, and Occupants of Low Rise Residential Buildings**" pg. 28
   Found in Sec. 6, Table 12; Provides a persoective for understanding requirements related to radon testing in new residential construction.

6. "**Summary of Practice E-1465's Requirements for Radon Reduction in New Low-Rise Residential Buildings**" pg. 36
   Found in Appendix X2; is a two page summary of E-1465 and a visual table of contents.

172

ASTM E 1465-08
User Aides are Built into E-1465-08 System
1. Summary of E-1465 pg. 4

- The summary Section 4 is required in every ASTM Standard Practice
- E 1465 has a half page summary

ASTM E 1465-08
User Aides are Built into E-1465-08 System
2. Outline of Section 6 pg. 4

- Outline of Section 6,
- The "How-to-do-it" part of E 1465
- Provided in Section 4.4

4.4 The outline of Section 6, *Construction Methods for Soil Depressurization Radon Reduction* follows:

Construction Methods for Soil Depressurization Radon Reduction	6
Foundations Types	6.1
Ground Covers	6.2
Foundation Walls	6.3
Sub-Slab and Sub-Membrane Installation of Gas-Permeable Layer	6.4
Gas-Permeable Layer	6.4.1
Soil-Gas Collectors	6.4.2
Pipe Connections to Soil-Gas Collectors	6.4.3
Ground Water Drainage for Gas-Permeable Layers	6.4.4
Sealing Gas-Permeable Layer	6.4.5
Radon System Piping	6.5
Physical Requirements of Pipe	6.5.1
Pipe Size	6.5.2
Connection to Gas-Permeable Layer	6.5.3
Discharge from Vent Stack Pipes	6.5.4
Pipe Route	6.5.5
Radon System Piping Drainage	6.5.6
Radon System Fan Mounting Space and Piping Accessibility	6.5.7
Radon System Piping Supports, Labeling and Insulation	6.5.8
When to Install the Radon Fan	6.5.9
Radon Fan Installation	6.5.10
Radon System Monitor Installation	6.5.11
Maintain all Fire Ratings	6.6
Crawlspaces—Ventilation and Air Handling Equipment	6.7
Radon System Electrical Installation	6.8
Radon Labels	6.9
Radon Testing for New Residential Buildings	6.10

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. List of Jobs Table 1 pg.6

"Summary of Steps Performed Before Occupancy"

- Each job step includes references to appropriate sections of E 1465.

- **Possible Uses of Table 1:**
  - Table 1 helps builders integrate the construction of required radon system components into their building plans while removing details that interfere with radon systems.
    - Example: Add vent stack pipe route and space tor a radon fan and radon system monitor to building plans.

175

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. List of Jobs Table 1 pg.6 (cont.)

"Summary of Steps Performed Before Occupancy"

- **Possible Uses of Table 1 (cont.):**
  - Table 1 helps builders modify their master project schedule or time line.
    - Example: Provide time for the radon testing.
  - Table 1 helps builders modifying the detailed specifications used to manage subcontractors and tradesman.
    - Example; A properly wired junction box suitable for the radon fan could be added to the electrician's list of requirements

176

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. List of Jobs Table 1 pg.6 (cont.)

TABLE 1 Construction of Radon Systems with Fan-Powered and Passive Pipe Routes
Summary of Steps Performed Before Occupancy

Assuming Radon Fan is Installed

Step No.	Summary Step Description	Reference to Practice	Pipe Route	
			Fan-Powered	Passive
	Construction References		6.1 through 6.12	
	Before Occupancy Steps:		Is step required or optional?	
	Are the following construction steps required or optional before occupancy?			
1	A) Specify Air Handling Equipment Placement	per 6.4.5.4 and 6.7.3	Required	Required
	B) Specify Vent Stack's Pipe Route through House	per 6.5.5	Required	Required
2	Build Foundation	per 6.1, 6.3, and 6.7	Required	Required
3	Install Gas-Permeable Layer	per 6.4.1 through 6.4.4	Required	Required
	Install Soil-Gas Collector(s)			
	Install Connections to Soil-Gas Collector(s)			
4	Install Soil-Gas-Retarder	per 6.2.3	Required	Required
5	Install Concrete Slab or Sealed Membrane Ground Cover, see 6.7.2		Required	Required
	A) Slab-on-Grade with Concrete Floor Slab	per 6.1.1, 6.2, 6.2.1, and 6.4.5	Required	Required
	B) Basement with Concrete Floor Slab	per 6.1.2, 6.2, 6.2.1, and 6.4.5	Required	Required
	C) Crawlspace with Concrete Floor Slab*	per 6.1.3, 6.1.3.1, 6.2, 6.2.3, and 6.4.5	Required	Required
	D) Crawlspace with Thin Concrete Floor Slab*	per 6.1.3, 6.1.3.2, 6.2, 6.2.3, and 6.4.5	Required	Required
	E) Crawlspace with Sealed Membrane*	per 6.1.3, 6.1.3.3, 6.2, 6.2.3, and 6.4.5	Required	Required
	F) Combination Foundations	per 6.1.4	Required	Required
6	Install Radon System Piping through Roof; Install Pipe Insulation and Attach Radon Pipe Labels; Maintain Fire Ratings	per 6.5.1 through 6.5.8 and 6.6	Required	Required
7	Install Electrical Wiring	per 6.8	Required	Required
8	For fan-powered system: Test building with initial test protocol	per 6.10	Required	Required
	For passive system: Test building with post-mitigation protocol			
9	Evaluate radon test results	per 6.11	Required	Required
10	Determine when building is ready for fan installation	per 6.5.9	Required*	Required*
11	Install fan as required by 6.5.9 and 6.11	per 6.5.10	Required*	Required*
12	Install Radon System Monitor	per 6.5.11	Required*	Required*
13	Test building with fan operating with post-mitigation protocol	per 6.10	Required*	Required*
14	Evaluate radon test results	per 6.11	Required*	Required*
15	Attach all appropriate labels	per 6.9	Required	Required
16	Assemble and deliver documentation package	per 6.12.4	Required	Required
17	Deliver documented evidence of acceptable radon levels	per 6.12.5	Required	Required
18	Upgrades, Repairs, and Conversions	per 6.11.2 and 6.11.3	—	—

* At least one of these three sealed ground covers is required in each crawlspace.
# Not required when test results are acceptable in Step #9.

177

ASTM E 1465-08
User Aides are Built into E-1465-08 System
4. Gas-Permeable Layer Comparison Table 3 pg. 10

Table 3 compares the void space in typical crushed stone and typical geo-textile mat installations; section 6.4.1.3, *Not All Gas-Permeable Layers are Equal,* explains the comparison.

Clean crushed stone spread over the entire area within the building's footings provides the most efficient gas-permeable layer.

178

ASTM E 1465-08
User Aides are Built into E-1465-08 System
4. Gas-Permeable Layer Comparison Table 3 pg. 10 (cont.)

TABLE 3 Gas-Permeable Layer Comparison: Crushed Stone and Gas-Permeable Mat Typical Installations (To Facilitate the Comparison, Assumptions Were Made)[A,B,C,D]

Layer	Crushed Stone		Mat		%
Column Number	[1]		[2]		[2] ÷ [1]
Void Space (%)	40 %	40 %	95 %	95 %	238 %
Width of Slab	45 ft	13.7 m	45 ft	13.7 m	100 %
Length of Slab	60 ft	18.3 m	60 ft	18.3 m	100 %
Area of Slab	2700 ft²	250.8 m²	2700 ft²	250.8 m²	100 %
Thickness of Layer	4 in.	101.6 mm	0.8 in.	20.3 mm	20 %
Area of Coverage	2700 ft²	250.8 m²	474 ft²	44.0 m²	18 %
Volume of Permeable Layer	900 ft³	25.5 m³	31.6 ft³	0.9 m³	4 %
Total Void Space Volume	360 ft³	10.2 m³	30 ft³	0.8 m³	8 %

[A] Gas-permeable layer for (60 ft by 45 ft) (18.3 m by 13.7 m) or 2700 ft² (250.8 m²) building. The building footprint shown here is for purposes of this comparison only.
[B] The gas-permeable layer materials compared are broken stone and proprietary mat.
[C] Broken stone space used in comparison: (a) The broken stone layer is 4 in. (100-mm) deep. (b) The stone size is 1¼ in. (32 mm) which has 40 % void space.
[D] Mat space used in comparison: (a) This mat has in 16 in. (40.7 cm) wide strips and a reported void space of 95 %. (b) The mat is installed 1 ft (0.3 m) inside the building's interior perimeter. (c) An addition three strips of the mat, equally spaced and running parallel to the short side of the foundation footprint, are installed. (d) The mat is placed on the soil according to its manufacturer's instructions.

179

ASTM E 1465-08
User Aides are Built into E-1465-08 System
5. Summary of Short-Term Radon Tests Table 12 pg. 28

Table 12 compares the radon testing requirements for low-rise residential buildings:

1. New Finished and Never Occupied
2. New and Recently Occupied
3. Existing

180

ASTM E 1465-08
User Aides are Built into E-1465-08 System
5. Summary of Short-Term Radon Tests Table 12 pg. 28

TABLE 12 Summary of Short-Term Radon Test Requirements and Recommendations for Contractors, Owners and Occupants of Low Rise Residential Buildings

Building Status	New, Finished, and Never Occupied Building			New and Recently Occupied for the First Time			Existing (See Practice E 2121)		
Type Radon Reduction System Installed	None[A]	Passive Operating	Fan Powered Pipe Route	None[A]	Passive Operating	Fan Powered Pipe Route	None[A]	Passive	Fan Powered
Type Test									
Initial Radon Test:			No fan			No fan			Fan off
Required before occupancy?[B]	No		Yes	No		Yes	No		No
Recommended before purchase?[C]	Yes		Allowed	Yes		Allowed	Yes		Yes
Recommended after occupancy?[D]	Yes		Yes	Yes		Yes	Yes		Yes
Post-mitigation Test:			Fan-powered			Fan-powered			Fan on
Required before occupancy?[E]	No	Yes	Yes	No	Yes	Yes	No	No	No
Required after operating radon system installation?[F]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recommended before purchase?[C]	Yes	Allowed	Allowed	Yes	Allowed	Allowed	Yes	Yes	Yes
Recommended after occupancy?[D]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recommended every two years?[G]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional Tests[H]									
Recommended every two years?[G]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is testing recommended after ownership changes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is testing recommended after occupants change?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is testing recommended after HVAC systems are changed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is testing recommended after structural changes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is testing recommended after significant change in use?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[A] Residential buildings that do not have a radon system installed; such buildings do not comply with this practice or Practice E 2121.
[B] This practice requires a post-mitigation radon test before occupancy for passive systems; an initial radon test before occupancy is required for powered systems, and when the initial test results are not acceptable a post-mitigation test result is required after the system's fan is operating. (See 6.10.2 and 6.10.3.)
[C] U.S. EPA recommends testing for radon before a house is sold (4).
[D] U.S. EPA recommends testing for radon after occupancy in new and existing houses at least once every two years (4).
[E] This practice requires post-mitigation radon tests for operating passive and operating fan-powered radon systems; for fan-powered type systems that do not have their fans operating, an initial test is required. (See 6.10.2 and 6.10.3.)
[F] This practice and Practice E 2121 require post-mitigation radon tests for all buildings with newly installed radon systems. This practice specifies post-mitigation testing before occupancy, but in cases where the radon system was not enabled before occupancy, the building is required to have an initial radon test before occupancy (see (4), Table Footnote E, 6.10.2, and 6.10.3).
[G] U.S. EPA, this practice, and Practice E 2121 recommend that residential buildings with operating radon systems be retested for radon every two years. (See (4) and 6.9.3.)
[H] U.S. EPA recommends retest for radon every two years and whenever significant changes in the use or physical characteristics of a residential building occur. Use the appropriate test type for these additional tests. (See (1, 4) and 6.9.3.)

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Summary of E-1465-08's Requirements Appendix X2 pg. 36

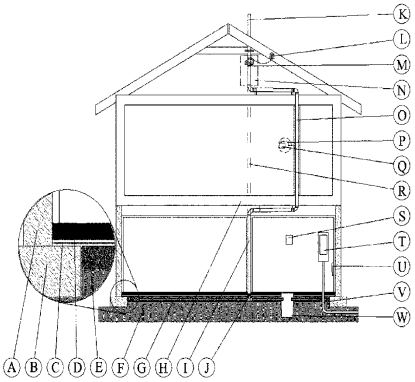
Appendix X2 with its Figure 2.1, pointers and corresponding notes provide:

1. A summary of E 1465 and
2. A visual table of contents.

ASTM E 1465-08

User Aides are Built into E-1465-08 System

6. Summary of E-1465-08's Requirements (cont.) Appendix X2 pg. 36



E Gas-Permeable Layer—A gas-permeable layer/soil-gas collector assembly is required under all slabs and membranes (see 6.4). The gas-permeable layer must be sealed on top, on the bottom, and at its sides/edges (see 6.4.5). An excellent gas-permeable layer is a 4 in. (100 mm) bed of clean aggregate of (¾ to 1½ in. (25 to 38 mm) broken stone); certain other gas-permeable layer types are permitted (see Table 2).
F Soil—Undisturbed soil is assumed to seal the bottom of the gas permeable layer (see 6.4.5.3).
G Soil-Gas Collector—Soil-gas collectors must be built into every gas-permeable layer (see 6.4.2). A common soil-gas collector is 4 in. (100 mm) perforated rigid or flexible drain pipe; others are permitted (see 6.2.4, 6.5.1.3, and Table 4). The soil-gas collector must be connected to the radon vent stack (see 6.4.3 and Table 5).
H Thermal Envelope—Non-insulated passive vent stacks must pass through the space within the thermal envelope of the building (see 6.5.5).
I Radon System Piping—Is plastic (PVC or ABS) pipe (see 6.5); it terminates above the roof; it must have been designed to have sealed joints and for use above ground (see 6.5.1.2). It is connected to the gas-permeable layer (see 6.5.3). Its pipe routes are configured for either fan-powered (see 6.5.5.1) or passive (see 6.5.5.2) operation. The nominal pipe size is 4 in. (100 mm) ID (see 6.5.2). All required fire ratings must be maintained as radon piping is installed (see 6.8). Radon system piping must be supported and labeled and could require insulation (see 6.5.6; see also Notes O and R).
J Rubber Coupling/Adaptor—Joins suction point pipe (an above ground pipe type) to soil-gas collector (a below ground pipe type) (see Note 1 of Table 6); the rubber coupling/adaptor should be installed under the sealed ground cover.
K Discharge Separation—Vent stack discharge must be separated from openings into occupiable spaces (see 6.6.4). Radon vent stacks should terminate above the ridge of the highest roof.

ASTM E 1465-08

5. Finding Information in ASTM E 1465-08

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. Construction Details (cont.)

Sect.	6. Construction Methods - Table of Contents	Page
6.1	Foundation	5
6.2	Ground Covers	7
6.3	Foundation Walls	8
6.4	Gas-Permeable Layer (See separate ToC)	9
6.5	Radon System Piping (See also Tables 7 (p.13), 8 (p.16) and 10 (p. 22)	22
6.6	Fire Ratings	26
6.7	Crawlspace	26
6.8	Electrical	27
6.9	Labels	27

185

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. Construction Details (cont.)

Sect.	6.4 Gas-Permeable Layer - Table of Contents	Page
6.4.1	Gas-Permeable Layer (See also Table 2 on p. 9)	9
6.4.2	Soil-Gas Collectors (See also Table 4 on p. 10)	11
6.4.3	Pipe Connections to Soil-Gas Collectors (See also Tables 5 - 6 on pp.11 -12; and Fig's 3 – 8 on pp. 15 - 18)	13
6.4.4	Perimeter Drains, Internal and External (See also Table 9 on p. 20)	15
6.4.4.1	General Perimeter Drain Requirements	15
6.4.4.2	Internal Perimeter Drain Requirements (See also Fig.9 on p.19)	18
6.4.4.3	Exterior Perimeter Drain Requirements (See also Fig.10 on p.19)	21
6.4.5	Sealing Gas-Permeable Layer	21

186

ASTM E 1465-08
User Aides are Built into E-1465-08 System
Finding Information in E-1465-08

1. General Information
2. Radon Levels and Tests
3. Construction Details
   - Visual Table of Contents
4. Documentation
   - Labels and Documentation
5. Adobe Reader Tools for ASTM Digital Media

187

ASTM E 1465-08
User Aides are Built into E-1465-08 System
Finding Information in E-1465-08

1. General Information

Sections 4 and 4.4 (p. 4)

Section 4 is a shot summary of E 1465

Section 4.4 is Section 6's abbreviated table of contents.

Table 1 (p. 6)

Table 1 is a list of job steps, to be taken before occupancy, for installing the radon system's components.

188

ASTM E 1465-08
User Aides are Built into E-1465-08 System
Finding Information in E-1465-08

2. Radon Levels and Tests

Section 5 Significance and Use (p. 4)

Section 5 provides the performance goal of E 1465, certain context for establishing the **maximum "acceptable radon concentration"** and a perspective that is useful for specifying the radon system's options.

Section 6.10 Radon Testing …. (p. 29)

Section 6.10 provides information on radon testing.

.

189

ASTM E 1465-08
User Aides are Built into E-1465-08 System
Finding Information in E-1465-08

2. Radon Levels and Tests (cont.)

Section 6.13 (p. 33)

Recommendations to Owner/Occupant

Section 6.13 states that radon systems require maintenance and strongly recommends that radon testing is performed soon after occupancy, and regularly thereafter.

190

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. Construction Details

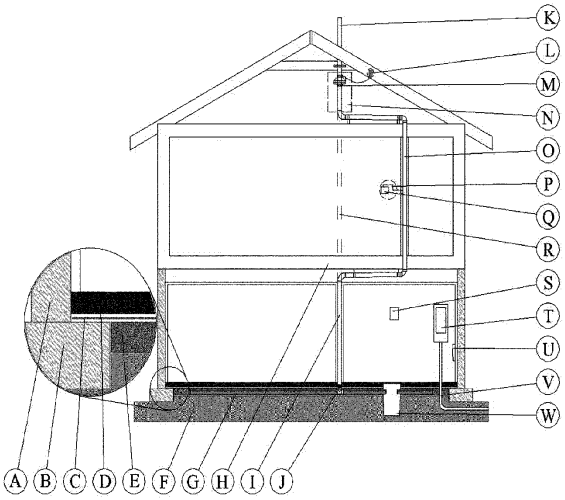


Fig. X2.1 Construction Details

191

ASTM E 1465-08
User Aides are Built into E-1465-08 System
3. Construction Details (cont.)

- **E Gas-Permeable Layer**—A gas-permeable layer/soil-gas collector assembly is required under all slabs and membranes (see 6.4).

  The gas-permeable layer must be sealed on top, on the bottom, and at its sides/edges (see 6.4.5).

  An excellent gas-permeable layer is a 4 in. (100 mm) bed of clean aggregate of (1 to 11/4 in. (25 to 28 mm) broken stone); certain other gas-permeable layer types are permitted (see Table 2).

- **F Soil**—Undisturbed soil is assumed to seal the bottom of the gas permeable layer (see 6.4.5.3).

192

ASTM E 1465-08

6. Review Underlying Concepts

193

ASTM E 1465-08

User Aides are Built into E-1465-08 System
6. Underlying Concepts

- E 1465 uses Soil Depressurization which is the most effective radon reduction strategy available.
- E 1465 provides credible results. Radon testing proves effectiveness in each building.
- E 1465 supports Two Modes of Operation for radon systems:
  - Passive and
  - Fan-Powered

194

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

- For E 1465 systems, the main difference between passive and the fan-powered systems is the vent stack's pipe route.
- Except for pipe route and pipe insulation in certain places, passive and fan-powered system installation is the same.
- E1465 radon systems are built-in and unobtrusive
- Three Possible System Outcomes with E 1465:
  1. Passive – Operating Passive
  2. Fan-Powered – Non-Operating
  3. Fan-Powered – Operating

195

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

- E 1465's Vent Stack with **Passive Pipe Route** becomes:
  - **Passive System** – Operating
    or
  - **Fan-Powered System** – Operating
- E 1465's Vent Stack with **Fan-Powered Pipe Route** becomes:
  - **Not-Operating Fan-Powered System**
    (with no fan installed)
    or
  - **Fan-Powered System** – Operating

196

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

- Two radon test protocols used in E 1465:
  - Initial Radon Test
  - Post-Mitigation Radon Test
- Test protocol differences in E 1465:
  - During Initial Radon Test period
    No mitigation system(s) allowed to operate
  - During Post-Mitigation Radon Test period
    Mitigation system(s) must operate

197

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

- In E 1465 systems with **passive pipe routes are convertible to fan-powered operation.**
- In E 1465 the **radon fan and radon system monitor** are **installed when justified** by radon test result.
- In E 1465 the radon system is considered complete when **documented evidence of acceptable (indoor) radon concentration has been presented to building owner.**

198

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

- Water control measures are not required by E 1465, but if they are installed they must not interfere with radon reduction systems.
- E 1465 has specific requirements for integrating perimeter drains with soil-gas collectors in the gas-permeable layer.

199

ASTM E 1465-08
User Aides are Built into E-1465-08 System
6. Underlying Concepts (cont.)

The purposes of the soil-gas collector are:

1. to eliminate air-flow restrictions in the radon vent stack where it attaches to the gas-permeable layer,
2. to distribute the negative pressure field more evenly through the gas-permeable layer, and
3. to facilitate integration of interior perimeter drains with soil depressurization radon systems.

200

ASTM E 1465-08

The End

Radioactive Radon in Maine

Prepared by

Jonathan Dyer B.S., ESIII - Maine Radon Coordinator

jonathan.dyer@maine.gov

Andrew Hunt B.S., ESII – Assistant Maine Radon Coordinator

andrew.hunt@maine.gov

Phone: (207) 287-5743

Maine Center for Disease Control and Prevention

201