ANSI/AARST **CC-1000** 201X

An American National Standard

Soil Gas Control Systems In New Construction of Buildings

This document does not address 1 & 2 Family Dwellings and Townhouses that are three stories or fewer above grade.

AARST CONSORTIUM ON NATIONAL RADON STANDARDS

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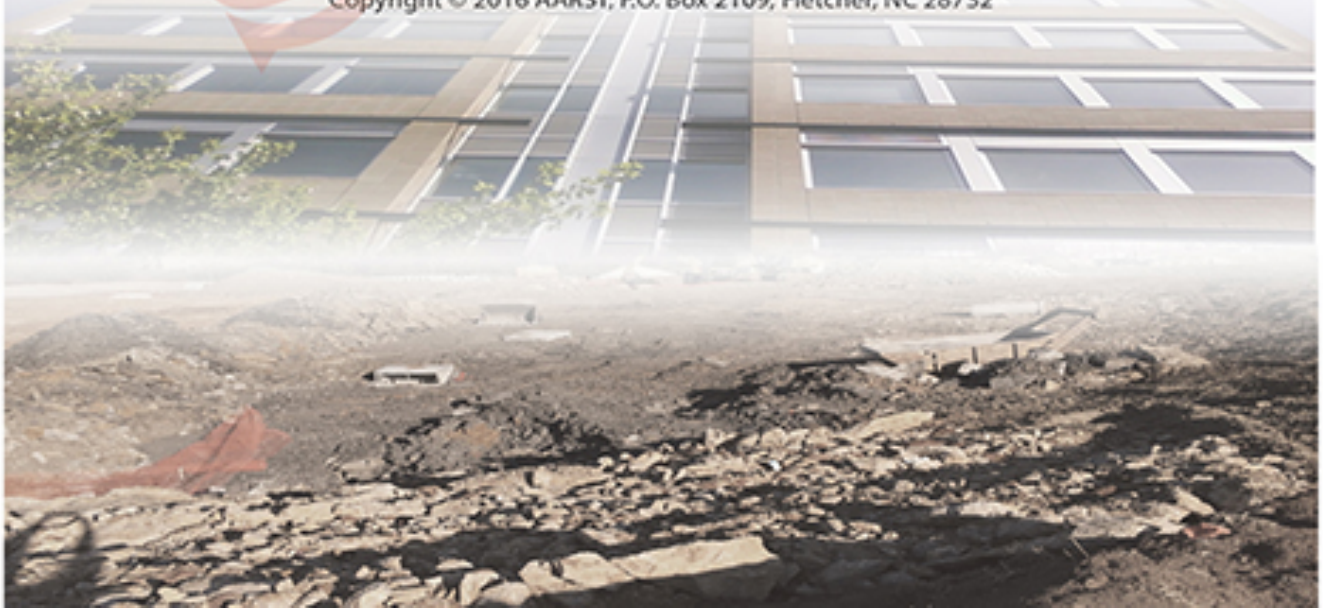

Public Review: CC-1000 *- 09/2016*

Soil Gas Control Systems in New Construction of Buildings

COMMENT DEADLINE: October 31st, 2016

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Rev. 06-01-2008

Scope Summary and Introduction

The provisions in this standard provide prescriptive minimum requirements for the construction of any building intended for human occupancy, except for 1 and 2 family dwellings, in order to reduce occupant exposure to radon and other hazardous soil gases. This standard addresses construction of buildings that include, among others, the use of a building or structure, or a portion thereof for multifamily or congregate residential occupancies, educational occupancies and commercial occupancies.

Significance of Purpose and Historical Perspective

Radon is the second leading cause of lung cancer in the general population and the leading cause of lung cancer among nonsmokers.[1] Radon exposure is the cause of approximately 21,000 U.S. lung cancer deaths each year.[2] This risk is largely preventable.

Since 1988, the Indoor Radon Abatement Act has authorized U.S. state and federal activities to reduce citizen risk of lung cancer caused by indoor radon concentrations. Since the early 1990s, the U.S. Environmental Protection Agency (EPA) has advised all U.S. schools to test for radon and to reduce levels to below 4 pCi/L[3].

In 1999, the National Academy of Sciences confirmed that any exposure to radon holds a degree of risk with publication of BEIR VI. [2] In addition, the Academy's BEIR VII committee stated that exposure to radiation, including any concentration of radon, carries risk.

In 2009, the World Health Organization's *WHO Handbook on Indoor Radon* confirmed the association between indoor radon exposure and lung cancer, even at the relatively low radon levels found in residential buildings.[1]

Initiated in 2010, the U.S. *Federal Radon Action Plan (FRAP),* followed by the *National Radon Action Plan* (NRAP), has highlighted an *ultimate* public health goal of eliminating preventable radon-induced cancer. The FRAP is the result of a collaborative effort led by the U.S. Environmental Protection Agency (EPA) with the U.S. Departments of Health and Human Services (HHS), Agriculture (USDA), Defense (DOD), Energy (DOE), Housing and Urban Development (HUD), Interior (DOI), Veterans Affairs (VA) and the General Services Administration (GSA). And the NRAP, led by American Lung Association, represents a collaborative effort between several federal and national organizations including American Association of Radon Scientists and Technologists (AARST) and the Conference of Radon Control Program Directors (CRCPD).

1 World Health Organization, "WHO Handbook on Indoor Radon: A Public Health Perspective" 2009

2 National Academy of Sciences, "Biological Effects of Ionizing Radiation" (BEIR VI Report) 1999

3 USEPA, "Radon Measurement In Schools", July 1993 (EPA-402-R-92-014)

Development and Maintenance of This Standard

The consortium consensus processes developed for the AARST Consortium on National Radon Standards and as accredited to meet essential requirements for American National Standards by the American National Standards Institute (ANSI) have been applied throughout the process of approving this document.

This standard is under continuous maintenance by the AARST Consortium on National Radon Standards for which the Executive Stakeholder Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form and instructions may be obtained in electronic form at **www.radonstandards.us**

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Notice of right to appeal: **(**See Bylaws for the AARST Consortium on National Radon Standards available at **www.radonstandards.us**.) Section 2.1 of Operating Procedures for Appeals (Appendix B) states, "Persons or representatives who have materially affected interests and who have been or will be adversely affected by any substantive or procedural action or inaction by AARST Consortium on National Radon Standards committee(s), committee participant(s), or AARST have the right to appeal; (3.1) Appeals shall first be directed to the committee responsible for the action or inaction."

Keywords

Radon, Radon Gas, Radon Test, Radon Mitigation, Radon Resistant New Construction, RRNC, New Construction, Schools, Large Buildings, Multifamily

Metric Conversions

Conversions from English-American measurement units to the International System of Units (SI) are rendered herein with literal conversion. The conversions are not always provided in informational text or tables.

Table of Contents

SECTION 1: SCOPE

1.1. General

The provisions in this standard provide prescriptive minimum requirements for the construction of any building intended for human occupancy, except for 1 and 2 family dwellings [4] [5], in order to reduce occupant exposure to radon and other hazardous soil gases.

This standard and informational supplements[6] address construction of buildings that include, among others, the use of a building or structure, or a portion thereof for multifamily or congregate residential occupancies, educational occupancies and commercial occupancies.

1.2 Significance of use

This standard of practice stipulates requirements for design and installation of technologies to:

a) ensure buildings are capable of mitigating soil gas entry;

b) provide a means for qualified personnel to inspect and evaluate mitigation systems installed; and

c) provide responsible practices that can be recommended or adopted for use as requirements of a contract or local jurisdiction.

1.3 Applicability

Radon and other hazardous soil gas can be found in any location regardless of existing surveys, maps or listed sites. Local state radon programs often publish updated information on how often radon has been found locally and an older radon zone map published by EPA (www.epa.gov/radon) can be helpful where local data are not published.

1.4 Non-normative provisions

Provisions not required unless specifically referenced in adopted ordinance, contract or design requirements include: Annex A (Compliance inspections); Annex B (Active soil depressurization required); Annex C (Provide radon test kits); and Annex D (Conduct testing prior to occupancy).

1.5 Limitations

1.5.1 Action levels and guarantees

Compliance with provisions in this standard does not guarantee reduction of soil gas entry to the degree needed to achieve compliance with federal, state or local jurisdiction action levels for radon or other soil gas hazards.

1.5.2 Passive qualities for reducing soil gas entry.

1.5.2.1 Any intended benefits in reducing soil gas entry with passive systems are negated if a continuous sealed barrier has not been established between soil gas and airspaces within a building.

1.5.2.2 Building designs intended to optimize passive benefits can require more *soil gas vent systems* than the minimum requirements herein. In 1994, EPA recommended to rough-in ASD systems during construction of schools and large buildings but did not recommend using passive systems. [7]

1.5.3 Alternate mitigation methods.

Designs that employ heating, cooling or ventilation systems (HVAC) to supplement mitigation shall comply with ANSI/AARST RMS-MF *Radon Mitigation Standards for Multifamily Buildings* or ANSI/AARST RMS-LB *Radon Mitigation Standards for Schools and Large Buildings*, as applicable. Effectiveness requires sustained control of complex pressure relations within a building at all times a building is occupied over the life of the building.

1.5.4 Hazardous soil gases other than radon.

While methods and techniques employed in this standard are applicable for most soil gases, this standard does not include all design and safety features that can be required for soil gas or vapors other than radon. For additional health and safety considerations when the purpose of *soil gas control* is chemical vapor intrusion, see ANSI/AARST SGM-SF “*Soil Gas Mitigation in Existing Homes”*.

1.5.5 Sources of hazardous gas other than soil gas.

This standard does not address mitigation techniques for hazards not associated with soil gas, such as may be needed for airborne radon that results from radon in water, building materials or other less common radon sources

1.5.6 Changes to structure.

Effectiveness witnessed as a result of specifications in this standard cannot be guaranteed to be sustainable where modifications, alterations, structural changes or additions to a building occur.

1.5.7 Prior systems.

This standard shall not apply to systems that have been installed prior to the effective date of this standard.

1.5.8 Safety.

This standard is not intended to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices. It is the responsibility of the user of this standard to determine the applicability of regulatory limitations prior to use.

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4 As point of reference, see the International Building Code (IBC) (as published by the International Code Council) for occupancy groups A, B, E. F, H, I, M and R unless regulated by the regulated the International Residential Code (IRC) (as published by the International Code Council) for 1 & 2 Family Dwellings.

5 For 1 & 2 Family Dwellings, see ANSI/AARST CCAH *"Reducing Radon in New Construction of 1 & 2 Family Dwellings and Townhouses”*

6 For details on technology and best practices, see the *CC-1000 Companion Guidance Document"*

7 *"Radon Prevention in the Design and Construction of Schools and other Large Buildings"* EPA/625/R-92/016

SECTION 2: TERMS AND DEFINITONS

Terms not defined herein have their ordinary meaning as defined in "Webster's Collegiate Dictionary."

ACTIVE SOIL DEPRESSURIZATION (ASD). A fan-driven system to create a vacuum beneath a structure that is greater in strength than the vacuum applied to the soil by the building above.
BASE (OR BASE COURSE). The layer of *gas permeable* material on top of the subbase and directly under the slab
BRANCHES. Air duct piping that routes air from only one inlet or inlet network.
COLLECTION WELLS. Pits that are designed as a soil gas inlet or to transition or join multiple trunks or branches of an inlet trunk network.
CRAWL SPACE. A foundation type with an open area beneath livable or enclosed spaces that typically has either a concrete slab or earthen floor and is surrounded by foundation and/or partition components that typically includes flooring above the soil.
EQUIVALENT LENGTH. The resistance of a duct and additional resistance caused by a pipe elbow, valve, damper, orifice, bend, fitting, or other obstruction to flow, expressed in the number of feet of straight duct or pipe of the same diameter that would have the same resistance.
EXHAUST. A pipe or other piece of apparatus through which soil gases escape or are discharged.
EXHAUST PIPING. Sometimes referred to as a riser pipe, main stack or vent pipe, these air duct *trunk* or *branch* pipes transfer air between soil gas inlets or inlet networks within the Soil Gas Collection Plenum and the outside air exhaust location above the roof.
GAS PERMEABLE LAYER. Void space or permeable aggregate that allows hydraulic conductivity for soil gas movement into and across a *soil gas collection plenum.*
HYDRAULIC CONDUCTIVITY. The capacity of liquids or gas to pass through permeable materials.
INLETS. See *Soil Gas Inlets.*
INLET PIPING. Air duct piping that connects one or more *soil gas inlets* to *exhaust piping*.
INLET TRUNK NETWORK. Air duct pipe configuration that connects one or more *soil gas inlets* to *exhaust piping*.
MAIN TRUNKS. Air duct piping that routes the entire system air volume capacity from the soil gas collection plenum(s) to the system exhaust or termination point. Above slab main trunks are commonly referred to as the "main stack" or "riser pipe".
MITIGATION SYSTEM. Any system designed to reduce indoor concentrations of radon or other soil gas pollutants.
PLENUM. See *Soil Gas Collection Plenum*
PRIMARY TRUNKS. *Main trunks* that directly adjoin an ASD fan.
QUALIFIED MITIGATION PROFESSIONAL. An individual that has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon mitigation: a) as established in certification requirements of the National Radon Proficiency Program (NRPP) or the National Radon Safety Board (NRSB); and b) as required by statute, state licensure or certification program, where applicable.
RADON (Rn). A colorless, odorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium-226 (Ra-226) atoms. The atomic number is 86. Although other isotopes of radon occur in nature, in this document, radon refers to the gas Rn-222. Rn-222 is measured in picocuries per liter (pCi/L) or in becquerels per cubic meter (Bq/m^3)
SECONDARY TRUNKS. Air duct piping that routes only a portion of the system air volume capacity from more than one inlet.
SOIL GAS. Air within soil that can contain radon or other hazardous gasses or vapors.
SOIL GAS COLLECTION PLENUM. A three-dimensional enclosure, in whatever shape it may be, constructed for collecting radon and other soil gases from under slabs, soil gas retarders and from behind walls that surround a void or gas-permeable layer. This description of the cavity under a foundation observes that there are at least six sides to this enclosed airspace and that none are perfectly sealed, especially at the side facing soil.
SOIL GAS CONTROL. Planned control of soil gasses to reduce radon concentrations or other pollutants in the indoor air of a building.
SOIL GAS INLETS. Air transfer openings to the face of adjoining granular aggregate or soil sometimes referred to as suction points for ASD systems.
SOIL GAS RETARDER. Pliable plastic sheeting that establishes a barrier between soil gas and enclosed spaces within a building. Commonly referred to as "vapor barrier."
SOIL GAS VENT SYSTEM. Individual and complete configuration for controlled soil gas venting that includes *exhaust vent piping* extended from *gas permeable materials* within a *soil gas collection plenum(s)* to the system exhaust at the roof.
SUBBASE. A layer of gravel on top of the subgrade.
SUBGRADE. Native soil (or improved soil), usually compacted.
SYSTEM. See *Soil gas vent system*
TRUNKS. Air duct piping. See *Main Trunks* and *Secondary Trunks*

SECTION 3: REQUIREMENT SUMMARY

3.1 General.

Soil gas control shall be designed and constructed for all portions of foundation systems where there is enclosed space immediately above *crawl spaces* and slab-on-grade or basement slabs.

3.2 Soil gas vent systems required.

Soil gas vent systems shall be constructed for each ground contact portion of the building except garages ventilated in accordance with Section **4.8**. Each *soil gas vent system* shall include *exhaust piping* extended from *inlets* within *soil gas collection plenum(s)* to an exhaust location at the roof, in accordance with Sections **4** through **10**.

3.2.1 Each *system* shall be sized with no less capacity needed to allow a fan-driven *soil gas depressurization system (ASD)* to transport air volumes sufficient to establish a vacuum under each slab or *soil gas retarder*.

3.3 Air pressure within the building.

Building design shall include a review of air pressure relationships expected to result from individual HVAC systems and building features that can naturally induce negative air pressures (e.g., building height, elevator shafts, and stairwells). Corrections shall be made, as needed, to control the influences of building air pressure on soil gas entry in accordance with Section **11**.

3.4 Materials and specifications.

All materials specified for piping and *gas permeable* aggregates that are different from materials intended for the building design shall be appropriate for similar structures including acceptable tolerances for weight distribution across aggregate and piping below the slab. A qualified structural professional shall be consulted if there are uncertainties in meeting this requirement.

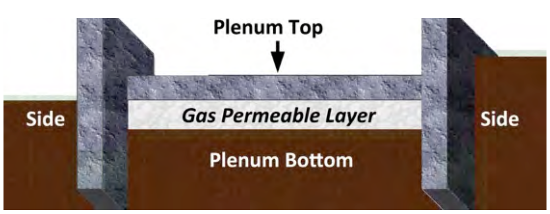
3.4.1 Changed Designs: When changes to the mitigation design are required due to the needs of structural systems or other building systems, the changed design features shall retain *system* capacity required in Section **3.2.1**.

SECTION 4: SOIL GAS COLLECTION PLENUMS

4.1 General.

Each *soil gas collection plenum* shall contain a *gas permeable layer* meeting specifications stipulated in Section **5.5** and be constructed with surrounding surfaces in a manner to sustainably restrict airflow between the *gas permeable layer* and spaces outside the enclosing surfaces of the *soil gas collection plenum.*

Figure 4.1 Example construction of plenum



4.1.1 Plenum bottom (e.g., subbase or subgrade).
The bottom of each *plenum* shall be constructed to achieve natural closure by way of earthen materials or geosynthetic methods in accordance with Section **5.1**.

4.1.2 Plenum sides (e.g., foundation walls).
Openings in the surrounding sides of each *plenum* shall be closed in accordance with Section **5.2**.

4.1.3 Plenum top (i.e., the surface facing interior spaces).
The top of each *plenum* shall be closed as specified in Section **6** to result in a continuous sealed barrier between soil gas and airspaces within the building. Concrete floors that form the *plenum* top shall be sealed in accordance with Section **6.2**. *Soil gas retarder membranes* over earth that form the *plenum* top where building design does not include concrete floors shall be installed in accordance with Section **6.3**.

4.2 Plenum size calculations.

The size of each individual *plenum* shall first be calculated from the inside perimeter dimensions of the surrounding foundation walls.

4.2.1 Divisions.
Utility piping, ductwork, thickened slab supports, grade beams or other obstruction that restricts airflow across a *gas permeable layer* shall be deemed the edge boundary of a *plenum* and thereby divide the gas permeable expanse into two or more individual *plenums.*

4.2.2 Foundation drain systems.
Exterior foundation drain systems that connect to *soil gas collection plenums* under the building shall be calculated for size based on the area of wall and foundation surfaces that adjoin permeable materials constructed to enhance groundwater drainage.

4.3 Soil gas vent systems per plenum size.

An independent *soil gas vent system* with an *exhaust* pipe extended from the *soil gas collection plenum* to the roof shall be installed with *exhaust pipe* sizing no less than specified in Table **4.3** for each individual *plenum* and combined set of joined *soil gas collection plenums.*

Table 4.3*	
4.3.1	**Basic Configuration**
Nominal Inside Pipe Diameter	Maximum nominal size of *Soil Gas Collection Plenum(s)* per duct size
3 inch [7.6 cm]	2,500 square feet (232 m^2)
4 inch [10.2 cm]	4,500 square feet (418 m^2)
6 inch (15.2 cm)	10,000 square feet (929 m^2)

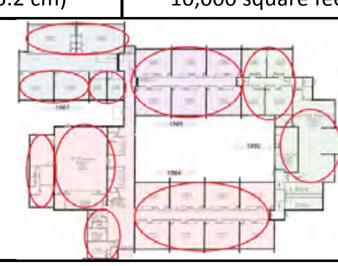


Figure 4.3

Table 4.3 Continued	
4.3.2 Credit Allowance for Inspected Plenums	
If inspections are conducted in accordance with Sections **5.10.2** and **6.5** verify compliance with Sections **5** and **6**, the maximum size of *Soil Gas Collection Plenum(s)* for these duct sizes shall be:	
Nominal inside pipe diameter	Maximum nominal size of *Soil Gas Collection Plenum(s)* per duct size
3 inch (7.6 cm)	3,500 square feet (325 m^2)
4 inch (10.2 cm)	6,200 square feet (575 m^2)
6 inch (15.2 cm)	14,000 square feet (1,300 m^2)
4.3.3 Additional Credit Allowance for Airtight Barriers	
If, in addition to Section **4.3.3**, a durable air barrier is provided between soil gas and indoor air that is virtually airtight (e.g., spray applied vapor barriers or other geomembranes intended to form homogenous closure), the maximum size of *Soil Gas Collection Plenum(s)* for these duct sizes shall be:	
Nominal inside pipe diameter	Maximum nominal size of *Soil Gas Collection Plenum(s)* per duct size
3 inch (7.6 cm)	4,000 square feet (372 m^2)
4 inch (10.2 cm)	7,100 square feet (660 m^2)
6 inch (15.2 cm)	16,000 square feet (1,486 m^2)
4.3.4 Penalty for Non-Compliance (Inadequate Plenum Closure or Gas Permeable Layers)	
Nominal inside pipe diameter	Maximum nominal size of *Soil Gas Collection Plenum(s)* per duct size
3 inch (7.6 cm)	1250 square feet (116 m^2)
4 inch (10.2 cm)	2250 square feet (209 m^2)
6 inch (15.2 cm)	5,000 square feet (465 m^2)
Any passive design	0 square feet (0 m^2)
Regardless of cause (e.g., design constraints, poor coordination or misdirected installation), these maximum sizes in Section 4.3.4 for *Soil Gas Collection Plenum(s)* and duct sizes shall apply to result in additional systems if either: a) a continuous sealed barrier between soil gas and airspaces within the building is not constructed or corrected to meet sealing requirements in Section **6**; or b) *gas permeable layers* and *soil gas Inlets* are not constructed to fully comply with Sections **5.5** and **5.7**.	

* Cross-sectional equivalent for inside pipe diameter is permitted.

4.4 Collective expanses and individual *plenum* size.

No less than 90% of any 4,500 square foot (418 m^2) slab or membrane expanse shall be vented by *soil gas inlets* that are joined to a *soil gas vent system.*

4.5 Joined *plenums.*

Multiple *plenums* joined from below or above a slab or membrane to a single *soil gas vent system* shall be permitted for *plenums* constructed with the same *gas permeable layer* specifications. To join multiple *plenums:*

a) The configuration of each plenum shall comply with Table **4.3** regarding duct pipe sizing in relationship to the individual *plenum* size*;*

b) The configuration of each plenum shall comply with Sections **5.5** through **5.8.5** in relationship to the connection of *soil gas inlets* for each *gas permeable layer;* and

c) *Exhaust pipe* sizing in relationship to the combined size of all *plenums* joined to each *soil gas vent system* shall comply with Table **4.3**.

4.6 Joined *soil gas vent systems.*

Multiple *soil gas vent systems* shall be permitted to join a larger *primary trunk exhaust pipe* for connection to a single exhaust location. Primary trunk *exhaust piping* that joins multiple *soil gas vent systems* shall be not less than the combined nominal cross-sectional area for inner diameters of all joined *exhaust pipes.*

Exception: Smaller primary trunk *exhaust piping* is permitted if supported by prorated calculations for the cross-sectional equivalent of duct pipe size of each *exhaust pipe* that is allocated by design to the size of each plenum or if supported by diagnostic evaluations in accordance with Section **7.4**.

4.7 Limiting *plenum* and *vent system* size.

Design considerations shall include conditions that can sometime warrant restricting the size of certain plenums, such as: to limit unintended transport or distribution of toxic vapors or explosive gas or to compartmentalize active soil gas control for specific occupied locations.

4.8 Garages not required.

Ventilated garages attached to a foundation system do not require *soil gas vent systems* if they meet or exceed requirements of Section 404 in the International Mechanical Code[8] for ventilation and pressurization of enclosed spaces adjoining the garage with the addition of ventilation and/or pressurization for enclosed spaces directly above garages.

SECTION 5: PLENUM CONSTRUCTION

5.1 Close the bottom of the *soil gas collection plenum(s)*.

5.1.1 Subgrade surface closure.

Existing or constructed materials that surround the bottom and sides of *gas permeable layers* and permeable components of foundation drain systems shall be earthen materials that contain more than 35% sand, rock fragment fines, clay and silt to restrict permeability; or be covered at all locations that do not meet this requirement with a *soil gas retarder* that is not overlapped or sealed at seams or edges.

[8] The International Mechanical Code (IMC) as published by the International Code Council.

5.1.2 Grade drainage.

Grading below *gas permeable layers* shall be sufficient to prevent collected water from obstructing portions of *inlet piping*, suction pits or *inlet trunk networks* within *soil gas collection plenums*.

5.2 Close the sides of the *plenum(s)* before installing gas permeable materials.

5.2.1 Gaps and penetrations through walls and footings.

Openings below grade in walls and footings that surround *soil gas collection plenums* shall be closed with appropriate cementious or damp proofing products to include all openings around utility penetrations for plumbing or electrical components and any other openings of similar or larger size.

5.2.2 Waterproofing.

All foundations walls and floors in contact with the soil shall be damp proofed or waterproofed. Waterproofing methods shall be consistent with Section 1805 of the International Building Code. [9]

5.2.3 Gaps and seams on exterior wall surfaces.

All gaps and seams on the exterior surface of foundation wall assemblies shall be closed, sealed or damp proofed to include where walls adjoin footings and attached garages, exterior parking lots, sidewalks, porches, steps and other adjoining constructed closures over soil.

5.2.4 Hollow masonry unit walls.

In a manner that forms a closed barrier between soil gas within the hollow masonry units and interior spaces, a course of hollow block masonry walls that is not vertically lower in elevation than the adjoining exterior grade shall be made of solid masonry units or shall be fully grouted. Closure is required for all openings in the wall below this closed course of masonry units, including:

a) fully grouted or solid masonry units shall surround openings in the wall such as for doors, windows and under masonry ledges such as often provided for brick veneer; and
b) all joints between blocks on both interior and exterior surfaces shall be fully grouted.

5.3 Foundation drain systems.

Requirements for *soil gas vent systems* shall apply to exterior foundation drain systems if an interior *soil gas collection plenum* is connected to an exterior foundation drain system.

5.3.1 The portions of exterior foundation drain systems that are constructed below grade with materials to enhance permeable paths for water drainage (e.g., gravel, perforated pipe or drainage mats) shall be constructed to include:

a) Closure to restrict airflow between outside air and the drainage system's water receptors, in accordance with Section **5.3.2**;
b) Closure to restrict airflow between outside air and the drainage system's disposal components in accordance with Section **5.3.3**; and
c) Inclusion in design for *soil gas vent systems* in accordance with Sections **4.2**, **4.3** and **5.3.4**.

5.3.2 Water receptors *(ground or surface water).*

Closure shall be provided for grade-level drains and open pipes above grade such as roof or window well drains that drain into the exterior foundation drain system. Closure shall be accomplished by surrounding piping and pipe ends with aggregate or soil, capping open pipes, or one-way flow valves with access provided for future maintenance or equivalent materials or methods.

5.3.3 Water disposal *(over ground or storm sewer).*

Closure for water discharge piping that opens to outside air or connects to a storm sewer shall be provided by means of a one-way flow valve with access provided for future maintenance or equivalent method.

5.3.4 Exterior foundation wall drainage.

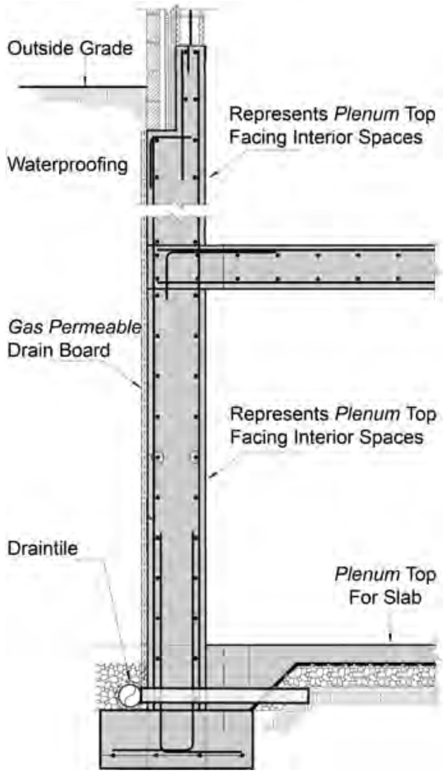
Portions of exterior foundation wall surfaces that directly adjoin native or fill soil and are more than 3 feet (1 m) vertically higher in elevation than adjoining interior *soil gas collection plenums* are not required to be included in calculations for the size of *joined plenums* or constructed as *soil gas collection plenums*. These exterior foundation wall surfaces shall however be waterproofed in accordance with Section **5.2.2** to include all seams and openings in the wall in accordance with Section **5.2.3**. When gas permeable materials or drainage products do adjoin these exterior foundation walls, closure of openings to outside air in accordance with Sections **5.3.2** and **5.3.4** is required. See figure **5.3**.

5.3.5 Foundations below the water table (e.g., wetlands).

Where it is known that foundation walls and floors will frequently be below the water table for extended durations, an evaluation shall be made for the expected vertical elevation of the water table both during floods and during droughts. When the water table is expected to be above the basement floor throughout the year, *plenums* below the foundation are not required. If the water table is expected to recede below the foundation for extended durations, *soil gas collection plenums* with *soil gas vent piping* shall be constructed with attention to duct routing design and *soil gas inlets* below the slab. Designs options that do not penetrate the slab can include ducting from the exterior side rather than through the slab.

[9] The International Building Code (IBC) 2015 (as published by the International Code Council).

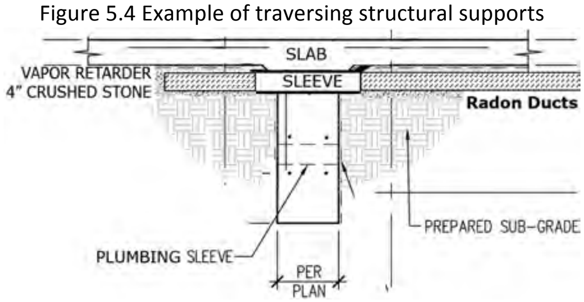
Figure 5.3 Example of foundation drain systems that inherently form *soil gas collection plenum* configurations that are rotated sideways.



5.4 Footings and joined *plenums.*

A means shall be designed and constructed to prevent obstruction from poured concrete and collected water for openings or ducts that traverse structural supports (e.g., footings, grade beams and thickened slab areas). Commonly, a pipe sleeve is placed and secured prior to casting structural supports for this purpose. When geotextile mats are used for ducting, the mat is commonly mounted to a flat surface to extend ducting across structural supports prior to casting concrete.

Figure 5.4 Example of traversing structural supports



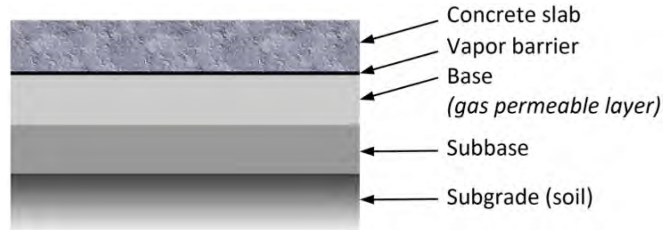
5.4.1 When air transfer is constructed with an opening (e.g., under partition doorways) rather than ducted with pipe, the size of the openings shall be no less than required in Section **5.7.1** for open *inlets.* When the opening is filled with gravel, it shall be sized to accommodate the combined area for unobstructed openings between stones as required in Section **5.7.1**.

5.5 Gas permeable layers.

5.5.1 General.

A gas permeable layer shall be provided under the top of each *plenum* (e.g., concrete slab or vapor barrier) as often described as the location for base course aggregate.

Figure 5.5.1 Construction example



5.5.2 Gas permeable layer configurations.

Each gas permeable layer shall consist of aggregate or void space that allows *hydraulic conductivity* for air movement across the *gas permeable layer*. To ensure sufficient hydraulic conductivity, the *gas permeable layer* configuration shall be one of the following:

a) A uniform layer not less than 4 inches (10 cm) in depth of gravel or crushed stone that meets ASTM C33 requirements for size numbers 5, 56, 57 or 6.

   These aggregates contain a high percentage of nominally 3/4-inch (19mm) stone with less than 5% fines; or

b) A void space that allows unabated air movement across the entire *soil gas collection plenum* such as under plastic membranes placed over open soil in crawl spaces or engineered voids under concrete; or

c) Sand, fine gravel and soils if permitted and with systems configured in accordance with Section **5.5.3**.

5.5.3 Sand, fine gravel and soils.

Materials as specified in Table **5.5.3** shall be permitted when all of the following design features are provided:

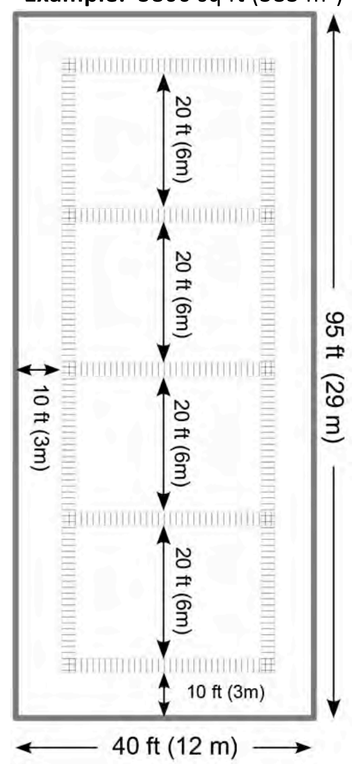
a) A uniform layer of the aggregate not less than 4 inches (10 cm) in depth is provided or exists;

b) Main trunk, secondary trunk or branch ducting, such as within geotextile drainage matting or perforated pipe are placed within the gas permeable layer at distances no greater than 20 feet (6 m) apart. When using perforated piping, the piping shall be placed in a trench backfilled with clean aggregate meeting the criteria of Section **5.5.2.a** surrounding the pipe on at least 2 sides. The cross-sectional area of the aggregate and pipe soil gas collector shall be at least 50 square inches (323 sq cm);

c) Inlets into the ducting are to be no closer than 12 inches (30 cm] and no further away than 10 feet (3 m) from foundation walls or other surfaces that represent the sides of the soil gas collection plenum; and

d) The configuration or duct network shall provide no less than 1.0 in^2/ft (6.5 cm2/m) of unobstructed inlet openings to aggregate in a continuous manner across the developed length of perforated pipe or face of geotextile drainage matting.

Table 5.5.3
Alternative Gas Permeable Layer Requirements

Options	Allowed If Including Required System Design Features	Restricted Use	Example Of Required System Design Features
Smaller Stone Option	This option shall be in accordance with size numbers 467, 67, 7, and 8 as classified by ASTM C33. These aggregates contain a high percentage of nominally 3/8-inch (9.5 mm) stone.		**Example:** 3800 sq ft (383 m^2) 
Sand Option	This option shall be in accordance with size number 9 as classified by ASTM C33. These aggregates contain a high percentage of nominally 0.2 inch (4.75 mm) to 0.1 inch (2 mm) granules.	Not permitted for fine sands, silt and clay with more than 10% of the aggregate < 0.05 inch (1 mm).	
Soil Option	This option shall be native soil existing at the building location with uniform characteristics for fragmental aggregate. The native soil shall consist of too little fine earth to fill interstices larger than 1 mm between stones, cobbles, gravel and very coarse sand particles after compaction occurs.	Not permitted when containing more than 35% of sand, rock fragment fines, clay and silt. Not permitted when containing more than 10% high plasticity clay or silt (e.g., expansive soil with a liquid limit ≥50%)	

5.5.4 Other gravel or crushed stone options.

5.5.4.1 A uniform layer of gravel or crushed stone not less than 4 inches (10 cm) in depth with size numbers 1, 2, 3, 4 and 367 as classified by ASTM C33 shall be permitted as an alternative to **Section 5.4.2a** if confirmed to be acceptable for:

a) structural support requirements of the building or slab; and
b) sustainable integrity of adjoining soil gas retarders.

These aggregates contain a high percentage of 3-inch (75 mm) stone; 2-inch (50 mm) stone; 1.5-inch (37.5 mm) stone; or 1-inch (25 mm) stones, respectively.

5.5.4.2 Gravel or crushed stone size #67 as classified by ASTM C33 shall be permitted as an alternative to Section 5.4.2a when applied as a uniform layer not less than 8 inches [20 cm] in depth and *inlet* size is doubled or augmented to achieve compliance with Section **5.7.1**.

This aggregate contains a high percentage of nominally 3/8-inch (10mm) stone with less than 5% fines

5.5.5 Depth of gas permeable aggregates

5.5.5.1 Exceeding required 4-inch depth (encouraged). Uniform layers of *gas permeable* aggregates shall be permitted to exceed 4 inches (10 cm) in depth, as sometimes desired for enhanced pressure field extension (PFE) or needed to prevent potential damage to concrete that is supported inconsistently as a result of subgrade soil adjoining fixed height surfaces (e.g., blocks or rigid piping).

5.5.5.2 Limits on less than 4-inch depths.
Portions of *gas permeable layers* that are less than 4 inches (10 cm) in depth that can result from limited maneuverability of grading machinery are permitted only to the extent that the hydraulic conductivity for air movement across the nominal breadth of *gas permeable layer* is not reduced.

5.6 Duct sizes above and within the *gas permeable layer*.

Table 5.6 Cross-sectional Area Dimensions	
Pipe ID (inner diameter)	**Cross-sectional Area**
2-inch (50 mm)	3.1 sq. in. (20 cm^2);
3-inch (75 mm)	7.1 sq. in. (46 cm^2)
4-inch (100 mm)	12.6 sq. in. (81 cm^2)
6-inch (150 mm)	28.3 sq. in. (182 cm^2)

5.6.1 *Primary* and *main trunk* sizing.
Duct piping for *exhaust vent pipes* or within *soil gas collection plenums* that route the entire system air volume from the *soil gas collection plenum(s)* to the system exhaust location shall not be less in size than required in Table **4.3**.

5.6.2 *Secondary trunks* and *branches.*
Smaller duct piping that routes only a portion of the system air volume shall be sized in accordance with Table **4.3** as applicable for each individual plenum and comply with Section **5.7** for inlet capacity.

5.6.3 All duct sizing.
All ducts, including *secondary trunk* and *branches* that route only a portion of the system air volume, shall not be less in size than the nominal cross-sectional inside diameter of 3-inch (7.6 cm) pipe.

Exceptions: When provided for condensate control or when it is known that a fan-driven air volume less than 40 cfm (1.1 m^3/min) is adequate to establish a vacuum within a *soil gas collection plenum.* For these situations, *branch* piping or *secondary trunks* that are not less than 2-inch (50 mm) ID are permitted in lengths to individually not exceed the *equivalent length* of 25 feet (7.6 m). Such pipes shall not be used for soil gas control with plenums that are more than 800 square feet (74 m^2) in size.

5.6.4 Size changes.
The size of *exhaust vent piping* between the connection to *inlets* or *inlet ducting* below the top of the *plenum* and the point of discharge or termination at the roof shall not be reduced in the direction of airflow toward the exhaust location.

Exception: It shall be permitted to reduce pipe size in the direction of airflow toward the exhaust location when pipes larger than the minimum size for the *main trunk* or *secondary trunks* are employed along the pipe route for a particular purpose, such as to: join larger sized *inlets*; minimize pressure loss; facilitate condensate control or to slow airflow velocity in an effort to reduce noise.

5.6.5 Transitions.
Transition connections between different materials or shapes shall maintain cross-sectional dimensions of the connected *main trunk, secondary trunk* or *branch* ducting.

5.6.6 Airflow resistance within *Inlet trunk networks*.
The design and construction of *Inlet trunk networks* below a slab or membrane shall include consideration to avoid excessive airflow resistance at the furthest distances away from the location of the network transition to *exhaust piping*. Examples of concern include piping with *equivalent lengths* that exceed:

a) 75 feet (23 m) for 3-inch (7.6 cm) pipe;
b) 150 feet (46 m) for 4-inch (10.2 cm) pipe; and
c) 440 feet (134 m) for 6-inch (15.2 cm) pipe.

5.7 Soil gas *Inlets* and airflow capacity

5.7.1 Individual *inlet* minimum capacity *(gravel)*.
For gravel or crushed stone classified by ASTM C33 as sizes #1 through #6, the combined total area for unobstructed openings between stones that adjoin an open void within a suction pit or perforations in perforated pipe shall be not less than **twice** the equivalent cross-sectional diameter of the duct pipe size applicable to the size of the *plenum* as specified in Section **4.3**. See Table **5.7.1**.

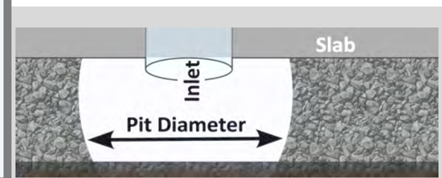
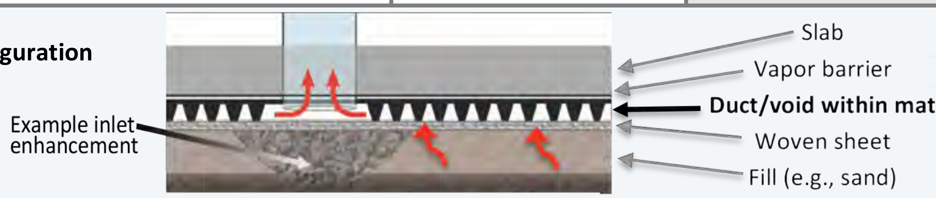
5.7.2 Inlets under *soil gas retarders* in crawl spaces.
The configuration shall be constructed to ensure the air transfer openings extend under all portions of the *soil gas retarder(s)*. In addition:

a) Inlet openings shall be no less than 12 inches (30 cm) away from the sides of the *plenum*;
b) The combined total area of *inlet* openings for perforations and open ends of pipe shall be not less than **twice** the equivalent cross-sectional diameter of the duct pipe size applicable to the size of the *plenum* as specified in Table **4.3**.
c) At a minimum, perforated pipe or equivalent material not less than 10 feet (3 m) in length and 3 inch (7.6 cm) nominal diameter shall be provided for each connection to *trunk* or *branch* piping.

5.7.3 Whole system minimum *inlet* capacity.
The combined total area of all unobstructed inlet air transfer openings on the face of aggregate or soil shall be not less than **twice** the equivalent cross-sectional pipe diameter required in Section **4.3**, *"Soil gas vent systems per plenum size."*

Exceptions: Inlets adjoining layers of sand, fine gravel and soils shall be in accordance with Section **5.5.3**. Void space constructed without obstruction under concrete shall have inlet openings not less than the equivalent size required in Table **4.3**.

Table 5.7.1 Examples Of Minimum Inlet Air Transfer Capacity

Minimum surface-face for gravel size numbers 5, 56, 57 or 6 to achieve required air transfer openings between stones.		Common Examples:		
			 Equivalent openings per length of perforated pipe	
Duct pipe size	**Minimum surface face of the gravel**	**Open face of gravel for pits with a 4" (10 cm) layer gravel.**	Minimum for ASTM F705, F758, D2729, AASHTO 252: *1.0 in^2/ft (6.5 cm^2/m)*	*Other product examples*
3" (7.6 cm)	214 sq in (1,383 cm^2)	= 4" x 12" diameter pit (10 cm x 30 cm)	3" x 18 ft (5.4 m)	
4" (10.2 cm)	381 sq in (2,458 cm^2)	= 4" x 16" diameter pit (10 cm x 33 cm)	4" x 32 ft (10 m)	4" x 7 ft (2.3 m) *2.0 in^2/ft (19.5 cm^2/m)*
6" (15.2 cm)	857 sq in (5,531 cm^2)	= 4" x 24" diameter pit (10 cm x 61 cm)	6" x 71 ft (22 m)	6" x 40 ft (12 m) *2.0 in^2/ft (19.5 cm^2/m)*
Example Geotextile Mat Configuration				

5.7.4 Inlet obstructions (perforated pipe).

5.7.4.1 Perforated pipe shall be oriented or augmented to provide unobstructed *inlet* openings to soil gas while also providing water drainage from the bottom portion of the piping. The calculation for openings to soil gas in perforated pipe as specified in Section **5.7.1** shall not include openings that are effectively closed by virtue of adjoining surfaces of *soil gas retarders,* concrete or packed soil. Drainage of these air ducts shall include no less than one 1/2-inch (1.3 cm) diameter opening located near the bottom of piping for every 10 feet of developed duct pipe length.

5.7.4.2 Pipe perforations shall not be large enough to allow gravel to enter and obstruct the duct. Where perforated pipe is placed in a layer of sand or small stone, materials or methods shall be employed to not allow sand or small stone to enter perforations and thereby obstruct the duct.

5.7.5 Geotextile mats and woven fabric products.

5.7.5.1 The void space within the mat represents air duct piping and shall comply with Section **5.6** including retention of cross-sectional dimensions for *main trunk, secondary trunk* or *branch* ducting and transitions. Soil gas *inlet* surfaces or openings shall comply with Section **5.7**.

5.7.5.2 Woven geotextile products such as those intended to retain integrity for the size of inlet openings and ducting shall not be used as a standalone *inlet*, duct or *gas permeable layer*.

5.8 Transition connection to *exhaust vent piping*.

5.8.1 General.

Rigid, non-perforated piping in accordance with specifications stipulated in Section **9** *(Soil gas exhaust vent pipe)* shall be configured to transition from *soil gas inlets* or *inlet trunk networks* within *soil gas collection plenum(s)* to above the concrete slab or *soil gas retarder* membrane that represents the top of the *plenum*.

5.8.2 Transition air volume and pressure loss.

The portion of non-perforated piping or materials configured to connect between *soil gas inlets* or *inlet trunk networks* to above the concrete slab or *soil gas retarder* membrane shall be:

a) sized no less than the *exhaust vent pipe* (e.g., *main trunk, secondary trunk* or *branch* pipe) above the concrete slab or *soil gas retarder* membrane and retain flow capacity in accordance with Section **5.6**; and

b) included in calculations for maximum pipe length as stipulated in Section **8.5**, *"Exhaust vent pipe length and pressure loss."*

5.8.3 Future Connection to *Exhaust Piping*

Exhaust vent piping that transitions from the *gas permeable layer* to above a slab or membrane shall extend no less than 2 feet (60 cm) above the slab or membrane and shall be temporarily capped or closed during construction to prevent debris from entering. The portion of pipe that will reside above the slab or membrane shall be marked or labeled with the words "*radon* vent," "*soil gas* vent" or similar wording.

5.8.4 Sump inlets not permitted.
Inlet openings in the form of duct or exhaust piping are not permitted on sump lids.

5.8.5 Collection wells or pits.
Pits that are designed to transition or join multiple trunks or branches shall be permitted as a means to minimize pressure loss where multiple ducts are joined.

Figure 5.8.5a Example Well/Pit: Open to Soil Gas

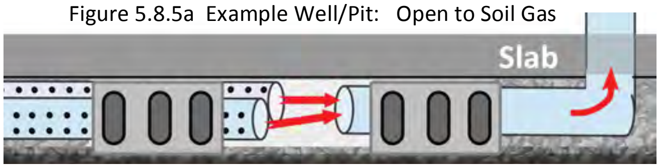
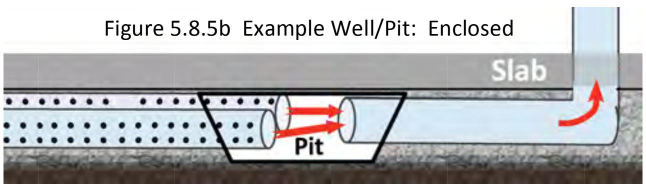


Figure 5.8.5b Example Well/Pit: Enclosed



5.9 Test ports.
Test ports required in Section **7** shall be installed prior to closure of membranes over soil and casting of slabs when drilling through a cured slab will present hazards or could compromise other building systems such as:

a) post-tension slabs with steel tendons;
b) radiant heat systems with heat conveyance components located within or under a slab); and
c) spray-applied vapor barriers and geomembranes intended to form a homogenous closure for chemical containment.

5.10 Prior to placement of concrete or soil gas retarders.
5.10.1 Secure the ducting.
All subslab or submembrane fittings shall be mechanically fastened, taped or secured in a manner to help avoid dislocation that can occur during installation of aggregate, *soil gas retarders* and concrete.

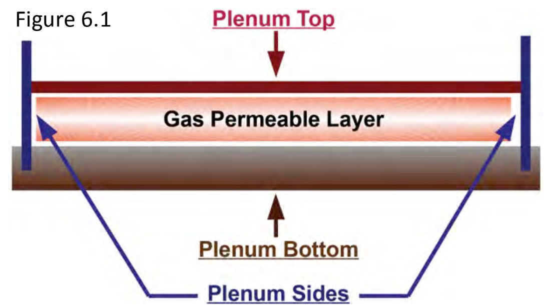
5.10.2 Inspect the open plenum.

Notice: This provision is not mandatory unless:
*a) required for exercising design options for larger soil gas collection plenums in accordance with Sections **4.3.2** and **4.3.3**; or*
*b) specifically referenced in contract or local ordinance. See **Annex A**.*

An inspection shall be conducted prior to placement of concrete or soil gas retarders over a *gas permeable layer* to verify that all inlets and ducting are secured and that *gas permeable layer* materials and closed surroundings are compliant with this standard. The inspection shall include items listed in **Exhibit 1**. A record of the inspection(s) shall be retained in accordance with Section **12**.

SECTION 6: CLOSE THE TOP OF THE PLENUM

Figure 6.1



6.1 General.
A continuous sealed barrier is required between the gas permeable layer and the interior of the building to break the air transfer connection between soil and indoor air. The capacity for the closure of concrete floors and *soil gas retarders* to degrade over time shall be considered when choosing materials and methods for sealing the top of the soil gas collection plenum(s). Considerations shall include:

a) building settlement or movement;
b) shrinking or cracking of building materials; and
c) potential needs to access mechanical systems under floors.

6.2 Closure of concrete floors.
Soil gas retarder material shall completely cover the area under the concrete floor and be placed between the gas permeable layer and the concrete slab. The *soil gas retarder* materials and installation shall be no less than specified in Section **6.4**.

Exception: Alternatives to the *soil gas retarder* are permitted only where *ASD* fans are installed concurrently with the *soil gas vent system* and a continuous sealed barrier between soil gas and indoor air is constructed to achieve sustainable closure including requirements of Section **6.2.3**.

6.2.1 Above the *soil gas retarder.*
The concrete floors shall be cast directly upon a *soil gas retarder* with the following exceptions:

a) Where sheet foam board insulation or woven geotextile matting is installed under the concrete floor, it is permitted that the *soil gas retarder* be installed below the foam board insulation or woven matting; and
b) A thin layer of fabric or fill material for water drainage or protection of the *soil gas retarder* is permitted between the *soil gas retarder* and the concrete floor when the layer is no greater in depth than is required for such purposes. Appropriate considerations include: the potential for groundwater above a *soil*

gas retarder to pool and leach into the concrete to cause moisture concerns on the top sides of the slab, and aggregate fills above the *soil gas retarder* that can introduce a radon source not previously present and not addressed herein.

6.2.2 Construction joints in interior concrete floors.

Permanent closure shall be provided for all concrete joints around the perimeter of each slab and at all expansion or contraction joints by means of:

a) gasket materials made of closed cell polyethylene that are manufactured for filling joints and have a tear-off edge strip. These products can retain closure of joints after concrete shrinkage from curing; or
b) caulk applied after the concrete cures with caulk that complies with ASTM C920 class 25 or higher or equivalent. The curing period before caulk is applied shall be 28 days unless a qualified concrete or structural professional has verified concrete mixtures allow a shorter curing period; or
c) caulk applied prior the complete curing of concrete if a structural professional verifies that concrete shrinkage is expected to result after curing in joints that are less than 1/8th of an inch (4 mm) in width. The verification shall consider the concrete mixture and the slab size(s).

6.2.3 Molded or saw-cut control joints in concrete floors.

In any situation where a *soil gas retarder* is not placed between the slab and the gas permeable layer, all molded or saw-cut control joints shall be sealed with caulk complying with ASTM C920 class 25 or higher or an equivalent method.

6.2.4 Openings and penetrations.

Openings and penetrations in the top of all soil gas collection plenums shall be sealed against air leakage to include openings around plumbing, *exhaust vent pipes*, mechanical piping, structural supports and gaps to the inside of hollow structural posts and electrical conduits that are open to soil.

Sealing of the penetration or opening shall be achieved with caulk that complies with ASTM C920 class 25 or higher or equivalent, closed cell gasket materials or equivalent method. When caulk is used to seal a crack, joint or opening greater than 1/2 inch (13 mm) in width, foam backer rod or other comparable filler material shall be inserted into the joint to support the caulk as it cures.

6.2.5 Block-outs and pits.

Prior to completion of room finishings, openings in the concrete slab that are constructed to facilitate plumbing or other utility needs shall be closed with non-shrink grout, sealed covers or other appropriate method.

6.2.6 Sump pits.

Sumps or other pit openings in interior floors that connect to soil air and require access for maintenance shall have a rigid lid that is sealed with gasket material or silicone caulk and mechanically fastened in a manner to facilitate removal. The lid shall be made of sturdy and durable plastic such as polycarbonate plastic or other rot-resistant, rigid material sufficient to support anticipated loads in the area of use. Pipe and wiring penetrations through the lid shall be sealed. Gaps between the intersection of the sump basin and the floor or membrane shall be sealed with a caulk complying with ASTM C920 class 25 or higher, or equivalent method.

6.2.6.1 Pits that receive water from above concrete or *soil gas retarders* shall be provided a means to retain water control capabilities of the sump such as an independent floor drain with a one-way flow valve or other mechanical means.

6.2.7 Floor drains.

Floor drains and condensate drains shall not allow *soil gas* entry. Access openings in the floor provided for drain maintenance shall not allow *soil gas* entry.

6.2.8 Air ducts.

Air ducts located below concrete slabs or *soil gas retarders* shall be sealed to prevent *radon* entry and constructed in accordance with the International Mechanical Code (IMC)[10].

6.2.9 Label sealed components.

A label or marking shall be provided for sump lids, block-outs, access openings and other closed surfaces that could require access in the future to indicate these are components of a mitigation system. The label title shall state “Component of a Radon Reduction System” or similar wording and include additional text such as “Return to a closed condition if opened, accessed or damaged.”

The labels or markings shall be placed on the component and/or located in a conspicuous place or places (such as at access panels).

6.3 Crawl space earthen floors

6.3.1 General.

A *soil gas retarder* shall be installed to cover the top of all exposed earth not covered by concrete in a manner that conforms to all contours of the grading with materials and installation no less than specified in Section **6.4**.

6.3.2 Seal the perimeter of the *soil gas retarder*.

The *soil gas retarder* membrane shall turn up onto foundation walls not less than 6 inches (15 cm) and shall be continuously sealed to the wall along the full perimeter.

a) For flat wall surfaces, the membrane shall be sealed to the foundation walls and supports with a caulk

[10] The International Mechanical Code (IMC) as published by the International Code Council.

complying with ASTM C920 class 25 or higher or equivalent method.

b) For irregular surfaces, alternative materials and methods are permitted so long as durable closure of the soil gas collection plenum is achieved.

6.3.3 Penetrations (*soil gas retarders*).
The opening for penetrations of a *soil gas retarder* described in Section **6.2.2** shall be as small as practical and sealed in a permanent, airtight manner. Appropriate seal materials shall be applied for exhaust vent piping and other utility pipes such as gasket fittings, pipe clamps or an appropriate sealant. Other openings in the *soil gas retarder* such as for sumps, drains and air ducts located within a crawl space shall be sealed in accordance with Sections **6.2.3** through **6.2.8.**

6.3.4 Surface water relief (crawl space *soil gas retarders*).
Designs shall include a plan to address surface water that can accumulate on the top of the membrane due to ground water entry from above the membrane or plumbing leaks. The plan shall include access to the crawl space for remedial action or systems such as sumps or trapped drains that are adequate for control of collected surface water.

6.3.5 Label crawl spaces or *soil gas retarders*.
A label or marking shall be located in a conspicuous place or places (such as on the *soil gas retarder* and at access panels) to identify that the membrane is a component of a mitigation system. The label title shall state "Radon Reduction System" or similar wording and include additional text such as "Return the *soil gas retarder* membrane to a closed condition if accessed or damaged."

6.4 Materials and installation for all *soil gas retarders.*

6.4.1 Under Concrete Slabs.
Polyethylene sheeting of not less than 6 *mils* (0.152 mm) in thickness or equivalent (e.g., cross-laminated polyethylene sheeting of not less than 3 *mils* [0.076 mm] in thickness) shall be installed in accordance with Section **6.3.2**. Alternative products include spray-applied vapor barriers and geomembranes intended to form a homogenous closure for chemical containment.

6.4.2 Over crawl space earthen floors.
The *soil gas retarder* membrane shall meet ASTM E1745 Class A, B or C and be installed in accordance with Sections **6.3**, **6.4.3** and **6.4.4**. For crawl spaces or portions of a crawl space that are expected to be regularly accessed for maintenance, storage or other purposes, thicker materials or protection of the membrane can be appropriate and the *soil gas retarder* shall be fastened to the walls in a durable manner.

6.4.3 Seams.
The seams between adjacent membrane sheets shall be overlapped not less than 12 inches (30 cm) and shall be sealed by one of the following methods:

a) A tape recommended by the membrane manufacturer; or
b) Caulk compliant to ASTM C920 class 25 or greater; or
c) An equivalent method.

6.4.4 Repairs.
Tears or punctures in the membrane shall be sealed by one or more of the following methods:

a) A tape recommended by the membrane manufacturer; or
b) An additional sheet of the membrane material that covers and overlaps the tear or puncture not less than nominally 12 inches (30 cm) on all sides and that is sealed with a caulk complying with ASTM C920 class 25 or greater; or
c) An equivalent method.

6.5 Inspect plenum closure prior to indoor finishings.

Notice: This provision is not mandatory unless:

*a) required for exercising design options for larger soil gas collection plenums in accordance with Sections **4.3.2** and **4.3.3**; or*
*b) specifically referenced in contract or local ordinance. See **Annex A**.*

Prior to completion of indoor finishings, an inspection shall be conducted to verify compliance with this standard and ensure a continuous sealed barrier has been constructed between soil gas and airspaces within the building. The inspection shall include items listed in **Exhibit 2**. A record of the inspection(s) shall be retained in accordance with Section **12**.

SECTION 7: PRESSURE FIELD EXTENSION EVALUATION

7.1 General.

After slabs have been cast or soil gas retarders in crawl spaces have been installed, an evaluation of newly constructed *soil gas collection plenums* shall be conducted to verify that no changes are needed for the design of *exhaust vent pipe* assemblies that will soon be constructed. The evaluation shall include connecting a fan to the *primary trunk* of the *exhaust vent pipe* and measuring the resulting vacuum within the *gas permeable layer(s)* at strategic locations.

7.2 Test port locations.

Strategic locations of test ports shall include all of the following locations:

a) Test port locations remotely distant from the *exhaust vent pipe* transition to below the slab or soil gas retarder that are sufficient in number to:
    i) evaluate effectiveness of soil gas transport across the major expanse of the slab or membrane; and
    ii) evaluate consistency of soil gas transport across *soil gas collection plenums* that are joined to a shared *exhaust vent pipe.*

b) Not less than one test port for each outer quadrant area of the building while also achieving one test port for each *soil gas vent system* and each *soil gas collection plenum* joined to a single *soil gas vent system;* and

c) For larger expanses allowed in Section **4.3.3** and **4.3.4**, not less than one test port for each outer quadrant area of *soil gas collection plenums* that are 8,000 sq. ft. (744 m^2) or larger while also achieving one test port for each additional 8,000 sq. ft. (744 m^2) area;

Exception**:** Where there are no openings or utility penetrations through the slab or soil gas retarder, test ports are not required for plenum areas that are less than 64 square feet (6 m^2), or collectively represent less than 10% of any 4,500 square foot (418 m^2) area.

7.2.1 Preinstalled test port locations.

Where test ports are installed prior to casting slabs as required in Section **5.9**, additional test port locations shall include:

a) ground contact rooms designed to be under significant negative pressure (e.g., certain industrial use kitchens, clean-rooms or similar); and

b) additional locations, as required, for measuring concentrations of hazardous soil gas or vapors.

7.3 Test port design.

Test ports required for evaluating PFE and/or soil gas concentrations are most commonly created by drilling 1/4 to 1-inch (6 mm to 2.5 cm) diameter holes through the slab with care to vacuum debris from each hole to achieve unobstructed air transfer of soil gas. The test ports shall be:

a) closed at the top during and after construction but reasonably accessible for future measurements without destructive or significant disassembly of building components or finishes;

b) installed in a safe manner so as not to present hazards to future occupants; and

c) prominently documented in as-built diagrams.

7.3.1 Preinstalled test port design.

Each port opening above the slab shall be in an accessible location in accordance with Section **5.9** and either:

a) replicate a vertically drilled 1/4 to 1-inch (6 mm to 2.5 cm) diameter hole through the slab; or

b) connect with tubing that is 1/4 to 1-inch (6 mm to 2.5 cm) inner diameter to a remotely located port opening within the *gas permeable layer(s).*

7.3.1.1 Open ends of the port tubing within the *gas permeable layer(s)* shall be inserted into a constructed void space in a manner that achieves an unobstructed inlet for air transfer that will not be compromised during construction. For example, 1/2-inch (1.3 cm) ID tubing should be inserted into a constructed void space not less than 1 pint (0.5 L) in size or into perforated pipe not less than 1 foot (30 cm) in length for equivalent air transfer capacity.

7.3.1.2 Port tubing shall extend from the port inlet(s) to above a slab or membrane in accordance with Section **5.8.3** and result in being unobstructed with durable qualities associated with tubing in conduit. The tubing shall be resistant to rust degradation and if chemical contaminates are known to be in the soil, an environmental engineer shall be consulted for choosing products that are resistant to chemical degradation.

7.4 The PFE evaluation.

The pressure measurements shall be recorded and compared for evidence of:

a) Poor effectiveness (i.e., unexpectedly low vacuum at all test ports associated with the same *exhaust vent pipe*); and

b) Inconsistencies (i.e., unexpected differences between vacuum at one test port compared to another test port that is associated with the same *exhaust vent pipe*.)

If poor effectiveness or inconsistency is indicated, a *qualified professional* shall conduct an investigation to identify unclosed openings in the *soil gas collection plenums(s)* and any changes that may be needed for number and locations of soil gas inlets and *exhaust vent pipes*.

SECTION 8: SOIL GAS EXHAUST VENT PIPE

8.1 General.

Exhaust vent pipes (i.e., vent pipe, riser pipe, *primary trunk* or *main trunk*) shall be sized and configured to comply with Sections **4.2**, **4.3**, **5.5** and **5.8**.

8.2 Slope.

Exhaust vent piping shall have a slope of not less than 1/8 inch per foot (3.2 mm per 30 cm) that slopes downward towards the soil. The developed length for any sloped section of horizontal pipe in excess of nominally 15 feet (5 m) shall be avoided to the extent practicable. When the required slope or drainage cannot be achieved, other methods for draining collected water shall be provided.

8.3 Prevention from air and water leakage.

All *exhaust vent piping,* except the intake and exhaust locations, shall result in an air and water tight duct system.

8.3.1 *Exhaust vent piping* that extends between the location designated for an *ASD fan* and the point of exhaust outside the building shall not be installed in, or pass through or pass under the conditioned space of the building.

8.4 Pipe support.

Above ground piping shall be supported by the structure of the building using hangers or strapping designed for piping support. Supports for plastic horizontal piping shall be installed at intervals not exceeding 4 feet (1.2 m) and supports for vertical piping shall be installed at intervals not exceeding 10 feet (3 m). Support locations and pipe routing shall include consideration to inhibit both lateral and vertical movement of duct piping that can result in compromised pipe joint connections and avoid of locations susceptible to blunt force impact. Duct piping and fans shall be mounted and secured in a manner that minimizes transfer of vibration to the structural framing and finishes of the building.

8.5 *Exhaust vent pipe* equivalent length and pressure loss.

From its connection at the soil (i.e., *gas permeable layer* materials) to the point of exhaust at the roof, *exhaust vent piping* shall be nominally no more than these *equivalent lengths*:

a) 75 feet (23 m) for 3-inch (7.6 cm) exhaust piping;
b) 150 feet (46 m) for 4-inch (10.2 cm) exhaust piping;
c) 440 feet (134 m) for 6-inch (15.2 cm) exhaust piping.

The calculated *equivalent length* for duct pipe materials that do not have smooth inner surfaces shall be nominally reduced with a goal of no less than 1 WC inch pressure loss, or reduced by 25%.

8.6 Piping materials.

The exhaust vent piping that extends from the *soil gas collection* plenum to the point of exhaust shall be rigid, non-perforated pipe that is suitable for drainage of condensate water, which occurs naturally and consistently within piping.

8.6.1 PVC piping.

PVC pipe shall comply with ASTM D2665, F891 or F1488. The pipe wall thickness shall be Schedule 40.

8.6.2 Alternative materials.

Alternative materials specified in codes for "Subslab Soil Exhaust Systems"[11] shall be permitted such as ABS plastic pipe and iron, steel, copper or other materials permissible by code. Alternative pipe materials that do not meet durability specifications in ASTM D1785 for Schedule 40 shall be permitted as an alternative material for use only when within enclosed wall cavities. Support for above ground alternative duct pipe materials shall be in accordance with code[12] and manufacturer specifications.

8.7 Joints.

Plastic pipe joints shall be solvent welded.

8.7.1 PVC plastic pipe joints.

The joint surfaces for PVC plastic pipe and fittings to be solvent welded shall be prepared with a primer conforming to ASTM F656. PVC plastic pipe joints shall be solvent welded in accordance with the pipe manufacturer's instructions with solvent cement conforming to ASTM D 2564.

8.7.2 Alternative pipe materials.

Alternative pipe materials identified in Section **8.6.2** (e.g., ABS plastic, iron, steel and copper) shall be joined in accordance with the pipe manufacturer's instructions and as required by code.

8.7.3 Flexible coupling disconnects.

Where disassembly may be required in the future for maintenance purposes, the disconnect shall consist of two unconnected portions of pipe joined with a flexible coupling that complies with ASTM D5926, ASTM C1173 or an equivalent method. Allowable uses for a flexible coupling disconnect shall include:

a) where joining duct piping materials that are incompatible for solvent welding;
b) at locations where physical constraints inhibit the ability to join duct pipe materials by means of a solvent weld;
c) at locations allowed by code to provide temporary access to areas requiring maintenance or inspection, such as access to mechanical equipment by removal and airtight replacement of duct pipe sections; and
d) to minimize noise by breaking the direct transfer of fan vibration energy to other duct piping.

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[11] As a point of reference for alternative piping, see the International Mechanical Code (IMC) Section 512.2 (as published by the International Code Council).

[12] As a point of reference for alternative piping support, see the International Mechanical Code (IMC) Section 303 (as published by the International Code Council).

8.8 Pipe routing and thermal insulation.

8.8.1 Routing duct pipe within the building.
When *ASD* fans are not installed concurrently with the *soil gas vent system*, *exhaust vents*:

a) shall not adjoin exterior building walls or traverse other locations, except attics, where the piping is exposed to temperatures that can be colder than indoor air, and
b) shall be provided with insulation that has an R-value of no less than 4 or greater where *exhaust piping* extends through attics or other areas that are outside the heated and cooled envelope of the building.

8.8.2 Insulation required.
As required by codes or climate conditions, duct piping shall be provided with insulation.

8.8.2.1 Where it is likely on a regular basis (e.g., annually or every few years) that freezing temperatures will result with ice buildup within duct piping that would adversely affect long-term system performance, duct piping shall be provided with insulation that is protected from the elements and has an R-value of no less than 4 or greater depending upon climate extremes.

8.8.2.2 Where it is likely that condensation will occur on the exterior surface of duct piping to the extent damage would occur to adjacent building materials, duct piping shall be provided with insulation having an external vapor barrier and an R-value not less than 1.8.

8.9 Provision for ASD fan(s).

8.9.1 Fan location.
A location for each *ASD fan* shall be identified. The location designated for *ASD fans* shall be only outdoors, in attics or in garages that meet ventilation requirements of Section **4.3.5**. The location for *ASD fans* shall only be on vertical *exhaust vent piping. Exhaust vent piping* from the designated ASD fan location(s) to the termination point of *exhaust pipe* outside the building shall not be located inside or below conditioned or occupiable space.

8.9.2 Fan installation access (attics).
A space having a vertical height of not less than 48 inches (122 cm) and a diameter of not less than 21 inches (53 cm) shall be provided where the *ASD fan* will be installed if required. The *ASD* pipe shall be centered in this space. The *exhaust pipe* at this location shall be labeled or marked with the words "*radon* fan location," "*soil gas* fan location" or similar wording.

8.9.2.1 Fan service access (attics).
Service access shall be provided for each *ASD fan* location in an attic to allow installation of *ASD fans* and replacement of same. The service access entry shall be located not greater than 20 feet (6 m) from the *ASD fan* location unless access meeting Section 306.3 of the International Mechanical Code[13] is provided.

8.9.3 Fan mounting and activation.
ASD fans shall not be mounted to *exhaust piping* that connects to soil gas unless they can be electrically energized within three days.

8.9.4 Electrical.
Conductors from a dedicated breaker shall be provided within 6 feet (1.8 m) of *ASD fan* locations to supply a boxed outlet. The boxed outlet shall be labeled or marked with the words "*radon* fan," "*soil gas* fan" or similar wording. The breaker shall provide continuous service when activated and shall not be joined to mechanical or automated systems that could deactivate the breaker.

8.9.4.1 Collateral mitigation (electrical):
When a single mitigation system is designed to satisfy mitigation needs in more than one unit, dwelling or area within a shared building, power provided to the system shall be from a source that is electrically metered independent from individual units unless the meter is common to all units, dwellings or areas.

8.9.4.2 Label the breaker.
The receptacle and the over-current device for the branch circuit that would supply the *ASD fan* shall be labeled or marked with the words "*radon* fan," "*soil gas* fan" or similar wording.

8.9.5 Provision for ASD fan monitor(s).
The location for fan monitors (e.g., pressure gauge) shall be designated and labeled during construction in accordance with Section **12.1.1** or **12.2.9**, as applicable, unless the system is designed to be remotely monitored. Fan monitor locations shall be readily accessible for occupants or building staff to view or inspect the fan monitor(s):

a) in locations frequently visited by building staff; or
b) in locations frequently visited by occupants when an individual *soil gas vent system* is designed to satisfy the mitigation needs of only one unit, dwelling or area within a shared building; or
c) in locations that are accessible and visible or audible for all occupants of the building; or
d) in no less than two areas divided for separate occupancy use when an individual *soil gas vent system* is designed to satisfy mitigation needs in more than one unit, dwelling or area within a shared building.

8.9.5.1 Physical access to fan monitors.
When *exhaust piping* at the designated location for a fan monitor is to be enclosed, access panels shall be provided to allow physical access to the monitor. The access panels shall meet applicable fire-rating requirements.

[13] As point of reference for required service access in attics, see the International Mechanical Code (IMC) Section 306.3 (as published by the International Code Council).

8.9.5.2 Remotely located fan pressure monitors.

When the designated location for a fan pressure monitor does not immediately adjoin *exhaust piping*, rigid tubing shall be provided between the *exhaust piping* and the inlet hose of the pressure monitor.

8.9.5.3 Labeling required.

The *exhaust pipe* at the designated location for each fan monitor shall be labeled or marked to include the words "This location reserved for a fan monitor should a soil gas fan be installed," or equivalent wording. Related components, such as access panels and exposed remote monitor tubing, shall be labeled or marked to identify that the item as a component of a *radon* or *soil gas* vent system.

8.10 Labels required for *exhaust piping*.

8.10.1 *Exhaust vent piping* shall be labeled or marked on each floor level of the building and within each room or accessible service area that *exhaust piping* traverses.

8.10.2 The label or marking shall identify that the item is a component of a *radon* or *soil gas* vent system.

8.10.3 The labels or marking shall be at intervals not greater than 20 feet [6 m] along the developed length of *exhaust piping*.

8.10.4 Label or marking locations on *exhaust piping* that are exposed and not enclosed behind walls shall be visible within eyesight of approaching service personnel.

SECTION 9: EXHAUST LOCATIONS

Distance requirements in Section 9 shall be measured around intervening obstacles.

9.1 Outdoors.

The exhaust of all *soil gas vent systems* shall be to the outdoors and shall be directed upward without obstruction to exhaust airflow at an angle that does not deviate more than 45 degrees from a vertical exhaust trajectory.

9.1.1 Protection from debris.

Wire mesh or equivalent rodent/insect screen (mesh not smaller than 1/2 inch [13 mm]) shall be provided at the point of exhaust to prevent debris or small animals from entering.

9.1.2 Not permitted.

Rain caps, horizontal discharge and downward discharge configurations shall not be permitted.

Exception: In certain regions or locations where conditions such as pervasive torrential rain or blockage from falling debris are known to be a concern.

9.1.3 Damage to building materials.

The exhaust shall not be installed in a manner that would allow the airflow from a fan-driven exhaust to directly strike building materials such as exterior walls or roof eaves.

9.2 Elevation and vertical walls.

The point of exhaust shall be located:

a) not less than 10 feet (3 m) above grade nearest the point of discharge;
b) not less than 1 foot (30 cm) above a pitched roof at the point penetrated and not less than 18 inches (46 cm) above a flat roof;
c) not less than 6 inches (15 cm) above vertical walls and enclosing roof components (e.g., parapet roof or walls adjoining equipment wells) that are located within 10 feet (3 m) horizontally from the point of *exhaust*; and
d) not less than 10 feet (3 m) horizontally from a vertical wall that extends above the roof penetrated.

9.3 Windows, doors and other openings.

The point of exhaust shall be not less than 2 feet (60 cm) above or not less than 10 feet (3 m) horizontal distance away from openings created in a structure or an adjacent structure for operable windows, operable doors and other gravity intake openings normally associated with dwellings or similarly sized occupiable units in low-rise structures.

Exception: Ventilation openings into attics, provided that the attics do not contain mechanical air handling systems or sizable passive openings that allow attic air to mix with the air inside occupiable areas.

9.4 Equipment air intakes.

For openings created in a structure or an adjacent structure for mechanical equipment air intakes, to include fan-driven intakes and gravity intakes for mechanical systems, the point of exhaust shall be:

a) not less than 30 feet (9 m) in distance away from mechanical equipment air intakes; or
b) not less than 5 feet (3 m) above the top of mechanical equipment air intake openings that are between a 20-foot (6-m) and 30-foot (9-m) horizontal distance away from the point of exhaust; or
c) not less than 10 feet (3 m) above the top of mechanical equipment air intake openings that are less than a 20-foot (6-m) horizontal distance away from the point of exhaust.

9.5 Decking, patios, sidewalks or exterior corridors.

The point of exhaust shall be not less than 10 feet (3 m) above or a 20-foot (6-m) distance away from exterior flooring surfaces where individuals traverse or congregate that are above or horizontal to the point of discharge.

9.6 Inspect the soil gas exhaust vent pipe prior to completion of indoor finishings.

*Notice: This provision is not mandatory unless specifically referenced in contract or local ordinance. See **Annex A**.*

Prior to completion of indoor finishings, an inspection shall be conducted to verify compliance for *soil gas exhaust vent piping* in accordance with Sections 8 through 9. The inspection shall include items listed in **Exhibit 3** and be retained in records in accordance with Section 12.

SECTION 10: COMPLETION OF SYSTEMS

10.1 Labeling or marking required for all systems.

Labels or markings shall be provided within eyesight or in conspicuous places in accordance with the sections listed in Table **10.1**.

Table 10.1 Labeling or Marking Required For All Systems	
6.2.9	Sealed components
6.3.5	Crawl space membranes and/or access hatches
8.9.1	Designated location for mounting *ASD fans*
8.9.4	Electrical conductor boxes
8.9.4.2	Electrical breakers
8.9.5.3	Designated fan monitor location
8.10	*Exhaust piping*
11.5	HVAC components associated with mitigation

10.1.1 Label specifications

All labels shall be made of durable materials. All label lettering and other annotation on systems shall be of a color in contrast to the color of the background on which the lettering is applied. All label titles as specified within each provisions identified in Table **10.1** shall be provided in lettering of a height of not less than 1/4 inch (6.35 mm). Additional information on the labels, where approproate shall have lettering of a height of not less than 1/8 inch (3.18 mm).

10.2 Systems with no active fan (e.g., ASD fan)

System completion includes the documentation required in Section **12**.

10.3 Activation with ASD Fan.

10.3.1. Fan monitor label.

A label shall be provided at each designated location for fan monitor(s) identified for the system in Section **8.9.5.3**. The label's title shall state, "Soil Gas Vent System," "Radon Vent System" or similar description and the label shall include the following information:

a) A description of the fan monitor(s) to include:
   - How to interpret the monitor;
   - A list of actions to take if the fan monitor indicates system degradation or failure; and
   - A routine inspection advisory to check the monitor(s) at least quarterly or as otherwise specified in an operational and maintenance plan;

b) An advisory statement that the building should be tested for *radon* at least every 2 years or as required or recommended by state, local or federal agencies;

c) Additional information resources, such as *radon* resources at www.epa.gov/radon and the *radon* hotline 1-800-SOS-RADON (767-7236); and

d) The words "For information, contact: ____."

   (Insert name and phone number of the installer or party designated responsible for operation, maintenance, monitoring and management of the system(s).

10.3.2 Fan Installation.

ASD fan selections shall be determined by a qualified radon professional and installed in accordance with the manufacturer's instructions.

10.3.3 Flexible coupling connectors required.

ASD fans shall be connected to the *ASD* piping using flexible unshielded couplings complying with ASTM D5926 or ASTM C1173 or an equivalent method. Connections shall be air- and water-tight.

10.3.4 Fan start-up.

ASD fans shall be electrically energized upon installation in the *ASD* system piping.

10.3.5 Disconnect required.

Where the fan is not cord and plug connected, a means of electrical disconnect shall be provided for, and in eye sight of, the *ASD fan*.

10.3.6 ASD fan monitors required.

Each *ASD* fan shall be provided with a system negative pressure monitor to indicate system operation. The fan monitor shall be simple to interpret and located in accordance with Section 8.9.5.

Exception: If telemetric indicators/remote monitors are integrated in the system or if the visual or audible monitor:

a) indicates when the fan(s) has no power; or
b) indicates when a fan is outside the intended performance range.

10.3.6.1 Monitor durability:

Fan monitors, including if located outside of a building, shall be protected from the elements and durable for the situation.

10.3.6.2 Automatic reset.

Pressure activated electrical *ASD* system monitors, whether visual or audible, shall be supplied by un-switched electrical circuits and designed to reset automatically when power is restored after power supply failure. Battery operated monitoring devices shall not be used except where they are equipped with a low power warning feature.

SECTION 11: HVAC EVALUATIONS REQUIRED [14].

11.1 General:

The intended building design and mechanical ventilation systems shall be evaluated by a heating and cooling design specialist for natural and mechanically induced negative pressure in enclosed spaces with respect to:

[14] For general applicability of these methods and impact on other indoor air quality issues, see *"Indoor Air Quality Guide – Best Practices for Design Construction and Commissioning"* published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). www.ashrae.org

a) locations below and to the side of the exterior foundation surfaces that adjoin soil and other earthen aggregates; and
b) adjoining parking garages that are not constructed with *soil gas vent systems*.

11.1.1 The evaluation shall include the building design and mechanical system response to changing diurnal and seasonal outdoor temperatures that alter both:

a) pressures induced by mechanical system operation; and
b) natural negative pressure commonly observed in taller buildings due to unobstructed vertical air passageways such as stairwells, elevator shafts and other thermal bypasses between floors.

11.2 Controlled negative pressure.
The combination of HVAC design (e.g., duct balancing and air handler capacity) and compartmentalized isolation of interior airspaces shall be designed to avoid excessive negative pressure with a design goal to result in nominally neutral or positive air pressure within the enclosed spaces. Locations of concern specifically include enclosed spaces that immediately adjoin crawl spaces, slab-on-grade or basement slabs, rooms with walls that adjoin soil and other earthen aggregates, and attached garages.
Exception: Enclosed spaces that are intentionally designed to be under negative pressure (e.g., bathrooms and kitchens).

11.3 Appropriate designs.
HVAC designs for mitigating negative pressure shall be reviewed for: compliance with ASHRAE ventilation standards[15]; unnecessary energy consumption[16]; and design capabilities to accommodate degradation to the system's functionality that often occurs over time.

11.4 Controls.
Controls for mechanical equipment shall be configured and verified after building construction to consistently meet design goals across normal fluctuations in diurnal and seasonal outdoor temperatures.

11.5 Label monitors, controls and startup.
Control settings and fan monitors shall have a label on or in close proximity to the mechanism that describes the purpose of the control and general instructions for operation. System control settings for any mechanical equipment shall be clearly marked to indicate the settings that existed at the time design goals were verified to have been achieved

11.6 Documentation of evaluations and actions.
A written evaluation and related actions shall be provided by the heating and cooling design specialist and included in the operation, maintenance and monitoring (OM&M) manual.

11.7 HVAC use for supplemental mitigation.
The design and installation of HVAC systems shall comply with ANSI/AARST RMS-MF *Radon Mitigation Standards for Multifamily Buildings* or ANSI/AARST RMS-LB *Radon Mitigation Standards for Schools and Large Buildings*, as applicable to the intended use of the building.

SECTION 12: DOCUMENTATION

12.1 Operation and maintenance plan.
A written operations and maintenance plan for the mitigation system(s) shall be created that is suitable for distribution to maintenance personnel and other appropriate parties to provide tools for operating and maintaining systems. The plan shall include stipulations in Section **12.1.1** through Section **12.1.3**:

12.1.1 A description of systems as installed.
Documentation of systems installed shall include narrative that describes:

a) basic operating principles; and
b) system components that are also labeled on a floor plan diagram such as may be complemented with photographic documentation.

12.1.2 Designated responsibilities.
Documentation shall include a statement that indicates what party or parties are responsible for future maintenance and monitoring for effectiveness of the mitigation system(s).

12.1.3 Active systems (ASD and/or non-ASD).
If active systems are installed, the plan shall include all applicable details stipulated in Table **12.1.3** and information regarding fan monitors shall be prominently portrayed to include:

a) A description of the fan monitor(s);
b) A routine inspection advisory to check the monitor(s) at least quarterly or as otherwise specified in an operational and maintenance plan;
c) Documented startup parameters such as pressure gauge readings that existed at the time successful mitigation was initially achieved; and
d) A list of actions to take if the fan monitor indicates system degradation or failure.

[15] For further information, see ANSI/ASHRAE Standard 62.1-2013 "Ventilation for Acceptable Indoor Air Quality" for buildings that are more than three stories tall or ANSI/ASHRAE Standard 62.2-2013 "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings"

[16] For further information, see ANSI/ASHRAE/ USGBC/IES 189.1-2011, "Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings," or ICC 700-2008, "National Green Building Standard for Residential Construction".

Table 12.1.3 Operation and Maintenance (O&M) Plan Requirements for Active ASD and/or Non-ASD Systems
(These steps can be integrated into an overall indoor air quality plan)

Controls and Mechanical System Monitors	Maintenance Inspections of Controls and Monitors	Frequency of Inspection
***Document Startup Details**:* A description shall be provided for the fan monitors, control settings and other operating parameters that existed at the time successful mitigation was initially achieved. The description should include explicit detail for comparison during inspections and repair, including: a) descriptions of equipment labeling and annotations for fan monitors, control settings and other operating parameters; b) exact locations of fan monitors, electronic telemetry/monitoring equipment, permanent test ports,, electrical disconnects and other components; c) instructions for equipment sufficient to interpret labels, annotations and the designed operating parameters for the equipment. When applicable, include manufacturer instructions; d) a list of appropriate actions for the Client(s) to take if fan monitor devices or other inspection procedures indicate the system(s) are not operating as designed; and e) documented measurements for balance of airflow in and airflow out of HVAC system(s) when HVAC is a component of a mitigation system.	The operations, maintenance and monitoring (OM&M) manual provided shall observe that routine inspections of controls and monitors are a minimum obligation and required component of a long-term risk management plan. The following inspections shall be written into the OM&M plan as required actions: a) inspection of fan monitors, control settings and other operating parameters to ensure the system(s) are operating as designed; b) investigation and correction of any conditions that are found to indicate component failure or inconsistencies with designed operating parameters for the system(s); c) maintenance of records assimilated into the overall building OM&M documentation; and The plan shall stipulate that a qualified professional should perform these inspections and if performed by in house maintenance staff, such staff shall be trained in system operations.	The plan shall stipulate recommendations and any requirements for the frequency of inspections of controls and monitors, as deemed appropriate to the situation. It is recommended that the plan stipulate inspections be conducted at least quarterly of all fan monitors, controls and, as applicable, filters and vent openings. The plan should also recommend inspections of mechanical equipment in addition to controls and monitors subsequent to a motor replacement or any catastrophic event that could damage system components.
Mechanical Equipment	**Mechanical Equipment Inspections**	**Frequency of Inspection**
Include Equipment Details and Instructions: a) Include manufacturer instructions and instructions specific to design configurations, as appropriate; b) Documentation should include exact locations of fans, electrical disconnects and other components; and c) Include a list of appropriate actions for the Client(s) to take if the fan monitor warning device indicates system degradation or failure. A list of potential repair items for ASD systems should include: i. fan monitor repair or replacement (e.g., reconnect or replace oil in U-tube); ii. electrical repair; iii. fan or boot replacement; and iv. sealing of foundation openings to soil or piping connections.	The OM&M plan provided shall observe that mechanical equipment inspections should include all seals, straps, fasteners, electrical system (including switch operation), boots, performance indicators, labels, pipe condition, filters, inlet grills and fan operation. If applicable, airflow in and airflow out of HVAC system(s) and duct balance should be checked to ensure that no significant changes have occurred. Examples of HVAC inspection items: i. functionality of HVAC filters; ii. room differential pressure test; iii. fresh-air damper settings; and iv. verification for supply air into rooms of interest.	It is often customary that recommendations include inspection of mechanical equipment by a qualified professional no less than every 2 years.

12.2 OM&M manual.

To provide tools essential for future efforts in long-term risk management, a written operations, maintenance and monitoring (OM&M) manual for the mitigation system(s) shall be created and distributed to appropriate parties upon completion of the project. The OM&M manual shall include all of the following components:

12.2.1 The operation and oaintenance plan as required in Section **12.1**.

12.2.2 Service contact information.
Documentation shall include contact information for design or service inquiries and identification of the persons responsible for adherence to these protocols to include:

a) Name, address and phone number;
b) Relevant radon mitigation certification and/or licensing number; and
c) Signature (manual, or electronic in conformance with the Electronic Signatures in Global and National Commerce [E-SIGN] Act).

12.2.3 Records of inspections, as required, for compliance verification (e.g., **Exhibits 1**, **2** and **3**).

12.2.4 Records of PFE diagnostics conducted in accordance with Section **7** and other diagnostic information.

12.2.5 A written evaluation and related actions regarding natural and mechanically induced negative pressure in enclosed spaces that adjoin soil and garages in accordance with Section **11**.

12.2.6 Any adverse conditions observed.
Documentation shall include a description of any important observations that might adversely affect the mitigation system(s) or other building systems and any deviations from this standard or state requirements.

12.2.7 Other essential information for future reference and operation or repair considerations shall be provided either in an information package that contains the OM&M plan or independently distributed, to include:

a) Pre- and post-mitigation test data if available;
b) Copies of contracts and warranties;
c) Copies of building permits when required and available; and
d) An estimate of the annual operating costs.

12.2.8 A recommendation that a copy of all testing reports for radon and other soil gases be kept with the OM&M manual to facilitate long-term risk management and future operation and maintenance of the system(s).

12.3 OM&M Manual recommendation to test for radon.

The statements regarding radon testing in Sections **12.3.1** through **12.3.4**, or equivalent statements, shall be included in the OM&M manual:

12.3.1 **Radon testing recommended**
• "It is recommended that all new buildings be tested for radon gas after initial construction in accordance with standard practices specified in national[17], federal or state standards regardless of steps taken during building construction to reduce soil gas entry";
12.3.2 **Elevated radon concentrations (e.g., ≥ 4 pCi/L)**
• "If testing at any time indicates concentrations above the action level, it is recommended to conduct evaluations of the mitigation systems(s), corrections and further testing until testing indicates radon concentrations have been mitigated to below the action level. It is recommended that all buildings where elevated radon has been found and mitigated be retested in accordance with standard practices specified in national, federal or state standards at least every 2 years."
12.3.3 **If passive or non-ASD systems are installed**
• "If the mitigation system is based on passive methodologies or includes pressurization or dilution of building air, additional seasonal testing is required. Conduct post-mitigation or diagnostic radon testing during the first year subsequent to construction to verify if system capacity and control settings are effective under stressed or different seasonal conditions. Repeat testing procedures to verify effectiveness is retained for both: a) heating season (i.e., when outdoor temperatures at least at night are less than 65˚ F [18 C]); and b) cooling season (i.e., when outdoor temperatures at least in daytime are greater than 83˚ F [28 C])."

[17] National measurement standards include, as applicable: ANSI/AARST MAMF *"Protocol for Conducting Radon and Radon Decay Product Measurements In Multifamily Buildings"*; ANSI/AARST MALB *"Protocol for Conducting Measurements of Radon and Radon Decay Products In Schools and Large Buildings"*; or ANSI/AARST MAH *"Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes"*.

12.3.4 **Low concentrations (e.g., < 4 pCi/L)**
(per initial testing or after activating mitigation systems)

- Retest the building(s) at least every 5 years and in conjunction with any sale of a building.
- In addition, be certain to test again when any of the following circumstances occur:
  - ✓ A new addition is constructed or alterations for building reconfiguration or rehabilitation occur;
  - ✓ A ground contact area not previously tested is occupied;
  - ✓ Heating or cooling systems are altered with changes to air distribution or pressure relationships;
  - ✓ Ventilation is altered by extensive weatherization, changes to mechanical systems or comparable procedures;
  - ✓ Sizable openings to soil occur due to:
    - ground water or slab surface water control systems are added or altered (e.g., sumps, perimeter drain tile, shower/tub retrofits, etc.); or
    - natural settlement causing major cracks to develop;
  - ✓ Earthquakes, construction blasting or formation of sink holes nearby; or
  - ✓ A mitigation system is altered, modified or repaired.

SECTION 13: ADDITIONAL CONSIDERATION FOR CHEMICAL VAPOR INTRUSION[18] AND OTHER HAZARDOUS SOIL GASES

13.1 Lines of evidence and collective expanses.
When lines of evidence indicate that the spatial distribution of a hazardous gas or chemical of concern may be limited to only one portion of a building, an evaluation shall be made for the appropriateness of limiting *plenum* sizes that are joined to each *soil gas vent system* (e.g., to less than 4,500 square feet [418 m^2] expanses). The criteria for determining appropriate limits shall include the likely need of *ASD fan* control for areas where there is a known soil gas concern.

13.2 Duct pipe materials.
An evaluation shall be made prior to installation regarding corrosive effects that chemicals may have on the iron, steel, copper or other pipe materials.

13.3 Additional *ASD fan* considerations
An explosion-proof fan as specified by codes[19] for appropriateness is required when evaluations of the chemical(s) or substances of concern indicate that gasses passing through the fan could result in a fire, explosion and serious personal injury to workers and building occupants. Most inline fans commonly used for radon reduction are not rated as explosion proof.

13.4 Sealant material considerations.
An evaluation shall be made prior to installation for sealant products used in order to avoid sealant products that are known to have long curing periods or contain constituent chemicals identified for mitigation.

13.5 Soil gas retarder materials.
An evaluation shall be made prior to installation for the known chemical(s) of concern in relationship to manufacturer guidance on soil gas retarder materials to help ensure degradation of the material will not occur over time. For situations where the purpose of the membrane is to help prevent liquids or gases from passing through membrane materials, less permeable products than specified in Section 6.4 *(Materials and installation for all soil gas retarders)* shall be considered.

13.6 System monitors.
In addition to all requirements of Section 9.2 *Fan Monitors*, an evaluation shall be made prior to installation for situations where chemical hazards are present, such as those associated with immediate or short-term acute risk that could warrant additional monitoring such as:

a) pronounced visual or audible notification;
b) continuous gas monitoring as a trigger for the alarm system or for occupant monitoring; or
c) telemetric monitoring services.

[18] For additional health and safety considerations when the purpose of *soil gas control* is chemical vapor intrusion, see ANSI/AARST SGM-SF *"Soil Gas Mitigation in Existing Homes"*.

[19] See the National Electric Code published by NFPA: http://www.nfpa.org

ANNEXES AND RELATED EXHIBITS

ANNEX A (Non-Normative): Inspections for compliance.

Inspections for compliance are important at the following junctures for system success but shall not be required unless: a) required for exercising credit options in Section **4.3**; or b) specifically referenced in the adopting ordinance, contract or design requirements.

Adoption:

To render these inspections as required, cite Annex A or any of the following individual provisions in the ordinance, contract or design specifications.

A-1 Inspection prior to closure over soil by concrete or *soil gas retarders* for design, materials and secure fastening:

Section **5.10.2**: An inspection shall be conducted to verify all inlets and ducting are secured and that *gas permeable layer* materials and closed surroundings are compliant with this standard prior to placement of concrete or soil gas retarders over a *gas permeable layer.*

A-2 Inspection prior to completion of indoor finishings to verify plenum sealing and closure:

Section **6.5**: Prior to completion of indoor finishings, an inspection shall be conducted to verify a continuous sealed barrier has been constructed between soil gas and airspaces within the building.

A-3 Inspection prior to completion of indoor finishings to verify exhaust vent pipe compliance:

Section **9.6**: Prior to completion of indoor finishings, an inspection shall be conducted to verify compliance for exhaust vent piping in accordance with Sections **8** through **9**.

ANNEX B (Non-Normative): ASD fans required.

Soil gas control-vent systems that are fan driven for *Active Soil Depressurization* (ASD) provide both the best assurance for mitigation of soil gas entry and the most consistent reduction in occupant exposure to hazardous soil gases. However, the installations of fans shall not be required unless specifically referenced in the adopting ordinance, contract or design requirements.

Adoption:

To cause fan-driven systems to be required, cite Annex C-1 in the ordinance, contract or design specifications.

B-1 Fans shall be provided in accordance with Section 10 to result in *Active Soil Depressurization* (ASD) systems.

ANNEX C (Non-Normative): Provide radon test kits.

Post-construction testing is the only way to verify that occupants will not be exposed to hazardous soil gas. However, post-construction testing shall not be required unless specifically referenced in the adopting ordinance, contract or design requirements.

Adoption:

To ensure building owners are provided tools to evaluate hazards from radon gas, cite Annex D-1 in the ordinance, contract or design specifications.

C.1 Radon test kit(s) required.

A minimum of one long-term radon-in-air test kit from a certified/licensed laboratory shall be provided for the occupants of each ground contact dwelling, unit or occupancy use area.

ANNEX D (Non-Normative): Conduct testing prior to occupancy.

Post-construction testing is the only way to verify that occupants will not be exposed to hazardous soil gas. However, post-construction testing shall not be required unless specifically referenced in the adopting ordinance, contract or design requirements.

Adoption:

To ensure occupants will not be exposed to hazards from radon gas, cite Annex **E-1** and/or Annex **E-2** in the ordinance, contract or design specifications.

D.1 Radon testing prior to occupancy.

A *radon* test shall be performed prior to occupancy and shall be performed by a *certified/licensed* measurement professional. Testing shall be performed in accordance with applicable state protocols or requirements; or if there are no state protocols or requirements for the style of constructed building, in accordance with national standards that include, as applicable: ANSI/AARST MAMF *"Protocol for Conducting Radon and Radon Decay Product Measurements In Multifamily Building"*; ANSI/AARST MALB *"Protocol for Conducting Measurements of Radon and Radon Decay Products In Schools and Large Buildings"*; or ANSI/AARST MAH *"Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes"*.

Where testing results are greater than the national action level, a *certified/licensed mitigator* shall be required to perform *diagnostic tests* and remediation action, and *radon* testing shall be required until *radon* concentrations below the national action level are achieved.

D.2 Testing prior to occupancy for other soil gasses or vapors.

Testing shall be performed prior to occupancy by a qualified measurement professional for the following soil gases or vapors of concern:

Soil gases or vapors of concern:	Reference source for action level:
____	____
____	____
____	____
____	____

Where testing results are greater than the state or federal action level, remediation action and follow-up testing shall be required until soil gas concentrations to below the action level are achieved. Fan activation and diagnostic evaluations by a qualified mitigation professional are commonly the first steps in such remedial actions.

EXHIBITS
(Example Inspection Forms)

Exhibit 1

Inspection prior to closure over soil by concrete or soil gas retarders shall include:

1. **Subgrade closure** (§5.1):
   Soils or *soil gas retarders* that surround gas permeable layers are restrictive to airflow and grading is sufficient to prevent collected water from obstructing *inlets* and *inlet piping*.
2. **Foundation walls** (§5.2):
   Walls that surround *soil gas collection plenums* are damp proofed with openings such as around utility penetrations closed.
3. **Foundations drains** (§5.3):
   If connected to gas permeable layers, included in design requirements for *soil gas collection plenums.*
4. **Footings and joined plenums** (§5.4):
   Soil gas ducts that traverse footings are not obstructed.
5. **Gas permeable layers** (§5.5):
   Aggregates, voids and configurations meet or exceed minimum requirements.
6. **Ducting** (§5.6):
   Duct sizing within and above gas permeable layers meet or exceed minimum requirements.
7. **Soil gas inlets** (§5.7):
   Inlet openings to soil gas meet or exceed airflow capacity requirements.
8. **Transition to exhaust piping** (§5.8):
   The transition of *inlets* and *inlet piping* to exhaust pipe(s) above the slab(s) or soil gas retarder(s) do not diminish designed airflow capacity.
9. **Test ports** (§5.9):
   If required, test ports meet minimum requirements.
10. **Secured ducts and inlets** (§5.10):
   Ducting and inlet configurations are secured in place in a manner to help avoid dislocation.

Exhibit 2

Inspection prior to completion of indoor finishings to verify plenum sealing and closure shall include:

1. **Continuous barrier** (§6.1):
   A continuous sealed barrier between soil gas and the interior of the building is complete.
2. **Closed concrete floors** (§6.2):
   All gaps and openings are closed and sealed in accordance with minimum requirements.
   - Above the soil gas retarders (§6.2.1):
   - Construction joints (§6.2.2):
   - Molded/sawed control joints (§6.2.3):
   - Openings and penetrations (§6.2.4):
   - Block-outs and pits (§6.2.5):
   - Sump pits (§6.2.6):
   - Floor drains (§6.2.7):
   - Air ducts (§6.2.8):
   - Labels for sealed components (§6.2.9):
3. **Earthen floors** (§6.3):
   All exposed earth not covered by concrete (e.g., crawl spaces) is covered with soil gas retarders that are closed and sealed in accordance with minimum requirements.
   - Sealed perimeter (§6.3.2):
   - Penetrations (§6.3.3):
   - Surface water relief (§6.3.4):
   - Labeling (§6.3.9):
4. **Soil gas retarders** (§6.4):
   All materials and installation comply with minimum requirements.
   - Under concrete slabs (§6.4.1):
   - Over earthen floors (§6.4.2):
   - Seams (§6.4.3):
   - Repairs (§6.4.4):

Exhibit 3

Inspection prior to completion of indoor finishings to verify exhaust vent pipe compliance shall include:

1. **Sizing and Configuration** (§8.1): ☐
   All duct pipes and joined pipe configurations comply with minimum size requirements.
2. **Slope** (§8.2): ☐
   Pipe slope or other methods are configured to drain collected water within piping.
3. **Air and water duct piping** (§8.3): ☐
   All exhaust piping, except the intake and exhaust locations are air and water tight.
4. **Pipe support** (§8.4): ☐
   Code compliant. Supports for plastic horizontal piping are installed at intervals not exceeding 4 feet (1.2 m) and supports for vertical piping are installed at intervals not exceeding 10 feet (3 m) in a manner that meets minimum requirements.
5. **Exhaust pipe equivalent length** (§8.5): ☐
   Each exhaust from above the slab(s) or soil gas retarder(s) to the roof does not exceed the calculated equivalent length restrictions.
6. **Pipe materials** (§8.6): ☐
   Pipe materials meet minimum requirements
7. **Pipe joints** (§8.7): ☐
   Pipe joints and installation meet minimum requirements
8. **Routing and thermal insulation** (§8.8): ☐
   Pipe routing and thermal insulation meet minimum requirements
9. **Provision for ASD fan** (§8.9): ☐
   Meets minimum requirements for location and access with electrical outlet and designated fan monitors location.
10. **Pipe labeling** (§8.10): ☐
    Each floor and within each room or accessible service area where exposed pipe may be encountered.
11. **Exhaust location** (§9.1): ☐
    Outside the building and directed upward without obstruction to exhaust airflow.
12. **Elevation and vertical walls** (§9.2): ☐
    Exhaust location not less than 10 ft (3 m) above grade and not less than 10 feet (3 m) away from vertical walls that extend above the roof penetrated.
13. **Windows and other openings** (§9.3): ☐
    Exhaust location not less than 2 feet (60 cm) above or not less than 10 feet (3 m) horizontal distance away.
14. **Equipment air intakes** (§9.4): ☐
    Exhaust location meets one of the distance options permitted.
15. **Decking or exterior corridors** (§9.4): ☐
    Exhaust location not less than 10 feet (3 m) above or not less than 20 feet (6 m) horizontal distance away.

Soil Gas Control Systems In New Construction of Buildings

Acknowledgement

This standard was developed through the efforts and deliberations of the consensus body for "Soil Gas Control Systems in New Construction of Buildings (CC-1000), representing a cross-section of stakeholder interests and vantage points.

Deep appreciation is both expressed and deserved for years of contributions in time and wisdom provided by the following consensus body members and staff:

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(Educators)	Chad Robinson (KS)	Midwest University Radon Consortium (MURC)
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(Proficiency Program)	Bruce Snead (KS)	AARST-NRPP (Policy Advisory Board)
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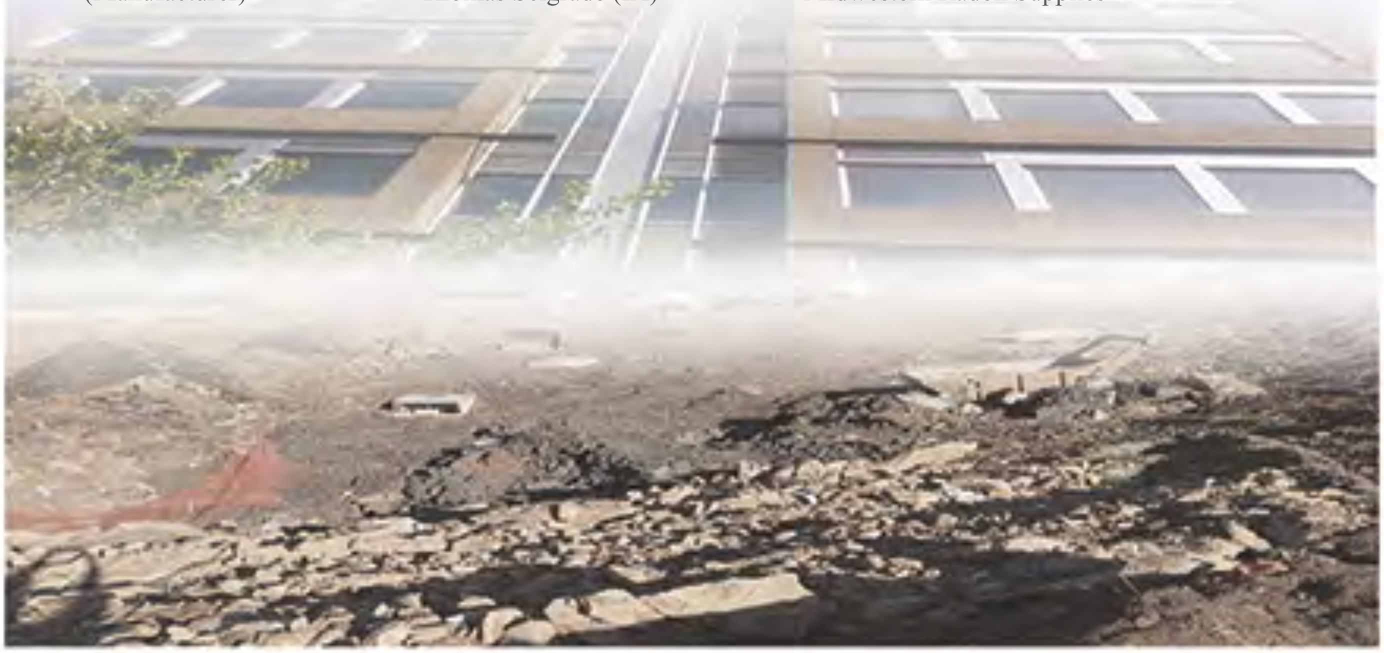
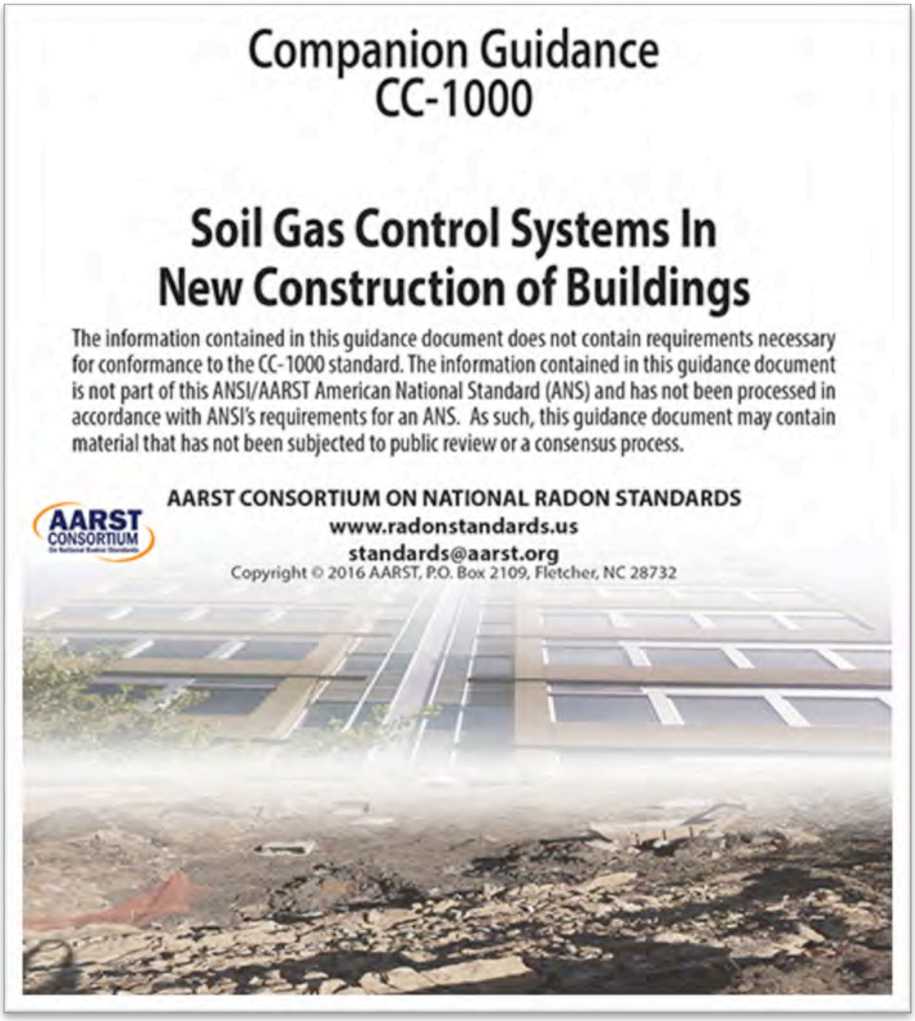
(Manufacturer)	Thomas Selgrade (IA)	Midwestern Radon Supplies



Companion Guidance to be included
that contains no requirements and is therefore <u>not included for public review</u>.



Examples of informational content being prepared:

CG 1.0 Calculation tables that can be helpful for meeting CC-1000 requirements.

- 1.1 Ducting (diameter capacity and transition equivalence to inlets)
- 1.2 Aggregate and inlet transfer equivalence and hydraulic conductivity
- 1.3 Equivalent length examples for ducting

CG 2.0 Procedural lists of activities broken out by discipline:

- 2.1 System designers
- 2.2 Grading and flatwork
- 2.3 Pipe installers
- 2.4 Electrical service
- 2.5 Mechanical HVAC engineering
- 2.6 Inspectors and measurement professionals