ANSI/AARST

SGM-SF 2017 *with 12/20 revisions*

An American National Standard

Soil Gas Mitigation Standards for Existing Homes

AARST CONSORTIUM ON NATIONAL RADON STANDARDS
www.standards.aarst.org

SGM-SF 2017 *with 12/20 revisions*

Soil Gas Mitigation Standards for Existing Homes

Scope Summary and Introduction

This standard specifies practices, minimum requirements and, general guidance for reducing soil gas entry into existing homes in order to mitigate occupant exposures to certain hazardous soil gases, including *radon* gas, chemical vapors and other hazardous gases. This standard of practice is applicable to residential structures to include: those not more than three stories above-grade in height, those often classified as single-family structures, and those that contain not more than four attached *dwelling* units on a contiguous foundation.

12/20 Revisions for 2021

This publication is the first in a series of mitigation standards updates that seek to harmonize and improve as many provisions as possible across ANSI/AARST SGM-SF, RMS-MF and RMS-LB. While recommended for immediate use, the effective date of this revised standard for compliance purposes is Sept. 1st, 2021.

Substantive changes: Continuous maintenance efforts have resulted in harmonized updates for most provisions in Sections 6, 7 and 8 for *active soil depressurization (ASD)* to read the same in RMS-LB (schools and large buildings), RMS-MF (multifamily buildings) and SGM-SF (existing homes).

Editorial changes: Reconciliation for harmonized order of content, informational renderings and page layout.

Significance of Purpose

Radon is the leading cause of lung cancer among nonsmokers and the second leading cause of lung cancer in the general population. Most people receive their greatest exposure to radon in their homes. Radon in U.S. homes causes approximately 21,000 lung cancer deaths each year.[1] Be it at home, work or school, an individual's exposure to radon gas combines over time to increase the risk of preventable lung cancer.

The risk of adverse health effects from inhalation of toxic chemicals in the form of vapor or particulate matter can be significant. The level of concern depends upon the nature, frequency and duration of exposure to the chemical(s). Where *chemicals of concern* are present in soils adjoining a building, *mitigation* methods for chemical vapor concentrations in indoor air are similar.

This document contains minimum requirements and guidance designed to respond to the health threat of *radon* gas, chemical vapors and other hazardous soil gases.

Historical Perspective

In the 1950s, studies confirmed increased incidence of radon-induced lung cancer for workers in underground mines.

In the 1980s, studies found that exposure to radon in homes can exceed exposures found in studies of mine workers.

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, USEPA has advised all U.S. schools to test for radon and to reduce levels to below 4 pCi/L[3].

In 1999, with the publication of BEIR VI[1], the National Academy of Sciences confirmed that any exposure to radon holds a degree of risk. 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.[2]

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.

Designation: SGM-SF

As used for catalogue identification, "SGM-SF" stands for Soil Gas Mitigation in Single Family homes.

Normative References

Referenced publications, including those delineated as normative, are found in Appendix B.

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

[2] World Health Organization, "WHO Handbook on Indoor Radon: A Public Health Perspective" 2009

Adoption

These standards of practice can be adopted as requirements for contractual relationships or adopted as recommendations or requirements of an authority or jurisdiction such as for private proficiency programs, a state radon program or other governmental body. AARST recommends that any authority or jurisdiction considering substantial modifications of this document as a condition of its use seek consensus within the consortium process at AARST Consortium on National Radon Standards prior to adopting a modified version. This provides the jurisdiction with a higher degree of expertise across diverse stakeholders and offers the Consortium on National Radon Standards an opportunity to update this document as appropriate.

Assessing Qualifications of Individuals

Compliance with all portions of this standard includes both entry-level and advanced knowledge and skill sets.

It is intended that:

1. Mitigation installers or interns be capable of tasks needed to install ASD systems (e.g., Sections 6, 7, and 8)
2. Qualified **radon** mitigation professionals be additionally capable of ASD design, oversight and tasks relative to single family residences (e.g., Sections 4, 5 and 8 through 11);
3. Qualified **soil gas** mitigation professionals be additionally knowledgeable of chemical vapor considerations (e.g., Sections 11, 13 and Appendix A); and
4. An additional level of knowledge and skill is needed for buildings more complex than single family residences and for design of most Non-ASD mitigation methods (e.g., Section 12).

AARST Consortium on National Radon Standards

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The Consortium Consensus Process

The consensus process 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) has been applied throughout the process of approving this document.

Continuous Maintenance

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 revisions, including procedures for timely consensus action on requests for change to any part of the standard. User tools are also posted online as they become available (such as templates for field notices, inspection forms).

For access to details: (www.standards.aarst.org/public-review)

Notices

Notice of right to appeal: Bylaws for the AARST Consortium on National Radon Standards are available at www.standards.aarst.org/public-review. 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."

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Soil Gas Mitigation Standards for Existing Homes

Note—12/20 Revisions (Sections 1 -5 do NOT contain changed requirements)

1.0 SCOPE

1.1 This standard of practice specifies practices, minimum requirements and general guidance for reducing soil gas entry into existing homes in order to mitigate occupant exposures to certain hazardous soil gases, including *radon* gas, chemical vapors and other hazardous gases.

This standard of practice is applicable to residential structures to include: those not more than three stories above grade in height; those often classified as single-family structures[3]; and those that contain not more than four attached *dwelling* units on a contiguous foundation.

1.1.1 This standard of practice addresses a wide range of *mitigation* methods and additionally provides guidance for health and safety, system design, system installation, and ongoing stewardship.

1.1.2 This standard of practice is applicable to existing homes be they rented or owned, including timeshare properties.

1.2 Limitations

1.2.1 *Water and building materials*

This standard of practice does not specify *radon mitigation* practices associated with *radon* in water, building materials or other less common sources of *radon* gas.

1.2.2 *Outside air and combustible gas*

This standard does not address mitigating hazards from gases or substances in outside air and does not fully address all practices associated with *mitigation* of potentially combustible soil gases.

1.2.3 *Removal of contaminated source materials*

This standard does not address practices or techniques associated with removal of contaminated source materials, including:

a) chemically contaminated earth and groundwater within or immediately under a building;

b) capture, containment and disposal of chemically contaminated vapor or condensate; and

c) chemical products be they stored or associated with building materials.

1.2.4 *Attached dwellings*

This standard of practice does not specify all practices that may be appropriate when structures contain two or more attached *dwellings*. See ANSI/AARST RMS-MF *Radon Mitigation Standards for Multifamily Buildings* Section 8.3.5 and Section 10.4 regarding *collateral mitigation*.

1.2.5 *Jurisdictional compliance*

This standard does not contain all code or other requirements of the jurisdictions where the *mitigation* system is being installed. Although the provisions in this standard have been reviewed for potential conflicts with other regulatory requirements, adherence to this standard does not guarantee or supersede compliance with the applicable codes or regulations of any federal, state or local agency with jurisdiction.

1.2.6 *Safety*

This standard of practice 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.

[3] As point of reference, see the International Residential Code (IRC) Section R101.2 .

1.2.7 *Design and warranties*

This standard is not intended to be used as a design manual, and compliance with its provisions will not guarantee reduction of indoor *radon* to any specific concentration.

2.0 APPLICABILITY

2.1 Mandatory Conventions

The terms "shall", "required" and "normative" indicate provisions herein that are considered mandatory. Terms such as "should," or "recommended" and provisions prefaced by the term "Note" or "Informative" indicate provisions that are considered to be helpful or good practice, but which are not mandatory.

2.2 Prior Systems

This standard shall not apply to *mitigation* systems installed prior to its effective date, except when a previously installed system is altered. This standard shall apply to only the aspects of the system that are altered, and the *contractor* shall recommend to the *client* in writing that the noncompliance items be upgraded or altered to meet current standards. For the purposes of this standard, altering a *radon mitigation* system does not include activities such as replacing worn out equipment while leaving the remainder of the system unchanged.

2.3 Adoption and Use

2.3.1 *Soil gas mitigation objectives*

Note—A Soil Gas Mitigation system can be installed to meet one or more of the following objectives:

a) Reduce *radon* below the international, federal, state, or recognized reference level or action level on indoor *radon* or below an agreed-upon concentration for indoor radon;

b) Reduce *chemicals of concern (COCs)* or other hazardous gas or vapor from soil gas to below applicable state and/or federal guidelines and/or standards in indoor air or below an agreed-upon concentration over an agreed-upon period of time in indoor air;

c) Provide proactive soil gas *mitigation*: Proactive systems are the result of preemptive action based on suspected hazards rather than hazards confirmed by measurements. Proactive systems shall comply with all provisions of this standard, with the exception of gas concentration measurements that are recommended but not required; and

d) Provide emergency or rapid response with temporary *mitigation* means. See Section 13.6.

2.3.2 *Limits to application*

Practices for installing *radon* reduction systems shall comply with all provisions of this standard with the exception of Section 13. Practices for installing systems to reduce hazards from chemical vapor intrusion shall comply with all provisions of this document with the exception of Sections 9 and 10.

3.0 QUALIFIED CONTRACTORS

3.1 Contractors

The use of the term "Contractor" within this standard refers to any person(s) or contracting firm, regardless of the organizational structure of the entity that installs a *mitigation* system.

3.2 Contractors, Teams and Qualifications

The *contractor*, contracting team, or management team shall include individuals who have appropriate technical knowledge, skills, and experience required to mitigate soil gas concerns, including at least one "Qualified Radon or Soil Gas Mitigation Professional.

3.2.1 *Qualified **radon** mitigation professional*

A "Qualified Radon Mitigation Professional" for the purposes of this document is defined as:
"An individual that has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon *mitigation* of existing homes:

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.

Note—For chemical vapor intrusion, see additional requirements in Section 13.1 for *Qualified Soil Gas Mitigation Professionals*.

3.3 Quality Management

3.3.1 The *contractor*, contracting team or management team shall have or establish a *Quality Management System* that is applied to each project and includes a Quality Assurance Manual and *Quality Control* procedures documented for each job site.

3.3.2 *Oversight required*

A *qualified radon* or soil gas *mitigation professional* shall be physically present and immediately available to direct, instruct and oversee activities of other individuals, *mitigation installers* and other professionals engaged in installation activities for the *mitigation* system(s).

3.3.3 *Qualified control tracking*

At a minimum, it is required that *quality control* efforts retain evidence on pertinent details to include:

a) identification of staff responsible for standards compliance for each specific installation;

b) floor plan sketches of system components stipulated in Section 5.4.1 as rendered during building evaluations and/or as finalized for *client* distribution; and

c) descriptions of conditions found under slabs and resulting *suction pit* description after actions were taken to comply with requirements for *suction pit* size as stipulated in Section 6.1.1.

3.3.4 *Other qualified professionals*

Informative advisory—Other persons working with the *contractor* or management team (e.g. design, utilities, engineering and facilities staff) should be qualified for their discipline. Such persons should maintain applicable licenses or certifications and acquire permits as required by the jurisdiction where the *mitigation* work is performed.

4.0 GENERAL PRACTICES

4.1 Assemble Building Information

4.1.1 *Existing radon measurements*

Any available test results shall be reviewed in developing an appropriate *mitigation* strategy.

Note 1—*Contractor* review of all measurements is important when developing an appropriate *mitigation* strategy.

Note 2—For measurements of hazardous vapors and gases other than radon, see Section 13.

4.1.1.1 Interpretations

If the most recent *radon* tests were not performed in accordance with the EPA, state or ANSI/AARST measurement protocols, the *client* shall be informed, and a retest shall be recommended.

Both written and verbal interpretations and recommendations made by or handed out by the *contractor* regarding health risks associated with *radon* shall be provided in accordance with the latest version of the appropriate EPA documents, or documents developed by the state in which the work is being done. Relevant EPA documents for *radon* include *"A Citizens Guide to Radon"* and the *"Homebuyers and Sellers Guide to Radon."*

4.1.2 *Building specifications*

Note—The *contractor* should request that the *client* provide any available information on the building (e.g., construction specifications) that might be of value in determining the *mitigation* strategy.

4.2 Proposals

4.2.1 *Initial interactions/proposals*

The system objectives shall be identified prior to initiation of the system design and installation.

Note—See Section 2.3.1. The *contractor* should also identify when system maintenance and monitoring are the responsibility of someone other than the occupant or future occupants

4.2.2 *Written proposal requirements*

Contractors shall provide *clients* the following written information prior to initiation of the work:

a) The *qualified mitigation professional's*:
   1. name, address and phone number;
   2. relevant *radon mitigation* certification and/or licensing number; and
   3. signature (manual or electronic in conformance with the Electronic Signatures in Global and National Commerce [E-SIGN] Act);

b) A description of the proposed *mitigation* system(s) and a description of the long-term *operation, maintenance, and monitoring plan (OM&M)* applicable for the proposed *mitigation* design.

   Note—See Sections 5.2, 10.0 and 13.7);

c) A statement that describes options and costs for initial post-*mitigation* testing, including the option of third-party testing.

d) The conditions of any warranty or guarantee including whether the *contractor* warrants that the proposed system(s) will or will not reduce the *radon* concentrations below a specified threshold;

e) An estimate of installation costs and annual operating costs with the understanding that costs for energy and prorated estimates for fan replacement, labor, and testing may change in the future; and

f) The *contractor* shall clearly state in proposals, and subsequent to installation(s) in accordance with Sections 10.1.1. e and 13.7.2.1 c, any limitations that the *contractor* places on the scope of work and any limitations on professional obligations.

   Note—For example, upon completion of an installation or initial retest, it is customary practice that all obligations for implementation of an *OM&M* plan and any perceived professional obligations for risk management are transferred to the *client* or property owners in writing. Otherwise, participation in *OM&M* is typically stipulated in extensive detail under a separate agreement.

4.3 Notification and Hazards

4.3.1 *Ventilation*

The *client* shall be informed, prior to starting work, of the need to ventilate work areas during and after the use of sealants, caulks or bonding chemicals containing volatile solvents. Ventilation shall be provided as recommended by the manufacturer of the material.

4.3.2 *Access notices*

Whenever the occupant of the home is not the property owner or *client*:

a) The *contractor* shall request that the *client(s)* provide notices to occupants a minimum of 24 hours before entering the *dwelling* and in a manner that meets existing owner agreements and local laws, if applicable; and

b) The *contractor* shall request in writing that notices to occupants and other impacted residents include instructions, warnings or guidance for specific disruptive or hazardous situations.

Note—See Exhibit A-1 for a sample "Contractor to Client" notice; Exhibit A-2 for a sample "Management to Facilitating Staff" notice; and Exhibit A-3 for a sample "Management to Occupant" notice.

4.3.3 *Occupant sealant advisories*

Informative advisory—It is recommended that the *contractor* post or leave notices for affected occupants when using sealants. See Exhibit B for an example of such notice.

4.3.4 *Material safety data sheets (SDS)*

Material Safety Data Sheets (MSDS or SDS) shall be made available to the *client* upon request.

4.4 Jurisdictional Authorities

4.4.1 *Jurisdictions*

The *contractor* shall comply with all applicable testing, *mitigation* and reporting requirements issued by the federal, provincial, tribal, state or local jurisdiction that apply to the contract where the *mitigation* is being performed. The *contractor* shall notify the *client* of any reporting requirements published by the state or local jurisdiction where the *mitigation* is being performed.

4.4.2 ***Local jurisdictions*** (*informative*)

Radon—Information to locate State Radon Offices in the United States can be found at www.epa.gov/radon/find-information-about-local-radon-zones-and-state-contact-information#stateradon

Vapor Intrusion—Information to locate State Offices in the United States can be found at www.itrcweb.org/Team/Public?teamID=50

4.4.3 *Building codes*

All components of the *mitigation* work shall be in compliance with the applicable mechanical, electrical, building, plumbing, energy and fire prevention codes, or any other regulations of the jurisdiction where the work is performed. For localities having no relevant code requirements, the most recent version of nationally published codes shall be observed to help assure safety of occupants and building integrity.

4.4.4 ***Licenses and permits*** required by local ordinances shall be obtained.

5.0 SYSTEM DESIGN

5.1 Health and Safety

Mitigation systems shall be designed and installed to avoid the creation of health or safety hazards.

5.2 Long-Term Considerations

Note—The design and resulting *operations, maintenance, and monitoring plan* (*OM&M*) should include consideration for facilitating and easing the *client's* ability to conduct maintenance.

5.3 Appropriate Systems

Appropriate design features shall be considered, such as:

a) ***Practicality***
   Observance that controlling pollutants at their source rather than after entry to the indoors becomes more important as buildings are designed or retrofitted to be more energy efficient;
b) ***Durability***;
c) ***Acceptable aesthetics*** (including system appearance, noise and occupant comfort);
d) ***Ease of service;*** and
e) ***Long-term cost*** (that includes power consumption, conditioned air loss and maintenance and future replacement costs of system components).

5.3.1 *Other building systems*

The *mitigation* system shall be designed and installed to avoid compromising the function of any mechanical system or ground water control system and to avoid obstructing doorways or windows and accessibility to switches, controls, electrical boxes or equipment requiring maintenance.

5.3.2 *Permanent systems required*

Mitigation systems shall be designed and installed as an integral, permanent addition to the building.

Exception: See Section 13.6 for guidance immediate health concerns and related limits on temporary system use.

5.4 Nondestructive Investigation

An investigation of the building structure(s) shall be conducted by a *qualified radon* or *soil gas mitigation professional* prior to initiating *mitigation* work.

Note—The investigation is intended to identify any specific building characteristics and configurations that may affect the design, installation and effectiveness of a *mitigation* system.

5.4.1 *Document review*

Note—The *contractor* should review all available construction drawings and other information regarding the building that might be of value in determining the *mitigation* strategy.

5.4.2 *Create diagrams*

A floor plan diagram or series of diagrams shall be developed for retention in *quality control* records or as provided to a *client* and should be complemented with photographic documentation of areas of the building to be mitigated.

5.4.3 *Visually inspect the building*

A visual inspection shall be conducted to help identify any specific building characteristics, hazards and configurations that may affect the design, installation and effectiveness of a *mitigation* system.

Note—Examples include:

a) significant slab openings, crawlspaces, adjoining slabs, slab floor and exterior wall integrity, and potential footing locations;
b) the design nature of heating, ventilation and cooling (HVAC) systems that may cause significant building *depressurization* or have ducting in contact with the soil;
c) identification of fire-rated assemblies or separation required (including for fire-rated party walls between different *occupied* spaces and fire-rated floor assemblies); and
d) identification of general safety concerns that may warrant precautions for worker or occupant health as described in Section 11.2.

5.4.3.1 The *contractor* shall provide timely documented notice to the *client* for conditions found that present safety concerns or unexpected challenges to envisioned *mitigation* designs.

5.4.4 *Design diagram*

The design plan of the proposed layout of the *mitigation* system shall be annotated on a diagram to include components of the *mitigation* system, such as *active soil depressurization (ASD)* fans, piping and *suction points*.

5.5 Diagnostic investigation

Informative advisory—Diagnostic procedures are recommended and sometimes required to enable appropriate and effective system design. Section 13.2 stipulates required *ASD* diagnostics when the purpose of the *mitigation* is for chemical vapor intrusion.

Note—*Diagnostic procedures* chosen will depend upon the level of complexity for identifying or characterizing conditions under, beside and within buildings to adequately project the effects of various system designs. *Diagnostic* investigation can include one or multiple procedures such as: sub-slab *pressure field extension (PFE)* tests or analysis; visual assessment(s); characterization of pressure or air exchange rates between indoors and outdoors and also between floors or adjoining air spaces; and *diagnostic radon measurements* or other contaminant measurements at locations of interest (e.g., mechanical spaces, groundwater and spaces not in ground contact).

5.5.1 *ASD designs*

Informative advisory—For design of *ASD* systems, it is recommended and sometimes required to conduct a *PFE Analysis*. PFE Analysis is a set of commonly needed diagnostic techniques to aid design and optimization of soil depressurization systems. Procedures are:

a) *PFE* testing needs to be conducted under closed-building and normal operating conditions for the building.
b) Qualitative evidence is sought to identify the distance potential of *PFE* across the *soil gas collection plenum* (e.g., airspace under slabs or soil gas retarder). Measurements are made and recorded at a point distant from each *suction point* to verify intended design.
c) Quantitative measurements are also employed for analytical determination of:

1. air volume capacity needed to overcome leakage from any side of the *soil gas collection plenum* such as at the soil or at foundation cracks; and
2. vacuum strength needed to overcome indoor air pressures and resistance posed by fill materials within the *soil gas collection plenum*.

5.5.1.1 Quantitative Measurements

When conducting *PFE Analysis*, it shall be conducted using a differential pressure gauge that is:

a) capable of reading to 1/1000 inch water column (.25 Pa); and
b) calibrated in accordance with national standards or manufacturers' recommendations.

5.5.1.2 Reliance on Experience in Like Structures

Note—Information gained at one structure regarding air volume and fan vacuum needs can sometimes be applied to similar structure(s). For this consideration:

a) The like structures being compared need to be of similar size, geological and sub-slab characteristics, and built with similar construction practices;
b) At least one *PFE* measurement is made in each structure that indicates a similar distance for *PFE*; and
c) Sufficient additional information is gained from each structure to indicate like conditions exist.

Informative advisory—Should past experiences not include *mitigation* efforts in like structures, a full *PFE analysis* is highly recommended to ensure system effectiveness and reduce unnecessary or unexpected costs of repeated retests and further remedial action.

5.5.2 *Non-ASD methods*

Diagnostic procedures stipulated in Section 12 are required prior to installation. Subsequent verification after installation is also stipulated in Section 12 and often includes repeated *diagnostic procedures* and additional testing of indoor air.

5.6 Design Decisions

Note—Mitigation methodology and design are dependent upon information gained from the non-destructive evaluation that is confirmed by diagnostics.

The flowcharts that follow in Figure 5.6.1 and Figure 5.6.2 illustrate example procedures for determining the appropriateness and feasibility of design choices.

Figure 5.6.1 SGM-SF: Example Design Decision Flowchart—ASD Methods

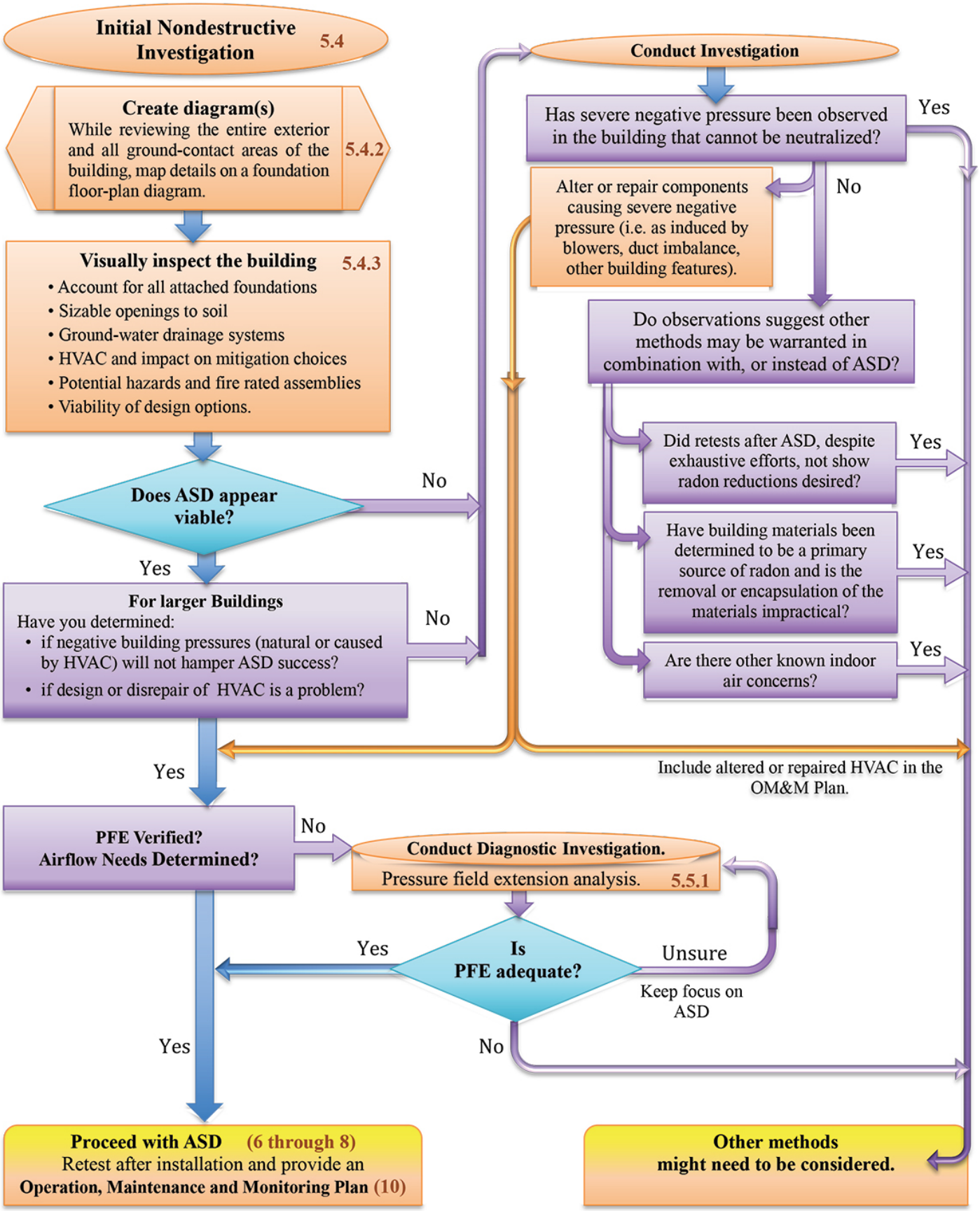
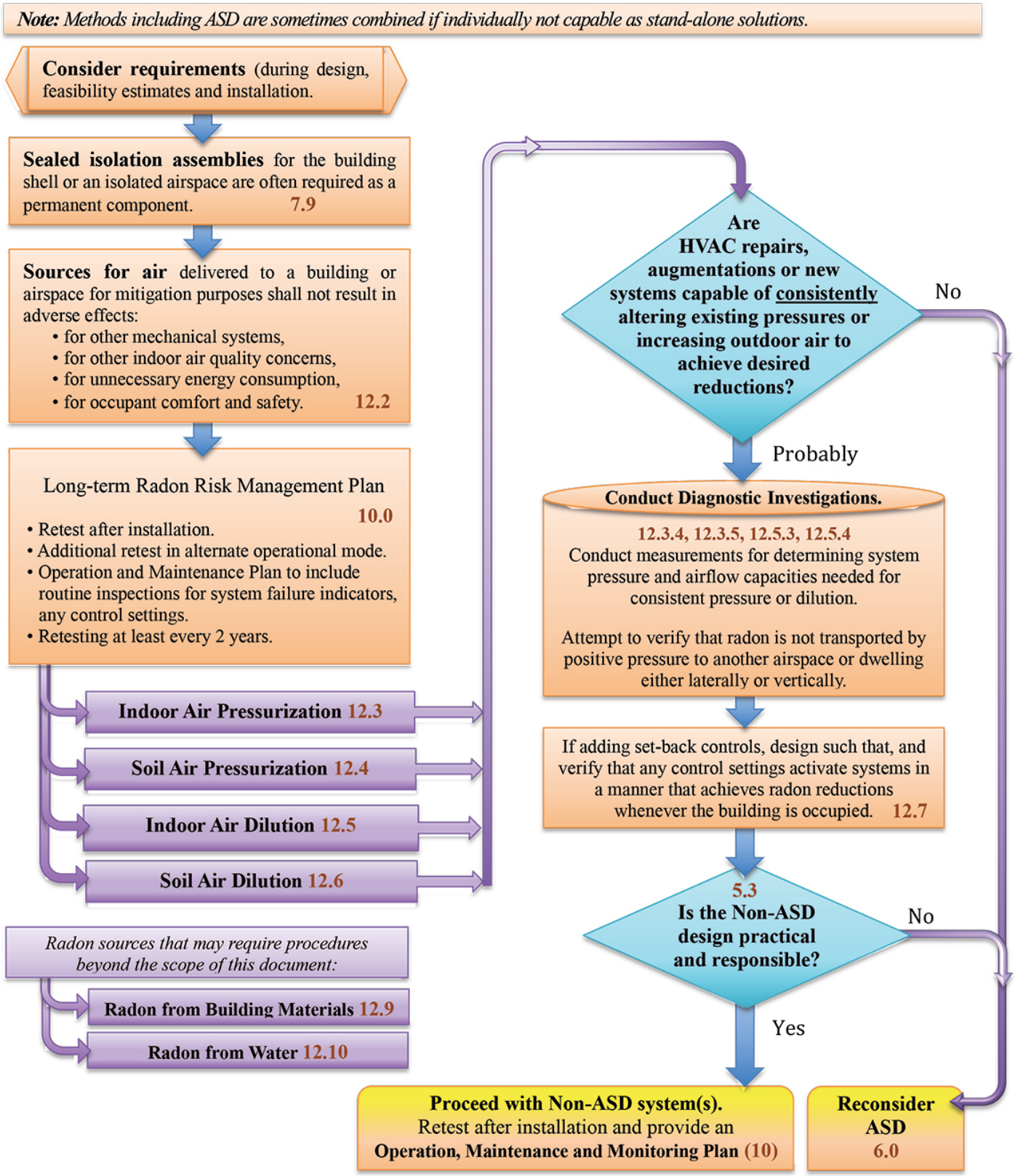


Figure 5.6.2 SGM-SF: Example Design Decision Flowchart— Non-ASD Methods

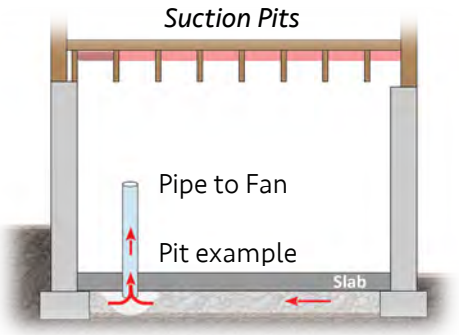


6.0 ACTIVE SOIL DEPRESSURIZATION (ASD)

6.1 *ASD* Suction Points

6.1.1 *Suction pits*

A cleared void space shall exist or be created below all *suction points* through slab floors and to the side of all *suction points* through walls, unless excavation is not practicable. This cleared void space shall be not less than 0.25 ft^3 (7 dm^3) which equates to 2.0 US gallons (8 L) of excavated sub-slab soil/aggregate.



Exception: Where multiple *suction points* are employed, secondary *suction pits* designed for condensate drainage or airflow balance are permitted to have a smaller cleared void space.

Informative advisory—Where sub-slab material exhibits poor permeability, larger pits are recommended, such as 1 ft^3 (28 dm^3) or larger. This void equates to 7.5 US gallons (28 L) or more of sub-slab aggregate.

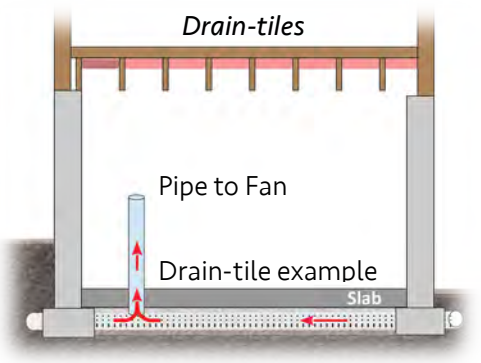
Note—Pit size needs are based on permeability of the sub-slab material. If the combined surface area of exposed pore openings between granules of soil, sand or gravel is less than the cross-sectional open surface area of the suction pipe, as shown in Table 6.3.4, a larger pit will likely enhance *PFE*.

6.1.1.1 Seal the Suction Point

Gaps in concrete surrounding suction pipes shall be sealed in a permanent, airtight manner.

When using caulk, the gap opening shall be cleaned and sealed with caulk complying with ASTM standard C920 class 25 or greater.

To support caulk while it cures, gap openings greater than 1/2 inch (13 mm) in width shall be pre-filled as needed with *backer rod* or comparable material prior to applying caulk.



6.1.1.2 Drain-tile Suction

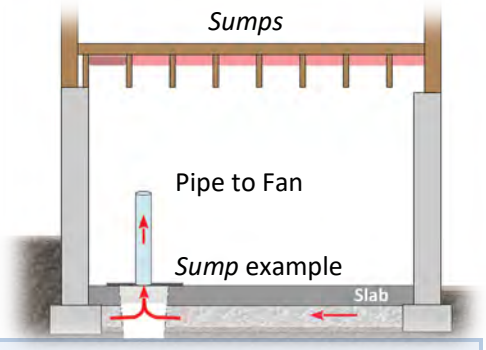
Where the *suction pit* or suction piping directly accesses soil air from a drain-tile, the configuration shall not result in compromising the capacity of the water drainage system.

6.1.2 *Sumps*

Informative advisory—Sumps that connect to soil air should not be used as the primary *suction point* unless other options are inadequate for achieving *PFE*. Concerns include compromised accessibility to pumps, increased noise, and some localities disallow use of a *sump* as the primary *suction point*.

6.1.2.1 Seal the Suction Point (sumps)

Where sumps are used as a *suction point*, *sump* lids shall be sealed in accordance with Section 7.5 in an airtight manner.



6.1.2.2 Accessibility to Sumps

Provisions of Section 7.5 for sealing sumps shall be observed to include that a physical access port or equivalent is required. Flexible coupling disconnects for suction piping, in accordance with Section 6.2.6, shall be provided to ease *sump* lid removal.

Informative advisories—(1) The suction pipe should not extend lower than 1 inch below the *sump* lid.

(2) Visual access to conditions in the pit is recommended.

(3) Flexible coupling disconnects should be located such as to facilitate easy removal of the cover.

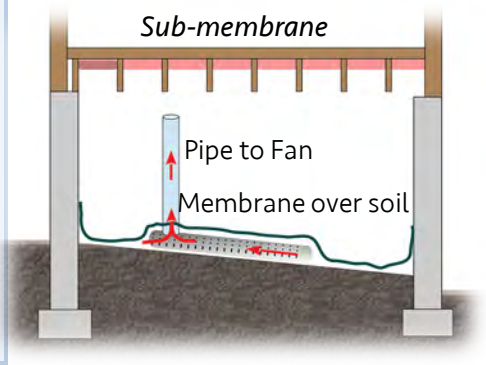
6.1.2.3 Labels Required (*sumps*)
Sump lids shall be labeled in accordance with Section 8.4.6 a.

6.1.3 *Sub-membrane suction points*
For sub-membrane *depressurization* (SMD), suction pipe ducting shall extend under the *soil gas retarder* membrane and shall be installed to prevent obstruction of air volume flow at the air inlet opening(s) of the suction pipe(s). The suction pipe inlet configuration shall be made open to soil air in a manner that allows *PFE* under the entire expanse of the membrane.

Informative advisories—(1) To prevent membrane material from obstructing suction pipes, it is recommended to attach not less than 3 feet (1 m) of perforated pipe to suction pipe air intakes.

(2) To prevent restricted *PFE*, such as where membrane material might adhere to moist soil, it is best to attach ≥ 10 feet (3 m) of perforated pipe. Geotextile matting can also achieve the intent of this recommendation.

(3) For large membranes, longer lengths of perforated pipe or multiple *suction points* are recommended.

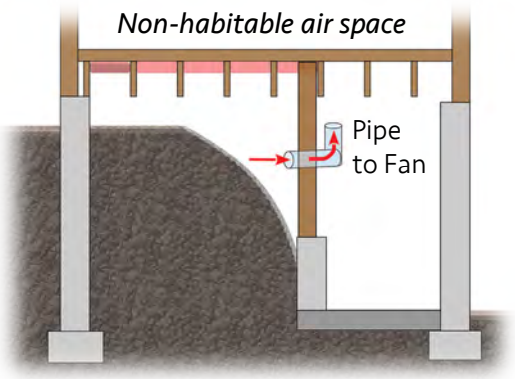


6.1.3.1 Seal the Suction Point (membranes)
The opening around penetrations of a *soil gas retarder* shall be sealed in a permanent, airtight manner. Appropriate seal materials shall be applied for *ASD* duct piping and other utility pipe penetrations through the membrane such as gasket fittings, pipe clamps, roof flashing or an appropriate sealant.

6.1.3.2 Seal the Membrane(s)
The *soil gas retarder*, including seams and edges, shall be sealed to resist air movement between soil and air above the membrane and installed in accordance with Sections 7.6 and 7.7.

6.1.3.3 Labeling Required (membranes or *crawl space* access)
Membranes or *crawl space* access locations shall be labeled in accordance with Section 8.4.6 b.

6.1.4 *Non-habitable air spaces*
Note—These *ASD* systems depressurize an entire airspace that is not used or constructed for habitation. Examples include *crawl spaces*, utility tunnels, under raised flooring, behind partitioned walls and sometimes entire rooms.



6.1.4.1 Sealing (non-habitable air spaces)
When depressurizing a *non-habitable airspace,* sealing of all surfaces of the *non-habitable airspace* that adjoin both indoor and outside air shall be performed in accordance with Section 7.9 *Sealed Isolation Assemblies.*

6.1.4.2 Prohibition 1
Depressurization of *non-habitable airspaces*, such as *crawl space depressurization*, shall not be installed unless conditions exist where an area cannot be safely accessed or has insufficient height to work in.

6.1.4.3 Prohibition 2
Depressurization of *non-habitable airspaces* shall not be used as a *mitigation* system when:

a) atmospherically vented combustion appliances are installed within the airspace to be depressurized;

b) adequate isolation cannot be created between the *non-habitable airspace* and surrounding airspaces containing one or more atmospherically vented combustion appliances. Resulting configurations shall not induce *flue gas spillage* described in Section 11.2.2; and

c) the extent of inaccessible openings between the isolated space and both interior and exterior areas surrounding the isolated space has not been evaluated and accounted for in system design and installation.

Regardless if creation of access is needed or if extensive efforts are required to seal or further partition the isolated airspace, the resulting system shall not cause the structure to become unsafe or adversely affect the performance of the building to include:

a) Adverse impacts to building systems (with the most notable being *flue gas spillage* from atmospherically vented combustion appliances located elsewhere in the building); and

b) Excessive energy penalties and damage to building components (with the most notable being hot, cold and humid outside air drawn into a *non-habitable airspace* by the *mitigation* system).

Note—Sub-membrane *depressurization* (SMD) for open earth *crawl spaces* is a preferred *mitigation* method to minimize energy penalties and damage to building components, even if access needs to be created.

6.1.4.4 Safety Requirements (*non-habitable airspaces*)

Where entry into a non-habitable air space being depressurized might occur in the future for maintenance or other reason, precautionary safety features are required to prevent exposures to excessive *radon* or chemical vapor exposure that can result within the *depressurized* airspace. Safety features shall include:

a) Access ports to non-habitable air spaces shall be labeled in accordance with Section 8.4.6 c to provide warning and instructions, such as for ventilating the airspace prior entry or, as warranted, other precautions and instructions;

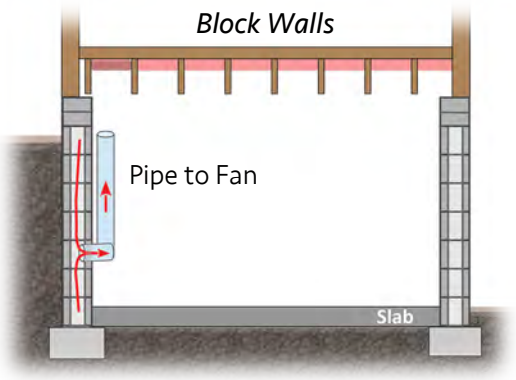
b) Doors and access port hatches that can be opened without the use of tools shall be provided hardware to facilitate adding a lock to prevent incidental entry; and

c) Fan monitors required in accordance with Section 8.2 shall be located where they can be accessed without entering the depressurized non-habitable air space.

6.1.5 *Block walls*

6.1.5.1 Suction Pipe Locations

Note—Suction pipe locations for Block Wall *Depressurization* will depend on the configuration of the hollow void network(s) within walls to be depressurized and the ability to close openings that surround the void network(s).



6.1.5.2 Sealing (block walls)

For Block Wall *Depressurization*, all accessible openings and gaps in the wall that surround the hollow void network being depressurized shall be closed in accordance with Section 7.4.1 to resist air movement between the depressurized void network and both indoor and outdoor air.

Informative advisory—If the top or wall surfaces of the void network cannot be closed to resist air entry into the voids, *depressurization* of the block wall(s) may not be possible. Where openings are not accessible, closure of voids in a course of blocks below the inaccessible openings at a location above outside grade should be considered to isolate a smaller void network for *depressurization*.

6.2 *ASD* Piping

6.2.1 *Air and water-tight*

All duct piping and fittings that transport air shall result in being air- and water-tight, except at soil gas intake locations, exhaust locations and fan monitor test ports.

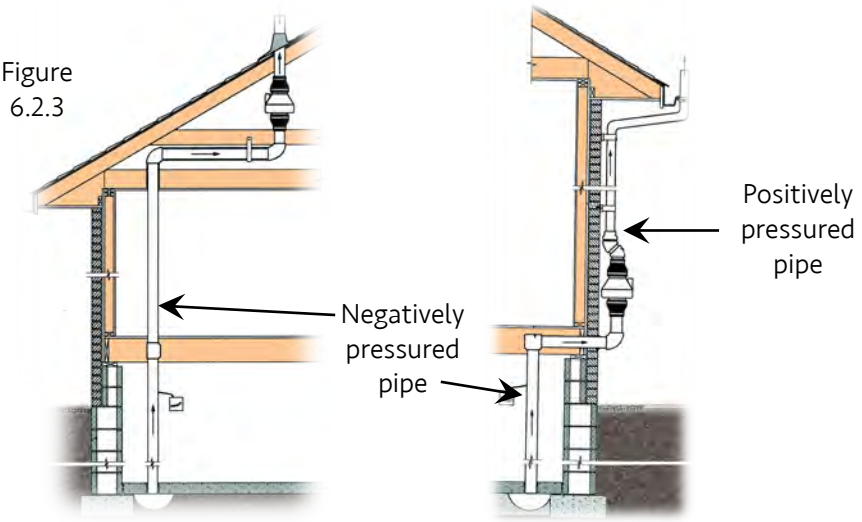
6.2.2 *Slope required*

Above-ground duct piping shall have a continuous downward slope toward the *suction point*(s) of not less than 1/8 inch (3.2 mm) per foot (30 cm) to allow condensation or rainwater within the pipes to drain downward into the ground beneath the slab or soil-gas retarder membrane. When drainage cannot be achieved, other methods for draining collected water shall be provided. Configurations that result in obstructed airflow as a result of allowing water to collect within duct piping are prohibited.

6.2.3 *Positively-pressurized pipe*

Positively-pressurized *ASD* duct piping or other positively pressurized components of an *ASD* system shall not be installed in or pass through or pass under the conditioned space of the building.

Figure 6.2.3



6.2.4 *Labels required (duct piping)*

Duct piping shall be labeled in accordance with Section 8.4.4.

6.2.5 *ASD pipe materials*

All *ASD* duct piping, except piping routed below concrete slabs or under *soil gas retarder* membranes shall be rigid, non-perforated and meet the following requirements:

a) ABS plastic piping shall comply with ASTM D2661, F628 or F1488. Pipe wall thickness shall be Schedule 40 with solid, cellular core or composite wall. ABS pipe joints shall be solvent welded in accordance with the pipe manufacturer's instructions, with solvent cement conforming to ASTM D 2235.

b) PVC plastic piping shall comply with ASTM D2665, F891 or F1488. Pipe wall thickness shall be Schedule 40 with solid, cellular core or composite wall. PVC pipe joints shall be joined in accordance with the pipe manufacturer's instructions with cement conforming to ASTM D2564. The joint surfaces for PVC plastic pipe and fittings to be solvent welded shall be prepared with:

   1. a primer conforming to ASTM F656; or
   2. a self-priming product; or
   3. as otherwise stipulated in the pipe manufacturer instructions.

c) All *ASD* plastic pipe fittings shall be of the same material as the plastic piping they are joined to and solvent welded unless joined with flexible couplings in accordance with Section 6.2.6.

Exception 1: Alternative pipe materials

Alternative materials specified in codes for "Above-Ground Drainage and Vent Pipe" [4] are permitted. Alternative pipe materials that include iron, steel and copper piping shall be joined in accordance with the pipe manufacturer's instructions and as required by code.

For buildings classified as single family structures that contain not more than four attached *dwelling* units on a contiguous foundation, other pipe products are permitted for use where deemed acceptable by:

a) Local state licensing/certifying programs that provide written acceptability for the product; or

b) Local code authorities for locations that have no state licensing/certifying program.

Exception 2: Downspout material on exteriors

Downspout and other light-duty rigid materials of appropriate durability are permitted for duct piping use if all of the following requirements are met:

a) The material shall be installed only at exterior locations at the pressure side of the *ASD* system;

b) Duct size shall be in accordance with Section 6.3.7;

c) Materials shall be no less than equal to the commercial durability of existing downspout materials used for such buildings where the system is being installed.

Exception: Where the building is a designated heritage preservation site or operates under similar covenants, the materials used for exterior ducting are permitted to vary according to the historic preservation guidelines or other covenant requirements;

d) Use of the specific material shall be acceptable to the *client* and, if applicable, state licensing or certifying authorities; and

e) Joined connections for downspout materials and joints shall be welded to achieve a watertight seal or sealed and *mechanically fastened* at each joined connection using hardware fasteners that are weather-rated for outdoor use. When joined connections are sealed and *mechanically fastened*:

1. Sealants shall be applied to the inner junction between joined downspout materials in a manner to both establish a complete seal and protect sealants at the bonded location from degradation. Sealants shall be durable and suitable for use on gutter materials; and
2. Where pre-formed or modified flange connections are used to join sections of duct material, the upper portion of duct material at each connection shall be flanged inward and inserted downward into the lower portion of duct material to allow water and condensate to fully drain downward without collecting water and ice at joint connections.

6.2.6 *Flexible couplings*

Flexible coupling disconnects that comply with ASTM D5926, ASTM C1173 are permitted as an alternative for joining two portions of *ASD* duct piping if they establish a secure watertight connection. Equivalent watertight methods are also permitted, such as threaded pipe or union disconnect. Flexible coupling disconnects or equivalent methods are permitted for situations that include:

a) where piping disassembly may be required in the future for maintenance purposes, such as required at sumps and where connecting an *ASD* fan;

b) where joining duct piping materials that are incompatible for solvent welding;

c) where physical constraints inhibit the ability to join duct pipe materials by means of a solvent weld;

d) where intended to minimize noise by breaking the direct transfer of fan vibration to duct piping; and

[4] As point of reference for alternative piping, see the International Residential Code (IRC) Section 3002.1(1).

e) where local codes allow temporary removal and airtight replacement of *ASD* pipe sections to provide access to areas requiring maintenance or inspection of equipment as described in Section 6.2.9.

6.2.7 *Secure duct piping*

6.2.7.1 Duct piping shall be fastened securely to the structure of the building with hangers, strapping or other supports that will adequately and durably secure the duct material. To durably withstand natural forces such as wind, ice and degradation over time, requirements include:

a) Mechanical hardware or fasteners shall be durable for the purpose and weather-rated when employed outdoors;

b) The anchoring method and fastening materials shall be suitable to secure the anchors in a durable manner to whatever building surface is chosen for securing the duct piping;

c) Existing plumbing pipes, ducts or mechanical equipment shall not be used to support or secure duct piping; and

d) Fastening systems that rely only on extending a nail or screw through the duct piping and into a wall or other supporting surface shall not be used to secure duct piping.

6.2.7.2 Supports for *ASD* plastic piping shall be installed no less than every 10 feet (3 m) on vertical piping and 4 feet (1.2 m) on horizontal piping. Alternate *ASD* duct materials identified in Section 6.2.5, such as iron, steel or copper, shall be secured in a manner that meets codes [5] and manufacturer recommendations.

Informative advisory—Configurations that prevent both lateral and vertical movement of duct piping are far less vulnerable to failed joint connections, dislodged rubber couplings and water leaks.

Where exposed, such as in basements and attics, pipe lengths that can move laterally or vertically are commonly witnessed to cause failed or leaking joint connections. This is known to occur merely as a result of occupants or workers jarring or bumping into pipes, or by natural forces such as wind.

6.2.8 *Unnecessary noise*

Duct piping, fans and support configurations shall be installed in a manner that minimizes transfer of vibration to the structural framing of the building.

Suction pipe openings, such as under membranes and in *non-habitable airspaces,* shall be configured to minimize unnecessary objectionable air-rushing noise if the noise can be heard inside occupiable spaces.

Note—Section 6.3.8 *Air Velocities* provides guidance on air-rushing noise at the *point of exhaust*. Common methods to reduce other objectionable air-rushing noise, such as under a membrane, include:

a) reducing the size of air inlet pipe openings (if air volume flow of the duct pipe is greater than needed to establish a vacuum);

b) extending perforated pipe under a membrane or into a *non-habitable airspace* to allow the same air volume to enter more slowly through dozens of slits or holes; and

c) altering whole system airflow (when pipe or fan are transporting significantly more air than needed to establish a vacuum in all airspaces being depressurized).

6.2.9 *Provide access clearance*

Duct pipe routing shall not:

a) block egress from entrances and exits to the building, including those designated for fire and safety;

c) compromise effectiveness of fire suppression systems; or

[5] As point of reference for securing alternative piping, see, as applicable, the International Mechanical Code (IMC), the International Plumbing Code (IPC) or the International Residential Code (IRC) that are published by the International Code Council.

b) block any necessary access to any areas requiring maintenance or inspection such as mechanical equipment or a *crawl space*.

Exception: Flexible coupling disconnects or equivalent methods prescribed in Section 6.2.6 are permitted where allowed by code to provide access by temporary removal and airtight replacement of *ASD* pipe sections.

6.2.10 *Protect ducts from the elements (insulation)*

Duct piping shall be provided with thermal insulation in accordance with the following two requirements:

a) Where it is likely on a regular basis (e.g., annually or every few years) that freezing temperatures will result in ice buildup within duct piping that would adversely affect system performance, duct piping shall be provided with thermal insulation that is protected from the elements. Under this condition the insulation R-value shall be not less than 4.
Note—For more extreme climates, greater R-values may be appropriate; and

b) Where it is likely that condensation on exterior surfaces of duct piping would damage building materials, duct piping shall be provided with thermal insulation. Under this condition, the insulation shall have an external vapor barrier and shall have an R-value of not less than 1.8.

6.2.11 *Observe codes* [6]

Informative advisory—Codes that impact choices for pipe routing include but are not limited to:

a) Codes intended to maintain the integrity of a building's structural members.
These codes place limits on the extent and location for sawing, notching and boring holes in a building's structural support members. In example, codes normally prohibit:
   1. notches in solid wood joists, rafters and beams within the middle 1/3rd of its span and notches greater than 1/6th of its width, and
   2. holes that are closer than 2 inches to the top or bottom of solid wood members;

b) Fire codes intended to inhibit the spread of fire and smoke.
In example, national codes normally prohibit flammable materials such as plastic pipe from:
   1. touching or being too close to heat sources to include flues and chimneys,
   2. compromising fire/smoke barriers between floors (e.g., metal barriers in flue chases), and
   3. penetrating a fire-rated assembly unless specific procedures are taken, such as installing fire collars to control the spread of fire and smoke (e.g., a garage wall or ceiling if constructed as a fire-rated component and at penetrations into upper floor *dwellings*); and

c) Codes and local utility company restrictions regarding proximity of piping and electrical components that could:
   1. inhibit access for inspection and repairs, and
   2. be ignition sources for flammable materials (such as an electrical switch that is located near natural gas meters and liquid propane or gasoline holding tanks).

Note—The Companion Guidance provided with ANSI/AARST SGM-SF provides examples of code text.

[6] As point of reference, see the International Residential Code (IRC) as published by the International Code Council.

6.3 *ASD* Pipe Sizing

ASD duct piping shall be sized and configured to result in adequate capacity to transport the volume of air required for establishing a vacuum under each slab or membrane and within each airspace being depressurized by the *ASD* system.

6.3.1 *Minimum inside diameter—air volume capacity*

ASD duct piping from the exhaust point to the *soil gas collection plenum(s)* shall be equivalent or greater than the cross-sectional area of a 3-inch (75-mm) ID pipe or as determined by *PFE* Analysis.

6.3.2 *When larger air volume needs are indicated*

Where *PFE* Analysis indicates the necessary airflow for the entire system is more than 80 *cubic feet per minute (cfm)* (2.3 m^3/min), duct piping from the exhaust point to the *soil gas collection plenum(s)* shall be equivalent or greater than the cross-sectional area of a 4-inch (100-mm) ID pipe.

6.3.3 *When smaller air volume needs are verified*

Where *PFE* Analysis indicates the necessary airflow for the entire system is equal to or less than 40 *cfm* (1.1 m^3/min), 2-inch (50-mm) ID duct piping from the exhaust point to the *soil gas collection plenum(s)* is permitted. If airflow exceeds 40 *cfm* (1.1 m^3/min) due to fan pressures much stronger than normally employed, such as greater than 6 inches WC (1500 Pa), 2-inch (50-mm) ID pipe is only permitted if both:

a) The system still meets the needs for an appropriate design, as described in Section 5.3; and

b) Adequate air volume transport is achieved for establishing a vacuum within each airspace being depressurized.

6.3.4 *Equivalent cross-sectional area*

Multiple pipes of various sizes that are joined in a parallel manner to result in a combined air volume capacity that is not less than the equivalent cross-sectional area of pipe diameters required in Sections 6.3.1 and 6.3.2 shall be permitted.

The minimum pipe diameter through parallel pipe sections shall be 2-inch (50-mm) ID pipe.

Note—Three 2-inch (50-mm) pipes in parallel are necessary to meet this requirement when connecting to a single 3-inch pipe.

Informative Table 6.3.4
Cross-sectional Area Dimensions

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)

6.3.5 *Maintain whole-system air volume capacity*

The configuration shall not reduce duct pipe diameters or dimensions in the direction of airflow from the soil gas inlet(s) to the exhaust location to result in less whole-system air volume capacity than achieved with pipe sizes specified in Sections 6.3.1, 6.3.2 or 6.3.3. All components of the ducting system that reduce air volume transport capacity shall be accounted for in meeting this requirement, to include any rain caps or other obstructions at exhausts and circumference or size of slab penetration connections to soil gas.

6.3.6 *Multiple suction points*

Each suction pipe shall be sized to provide air volume capacity sufficient to establish a vacuum under each slab or membrane and within each airspace being depressurized by the *ASD* system.

Where air valves, dampers or baffles are used to adjust airflow balance:

a) their location, settings and design shall be included in "as built records" for the system; and

b) they shall be marked or labeled to indicate their purpose, settings and instructions, such as "Radon System Air Valve. Do Not Alter From Marked Setting," or similar wording.

6.3.6.1 Drainage

When multiple *suction points* are employed, piping extended to secondary *suction pits* exclusively designed for condensate or rainwater drainage do not require any specific pipe diameter.

6.3.7 *Sizing for gutter downspout duct materials*

A natural reduction to airflow capacity shall be accounted for when using gutter downspout in accordance with Section 6.2.5 Exception 2. Because crimped downspout flange connections reduce airflow capacity, gutter downspout materials employed shall be:

a) no less than 3 x 4 inch downspout material (75 x 100 mm) to meet capacities stipulated in Section 6.3.1 for 3-inch (75-mm) ID pipe; and

b) no less than 4 x 5 inch downspout material (100 x 127 mm) to meet capacities stipulated in Section 6.3.2 for 4-inch (100-mm) ID pipe. When even larger air volume needs are indicated, duct size shall increase respectively.

Gutter downspout material that is less than 3 x 4 inches (75 x 100 mm) shall not be permitted unless, in accordance with Section 6.3.3, *PFE* Analysis indicates that the necessary airflow for the entire system is equal to or less 40 *cfm* (1.1 m^3/min).

6.3.8 *Air velocities*

Informative advisory 1—Maximum airflow speed

Air speed/velocity within duct piping should be less than 2,000 *feet per minute (fpm)* (610 m/min) to prevent condensed vapor from being drawn upward within piping rather than naturally falling by virtue of gravity to its intended destination (e.g., soil).

In addition, air rushing noise will usually reach an objectionable threshold at *ASD* exhaust locations with air velocities of about 1,600 *fpm* (488 m/min) or faster.

• Air velocities of 1,600 *fpm* (488 m/min) result when air is driven at:

a) 80 *cfm* (2.3 m^3/min) through: 3-inch (75-mm) pipe
or 3 x 4 inch (75 x 100 mm) downspout

b) 140 *cfm* (4.0 m^3/min) through: 4-inch (100-mm) pipe
or 4 x 5 inch (100 x 127 mm) downspout

c) 315 *cfm* (8.9 m^3/min) through: 6-inch (150-mm) pipe
or 5 x 6 inch (127 x 152 mm) downspout

d) 35 *cfm* (1.0 m^3/min) through: 2-inch (50-mm) pipe
or 2 x 3 inch (50 x 75 mm) downspout

Informative advisory 2—Minimum airflow speed

Air speed/velocity at the system exhaust that is much lower than 300 *feet per minute (fpm)* (92 m/min) should be considered a benchmark that might indicate:

— more work to enhance *PFE* may be needed to achieve *mitigation* goals;
— enhanced expectations of exhaust icing or freeze-up during extreme cold weather;
— expectations of premature fan failure, if the cause is poor *PFE*; or
— a high vacuum fan is not aiding *PFE* but may cause adverse effects, such forcing liquid from U-tube manometers or forcing sand under the building out the exhaust of a system.

• 300 *fpm* (92 m/min) equates to:

a) 20 *cfm* (0.6 m^3/min) through a 3-inch (75-mm) pipe;
b) 26 *cfm* (0.7 m^3/min) through a 4-inch (100-mm) pipe;
c) 60 *cfm* (0.7 m^3/min) through a 6-inch (150-mm) pipe; and
d) 9 *cfm* (0.2 m^3/min) through a 2-inch (50-mm) pipe.

6.4 *ASD* Exhaust Discharge

6.4.1 *General*

6.4.1.1 Measuring Distances

Distances shall be measured between the closest point of the exhaust opening to the closest point of all location requirements specified in Section 6.4 using the shortest distance, as if a string were stretched between them.

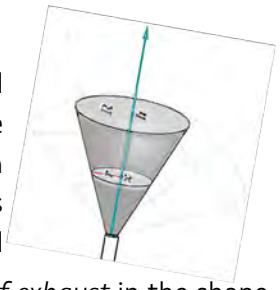
6.4.1.2 Definitions

Definitions a), b), c) and d) of this Section 6.4.1.2 shall apply to exhaust requirements in Section 6.4:

a) *Openings in structure* The openings created in structural walls or roofs for the purpose of mounting windows, skylights, doors or other assemblies that might open to outdoor air;

b) *Operable openings* The operable or constantly open portion of windows, skylights, doors and other openings designed to readily operate for increasing ventilation with outdoor air;

c) *Exhaust trajectory* The angle of the pipe or elbow at the *point of exhaust*.



The angle of the exhaust trajectory from the open end of the pipe or elbow is geometrically defined as the straight- or center-line axis that extends outward from the geometric center of the exhaust opening and is perpendicular to the plane of the exhaust opening; and

d) *Exhaust spread* The exhaust spread extends outward from the *point of exhaust* in the shape of a circular cone. The tip or apex of the cone is at the geometric center of the exhaust opening and the cone profile grows larger as distance from the *point of exhaust* increases.

Note—The total directional spread of the exhaust or cone is defined in degrees by the offset-axis angle of the cone profile compared to the cone's center-line axis. Expanding outward from the *point of exhaust*:

- An exhaust spread radius of 45˚ equals an exhaust spread diameter of 90˚.
- An exhaust spread radius of 11˚ equals an exhaust spread diameter of 22˚.

6.4.2 *Outdoors*

The *point of exhaust* for all soil gas vent systems shall be located outdoors.

6.4.3 *Directional spread (restrictions)*

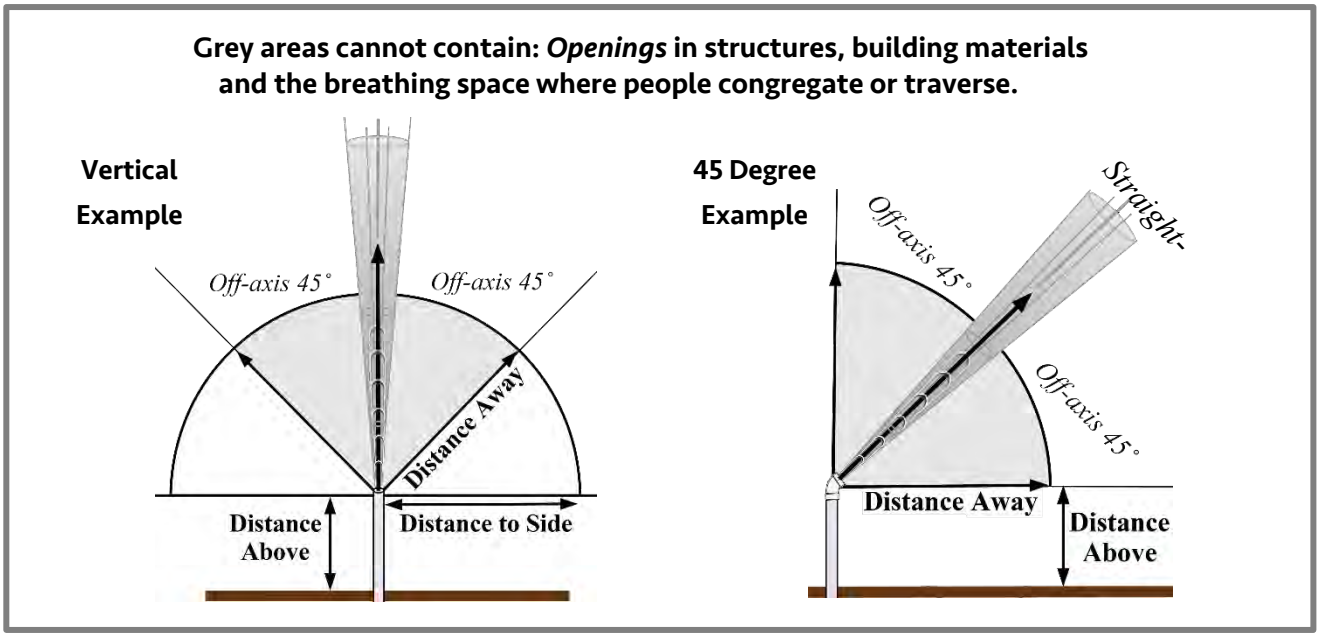
The *exhaust trajectory* with an *exhaust spread radius* of 45˚ shall not encounter *openings* in any structures, building materials or the breathing space where individuals congregate or traverse within 10 feet (3 m) from the *point of exhaust*.

Exception: Composite or otherwise layered water-tight roofing materials.

6.4.4 *Straight-line trajectory (restrictions)*

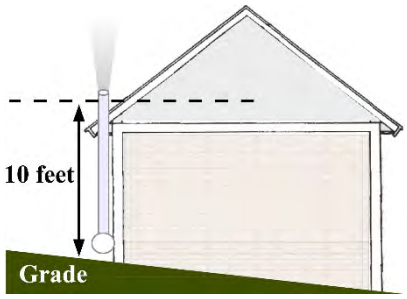
The *straight-line exhaust trajectory* with an *exhaust spread radius* of 11˚ shall not encounter *openings* in any structures, attic ventilation openings, building materials or the breathing space where individuals congregate or traverse within 20 feet (6 m) from the *point of exhaust*.

Figure 6.4



6.4.5 *Elevation above grade*

The *point of exhaust* shall be located not less than 10 feet (3 m) above grade nearest to the *point of exhaust* and shall be compliant with Section 6.4.3 *Directional spread* and Section 6.4.4 *Straight-line trajectory.*

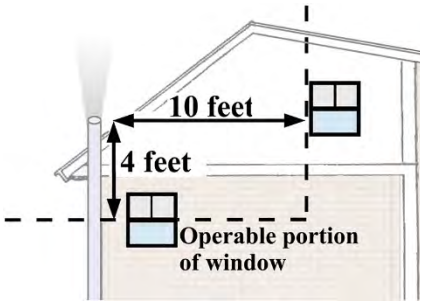


6.4.6 *Separation from operable openings in structures*

The *point of exhaust* shall be compliant with Section 6.4.3 *Directional spread* and located either:

a) not less than 10 feet (3 m) horizontally to the side *operable openings* in structures; and

b) not less than 4 feet (120 cm) above *operable openings* in structures.

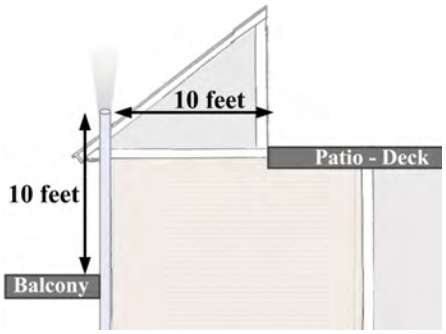


6.4.7 *Separation from people*

In relationship to exterior flooring surfaces such as decking, patios, sidewalks and exterior corridors where individuals congregate or traverse, the *point of exhaust* shall be:

a) not less than 10 feet (3 m) above or horizontally to the side of exterior flooring surfaces; and

b) compliant with Section 6.4.3 *Directional spread* for an elevation of not less than 10 feet (3 m) above exterior flooring surfaces.

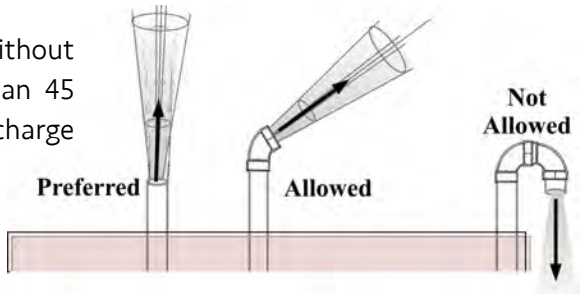


6.4.8 *Equipment Wells and Parapet roofs*

The *point of exhaust* relative to open equipment well airspaces or parapet roof construction, where areas are enclosed by more than two walls, shall comply with Section 6.4.3 *Directional spread*, to include the breathing space where individuals conduct maintenance.

6.4.9 *Angled Trajectories*

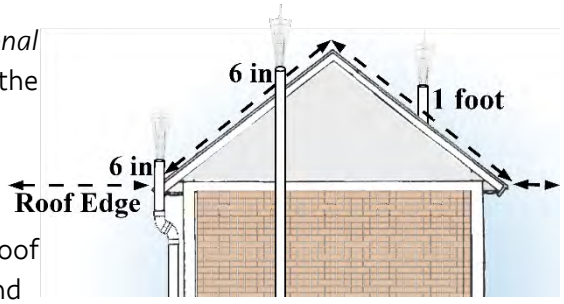
The *point of exhaust* shall be directed upward without obstruction at an angle that does not deviate more than 45 degrees from a vertical exhaust trajectory. The exhaust discharge shall not exhaust downward.



Exceptions: 90 degree horizontal exhausts shall comply with requirements in Section 6.4.12

6.4.10 *Roof*

The *point of exhaust* shall comply with Section 6.4.3 *Directional spread* and, unless all requirements of Section 6.4.11 are met, the *point of exhaust* shall be:



a) not less than 1 foot (30 cm) above a pitched roof at the point penetrated;

b) not less than 6 inches (15 cm) above the edge of the roof when *ASD* piping is attached to the side of a building; and

c) not less than 18 inches (46 cm) above a flat roof.

6.4.11 *Below the roof*

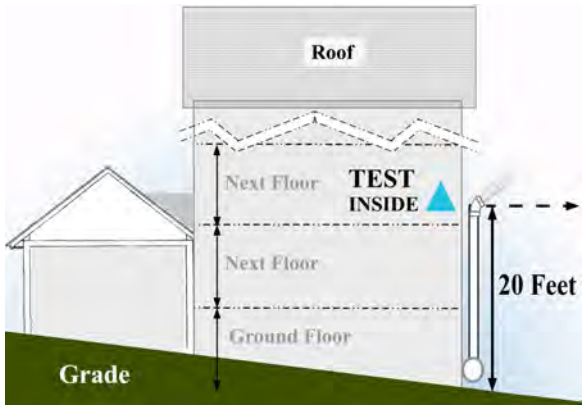
The *point of exhaust* shall be permitted to be located below the edge of the roof if the configuration complies with all other requirements of Section 6.4 and all of the following requirements are met:

a) The justification for not locating the exhaust above the edge of the roof shall be recorded in the operations and maintenance plan and shall be based upon either:

1. the inability to comply with other requirements of Section 6.4 if the *point of exhaust* were located above the roof, or
2. the edge of the roof exceeds 20 feet (6m) above grade nearest to the *point of exhaust*;

b) The *point of exhaust* shall be not less than 20 feet (6m) above grade nearest to the *point of exhaust*; and

c) Testing shall be conducted within the occupiable area that immediately adjoins the 45˚ *Directional spread* required in Section 6.4.3. This testing is required no later than in conjunction with the initial post-*mitigation* test and shall be recommended for inclusion in all future post-*mitigation* tests.



Informative advisory—Where time constraints allow, long-term testing subsequent to an initial short-term test is recommended.

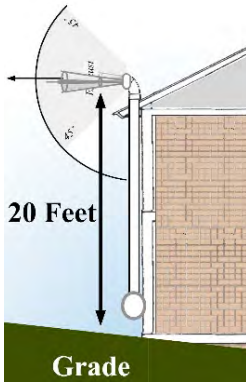
6.4.12 *Horizontal trajectory*

While it is best practice to avoid horizontal trajectories, 90 degree horizontal exhaust trajectories are permitted if compliant with all other distances required in Section 6.4 and Section 6.4.12.1 or Section 6.4.12.2.

6.4.12.1 90-Degree Horizontal Discharges

If passing the edge of the roof, the *point of exhaust* for a 90-Degree horizontal discharge shall not be less than 20 feet (7.5 m) above grade nearest to the *point of exhaust*. The *point of exhaust* shall comply with Section 6.4.3 *Directional spread* including for distances above the breathing space where individuals congregate or traverse as stipulated in Section 6.4.7.

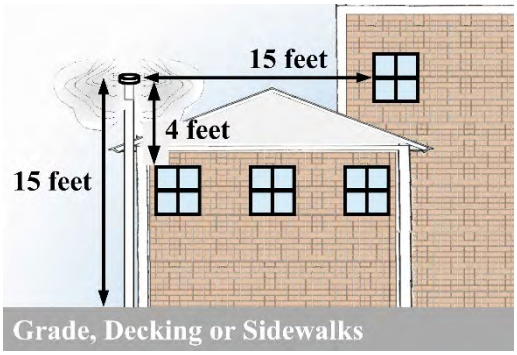
Where "T" style rain caps are configured for 90-Degree horizontal discharge in two directions, both discharge trajectories shall meet these requirements.



Informative advisory—Exhausts at a 90-degree angle are prone to form icicles during freezing weather that can fall to cause harm to property or individuals.

6.4.12.2 Rain Caps

The *point of exhaust* for diffused horizontal discharges shall not be less than 15 feet (4.6 m) above grade nearest to the *point of exhaust* and not less than 4 feet (120 cm) above or 15 feet (4.6 m) away from *operable openings* into the structures, such as windows, skylights and doors.



6.4.13 *Increased distances for large capacity systems*

When the *ASD* system is designed for larger airflow capacities with duct piping larger than 4-inch (100-mm), distances shall be increased beyond what is required in Section 6.4 to comply with Table 6.4.13.

Table 7.4.13

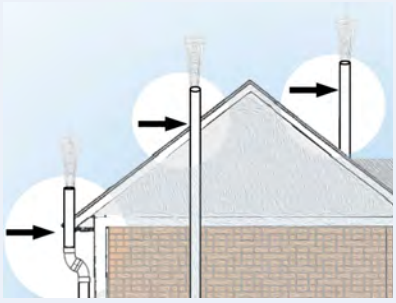
Pipe ID *As in Section 6.4* **3"- 4" Pipe** (10 cm)	Distance Away Directional spread *As in Section 6.4.3* **10 ft** (3 m)	Distance Away Straight-line *As in Section 6.4.4* **20 ft** (6 m)	Distance Above, Below or To Side Grade, *Operable Openings* and People *Sections 6.4.5, 6.4.6 and 6.4.7*
For Larger Pipe ID	***Increase to***	***Increase to***	***Increase by***
6" (15 cm)	12 ft (3.6 m)	25 ft (7.6 m)	2 ft (1.8 m)
8" (20 cm)	18 ft (5.5 m)	30 ft (9 m)	4 ft (2.4 m)
10" (25 cm)	20 ft (6 m)	40 ft (12 m)	6 ft (1.8 m)
For pipe larger than 10" (25 cm)	Shall be increased to meet or exceed ASHRAE 62.1 2016, Appendix B, Separation of Exhaust Outlets and Outdoor Air Intakes		

6.4.14 *Protection from the elements*

6.4.14.1 *Informative advisory*—Installation of an *ASD* system should include efforts to:

a) Provide support directly below fan locations and the discharge location that is adequate to ensure structural integrity of the pipe configuration.

For example, a physical support should be provided within 3 feet (91 cm) of the *point of exhaust* or within 18 inches (46 cm) above and below fans located in attics when pipe configurations might otherwise allow lateral or vertical movement of duct piping;



b) Locate or configure the exhaust assembly in a manner that avoids blockage or damage to the exhaust piping as a result of snow, ice curl or other forces; and

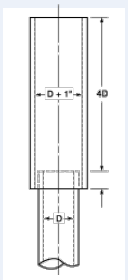
c) Secure and meet code requirements for any piping that extends high enough to require tethering or other means of lateral stability.

6.4.14.2 Icing— *Informative advisory*

The configuration for exhaust airflow should be designed and installed to minimize significant airflow blockages from ice.

6.4.14.3 Rain and Debris— *Informative advisory*

In locations that experience blockage from debris or pervasive torrential rain or high winds each season, rain caps may sometimes be warranted. For concerns of debris or small animals that may enter the piping, the best choice is usually wire mesh described in Section 6.4.14.4. For torrential rain, a better choice is often a rain diverter as shown in this the diagram.



6.4.14.4 Wire Mesh or Equivalent— *Informative advisory*

Rodent/insect screen (mesh not smaller than 1/2 in. [13 mm]) is permitted and recommended where the *contractor* or *client* is concerned that debris or small animals might enter the *point of exhaust*, or that fan blades might cause injury to occupants. The resulting configuration required by Section 7.3.5 would not substantially diminish whole-system air volume capacity of the *ASD* system.

6.5 *ASD* Fan Installation

6.5.1 *Fan design*

Note—Except for this provision (6.5.1), 12/20 revision updates include all of Section 6.5.

ASD fans chosen shall be designed or otherwise sealed to reduce the potential for leakage of water or soil gas. *ASD* fans mounted on the exterior of buildings shall be rated for outdoor use or installed in a weatherproof protective housing that results in a code compliant configuration with protection against electrical shock. *ASD* fans chosen shall be designed to allow rainwater or condensation from within *ASD* piping to pass through or around the fan when activated. *ASD* fans chosen shall be designed to accommodate continuous activation over a durable life span. *ASD* fans shall originate from a manufacturer that lists *ASD* (*radon mitigation*) as one of the fan's intended uses.

Note—*ASD* fans chosen should be designed to minimize objectionable noise.

6.5.2 *Safe locations required*

To circumvent accidents that can result in systems leaking *radon* and soil gas into *occupied* spaces due to a failed pipe joint or other sealed connection:

a) *ASD* fans shall not be installed in the conditioned (heated/cooled) or otherwise occupiable space of a building; and

b) *ASD* fans shall not be installed in any location directly beneath the conditioned or otherwise occupiable space of a building, such as a fan installation within a basement, *crawl space* or enclosed garage beneath occupiable space.

6.5.3 *Approved locations*

Where compliant with requirements in Section 6.5.2:

a) *ASD* fans are to be installed in attics, on the exteriors of buildings, or in garages that are not beneath conditioned or otherwise occupiable spaces.

Note—Ventilated attics or the exterior of the building are preferred locations. Considerations also include locations that avoid objectionable noise from fan vibration and exhaust air; and

b) *ASD* fans shall not be installed below ground.

Exception: Locations that are created or exist below grade that are not beneath conditioned or otherwise occupiable space of a building, such as outside the building shall be permitted if configured to protect the fan and electrical components from damage and degradation. Such locations or any enclosures created shall include reasonable access for maintenance and adequate groundwater control such as drainage and, as applicable, *sump* pump systems. As applicable, all electrical components, including wiring and service switch configurations, shall be rated for use in wet or damp environments.

6.5.4 *Fan Installation*

Installation of *ASD* fans shall comply with the following requirements:

a) *ASD* fans shall be sized to provide the pressure difference and airflow capacity necessary to achieve the *mitigation* goals;

b) *ASD* fans shall be installed in a configuration that avoids condensation buildup in the fan housing. To achieve this requirement, *ASD* fans shall be installed on vertical runs of *ASD* piping or in accordance with the manufacturer's specifications;

c) *ASD* fans shall be mounted to piping using flexible couplings that comply with ASTM D5926 or ASTM C1173 or using an alternative method specified by the manufacturer that achieves a watertight connection; and

d) *ASD* fans subject to extreme climate conditions shall be protected with thermal insulation, as needed, in accordance with Section 6.2.10.

Note—12/20 revisions This section is now identical for ANSI/AARST SGM-SF, RMS-MF and RMS-LB

7.0 SEALING

7.1 Background and Accessibility

Sealing is not to be regarded as a permanent, stand-alone *mitigation* method. The purpose and viable goal of sealing efforts are limited to achieving a continuous air barrier that resists air movement between soil and indoor air.

Note—The use of sealing alone has not been shown to significantly or consistently reduce *radon* entry into buildings.

7.1.1 *Accessibility to cracks and openings*

For the purpose of sealing requirements herein, the term "accessible" shall mean accessible without destructive or significant disassembly of building components or finishes. Inaccessible openings or cracks shall be disclosed to the *client* and included in *operation, maintenance and monitoring (OM&M)* documentation if they may compromise the performance of a *mitigation system* and are determined to be beyond the ability of the *contractor* to seal.

7.2 Sealant Materials

7.2.1 *Caulking cracks*

When sealing cracks in slabs or foundation walls, the caulks and sealants shall be durable materials, such as urethane or polyurethane, complying with ASTM standard C920 class 25 or greater or equivalent material. Caulks and sealants shall be applied according to the manufacturer's recommendations.

> *Informative advisory*—The chances of adverse effects on occupants from exposure to curing compounds are likely to increase with increased volumes of product application. When using such products, it is recommended to notify occupants of related hazards, such as illustrated in Exhibit C. Products that emit low volumes of chemical vapors during curing are recommended for protection all occupants and prospective occupants as a public health matter, and especially for sensitive occupants.

7.2.2 *For larger gaps*

Where a crack or joint is greater than 1/2 inch (13 mm) in width, foam *backer rod* or other comparable filler material to support wet caulk until it cures shall be inserted into the existing gap prior to applying caulk.

7.2.3 *For larger openings*

When sealing larger openings to soil in slabs and foundation walls, the materials shall be durable, such as: nonshrink cementitious products; expanding foam; plastic; or other comparable materials and methods appropriate for the application.

7.2.4 *For heated pipes and flues*

When sealing openings around combustion appliance flues and hydronic heat or steam pipes, noncombustible materials shall be used.

7.2.5 *For sump lids and hatchway doors*

For *sump* lids, hatchway doors or other items that require access in the future, nonpermanent sealant materials are required, such as silicone caulk, gasket materials or other equivalent method.

7.3 Accessible Slab Cracks

Accessible openings to soil around suction piping, utility penetrations and where the slab meets the foundation wall shall be closed or sealed to resist air movement between soil and indoor air.

> *Informative advisory*—Accessible cracks across a slab that are greater than 1/16 inch (1.6 mm) in width should also be sealed. It is further recommended to seal accessible expansion or control joints in a slab.

7.3.1 *Perimeter channel drains*

Accessible gaps to soil at perimeter channel drains and foundation drainage boards shall be closed or sealed to the extent practical without compromising water control capability of the perimeter drainage system. Where sealing perimeter channel drain gaps, methods shall employ materials that will achieve closure yet retain flexibility to allow natural movement of foundation slabs and walls.

7.4 Other Openings to Soil

Other accessible and significant openings to soil in slabs or walls shall be sealed to resist air movement between soil and indoor air, such as: at support posts; electrical conduits that are open to soil; and openings for plumbing fixtures under bathtubs.

7.4.1 *Block walls*

Where Block Wall *Depressurization* is installed, all accessible openings and gaps in hollow block masonry walls that surround the hollow void network being depressurized shall be closed to resist air movement between the depressurized void network and both indoor air and outdoor air. Closure shall result in resisting migration of air into the depressurized void network, to include:

a) open blocks at the top course of hollow block masonry walls and open blocks under door or window openings; and
b) cracks or openings in the block walls, both inside and outside of the building.

Materials used to close openings and gaps shall be in accordance with Sections 7.2.3, 7.2.4 or equivalent.

7.4.2 *Basement de-watering systems*

If an *ASD suction point* must be installed into a basement de-watering system, exposed openings into the drainage system that can be sealed without compromising water drainage features shall be sealed, to include as required in Section 7.3.1.

Informative advisory—The vacuum extension needed under a slab will often not occur if the *suction point* is drawing most of its air from nearby openings in the slab. The *suction point* location compared to nearby openings in a slab must be considered for achieving *mitigation* system goals. Consistent with this concern, it is best to close any exposed block wall foundation openings that are above the floor adjacent to a depressurized de-watering system.

7.5 Sumps and Pits

Sumps or other accessible pit openings in the interior slab(s) that connect to soil air shall be covered and sealed to the extent possible without compromising the water control capability of the *sump*. The manner of closure shall also not compromise safety concerns, such as emergency pressure relief discharge from hydronic heating system water boilers. Covers are not required for pits that do not connect to soil air.

7.5.1 *Sump cover specifications*

Sumps in interior floors that connect to soil air shall have a rigid lid 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. The lid shall be *mechanically fastened* in a manner to facilitate removal for maintenance. The lid shall be sealed to resist air movement between soil gas and indoor air with a gasket or with nonpermanent caulk such as silicone. Penetrations through the lid such as gaps around electrical wiring, water ejection pipes and *ASD* piping shall be sealed.

7.5.1.1 Access

Sump covers shall include a removable port or section of the lid no less than 4 inches (10 cm) in diameter or equivalent method when a *sump* pump is installed in the pit to allow physical access for routine verification that pumps are operational.

Informative advisory—It is recommended that *sump* covers are designed to allow visual access to permit observations of conditions in the *sump* by way of a lid window, transparent lid or similar method.

7.5.1.2 Labeling Required (*sump* covers)

Sump lid labels shall be provided in compliance with Section 8.4.6 a.

7.5.3 *Sump pump water discharge*

If flexible rather than rigid water discharge piping is found, the *contractor* shall recommend in writing that rigid pipe for water discharge from permanent *sump* pumps be installed. *Sump* pumps or piping configurations for water discharge from the *sump* pump shall have a backflow prevention valve as typically provided to protect against pump failures. Should there be a need for the *contractor* to alter the destination of discharged *sump* water, the destination shall meet requirements of local authorities.

7.5.2 *Surface water relief (slabs)*

An alternative drainage system shall be provided and installed in accordance with guidance in Section 7.8.1 when sealing a *sump* or other slab opening that is the only drain relief for excess water on the slab surface.

7.6 Membranes Over Exposed Soil

Informative advisory—To break the connection between soil gas and indoor air, soil and other fill material in *accessible crawl spaces* should be covered with concrete or a *soil gas retarder* membrane.

7.6.1 *Soil gas retarder material (membranes general)*

Soil gas retarders shall meet ASTM E1745 class A, B or C.

Note—These specifications include permeance, tensile strength and puncture resistance.

Informative advisory—Thicker sheeting or other means to protect the membrane are recommended where *crawl spaces* are used for storage or frequently entered for maintenance of utilities or equipment.

7.6.2 *Seams (membranes general)*

Seams where membrane materials are joined shall be sealed in accordance with Section 7.7.1 when sub-membrane *depressurization* (SMD) is employed. Otherwise, seams between adjacent membrane sheets shall be overlapped not less than 12 inches (30 cm).

7.6.3 *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 6 inches (15 cm) on all sides and that is sealed with a caulk complying with ASTM C920 class 25 or greater or an equivalent method.

7.6.4 *Label membranes or access ports*

Membranes or the *crawl space* access port shall be labeled in accordance with Section 8.4.6 b.

7.6.5 *Surface water relief (membranes)*

Informative advisory—When observing indications that water is likely to collect on the surface of a membrane, it is best to inform the *client* of observations, and to include any maintenance recommendations in *OM&M* documentation. Recommended solutions to consider include installing drainage for surface water in the lowest location in accordance with guidance in Section 7.8.1.

7.6.6 *Securing the membrane*

The membrane shall be durably secured to the walls or other surfaces for *crawl spaces* or portions of a *crawl space* that are expected to be regularly accessed for maintenance, storage or other purposes.

7.6.7 *Wood components*

Any wood installed as part of a *mitigation* system that directly contacts masonry or soil, such as when employed to secure a membrane, shall be resistant to decay and insects or otherwise protected.

7.7 Sub-Membrane Depressurization (SMD)

In addition to all requirements in Section 8.6, *soil gas retarder* membranes associated with *SMD* shall be sealed in accordance with Section 7.7.1 through Section 7.7.4 to result in a closed *soil gas collection plenum* under the membrane that resists air movement between soil and air above the membrane.

7.7.1 *SMD—Seams*

The seams between adjacent membrane sheets shall be overlapped and sealed with a compatible sealant or a caulk complying with ASTM C920 class 25 or greater, or a method such as membrane tape recommended by the manufacturer that results in an equivalent durable bond.

7.7.2 *SMD—Pipe penetrations*

The opening around penetrations of a *soil gas retarder* for *ASD* duct piping and other utility pipe penetrations shall be fully closed using materials and methods that result in permanent closure.

Note—Gasket fittings, pipe clamps, roof flashing or an appropriate sealant are commonly used.

7.7.3 *SMD—Walls and foundation supports*

Membranes attached to foundation walls and at penetrations for foundation support components shall be sealed in a manner to resist soil gas movement between the soil and air above the membrane, to include:

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

7.7.4 *SMD—Inaccessible areas*

When portions of the *crawl space* cannot be accessed or have insufficient height to work in a safe manner as established by the Occupational Safety and Health Administration (OSHA) or other authorities, the edges of the membrane within the boundaries of accessible areas shall be closed.

Where it can be demonstrated to be warranted, systems are permitted with a portion of the membrane edges to remain unclosed. Because this *mitigation* design inevitably combines sub-membrane *depressurization* (SMD), *crawl space depressurization* (CSD) and/or soil gas dilution, open membrane edges shall be disclosed to the *client(s)* in accordance with Sections 10.1.1 e *(Information package)* and 13.7.2.1 e *(OM&M manual)* along with justification for the design. Such design and installation shall also meet any additional requirements in Sections 6.1.4 (*Non-habitable air spaces)* and Section 12.6 (*Soil gas dilution)*.

Note—The larger the area addressed by Sub-membrane *depressurization*, the greater the effectiveness of soil gas control while minimizing adverse effects of energy penalties and moisture within the *crawl space*.

7.8 Drains

7.8.1 *Drains to soil*

Informative advisory—It is recommended that a one-way flow drain or equivalent method with adequate flow capacity be installed for any drain that discharges directly into the soil beneath the slab, through solid pipe to a dry well, or has other exposure to the soil.

Considerations to weigh regarding use of one-way flow valves include: (1) potential for debris to clog the valves and designed capacity of the valve to drain adequate volumes of water, and (2) whether the airflow leaks between soil and indoor air could contribute to backdraft of atmospherically vented combustion appliances or defeat efforts to establish *PFE*.

7.8.2 *Utility drains to soil*

Openings in the slab or at *sumps* that serve for mechanical system water drainage and are likely to draw soil air into a building shall be modified to stop this airflow. The modification shall retain drainage capability, such as the use of a one-way flow valve, re-routing the drain line into a condensate pump or floor drain, or a trap in the drain that provides a minimum of 6 inches (15 cm) or greater.

7.8.3 *Drains to daylight*

Informative advisory—A one-way flow valve or other mechanical means should be installed when a *mitigation* system is designed to draw soil gas from drain tiles (internal or external) that discharge water to daylight. This prevents outside air from entering the *ASD* system while allowing an unobstructed flow of drain water to drain out of the water control system.

7.9 Sealed Isolation Assemblies

Sealed isolation assemblies are not to be regarded as a permanent, stand-alone *mitigation* method.

Note—*Sealed isolation assemblies* are sometimes employed to help break the connection between soil air and living spaces in order to isolate an airspace for *depressurization* or *pressurization*. A *sealed isolation assembly* might be the entire building shell when whole-building *pressurization* is applied, or an isolated airspace such as a *crawl space*; false floor, wall or ceiling; or other room below or adjacent to *occupied* spaces. Sealing can include sealants or gaskets on hatches or doors; sealed partition walls, floors or ceilings; and other configurations that resist air migration across a partition or any component of the isolation assembly. *Sealed isolation assemblies* can sometimes prevent adverse effects on combustion appliances located in an adjoining airspace. *Sealed isolation assemblies* are critical for appropriate implementation of *crawl space depressurization* (CSD).

7.9.1 *Sealing (isolation assemblies)*

When applying *depressurization* or *pressurization* to air within a *sealed isolation assembly*, any accessible openings between the isolated space and areas surrounding the isolated space shall be sealed to resist air movement between the isolated airspace and both indoor air and outdoor air. Access doors or hatches that are not to be permanently sealed shall be fitted with airtight gaskets and a means of positive closure.

7.9.2 *Labeling required (isolation assemblies):*

Access ports into *sealed isolation assemblies* shall be labeled in accordance with Section 8.4.6 c.

8.0 FOR ALL SYSTEMS AND METHODS

8.1 Long-Term OM&M Plan

A long-term *operation, maintenance and monitoring (OM&M)* plan is required for all *mitigation* methods.

8.2 System Monitors

8.2.1 *Viewable operating range monitors*

All *mitigation* systems that incorporate a fan shall include a system monitoring mechanism to directly indicate if the fan, blowers or other integral mechanical components are operating within the established operating range. Design and installation of such monitors shall comply with requirements in both a) and b) of this Section 8.2.1.

a) Continuous Display
The monitoring device shall provide continuous display of a measured value within the established operating range, such as displayed on a manometer pressure gauge or electrical amperage gauge. The monitor shall be located where it is readily seen and protected from damage or degradation.

b) Start up values
Monitoring devices that continuously display a viewable operating range shall be clearly marked or labeled to indicate the measured pressure, airflow volume or amperage readings that existed at the time *mitigation* goals were achieved.

Exception: Fan monitors that provide remote electronic monitoring and notification in the event of *ASD* fan or other mechanical failure, such as to accommodate where occupants are not the *responsible party* for system maintenance.

8.2.2 *Active notification monitors*

In addition to viewable operating range features required in Section 8.2.1, a monitoring mechanism is required that actively alerts occupants or other responsible individuals in the event of fan or other mechanical failure. The alert mechanism shall include one or more of the following warning signals:

a) audible notification that is clear and distinct; or

b) visual light notification that is vividly observable; or

c) notification by telemetric means, such as by email or other electronic communication.

Informative advisory—Sensors that trigger active notification are typically air pressure sensors, airflow sensors or circuits that detect electrical flow. Each method has its strengths and weaknesses. Product features that deserve strong considerations include but are not limited to:

a) Lasting service: For example, products that expose electrical or sensitive components to humid airflow within *ASD* piping can be prone to premature failure;

b) False notifications: Examples are temporary or seasonal conditions that can result in power outages, low pressure or low airflow. Delayed notification in terms of hours or even weeks is an example of methods that circumvent false notifications; and

c) Use restrictions: Monitors that can reliably detect fan failure for *ASD* systems that inherently generate weak pressure or airflow.

8.2.3 *Required for all system monitors*

Requirements for all mechanisms or systems that monitor fan or airflow functionality include:

a) System monitors shall be protected from the elements, including if located outside of a building, and durable for the ambient environmental conditions;

b) System monitors shall be labeled in accordance with Section 8.4.3;

c) Battery operated components shall not be used unless they are equipped with a low-power warning feature;

d) Components that require electricity for indication of system failure shall be on non-switched circuits and designed to reset automatically when power is restored after power supply interruptions; and

e) Components that require electricity for indication of system failure shall not be powered by the same branch circuit as the *mitigation* system fan(s).

Exception: Where the monitoring system has an independent means, such as a battery backup system, that actively alerts occupants or other individuals of component failure or branch circuit deactivation.

Note—Section 8.3 is NOT part of the 12/20 revision updates
Until updates are complete, the following previously published provisions remain in effect.

8.3 **Electrical**

The electrical service for *ASD* Fans shall comply with the following provisions in addition to all other electrical code requirements. [7]

8.3.1 *Disconnect required*

For *ASD* fans, a means of electrical disconnect shall be provided for in the line of sight and within 6 feet (1.8 m) of the mitigation system fan(s).

Exception: A switch remote from the fan location shall be permitted when concerns sufficiently warrant preventing inadvertent deactivation of the fan.

8.3.2 *Labels required (disconnects)*

Labeling shall comply with Section 8.4.5.

8.3.3 *Protection from shock*

All outdoor wiring for *ASD* fans shall be protected in conduit, unless otherwise permitted by local code, and shall not be a plug disconnect.

8.3.4 *Not allowed*

Wiring shall not be located in or chased through the ASD duct piping.

Note—12/20 revision updates continue to include the remaining portions for Section 8.

8.4 Labeling

8.4.1 *Label materials and lettering*

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. The minimum lettering size shall conform to requirements a) and b) of this Section 8.4.1.

a) Label titles shall be with lettering of a height not less than 1/4 inch (6 mm).

b) Additional informational text shall be with lettering of a height not less than 1/8 inch (3 mm).

8.4.2 *Primary labels*

A system description label shall be placed on a primary component of each system, such as on duct piping near an *ASD* fan monitor, or within 12 inches (30 cm) of the electric service panel or other prominent location. System monitor devices shall have a label on or in close proximity to the mechanism that describes how to interpret the monitor and actions to take if a monitor indicates fan failure or degraded fan performance.

[7] As required by local statutes. For further information, see the National Electric Code® (NEC) as published by NFPA.

The primary label titles shall portray the system purpose, such as “Radon Reduction System” or "Soil Gas Control System." Information required on, or in immediate proximity to, the label(s) shall include content required in Sections 8.4.2.1 or 8.4.2.2 2 of this Section 8.4.2.

8.4.2.1 Owner-Occupied Maintenance

For systems installed in individually owned and *occupied dwellings* or units where system maintenance and monitoring for continued effectiveness will be the responsibility of the owner, the primary label shall include:

a) Date of installation;

b) Maintenance and monitoring instructions, to include:

1. A description of the system monitors and actions to take if the system monitors indicate system degradation or failure, and
2. A recommendation to verify continued system effectiveness over time, such as:
   - a recommendation to conduct a *radon* test at least every 2 years, or
   - other monitoring procedures as specified in an *OM&M plan* for *radon* or *chemical vapor intrusion* systems;

c) State and federal informational resources, to include websites or phone numbers; and

d) The installer’s name, phone number and applicable certification/license identification.

Fig. 8.4.2.1 Example

RADON REDUCTION SYSTEM
Installed: _____ WC” ____
Maintenance
(1) Routinely Check Pressure Gauge
The fan is active if oil level on the left is different from the right.
If the fan appears to be off:
√ Check hose connection on gauge
√ Check electrical (switch or breaker)
√ If still indicating a problem, call for service.
(2) Retest for radon every 2 years
For Service: 1-800-RN2-2222
R. Smith RPP# 54321
Health Department Contacts:
www.epa.gov/radon; the radon hotline 1-800-SOS-RADON (Persons with hearing or speech difficulties should call 711.); or at www.epa.gov/radon/find-information-about-local-radon-zones-and-state-contact-information

8.4.2.2 Independent Maintenance

Where system maintenance and monitoring are the responsibility of someone other than the occupant:

a) Informational content on a primary label that is observable to building maintenance staff or occupants shall include:

1. A description of system monitor(s) or monitoring systems and, as applicable, actions to take if the system monitor indicates system degradation, and
2. The name and contact information of the party responsible for maintenance and repairs.

Fig. 8.4.2.2 Example

RADON REDUCTION SYSTEM
System Fan Monitor
The system fan is active if oil level on the left is different from the right. Please call to report if the fan appears to be off.
This system is under the care of:
R. Smith, L.L.C 1-800-RN2-2222

b) The *client* shall be advised in writing that it is the responsibility of the *client* to ensure the current party who owns maintenance obligations is identified on, or in immediate proximity to, this primary label.

c) The *OM&M manual* shall observe that it is incumbent upon current and future parties responsible for system maintenance and monitoring to keep this label up-to-date.

8.4.3 *System equipment*

System equipment shall be marked or identified with a label title that portrays the system purpose, such as “Radon Reduction System” or "Soil Gas Control System." The labeling shall also comply with requirements in a), b) and c) of this Section 8.4.3.

a) Mechanical Equipment
ASD fans and other system air handling and mechanical equipment shall be labeled.

b) System Monitors
The system monitoring device(s) shall be provided a label in close proximity to the mechanism, such as a primary label or other label, that includes:
1. Information on how to interpret the monitor; and
2. What to do if a monitor indicates fan failure or degraded fan performance; and

c) System Controls
Where systems include controls for any mechanical equipment, including dampers, system controls shall have a label on or in close proximity to the control mechanism. General instructions for operation shall be provided and system control settings that existed at the time *mitigation* goals were achieved shall be clearly marked on the equipment, a label or provided with equipment instructions.

8.4.4 *Label duct piping*
Interior duct piping shall be marked with not less than one label at each floor level to portray the system purpose, such as "Radon Reduction System" or "Soil Gas Control System."

Informative advisory—For *ASD* systems, duct piping labels should be affixed at intervals not greater than 10 feet (3 m) along the developed length of piping.

8.4.5 *Label electrical disconnects*
Disconnects such as switches or outlets providing power to plugged connections for *mitigation* system fans shall be labeled or marked to indicate their purpose. The label title shall identify that the disconnect as a component of a *radon* or, as applicable, *soil gas mitigation* system, such as "Radon Fan – Do Not Turn Off," or "Radon Fan – Do Not Unplug."

Informative advisory—The circuit breaker(s) protecting the *mitigation* system fan circuit(s) should also be labeled with the text such as "Radon Fan" or "Soil Gas Fan."

8.4.6 *Label sealed components*
Certain components that are sealed to resist air movement between soil and indoor air shall be labeled in accordance with requirements in a), b), c) and d) of this Section 8.4.6.

a) Sump Covers
Sump lids shall be identified with a label that portrays the lid as a component of a *radon* or, as applicable, *soil gas mitigation* system. Instructions, such as "Component of a Radon Reduction System. Do not tamper with or disconnect" are recommended but not required.

b) *Crawl Space*s or Membranes
Where *soil gas retarder* membranes have been installed, a label or marking shall be located in a conspicuous place or places such as at access panels or immediately visible once entering the *crawl space*, such as on membrane material near the access location. The label shall include:
1. A label title that states "Radon Reduction System" or "Soil Gas Control System" or otherwise indicates the presence of a *mitigation* system component; and
2. Instructions, such as "Do Not Alter. Damage or alteration to plastic membrane sheeting can negatively impact system performance".

c) Access Locations (into *Non-habitable Airspaces* and *Sealed Isolation Assemblies*)
Where *mitigation* methods address air within a *non-habitable airspace* or other *sealed isolation assembly* that can be accessed, labels shall be provided in a conspicuous place on the outside of access ports, hatches and doors into the airspace or immediately visible once entering the airspace. The label shall include:
1. A label title that states "Radon Reduction System" or "Soil Gas Control System" or otherwise indicates a presence of a *mitigation* system component;

2. Instructions, such as "Keep closed. Leaving open can negatively impact building safety" or similar instructional wording; and
3. Essential health and safety guidance where there are known health and safety hazards, such as
    a. "Warning—Entry into this airspace can be hazardous. Precautions to ventilate this area are recommended"; and
    b. Applicable descriptions of recommended personal safety procedures, such as the possible need for protective gloves, clothing, respirators or other personal safety equipment.

8.5 Inspection for Compliance

Prior to delivery and release of the completed system(s) for use, a *qualified radon mitigation professional* or *qualified soil gas mitigation professional*, as applicable, shall have verified:

a) compliance with this standard;
b) conformance with the intended design criteria; and
c) compliance with local statutes and codes, including for related work conducted by other qualified professionals, as applicable and to the extent practicable.

Any items found to not be in compliance with this standard and local statutes or codes shall be changed to be in compliance.

Exceptions: Professional obligations to identify and correct items that are noncompliant with this standard of practice or local statutes or codes shall have limits in accordance with Section 8.5.1.

8.5.1 *Limitations of professional obligations*

Contractor obligations regarding inspection for compliance shall be limited to visual inspection and photographic evidence of readily accessible components that do not require disassembly of components or finishings to achieve access. Limits to a *contractor's* obligations shall include:

a) *Contractors* shall not be obligated to meet a minimum requirement in this standard of practice where the requirement is found to be in violation of local statutes or codes; and
b) *Contractors* shall not be obligated to have identified all items that may be noncompliant with local statutes or codes due to:
    1. inherent limits of a visual inspection.
    2. existence of conditions of that are outside the scope of work and skill sets normally associated with soil gas *mitigation*, such as preexisting conditions of mechanical or electrical systems.
    3. reliance on superior capabilities reasonably expected from contracted specialists for knowledge of statute and code compliance; or
    4. deviations or interpretations of a local jurisdiction that may subjectively or factually conflict with national or regional trends in code and code interpretation.

8.5.2 *Review With Clients*

Informative advisory—After installation(s), it is recommended that the *contractor* provide an educational review of the *mitigation* system(s) to the *client*. The review should include operating principles of the system(s), operation and maintenance of the systems(s) and all other components of the *OM&M plan*.

8.6 Retention of Records

Records of all *mitigation* work performed shall be kept for no less than: 6 years, as long as state regulations require, or for the period of any warranty, whichever is longest. Health and safety records including *mitigation Installer radon* exposure logs, as applicable, and other appropriate medical monitoring records shall be maintained for as long as required by state or federal statutes.

Informative advisory—Health and safety records should be maintained for a minimum of 20 years.

Note—12/20 revision (The remainder of this document does NOT contain changed requirements)

9.0 RADON POST-MITIGATION

9.1 Post-*Mitigation* Functional Evaluation

9.1.1 *For ASD systems*

In conjunction with activating an *active soil depressurization (ASD)* system, the suction in system's main riser piping (e.g., fan monitor) shall be measured and recorded.

Informative advisories—**(1)** At least one *pressure field extension (PFE)* measurement is strongly recommended upon completion of installation. This practice is widely witnessed to reduce unnecessary or unexpected costs of repeated retests and further system enhancement. **(2)** Post-*mitigation PFE* measurements should be considered particularly important where the *contractor* has little experience in similar buildings. **(3)** Locations where *PFE* tests are made should be recorded and the test holes or test ports be closed in a nonpermanent fashion to facilitate any future needs. **(4)** It is further recommended to include consideration for worst-case conditions when evaluating the results of post-*mitigation PFE* measurements.

9.1.2 *Inspection for compliance*

Note—Section 8.5 contains requirements to inspect the system after installation.

9.2 Initial Radon Test After Mitigation

To provide an initial measure of system effectiveness, a short-term *radon* measurement shall be conducted no sooner than 24 hours after a *mitigation* system is operational and within 30 days after installation of the system(s).

Exception: It shall be permissible that the initial retest after *mitigation* is delayed beyond 30 days in accordance with Section 13.6.2.

9.2.1 *Non-ASD*

If applicable, additional testing requirements in Section 12 for non-*ASD* systems shall also be conducted.

9.2.2 *Qualified Measurement Professionals*

For the purpose of this document, a Qualified Measurement Professional is an individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to *radon* measurement in single-family residences:

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.

9.2.3 *Contractor obligations*

Contractor obligations to ensure post-*mitigation* testing is conducted have been satisfied once post-*mitigation* test results are accepted by the *client* as satisfactory evidence for the initial status of system effectiveness. For the purposes of this initial post-*mitigation* test, *contractor* obligations are satisfied regardless of whether this testing is conducted by:

a. an independent, qualified measurement professional; or
b. the *contractor* who installed the *mitigation* system(s), if also a qualified measurement professional (and if allowed by local statutes or code). To avoid any appearance of conflict of interest, the *contractor* shall recommend to the *client* that post-*mitigation* testing be conducted by an independent qualified measurement professional; or
c. the owner or occupant of the home.

9.2.3 .1 Exception: *Contractor* obligations to obtain some form of test data that sufficiently demonstrates initial system effectiveness are, under this standard, satisfied when the *client* and *client* representatives or other person responsible for the property:

a) refuse to provide access or retest reports, or
b) are nonresponsive to outreach efforts to coordinate testing or obtain test reports; or
c) are prohibited by state or local law from contacting the person(s) responsible for the property.

If access is refused or legally unavailable, or if reasonable efforts across 3 months after installation do not result in a response, the *contractor* shall forward a *radon* test kit to the property in care of the current occupant. The

firm analyzing the test kit shall be an independent laboratory listed with NRPP or NRSB or the state *radon* laboratory licensing or certification program and be provided instructions to deliver copies of the test results to the person(s) who conducted the test. The *contractor* should also instruct the independent laboratory to forward a copy of the test results to the *contractor* for retention in the *contractor's* records.

9.2.4 *Test devices*

Radon test devices employed shall be listed as approved by either the National Radon Proficiency Program (NRPP) or the National Radon Safety Board (NRSB), or as required by the state where the measurement is being performed.

9.2.5 *Test protocols*

All testing shall be conducted in accordance with the most current version of ANSI/AARST MAH *"Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes"*; in accordance with Section 9.2.3.1; and, in accordance with any state protocols and requirements, where applicable.

10.0 RADON DOCUMENTATION

Long-term Operation, Maintenance and Monitoring OM&M

Informative advisory—The potential risk from *radon* exists as long as a building is *occupied*. Therefore, *mitigation* systems represent an essential component for long-term risk management.

10.1 Essential information

To provide tools essential for occupant efforts in long-term risk management, the *contractor* shall provide an information package labeled "Radon Mitigation Information" or similar wording that prominently includes essential components for *operation, maintenance and monitoring* (*OM&M*). The information package shall be securely attached to the system in a visible location or otherwise provided to the *client*. If no portion of the system is installed in the livable space, the information package shall be installed in an appropriate interior location, such as the mechanical room.

10.1.1 **The information package** shall prominently include all of the following essential information:

a) ***A recommendation to retest*** at least every 2 years and as further stipulated in the most current version of ANSI/AARST MAH *"Protocol for Conducting Radon and Radon Decay Product Measurements In Homes"* or other local state-required or federally recommended protocols;

b) *Fan monitors*
   a) A description of the fan monitor(s) and a recommendation to check the monitor(s) monthly or as otherwise specified in an operational and maintenance plan.
   b) Documented startup parameters including pressure gauge readings that existed at the time successful *mitigation* was initially achieved.
   c) A list of actions for the *client(s)* to take if the fan monitor indicates system degradation or failure;

c) ***A description of the mitigation system(s)*** as installed to include:
   a) Basic operating principles; and
   b) System layout narrative or with system components labeled on a floor plan sketch such as may be complemented with photographic documentation;

d) ***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;

e) ***A statement of limitations*** the *contractor* places on professional obligations, future maintenance and monitoring of the *mitigation* system(s) effectiveness; and

f) ***Contact information*** for service inquiries and identification of the *qualified mitigation professional* responsible for adherence to 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).

g) ***Additional retest guidance*** to be provided in the information package:

"In addition to a retest every two years to ensure the *mitigation* system effectiveness, *radon* concentrations should also be retested 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* or a home is newly *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:
  - groundwater or slab surface water control systems are added or altered (e.g., sumps, drain tiles, shower/tub retrofits, etc.) or
  - natural settlement causing major cracks to develop;
- ✓ Earthquakes, construction blasting, or formation of sink holes nearby; or
- ✓ An installed *mitigation* system is altered or repaired."

10.1.2 *Historical Information*

Other 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;

c) Copies of contracts and warranties;

d) Copies of building permits when required and available; and

e) An estimate of the annual operating costs.

10.2 When Not-Owner Occupied

For systems not individually maintained by the individual owner and occupier of the home, the *contractor* shall provide the *client(s)* an information package or system *operations manual* that additionally includes components of an *OM&M* plan, in accordance with Section 13.7.2 and Table 13.7.

10.3 If Non-*ASD* Systems are Installed

The *OM&M* plan shall prominently include additional recommended testing in accordance with Section 12 *(Non-ASD Systems)* and maintenance guidance in accordance with Section 13.7.2 and Table 13.7.

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11.0 HEALTH AND SAFETY

Advisory

Although this document contains specific health and safety recommendations, it cannot address all of the health and safety concerns associated with *mitigation* installations. Users of this document own the responsibility for establishing appropriate safety practices.

11.1 Mitigation Installers

Federal, state and local standards or regulations relating to *mitigation installer* safety and health, including occupational *radon* exposure, shall be complied with. Appendix A provides references for some applicable publications from OSHA and the National Institute for Occupational Safety and Health (NIOSH). In addition, the following requirements that are specifically or uniquely applicable for the safety and protection of *radon mitigation installers* shall be met:

11.1.1 *Mitigation installer protection plan*

A *mitigation installer* protection plan shall be maintained. Where applicable, the *mitigation installer* protection plan shall be approved or accepted by any state or local regulating agencies that require their review of such a plan. The plan shall be available to all *mitigation installers* and be reviewed with each *mitigation installer* at least once a year.

Note—Confirmation of a *mitigation installer*'s knowledge of the *mitigation installer* protection plan should be recorded with the *mitigation installer's* signature and date.

Informative—Review of the *mitigation installer* protection plan should include:

- safe use of all job site equipment including safe practices when using ladders or scaffolding;
- safe procedures for identifying and avoiding electrical hazards on a job site;
- safe procedures that should include employing a buddy system whenever conducting work in *crawl spaces*; confined spaces; and where hazards from excavation, falling or heat exhaustion exist;
- monitoring of adequate oxygen and the potential for hazardous chemical or explosive gases;
- discussion of hantavirus symptoms and appropriate response;
- suspected contaminants in soil;
- Safety Data Sheets (SDS); and
- accident response and access locations for emergency care, including for those accidents that can occur when handling caustic solvents and bonding chemicals.

When chemical or waste contaminants are expected, an appropriate health and safety plan shall be developed and followed to limit hazardous exposure for *installers* within appropriate exposure limits for occupants and *installers*.

11.1.1.1 Safety Equipment

Appropriate safety equipment shall be available on the job site, including but not limited to: hard hats, eye protection, hearing protection, respiratory protection, steel-toe boots, and protective gloves as appropriate during cutting, drilling, grinding, coring or other activities.

11.1.1.2 Work Area Contaminants

In any planned work area where it is suspected contaminants such as asbestos, lead paint, mold or other toxins may exist, work shall be conducted in a manner that meets applicable regulations and maintains consideration for the health and safety of both workers and occupants.

11.1.1.3 Briefings

Each *mitigation installer* shall receive a safety briefing and be provided the opportunity to review applicable material Safety Data Sheets (SDS) for all hazardous materials used and be informed of the safety procedures required for each. SDSs shall be available on jobsites.

11.1.1.4 Ventilation

Work areas shall be ventilated when practical to reduce a *mitigation installer's* exposure to *radon*, *radon* decay products, dust or other airborne pollutants.

11.2 Both Workers and Occupants (General Precautions)

11.2.1 *Job site hazards*

Informative advisor—The *contractor* should take precautions to protect from jobsite hazards. Where appropriate, the *contractor* should post or provide notices, restrict access to job site areas or cease work until safe conditions can be secured. Where appropriate, the *contractor* should ventilate areas to reduce exposure to elevated *radon* concentrations, sealant vapors or other airborne hazards.

11.2.1.1 *Informative advisory*—A review of existing documents and action plans regarding hazardous conditions should be conducted prior to diagnostics or initiation of an installation.

11.2.1.2 Note—Jobsite hazards encountered during the design and *mitigation* process and appropriate actions can include:

a) Care to discharge soil gas to outside air during *pressure field extension (PFE)* diagnostics.

b) Prior to diagnostics or during installation, it is sometimes appropriate that utility line locations be identified in the immediate areas where drilling through slabs will occur. Care should be taken to recognize that design drawings do not always represent actual installations or retrofit installations. Care is important for protecting the integrity of building systems and worker health when drilling through concrete slabs. Careful evaluations should be made for radiant heat systems within or under slabs and for steel tendons within post-tension slabs that, if ruptured, can result in serious bodily harm;

b) When health or safety concerns arise for contaminants prior to or during installations such as for chemical or waste pollutants in soil, the *contractor* should request confirmation testing or removal of such contaminants; and

c) When confined areas such as a crawlspace are determined to be hazardous working environments, the *contractor* should seek safe alternatives. Such alternatives could include altering system(s) design or creating safe means of egress to the confined area.

11.2.2 *Flue gas spillage*

Altering pressure in the building, directly or indirectly, may cause *flue gas spillage* from combustion appliances. *Clients* and impacted residents shall be advised of any significant *flue gas spillage* that is observed. If *flue gas spillage* is observed to result from the *mitigation* system operation, the system shall be deactivated until the condition has been evaluated and corrected. In such event, the *client* or impacted resident shall be advised to contact an HVAC *contractor* or other qualified person to evaluate and correct any significant *flue gas spillage* condition as well as to verify proper appliance installation and performance.

Note—In addition, the *client* should be directed to sources of additional information such as those found at:

- www.cpsc.gov/cpscpub/pubs/466.html
- www.epa.gov/iaq/homes/hip-combustion.html
- Appendix D of the International Fuel and Gas Code (as published by the International Code Council).

11.2.3 *Asbestos*

Note—Deteriorating, damaged or disturbed products containing asbestos can pose a serious health threat to occupants and workers. Asbestos-containing materials can include materials for insulation, fireproofing, acoustical materials and floor tiles. Asbestos inspection reports, if even in existence, do not always specify the location of asbestos and previously hidden asbestos-containing materials which can be exposed during construction or renovations.

11.2.3.1 In any planned work area where it is suspected that asbestos may exist and be disturbed, work shall not be conducted until an accredited asbestos inspector that is licensed by the state or local jurisdiction, where applicable, determines that such work will be undertaken in a manner that complies with applicable asbestos regulations.

Informative advisory—The *client* should be notified that proper assessment and abatement procedures are to be followed as regulated by NESHAP, OSHA, the LSHR and state and local regulations for the protection of the health and safety of occupants, and *contractors*.

For more information, see www.epa.gov/asbestos

11.2.4 *Lead-based paint*

Note—Common renovation activities such as sanding, cutting and demolition can create hazardous lead dust and chips by disturbing lead-based paint, which can be harmful to adults and children.

11.2.4.1 *Informative advisory*—Any activity that disturbs paint (unless it is known by testing to not be lead-based paint) in pre-1978 target housing is subject to the EPA Lead Renovation, Repair and Painting (RRP) rule (40 CFR 745, Subparts E and Q). EPA has established the Lead-Safe Certification Program for *contractors* in response to this concern. For more information, see www.epa.gov/getleadsafe

In addition, all target housing that is federally owned and target housing receiving federal assistance fall under "The Lead Safe Housing Rule" (24 CFR Part 35 Subparts B through R). Please refer to Subpart R—Methods and Standards for Lead-Paint Hazard Evaluation and Hazard Reduction Activities (24 CFR Section 35.1300 through 1355) for HUD specific methods and standards that would be applied for target housing. The Lead Safe Housing Rule is available at www.hud.gov/healthyhomes

Additional information is available at HUD's Office of Healthy Homes and Lead Hazard Control. www.hud.gov

11.3 Radon Mitigation

All *mitigation installers* for *radon* reduction systems shall be advised of the hazards of exposure to *radon* and the need to apply protective measures when working in areas of elevated *radon* concentrations.

Each *installer's* exposure to *radon* at each work site shall be recorded and maintained in a manner as required by jurisdictions of authority. For calculating exposure estimates: *Working Level Month (WLM)* calculations shall be based upon the *mitigation installer's* exposure hours times *radon* measurements (*pCi/L*) divided by 100, divided by 170. Calculations for *pCi/L*/day shall be based on the *mitigation installer's* exposure hours, divided by 24. These calculations shall apply to one of the following *radon* or *radon* decay product measurements for the *mitigation installer's* exposure at each work site:

a. The highest pre-*mitigation* indoor *radon* measurement;
b. Actual jobsite measurements of radon; or
c. The measurements from a *radon* dosimeter such as an alpha track or comparable device consistently worn at the job site by a *mitigation installer*. The *radon* dosimeter shall be stored in a low-*radon* environment during nonworking hours, and thereby all exposure to the *radon* detector is assumed to be the *mitigation installer's* exposure.

A *mitigation installer's* exposure shall be limited to less than 5,700 *pCi/L*/days or 4 *working level months* (*WLM*) over any 12-month period. An equilibrium ratio of 100% shall be used to convert *radon* levels to *radon* decay product levels. Practices shall be arranged to keep *mitigation installer's* WLM or *pCi/L*/day exposure as low as can be reasonably achieved.

11.4 Chemical Vapor Mitigation

11.4.1 *Understanding chemical exposure*

Informative advisory—Three groups of people, or "receptors," can potentially be exposed to chemical contaminants other than *radon* at residential locations where *mitigation* systems are installed: system installation personnel, system monitoring personnel and residents. See Table 11.4.1.

Table 11.4.1 Chemical Exposure Scenarios

Summary of various exposure scenarios associated with the installation and maintenance of *mitigation* systems.

Receptor (Persons)	Media to Which Exposed	Routes of Exposure	Common Exposure Durations	Hazards Related to Installations	Hazards Related to Frequency of Exposure
Personnel: Installation of *Mitigation* System for Chemical Vapor Intrusion	Sub-slab soil	1. Dermal contact 2. Ingestion following hand-to-mouth 3. Inhalation of vapor / particulates 4. Ingestion of particulates	2-hr/event	Varies depending upon chemicals present on each jobsite and materials used during *mitigation* system installation	Varies from one-time acute exposure to a series of acute exposures over many years (that can combine to result in a subchronic or chronic risk scenario)
	Indoor air	Inhalation of vapor and, to a lesser extent, particulates	6-hr/event		
Personnel: Monitoring Events	Indoor air	Inhalation of vapor	1-hr/event		
Residents	Indoor air	Inhalation of vapor	12-24 hours/day	Short-term and dependent upon materials used during *mitigation* system installation	

11.4.2 *Disclosure*

All *mitigation installers* for systems intended to reduce occupant exposure to hazards from chemical vapor intrusion or other soil gas of concern shall be advised of the known hazards of exposure to such substances and the need to apply protective measures when handling and controlling the hazardous substance.

11.4.3 *Worker personal protection*

Informative advisory—Efforts to reduce exposure to hazardous chemicals and substances are paramount when mitigating chemical vapor intrusion. Personal Protection Equipment (PPE) such as impermeable gloves and clothing are important for minimizing dermal contact. Ventilating the workspace and the use of respirators that are suitable for chemical vapors expected to be present are equally important.

Note—OSHA mandates special requirements and worker training under certain circumstances. It is also recommended to test for *radon* gas and monitor for hazardous or explosive gasses.

For guidance, see:

- The NIOSH pocket guide to chemical hazards: www.cdc.gov/niosh/npg/
- USEPA Benchmarks: www.epa.gov/superfund/health/conmedia/soil/pdfs/tbld2rev.pdf
- ATSDR (The Agency for Toxic Substances and Disease Registry)
  - list of contaminants commonly encountered: www.atsdr.cdc.gov/SPL/index.html
  - and their minimal risk levels: www.atsdr.cdc.gov/mrls/index.asp

11.4.4 *OSHA's HAZWOPER standard*

Informative advisory— OSHA requirements are summarized in this following excerpt.

"The Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) applies to five distinct groups of employers and their employees. This includes any employees who are exposed or potentially exposed to hazardous substances -- including hazardous waste -- and who are engaged in one of the following operations as specified by 1910.120(a)(1)(i-v) and 1926.65(a)(1)(i-v):

- clean-up operations -- required by a governmental body, whether federal, state, local, or other involving hazardous substances -- that are conducted at uncontrolled hazardous waste sites;
- corrective actions involving clean-up operations at sites covered by the Resource Conservation and Recovery Act of 1976 (RCRA) as amended (42 U.S.C. 6901 et seq.);
- voluntary clean-up operations at sites recognized by federal, state, local, or other governmental body as uncontrolled hazardous waste sites;

- operations involving hazardous wastes that are conducted at treatment, storage, and disposal facilities regulated by Title 40 Code of Federal Regulations Parts 264 and 265 pursuant to RCRA, or by agencies under agreement with U.S. Environmental Protection Agency to implement RCRA regulations; and
- emergency response operations for releases of, or substantial threats of releases of, hazardous substances regardless of the location of the hazard."

For additional information, see www.osha.gov/html/faq-hazwoper.html

11.4.5 *Contaminated indoor air*

Informative advisory—See requirements in Section 13.1.3. Some chemicals are more toxic via inhalation relative to other routes of exposure. An approved program for use of respirators or other protective action may be required.

11.4.6 *Contaminated soil*

Informative advisory—See requirements in Section 13.1.3. Regardless of known site contaminants in soil, groundwater or condensate, special procedures are often required when handling derived waste from any contaminated site. Considerations can include, among other responsible practices, establishing off-site eating areas and cordoning off restricted areas.

11.4.7 *Explosive or fire hazards*

Note—For worker health guidance, see: The NIOSH pocket guide to chemical hazards: www.cdc.gov/niosh/npg/

Partial List of Chemicals Commonly Associated with Explosive or Fire Hazards (and potential sources)	
Advisory—Lists provided herein are intended to shed light on some of the more common contaminants found at contaminated residential sites. There are many thousands of contaminants in commerce and others that occur naturally. Compiling a definitive list of contaminants that might be encountered is not feasible.	
Health Advisory—Responsible care with explosive gases should include monitoring equipment for detection of hazards, safe tools and an emergency response plan, policy and process in the event of accident.	
Gasoline	(contains benzene, toluene, ethylbenzene, xylenes [BTEX], other substituted aromatics, alkanes, alkenes, etc.)
Kerosene/Jet Fuel	(less of a hazard than gasoline because the volatile content is lower)
Diesel Fuel/#2 Fuel Oil	(less of a hazard than gasoline because the volatile content is lower)
Acrolein	(2-propenal)
Methane	(natural gas - odorless, naturally occurring product of biodegradation; petroleum degradation)
1,3-butadiene	
para-Cresol	(4-hydroxytoluene or 4-methylphenol)
Carbon disulfide	
Acetone	
ortho-Cresol	(2-hydroxytoluene or 2-methylphenol)
Formaldehyde	
Diethyl ether	
Acrylonitrile	
Methyl isobutyl ketone	

12.0 NON-*ASD* SYSTEMS AND METHODS

12.1 For All Non-*ASD* Methods

Informative advisory—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 (ASHREA). www.ashrae.org

12.1.1 *Appropriateness of design*

All systems and methods shall meet the needs for an appropriate design, in accordance with Section 5.3.

12.1.2 *Combination of methods and/or systems*

Each method applied shall be installed to conform with requirements of Section 8 *All Systems and Methods*.

12.1.3 *Important maintenance inspections*

A regiment of routine inspection shall be recommended in accordance with

a) Section 13.7.2 in an operation, maintenance and monitoring (*OM&M*) manual;
b) Table 13.7 to include all filters, exterior intake and exhaust vents, duct balance, controls and other components; and
c) Section 10.3 or Table 13.7, as applicable.

12.1.4 *Pressurization or dilution methods*

12.1.4.1 Qualified Ventilation Professional

When changes are made to ventilation system design, all requirements of the local jurisdiction for qualifications such as licensing or certification programs shall be observed.

Informative advisory—In addition to requirements in Section 3.2, the contractor, contracting team or management team should include at least one "Qualified Ventilation Professional" when modifying ventilation. A "Qualified Ventilation Professional" is an individual qualified, at a minimum, to conduct and evaluate airflow dynamic measurements as required by various provisions within this annex. The appropriate technical knowledge requires hands-on experience and training as obtained by: trade-specific courses such as for energy auditing; specific *radon* training courses; design of HVAC; or mechanical engineering.

12.1.4.2 Diagnostics Evaluations Required

Diagnostic evaluations shall be performed prior to installation or augmentation of systems when methods that entail building *pressurization* or building dilution are being considered. *Diagnostic* evaluations are needed to:

a) ensure feasibility of desired *radon* reductions with such methods; and
b) aid considerations of unintended consequences regarding energy penalties and health, safety and comfort of occupants.

12.1.4.3 *Informative—OM&M* Maintenance Inspections

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:

a) functionality of *HVAC* filters;
b) room differential pressure test;
c) fresh-air damper settings; and
d) verification for supply air into rooms of interest.

12.1.4.4 Seasonal Test Validation—*OM&M*

A notice regarding additional testing is also required when *mitigation* methods include *pressurization* or dilution. Where employed, the *OM&M* plan shall prominently include the following statement:

"The mitigation system includes *pressurization* or dilution of building air and requires additional and ongoing testing. In locations where elevated *radon* concentrations were originally found, conduct post-mitigation or *diagnostic radon testing* during the first year subsequent to installation to verify if system capacity and control settings are effective under stressed or different seasonal conditions. To satisfy this requirement, conduct such testing at least once in the heating season (e.g., November to March, when heating systems are active) and once in the cooling season (e.g., May to August, when cooling systems are active)."

12.1.5 *Long-term OM&M plans required*
All *ASD* and non-*ASD* methods applied shall be accompanied with an *OM&M* Plan in accordance with Section 13.7 that includes all applicable provisions for each method.

12.2 Sources for Air Delivered to a Building

Informative advisory—A variety of the options may be present for sources of air (or make-up air) when needed for *pressurization* or dilution systems. Many of these choices can however have profound adverse effects on energy consumption and occupant comfort or safety.

12.2.1 *Capacity (sources of air)*
System design and installation shall result in a configuration with adequate capacity to continually provide the required volume of air needed to achieve *mitigation* goals.

12.2.2 *Adverse effects*
Sources for air delivered to the airspace being mitigated shall not result in adverse effects on the building including for: other mechanical systems (i.e., back draft of combustion appliances); other indoor air quality concerns[8]; unnecessary energy consumption[9]; and occupant comfort and safety.

12.2.3 *Air intake and distribution vents*

a) Vent Blockage
Vents shall be in locations unlikely to be inadvertently blocked by stored or standing items and natural obstructions such as snow or foliage.

b) Vent Protection
Vents shall be protected at both internal and external locations with vent covers, wire mesh or screening in order to prevent blockage from debris, entry of animals or injury to occupants.

c) Intake Vents – Air Quality
Intake vents shall be in locations where airborne pollutants (e.g., vehicle emissions, trash containers and combustion appliance emissions) are distant enough from the intake to not enter the building and adversely affect the comfort and safety of occupants.

d) Interior Intake Vents - Adverse Effects
Intake vent locations within a building shall be located and installed to not adversely affect energy consumption, other building systems including combustion appliances, and occupant comfort and safety.

e) Duct Balance
Contractors shall verify that the balance of incoming and outgoing airflow does not create a negative pressure within portions of the building in contact with the soil.

12.2.4 *Outdoor air systems*
Requirements for mechanical systems that introduce outdoor air into a building include:

a) Protective Capacity
Systems shall be configured to constantly deliver the air volume and velocity needed to achieve *mitigation* goals whenever any portion of the building is *occupied*, in accordance with Section 12.7.

b) Distances—Supply and Exhaust Ports
For HRV and ERV installations, interior supply and exhaust ports shall be located a minimum of 12 feet (3.8 m) apart. The exterior supply and exhaust ports shall be positioned to avoid blockage by snow or leaves and be a minimum of 10 feet (3 m) apart.

c) Condensate Drainage
Adequate drainage capacity shall be considered in design and provided to accommodate condensate water from systems.

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

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

Note—Floor drains to the sanitary sewer system or other foundation drain systems are recommended for meeting this need. HRV and ERV systems often condensate a continuous flow of water during certain seasons.

Informative advisory

Economizer systems, heat recovery ventilators (HRV) and energy recovery ventilators (ERV)

- Economizer systems typically include controls that automatically activate dampers on return air ducts for using untampered outside air to reduce the cost of cooling a building. These systems often require modification in order to bring outside air into a building at all times.
- HRV units are a commonly preferred tool for adding outdoor air to a *dwelling* due to energy savings when compared to energy consumption for delivering untempered outside air into a building.
- ERV units (similar to HRV) often require modification for bringing outside air into a building at all times.

12.2.5 *Important maintenance inspections*

A regimen of routine inspection shall be recommended in accordance with Section 13.7.2 or as stipulated in an *OM&M* plan that is in accordance with Table 13.7 to include all filters, exterior intake and exhaust vents, duct balance, controls, and other components.

12.2.6 Passive *vents (soil air or indoor air dilution)*

Informative advisory—See Section 12.13.3 for guidance and additional requirements associated with passive ventilation.

12.3 Indoor Air Pressurization

Note—Establishing positive pressure in the airspaces close to soil can, under certain conditions, be effective in stopping soil gas entry. Pressurized buildings or airspaces can in some cases be achieved with permanently installed and continually effective mechanical systems. An air source from upper floors or the building exterior is ducted into a confined airspace with enough air volume provided at a sufficient rate (*cfm*) to result in a positively pressured airspace.

When Indoor Air Pressurization is employed:

12.3.1 *Capacity (pressurization)*

Mechanical components, newly installed or augmented, shall result in adequate capacity to constantly deliver the air volume provided at a sufficient rate (*cfm*) needed to overcome leakage in the outer shell of the building, airspace or isolated assembly. Systems shall be configured in a manner that can produce consistent positive pressure within the airspace being pressurized.

12.3.2 *Sources for air*

Sources for air delivered to the airspace being pressurized shall comply with Section 12.2.

12.3.3 *Sealing (pressurization)*

The building or airspace(s) being pressurized shall be augmented as needed to result in a permanently *sealed isolation assembly* in accordance with Section 7.9.

Exception: Access doorways for the building or airspace being pressurized are not required to be gasketed. However, a mechanical means to automatically achieve positive closure of doors subsequent to entry and exit shall be provided.

12.3.4 *Unintentional radon transport*

For systems applied to portions of the building or an airspace rather than the entire building, considerations shall be made during design with attempts to verify after installation that *radon* is not transported to another portion of the building by the *pressurization* system. Considerations are to include the potential for systems to inadvertently drive *radon* under the building or through partitions into adjoining areas located laterally or vertically from the pressurized airspace. Airspaces or occupiable areas adjoining laterally or vertically to the pressurized area shall be tested for *radon* during either *diagnostic procedures* or after installation.

Informative advisory—Soil gas should be expected to contain a variety of hazards that may include: highly concentrated radon gas or other gases that may be toxic or combustible; vapors that can contain hazardous concentrations of chemical compounds; and, quite normally, dense water vapor that can enhance biological growth once having entered a building.

12.3.5 *Prior to system installation or augmentations:*

a) A Qualified Ventilation Technician shall employ pressure and airflow measurements as needed to evaluate system capacity requirements for the design stipulated in Section 12.3.1.

Note—Blower door measurements during system design are recommended to quantify the capacity needs of the system;

b) Sources for air to be delivered to the airspace shall be evaluated for viability of meeting requirements in Section 12.2.; and

c) An attempt shall be made to evaluate the potential that *pressurization* might inadvertently transport *radon* to other airspaces, in accordance with Section 12.3.4.

12.3.6 *After installation or augmentations:*

a) A Qualified Ventilation Technician shall verify with pressure and airflow measurements that adequate capacity for required operating parameters stipulated in Section 12.3.1 were achieved. These measurements shall be recorded in accordance with Section 10.1.2 and often include : total airflow in and total airflow out, temperature in and temperature out, air density, altitude and other operating parameters;

b) Sources for air delivered to the airspace shall be verified for compliance with Section 12.2; and

c) An attempt shall be made to verify if the system is inadvertently transporting *radon* to other airspaces, in accordance with Section 12.3.4; and

12.3.7 A long-term *OM&M* plan is required in accordance with Section 13.7.

12.4 Soil Air Pressurization

Note—Establishing positive pressure in the gas permeable layer or airspace between occupiable spaces and the soil can, under certain conditions, be effective to stop *radon* entry. Active Soil *Pressurization* can, in some cases, be achieved with permanently installed mechanical systems where an air source from upper floors or outdoors is ducted into the gas permeable layer under the foundation or airspace in contact with soil. Where airflow (*cfm*) needs are similar, Active Soil *Pressurization* systems might resemble inversely-applied *ASD* systems.

Informative advisory—These upside-down systems have more often been employed for special conditions in which natural sub-slab aggregates are so porous that establishing a vacuum under the foundation is not possible.

When Soil Air Pressurization is employed:

12.4.1 *Sources for air*

Sources for air delivered to the airspace being pressurized shall comply with Section 12.2.

12.4.2 *Sealing*

Sealing shall be in compliance with Section 7 in order to help break the connection between soil air and living spaces.

12.4.3 *Unintentional radon transport*

Considerations shall be made during design with attempts to verify after installation that *radon* is not transported to another airspace or occupiable portion of the building in accordance with Section 12.3.4.

12.4.4 A long-term *OM&M* plan is required in accordance with Section 13.7.

12.5 Indoor Air Dilution

Note—By way of mechanical or passive ventilation components, the introduction of outdoor air to a building or airspace can, under certain conditions, be effective to dilute concentrated gases or vapors that may pose hazards to occupants as a result of soil gas entry into a building. There are also times when additional ventilation is desired for other purposes.
Informative advisory—The high volumes of added outdoor air required to dilute *radon* gas and many other gases or vapors to acceptable concentrations will often result in unacceptable energy penalties, especially when accounting for occupant comfort. As a stand-alone method, practicality increases for buildings with tight, energy-efficient construction.

When Indoor Air Dilution is employed:

12.5.1 *Capacity (dilution)*
Mechanical or passive components that are newly installed or augmented shall result in a configuration with adequate capacity to continually provide the required volume of dilution air needed to achieve desired goals for *radon* reduction.

12.5.2 *Sources for air*
Sources for air delivered to the airspace being pressurized shall comply with Section 12.2.

12.5.3 *Coupled with pressurization*
Considerations shall be made during design with attempts to verify after installation the potential for positive pressure to result from the system to an extent that *radon* is transported to another airspace in accordance with Section 12.3.4.

12.5.4 *Prior to system installation or augmentations*

a) A Qualified Ventilation Technician shall employ pressure and airflow measurements as needed to evaluate system capacity requirements, energy penalties and feasibility for the design stipulated in Section 12.5.1.

   Note—Blower door measurements during system design are recommended to quantify the capacity needs of the system;

b) Sources for air to be delivered to the airspace shall be evaluated for viability of meeting requirements in Section 12.2.; and

c) Measurement procedures shall include an attempt to evaluate the potential for the system to change an airspace or portion of the building from negative to positive pressure. If this is found to occur, the requirements of Section 12.3.4 shall also apply.

12.5.5 *After installation or augmentations*

a) A Qualified Ventilation Technician shall verify with pressure and airflow measurements that adequate capacity for required operating parameters stipulated in Section 12.5.1 were achieved. These measurements shall be recorded an reported in accordance with Section 10.1.1 and often include the system's: total airflow in and total airflow out, temperature in and temperature out, air density, altitude and other operating parameters;

b) Sources for air delivered to the airspace shall be verified for compliance with Section 12.2.; and

c) Measurement procedures shall include an attempt to verify if the system has changed an airspace or occupiable portion of the building from negative to positive pressure, whereby the requirements of Section 12.3.4 shall also apply; and

12.5.6 A long-term *OM&M* plan is required in accordance with Section 13.7.

12.6 Soil Air Dilution

Note—Inducing outdoor air ventilation in the gas permeable layer or airspace between occupiable spaces and the soil can, under certain conditions, be effective to dilute *radon* prior to entry. Examples include passive or mechanically vented crawl spaces or rooms.

12.6.1 *Requirements for soil air dilution*
All designs and installations of mechanical systems that induce soil air dilution shall comply with all requirements for Section 12.4 (Indoor Air Dilution).

12.6.2 *Passive venting*

Vents to outside air that are not associated with economizer *setback* systems shall be non-closeable when installed to increase the natural ventilation of a crawlspace, soil or interior spaces for *mitigation* purposes.

Note—See Section 12.13.3

12.7 Controls for Variable Activation

Note—Controls often serve comfort and energy conservation needs by variably cycling the system(s) activation or capacity based upon occupancy patterns and seasonal effects on building systems.

12.7.1 *System(s) activation*

Controls for mechanical equipment shall be configured and verified to activate systems and achieve *mitigation* goals whenever each portion of the building is *occupied*.

12.7.2 *Labeling required (controls)*

Control settings and fan monitors shall be labeled and annotated in accordance with Section 8.4.3 c.

12.8 HVAC Repairs or Modifications

12.8.1 *Incidental repairs*

When an incidental failure or condition of a component is suspected of causing *radon* entry and it can be repaired in a permanent fashion, *diagnostic radon tests* after completing incidental repairs are an allowed consideration. Should retests indicate *mitigation* has resulted from an incidental repair: A "Long-Term *OM&M* Plan" in accordance with Section 13.7.2 is required.

Note—The inspection regimen stipulated in Table 13.7 should include observance of items or similar components that appear prone to routine failure and any related systems that are volatile to alteration over time.

12.8.2 *Modifications to HVAC systems and controls*

The intended non-*ASD* methodology for *mitigation* shall be identified within this Section 12 (Non-*ASD* methods) and any resulting actions shall be in compliance with applicable provision(s) of this Section 12.

Regardless if the choice of *mitigation* method was influenced by desires to address other indoor air quality concerns, an OM&M Plan in accordance with Section 13.7.2 is required when augmenting *HVAC* systems or controls to include all applicable provisions for each method applied.

Informative advisories

a) Modifications should comply with appropriate ventilation standards.[10]

b) It is also strongly recommended to ensure that the design capabilities of the system are more than is minimally required so that any degradation to the system's functionality over time can be accommodated as needed.

12.9 Building Materials

Note—Where it has been determined that building materials are a primary source of elevated *radon* concentrations, see Section 12.5 (*Indoor Air Dilution*) as a consideration, if applicable. Other considerations currently beyond the scope of this document include encapsulation, isolation or removal of building materials.

12.10 Water

12.10.1 *Radon from water*

Note—Where it can be determined that *radon* from a water supply is a primary source of elevated *radon* concentrations in air, aeration and charcoal filtration are common methods employed to achieve *radon* reductions. Such methods are currently beyond the scope of this document.

12.11 Source Removal

Informative advisories—Methods for removal of hazardous source material are currently beyond the scope of this document, to include:

a) excavation for removal of contaminated earth;

b) biological or chemical methods that seek to neutralize toxicity of contaminated earth; and

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

c) SVE — Soil Vapor Extraction (including recapture methods and disposal of contaminants of concern. For information, see EPA's "Soil Vapor Extraction (SVE) Technology" EPA-600-R-18-053.

12.12 Air Cleaning

Informative advisory—Radon gas itself cannot be cleaned from indoor air. *Radon's* decay products that do represent the substantial risk from *radon* exposure are partially cleaned from the air as solid particles. A portion of these elements have attached are cleaned from the air with filtration or other technologies or activities. However, challenges of using air cleaning as a *mitigation* method that are beyond current technology include:

a) the degree to which *radon* decay products and their associated risks can be verified to have been truly removed from the air;

b) system designs to ensure consistency of air cleaning along with mechanisms to adequately warn occupants when filters or systems degrade in performance; and,

c) system design specifications and standards that can ensure all *radon* decay products, including those not attached to solid particles and those that constantly form downstream from any air handler system, are removed from the air throughout multiple effected airspaces.

Currently published and peer reviewed science does not support that the amount of risk reduction sought can be quantified or verified for consistency with current technologies. Consistent with EPA technical guidance publications[11], air cleaning as a means of reducing the risk from *radon* is not recommended as a *mitigation* method.

12.13 Passive Methods and Systems

Informative Advisory—Passive Methods

Where any passive method is employed as a standalone *mitigation* method, vigilance is warranted for verifying effectiveness with indoor measurements to include testing for seasonal differences and other effects across time.

Note—Under specific circumstances, passive technologies for reducing soil gas entry can be effective to the degree to which:

a) the connection between soil air and living spaces can be broken; and

b) natural forces that drive soil gas into a building can be minimalized or neutralized

However: Achieving a complete and comprehensive break in the connection between soil air and indoor air is not truly possible or sustainable; and efforts to counter natural forces that drive soil gas entry using passive means are often unreliable or unsustainable.

12.13.1 *Sealing openings to soil*

Sealing is not to be regarded as a permanent, stand-alone *mitigation* method.

Informative advisory—Historically, technology portrayed by EPA for soil gas *mitigation* has included a wide scope of options accompanied by an evaluation of cost and effectiveness. Between 1986 and 1992, this resulted in a phased-in strategy of trying sealing alone as a first step. Considerations included cost and studies that indicating as much as a 50% reduction could sometimes be achieved by sealing alone. By 1992, field experience of unreliable effectiveness and sustainability warranted the following position statement: "EPA does not recommend the use of sealing alone to reduce radon because, by itself, sealing has not been shown to lower radon levels significantly or consistently." [12]

12.13.2 *RRNC—Home construction design*

Note—Techniques employed during new construction of buildings are beyond the scope of this document. See ANSI/AARST CCAH, *"Reducing Radon in New Construction of One & Two Family Dwellings and Townhouses."* The practices therein, that are normally not practical after construction, are based on both:

a) breaking the connection between soil air and indoor air; and

b) minimizing natural forces that drive soil gas into a building.

[11] EPA/625/8-87/019 January 1988 "Radon Reduction Techniques for Detached Houses (Second Edition)" (Section seven, third paragraph) and EPA/626/6-88/024 August 1988 "Application of Radon Reduction Methods" (Section 10.6, third paragraph).

[12] The EPA "Consumer's Guide to Radon Reduction" 402-K92-003, August 1992 and 402/K-10/005, December 2016

12.13.3 *Passive soil air or indoor air dilution*

Foundation vents shall be non-closeable when installed specifically to increase the natural ventilation of a crawlspace or other interior space for *mitigation* purposes. Vents to outside air that are not associated with economizer *setback* systems shall be non-closeable when installed to increase the natural ventilation of a crawlspace, soil or interior spaces for *mitigation* purposes.

Informative advisory—In areas subject to subfreezing conditions, the need to insulate, isolate or apply heat-tape to water supply and distribution pipes in the *crawl space* should be considered when installing foundation vents.

12.13.4 *Passive mechanical systems*

Note—Such methods have included wind-driven turbines, solar-powered fans and piping configurations that seek to enhance the effect of wind for generating negative pressure within *ASD* piping.

Informative advisory—A wide variety of mechanisms or configurations have been tried and studied for countering the natural energy forces that drive soil gas into a building. Such technologies have not yet demonstrated reliability for consistent and sustainable *mitigation*. Therefore, such technology is beyond the scope of this document.

13.0 ADDITIONAL REQUIREMENTS—VAPOR INTRUSION

13.1 Qualified Professionals and Teams

13.1.1 *Qualified professionals are required*

Qualified contracting or management teams shall include at least one "Qualified Soil Gas Mitigation Professional." For compliance with the intent and purposes of this standard, persons, including soil gas *mitigation* professionals, hazardous waste consultants and system designers, shall be qualified for their apportioned task.

13.1.2 *Qualified **Soil Gas** mitigation professionals*

"Qualified Soil Gas Mitigation Professionals" are defined as "An individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to *radon mitigation* and additionally specific to *mitigation* of existing homes for soil gas entry that contains hazardous chemicals, vapors or gas:

a) as established in the chemical vapor intrusion requirements for certification 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."

Criteria for determining qualifications or credentials for professionals who mitigate exposure to chemical vapor intrusion or other gases include demonstration of all qualification criteria associated with a radon mitigation professional and additional training and skills needed to comply with Sections 11 and 13 of this standard.

13.2 Assemble Site Information

13.2.1 *Handling and control of hazardous substances and condition*

The *contractor* shall request from the *client* a written statement confirming any need, or if there is not a need, for special considerations in handling and control of hazardous substances and other site conditions, to include:

a) Worker Exposures: This consideration is specific to maximum concentrations that workers should expect to encounter from inhalation, ingestion and dermal exposures to hazardous substances;

b) Groundwater and Soil: This consideration is specific to soil and groundwater toxicity that might be encountered in close proximity under the building, including groundwater that can intermittently be found in *sump* wells or intruding above slabs and into *crawl spaces*;

c) Contaminated Vapor: This consideration is specific to contaminated vapor exhausted from *active soil depressurization (ASD)* systems and evaluations after installation for compliance with federal, state or local requirements or guidance;

d) Flammable or Explosive Gasses or Vapors: This consideration is specific to flammable or explosive gasses or vapors; and

e) Other Known Hazards: This consideration is specific to safety hazards as known by the *client* for each building being mitigated to include, among others, pesticides, asbestos, lead paint, fire hazards, underground utility dangers or other hazards.

Responses shall be sought from the *client* in these regards, and the *overseeing team*, *overseeing professional* or Environmental Consultants shall provide safety guidance related to known chemical hazards at the site. It is highly recommended that the *contractor* obtain written information sufficient to facilitate responsible practices prior to contract engagement or initiation of *mitigation* activities.

Note—See the Companion Guidance for discussion on activities that normally are outside the scope of work.

13.2.2 *Existing measurements (chemical vapor intrusion)*

The *contractor* shall request from the *client* all measurement reports and *diagnostic* information available related to the common building structure(s) or portion(s) of the building(s) to be mitigated. This includes:

a) existing measurements of chemicals or substances that relate to the purpose of the *mitigation* project, including chemical(s) of concern, regulatory action levels for site classification and supporting toxicology information;

b) existing indoor air measurements, sub-slab measurements, groundwater measurements, outdoor air measurements, and existing data regarding soil gas origination and pathway of migration; and

c) information on diagnostics conducted or planned and information on any other concurrent remedial actions.

13.2.2.1 Additional Testing or Diagnostics

The *contractor* shall advise the *client* in writing if additional testing or diagnostics are recommended when existing disclosures are insufficient to characterize the dynamics of soil gas entry into the building as it relates to diminished capacity for either:

a) design of appropriate *mitigation* system(s); and/or
b) protection for all workers and occupants of the building during *mitigation* diagnostics and system instillation.

The *contractor* shall advise the *client* that additional testing or diagnostics may be warranted under the following conditions:

a) Tested locations were of insufficient quantity;
b) Time periods do not reflect average conditions for building occupancy;
c) If test data beyond 1-year-old cannot be compared or be considered to reflect current conditions; or
d) Testing practices do not comply with national protocols, state protocols or approved alternate methods deemed otherwise adequate by the *contractor* due to lack of appropriate closed-building conditions, test locations, test durations or approved test devices.

Exceptions: The *contractor* is permitted to proceed with *mitigation* designs and installations when extenuating circumstances warrant immediate action.

Note—Examples of situations that could warrant action, even though existing test surveys are insufficient, include but are not limited to:

a) protection of occupants in areas that clearly indicate elevated radon or other pollutant concentrations;
b) protection of occupants preemptively when perceived concerns or evidence suggests a potential concern exists; and
c) time constraints for building use schedules and other *client* concerns.

13.3 Building Investigations

13.3.1 *Additional visual inspections*

In addition to all requirements of Section 5.4 *(visual inspections)*, observations of failed or inadequate groundwater control systems shall be reported to include: standing water in a basement or *crawl space*; evidence of groundwater intrusion; and failed pumps or *sump* systems inappropriately discharging contaminants. The *contractor* shall document and provide immediate or timely notice to the *client* regarding any safety hazards observed that were not identified in documentation received from the *client*.

13.3.2 *Diagnostics required*

When the purpose of *mitigation* includes chemical vapor intrusion, *diagnostic procedures* are required prior to or no later than the onset of determining the final system design.

Informative advisory—**To what extent are diagnostics warranted?**

The cost of enhanced diagnostics can significantly reduce more excessive long-term stewardship costs while maximizing reliability of citizen protection. Rewards of careful diagnostics include savings for unexpected test expenses incurred, along with costs for correcting misguided designs or poorly performing systems.

13.3.3 *Additional ASD diagnostics*

Pressure field extension (PFE) analysis in accordance with Section 5.5.1 is required.

13.3.3.1 *PFE* Testing

PFE test locations shall be created, evaluated and documented in the *OM&M* plan. Minimum requirements include:

a) The air pressure differences shall be evaluated and documented for natural state (pre-*mitigation*) and the effect of fan-induced vacuum as indicated for each permanent and temporary *diagnostic* hole or *PFE* test location;
b) At a minimum, *PFE* pressure differences are to be evaluated under closed-building and normal operating conditions.

Note—Other evaluations such as comparing more stressed building pressure conditions can sometimes be warranted, subject to the discretion of the *qualified soil gas mitigation professional*; and

c) The post-*mitigation* condition immediately after installation shall also be documented in accordance with Section 13.4.1.1.

13.3.3.2 *PFE* Test Locations

The test locations for *PFE* evaluation shall include:

a) no less than three locations for any residential structure;

b) no less than one location for each slab floor of the building to include each basement, upper slab, garage and other slab-on-grade area that is greater than 64 square feet (6 m^2).

Note—It is recommended to create and evaluate a *PFE* test location in each quadrant of the *soil gas collection plenum*;

c) To the extent that visual inspection or diagnostics indicate that a sub-slab area might be divided by footings or other obstruction, additional *PFE* test locations shall be created and evaluated as needed to characterize the nature and potential of multiple *soil gas collection plenums*;

c) no less than one location for each membrane installed over open soil; and

d) locations chosen in a manner to evaluate conditions that are remote from the *suction point*, such as the most distant accessible slab locations.

Informative advisory—Other locations of suspected concern should be evaluated for *PFE* based on the judgment and experience of the *qualified soil gas mitigation professional* .

13.3.3.3 *PFE* and Soil Gas Sampling Ports

Locations determined to be appropriate for facilitating future inspection of *PFE* effectiveness and/or soil gas concentrations shall be identified and configured in a manner to result in permanent test ports.

The test port locations shall be:

a) prominently documented in the *OM&M* plan;

b) reasonably accessible for future measurements without destructive or significant disassembly of building components or finishes;

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

d) installed in a manner to help ensure that use of the permanent test port is not compromised over time, such as by:

1. implementing hardware to allow easy access and closure of the test port in a manner that facilitates cleaning out the test port in the future; and
2. removing a portion of packed fill or expansive soils that can often exist under a test port.

The opening around test port penetrations of a slab or soil gas retarder shall be sealed in a permanent, airtight manner with appropriate materials and configuration to durably secure the test port in place.

13.3.3.4 Reporting and Records

Requirements include:

a) Ad-hoc Reporting
The *contractor* shall provide the *client* timely notice of unexpected conditions revealed during visual investigations or diagnostics that can significantly impact occupant health, budgets, schedules or scope of work;

b) Final Reporting
The *OM&M* plan shall provide information and data sufficient to characterize *PFE* analysis as witnessed upon completion of the installation; and

c) Future Data Logs
The *contractor* shall record or advise the *client* to record test data from the test ports during each monitoring event subsequent to initial installation.

13.3.3.5 *PFE* Fluctuation

Informational advisory—It is not uncommon for the test port data several weeks after installation (e.g., during the initial air testing) to be more representative of future *PFE* test data. It is thereafter not uncommon to see

mild variations dependent upon the season. *PFE* test data witnessed when outdoor temperatures are within 10 F of the average for coldest local temperatures will typically characterize worst-case *PFE* (See Annex B-3 and B-4 for indoor air test recommendations).

13.4 Additional System Specifications

13.4.1 *Durable ASD pipe configurations*

Informational advisory—Design and installation of *ASD* should result in pipe configurations that are highly resistant to water escaping the pipe at any location other than as designed (e.g., to the ground beneath the slab or soil-gas retarder membrane). Water forms consistently within *ASD* piping during colder seasons as vapor condensates. This water can sometimes contain concentrated chemicals and warrant special evaluation and cleanup procedures if escaped from piping. Best practices for enhanced durability

a) Ensure that primers and solvents are applied in accordance to pipe manufacturer instructions;
b) Avoid any off axis and partial insertions of pipe into the receiving elbow, coupling or other joint and minimize the number of joint connections;
c) Ensure supports and routing design protects pipe joints from movement as a result of blunt force impact or even incidental movement of a horizontal pipe that can twist joint connections and eventually cause joints to leak.

13.4.2 *Non-habitable air spaces*

Informational advisory—Depressurization of non-habitable airspaces as described in Section 6.1.4 should include design features to provide sufficient outside air to inhibit soil gas vapors or outdoor humidity from condensing on building materials.

13.4.3 *ASD pipe material*

13.4.3.1 Downspout materials identified as an alternative to plastic pipe in Section 6.2.5, Exception 2, are not permitted for use as *ASD* duct pipe materials when *ASD* goals include *mitigation* of chemical vapor intrusion.

Note—Such materials enhance the likelihood of condensed water escaping from the duct material that can sometimes contain concentrated chemicals.

13.4.3.2 For pipe materials identified in Section 6.2.5, Exception 1, an an evaluation shall be made prior to installation for appropriateness as it relates to corrosive effects that chemicals may have on the iron, steel, copper or other pipe materials.

13.4.4 *Exhaust configuration*

Informational advisory—The exhaust configuration, including straight-line discharge separation specified in Section 6.4, should be reviewed by the overseeing team for acceptability and for any need to be additionally modified due to consideration of both system airflow and stack gas concentration measured or modeled.

13.4.5 *Additional ASD fan requirements*

An explosion-proof fan or as appropriately specified by codes[13] 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.

Note—Most inline fans commonly used for radon reduction are not rated as explosion proof. See the Companion Guidance for more information.

Informative advisory—The electrical power should be disconnected from the fan unit in any situation where the gas concentration is expected or found to exceed 10% of the Lower Explosion Limits (LEL) as published for certain common chemicals.

13.4.6 *Sealant materials*

The *contractor* shall advise the *client* if any sealant products used are known to have long curing periods or contain constituent chemicals identified for *mitigation*.

Note—Curing compounds, including constituent chemicals identified for *mitigation* that have not stabilized to a benign or minimal state, can corrupt post-*mitigation* tests.

[13] See the latest version of the National Electric Code published by NFPA: www.nfpa.org

13.4.7 *Soil gas retarder materials*

The *contractor* shall account 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 when in contact with the chemical of concern.

Informative advisory—For *ASD* systems that incorporate Sub-membrane *Depressurization* (SMD) and other active *mitigation* systems that pressurize or depressurize an airspace, such as indoor air *pressurization* (Section 12.3), sustainability is the overwhelming priority. Success or optimization in these systems is most prominently reliant upon the durability of a closed air barrier at all points of its assembly. 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 7.6.1 (soil gas retarder material) should be considered.

13.4.8 *Labeling for soil gas mitigation (chemical vapor)*

All system components shall be labeled in accordance with Section 8.4.

13.5 Post-Mitigation Inspections

13.5.1 *Functional inspection*

13.5.1.1 *ASD* Additional *PFE* Measurements

In conjunction with activating an *ASD* system, the suction in system piping at the main riser (e.g., Fan Monitor) and all other locations where *PFE* tests are made shall be measured and recorded for inclusion in the system(s) *OM&M* plan.

Informative advisory—PFE Goals: Goals for the degree of *PFE* demonstrated should support the likelihood of continuous success in adequately reducing soil gas entry.

13.5.1.2 Appropriate Design Required

All *mitigation* systems and methods shall meet the needs for an appropriate design (Section 5.3).

Note—To achieve requirements in Sections 5.3, optimal evidence of effectiveness provided by *PFE* measurements for airflow and vacuum capacity should indicate not less than but also not excessively more than needed to consistently reduce soil gas entry.

13.5.1.3 Inspection for compliance

Note—See Section 8.5.

13.5.1.4 Review with *client(s)*

Note—See Section 8.6.

13.5.1.5 Post-Mitigation Testing for Chemicals of Concern

Due to various considerations, *qualified soil gas mitigation professionals* are not required under this standard to ensure post-*mitigation* measurements of hazardous chemical vapors or other substances are conducted.

13.6 Rapid Response Situations

13.6.1 *Addressing urgent situations*

For the purposes of this document, "Rapid Response" denotes situations when action is required quickly or immediately due to hazards present. See A-1.3 for descriptions of situations that can warrant a rapid response.

Informative advisories—Rapid response actions can include:

a) Vacating the Property
When acute safety concerns are present and cannot be immediately mitigated, occupants and workers should be evacuated from the building until safe conditions can be established.

b) Enhanced Ventilation
Ventilation with outside air is normally the first consideration as a temporary means to enhance safety. However, care must be exercised for any temporary effort. The amount of ventilation immediately achieved may not be adequate to achieve safe conditions. In addition, ventilation with outside air is seldom viable as a permanent solution. See Section 12.4.

c) Mechanical Solutions
A variety of mechanical systems can often be temporarily augmented or installed to enhance safety. Care must be exercised for all temporary efforts since the amount of reduced hazard achieved may not be adequate for achieving safety. Rapid response options include:

1. A temporary *ASD* system not necessarily conforming with all requirements of Section 6;
2. Enhanced Mechanical Ventilation: The addition of temporary blowers and/or manipulation of *HVAC* air handler controls. (See Sections 12.3, 12.4 and 12.8); or
3. Other methods that might be applicable but with less certain protections such as carbon filtration of indoor air or sealing large openings to soil. (See Sections 12.12 and 12.13).

13.6.2 *Limits on temporary solutions*

All *contractor* correspondence shall indicate that use of a *mitigation* system that is not fully installed or not designed as an integral, permanent addition to the building is limited to no longer than 30 days for *occupied* buildings except with the following requirements for specific cases:

a) The use of such temporary system is limited to no longer than 90 days when diagnostics for optimizing final design can be justified to necessitate delay in the installation of a permanent system; or

b) The use of such temporary system is limited to no longer than 90 days subsequent to completion of major renovation, change in building use, or building permit requirements that necessitate delay in the installation of a permanent *mitigation* system; or

c) The use of such temporary *mitigation* system shall be extended only to a point that is reasonably appropriate when multiple parties or jurisdictions of authority must individually and collectively approve the installation plan and the logistics of such approval process thereby necessitate a delay in the installation of a permanent *mitigation* system.

13.6.2.1 Label Temporary Systems

The *contractor* shall place label(s) in a conspicuous location on the system or system components stating the words "Temporary Soil Gas Mitigation System" and the date of implementation. The label(s) shall also include a description of the temporary system and an estimated date for completion of a permanent system that shall not exceed the time limits in Section A-3.1 The label shall include the *responsible party* or representative, phone number, and applicable certification number and certifying agency.

Note—See label example in Exhibit D.

13.6.2.2 Risk Communication (Temporary Systems)

The *contractor* shall notify the *client* of labeling requirements and its content upon implementation of the temporary system.

13.6.2.3 Request Notification to Occupants

The *contractor* shall request that the *client* assign a designated party to make all appropriate notifications to occupants and facilitating staff about the temporary nature of the system and related health risk.

Note—It is recommended that the *contractor* obtain signed acknowledgment from the *client* that the request for notification to occupants was received.

13.7 Documentation—Chemical Vapor Intrusion

13.7.1 *Occupant information package*

To provide tools essential for occupant efforts in long-term risk management, the *contractor* shall provide an information package labeled "Soil Gas Mitigation Information" or similar wording that prominently includes essential components for operation and maintenance.

13.7.1.1 The information package tailored for occupants shall prominently include the following essential information:

a) *Fan monitors*
   a) A description of the fan monitor(s) and a recommendation to check the monitor(s) monthly or as otherwise specified in an operational and maintenance plan.
   b) Documented startup parameters including pressure gauge readings that existed at the time successful *mitigation* was initially achieved.
   c) A list of actions to take if the fan monitor indicates system degradation or failure;

b) *System description*
A description of the *mitigation* system(s) as installed to include:
   a) Basic operating principles; and
   b) System layout narrative or with system components labeled on a floor plan sketch such as may be complemented with photographic documentation;

d) *Health contacts*
Health contact information shall be provided for state or federal resources such as, "For chemical vapor intrusion, see www.epa.gov/vaporintrusion"; and

f) ***Service contact information*** (to include name and phone number of the agent of the *responsible party* or regulatory agency program).

13.7.2 *Client Operations Manual*

The *contractor* shall provide the *client* or *overseeing team* a written *OM&M manual* after installation of the *mitigation* system(s). Essential information that any *client*, property owner, occupant, or designated/responsible person needs to facilitate basic maintenance and monitoring shall be included.

13.7.2.1 **The *OM&M* manual**, often tailored for the *overseeing team's* review, amendment and integration into a final *OM&M* plan shall prominently include all of the following information:

a) ***Fan monitors***, in accordance with Section 13.7.1.1 a);

b) ***System descriptions:***
   a) Descriptions in accordance with Section 13.7.1.1 b;
   b) Operation & Maintenance information in accordance with Table 13.7; and
   c) location of permanent test ports;

c) ***Warranty limitations***
A statement of limitations the *contractor* places on professional obligations, future maintenance and monitoring of the *mitigation* system(s) effectiveness;

d) ***Health contacts information*** in accordance with 13.7.1.1 d;

e) ***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; and

f) ***Contact information*** for service inquiries and identification of the *qualified mitigation professional* responsible for adherence to 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).

13.7.2.2 Historic Information

Other essential information provided for future reference and operation/repair considerations shall include:

a) Pre- and post-*mitigation* test data if available;
b) Pre- and post-*mitigation* investigation summary;
c) A copy of the occupant information package;
d) Copies of contracts and warranties;
e) Any building permits required; and
f) An estimate of the annual fan electrical usage

13.7.2.3 Stewardship Guidance

The *qualified soil gas mitigation professional* shall include guidance recommendations in the *client* Operations Manual for post-*mitigation* monitoring events and testing in accordance with Table 13.7, unless otherwise established in coordination with the *overseeing professional*. Informative example:

"Initial evaluations for system effectiveness should entail indoor measurements of chemicals or substances of concern. Additional evidence of effectiveness should be sought to include measurements of *pressure field extension (PFE)* and any other surrogate means deemed appropriate to aid verification of effectiveness. Confirmation of continuous effectiveness depends upon repeating indoor measurements and other procedures under various weather conditions to complete at least one evaluation of seasonal impacts on system effectiveness. Comparisons of all information gained from these monitoring events can be useful when developing strategies for long-term monitoring and stewardship.

The initial monitoring event should normally be conducted by the designated member of the project team no sooner than 2 weeks after *mitigation* unless specified differently by a regulatory authority (e.g., when acute risks are present).

Other optional surrogate methods to aid verification of effectiveness of reducing soil gas entry, such as measuring indoor radon gas, should be included in post-*mitigation* monitoring events, as appropriate. In addition, measurements of concentrations within *ASD* piping can be useful when source depletion is anticipated and a baseline is needed for comparing against future measurements.

Ongoing monitoring events that include inspection of mechanical components and *pressure field extension* are recommended each year.

Ongoing monitoring events that include tests of indoor air concentrations are recommended every two years."

13.7.2.4 Statement of Client Obligations

To inform the *client* regarding inherent obligations of the building owner and managers to maintain an *OM&M* plan, the following statement shall be included with the *client* operations manual:

"**Stewardship Required.**

Current and future occupants or purchasers of the property should be able to verify by documentation that the minimum requirements of an operation, maintenance, and monitoring plan (*OM&M*) have been maintained.

Essential requirements for long-term risk management are satisfied when building owners and managers:

1) Perform maintenance inspections as stipulated in the operational and maintenance plan and, at a minimum, recommend that occupants check fan monitors at least quarterly to verify system operation.
2) Maintain equipment, any annotation on equipment and any instructions (including documentation for control settings that existed at the time successful reductions were initially achieved). Ensure that system components and any system controls are inspected as recommended in the *OM&M* plan. *OM&M* plans often recommend yearly inspections and inspections by a qualified professional every 2 years.
3) Conduct monitoring events and testing as recommended in the *OM&M* plan;
4) Disclose the existence of the *mitigation* system and its purpose for protecting health and safety to current and future occupants or tenants.
5) Disclose the *OM&M* plan and all known relevant history including this statement of inherent obligations to prospective purchasers of the property."

Table 13.7 Operation, Maintenance and Monitoring (OM&M) Manual Requirements

Controls and System Monitors Documentation	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. Note—The description should include explicit detail for comparison during inspections and repair, including: ✓ descriptions of equipment labeling and annotations for fan monitors, control settings and other operating parameters; ✓ exact locations of fan monitors, electronic telemetry/monitoring equipment, permanent test ports, electrical disconnects and other components; ✓ instructions for equipment sufficient to interpret labels, annotations and the designed operating parameters for the equipment. When applicable, include manufacturer instructions; ✓ a list of appropriate actions for the *client(s)* to take if fan monitor devices or other inspection procedures indicate that the system(s) are not operating as designed. ✓ If non-*ASD* pressure or dilution methods are employed (see Section 12), include documented measurements for balance of airflow in and airflow out of air handler system(s).	The *OM&M* plan 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 that the system(s) are operating as designed; b) investigation and correction of any conditions that are found to indicate component failure or inconsistencies in designed operating parameters for the system(s); c) maintenance of records assimilated into the overall building *OM&M* documentation; and d) The plan shall stipulate that a qualified professional should perform these inspections.	The plan shall stipulate recommendations and any requirements for the frequency of inspections of controls and monitors (as deemed by the *contractor* as appropriate or as determined in coordination with an *overseeing professional*). Note 1—Systems with controls for seasonal adjustment should be inspected more frequently. Note 2—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 Documentation	**Mechanical Equipment Inspections**	**Frequency of Inspection**
Provide Equipment Details and Instructions: ✓ Include manufacturer instructions and specific design instructions, as appropriate; ✓ Documentation should include exact locations of fans, electrical disconnects and other components; and ✓ Include a list of appropriate actions for the *client(s)* to take if the fan monitor warning devices indicate 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 vent piping connections.	The *OM&M* plan provided shall observe that mechanical inspections should include: a) performance indicators, labels and fan operation; b) all seals, straps, fasteners, fan boots and pipe condition; and c) the electrical system (including switch operation) and other related building systems (e.g., *sump* pumps and combustion appliances). If non-*ASD* methods are employed, the plan shall observe additional mechanical inspections stipulated in Section 12.	The plan shall stipulate that a detailed inspection of mechanical equipment be conducted at each monitoring event in accordance with this Table 13.7 or as determined in coordination with an *overseeing professional*. Note—It is customary that recommendations include inspection of mechanical equipment by a qualified professional no less than every 2 years.

Appendix A

INFORMATIVE — CHEMICAL VAPOR INTRUSION

A-1 Understanding Chemical Exposure Concerns

A-1.1 *Health Risks*

The risk of adverse health effects from exposure to a toxic chemical or substance depends on the nature, frequency and duration of exposure to the chemical(s). Variables associated with the nature of the exposure include:

a) the concentrations of chemicals present;

b) the environmental medium in which the chemicals are present (e.g., indoor air, liquids or solid, including soil and/or groundwater); and

c) the route of exposure:

- Inhalation of vapor-phase contaminants or particulate matter containing sorbed contaminants (or hazardous building material particulates) that result in absorption of contaminants or adverse effects in the respiratory system. Note that some chemicals are more toxic via inhalation compared to other routes of exposure because chemicals that are absorbed from the respiratory system are not passed through the liver first where some degree of detoxification can otherwise occur.
- Dermal contact resulting in absorption of contaminants through the skin
- Ingestion resulting from hand-to-mouth actions following dermal contact
- Ingestion of particulate matter as a result of inhalation and then swallowing of particulates

A-1.2 *Site classifications*

Formal site classifications or listings are based upon state requirements and/or information obtained by firms that have provided assessment of a site.

A-1.3 *Informational description of site classifications*

Class 3: Continuous or Chronic Risk Concerns of harmful effects from average low-level exposure (e.g., ≥ 26 years) or repeated exposure events to somewhat higher concentrations that can result in a similar degree of hazardous average exposure.
Class 2: Subchronic Risk Concerns of harmful effects with average exposure across 10% of a life span or repeated exposure events to higher concentrations that can result in a similar degree of hazardous average exposure.
Class 1: Acute Risk Concerns of harmful effects from immediate or short-term exposure (e.g., < 30 days).
Rapid Response Situations with immediate concern when estimated exposure concentrations exceed health-protective concentrations for short-term or acute exposure.

A-1.4 *Partial list of chemicals commonly associated with contaminated soil*

Advisory Note 1 Lists provided herein are intended to shed light on some of the more common contaminants found at contaminated residential sites.	
Arsenic	naturally occurring; industrial discharges
Cadmium	
Hexavalent chromium	
Mercury	
Lead	naturally occurring; industrial discharges; older paint residues
Polynuclear aromatic hydrocarbons (PAHs)	products of combustion (such as creosote, soot); petroleum constituents (diesel fuel, fuel oils)

A-1.5 *Partial list of chemicals commonly associated with contaminated indoor air (and potential sources)*[14]

Advisory Note 2 There are many thousands of contaminants in commerce and others that occur naturally. Compiling a definitive list that might be encountered at a contaminated property is not feasible.	
Benzene	(Collectively known as BTEX; gasoline, diesel fuel, #2 fuel oil)
Toluene	
Ethylbenzene	
Xylenes	
Carbon tetrachloride	(tetrachloromethane; chemical releases from cleaning fluids or other industrial discharges)
Tetrachloroethylene	(perchloroethylene, or PCE; chemical releases at dry cleaning facilities; other industrial discharges)
Trichloroethylene	(TCE; degradate of PCE; other industrial discharges)
cis-1,2-Dichloroethylene	(cis-1,2-DCE; degradate of TCE; other industrial discharges)
trans-1,2-Dichloroethylene	(trans-1,2-DCE; degradate of TCE; other industrial discharges)
Vinyl chloride	(VC; degradate of cis-1,2-DCE and trans-1,2-DCE; other industrial discharges)

A-2 Guidance for Teams

A-2.1 *Roles and responsibilities*

Informative advisories—Efforts to reduce occupant exposures to hazardous soil gas often times begin with decisions made by persons responsible for possible vapor intrusions into a property. This Responsible Party (RP) can be the property owner(s) or extend to include private businesses and/or governmental agencies.

Commissioning

When achieving an objective requires persons qualified in varied disciplines with different skill sets, a commissioning process first engages identification of roles and responsibilities of an *Overseeing Team*. The *overseeing team* will normally include:

a) The Responsible Parties;
b) Regulatory Authorities when compliance with local, state or federal regulatory standards is required; and
c) An *Overseeing Professional* to assemble and coordinate a qualified team of professionals of diverse skill sets.
   Qualified contracting or management teams for vapor intrusion normally include at least one qualified Environmental Consultant (EC).

Soil Gas Mitigation

Design, implementation and stewardship of techniques to reduce soil gas entry require technical knowledge and skills specific to:

a) fluid mechanics of building air pressure and its dynamic interaction with distribution and entry of both soil gas and outdoor air; and
b) building construction practices.

[14] States or local jurisdictions often publish more complete guidance and jurisdictional requirements.
For further information, see the U.S. Environmental Protection Agency (EPA). 2015a. Vapor Intrusion Screening Level (VISL) Calculator, User's Guide at: www.epa.gov/oswer/vaporintrusion/guidance.html
For worker health guidance, see: The NIOSH pocket guide to chemical hazards: www.cdc.gov/niosh/npg/

A-2.2 *Mitigator needs*

Informative advisory—When commissioning goals include reduction of soil gas entry, needs of a Soil Gas Mitigation Professionals include:

a) A specific Scope of Work;
b) Overall remediation goals with current strategy and rationale for design and objectives;
c) Known Hazards for each building being mitigated to include, among others:
   - chemical(s) of concern, regulatory action levels for site classification and toxicology standards.
   - a determination for any need, or if there is not a need, for special considerations during removal, handling and control of hazardous substances;
d) Information needed to achieve appropriate system design and implementation.
e) Quantifiable Goals and Objectives, including the extent of reductions for soil gas entry needed to achieve *mitigation* goals; and
f) Project Management Specifications, such as *contractor* qualification requirements, deliverable and reporting schedules, and payment terms.

Note—See the Companion Guidance for sample RFP content.)

A-2.3 *Communication plan*

Informative advisory—A written plan should be developed in coordination with the *overseeing team* (i.e., senior staff, *RP*, oversight staff and communications staff) for communicating throughout the process to all affected parties. As appropriate, regulatory authorities and owners of affected properties that are not owner-*occupied* residences should participate in developing the plan. Recommended components include:

a) Specify which management staff member is responsible for onsite activities.
b) Specify the structure of additional communication paths between senior staff, facilitating staff, maintenance staff, measurement service provider(s) and the *qualified soil gas mitigation professional*.
c) Identify and provide contact information for those individuals who are authorized to respond to inquiries from owners, occupants and the public.
d) Develop notices (with instructions, general information and information on whom to contact for inquiries) that may be specific for each affected audience, including:
   1. facilitating staff that might normally include oversight staff, building managers, maintenance managers and other supervisors.
   2. occupants of the building.

   Note—See notice examples in Exhibits B and C.
e) Develop timetables and means for distribution of notices.

A-2.4 *Guidance regarding proposals.*

Informative advisory—In addition to proposal requirements in Section 4.2:

a) If not already provided in a Request for Proposal received, the *contractor* should request of the *client* information as to whether the site is listed as classified by the state or other jurisdiction;
b) The *contractor* should include in proposal content, in accordance with Section 4.2.2 f and Section 13.7.2.1 c any additional limits the *contractor* places on the stated scope of work relative to degree of participation in an *operations, maintenance and monitoring plan* (*OM&M*) and any handling and control of hazardous substances.

   Note—It is customary practice that *contractors* limit their scope of work and transfer certain obligations in writing to the *client* or Responsible Party. Common examples include significant or incidental handling, capture, disposal and management of contaminated substances such as contaminated soil, groundwater, condensate and vapor that exceed regulatory limits.
c) Cost estimates as required in Section 4.2.2 e should include total ownership costs for installation, operating and additional monitoring costs across a 5-year period.

Table A-3 Recommended Post-mitigation Monitoring Events for Chemical Vapor Intrusion

No prior assessment	Class 3 Continuous or Chronic Risk	**Rapid Response** indicated if estimated exposure exceeds health protective concentration for short-term or acute exposure Class 2 Subchronic Risk	Class 1 Acute Risk
If suspected concerns exist, **Preemptive *mitigation*** may be warranted.	Concerns of harmful effects from average low-level exposure across many years (e.g., ≥ 26 years) or repeated exposure events to somewhat higher concentrations	Concerns of harmful effects from average exposure across 10% of a life span or repeated exposure events to higher concentrations	Concerns of harmful effects from immediate or short-term exposure (e.g., < 30 days)

Initial Post-*mitigation* Monitoring Events

For Preemptive *mitigation*: Initial *PFE* and system pressure measurements. Indoor air measurements recommended but not required	Initial Frequency for a minimum of 1 year: Seasonally until a baseline is established that indicates successful effectiveness. (See Section 16.3)	Initial Frequency for a minimum of 1 year: Seasonally (or more frequently) until a baseline is established that indicates successful effectiveness. (See Section 16.3)	Initial Frequency for a minimum of 2 years: Seasonally (or more frequently) until a baseline is established that indicates successful effectiveness. (See Section 16.3)

Each monitoring event includes measurements of indoor air (contracted by responsible party) and measurements of *PFE*, system pressure and review for fan and mechanical systems.

Note: Longer durations or more frequent monitoring may be warranted dependent upon:
a) the degree to which measured concentrations exceed the action level, or
b) the degree of observed variability above the action level especially post-*mitigation*.

Note: *Radon testing is recommended pre-mitigation. Include in all initial monitoring events If concentrations found can aid evaluations of system effectiveness and confirm a health benefit.*

Monitoring Events Thereafter

Every year: Mechanical inspection (*PFE*, system pressure and mechanical systems.)

Every 2 years: Indoor air measurements

Increase frequency of monitoring events based on observed variability or evidence of plume movement.

***In addition,* concentrations should be retested if any of the following circumstances occur**:

- A new addition is constructed or significant renovation occurs;
- Heating or cooling systems are significantly altered resulting in changes to air pressures or distribution;
- Ventilation is significantly altered by extensive weatherization, changes to mechanical systems or comparable procedures;
- Significant openings to soil occur due to:
  - changes in water control systems (e.g. sumps, drain tiles, shower/tub retrofits, etc.) or,
  - natural settlement causing major cracks to develop;
- Earthquakes, construction blasting, or formation of sink holes nearby; or
- An installed *mitigation* system is altered or repaired.

Cessation of biennial indoor air measurements:

Biennial Indoor air measurements can be replaced with 5-year test cycles only for those buildings where:

a) Systems have shown continued effectiveness to the satisfaction of *jurisdictional authorities*; and
b) The *mitigation* systems are operated under a written operation and maintenance (O&M) plan that includes regular monitoring of mechanical equipment and requires a professional's signature verifying that systems continue to function in the same manner as the last test.

Informative advisory—Monitoring event procedures described in Appendix C-3 should be used in lieu of a different regimen of monitoring events required by state or other authority.

A-3 Monitoring Events and Stewardship

A-3.1 *Monitoring events*

Each post-*mitigation* monitoring event in Annex B should include: (1) measurement of indoor air; (2) *PFE* measurements; (3) system pressure measurements; and (4) review of fan and mechanical systems.

A-3.2 *Initial post-mitigation testing*

To provide an initial measure of *mitigation* effectiveness, the first post-*mitigation* monitoring event should be conducted no sooner than 2 weeks after *mitigation* unless specified differently by a regulatory authority (e.g., when acute risks are present). The 2-week delay period is warranted for reducing influences on indoor test results due to chemicals that may have adsorbed into building materials and finishings. This also allows chemical vapors and gasses to reach a state of equilibrium with indoor air that is more representative of future expectations when *mitigation* systems are active.

For acute risk situations, more frequent or multiple monitoring events should be considered prior to or in concurrence with seasonal post-*mitigation* monitoring.

A-3.3 *Initial seasonal verification*

To account for seasonal variations, monitoring events sufficient to evaluate effectiveness under each of the following conditions should, at a minimum, be considered:

a) Heating Season Conditions.
This is when the highest outdoor air temperatures are at least 10˚ F colder than indoor air—e.g., when outdoor temperatures are less than 65˚ F (18˚ C).

If seeking to help characterize temporary worst-case pressure-driven entry of soil gas and stressed *mitigation* system conditions, at least one monitoring event should be conducted when outdoor temperatures are within 10˚ F (5`˚ C) or colder than the average for coldest local temperatures;

b) Cooling Season Conditions.
This is when outdoor air temperatures are at least 10˚ F warmer than indoor air for a significant portion of the daytime—e.g., when daytime outdoor temperatures are more than 85˚ F (29˚ C).

This monitoring event helps evaluate if consistent activity of *HVAC* blowers temporarily enhance soil gas entry across this season; and

c) Mild Weather Conditions.
This is when the outdoor temperatures are similar to indoor temperatures of about 74˚ F (23˚ C).

This monitoring event helps evaluate if *HVAC* blowers temporarily inhibit soil gas entry during other seasons.

A-3.3.1 An additional monitoring event should be considered to evaluate effectiveness under other concerning condition(s) that can include:

a) During Low Water Table (dry soil conditions)
This monitoring event helps characterize if soil gas entry is temporarily enhanced due to a larger than normal volume of soil gas under a building.

b) During High Water Table (wet soil conditions)
Note that soil gas entry is typically inhibited during high water table conditions. However, other considerations may warrant this testing, such as when hazardous substances in liquid or aqueous form that are highly concentrated and reside in close proximity to the building.

A-3.3.2 Seasonal Evaluations

Any one of these seasonal conditions can result in enhancement or virtual cessation of soil gas entry for temporary or seasonal durations, depending upon building characteristics and mechanical systems.

It is recommended to continue seasonal monitoring events until a baseline is established for yearlong effectiveness. Restarting the regimen of seasonal monitoring events is recommended if system alterations are found to be warranted for improving system effectiveness. A longer duration or more frequent monitoring may be warranted dependent upon:

a) the degree to which measured concentrations exceed the action level, or
b) the degree of observed variability above the action level, especially post-*mitigation*.

A-3.3.3 Use of seasonal information

Information gained by the initial seasonal monitoring events can be used to guide protective stewardship choices for subsequent monitoring events by identifying conditions that represent average or worst-case conditions. If radon testing was included in seasonal monitoring and indicated consistency with other soil gas entry, inexpensive radon testing, if deemed acceptable, can sometimes suffice for future monitoring events.

A-3.3.4 Indoor Air Testing

To reproducibly account for testing variables such as natural day-to-night variability in soil gas entry and dilution after entry, it is recommended to:

a) Conduct short-term indoor air measurements under closed-building conditions for durations that should be no less than about 2 days;
b) Conduct at least one measurement in the lowest occupiable location within the home for use as the most reproducible measurement when evaluating seasonal measurement differences;
c) Follow appropriate guidance for sampling and laboratory analysis, such as EPA TO-15 and TO-17[15];
d) Conduct measurements of ambient outside air sufficient to characterize the influence of ambient concentrations on indoor measurement results; and
e) Use care to reduce influences on test results such as chemicals contained in household cleaning products.

Note—See Companion Guidance for guidance examples that help to control test conditions.

A-3.4 *Ongoing stewardship*

A-3.4.1 Mechanical Systems

It is recommended that inspection be conducted yearly for mechanical operations and system integrity, to include *PFE* and system pressure measurements and related mechanical systems and components.

A-3.4.2 Indoor Air Measurements

It is recommended that the monitoring events include measurements of indoor air at least every 2 years.

A-3.4.3 Cessation of Biennial Indoor Air Measurements

It is recommended that biennial retests for mitigated buildings be maintained for as many years as the system is operational unless replaced with 5-year test cycles for only those buildings where:

a) systems have shown continued effectiveness to the satisfaction of *jurisdictional authorities*; and
b) the *mitigation* systems are operated under a written operation and maintenance (O&M) plan that includes regular monitoring of mechanical equipment and requires a professional's signature verifying that systems continue to function in the same manner as the last test.

A-3.4.4 Additional Monitoring Events

Informative advisory—It is recommended to conduct additional monitoring events:

a) based on observed variability or evidence of plume movement; and
b) if any of the following circumstances occur:
   - ✓ a new addition is constructed or alterations for building reconfiguration or rehabilitation occur;
   - ✓ 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:
     - — groundwater or slab surface water control systems are added or altered (e.g., sumps, drain tiles, shower/tub retrofits, etc.); or
     - — natural settlement causing major cracks to develop;
   - ✓ earthquakes, construction blasting or formation of sink holes nearby; or
   - ✓ an installed *mitigation* system is altered or repaired.

[15] EPA/600/4-90/010 1990 Compendium of Methods for the Determination of Air Pollutants in Indoor Air, and EPA/625/R-96/01b 1999 Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air - Second Addition

A-3.4.5 Soil Gas Measurements

Soil gas measurements are often conducted in association with the initial site characterization. Soil gas measurements under the building and within *ASD* duct piping can be compared with measurements taken during initial *ASD* commissioning to help characterize evidence of a shifting or depleted source. Soil gas measurements within *ASD* duct piping are also employed to evaluate regulatory compliance with limits on discharged hazardous vapors.

Monitoring for changes of soil gas concentrations within duct piping is one procedure employed for chemical vapor intrusions sites when there is reason to believe that the system might eventually not be needed. However, check with your state regulatory agency for conditions that would fully warrant possible decommissioning.

A-3.5 *Decommissioning systems*

In certain instances, the source of hazardous soil gas can be found to have migrated away from a building or found to be depleted in hazardous concentrations, either naturally or as a result of remediation and related efforts. In such circumstances, considerations can include discontinued operation of soil gas *mitigation* systems and ongoing stewardship.

A-3.5.1 Decommission Decisions

Decisions to decommission a system due to evidence of a shifting or depleted source are beyond the scope of this document but normally include documented measurements of soil gas from under the building with the system inactive for an adequate period of time prior to the measurement. A test for radon gas should also be conducted at this time to inform the property owner if there are other reasons to warrant continued system operation.

A-3.5.2 Advise Property Owner

It is recommended to advise the owner that a resident can continue his/her own testing for continued verification

14.0 DESCRIPTION OF TERMS

Terms not defined herein have their ordinary meaning within the context of their use as defined in "Webster's Collegiate Dictionary."

Active soil depressurization (ASD): A family of radon *mitigation* systems involving mechanically-driven soil depressurization, including sub-slab *depressurization* (SSD), sub-membrane *depressurization* (SMD), block wall *depressurization* (BWD) and *crawl space depressurization* (CSD).

Backer rod: A semi-rigid closed-cell foam material resembling a rope (available in various diameters) that is used to fill around pipes, large cracks, etc. to assist in making a sealed penetration.

Becquerel per cubic meter (Bq/m^3): A unit of measure for the amount of radioactivity in one cubic meter of air. CONVERSION: 1 Bq/m^3 equals 0.027 picoCuries per liter (*pCi/L*).

Chemicals of Concern (COCs): Chemicals in vapor, liquids or soil that have been identified at a site location to potentially pose health and safety hazards.

Client: The person(s), or company that contracts with a *contractor* to install a *mitigation* system in a building.

Collateral mitigation: The ability to mitigate more than one *occupied dwelling* or unit with a single *mitigation* system.

Continuous Duty: A motor may be rated as either continuous duty or intermittent duty. Continuous duty rated motors are rated to be run continuously without any damage or reduction in life of the motor while intermittent duty motors must be allowed to stop and cool before restarting.

Contractor: Any person(s) or contracting firm regardless of organizational structure who installs a *mitigation* system. See Section 3 for descriptions of Qualified Mitigation Professionals.

Crawl space: A foundation type with an open area beneath the livable space of a *dwelling* that typically has either a concrete slab or earthen floor.

Cubic feet per minute (cfm): A measure of the flow rate of a fluid, such as air. CONVERSION: 1 cfm = 1.699 cubic meters/hour (m^3/hr).

Depressurization: A negative pressure induced in one area relative to another.

Diagnostic procedures: One or multiple procedures for identifying or characterizing conditions under, beside and within buildings to project the effects of various system designs. Diagnostic procedures can include: sub-slab *pressure field extension* tests or analysis; visual observations; characterization of pressure or air exchange rates between indoors and outdoors and also between floors or adjoining air spaces; and *diagnostic radon measurements* at locations of interest (e.g. common areas, mechanical spaces and spaces not in ground contact).

Diagnostic radon measurements: Diagnostic Radon Measurements are intended to confirm specific conditions or effects of *mitigation* activities. Test locations are identified by their relationship to the specific information being sought. Diagnostic Radon Measurements are not a substitute for testing in accordance with ANSI/AARST measurement protocols.

Dwelling: A building or portion of a building that is used, intended or designed to be built, used, rented, leased, let or hired out to be *occupied* or that are *occupied* for living purposes.

Feet per minute (fpm): A measure of the velocity rate of a fluid, such as air. CONVERSION: 1 fpm = 0.3048 meters per minute (0.3m/min).

Flue gas spillage: A condition in which the normal movement of combustion products up a flue (due to the buoyancy of the hot flue gases) is reversed, resulting in the combustion products entering the building. Flue gas spillage of combustion appliances (such as fireplaces and furnaces) can occur when *depressurization* in the house overwhelms the buoyant force of the hot gases. Flue gas spillage can also be caused by a blockage in the chimney or flue termination.

High-rise building: A building that is 75 feet (23 m) or higher.

HAC system: Heating and cooling (air conditioning) systems that are not designed to also supply outdoor air ventilation. HAC systems are common to single-family residences.

HVAC setback: HVAC "setback" is normally the automated or manual operation of system controls to cause different activity for heating, cooling and ventilation systems during *occupied* periods compared to un*occupied* periods.

HVAC system: Heating and cooling (air conditioning) systems that are additionally capable of supplying outdoor air ventilation. If they do not supply outdoor air ventilation, they are more technically referred to as *HAC systems*.

Informative: Informational content or guidance that is not considered mandatory by this document.

Intentional *collateral mitigation*: ASD system(s) intentionally designed to reduce radon concentrations in multiple *dwellings* that have each been identified by testing to indicate radon concentrations that exceed acceptable limits.

Jurisdictional authorities: Governing authorities that regulate specific installation requirements or manner of activities will normally include a combination of authoritative bodies as a result of laws or other requirements adopted at a local municipality, county, province or state. In addition, national jurisdiction will apply for a variety of activities that are regulated as a result of federal statues. In some cases, tribal or international laws or treaties result in an authority that holds jurisdiction over certain activities.

Mechanically fastened: A means of connection such as for duct joints or electrical connections that entails more than a pressure fit, glued or twist connection (i.e. mechanical screws employed to secure connection of wiring or ducting).

Mitigation: System or steps to reduce radon concentrations or other pollutants in the indoor air of a building.

Mitigation Installer: A staff member or sub-*contractor* who participates in installation of the *mitigation* system(s) and therefore, regardless of qualifications or other obligations herein, is included in considerations for worker health and safety.

Nontransient: Occupancy of more than 31 days.

Normal occupied operating conditions: The operational condition for the building or *unique sector* of the building that exists during the greatest amount of *significantly* occupied time.

Normative: Provisions or referenced documents that state practices considered mandatory and required by this document.

Occupied: Any area of the building that is occupied on a regular basis for more than 4 hours a day. See "Significantly occupied" and "Occupied work or school weeks"

Occupied work or school weeks: Those weeks that do not include vacation days such as national or religious holidays, winter breaks or similar weeks where test conditions do not represent *normal occupied operating conditions* for the building. See "Normal Occupied Operating Condition", "Occupied" and "Significantly occupied".

Operation, Maintenance and Monitoring plan (OM&M): A document that includes information on the operation and maintenance of installed system(s) and guidance for monitoring the effectiveness of the system in the future.

Operations Manual: A document that is normally compiled by the mitigator to provide requirements and guidance for operation and maintenance of the mitigation system(s). This manual is a component of an *Operation, Maintenance and Monitoring Plan (OM&M)* that additionally includes information on monitoring effectiveness of the system.

Overseeing Professional: An individual or firm that aids to assemble and coordinate a qualified team of professionals of diverse skill sets.

Overseeing Team: Those individuals associate with project commissioning for vapor intrusion projects that normally include: Responsible Parties; Regulatory Authorities when compliance with local, state or federal regulatory standards is required; and An Overseeing Professional to assemble and coordinate a qualified team of professionals of diverse skill sets.

Picocurie per liter (pCi/L): A unit of concentration radioactivity corresponding to 0.037 decays per second or 2.22 decays per minute in a liter of air or water. 1 pCi/L = 37 becquerels per cubic meter (Bq/m^3).

Pressure field Extension (PFE): The distance that a pressure change, created by drawing soil-gas through a *suction point*, extends outward in a sub-slab gas permeable layer, under a membrane, behind a solid wall or in a hollow wall.

Pressure field Extension Test: A *diagnostic* procedure to evaluate the potential effectiveness of an *ASD* system by using a shop vacuum or other fan or vacuum device to draw air from the space below a slab or from the cavities inside a block wall. Measuring the change in pressure at various small test holes through the slab or the block wall using a micro-manometer or heatless smoke can provide evidence of the potential effectiveness of an *ASD* system.

Pressure field Extension Analysis: For *ASD* design and optimization, an analysis of 1) qualitative evidence for the distance potential of Pressure Field Extension, and 2) quantitative measurements employed for determining vacuum pressure and air flow volumes required to achieve a consistent vacuum across the area observed for Pressure Field Extension.

Pressurization: A positive pressure induced in one area relative to another.

Qualified Radon Measurement Professional: An individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon measurement.

Qualified Mitigation Professional: For the purpose of this document, an individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon or soil gas mitigation.

Qualified Radon Mitigation Professional: For the purpose of this document, an individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon mitigation.

Qualified Soil Gas Mitigation Professional: For the purpose of this document, an individual who has demonstrated a minimum degree of appropriate technical knowledge and skills specific to radon mitigation and additionally specific to mitigation of soil gas that contains hazardous chemicals, vapors or gas.

Quality Control: For mitigation professionals, actions to retain evidence of actual operational and installation quality that is compared to intended goals for quality. The comparison is systematically used to control quality with corrective actions as needed on a jobsite or for improvements to operational procedures.

Quality Management System (QMS): A documented plan of action, often described as a QA plan, that includes *Quality Control* Procedures for tracking the difference between planned actions and the actual resulting installation or product with systematic review for managing and improving quality.

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)

Re-entrainment: The unintended re-entry into a building of radon or soil gas that is being exhausted by a mitigation system.

Responsible Party (RP): Can be the property owner(s) or extend to include private businesses and/or governmental agencies

Sealed isolation assemblies: The surrounding physical components to an airspace that might include the entire building shell or an isolated airspace within a building that has been sealed to resist air movement between the isolated airspace and both indoor air and outdoor air.

Setback: See *HVAC Setback*.

Significantly occupied: The time period when the building is typically *occupied* by the majority of the workers or students. See "Normal Occupied Operating Condition", "Occupied", "Significantly occupied" and "Occupied work or school weeks".

Soil gas collection plenum: A 3-dimensional enclosure for collecting radon and other soil gases from under slabs, soil gas retarders or from behind walls that surrounds a void or gas permeable layer. There are at least six sides to this enclosed airspace and none are perfectly sealed, especially at the side facing soil.

Suction pit: Space that exists or is created below the suction pipe.

Suction point: Location at which suction piping is routed through the slab, foundation, membrane, drain tile or *sump* cover.

Sump (Sump pit): A pit below the subsurface grade of a building, which is commonly intended as a component of a ground water control system. Sump pumps and drainage piping are often additional components of such ground water control systems.

Townhouse: A single family *dwelling* (also referred to as a townhome) that is constructed in a group of three or more attached units where each unit extends from the foundation to the roof and has a yard or public way on at least two sides.

Unique sector of a building: Portions of a common building that are individually classified by the general design and the intended design of each active heating, cooling and ventilation system (HVAC).

Unit: A building or portion of a building that is used, intended or designed to be built, used, rented, leased, let or hired out to be *occupied* or that is *occupied* for commercial, residential or public purposes.

Working level (WL): Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3 x 105 MeV of potential alpha energy. This number was chosen because it is approximately the alpha energy released from the decay products in equilibrium with 100 pCi of Ra-222. Exposures are measured in *working level* months (WLM).

Working Level Month (WLM): A unit of concentration radioactivity corresponding to 1 *working level* (WL) for 170 hours per month. Although this unit of measurement came from assuming 40-hour work week exposures, it is commonly used to set limits for annual exposure to radon decay product alpha energy.

Exhibit A-1

Sample Notice: "CONTRACTOR TO CLIENT"

Intention to Enter Dwellings

To: Property Management, Corp.
2013 Industrial University Avenue
Anytown, USA

Radon Company
Anytown, USA 800-000-0000

Dear Management and Supervising Staff,

We request that notice of the intention to enter the building be provided to occupant(s) and other impacted residents a minimum of 24 hours before we enter the building area(s) designated below and in a manner that meets any applicable laws.

In addition, we request that notices be provided to occupants and other impacted residents that include instructions, warnings or guidance for specific disruptive or hazardous situations that may include noise, sealant vapors or other disruptions..

Access is required to for: [ ] Building Investigation [ ] System Installation [ ] Maintenance

Building Address: _____

Building Area(s): _____

Scheduled Date_____ Day _____ Time_____

_____

Procedures are expected to include:

[ ] _____

_____

[ ] **Drilling into concrete floors**

[ ] **Application of sealants.** Occupant Advisory: Common construction sealants used to prevent radon entry at foundations and other locations will normally emit vapors that contain modest amounts of certain chemicals generally referred to as volatile organic compounds. The emissions occur mostly during application, but also to a lesser extent as they dry to form an airtight bond. While these chemicals are commonly used, some sensitive individuals may experience discomfort or other health effects when exposed to such chemicals. *Material Safety Data Sheets (MSDS) are available upon request.*

Symptoms that may indicate sensitivity to these vapors may include: nausea, headaches, dizziness, drowsiness and/or an allergic reaction. Special consideration should be made for the very young or elderly who cannot communicate symptoms experienced.

If symptoms are observed: Leave the area immediately to breathe fresh air. Avoid further exposure. If symptoms persist, get medical attention.

We thank you for your cooperation in helping to ensure safe and healthy homes.

Sincerely,
Radon Company, Anytown, USA

Exhibit A-2

Sample Notice : "MANAGEMENT TO FACILITATING STAFF"

Intention to Enter Dwellings

Dear Custodial, Maintenance and Educational Staff,

Important steps are being taken to lower the risk to occupants in this building from soil gas pollutants. In particular, radon gas is the second leading cause of lung cancer and the leading cause of lung cancer in nonsmokers in the U.S.

Your staff member contacts:

Staff authorized for responding to public inquiries: _____ Phn#_____

For logistics of onsite activities, contact: _____ Phn#_____

Access is needed and scheduled for:

Building: _____

Building Area(s): _____

Scheduled Date_____ **Day** _____ **Time**_____

Access is required to for: [ ] Building Investigations [ ] System Installation [ ] Maintenance

Procedures are expected to entail:

[ ] _____

_____

[ ] **Drilling into concrete floors**

[ ] **Application of sealants.** Occupant Advisory: Common construction sealants used to prevent radon entry at foundations and other locations will normally emit vapors that contain modest amounts of certain chemicals generally referred to as volatile organic compounds. The emissions occur mostly during application, but also to a lesser extent as they dry to form an airtight bond. While these chemicals are commonly used, some sensitive individuals may experience discomfort or other health effects when exposed to such chemicals. *Material Safety Data Sheets (MSDS) are available upon request.*

Symptoms that may indicate sensitivity to these vapors may include: nausea, headaches, dizziness, drowsiness and/or an allergic reaction. Special consideration should be made for the very young or elderly who cannot communicate symptoms experienced.

If symptoms are observed: Leave the area immediately to breathe fresh air. Avoid further exposure. If symptoms persist, get medical attention.

We thank you for your cooperation in helping to ensure safe and healthy homes.

Sincerely,

Management or Radon Company, Anytown, USA

Exhibit A-3

Sample Notice: "MANAGEMENT TO OCCUPANTS"

Intention to Enter Dwellings

Property Management Company
Anytown, USA 800-000-0000

Dear Building Occupants,

Important steps are being taken to lower the risk to residents in this building from soil gas pollutants. In particular, radon gas is the second leading cause of lung cancer and the leading cause of lung cancer in nonsmokers in the U.S. Radon is a naturally-occurring radioactive gas that can be present in some buildings at concentrations that are dangerous to you, your family and pets. Copies of EPA's *A Citizen's Guide to Radon* are available upon request or you can contact your State Radon Office (**http://www.epa.gov/radon/whereyoulive.html**) or EPA regional office for additional information on radon.

Staff authorized for responding to public inquiries: _____ Phn#_____
For logistics of onsite activities, contact: _____ Phn#_____

Access is needed and scheduled for:

Building: _____

Building Area(s): _____

Scheduled Date_____ **Day** _____ **Time**_____

Access is required to for: [ ] Building Investigations [ ] System Installation [ ] Maintenance

Procedures are expected to entail:

[ ] _____
_____

[ ] **Drilling into concrete floors**

[ ] **Application of sealants.** Occupant Advisory: Common construction sealants used to prevent radon entry at foundations and other locations will normally emit vapors that contain modest amounts of certain chemicals generally referred to as volatile organic compounds. The emissions occur mostly during application, but also to a lesser extent as they dry to form an airtight bond. While these chemicals are commonly used, some sensitive individuals may experience discomfort or other health effects when exposed to such chemicals. *Material Safety Data Sheets (MSDS) are available upon request.*

Symptoms that may indicate sensitivity to these vapors may include: nausea, headaches, dizziness, drowsiness and/or an allergic reaction. Special consideration should be made for the very young or elderly who cannot communicate symptoms experienced.

If symptoms are observed: Leave the area immediately to breathe fresh air. Avoid further exposure. If symptoms persist, get medical attention.

We thank you for your cooperation in helping to ensure safe and healthy homes.
Sincerely,
Management or Radon Company, Anytown, USA

Exhibit B

Sample Posted Notice: "CONTRACTOR TO OCCUPANTS"

Sealant Warning

Radon Company
Anytown, USA 800-000-0000

Dear Building Occupants,
Important steps are being taken to lower the risk to residents in this building.

The work has required **application of sealants.**

[✓] **Wet Caulk/Sealants**. Take care to not step in or touch sealants until they are dry.

[✓] **Vapor from sealants:** Common construction sealants used to prevent radon entry at foundations and other locations will normally emit vapors that contain modest amounts of certain chemicals generally referred to as volatile organic compounds. The emissions occur mostly during application, but also to a lesser extent as they dry to form an air-tight bond. While these chemicals are commonly used, some sensitive individuals may experience discomfort or other health effects when exposed to such chemicals.

Symptoms that may indicate sensitivity to these vapors may include: nausea, headaches, dizziness, drowsiness and/or an allergic reaction. Special consideration should be made for the very young or elderly who cannot communicate symptoms experienced. **If symptoms are observed:** Leave the area immediately to breathe fresh air. Avoid further exposure. If symptoms persist, get medical attention.

We thank you for your cooperation in helping to ensure safe and healthy homes.

Sincerely,
Radon Company, Anytown, USA

EXHIBIT C

TEMPORARY SYSTEMS

Figure C-1:
SAMPLE LABEL
WHEN INSTALLING
TEMPORARY SYSTEMS

Temporary Radon Reduction System	
Date Installed:	
Description of system:	
Estimated date for completion of a permanent system:	[ ] **Within 30 days.**
	[ ] **Within 90 days due to ongoing diagnostics.**
	[ ] **Within 90 days after renovations.**
	[ ] **Subject to the approval process of** _____
John Smith Radon Reductions, 866-041-0412, *Anywhere America,* *Cert# 109492 State Proficiency Board*	

Figure C-2:
SAMPLE RISK TABLE
FOR RADON
CONCENTRATIONS THAT
ARE HIGHER THAN 20 *PCI/L*

RADON RISK IF YOU HAVE NEVER SMOKED		
Radon Level	***If 1,000 people who never smoked were exposed to this level over a lifetime ****	
150 pCi/L	***About 270 people could get lung cancer***	***Estimated** for concentrations higher than provided in EPA's Citizen Guide to Radon*
100 pCi/L	***About 180 people could get lung cancer***	
50 pCi/L	***About 90 people could get lung cancer***	
20 pCi/L	***About 36 people could get lung cancer***	*As shown in EPA's Citizen Guide to Radon*
10 pCi/L	***About 18 people could get lung cancer***	
8 pCi/L	***About 15 people could get lung cancer***	
4 pCi/L	***About 7 people could get lung cancer***	
2 pCi/L	***About 4 people could get lung cancer***	
1.3 pCi/L	***About 2 people could get lung cancer***	
* Lifetime risk of lung cancer deaths from EPA's *Assessment of Risks from Radon in Homes* (EPA 402-R-03-003)		

NORMATIVE APPENDIX B

NORMATIVE REFERENCES

Published by the U.S. EPA

For the latest versions of USEPA documents see: www.epa.gov/radon/pubs

- A Citizen's Guide To Radon [EPA 402/K-12/002, December 2016]
- Home Buyers and Sellers Guide to Radon [EPA /K-13/002, March 2018]

Published by AARST

For the latest versions of ANSI/AARST documents see www.aarst.standards.org

- MAH "Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes"

Published by the NFPA

For the latest versions of NFPA documents see: www.nfpa.org

- The National Electric Code® (NEC)

Published by the International Code Council, Inc.

For the latest versions of ICC documents see: www.iccsafe.org

- The International Building Code®
- The International Mechanical Code®
- The International Plumbing Code®
- The International Residential Code®
- ICC 700, "National Green Building Standard for Residential Construction".

Published by ASTM International

For the latest versions of ASTM documents see: www.astm.org

- C920 Elastomeric Joint Sealants
- C1173 Flexible Transition Couplings for Underground Piping Systems
- D2235 Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
- D2661 Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings
- D2564 Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
- D2665 Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
- D5926 Poly (Vinyl Chloride) (PVC) Gaskets for Drain, Waste, and Vent (DWV), Sewer, Sanitary, and Storm Plumbing Systems
- E1745 Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs
- F656 Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings
- F628 Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe With a Cellular Core
- F891 Coextruded Poly(Vinyl Chloride) (PVC) Plastic Pipe With a Cellular Core
- F1488. Coextruded Composite Pipe

INFORMATIONAL REFERENCES

Published by the ASHRAE

For the latest versions of ASHRAE documents see: www.ashrae.org

- Indoor Air Quality Guide – Best Practices for Design Construction and Commissioning
- 62.1 "Ventilation for Acceptable Indoor Air Quality for buildings that are more than three stories tall"
- 62.2 "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings"
- 189.1, "Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings"

Other Health and Safety Publications

- World Health Organization, "WHO Handbook on Indoor Radon: A Public Health Perspective." 2009
- Swedish Radiation Protection Authority, "Radon in Estonia Dwellings, Stockholm" 2003
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INFORMATIVE APPENDIX C

CONSENSUS BODY MEMBERS

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

Mitigation Consensus Body 2019-2020

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SGM-SF Consensus Body 2014-2016

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SGM-SF
Companion Guidance

Advisory — The information contained in this guidance document is not part of this ANSI/AARST American National Standard (ANS) and does not contain requirements necessary for conformance to the SGM-SF standard. The information contained in this guidance document has not been processed in accordance with ANSI's requirements for an ANS. As such, this guidance document may contain material that has not been subjected to public review or a consensus process.

Discussion highlights

SGM-SF	*Summary - Discussion*
CG SECTION 1: SCOPE	SGM-SF covers virtually all mitigation methods that protect occupants from radon and chemical vapor intrusion.
CG SECTION 2: APPLICABILITY	SGM-SF does not apply to mitigation systems installed prior to its effective date.
CG SECTION 3: QUALIFIED CONTRACTORS	Training and quality control of services are essential when providing mitigation services.

Understanding Quality Management

Be it a single person or a large firm: The larger the volume of work and the more complex the projects are, the more valuable a Quality Management System (QMS) becomes.

- For managing quality, one compares written procedures (input) to successes and failures (output).
- Input information includes written procedures for staff member roles and responsibilities, standards, codes, customer satisfaction and worker safety.
- The output results are tracked (e.g., retest results, standards compliance and customer satisfaction).
- The comparison if written procedures and output results identifies actions necessary to improve procedures and installation quality.

CG Table 3.3 QMS fundamentals

Illustrated as compared to ISO 9001-2008 (the international standard for Quality Management Systems).

ISO 9001	**Quality Management Systems (QMS) for Mitigation Professionals**
• 1.0 Scope; 1.1 General; • 4.1 "General Requirements" • 5.0 Top Management; 5.4 Planning; 5.4.1 *Quality objectives:* "Quality objectives shall be measurable and consistent with the quality policy" (e.g. System Installation Quality).	**A QMS begins with two written policy statements on quality.** *The following statements are examples that are consistent with ISO 9001:* **1) System Installation Quality:** Mitigation systems that are in compliance with standards, codes and statutes while also, to the extent practicable, achieving customer satisfaction. In addition, all related activities are conducted in a safe manner for both workers and occupants. **2) System Quality Objectives:** Mitigation systems that will result, at a minimum, in reducing concentrations to below the target action level and, to the extent practicable, as low as reasonably achievable. In addition, the resulting systems will otherwise not jeopardize the health and safety of occupants or the public.
4.0 Quality management systems	**Summary Of Quality Plans & Quality Control**
4.2.1 Documented procedures	• Procedures (each juncture that may warrant written procedures). Normally, each important stage of installation would be broken out with a process or procedure that matched the quality goals.
4.2.1 Documented procedures include	• Interaction between the processes; and • Control of documents and records (to include approvals, reviews, updates, distribution and storage.

ISO 9001	Procedures should include recording conditions found and resulting "as installed" condition or configuration for: • Each ASD suction point (See Section 6.1); • ASD Pipe materials (See Section 6.2); • ASD Pipe sizing (See Section 6.3); • ASD Exhaust Discharge - Location and Design (See Section 6.4); • ASD Fan including model installed (See Section 6.5); • Sealing (Sections 7.1-7.4), Sump (Section 7.5), Membranes (Sections 7.6 and 7.7), Drains (Section 7.8), and Sealed Assemblies (Section 7.9); Fan Monitors (See Section 8.2); • Electrical (See Section 8.3); • Labeling (See Section 8.4); • Post mitigation functional inspection (See Section 9.1); • Post mitigation retests (See Section 9.2); • OM&M Plans - in detail (See Section 10); • Health and Safety (See Section 11); • Non-ASD Methods - (See Section 12);
Examples of mitigation topics that should have a written procedure **Documented procedures**	
5.0 "Management Responsibility" (Top Management Personnel) 5.1 Management commitment	Develop and implement a quality management system and continually improve its effectiveness by • communicating to the organization, • conducting reviews, and • ensuring the availability of resources.
5.2 Customer focus	Ensure that customer requirements are determined and are met.
5.3 Quality policy	Ensure that the quality policy is: 1) appropriate; 2) includes commitment to comply and continually improve; and 3) is communicated and understood within the organization.
5.4 Planning	Ensure that planning of the QMS is carried out.
5.5 Responsibility, authority and communication	Ensure responsibilities and authorities are defined and communicated within the organization. This effectively requires that all top management personnel and any key personal are identified in the plan.
5.5 Management review	Review the quality management system, at planned intervals, to ensure its continuing suitability, adequacy and effectiveness
6.0 Resource management;	
6.2 "Human Resources" *6.3 "Infrastructure"*	Personnel performing work shall be competent on the basis of appropriate education, training, skills and experience. For equipment, materials and support services needed to achieve quality.
7.0, *7.3 1 Design planning:*	The organization plans and controls the design and development.
7.3.2 Design Input	Standards, codes, customer and site specific needs.
7.3.3 Verifiable Design Outputs	1) Compliant to standards, codes and consumer satisfaction; 2) Objectives for health protection.
7.3.4 Design review:	Participants to include representatives of functions concerned with the design and development stage(s) being reviewed.
7.3.4 Design validation:	Compare input needs to expected outputs. Is the system is capable of meeting the quality objectives?
7.4.3 Verification of installation	Inspection that the installed configuration meets quality requirements
8.0 Analysis and improvement *8.2.3 Monitoring*	Apply suitable methods for monitoring and, where applicable, measurement of the effectiveness of QMS processes.
8.3 Control of failed quality	Take action appropriate to the effects, or potential effects, of the failure.

SGM-SF	*Discussion*
CG SECTION 4: GENERAL PRACTICES 4.1 Assemble Building Information 4.2 Proposals 4.3 Notification and Hazards 4.4 Jurisdictional Authorities and Codes	Existing measurements and building specifications are important to design of any soil gas mitigation system. Responsible proposals, notification to occupants and compliance with jurisdictional codes and statutes are components when providing professional service.
CG SECTION 5: SYSTEMS DESIGN 5.1 Health and Safety 5.2 Long-Term Considerations 5.3 Appropriate Systems 5.4 Nondestructive Investigation 5.5 Diagnostic Investigation 5.6 Design Decisions	Design features should facilitate long-term ease in maintaining, operating and monitoring effectiveness of the system. Nondestructive and diagnostic Investigations provide information to inform mitigation strategy and design decisions.

Discussion

Pressure Field Extension (PFE)

CG 5.5 ASD designs

PFE evaluations help to characterize conditions under a slab or membrane.

PFE evaluations include consideration that:

1. Conditions at one location under a slab or membrane can be very different at other locations across the floor;
2. You cannot tell for certain the degree of contributions to indoor soil gas concentrations that are coming from other foundation areas to the building;
3. PFE evaluations conducted in mild weather during the daytime will often have different results than those conducted under heating conditions across colder seasons.

Other considerations include:

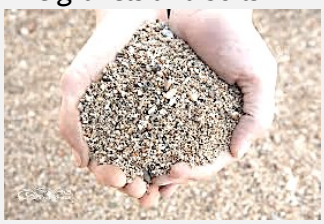
1. Restricted or blocked PFE due to tight soil or barriers such as footings; or
2) Diminished or lost PFE due to unclosed openings between soil gas and indoor or outdoor air.

Note—On occasion, PFE is similarly lost at large void spaces under a slab due to fill settlement or, in certain regions, due to natural caves, cavities or highly permeable stone aggregates that extend deep into the earth.

Understanding Permeability

Range of Hydraulic Conductivity of Natural Soils			
USCS class	Soil Type	Hydraulic Conductivity Range gallons per day/ft^2	Permeability description
GP	Uniform gravel	4,000 to 20,000	High
GW	Well-graded gravel	1,000 to 6,000	Moderate to high
SP	Uniform sand	100 to 4,000	Moderate to high
SW	Well-graded sand	20 to 2,000	Low to moderate
SM	Silty sand	20 to 100	Low
SC	Clayey sand	20 to 20	Low to very low
ML	Silt	1 to 2	Very low
CL	Clay	0.02 to 0.2	Very low to impermeable

This table helps illustrate the relative differences you can encounter that dictate the ease of extending a vacuum across distances. Those highlighted with gray present challenges in achieving PFE.

Gravel or crushed stone 	Abundant hydraulic conductivity exists with mostly 3/4 inch stones in aggregates classified in ASTM C33 numbers 5, 56, 57 or 6. These products are commonly used in new building construction. The size of pores you see between stones or aggregates is an indication of how permeable that aggregate layer is. Where the total size of the pores represents an open area smaller than the open end of a suction pipe, system airflow is inhibited.
Sands, fine gravels and soils 	Advisory — Sands that contain more than 10% fine sand, silt and clay should not be as gas permeable. Expansive soils or soils that contain more than 35% sand, fines, clay and silt should not be as gas permeable. Solid clay is impervious to air movement.

Unified Soil Classification System *(ASTM D 2487)*

MAJOR DIVISIONS			SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS OVER 50% > No.200 SIEVE SIZE	GRAVELS	CLEAN GRAVELS WITH LESS THAN 5% FINES	GW	Well-graded gravels or gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
	MORE THAN 1/2 OF COARSE FRACTION > No.4 SIEVE SIZE	GRAVELS WITH OVER 15% FINES	GM	Silty gravels, gravel-sand mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS	CLEAN SANDS WITH LESS THAN 5% FINES	SW	Well-graded sand or gravelly sands, little or no fines
			SP	Poorly graded sands or gravelly sands, little or no fines
	MORE THAN 1/2 OF COARSE FRACTION < No.4 SIEVE SIZE	SANDS WITH OVER 15% FINES	SM	Silty sand, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS OVER 50% < No.200 SIEVE SIZE	SILTS & CLAYS LIQUID LIMIT 50% OR LESS		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS LIQUID LIMIT GREATER THAN 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils

This table helps illustrate various soil compositions. Areas NOT highlighted with gray background are the most permeable.

PFE Measurements: All mitigators will encounter situations that require, in addition to "qualitative evidence" indicating airflow and direction, "quantitative measurements" that tell you exactly how much air volume and vacuum is needed. This an important tool to not disregard. Some seasoned mitigators immediately create pilot holes for PFE testing at 4 locations to evaluate each outer quadrant of a slab. Such practice can enhance PFE characterization of the sub-slab condition and save a lot of grief.

The goal: An ASD system that continuously controls the destination of soil gas with an appropriate degree of care to not compromise other building systems and health of occupants.

General: Inducing a negative pressure difference of about 1 pascal (4/1000 inch water column) within soil gas relative to indoor air is commonly witnessed to successfully reduce radon entry for most, if not all of the year. This is partly because even zero pressure difference reduces soil gas entry. However, the season when these measurements are conducted is a critical consideration.

Cold weather example: During coldest weather, even barely detectable PFE sometimes witnessed in challenging structures does not usually need additional protective buffer if success is confirmed by indoor measurements. This is because PFE will often be stronger in mild weather.

Cold weather example of concern: If during cold weather a strong vacuum such as 5 pascal (20/1000 inch water column) is applied, PFE vacuums are expected to increase in mild weather. With studies showing that about 40-50% of ASD exhaust air is often coming from within the building, high vacuum ASD systems with robust airflows increase the likelihood of unnecessary energy penalties and compromised building systems such as inducing flue gas spillage at combustion appliances.

Mild weather concerns: When PFE measurements are made in mild weather, the extent that negative pressure will increase within a building during cold weather is an unknown commodity. If negative pressure internal to the building during cold weather increases to overwhelm PFE witnessed, the system or portion of the system will temporarily cease to stop soil gas entry. As a protective buffer for this situation, seasoned professionals often seek to achieve about 2.5 pascal (10/1000 inch water column) pressure difference in mild weather, whenever possible.

Verification: Actual confirmation of adequacy would require testing under varied seasonal conditions.

SGM-SF	*Discussion*
CG SECTION 6: ASD SYSTEMS	
CG 6.1 ASD Suction Points 6.1.1 *Suction pits* 6.1.2 *Sumps* 6.1.3 *Sub-membrane suction point***s**	**Safety Advisory—**Post-tension slab construction is common for certain larger slab-on-grade buildings. Do NOT cut into a post-tensioned slab if there is a chance you will rupture a cable. Cables can burst out of the concrete taking life and limb. Before any slab work begins, have a competent or qualified person identify the cable locations.
6.1.4 *Non-habitable air spaces*	The term "Non-habitable air spaces" encompasses depressurization of a wide range of airspace configurations. These depressurization systems require special care to design and implement air barrier isolation of the airspace. (See Section 8.9 Sealed isolation assembly.) **Advisory**—Adverse effects for inadequate isolation can include failed systems, excessive energy penalties and flue spillage from atmospherically vented combustion appliances. **Advisory—**A Sealed isolation assembly can sometimes require creating access ports and extensive efforts for sealing the structural assembly.
6.1.5 *Block walls*	**Advisory—**When Block Wall Depressurization is applied directly to a wall, suction point considerations include the degree to which a complete air barrier can be established between soil gas within the blocks and indoor air.
CG 6.2 ASD Piping 6.2.1 *Air and water tight* 6.2.2 *Slope required*	**Advisory—**The constructed piping must be glued or sealed in a manner that does not leak water and be configured to drain water so that water droplets that naturally and persistently form within pipes do not collect to obstruct airflow.

6.2.3 *Positively-pressurized piping*	**Advisory—**The fan and piping from the fan to the exterior discharge must not be located in or pass through living space. Any accident that might compromise positively-pressurized components can deliver soil gas directly into living spaces.
6.2.4 *Labels are required*	Label the piping.
6.2.5 *ASD pipe materials* 6.2.6 *Joint materials and connections* 6.2.7 *Secure duct piping*	These provisions speak to durability of air duct pipe materials, connections and mounting support configurations.
6.2.8 *Unnecessary noise* 6.2.9 *Provide access clearance* 6.2.10 *Protect ducts from the elements*	These provisions speak to appropriate care for occupants to include minimizing objectionable noise from the system and obstructing access to equipment, entrances and exits, particularly as required by code for occupant safety. SGM-SF observes a need to insulate pipe in certain climates.
6.2.11 *Observe codes*	SGM-SF reminds professionals of codes associated with pipe installations that mandate protection of building materials and future workers and occupants.

CODE EXAMPLES RELEVANT TO INSTALLING ASD PIPE

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Advisory Note—This document DOES NOT contain all code requirements of the jurisdictions where the system is being installed. It is the sole responsibility of the practitioner to be knowledgeable regarding the current codes and codes applicable for the jurisdiction where work is being performed.

WORKING IN EXISTING BUILDINGS

code example: **IRC® APPENDIX J: EXISTING BUILDINGS AND STRUCTURES**

AJ102.1 General.
Regardless of the category of work being performed, the work shall not cause the structure to become unsafe or adversely affect the performance of the building; shall not cause an existing mechanical or plumbing system to become unsafe, hazardous, insanitary or overloaded; and unless expressly permitted by these provisions, shall not make the building any less conforming to this code or to any previously approved alternative arrangements than it was before the work was undertaken.

ROUTING PIPE

code examples: **IRC® CHAPTER 5**

R502.8 Drilling and notching. Structural floor members shall not be cut, bored or notched in excess of the limitations specified in this section. See Figure R502.8.

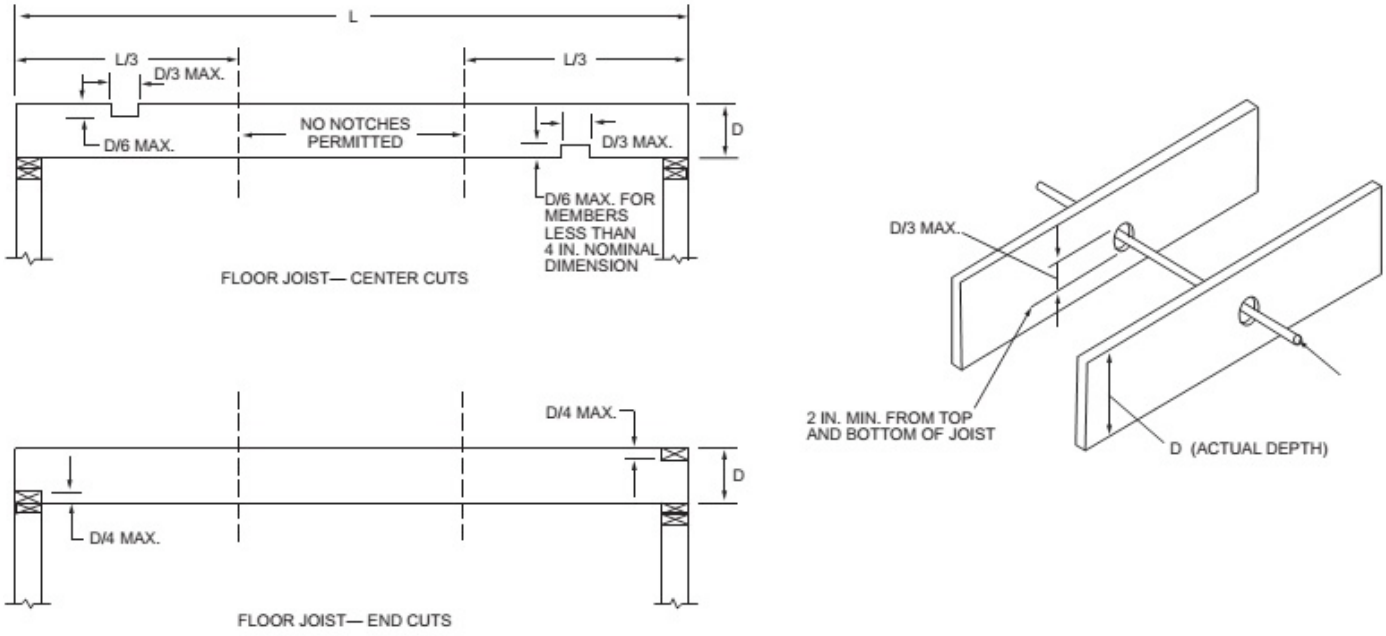


FIGURE 502.8 CUTTING, NOTCHING AND DRILLING

R502.8.1 Sawn lumber. Notches in solid lumber joists, rafters and beams shall not exceed one-sixth of the depth of the member, shall not be longer than one-third of the depth of the member and shall not be located in the middle one-third of the span. Notches at the ends of the member shall not exceed one-fourth the depth of the member. The tension side of members 4 inches (102 mm) or greater in nominal thickness shall not be notched except at the ends of the members. The diameter of holes bored or cut into members shall not exceed one-third the depth of the member. Holes shall not be closer than 2 inches (51 mm) to the top or bottom of the member, or to any other hole located in the member. Where the member is also notched, the hole shall not be closer than 2 inches (51 mm) to the notch.

R502.8.2 Engineered wood products. Cuts, notches and holes bored in trusses, structural composite lumber, structural glue-laminated members, cross-laminated timber members or I-joists are prohibited except where permitted by the manufacturer's recommendations or where the effects of such alterations are specifically considered in the design of the member by a registered design professional.

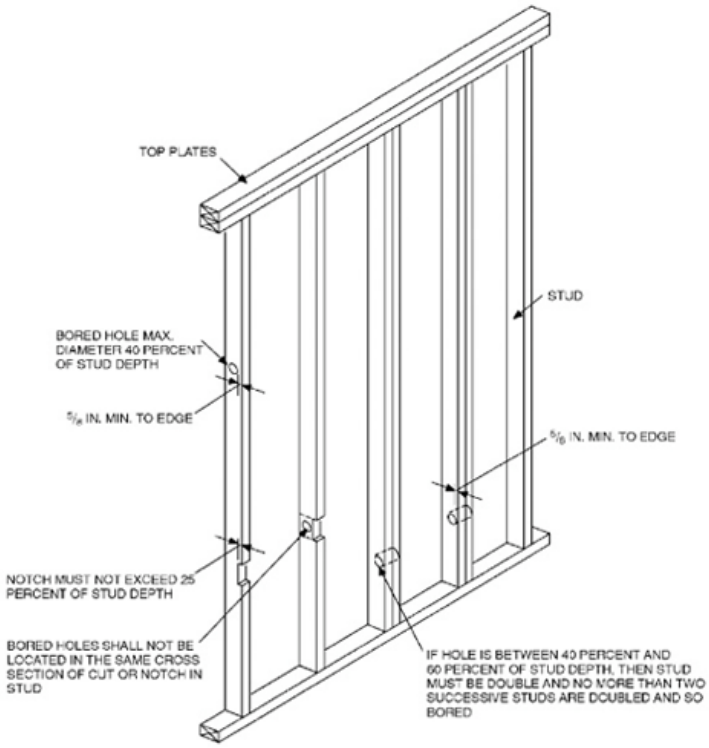
code examples: **IRC® CHAPTER 6**

R602.6 Drilling and notching of studs. Drilling and notching of studs shall be in accordance with the following:

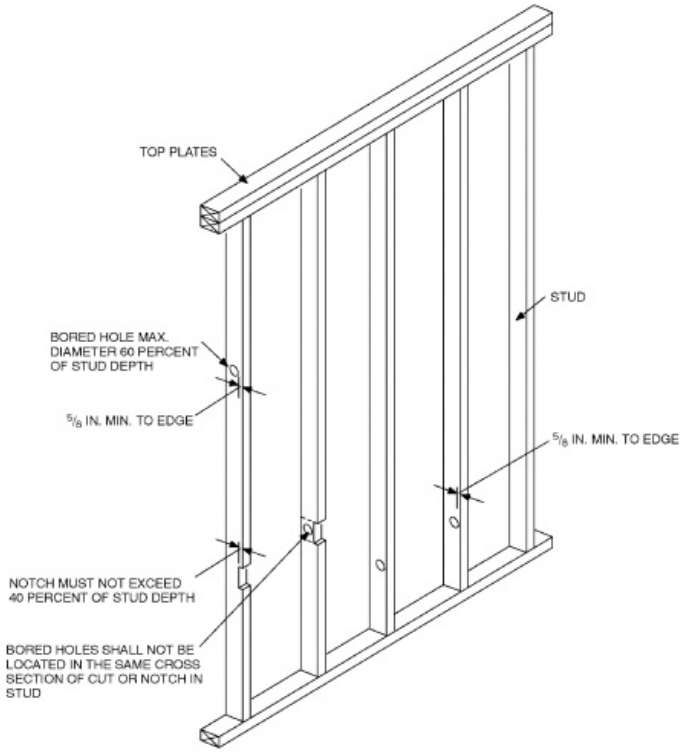
1. Notching. Any stud in an exterior wall or bearing partition shall be permitted to be cut or notched to a depth not exceeding 25 percent of its width. Studs in nonbearing partitions shall be permitted to be notched to a depth not to exceed 40 percent of a single stud width.

2. Drilling. Any stud shall be permitted to be bored or drilled, provided that the diameter of the resulting hole is not more than 60 percent of the stud width, the edge of the hole is no more than 5/8 inch (16mm) to the edge of the stud, and the hole is not located in the same section as a cut or notch. Studs located in exterior walls or bearing partitions drilled over 40 percent and up to 60 percent shall be doubled with not more than two successive doubled studs bored. See Figures R602.6(1) and R602.6(2).

Exception: Use of approved stud shoes is permitted when they are installed in accordance with the manufacturer's recommendations.



IRC FIGURE R602.6 (1) NOTCHING AND BORED HOLE LIMITATIONS FOR EXTERIOR WALLS AND BEARING WALLS



IRC FIGURE R602.6 (2) NOTCHING AND BORED HOLE LIMITATIONS FOR INTERIOR NONBEARING WALLS

R602.6.1 Drilling and notching of top plate. When piping or ductwork is placed in or partly in an exterior wall or interior load-bearing wall, necessitating cutting, drilling or notching of the top plate by more than 50 percent of its width, a galvanized metal tie of not less than 0.054inch thick (1.37mm) (16ga) and 1½ inches (38mm) wide shall be fastened across and to the plate at each side of the opening with not less than eight 16d (0.128 inch diameter) nails having a minimum length of 1½ inches (38mm) at each side or equivalent. See Figure R602.6.1.

Exception: When the entire side of the wall with the notch or cut is covered by wood structural panel sheathing.

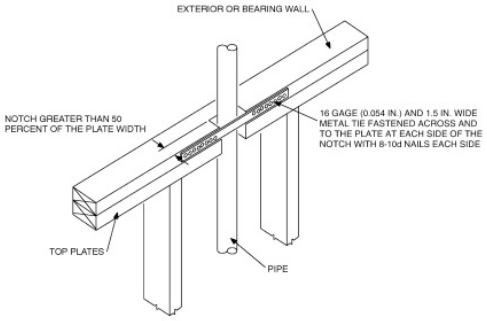


FIGURE R602.6.1 TOP PLATE FRAMING TO ACCOMMODATE PIPING

code examples: **IRC® CHAPTER 26** GENERAL PLUMBING REQUIREMENTS

P2605 SUPPORT P2605.1 General. Piping shall be supported in accordance with the following:

1. Piping shall be supported to ensure alignment and prevent sagging, and allow movement associated with the expansion and contraction of the piping system.
2. Piping in the ground shall be laid on a firm bed for its entire length, except where support is otherwise provided.
3. Hangers and anchors shall be of sufficient strength to maintain their proportional share of the weight of pipe and contents and of sufficient width to prevent distortion to the pipe. Hangers and strapping shall be of approved material that will not promote galvanic action. Rigid support sway bracing shall be provided at changes in direction greater than 45 degrees (0.79 rad) for pipe sizes 4 inches (102 mm) and larger.
4. Piping shall be supported at distances not to exceed those indicated in Table P2605.1.

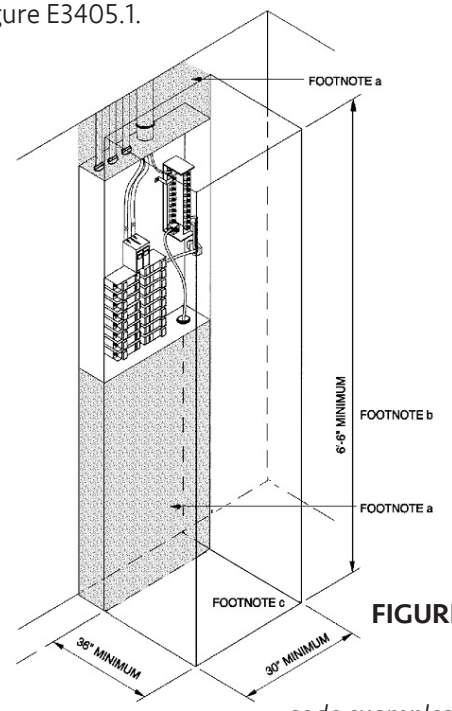
code examples: **IRC® CHAPTER 34** GENERAL REQUIREMENTS

E3402 BUILDING STRUCTURE PROTECTION

E3402.3 Penetrations of firestops and draftstops. Penetrations through fire blocking and draftstopping shall be protected in an approved manner to maintain the integrity of the element penetrated.

SECTION 3405 EQUIPMENT LOCATION AND CLEARANCES

E3405.1 Working space and clearances. Access and working space shall be provided and maintained around all electrical equipment to permit ready and safe operation and maintenance of such equipment in accordance with this section and Figure E3405.1.



a) Equipment, piping and ducts foreign to the electrical installation shall not be placed in the shaded areas extending from the floor to a height of 6 feet above the panelboard enclosure, or to the structural ceiling, whichever is lower.

b) The working space shall be clear and unobstructed from the floor to a height of 6 feet or the height of the equipment, whichever is greater.

c) The working space shall not be designed for storage.

d) Panelboards, service equipment and similar enclosures shall not be location in bathrooms, toilet rooms, clothes closets or over the steps of a stairway.

FIGURE 3405.1 WORKING SPACE AND CLEARANCES

code examples: **IRC® CHAPTER 10 CHIMNEYS AND FIREPLACES**

R1003.18 Chimney clearances. Any portion of a masonry chimney located in the interior of the building or within the exterior wall of the building shall have a minimum airspace clearance to combustibles of 2 inches (51 mm). Chimneys located entirely outside the exterior walls of the building, including chimneys that pass through the soffit or cornice, shall have a minimum airspace clearance of 1 inch (25 mm). The air space shall not be filled, except to provide fire blocking in accordance with Section R1003.19.

code examples: **IRC® CHAPTER 13 GENERAL MECHANICAL SYSTEM REQUIREMENTS**

M1306 CLEARANCES FROM COMBUSTIBLE CONSTRUCTION

M1306.1 Appliance clearance. Appliances shall be installed with the clearances from unprotected combustible materials as indicated on the appliance label and in the manufacturer's installation instructions.

SGM-SF	***Discussion***
OTHER ADVISORIES 6.2.11 Fire-rated Assemblies	Codes for **fire-rated** construction between a garage and living space have grown more protective in recent decades. Where a wall and/or ceiling assembly constitutes fire-rated separation, pipe penetrations must be configured to retain the existing fire-rated separation. Fire collars at pipe penetrations are commonly employed to meet this need.

11.1.1 Flue Gas Spillage from Combustion Appliances	The chances for **flue gas spillage** increases with ASD systems that either draw robust volumes of air from a home or draw air from a small room that contain an atmospherically vented combustion appliance.
11.2.3 Asbestos	Where suspected **asbestos** is observed and may be disturbed, postpone work until an accredited asbestos inspector is consulted.
11.2.4 Lead-Based Paint	In buildings constructed before 1978 where **lead-based paint** may be present, work practices may require compliance with the EPA Lead Renovation, Repair and Painting (RRP) Rule.

SGM-SF	*Discussion*
CG 6.3 ASD Pipe Sizing 6.3.1 The minimum inside diameter 6.3.2 larger air volume needs 6.3.3 smaller if needs are verified	ASD Pipe Sizing directly correlates to conditions below slabs or membranes in terms of air volumes that are needed to induce negative pressure.
6.3.4 Equivalent cross-sectional area 6.3.6 Maintain whole-system capacity 6.3.5 Multiple suction points 6.3.7 Alternative duct materials 6.3.8 Maximum and Minimum velocities	Multiple pipes joined in parallel must retain **equivalent capacity** for needs of air volume movement. Configurations must not result in reduced air movement capacity that is required for the whole system.
CG 6.4 ASD Exhaust Discharge	Exhaust configurations for SGM-SF have been harmonized with those in RMS-MF and RMS-LB 2018
CG 6.5 ASD Fan Installation	**Advisory—**The fan location is a health and safety consideration. It must not be located where a pipe connection failure can result in discharged soil gas entering the building.

SGM-SF	*Discussion*
CG SECTION 7.0 SEALING 7.1 *Background and Accessibility* 7.2 *Sealant Materials* 7.3 *Accessible Slab Cracks* 7.4 *Other Openings in Slabs or Walls*	A continuous air barrier that resists air movement between soil and indoor air is the goal. However, there are practical limits on the extent of sealing that is reasonable or necessary. Sealing efforts must not impair a buildings water drainage and control systems.
7.5 *Sumps* 7.6 *Membranes Over Exposed Soil*	Specifications are provided to help ensure both durable closure and reasonable access to sump pits and pumps. Appropriate material and installation specifications are provided for soil gas retarder membranes.
7.7 *Sub-membrane depressurization*	Section 7.7 adds more stringent closure requirements for membranes.
One challenging situation is when a portion of the crawl space is inaccessible for applying a membrane. In most cases, close all edges of the membrane that are accessible prior to where the crawl space extends into inaccessible areas. If a large expanse is inaccessible, it is still to enclose accessible portions of open soil for sub-membrane depressurization or choose a strategy to create access ports for complete soil closure.	

Note: Where it is unavoidable that membrane edges are left unclosed, the mitigation method combines Sub-Membrane Depressurization (SMD), Soil gas dilution and/or Crawl Space Depressurization (CSD). Be certain to comply with requirements associated with each method and include the details in the client's OM&M plan (e.g., information packet).	
7.8 *Drains*	Considerations for radon entry or loss of PFE include where a drain represents an opening between soil gas and living spaces or outside air.
7.9 *Sealed Isolation Assemblies*	Advisory—To depressurize or pressurize a partitioned crawlspace, wall cavity or the entire building, closure of all outer boundaries of a constructed or partitioned airspace is needed to control the path of soil gas migration. Creation of access ports may be required.

CG SECTION 8.0 REQUIREMENTS FOR ALL SYSTEMS 8.1 OM&M Plan Required 8.2 Fan Monitors	Be it a single-family home or multiple properties under the same management, written instructions for how to maintain and monitor for system failure are required. OM&M plans become more detailed when they apply to multiple systems or complex mitigation methods. Fans or air handlers associated with the mitigation system require fan monitors that indicate fan failure or changes in fan performance.
8.3 Electrical Requirements	SGM-SF provides a few specific requirements and reminds professionals of electrical codes that are critical for occupant safety.

CODE EXAMPLES RELEVANT TO ELECTRICAL REQUIREMENTS

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Code examples: **IRC® CHAPTER 37 BRANCH CIRCUIT AND FEEDER REQUIREMENTS**

E3701.4 Branch circuits with more than one receptacle. Conductors of branch circuits supplying more than one receptacle for cord-and-plug-connected portable loads shall have ampacities of not less than the rating of the branch circuit.

E3702.7 Branch circuits serving motor-operated and combination loads. For circuits supplying loads consisting of motor-operated utilization equipment that is fastened in place and that has a motor larger than 1/8 horsepower (0.093 kW) in combination with other loads, the total calculated load shall be based on 125 percent of the largest motor load plus the sum of the other loads.

E3702.14 Branch-circuits requirement – summary

	CIRCUIT RATING		
	15 amp	**20 amp**	**30 amp**
Conductors: Minimum size (AWG) circuit conductors		12	10
Maximum overcurrent-protection device rating Amerpere rating		20	30
Outlet devices: Lampholders permitted Receptacle rating (amperes)	Any type 15 maximum	Any type 15 or 20	N/A 30
Maximum load (amperes)	15	20	30

TABLE 3702.14 BRANCH-CIRCUIT REQUIREMENTS-SUMMARY

code examples: **IRC® CHAPTER 38 BRANCH CIRCUIT WIRING METHODS**

3802.3 Exposed cable. In exposed work, except as provider in Sections E3802.2 and E3802.4, cable assemblies shall be installed as specified in Sections E3802.3.1 and E3802.3.2.

E3802.3.1 Surface installation. Cables shall closely follow the surface of the building or running boards.

E3802.3.2 Protection from physical damage. Where subject to physical damage, cables shall be protected by rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 PVC rigid nonmetallic conduit, or other approved means. Where passing through a floor, the cable shall be enclosed in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 PVC rigid nonmetallic conduit or other approved means extending not less than 6 inches (152 mm) above the floor.

E3802.3.3 Locations exposed to direct sunlight. Insulated conductors and cables used where exposed to direct rays of the sun shall be listed or listed and marked, as being "sunlight resistance", or shall be covered with insulating material, such as tape or sleeving, that is listed or listed or listed and marked as being "sunlight resistant."

E3802.3.4 In unfinished basements and crawl spaces. Where type NM or SE cable is run at angles with joists in unfinished basements or crawlspaces, cable assemblies containing two or more conductors of sizes 8 AWG and larger shall not require additional protection where attached directly to the bottom of the joists. Smaller cables shall be run either through bored holes in joists or on running boards. Type NM or SE cable installed on a wall of an unfinished basement shall be permitted to be installed in a listed conduit or tubing or shall be protected in accordance with Table 3802.1. Conduit or tubing shall be provided with a suitable insulating bushing or adapter at the point the where cable enters the raceway. The sheath of the type NM or SE cable shall extend through the conduit or tubing and into the outlet or device box not less than ¼ inch (6.4 mm). The cable shall be secured within 12 inches (305 mm) of the point where the cable enters the conduit or tubing. Metal conduit, tubing, and metal outlet boxes shall be connected to an equipment grounding conductor complying with Section E3908.13.

code examples: **IRC® CHAPTER 39 POWER AND LIGHT DISTRIBUTION**

E3905.1 Box, conduit body or fitting—where required. A box or conduit body shall be installed at each conductor splice point, outlet, switch point, junction point and pull point except as otherwise permitted in Sections E3905.1.1 through E3905.1.6. Fittings and connectors shall be used only with the specific wiring methods for which they are designed and listed.

E3905.11 Damp or wet locations. In damp or wet locations, boxes, conduit bodies and fittings shall be placed or equipped so as to prevent moisture from entering or accumulating within the box, conduit body or fitting. Boxes, conduit bodies and fittings installed in wet locations shall be listed for use in wet locations. Where drainage openings are installed in the field in boxes or conduit bodies list for use in damp or wet locations, such openings shall be approved and not larger than ¼ inch (6.4 mm). For listed drain fittings, larger openings are permitted where installed in the field in accordance with the manufacturer's instructions.

E3906.1 Conductors entering boxes, conduit bodies or fittings.
Conductors entering boxes, conduit bodies or fittings shall be protected from abrasion.

E3908.4 Effective ground-fault current path. Electric equipment and wiring and electrically conductive material likely to become energized shall be installed in a manner that creates a low impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. Such circuit shall be capable of safely carrying the maximum ground fault current likely to be imposed on it from any point on the wiring system where ground fault might occur to the electrical supply source.

E3909 FLEXIBLE CORDS

E3909.1 Where permitted. Flexible cords shall be used only for the connection of appliances where the fastening means and mechanical connections of such appliances are designed to permit ready removal for maintenance, repair or frequent interchange and the appliance is listed for flexible cord connection. Flexible cords shall not be installed as a substitute for the fixed wiring of a structure; shall not be run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings or floors; shall not be concealed behind walls, floors, ceilings or located above suspended or dropped ceilings.

Code examples: **IRC® CHAPTER 41 APPLIANCE INSTALLATION**

E4101.3 Flexible cords. Cord-and-plug-connected appliances shall use cords suitable for the environment and physical conditions likely to be encountered. Flexible cords shall be used only where the appliance is listed to be connected with a flexible cord. The cord shall be identified as suitable for the purpose in the installation instructions of the appliance manufacturer.

Receptacles for cord-and-plug-connected appliances shall be accessible and shall be located to avoid physical damage to the flexible cord. Except for a listed appliance marked to indicate that it is protected by a system of double-insulation, the flexible cord supplying an appliance shall terminate in a grounding- type attachment plug. A receptacle for a cord-and-plug-connected range hood shall be supplied by an individual branch circuit. Specific appliances have additional requirements as specified in Table E4101.3 (see Section E3909).

SGM-SF	*Discussion*
CG SECTION 9.0 POST-MITIGATION (RADON) 9.1 Post-Mitigation Functional Inspection 9.2 Radon Retests After Mitigation	An inspection of functional components is required after mitigation. The effectiveness of the system can only be determined by a radon test.
CG SECTION 10.0 DOCUMENTATION (RADON) Long-Term Operation, Maintenance and Monitoring Plan	An information packet with written instructions essential for maintaining and monitoring for system failure (i.e., OM&M plan) is required much as it has been required for radon systems since 1993. When the occupant does not maintain the system or when non-ASD methods are employed, additional content is required.
CG SECTION 11.0 HEALTH AND SAFETY	See SGM-SF Section 11.0 for important guidance and requirements associated with worker and occupant health and safety.
CG SECTION 12.0 NON-ASD METHODS 12.1 All Non-ASD Methods 12.2 Sources for Air Delivered to a Building 12.3 Indoor Air Pressurization 12.4 Soil Air Pressurization 12.5 Indoor Air Dilution 12.6 Soil Air Dilution 12.7 Controls for Variable Activation 12.8 HVAC Repairs or Modifications 12.9 Building Materials Source 12.10 Radon From Water 12.11 Chemical Vapors From Water 12.12 Air Cleaning 12.13 Source Removal 12.14 Passive Systems/Technologies	**FUNDAMENTAL OVERVIEW** Protecting people from hazardous air entails either 1) Moving the hazardous air or source of air away from people 2) Encapsulating the hazardous source, or 3) Diluting the hazardous air ASD moves hazardous air away from people by manipulating the pressure relationship between soil and indoor air. But each method overlaps to some degree with the other two methods. Most Non-ASD methods for reducing indoor concentrations of airborne hazards include manipulation of building pressures or air change rates (i.e., dilution). Advisory – Such activities can prove fruitless or even hazardous if not conducted by a professional who is trained in disciplines associated with related building science.

SGM-SF	*Discussion*
CG SECTION 13 VAPOR INTRUSION REQUIREMENTS	Additional requirements when mitigating chemical vapor intrusion.
13.1 Qualified Professionals and Teams	**For Mitigation professionals—**Informational descriptions are provided for understanding interactions between parties that are more complicated than relationships with a single family. Persons qualified in varied disciplines with different skill sets are usually needed to accomplish reductions in occupant exposures to hazardous chemical vapors, gases and other substances. **For Commissioning teams—**It is recommended to engage a Qualified Soil Gas Professional at the onset of mitigation discussions.
13.2 Assemble Site Information 13.2.1 *Handling and control of hazardous substances and conditions*	**Advisory Example 1—**Details associated with evaluating and designing effective ground water control are beyond the scope of this document. A qualified and experienced ground water control specialist should be contracted or consulted when ground water control is needed. Evaluations of this condition normally include review of structural and exterior components that might have failed or are ineffective for ground water control. When grading and roof downspouts do not flow rainwater away from a building, the tremendous weight of water collecting in the soil will drive water below grade to forcefully intrude into a structure. **For Mitigation professionals and Commissioning teams—**It is very important to identify limits on the scope of work as described in SGM-SF Sections 4.2.2 d and and 4.2.2 f.
	Advisory Example 2—Approved processes for handling and disposing of contaminated soil are beyond the scope of SGM-SF.
	Advisory Example 3—Approved processes and designs associated with federal, state or local requirements when exhausting potent vapor concentrations are beyond the scope of SGM-SF.
	Advisory Example 4—Complete details for system design for mitigating the hazards of flammable gas are beyond the scope of SGM-SF.
Responses shall be sought	**Advisory—**Responsibility is inherently owned by the mitigation professional for safe practices during work.
13.2.2 *Existing Measurements*	**Advisory—**Not all indoor air VI measurements are conducted under closed-building conditions. Existing measurements need to be evaluated to optimize system design and worker health protection.
13.3 Building Investigations and Systems Design	**Advisory—**Pressure field extension (PFE) analysis is required and includes that test ports be provided for future verification of PFE. Advisory—Durability of pipe joint configurations is important to prevent condensed chemical compounds from escaping the pipe within a home.
13.4.2 *Non-habitable air spaces*	**Advisory—**Ventilation can be found justifiable but an evaluation of impacts to other portions of the building is important. See Annex A.

13.4.3 *Pipe material* 13.4.4 *Exhaust*	Greater care is needed to help prevent water from escaping the piping. With potent concentrations, it is sometimes prudent that exhaust locations be further away from ventilation openings and people than minimally required in SGM-SF. Filtration of exhaust can even be needed.
13.4.5 *Additional ASD fan requirements*	**Advisory—**Fan choices and spark resistance features must comply with the National Electric Code (NEC) for hazardous locations such as where flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. **Health Advisory—**It is extremely important to limit the concentration of chemicals in the airstream of an Active Soil Depressurization to well below the **Lower Explosion Limit (LEL)** for that gas. Failure to maintain gas concentrations below 10% of LEL could result in a fire, explosion and serious injury.

Tables 13.4.5

Examples of Explosion Proof Fan Classifications

Class	***Definitions***
Class I	Locations: Are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.
Class II	Locations: Are those which are hazardous due to the presence of combustible dust.
Class III	Locations: Are those which are hazardous due to the presence of easily ignitable fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities to produce ignitable mixtures.
Division	
Division I	Locations in which hazardous concentrations in the air exist continuously, intermittently, or periodically under normal operating conditions.
Division II	Locations in which hazardous concentrations are handled, processed, or used but are normally within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown.
Group (Class I)	
Group A	Atmospheres containing acetylene.
Group B	Atmospheres containing hydrogen, or gases (or vapors) of equivalent hazard, such as manufactured gas.
Group C	Atmospheres containing ethyl-ether vapors, ethylene or cyclo propane.
Group D	Atmospheres containing gasoline, hexane, naptha, benzine, butane, alcohol, acetone, benzol, lacquer solvent vapors, or natural gas.
Group (Class II)	
Group E	Atmospheres containing metal dust, including aluminum, magnesium and their commercial alloys and other metals of similarly hazardous characteristics.
Group F	Atmospheres containing carbon black, coal, or coke dust.
Group G	Atmospheres containing flour, starch, or grain dust.

The next pages provide Lower Explosion Limits (LEL) for certain common chemicals

Flammable / Combustible / Explosive Gases and Vapors

A reference for Lower Explosion Limits (LEL) for certain common chemicals

A reference chart of Lower Explosion Limits (LEL) Gases and Vapors	LEL in % by volume of air	NFPA Class	Flash point
Acetaldehyde	4.0	IA	-39°C
Acetic acid (glacial)	4	II	39°C to 43°C
Acetic anhydride		II	54°C
Acetone	2.6-3	IB	-17°C
Acetonitrile		IB	2°C
Acetyl chloride	7.3	IB	5°C
Acetylene	2.5		-18°C
Acrolein	2.8	IB	-26°C
Acrylonitrile	3.0	IB	0°C
Allyl chloride	2.9	IB	-32 °C
Ammonia	15	IIIB	11°C
Arsine	4.5 – 5.1	IA	Flammable gas
Benzene	1.2	IB	-11°C
1,3-Butadiene	2.0	IA	-85°C
Butane, n-Butane	1.6	IA	-60°C
n-Butyl acetate, Butyl acetate	1 – 1.7	IB	24°C
Butyl alcohol, Butanol	1	IC	29°C
n-Butanol	1.4	IC	35°C
n-Butyl chloride, 1-chlorobutane	1.8	IB	-6°C
n-Butyl mercaptan	1.4	IB	2°C
Butyl methyl ketone, 2-Hexanone	1	IC	25°C
Butylene, 1-Butylene, 1-Butene	1.98	IA	-80°C
Carbon disulfide	1.0	IB	-30°C
Carbon Monoxide	12	IA	-191°C Flammable gas
Chlorine monoxide		IA	Flammable gas
1-Chloro-1,1-difluoroethane	6.2	IA	-65°C Flammable Gas
Cyanogen	6.0 – 6.6	IA	Flammable gas
Cyclobutane	1.8	IA	- 63.9° C [11]
Cyclohexane	1.3	IB	-18°C - - 20°C
Cyclohexanol	1	IIIA	68°C

A reference chart of Lower Explosion Limits (LEL) Gases and Vapors	LEL in % by volume of air	NFPA Class	Flash point
Cyclohexanone	1 – 1.1	II	43.9 – 44°C
Cyclopentane	1.5 – 2	IB	- 37 to - 38.9°C
Cyclopropane	2.4	IA	-94.4°C
Decane	0.8	II	46.1°C
Diborane	0.8	IA	-90°C Flammable gas
o-Dichlorobenzene, 1,2-Dichlorobenzene	2	IIIA	65°C
1,1-Dichloroethane	6	IB	14°C
1,2-Dichloroethane	6	IB	13°C
1,1-Dichloroethene	6.5	IA	-10°C Flammable gas
Dichlorofluoromethane			Non flammable, -36.1°C
Dichloromethane, Methylene chloride	16		Non flammable
Dichlorosilane	4 – 4.7	IA	-28 °C
Diesel fuel	0.6	IIIA	>62°C (143°F)
Diethanolamine	2	IB	169°C
Diethylamine	1.8	IB	-23°C to – 26°C
Diethyl disulfide	1.2	II	38.9°C
Diethyl ether	1.9 – 2	IA	-45°C
Diethyl sulfide		IB	-10°C
1,1-Difluoroethane	3.7	IA	-81.1°C
1,1-Difluoroethylene	5.5		-126.1°C
Diisobutyl ketone	1		49°C
Diisopropyl ether	1	IB	-28°C
Dimethylamine	2.8	IA	Flammable gas
1,1-Dimethyl hydrazine		IB	
Dimethyl sulfide		IA	-49°C
Dimethyl sulfoxide	2.6 – 3	IIIB	88 – 95°C
1,4-Dioxane	2	IB	12°C
Epichlorohydrin	4		31°C
Ethane	3	IA	-135 °C Flammable gas

A reference chart of Lower Explosion Limits (LEL) Gases and Vapors	LEL in % by volume of air	NFPA Class	Flash point
Ethanol, Ethyl Alcohol	3 – 3.3	IB	12.8°C (55°F)
2-Ethoxyethanol	3		43°C
2-Ethoxyethyl acetate	2		56°C
Ethyl acetate	2	IA	-4°C
Ethylamine	3.5	IA	-17 °C
Ethylbenzene	1.0		15-20 °C
Ethylene	2.7	IA	
Ethylene glycol	3		111°C
Ethylene oxide	3	IA	−20 °C
Ethyl Chloride	3.8	IA	−50°C
Ethyl Mercaptan		IA	
Fuel oil No.1	0.7		
Furan	2	IA	-36°C
Gasoline (100 Octane)	1.4	IB	< −40°C (−40°F)
Glycerol	3		199°C
Heptane, n-Heptane	1.05		-4°C
Hexane, n-Hexane	1.1		-22°C
Hydrogen, dihydrogen, molecular H with two protons together	4	IA	Flammable gas
Hydrogen sulfide	4.3	IA	Flammable gas
Isobutane	1.8	IA	Flammable gas
Isobutyl alcohol	2		28°C
Isophorone	1		84°C
Isopropyl alcohol, Isopropanol	2	IB	12°C
Isopropyl chloride		IA	
Kerosene Jet A-1	0.6 – 0.7	II	>38°C (100°F) as jet fuel
Lithium Hydride		IA	
2-Mercaptoethanol		IIIA	
Methane (Natural Gas)	4.4 – 5	IA	Flammable gas
Methyl acetate	3		-10°C
Methyl Alcohol, Methanol	6 – 6.7	IB	11°C
Methylamine		IA	8°C
Methyl Chloride	10.7	IA	-46 °C
Methyl ether		IA	−41 °C
Methyl ethyl ether		IA	
Methyl ethyl ketone	1.8	IB	-6°C
Methyl formate		IA	

A reference chart of Lower Explosion Limits (LEL) Gases and Vapors	LEL in % by volume of air	NFPA Class	Flash point
Methyl mercaptan	3.9	IA	-53°C
Methyl-t-Butyl Ether (MTBE)	1.6	IB	-10°C
Morpholine	1.8	IC	31 – 37.7°C
Naphthalene	0.9	IIIA	79 – 87 °C
Neohexane	1.19		−29 °C
Nickel tetracarbonyl	2		4 °C
Nitrobenzene	2	IIIA	88°C
Nitromethane	7.3		35°C
Octane	1		13°C
iso-Octane	0.79		
Pentane	1.5	IA	-40 to -49°C
n-Pentane	1.4	IA	
iso-Pentane	1.32	IA	
Perchloroethylene (PERC)	13		none
Phosphine		IA	
Propane	2.1	IA	Flammable gas
Propyl acetate	2		13°C
Propylene	2.0	IA	-108°C
Propylene Oxide	2.3	IA	
Pyridine	2		20
Silane	1.5	IA	
Styrene	1.1	IB	31 – 32.2°C
Tetrachloroethene (PCE)			none
Tetrafluoroethylene		IA	
Tetrahydrofuran	2	IB	-14°C
Toluene	1.2-1.27	IB	4.4°C
Trichloroethene (TCE)	6		none
Triethylborane			-20°C
Trimethylamine		IA	Flammable gas
Trinitrobenzene		IA	
Turpentine	0.8	IC	35°C
Vegetable oil		IIIB	327°C
Vinyl acetate	2.6		−8 °C
Vinyl chloride	3.6		
Xylenes	0.9 – 1.0	IC	27 – 32°C
m-Xylene	1.1	IC	25°C
o-Xylene		IC	17 °C
p-Xylene	1.0	IC	27.2°C

SGM-SF	*Discussion*
13.4.6 *Sealant materials* 13.4.7 *Soil gas retarder materials*	Considerations are required regarding chemicals of concern in sealant curing compounds and soil gas retarders that resist degradation.
11.5.8 *System monitors* 13.4.9 *Labeling*	**Advisory—**Enhanced fan monitor choices can sometimes be warranted and labels require for appropriate verbiage.
13.5.1.3 Post-Mitigation Functional Inspection	For discussion of PFE adequacy, see CG 5.5.1).
13.5.1.4 Initial Post-Mitigation Testing (chemicals of concern)	The Soil Gas Mitigation Professional is not obligated to ensure post-mitigation testing and other monitoring events are conducted.
13.6 Rapid Response Situations	**Advisory—**There are limits on temporary solutions.
13.7 DOCUMENTATION REQUIRED FOR CHEMICAL VAPOR INTRUSION 13.7.1 Occupant Information 13.7.1.1: Client Operations Manual Table 13.7: Operation & Maintenance	Section13.7 spells out detailed documentation required to be provided by the soil gas mitigation professional. Final editing and packaging is often a joint effort with members of the overseeing team.

SGM-SF	*Discussion*
CG INFORMATIVE APPENDIX A CHEMICAL VAPOR INTRUSION **A-1 Understanding of General Chemical Exposure Concerns**	Section A-1 introduces basic concepts that are important to understand when mitigating chemical vapor intrusion.
A-2.1 *Roles and responsibilities* A-2.2 *Mitigator Commissioning Needs* A-2.3 *Communication Plan*	**A-2.1 For Commissioning teams—**Information is provided regarding needs of the mitigator during commissioning that also include appropriate establishment for lines of communication.

Table A-2.1 Example Commissioning Structure for Team Interactions

Activity	Deliverable	
Initiate Project - Commissioning Process *This event is a decision of property owner(s) in coordination with health departments and/or the commissioning team.*	**Document Roles and Responsibilities** *Owner and overseeing parties.* *The need for a Qualified Soil Gas Mitigation Professional should be identified at this time.*	Commissioning Team
↓	↓	
Decide Project Requirements *Normally includes short-term and long-term health protection and, if applicable, site cleanup.*	**Document Owner's Project Requirements** *All goals and specific details*	
↓	↓	
Develop Commissioning Process *General site plan*	**Document Commissioning Process** *Oversight process*	
↓	↓	
Set Contractor Requirements *As applied to staff and subcontractors*	**Document Specifications** *Minimum education, credentials, etc.*	Includes Qualified Soil Gas Mitigation Professional
↓	↓	
Design Approach to Requirements *Overseeing parties should include a Qualified Soil Gas Mitigation Professional during this phase.*	**Document Basis of Design** *Rationale*	
↓	↓	
Review Design to Requirements *Installation details compared to goals.*	**Design Review Report** *Conclusion of review*	
↓	↓	
Review Submittals *Overseers*	**Submittal Review Report** *Overseers*	
↓	↓	
Observe and Test *1) site assessment, 2) building diagnostics, and 3) post-installation test*	**Construction Checklists and Reports** *1) site assessment, 2) building diagnostics, and 3) post-installation test*	
↓	↓	
Resolve Issues *as needed*	**Issues and Resolution Log** *document as needed*	
↓	↓	
Assemble Systems Manual *OM&M Plan*	**Systems Manual** *Completed OM&M Plan*	
↓	↓	
Conduct Training *For long-term staff and OM&M personel*	**Training Plans and Records** *Document training and establish retention of logs*	Commissioning Team
↓	↓	
Postoccupancy Operation *First year or two testing to establish baseline for effectiveness.*	**End of Warranty Commissioning Report** *As established for each contractor and, if applicable, if decommissioning the installation.*	
↓	↓	
Assemble Commissioning Report *overseers*	Deliver Report *Overseers*	

Table A-2.2 Example Content Often Needed In Requests for Proposals (RFP)

1.0 RFP Universal Provisions:

1.1 Project Overview

1.1.1 Project Summary

1.1.2 Chemical Information – chemical of concern, sub-slab levels, IA levels, regulatory levels for site classification, mobile lab site characterization, toxicology standards, pathway and source identification

1.1.3 Quantifiable Goals and Objectives – What is the measure of success? (i.e. verified pressure differential, IA level reduction, specific mitigation area)

1.1.4 Project Schedule – specific deliverable dates for each phase of the project

1.1.5 Additional Information – bid schedule, site access, consultant POC, other concurrent remedial actions

1.1.6 Progress Reporting, Final Reporting – pilot testing, system design, system as-built, post-mitigation verification testing, photos, drawings, component specs sheets, MSDS info

1.1.7 Additional Project Requirements – onsite supervision, required meetings, risk communication, RP communication

1.1.8 Payment, Submittals – phase definition, budget deliverables (i.e. fixed price, performance contract), payment terms and conditions, schedule of values and mobilization

1.2 Contractor Requirements

1.2.1 Insurance – minimum requirements

1.2.2 Health and Safety – OSHA, HAZWOPER, health and safety program (to include hazardous communication program), site-specific health and safety program

1.2.3 Additional Contractor Requirements – responsible parties

1.3 Appendices

1.3.1 Sampling Data, Boring Logs

1.3.2 Previous Pilot Testing Data

1.3.3 Site Map, Drawings

2.0 RFP for Mitigation Design

2.1 All components of 1.0 (Universal Provisions)

2.2 Mitigation Standards, Regulatory Requirements – applicable ANSI standard, applicable regulatory requirements

2.3 Pilot Testing, Building Characterization–deliverables, such as PFE, vacuum and airflow testing, HVAC assessment

2.4 Power consumption analysis

2.5 Analog or digital controls, onsite or remote monitoring

3.0 RFP for Mitigation Installation

3.1 All components of 1.0 (Universal Provisions)

3.2 System Design Specs and Additional Specs – permitting, material characterization, soil testing and disposal specs, post-mitigation verification criteria, QC and startup procedures, decontamination and containment specs

3.3 Warranty – performance, system components, roof bonding, length of warranty

4.0 RFP for Operation and Maintenance

4.1 All components of 1.0 (Universal Provisions)

4.2 Highlighted or truncated logistical aspects for this work (e.g., inspection/maintenance frequency and deliverable dates)

4.3 System maintenance procedures (e.g., analog or digital controls, onsite or remote monitoring, PFE, system tuning)

4.4 Inspection reporting and maintenance logs

4.5 General Pricing Estimate Examples:

4.5.1	Mobilization (Crew Travel)	$ _____
4.5.2	Mobilization (Single staff member)	$ _____
4.5.3	Additional Suction Location (per)	$ _____
4.5.4	Vapor retarder materials	$ _____

SGM-SF	*Discussion*
Table A-3: Recommended Post-mitigation Monitoring Events For Chemical Vapor Intrusion **A-3:** **Monitoring Events and Stewardship** A-3.1 Monitoring events A-3.2 Initial post-mitigation testing A-3.3 Initial seasonal verification A-3.4 Ongoing stewardship A-3.5 Decommissioning Systems	**Appendix Table A-3** and subsequent guidance illustrates monitoring events that are in accordance with the consensus of the SGM-SF committee. Once baselines are established, ongoing monitoring and stewardship activities can be better defined.
A-3.3.3 **Discussion:** Surrogate testing methods, including radon gas	
Surrogate methods to monitor continued effectiveness of mitigation are commonly employed in lieu of an ardent regimen of indoor testing. PFE testing is the most common example. Indoor measurements of soil gases other than the chemical(s) of concern can also be an effective supplement. Radon is also well suited for evaluating continued reduction of soil gas entry. Testing for radon before and after mitigation can establish a baseline for surrogate correlation by comparing results with other indoor measurements. Naturally occurring radon is found everywhere on earth regardless of what survey maps might suggest. Initial indoor measurements as low as 2.5 pCi/L are common anywhere and can provide evidence for a difference between pre- and post-mitigation. Concentrations of 4 pCi/L or greater are even more helpful for estimating percentages of reduced soil gas entry and evidence of enhanced benefits to occupants.	
A-3.3.4 *Indoor air testing*	When possible, testing should be made under reproducible conditions.

Sample of closed-building protocols used in radon testing. These reflect CVI guidance at several state programs. (See ANSI/AARST *MAH*)

SAMPLE DOOR HANGER NOTICE

AIR TEST IN PROGRESS

Required closed-building conditions
(12 hours prior the test and during the test).

Keep closed	**Windows & Exterior doors** *(except for momentary use)*
Set to normal	**Heating & Cooling systems** *(kept between about 65˚ - 80˚ F)*
Operate normally	**Bathroom fans**
	Other ventilation units that are used in all seasons
Avoid excessive operation	**Exhaust systems** such as from laundries or for control of fumes from community kitchens
Outside air dampers closed	**Window air conditioners and unit ventilators**
Do not operate	**Window fans, whole building fans or other** systems that temporarily bring air into or out of the building for seasonal energy savings or comfort
	Fireplaces that burn solid, liquid or gas fuels, unless they are the primary sources of heat for the building

Sample of chemical product guidance drawn from state and national guidance that can also impact the reliability of CVI measurements.

SAMPLE DOOR HANGER NOTICE

AIR TEST IN PROGRESS

48-72 hours prior the test and during the test

Do not use	**Pesticides, glues, sealants, paints, thinners or varnishes**
	Cleaning compounds for bathrooms, appliances, furniture, floors and other all purpose cleaning products.
	Bleach, disinfectants, air fresheners or odor eliminators
	Cosmetics such as hair spray, nail polish remover, nail polish and perfume.
Do not	**Smoke in the house**
	Operate or store automobiles in an attached garage
	Store swimming pool products in the house or attached garage
	Store gasoline, oil, brake fluid, lubricants or solvents in the house or attached garage

For details see householdproducts.nlm.nih.gov

AARST CONSORTIUM On National Radon Standards

Approved American National Standard ANSI

SGM-SF 2017

Soil Gas Mitigation Standards for Existing Homes