Designation: E 2121 – 01

Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings[1]

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1. Scope

1.1 This practice describes methods for reducing radon entry into existing attached and detached residential buildings three stories or less in height. This practice is intended for use by trained, certified or licenced, or both, or otherwise qualified individuals.

1.2 These methods are based on radon mitigation techniques that have been effective in reducing radon levels in a wide range of residential buildings and soil conditions. These fan powered mitigation methods are listed in Appendix X1. More detailed information is contained in references cited throughout this practice.

1.3 This practice is intended to provide radon mitigation contractors with a uniform set of practices that will ensure a high degree of safety and the likelihood of success in retrofitting low rise residential buildings with radon mitigation systems.

1.4 The methods described in this practice apply to currently occupied or formerly occupied residential buildings, including buildings converted or being converted to residential use, as well as, residential buildings changed or being changed by addition(s), or alteration(s), or both. The radon reduction activities performed on new dwellings, while under construction, before occupancy, and for up to one year after occupancy, are covered by Guide E 1465.

1.5 This practice also is intended as a model set of practices, which can be adopted or modified by state and local jurisdictions, to fulfill objectives of their specific radon contractor certification or licensure programs. Radon mitigation performed in accordance with this practice is considered ordinary repair.

1.6 The methods addressed in this practice include the following categories of contractor activity: general practices, building investigation, systems design, systems installation, materials, monitors and labeling, post-mitigation testing, and documentation.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 6 for specific safety hazards.

2. Referenced Documents

2.1 *ASTM Standards:*

E 631 Terminology of Building Constructions[2]

E 779 Test Method for Determining Air Leakage Rate by Fan Pressurization[2]

E 1465 Guide for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings[2]

E 1745 Specification for Plastic Water Vapor Retarders Used in Contact With Soil or Granular Fill Under Concrete Slabs[2]

E 1998 Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances[2]

2.2 *Government Publications:*

EPA “A Citizen’s Guide to Radon (Second Edition),” EPA 402-K92-001, May 1992[3]

EPA “Consumer’s Guide to Radon Reduction,” EPA 402-K92-003, August, 1992[3]

EPA “Home Buyers and Sellers Guide,” EPA 402–K-00–008, July 2000[3]

EPA “Handbook, Sub-Slab Depressurization for Low-Permeability Fill Material,” EPA/625/6-91/029, July 1991[3]

EPA “Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Second Edition),” EPA/625/5–87/019, Revised January, 1988[3]

EPA “Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems,” EPA/625/R-93-011, October, 1993[3]

EPA “Radon Mitigation Standards,” EPA 402-R-93-078, April, 1994[2]

EPA “National Emission Standard for Asbestos,” 40 CFR 61, Subpart M

EPA “Asbestos School Hazard Abatement Reauthorization Act” regulation 40 CFR Part 763, Subpart E[3]

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventillation Performance.

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[2] *Annual Book of ASTM Standards*, Vol 04.11.

[3] Available from the U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

OSHA "Respiratory Protection Standard," 29 CFR 1920.134 (1998)[4]

OSHA "Safety and Health Regulations for Construction, Ionizing Radiation," 29 CFR 1926.53[4]

OSHA "Hazard Communication Standard for the Construction Industry," 29 CFR 1926.59[4]

OSHA "Asbestos Standard for the Construction Industry" 29 CFR 1926.1102[4]

OSHA "Occupational Safety and Health Regulations, Ionizing Radiation," 29 CFR 1910.96[4]

NIOSH "Guide to Industrial Respiratory Protection," NIOSH Publication No. 87–116[5]

NCRP "Measurement of Radon and Radon Daughters in Air," NCRP Report No. 97, 1988[6]

2.3 *ANSI/ASHRAE Standards:*

ANSI/ASHRAE Standard 62–1989, Ventillation for Acceptable Indoor Air Quality[7]

ANSI/ASHRAE Standard 62–1989, Ventillation for Acceptable Indoor Air Quality, Appendix B, Positive Combustion Air Supply[7]

3. Terminology

3.1 *Definitions*—Definitions of terms used in this practice are defined in accordance with Terminology E 631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *active soil depressurization (ASD)*, *n*—a family of radon mitigation systems involving mechanically-driven soil depressurization, including sub-slab depressurization (SSD), sump pit depressurization (SPD), drain tile depressurization (DTD), hollow block wall depressurization (BWD), and sub-membrane depressurization (SMD) (see Appendix X2).

3.2.2 *backdrafting*, *n*—a condition where the normal movement of combustion products up a flue (due to the buoyancy of the hot flue gases), is reversed, so that the combustion products enter the building (see *pressure-induced spillage*).

3.2.3 *communication test*, *n*—a diagnostic test to evaluate the potential effectiveness of a sub-slab depressurization system by applying a vacuum beneath the slab and measuring, either with a micromanometer or with a heatless smoke device, the extension of the vacuum field. Also called *pressure-field extension test.*

3.2.4 *contractor*, *n*—for the purposes of this practice, a contractor is one who contracts to performs radon reduction activities or is an employee of one who contracts to perform or performs radon reduction activities, with the expectation that payment will be received for the work performed. A person who does radon reduction activities as an employee of a building owner is also a contractor for purposes of this standard practice. Persons whose normal activity is not radon reduction, but who do work related to radon reduction like indoor air quality consultants, radon consultants, plumbers, building contractors, or employees of these persons are all viewed as contractors when performing radon reduction activities covered by this practice.

3.2.5 *crawlspace depressurization (CSD) (active)*, *n*—a radon mitigation technique designed to achieve lower air pressure in the crawlspace than in the rooms bordering and above the crawlspace. A radon fan, draws air from the crawl space and exhausts that air outside the building. Crawlspace depressurization is intended to mitigate rooms bordering and above the crawlspace but not the crawlspace itself. All CSD systems, for purposes of this practice, are active.

3.2.6 *depressurization*, *n*—a negative pressure induced in one area relative to another.

3.2.7 *diagnostic tests*, *n*—procedures used to identify or characterize conditions under, beside and within buildings that may contribute to radon entry or elevated radon levels or that may provide information regarding the performance of a mitigation system.

3.2.8 *drain tile depressurization (DTD) (active)*, *n*—a type of active soil depressurization radon mitigation system where the suction point piping attaches to a drain tile or is located in gas-permeable material near the drain tile. The drain tile or perimeter drain may be inside or outside the footings of the building.

3.2.9 *hollow wall depressurization (BWD) (active)*, *n*—a radon mitigation technique that depressurizes the void space within a foundation wall (usually a block wall). A radon fan installed in the radon system piping draws air from within the wall.

3.2.10 *manifold piping*, *n*—this piping collects the flow of soil-gas from two or more suction points and delivers that collected soil-gas to the vent stack piping. In the case of a single suction point system, there would be no manifold piping since suction point piping would connect directly to vent stack piping. The manifold piping starts where it connects to the suction points and ends where it connects to the vent stack piping.

3.2.11 *mechanically-ventilated crawlspace system*, *n*—a radon-control technique designed to increase ventilation within a crawlspace by use of a fan.

3.2.12 *mitigation system*, *n*—any system or steps designed to reduce radon concentrations in the indoor air of a building.

3.2.13 *natural draft combustion appliance*, *n*—any fuel burning appliance that relies on natural convective flow to exhaust combustion products through flues to outside air.

3.2.14 *occupiable spaces*, *n*—for purposes of this practice, are areas of buildings where humans beings spend or could spend time, on a regular or occasional basis.

3.2.14.1 *Discussion*—Examples of occupiable spaces are those that are or could be used for sleeping, a work shop, a hobby, reading, student home work, a home office, entertainment (TV, music, computer, etc.), physical work-out, laundry, games, or child's play.

3.2.15 *pressure-field extension*, *n*—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

[4] Available from the U. S. Department of Labor, Occupational Safety and Health Administration, Office of Public Affairs, Room N3647, 200 Constitution Avenue, Washington, DC 20210.

[5] Available from the National Institute for Occupational Safety and Health, 200 Independence Avenue, SW, Room 715H, Washington, DC 20201.

[6] Available from the National Commission on Radiation Protection and Measurement, 7910 Woodmont Avenue, Suite 800, Bethesda, MD 20814.

[7] Available from the American Society of Heating, Refrigerating, and Air Conditioning Engineers, 1791 Tullie Circle, N.E., Atlanta, GA 30329.

a membrane, behind a solid wall, or in a hollow wall (see *communication test*).

3.2.16 *pressure-induced spillage*, *n*—the unintended flow of combustion gases from an appliance/venting system into a dwelling, primarily as a result of building depressurization (see *backdrafting*).

3.2.17 *radon system piping*, *n*—this active or passive soil depressurization piping is composed of three parts: suction point piping, manifold piping, and vent stack piping.

3.2.18 *re-entrainment*, *n*—the unintended re-entry of radon into a building from leaks in the radon system piping, from leaks in the fan housing, or from the discharge of the vent stack piping.

3.2.19 *soil-gas*, *n*—the gas mixture present in soil, which may contain radon.

3.2.20 *soil-gas-retarder*, *n*—a continuous membrane or other comparable material used to retard the flow of soil gases into a building. See Specification E 1745 for permeance and durability of water vapor retarders that may be used as soil-gas-retarders.

3.2.21 *submembrane depressurization (active)*, *n*—a radon mitigation technique designed to achieve lower air pressure under a soil-gas-retarder membrane than above it. For example, a soil-gas-retarder membrane could be used to cover the soil found on a crawlspace floor. A radon fan installed in the radon system piping draws air from below the soil-gas-retarder membrane.

3.2.22 *sub-slab depressurization (active)*, *n*—a radon mitigation technique designed to achieve lower air pressure under a floor slab than above it. A radon fan installed in the radon system piping draws soil-gas from below the floor slab.

3.2.23 *sub-slab depressurization (passive)*, *n*—a radon mitigation technique designed to achieve lower air pressure under a floor slab than above it. The radon system piping is routed through the conditioned (heated and cooled) space of a building.

3.2.24 *suction point piping*, *n*—one end of this piping penetrates the slab, the solid wall, the hollow wall, the membrane, the sump cover, or the drain tile. The other end extends outward to the first accessible pipe connection beyond the penetration of the soil-gas barrier.

3.2.25 *sump pit depressurization (SPD) (active)*, *n*—a type of active soil depressurization radon mitigation system where the suction point piping enters the sump pit, that has a sealed gasketed cover, through the side or through the cover.

3.2.26 *vent stack piping*, *n*—this piping collects the soil-gas from the suction point or from the manifold piping of multi-suction point systems. There are no branches in vent stack piping; soil-gas is collected at one end of the vent stack piping and discharges from the building at the other end. In active soil depressurization systems, the radon fan is installed in the vent stack piping.

3.2.27 *ventilation*, *n*—the process of introducing outdoor air into a building.

3.2.28 *working level (WL)*, *n*—a unit of radon decay product exposure. Numerically, any combination of short-lived radon decay products in one litre of air that will result in the ultimate emission of 130 000 MeV of potential alpha energy. This number was chosen because it is approximately the total alpha energy released from the short lived decay products in equilibrium with 100 pCi of Rn-222.

3.2.29 *working level month (WLM)*, *n*—a unit of exposure used to express the integrated human exposure to radon decay products. It is calculated by multiplying the average working level to which a person has been exposed by the number of hours exposed and dividing the product by 170.

4. Summary of Practice

4.1 This practice describes methods for mitigating elevated levels of radon in existing attached and detached residential buildings three stories or less in height.

4.2 The mitigation process is described in terms of the categories of activity associated with radon mitigation and includes: general practices, building investigation, systems design, systems installation, materials, monitors and labeling, post-mitigation testing, and contracts and documentation.

4.3 The systems installation category contains subsections describing the specific requirements applicable to each of the components of radon mitigation systems, for example, radon system piping, radon fans, sealing, electrical, etc.

5. Significance and Use

5.1 The purpose of the methods, systems, and designs described is this practice is to reduce radiation exposures for occupants of residential buildings caused by radon and its progeny. The goal of mitigation is to maintain reduced radon concentrations in occupiable areas of buildings at levels as low as reasonably achievable. This practice includes sections on reducing radiation exposure caused by radon and its progeny for workers who install and repair radon mitigation systems. The goal for workers is to reduce exposures to radon and its progeny to levels as low as reasonably achievable.

5.2 The methods, systems, designs, and materials described here have been shown to have a high probability of success in mitigating radon in attached and detached residential buildings, three stories or less in height (see EPA, "Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems"). Application of these methods does not, however, guarantee reduction of radon levels below any specific level, since performance will vary with site conditions, construction characteristics, weather, and building operation.

5.3 When applying this practice, contractors also shall conform to all applicable local, state, and federal regulations, and laws pertaining to residential building construction, remodeling, and improvement.

6. Safety Hazards

6.1 Contractors shall comply with all OSHA, state and local standards or regulations relating to worker safety and occupational radon exposure. Applicable references in the Code of Federal Regulations include those in 2.2. Contractors also shall follow occupational radon guidance in 2.2.

6.2 In addition to OSHA standards and NIOSH recommendations, the following requirements specifically applicable to the safety and protection of radon mitigation workers shall be met:

6.2.1 The contractor shall advise workers of the hazards of exposure to radon and the importance of protective measures when working in areas of elevated radon concentrations. In addition, the contractor shall advise employees of other potential hazards according to the hazard communication standard for the construction industry (see OSHA, "Hazard Communication Standard for the Construction Industry").

6.2.2 The contractor shall ensure that appropriate safety equipment, such as ventilators, respirators, hard hats, face shields, and ear plugs, are available on the job site during mitigation activities.

6.2.3 Work areas shall be ventilated to reduce worker exposure to radon, dust, or other airborne pollutants.

6.2.4 Consistent with OSHA permissible exposure limits, contractors shall ensure that employees are exposed to no more than four working level months (WLM) over a 12-month period (or the equivalent 68 000 pCi/L-h, when converted at an equilibrium ratio of 100 %. A WLM is calculated by multiplying the average working level to which a person has been exposed by the number of hours exposed and dividing the product by 170 h.

6.2.5 Contractors shall maintain records of employee exposure to radon sufficient to verify that field employees are exposed to less than 4 WLM in any 12-month period.

6.2.6 Where ventilation cannot reduce radon levels to less than 0.3 WL, contractors shall provide the respiratory protection that is required to comply with 6.2.4. When unable to make working level measurements, a radon concentration of 30 pCi/1 (1,100 Bq/m^3) shall be used in lieu of 0.3 WL. The contractor should provide respiratory protection that conforms with NIOSH "Guide to Industrial Respiratory Protection," and the OSHA "Respiratory Protection Standard," which covers fit tests for employees and other items related to respirators.

6.2.7 Radon mitigation work shall not be conducted in any work area suspected of containing friable asbestos material, or where work would render non-friable asbestos material friable, until a determination has been made by a properly trained or certified person that such work will be undertaken in a manner which complies with applicable asbestos regulations, including those of EPA and OSHA (see 2.2).

6.2.8 Contractors shall advise employees of the potential hazards, of the materials and supplies used, and provide applicable material safety data sheets (MSDS).

7. Standard Practices for Radon Mitigation

7.1 *General Practices*:

7.1.1 Radon mitigation systems shall be designed and installed to conform to applicable building codes and maintain the function and operation of all existing equipment and building features, for example, doors, windows, access panels, etc.).

7.1.2 Prior to starting work, the contractor shall inform the client of the nature of work to be done, the anticipated use of any potentially hazardous solvents or other materials, and the need to ventilate work areas during and after the use of such materials as recommended by the manufacturer of the material.

7.1.3 Prior to installing a radon mitigation system, a visual inspection of the building should be conducted to evaluate characteristics of the building which might affect radon mitigation system performance.

7.1.4 If a contractor has concerns about backdrafting potential at a particular site, the contractor should recommend that a qualified person inspect the natural draft combustion appliances and venting systems for compliance with local codes and regulations. The contractor should recommend that the building owner bring any combustion appliance or venting system, found to be noncomplying, into compliance.

7.2 *Systems Design*:

7.2.1 All radon mitigation systems shall be designed and installed as permanent, integral additions to the building.

7.2.2 All radon mitigation systems shall be designed and installed to avoid the creation of other health, safety, or environmental hazards to building occupants, such as backdrafting/spillage, of natural draft combustion appliances, constricting or blocking building exits with pipe runs, or degradation of fire rated assemblies with pipe, or cabling penetrations, or both.

7.2.3 Radon mitigation system design is not limited to safety, radon reduction effectiveness, and compliance with building codes and regulations. Radon reduction system design also is concerned with installation costs, operating costs, energy usage, durability, reliability, maintainability, physical comfort for occupants and quietness for occupants and neighbors, as well as impact on interior and exterior building appearance.

7.3 *System Installation*:

7.3.1 *General Requirements*:

7.3.1.1 All components of radon mitigation systems designed and installed in compliance with provisions of this practice also shall be in compliance with the applicable mechanical, electrical, building, plumbing, energy and fire prevention codes, standards, and regulations of the local jurisdiction.

7.3.1.2 When portions of structural framing members must be removed to accommodate radon system components, the amount of the member removed shall be no greater than that permitted for plumbing installations by applicable building or plumbing codes.

7.3.2 *Radon System Piping Installation Requirements*:

7.3.2.1 *Radon System Pipe Size*—Also see Appendix X3. All vent stack piping shall be solid, rigid pipe not less than 3-in. (75-mm) inside diameter (ID). The vent stack piping's ID shall be at least as large as the largest used in the manifold piping. All manifold piping shall be rigid pipe not less than 3-in. (75-mm) inside diameter (ID). The manifold piping's ID shall be at least as large as that used in any suction point. Manifold piping to which two or more suction points are connected shall be at least 4 in. (100 mm) ID. When installing manifold pipes to which three or more suction points need to be installed, the contractor may benefit from guidance in an industrial ventilation manual. All suction point piping shall be rigid pipe not less than 3-in. (75-mm) inside diameter. Not withstanding the minimum radon system piping diameters specified herein, alternate pipe sizes may be used when sufficiently justified by field diagnostic measurements, including static pressure, air velocity, and rate of air flow measurements, and documented using the methodologies found in

"Industrial Ventilation: A Manual of Standard Practice, 23rd Edition,"[8] or its equivalent. When alternate pipe sizes and shapes are used, a statement of justification, including justification methodology, calculations employed, and all site specific field data collected shall be prepared. A copy of the justification shall become part of the system documentation and shall be provided to the building owner.

7.3.2.2 All pipe joints and connections in radon mitigation systems, both interior and exterior, shall be sealed permanently. Exceptions include installation of radon fans (see 7.3.3.6) and sump covers (see 7.3.2.8).

7.3.2.3 Radon system piping installed in the interior or on the exterior of a building, should be insulated where condensation on the pipe's exterior may drip onto and damage ceilings and floors, etc., and where water vapor, from the soil, may condense inside the pipe, and then freeze partially or fully blocking the soil-gas exhaust.

7.3.2.4 Radon system piping shall be fastened to the structure of the building with hangers, strapping, or other supports that will secure it adequately. Radon system piping shall not be attached to or supported by existing pipes, ducts, conduits, or any kind of equipment. Radon system piping shall not block window and doors or access to installed equipment.

7.3.2.5 Supports for radon system piping should be installed at least every 6 ft (2 m) on horizontal runs. Vertical runs shall be secured either above or below the points of penetration through floors, ceilings, and roofs, or at least every 8 ft (2.5 m) on runs that do not penetrate floors, ceilings, or roofs.

7.3.2.6 To prevent blockage of air flow into the bottom of suction point pipes, they shall be supported and secured in a permanent manner that prevents their downward movement to the bottom of suction pits or sump pits, or into the soil beneath a soil-gas-retarder membrane. For guidance on submembrane piping, see 7.3.8.3.

7.3.2.7 Horizontal runs in radon system piping shall be sloped to ensure that water from rain or condensation drains downward into the ground beneath the slab or soil-gas-retarder membrane.

7.3.2.8 If suction point pipes are installed to draw soil gas from sump pits, the system shall be designed to facilitate removal of the sump pit cover for sump pump maintenance.

7.3.2.9 To reduce the risk of vent stack blockage due to heavy snow fall, to reduce the potential for re-entrainment of radon into the living spaces of a building, and to prevent direct exposure of individuals outside of buildings to high levels of radon, the discharge from vent stack pipes of active soil depressurization systems shall meet the following minimum requirements. They shall be:

(1) Vertical and upward, outside the structure, at least 10 ft (3 m) above the ground level, above the edge of the roof, and shall also meet the separation requirements of (*2*) and (*3*). Whenever practicable, they shall be above the highest roof of the building and above the highest ridge.

(2) Ten feet (3 m) or more away from any window, door, or other opening into conditioned or otherwise occupiable spaces of the structure, if the radon discharge point is not at least 2 ft (0.6 m) above the top of such openings.

(3) Ten feet (3 m) or more away from any opening into the conditioned or other occupiable spaces of an adjacent building. Chimney flues shall be considered openings into conditioned or otherwise occupiable space.

(4) For vent stack pipes that penetrate the roof, the point of discharge shall be at least 12 in. (0.3 m) above the surface of the roof. For vent stack pipes attached to or penetrating the sides of buildings, the point of discharge shall be vertical and a minimum of 6 in. (150 mm) above the edge of the roof and in such a position that it can neither be covered with snow, or other materials nor be filled with water from the roof or an overflowing gutter. In areas where it snows the point of discharge shall be 12 in. (0.3 m) above the surface of the roof.

(5) When a horizontal run of vent stack pipe penetrates the gable end walls, the piping outside the structure shall be routed to a vertical position so that the discharge point meets the requirements of (*1*), (*2*), (*3*), and (*4*).

(6) Points of discharge that are not in a direct line of sight from openings into conditioned or otherwise occupiable space because of intervening objects, such as dormers, chimneys, windows around the corner, etc. shall meet the separation requirements of (*1*), (*2*), (*3*), (*4*) and (*5*).

NOTE 1—Measurements from the point of discharge to openings into the conditioned or otherwise occupiable spaces of the structure shall be made from the point of discharge to the closest part of any opening into such space. For example, to determine compliance with 7.3.2.9, when the location of a planned vent stack discharge can not be seen from a dormer window, the contractor would determine whether the required separation existed by routing a flexible measuring tape between the planned discharge point location and the part of the dormer window that is the shortest distance away. The measuring tape must follow the shortest possible path, and be allowed to bend where it passes intervening part(s) of the dormer.

7.3.3 *Radon Fan Installation Requirements*:

7.3.3.1 Radon fans shall be sized to provide the pressure difference and air flow characteristics necessary to achieve the radon reduction goals established for the specific mitigation project. Guidelines for sizing radon fans and piping can be found in "Industrial Ventilation: A Manual of Standard Practice, 23rd Edition,"[8] and in Appendix X3.

7.3.3.2 Radon fans used in active soil depressurization (ASD) radon mitigation systems shall be installed either outside the building, or inside the building, outside of occupiable space and above the conditioned (heated/cooled) spaces of a building. Radon fan location is chosen to minimize the risk of radon entry into living spaces which could result from leaks in radon fan housings or in the vent stack piping above the radon fan. Preferred locations include places on the exterior of the building, unconditioned house and garage attics not suitable for occupancy, and other unconditioned house and garage locations not suitable for occupancy, which have no occupiable or conditioned spaces above them.

7.3.3.3 Radon fans shall be installed in a configuration that avoids condensation buildup in the radon fan housing.

7.3.3.4 Radon fans mounted on the exterior of buildings shall be rated for outdoor use or installed in a weather proof protective housing.

[8] Available from American Conference of Industrial Hygienists, Inc., 1330 Kemper Meadow Dr., Suite 600, Cincinnati, OH 45240.

7.3.3.5 Radon fans shall be mounted and secured in a manner that minimizes transfer of vibration to the structural framing of the building.

7.3.3.6 To facilitate maintenance and future replacement, radon fans shall be installed in the vent pipe using removable couplings or flexible connections that can be tightly secured to both the radon fan and the vent pipe.

7.3.3.7 Outside air intake vents of fan powered systems shall be screened to prevent the intake of debris. Screens shall be removable to permit cleaning or replacement and building owners shall be informed of the need to periodically replace or clean such screens.

7.3.4 *General Sealing Requirements*:

7.3.4.1 Openings around the suction point piping penetrations of the slab, accessible openings around utility penetrations of the foundation walls and slab, and other openings in slabs cast over gas permeable soils or aggregates, that reduce the pressure field extension, and the effectiveness of soil depressurization systems, shall be sealed, using methods and materials that are permanent and durable. For guidance on sump pits and sump pit covers see 7.3.6.1 and 7.3.6.2.

7.3.4.2 It is sometimes appropriate to seal openings and cracks that exist where the slab meets the foundation wall (floor-wall joint) with urethane caulk or equivalent material. When the opening is greater than ½ in. (13 mm) in width, a foam backer rod or other comparable filler material may be inserted in the opening before application of the sealant; other accessible cracks and openings found in slabs, walls, or around utility penetrations; or channel and french drains. See 7.3.13.3.

NOTE 2—Field experience has shown that sealing the floor-wall joint and small cracks in the slab of poured concrete foundation systems of sub-slab depressurization (SSD), sump pit depressurization (DPD), and drain tile depressurization (DTD) systems usually is not necessary when an active soil depressurization is employed. Sealing is desirable when significant below grade air leakage is occurring, or when the air flow into the gas permeable layer below the slab is creating objectionable noise. Failure to limit air flow into the depressurized soil of an active soil depressurization system may be a contributing factor to a backdraft condition. Submembrane depressurization (SMD) and block wall depressurization (BWD) systems, active or passive, and any passive radon reduction system requires more thorough sealing.

7.3.4.3 When installing baseboard-type suction systems, all seams and joints in the baseboard material shall be joined and sealed using materials recommended by the manufacturer of the baseboard system. Baseboards shall be sealed to walls and floors with adhesives also designed and recommended for such installations.

7.3.4.4 Utility and other penetrations through a soil-gas-retarder membrane shall be sealed.

7.3.5 *Active Sub-Slab Depressurization (SSD) Requirements*:

7.3.5.1 To enhance pressure field extension, when the sub-slab material exhibits poor gas-permeability, it is helpful to excavate as much as 1 ft^3 (28 L) of sub-slab material below and around each suction point pipe. Even when the sub-slab material is highly permeable, like crushed stone, the end of the suction point pipe should have an excavated hole, at least one pipe diameter deep, directly below it.

7.3.6 *Sump Pit Requirements*:

7.3.6.1 Sump pits or other large openings in slabs or basement walls that allow a significant amount of soil gas leakage into the basement or air leakage into the sub-floor areas should be covered and sealed (see 7.4.7 and 7.4.8 for details on sump covers and sealing materials).

7.3.6.2 When a radon mitigation system is designed to draw soil-gas from a sump pit, a sump cover shall be installed as described in 7.3.13.4, 7.4.7, and 7.4.8.

7.3.7 *Drain Tile Depressurization (DTD) Requirements*:

7.3.7.1 Whenever a DTD radon mitigation system that is intended to depressurize a sub-slab area by drawing soil-gas from a perimeter drain tile loop (internal or external) is installed, all drain lines extending from the drain tile loop to daylight shall have a one-way flow valve, a water trap, or other control device installed to prevent outdoor air from entering the sub-slab area. The control device is intended to prevent air from entering the drain line but not prevent water from flowing out of the drain line.

7.3.8 *Submembrane Depressurization (SMD) Requirements*:

7.3.8.1 Any seams in soil-gas-retarder membranes (not covered by concrete slabs) used for submembrane depressurization systems, passive or active, shall be lapped at least 12 in. (300 mm). The membrane's seams shall be sealed. The membrane shall be sealed around posts and other penetrations. The membrane shall be sealed, at its edges, to the walls to the extent practical. When there are indications that water is likely to collect on the membrane, it shall be fitted with trapped drains at the lowest part of the locations that are likely to be wet.

7.3.8.2 Passive submembrane depressurization systems, which are installed while anticipating possible activation, shall meet all the requirements for an active submembrane depressurization (SMD) systems, but without the radon fan and monitor.

7.3.8.3 Active submembrane depressurization (SMD) systems may be noisy. The noise can be reduced by sealing the membrane (see 7.3.8.1) and the design of the submembrane suction point. Sealing reduces the amount of air leakage and its associated noise, and also improves the pressure field extension under the membrane. Submembrane suction point designs, that bury a special intake end of a suction point pipe in a deep bed of clean 1-in. (25-mm) aggregate, significantly reduce the noise associated with air entering the end of the suction point pipe. The special suction point pipe's intake end has eight or more horizontal or vertical slots, each being ½ in. (13 mm) wide, and cut into the lowest foot (0.3 m) of the suction point pipe. If the slots are horizontal, they go half way through the pipe.

7.3.9 *Hollow Block-Wall Depressurization (BWD) Requirements*:

7.3.9.1 When a hollow block wall depressurization (BWD) system is used to mitigate radon, openings in the tops of such walls and all accessible openings or cracks in the interior surfaces of the walls should be closed and sealed with polyurethane or equivalent caulks, expandable foams, or other fillers and sealants. Large, inaccessible openings or cracks should be disclosed to the client and included in the documentation.

7.3.10 *Crawlspace Depressurization (CSD)*—Crawlspace