Designation: E 2121 – 03

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[3]

E 1998 Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances[3]

2.2 *Government Publications:*

EPA "A Citizen's Guide to Radon (Second Edition)," EPA 402-K92-001, May 1992[4]

EPA "Consumer's Guide to Radon Reduction," EPA 402-K92-003, August, 1992[4]

EPA "Home Buyers and Sellers Guide," EPA 402–K-00–008, July 2000[4]

EPA "Handbook, Sub-Slab Depressurization for Low-Permeability Fill Material," EPA/625/6-91/029, July 1991[4]

EPA "Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Second Edition)," EPA/625/5–87/019, Revised January, 1988[4]

EPA "Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems," EPA/625/R-93-011, October, 1993[4]

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[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 Ventilation Performance.

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

[3] *Annual Book of ASTM Standards*, Vol 04.12.

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

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[4]

OSHA "Respiratory Protection Standard," 29 CFR 1920.134 (1998)[5]

OSHA "Safety and Health Regulations for Construction, Ionizing Radiation," 29 CFR 1926.53[5]

OSHA "Hazard Communication Standard for the Construction Industry," 29 CFR 1926.59[5]

OSHA "Asbestos Standard for the Construction Industry" 29 CFR 1926.1102[5]

OSHA "Occupational Safety and Health Regulations, Ionizing Radiation," 29 CFR 1910.96[5]

NIOSH "Guide to Industrial Respiratory Protection," NIOSH Publication No. 87–116[6]

NCRP "Measurement of Radon and Radon Daughters in Air," NCRP Report No. 97, 1988[7]

2.3 *ANSI/ASHRAE Standards:*

ANSI/ASHRAE Standard 62–1989, Ventillation for Acceptable Indoor Air Quality[8]

ANSI/ASHRAE Standard 62–1989, Ventillation for Acceptable Indoor Air Quality, Appendix B, Positive Combustion Air Supply[8]

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 submembrane 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 is no manifold piping since the suction point piping connects directly to the vent stack piping. The manifold piping starts where it connects to the suction point piping 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 human 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

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[5] 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.

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

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

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

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 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 (SMD) (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 (SSD) (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 pipe of single suction point systems 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 is discharged 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 in 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, including 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 shall 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, 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,"[9] 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. The discharge from vent stack pipes 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,"[9] 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.

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

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.

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 *Sealing the Floor-Wall Joint*—Sealing openings and cracks where the slab meets the foundation wall is sometimes appropriate. When urethane caulk or equivalent material is to be used, and when the joint is greater than ½ in. (13 mm) in width, a foam backer rod or other comparable filler material should be inserted into the joint before the application of the sealant. For guidance on channel and French drain sealing, 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 depressurization is usually not the first choice radon mitigation method for crawlspaces because of its greater potential for hazardous failure, that is, backdrafting, and the probability of a high energy loss associated with its operation during the colder and hotter months.[10] Sub-slab and submembrane depressurization are the crawlspace mitigation methods that should be used whenever possible.

7.3.10.1 When crawlspace depressurization (CSD) is used for radon mitigation, cracks and openings in floors above the crawlspace, which would permit conditioned air to pass from the living spaces to the crawlspace shall be sealed to the extent practicable. Openings or cracks that are determined to be inaccessible or beyond the ability of the contractor to seal shall be disclosed to the client and included in the documentation.

7.3.10.2 Crawlspace depressurization (CSD) shall not be used as a radon control system when combustion appliances are installed within the crawlspace, or within an abutting crawlspace or basement, or where adequate isolation (from depressurization) does not exist or cannot be created in a practical manner, between interior spaces containing one or more combustion appliances and the crawlspace.

7.3.10.3 Crawlspace depressurization (CSD) shall not be used as a radon control system when evidence suggests that friable asbestos material exists in the crawlspace, or when work in the crawlspace would render nonfriable asbestos material friable. If asbestos is to be removed from the crawlspace, to allow the installation of a crawlspace depressurization (CSD) system, the contractor shall employ trained and certified asbestos removers whose work will be undertaken in a manner which complies with applicable asbestos regulations, including those of EPA and OSHA (see 2.2).

7.3.11 *Combination Foundations*:

7.3.11.1 Buildings with elevated radon levels may have more than one foundation type. Mitigation may be required in parts of the building involving one or more foundation types. Foundation types include slab-on-grade, basement, and crawlspace. Isolation of foundation spaces using barriers intended to keep radon from passing, for example, from the crawlspace to the basement or vise versa are not recommended, because walls built using available building trade techniques, usually do not accomplish their isolation objective. In addition, if the purpose of the isolation is to seal off the crawlspace to enable crawlspace depressurization, it is not recommended. Crawlspace depressurization usually is not the first choice radon mitigation method for crawlspaces because of its greater potential for hazardous failure, that is, backdrafting, and the probability of a high energy loss associated with its operation during the colder and hotter months. Sub-slab and submembrane depressurization are the crawlspace mitigation methods that should be used whenever possible.

7.3.12 *Electrical Requirements*:

NOTE 3—For purposes of this section, electrical power is assumed to be provided by 120 V, 15, 20, or 30 ampere circuits; however, for all cases and all situations see 7.3.12.1 for guidance.

7.3.12.1 Wiring for all active radon mitigation systems shall conform to provisions of the "1999 National Electrical Code Handbook, Eighth Edition"[11] and any additional local regulations.

7.3.12.2 Wiring shall not be located inside the radon system piping or within any other heating or cooling ductwork.

7.3.12.3 Any plugged cord used to supply power to a radon fan shall be no more than 6 feet (2 m) in length.

7.3.12.4 No plugged cord may penetrate a wall or be concealed within a wall.

7.3.12.5 A disconnecting means is a switch, a plugged cord, or a branch circuit overcurrent device. A disconnecting means shall be present in the electric circuit powering radon fans. The disconnecting means shall be located within sight of the radon fan, except when the fan motor develops ⅛ th horsepower or less. The branch circuit overcurrent device is permitted to be the disconnecting means when the fan motor develops ⅛ th horsepower or less. The primary purpose of the fan's disconnecting means is to termporarily disconnect the fan's electric power when maintenance is performed. Operation of the radon fan's disconnecting means should not interrupt the power to other electrical devices in the dwelling. See "1999 National Electrical Code Handbook, Eighth Edition"[11] Articles 430-102(b) and 430-109(b), (c), and (f). Also see Appendix X4, Determining Radon Fan Motor Horsepower.

7.3.12.6 Flexible plugged cords, properly rated for electrical capacity and weather, may be used on radon fans inside or outside the building. These flexible plugged cords may also serve as a disconnecting means inside or outside the building. Radon fans, cords, plugs, receptacles, receptacle enclosures, switches, switch enclosures, etc. intended for outside use must have a weatherproof and unattended use rating, and are different than what is generally used inside the building. See "1999 National Electrical Code Handbook, Eight Edition."[11] (**Warning—**A hard-wired electrical connection (with a disconnect switch) may be a preferable alternative to a flexible plugged cord connection for radon fans installed outdoors. There are safety issues and other disadvantages to flexible plugged cords being installed outdoors. Children may play with the outdoor cord or receptacle. Because the protection of wires in an outdoor plugged flexible cord radon fan installation may not equal that of a hard wired outdoor installation, the wiring may be subjected to greater risk of accidental damage. The outside flexible plugged cord, which may be located where access to it is not easily controlled, can be unplugged to free the receptacle for other purposes, and the radon fan may not be plugged in again.)

7.3.13 *Drain Installation Requirements*:

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[10] Henschel, D.B., "Indoor Radon Reduction in Crawl Space Houses: A Review of Alternative Approaches," Indoor Air 2 (2), 1994, 272–278, available from International Society of Indoor Air Quality and Climate; ISIAO Secretariat, Via Magenta 25, 20020 Busto Garolfo (Milan), Italy.

[11] Available from National Fire Protection Association, Inc., One Batterymarch Park, Quincy, MA 02269.

7.3.13.1 If a drain flows directly into the soil beneath the slab or through solid watertight pipe to a soakaway or to daylight through a broken or perforated pipe, the drain pipe should have a trap or a one-way flow valve as described in 7.3.7.1.

7.3.13.2 If condensate drains from heating or air conditioning units terminate beneath the floor slab, a trap should be installed in the drain that provides a minimum 6-in. (150-mm) standing water seal depth, or the drain should be rerouted directly into a trapped floor drain, or connected to a condensate pump.

7.3.13.3 Perimeter (channel or French) drains, open to the soil, should be sealed in a manner that will retain the channel as a water control system. See EPA "Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems."

7.3.13.4 When a sump pit, which is the only system in the basement for protection or relief from excess surface water, is covered for radon control purposes, an alternative drainage system shall be provided. This alternative system may be a new trapped floor drain leading to the sump or a trapped drain installed in the sump pit cover.

7.3.14 *HVAC Installation Requirements*:

7.3.14.1 Modifications to an existing HVAC system, which are proposed to mitigate elevated levels of radon, shall be reviewed by a certified and licensed mechanical contractor.

7.3.14.2 Foundation vents that are installed specifically to reduce indoor radon levels by increasing the natural ventilation of a crawlspace, shall be noncloseable. In crawlspaces areas subject to freezing conditions, water supply, and other kinds of pipes or equipment, which could be damaged by freezing shall be insulated or otherwise protected from freezing.

7.3.15 *Heat Recovery Ventilation (HRV)*:

NOTE 4—HRV as a method for radon control is recommended only when an active soil depressurization system cannot be used, and the initial air exchange rate is low enough to indicate a high probability of success.

7.3.15.1 Heat recovery ventilation (HRV) systems shall not be installed in areas of the building that contain friable asbestos material or where the work would render nonfriable 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.

7.3.15.2 In HRV installations, interior supply and exhaust ports shall be a minimum of 12 ft (3.8 m) apart, horizontally. Exterior supply and exhaust ports shall be positioned a minimum of 12 in. (30 cm) above the ground or higher if necessary to avoid blockage by snow, leaves, or other things and be a minimum of 10 ft (3 m) apart, horizontally. Exterior supply and exhaust ports shall be located away from areas where stored material or equipment could block airflow. Exterior supply/intake ports shall be kept away from where car and truck exhaust or other air pollutants may be present.

7.3.15.3 Contractors installing HRV systems shall verify that the incoming and outgoing airflow is balanced to ensure that the system does not contribute to the negative pressure within the building. Contractors shall inform building owners that periodic filter replacement and inlet grill cleaning are necessary to maintain a balanced airflow. This maintenance information should be included in the documentation.

7.3.15.4 Both internal and external intake and exhaust vents in HRV systems shall be covered with wire mesh or screening to prevent entry of animals or debris, or injury to occupants.

7.4 *Materials*:

7.4.1 All mitigation system electrical components shall be listed.

7.4.2 As a minimum, all plastic radon system piping in depressurization systems shall be made of Schedule 20 PVC or ABS piping material. Schedule 40 piping is recommended for use in garages and in other internal and external locations subject to weathering or physical damage. For purposes of this section the piping, that is used under slabs or membranes to enhance pressure field extension in place of or in conjunction with an aggregate layer, is not considered to be radon system piping and does not have to be solid or rigid PVC or ABS pipe and does not have to conform to any particular wall thickness or pressure rating requirement. For piping used under slabs, membranes and in aggregate materials, however, crush strength is important because piping with no crush strength would be easily crushed or flattened by traffic or items stored over it.

7.4.3 Fittings used in radon system piping shall be of the same material as the piping itself. This material compatibility enables the required cementing of all piping connections; however, when mounting radon fans and when making removable connections which facilitate sump pit maintenance, rubber couplings suitable for use in sanitary sewer systems shall be used instead of cemented pipe joints. For radon fan installation and removal, see 7.3.3.6. For sump pit cover installation and removal see 7.3.2.8.

7.4.4 The plastic pipe cleaner and cement shall be compatible with the kind of plastic in the radon system piping and shall be used as recommended by its manufacturer.

7.4.5 When sealing cracks in slabs and other small openings around penetrations of the slab and foundation walls, caulks, and sealants designed for such application shall be used. Urethane sealants are recommended because of their suitability and durability.

7.4.6 When sealing holes for plumbing rough-in or other large openings in slabs and foundation walls that are below the ground surface, non-shrink mortar, grouts, expanding foam, or similar materials designed for such application should be used.

7.4.7 Sump pit covers shall be made of durable plastic or other rot proof rigid material and be designed to permit air-tight sealing. To enable easy removal for sump pump servicing, the cover shall be sealed using silicone or other nonpermanent type caulking materials or an air-tight gasket and mechanical fasteners. Sump lids with viewing ports are recommended to permit inspection of the sump without removing the lid.

7.4.8 Penetrations of sump covers to accommodate electrical wiring, water ejection pipes, or suction point pipes should be designed to permit air-tight sealing around penetrations, using caulk or grommets.

7.4.9 Flexible membranes installed in crawlspaces as soil-gas-retarders shall be a minimum of 6 mil (0.15-mm) (or 3-mil (0.08-mm) thickness if cross-laminated) polyethylene or equivalent flexible material. Heavier gage sheeting or a protective covering for the sheeting should be used when crawlspaces are used for storage, or frequent entry is required for maintenance of utilities. The durability of flexible membranes should be evaluated before the membranes are selected and installed. Polyethylene is damaged by the ultraviolet radiation in sunlight. See Specification E 1745 permeance and durability specifications for water vapor retarders, which may be used as soil-gas-retarders.

7.4.10 Any wood or other material that contacts masonry or soil shall be pressure treated, or otherwise protected and resistant to decay and insect attack. Such material would be used to attach membranes to crawlspace walls, etc.

7.5 *Monitors and Labeling*:

7.5.1 All active radon mitigation systems shall include a mechanism to monitor system performance (air flow or pressure) and provide a visual or audible indication of system degradation and failure. The mechanism shall be simple to read or interpret and be located where it is easily seen or heard. The monitoring device shall be capable of having its calibration quickly verified on site. The requirement to provide an airflow or pressure operated monitor, does not prohibit additional periodic or continuous use of approved radon test devices to confirm the ongoing effectiveness of the radon mitigation system.

7.5.2 If a pressure operated radon monitor is powered by house current, it shall be installed on a nonswitched circuit and be designed to reset automatically after a power failure. If the monitor is battery powered, it shall be equipped with a low-battery power warning feature.

7.5.3 Mechanical radon mitigation system monitors, such as manometer type pressure gauges, shall be clearly marked to indicate the initial pressure readings.

7.5.4 A system description label shall be placed on the mitigation system, the electric service entrance panel, or other prominent location. This prominently located label shall be legible from a distance of at least 3 ft (1 m) and display the following information: the words "Radon Reduction System," the installer's name and phone number, the date of installation, and an advisory that the building should be tested for radon, by a person qualified by training and certification and licensure, or the occupant at least every two years or as required or recommended by state or local agencies. In addition, all exposed and visible interior radon system piping shall be identified with at least one label on each floor that identifies the pipe as a part of a radon reduction system, such as "Radon Reduction System," "Radon System Pipe," "Component of Radon Reduction System," "Radon Pipe," etc.

7.5.5 The circuit breaker(s) controlling the circuits on which the radon fan and system failure warning devices operate shall be labeled using the word "Radon," for example, "Radon," or if two circuits, "Radon Fan," and "Radon Monitor." If other rooms and appliances are on the circuit, they should also be shown on the label.

7.6 *Post-Mitigation Testing*:

7.6.1 Upon completion of radon mitigation work, the contractor shall take steps to ensure that the effectiveness of the radon reduction system is demonstrated using one of three approaches: 1) the contractor leaves an approved radon test kit with the person responsible for the building and instructs that person, in writing, that a radon test should be performed using the supplied radon test kit or any other approved radon test kit; 2) the contractor hires a certified and/or licenced independent radon tester to perform the required radon test, or 3) the contractor uses the test results, when available, from a relocation company that has arranged for post-mitigation testing. Regardless of the approach used, the contractor shall advise the tester or relocation company that post-mitigation radon testing should be initiated no sooner than one day (24 h) and no later than 30 days following completion and activation of the mitigation system(s). In any case the contractor shall make deliberate attempts to obtain a copy of the post-mitigation test results and keep the copy as a part of the system documentation according to 7.7.1.

7.7 *Documentation*:

7.7.1 Contractors shall keep records of all radon mitigation work performed and maintain those records for three years or for the period of any warranty or guarantee, whichever is longer.

7.7.2 Health and safety records, including worker radon exposure logs, shall be maintained for a minimum of 20 years.

7.7.3 Upon completion of the mitigation project, contractors shall provide clients with information that includes:

7.7.3.1 Copies of contracts and warranties.

7.7.3.2 A description of the mitigation system installed and its basic operating principles.

7.7.3.3 A description of the proper operating procedures of any mechanical or electrical systems installed, including manufacturer's operation and maintenance instructions.

7.7.3.4 A list of appropriate actions for clients to take if the system failure warning device indicates system degradation or failure.

7.7.3.5 The name, address, and phone number of the contractor.

8. Keywords

8.1 depressurization; radon; radon entry; radon mitigation; radon reduction

APPENDIXES

(Nonmandatory Information)

X1. ACTIVE (FAN-POWERED) RADON MITIGATION METHODS

Table X1.1 may be used by readers to find the various mitigation methods covered by the standard.

TABLE X1.1 Active (Fan-Powered) Radon Mitigation Methods

Radon Mitigation Method	Practice Section	Definition Section
Active soil-depressurization (ASD)		3.2.1
Sub-slab depressurization (SSD)	7.3.5	3.2.22
Sump (pit) depressurization (SPD)	7.3.6	3.2.25
Drain tile depressurization (DTD)	7.3.7	3.2.8
Submembrane depressurization (SMD)	7.3.8	3.2.21
Hollow block wall depressurization (BWD)	7.3.9	3.2.9
Ventilation		3.2.27
Crawlspace depressurization (CSD)	7.3.10	3.2.5
Heat recovery ventilation (HRV)	7.3.15	

X2. ACTIVE SOIL DEPRESSURIZATION (ASD) PRINCIPLES OF OPERATION

X2.1 Radon is forced into dwellings through radon entry pathways, which are below ground level. These pathways are openings in foundation walls and floors like cracks, utility penetrations, and floor-wall joints. Other mechanisms for radon entry into dwellings include diffusion and emanation. Radon entry by diffusion, through apparently solid materials, is rarely significant in amount, and ignored when designing and installing ASD radon mitigation systems. Another extremely rare source of radon, is emanation from building material which contain some form of uranium or its progeny. Rising warm air inside the dwelling causes the air pressure in the lower levels of the dwelling to be reduced and the air pressure in the higher parts of the building to increase. This is called the stack effect.

X2.2 Wind can either pressurize or depressurize interior parts of a building, as well as change the air pressure on the exterior (above and below grade) of a building. The wind effect depends on the building configuration (shape, window, and door position etc.) and the wind's speed and direction. Air flows from a higher pressure place to a lower pressure place if there is an opening between the places. This is true in the colder winter months and in the warmer summer months. In the winter months, fresh air enters the lower levels of dwellings through above ground (grade) cracks and joints. Soil-gas, containing radon in various concentrations, enters through below grade foundation cracks and joints. This happens because in the winter, warm air inside the building rises (the stack effect), depressurizing the interior lower levels of the building. The continuous stack effect and the intermittent dwelling depressurizations due to exhausts from combustion appliances, bathroom and kitchen fans, clothes driers, etc., and the intermittent pressurization or depressurization associated with wind effects usually combine to create negative indoor air pressure, compared to outside (both above and below grade). In the summer, when it is cooler inside than outside, indoor air may be forced out of the dwelling through cracks and joints in the lower parts of the structure. This happens because cooler heavier air sinks (a reverse stack effect) and pressurizes the inside lower levels of the structure. The continuous reverse stack effect pressurization and the intermittent depressurizations due to exhausts from combustion appliances, bathroom and kitchen fans, clothes driers, etc., and the intermittent pressurization or depressurization associated with wind effects net out to either create a negative or positive indoor air pressure compared to outside, both above and below grade. When the indoor lower level's pressurizations/depressurizations net out to a negative pressure compared to below grade outdoor pressure, soil-gas, that may or may not contain radon, is drawn into the structure. When the indoor below grade pressurizations/depressurizations net out to be positive, indoor air flows out of the cracks and joints in the below grade parts of the structure and no soil-gas or radon enters the dwelling. Indoor radon concentrations generally are higher during the colder winter months.

X2.3 When an active soil depressurization (ASD) radon system is installed, one end of the radon system piping is connected to a gas-permeable layer of material just below the slab of the dwelling; and the other end is routed to a location outside the building, where the soil-gas containing radon, can be exhausted safely.

X2.3.1 A radon fan (generally rated between 50 and 150 W) is installed in the radon system piping as a means of depressurizing the gas permeable layer.

X2.3.2 If the soil between the footings of a dwelling is covered with a gas permeable layer, like crushed stone, the performance of an ASD system is enhanced. Ideally, the footings would rest on undisturbed soil of low permeability. When turned on, the radon fan pulls soil-gas from the gas permeable layer below the dwelling, that is, depressurizes that soil. When the fan is on, the active soil depressurization (ASD) system is on. By reversing the pre-mitigation air flows through the radon entry pathways, significant radon reduction is achieved. For the sub-slab depressurization (SSD) version of the ASD method of radon mitigation, indoor radon concentrations are significantly (80 to 99 %) reduced when air is flowing from inside the dwelling, through its below grade foundation cracks and joints, into the depressurized gas-permeable layer of soil underneath the dwelling.

X3. RADON SYSTEM PIPE SIZE AND RADON FAN SIZE AND LOCATION FOR SOIL DEPRESSURIZATION RADON REDUCTION SYSTEMS

X3.1 Radon system pipe and radon fan size considerations, for active soil depressurization systems, influence radon mitigation system effectiveness, durability, efficiency, noise, vibration, appearance and cost. These considerations also apply to passive soil depressurization system, because a design criteria of a passive soil depressurization system is that it can be activated. These considerations do not apply to heat recovery ventilator or crawlspace depressurization systems. Certain basic considerations can be stated easily, more complete discussions are available, see EPA "Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems," and "Industrial Ventilation: A Manual of Standard Practice," 23rd Edition," 1998[10].

X3.2 *Radon System Pipe Size Considerations*:

X3.2.1 *Nominal Pipe Size*—For active soil depressurization systems the nominal size of radon vent stack piping is 4-in. (100-mm) inside diameter; the minimum inside diameter of a radon vent stack is 3-in. (75-mm).

X3.2.2 *Wall Thickness*—When compared to a thinner walled pipe, a thick walled Schedule 40 pipe is stronger, more durable, more resistant to damage from the ultraviolet radiation in sunlight and quieter when air is flowing through it.

X3.2.3 *Capacity to Move Air*—The ability of a pipe to efficiently move air depends on its inside diameter. A 4-in. (100-mm) inside diameter pipe (ID) has approximately twice the area of a 3-in. (75-mm) ID pipe. An equal volume of air flows through a large diameter pipe easier and quieter than through a small diameter pipe. When an equal volume of air flows through a 3-in. (75-mm) ID pipe and a 4-in. (100-mm) ID pipe in the same amount of time, the velocity of the air in the 3-in. (75-mm) pipe is approximately twice the velocity of the air in the 4-in. (100-mm) pipe. The higher air velocity increases noise and vibration. The higher air velocity causes greater friction loss, more noise, and lower fan effectiveness.

X3.2.4 *Friction Loss*—Friction loss in radon system piping is important because it reduces the static pressure supplied by a radon fan that is available for depressurizing the soil in the active soil depressurization system. Since friction loss is dependent on pipe inside diameter and the velocity of air traveling through the pipe, larger diameter pipe may be necessary to accommodate the greater friction losses associated with longer or more complex piping configurations. Friction loss is increased, where pipes bend, change size, and merge; friction also increases as pipe runs lengthen. The friction loss for one 90° bend is up to 15 times that of a 1-ft (300–mm) length of pipe, depending on the velocity of air moving through the pipe. Long sweep pipe fittings have less friction loss than regular or sharp bends. Long sweep bends are commercially available from distributers of Schedule 40 PVC-dwv fittings which are used for sanitary sewer plumbing.

X3.2.5 *Noise*—Air flow noises and discharge point noises become objectionable at velocities of 1000 to 1500 ft/min (5 to 8 m/s), which is equivalent to 90 to 130 ft^3/min (2550 to 3680 L/min) in 4-in. (100-mm) pipe.

X3.2.6 *Intake Connection to Radon Fan*—Pipe without bends should be connected straight into radon fan intakes. If pipe bends are located within a distance of ten pipe diameters from the radon fan's intake, the efficiency of the fan may be reduced. For example, if 3-in. (75-mm) vent stack piping is connected to the intake of a radon fan, ideally that piping would be straight for a distance of 2 ft 6 in. (0.8 m) from the intake. Available space often prevents use of such a long length of straight vent stack pipe immediately below the radon fan, but as long a run as practicable, approaching ten pipe diameters in length should be used at this location.

X3.2.7 *Pipe Size and Fan Performance*—If a smaller diameter pipe is chosen for use because of its appearance, because it fits better, because of its cost, etc., the performance of the radon mitigation system piping may be compromised, because more of the fan's static pressure will be used to move air through the radon system piping rather than to depressurize the soil.

X3.2.8 *Durable, Long-Lived Design*—Radon systems designed with thicker-walled, larger diameter radon system pipes likely are to be stronger, and therefore more durable, and more effective at reducing indoor radon concentrations because when over time, foundation cracks widen and lengthen, and new cracks appear, there will be more capacity available to move the additional air through the piping.

X3.2.9 *Pipe Restrictions*—The radon system piping should not have built in restrictions, that is, the inside diameter of the vent stack pipe should not be smaller than the suction point pipe; and, the inside diameter of radon manifold piping should not be smaller than the inside diameter of any suction point pipe. The inside diameter of a vent stack pipe that is connected to a manifold, should not be smaller than the largest inside diameter pipe used in the construction of that manifold.

X3.3 *Radon Fan Size Considerations*:

X3.3.1 Families of commonly used radon fans draw between 50 and 150 W of power. One family of radon fans manages between 90 and 300 cfm (2550 and 8500 L/min) at a static pressure of 0.75 in. WG (190 Pa); another family handles between 15 and 60 cfm (425 and 1700 L/min) at a static pressure of 3 in. WG (750 Pa). The radon fan is selected to maintain the desired depressurization under the slab or membrane in the permeable layer. The pressure field extension test is useful in determining acceptable radon fan size and characteristics. The depressurization goal is to maintain 0.025 to 0.035 in. WG (6 to 9 Pa) everywhere under the slab, when the inside air pressure and the outside air are the same, as would be the case when the basement door of a basement foundation were left open.

X3.3.2 The larger diameter, more efficient radon system piping may cost more to install, but should provide quieter operation and improved soil depressurization performance for a given radon fan, because the radon fan does not have to provide additional static pressure to make up for friction losses in the piping system; the larger diameter pipe could also allow the installation of a smaller radon fan.

X3.4 *Radon Fan Location*—Active soil depressurization (ASD) systems, of all types, carry high concentrations of radon in the radon system piping. It is vital that radon fans in ASD systems be located and configured so as to minimize the potential for leaks, in the radon system piping or the fan itself, which result in radon re-entry or re-entrainment into occupiable spaces of the building. To address this issue, this standard practice limits the location of radon fans in ASD systems to areas outside the building or to non-occupiable spaces, which are above the conditioned space of the building. The result is that all radon system piping, which passes through occupiable space, is maintained under negative pressure relative to the ambient air. Any leaks, which might develop, in the occupiable space, would result in moving noncontaminated air into the radon system rather than allowing soil gas containing high concentrations of radon to escape. This practice is consistent with the management of other hazardous effluents.

X4. DETERMINING RADON FAN MOTOR HORSEPOWER

X4.1 Fan motor horsepower is an issue for radon contractors because wiring requirements change based on the horsepower of the fan's motor. Motors, ⅛ th or less horsepower, have different wiring requirements than higher horsepower motors. Some motors, appropriate for use in radon fans, develop less than ⅛ th horsepower and others develop more. The motors with the higher horsepowers are used for low suction ASD systems with 6 in. (150 mm) ID radon vent stack piping, and with high suction ASD systems that develop 15 in. WG (3.7 kPa) or more suction.

X4.2 Horsepower is not an issue when the disconnecting means is installed within sight of the fan, because the electric code does not prohibit the installation of the disconnecting means within sight of fans with ⅛ th or less horsepower motors.

X4.3 Because horsepower ratings are not provided on most radon fan labels, methods for determining the motor horsepower are suggested.

X4.3.1 Fan motor horsepower and efficiency, when not published, should be available from the fan's manufacturer or distributor.

X4.3.2 Radon fan motor horsepower can be calculated, when efficiency is know. The general formula is: Output (horsepower) equals input (watts) divided by 746 (which converts watts to horsepower) times the motor efficiency (factor). The equation is:

$$HP = \left(Watts / 746\right) X \left(Eff\right)$$

where:

HP = motor horsepower,
$Watts$ = the rating shown on fan's label,
Eff = fan motor efficiency.

To determine the horsepower of a 95 watt in-line tubular radon fan:

1. Assume an efficiency based on the fan's motor type. (Assume about 50 % for the motor type used in many in-line tubular radon fans.)
2. Solve the equation to determine that the 95 watt fan motor probably develops about 1⁄16 th horsepower, assuming 50% motor efficiency.

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