Designation: ~~E2121 – 13~~ E2121 – 21

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

This standard is issued under the fixed designation E2121; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 licensed, 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~~Practice E1465.

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 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.8 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* See Section 6 for specific safety hazards.

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[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. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E1465 Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings (Withdrawn 2017)[3]

E1745 Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

2.2 *Government Publications:*

EPA "Asbestos School Hazard Abatement Reauthorization Act," regulation 40 CFR Part 763, Subpart E.[4]

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

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

EPA "National Emission Standard for Asbestos," 40 CFR 61, Subpart M.[4]

EPA " Radon Mitigation Standards," EPA 402-R-93-078, April 1994.[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]

NCRP "Measurement of Radon and Radon Daughters in Air," NCRP Report No. 97, 1988.[5]

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

OSHA "Asbestos Standard for the Construction Industry" 29 CFR 1926.1102.[7]

OSHA "Hazard Communication Standard for the Construction Industry," 29 CFR 1926.59.[7]

OSHA "Occupational Safety and Health Regulations, Ionizing Radiation," 29 CFR 1910.96.[7]

OSHA "Respiratory Protection Standard," 29 CFR 1920.134, 1998.[7]

OSHA "Safety and Health Regulations for Construction, Ionizing Radiation," 29 CFR 1926.53.[7]

3. Terminology

3.1 *Definitions*—Definitions of terms used in this practice are defined in accordance with Terminology E631.

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 practice. Persons whose normal activity is not radon reduction, but who do work related to radon

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the ~~standard's~~standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from United States Environmental Protection Agency (EPA), ~~Ariel Rios~~ William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC ~~20460,~~20004, http://www.epa.gov.

[5] Available from the National Commission on Radiation Protection and ~~Measurement,~~ Measurement (NCRP), 7910 Woodmont Avenue, Suite 400, Bethesda, MD ~~20814,~~20814-3095, http://www.ncrponline.org.

[6] Available from Centers for Disease Control ~~&~~and Prevention (CDC), 1600 Clifton Rd., Atlanta, GA ~~30333,~~30329-4027, http://www.cdc.gov.

[7] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

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 (CSD) 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 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 E1745 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 (1100 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).~~<u>Safety Data Sheets (SDS).</u>

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. Where discrepancies exist between provisions of this practice and local or state codes that prevent compliance with this practice, the local or state codes shall take precedence.

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. Applicable ~~Material~~ Safety Data Sheets ~~(MSDS)~~(SDS) shall be made available to the client on request.

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.

7.1.5 System components, which are added, or existing system components, which are replaced, repaired, or altered, shall be in compliance with this practice. Existing system components, which are not repaired, replaced, or altered but are observed to be noncompliant with this practice, shall be reported to the client in writing. The report should reference the relevant sections of this practice.

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 from 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)~~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)~~3 in. (75 mm) ID. The manifold ~~piping's~~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)~~ (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)~~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

[8] Available from American Conference of Governmental Industrial Hygienists, Inc. (ACGIH), ~~1330 Kemper Meadow Dr.,~~3640 Park 42 Drive, Cincinnati, OH ~~45240,~~45241, http://www.acgih.org.