APPENDIX E

FLORIDA STANDARD FOR RADON-RESISTANT NEW COMMERCIAL CONSTRUCTION

CHAPTER E101 GENERAL

E101 General. The design and construction requirements set forth in the following chapters and sections shall constitute and be known as the *Florida Standard For Radon-Resistant Commercial Building Construction*, hereinafter referred to as "this standard."

E102 Intent. This standard was developed in accordance with Section 553.98, *Florida Statutes,* to minimize radon entry into newly constructed commercial buildings, in compliance with the state health standard. The design, construction, and operation of buildings are governed by a variety of codes, standards, guidelines, and regulations. Nothing in this standard is intended to create a conflict with existing health and life-safety regulations.

E103 Scope.

E103.1 Applicability. The provisions of this standard shall apply to the design and construction of new commercial buildings and additions to existing commercial buildings, except single family and multiple-family residential buildings of three or fewer stories above grade and those identified in Section E104.3. When adopted by county and local government, this standard shall be applied uniformly countywide. This standard shall not be modified by a local government or building-regulatory agency.

E103.2 Additions. When the cost of an addition to an existing building exceeds 50 percent of the current value of the building; only the addition must be brought into compliance with all applicable portions of this standard, as defined in Section E104.

E104 Compliance.

E104.1 General. Buildings designed and constructed in accordance with all the applicable provisions of this standard are deemed to comply.

E104.2 New buildings and additions. All new commercial buildings and additions to existing buildings shall meet the following compliance requirements of this standard:

1. Compliance with existing local building codes and Chapter 13 of *Florida Building Code, Building.*
2. Use of methods described in Chapters 3 and 4 of this standard.

E104.3 Exemptions. All buildings described below in Items 1 through 5 of this section are exempted from compliance with this standard. Buildings described in Item 6 are exempted from compliance with Sections E306 and E307, and Chapter 4 of this standard. Elevated buildings that comply with all provisions of Item 7 are exempted from compliance with other portions of this standard.

1. Temporary structures.
2. Free-standing greenhouses used exclusively for the cultivation of live plants.
3. Open-air reviewing stands, grandstands and bleachers.
4. Farm structures used only for storage or to shelter animals.
5. Residential buildings defined as one- or two-family detached houses or townhouse apartments with no more than three stories.
6. Buildings of occupancy classification S, storage, or H, hazardous (standard building code designations).
7. Elevated buildings that satisfy all the following conditions:
   a. The structure shall be separated from the ground by a vertical separation, measured between the final grade and the lower surface of the floor, of at least 18 inches (457 mm);
   b. All pilings, posts, piers or other supports shall be solid, or if hollow, shall be capped by a solid masonry unit or sealed at the surface of the soil with a construction complying with all applicable portions of Chapter 3 of this standard;
   c. Enclosures of any kind, including but not limited to chases, storage rooms, elevator shafts and stairwells, that connect between the soil and the structure, shall comply with all applicable provisions of Chapter 3 and shall have a soil contact area of less than five percent of the projected building floor area; and
   d. The perimeter of the structure, from the ground plane to the lower surface of the lowest floor, shall be totally open for ventilation.

E104.4 Required documentation. In order to comply with this standard, all structures must include in the construction documents provided for permitting, a summary of the radon-resistant design strategies being implemented in the structure. Additionally, the building owner shall be provided with a manual substantiating the radon resistance features. This manual shall include: a summary of the radon-resistant design strategies incorporated into the structure; a listing of the design specifications for all relevant motor-driven systems; a maintenance schedule for maintaining design specifications, including active soil depressurization and heating, ventilating, and air conditioning systems; and a listing of all critical adjustments, such as intake-air damper settings.

CHAPTER E201 DEFINITIONS

E201 General. For the purpose of this standard, certain abbreviations, terms, phrases, words and their derivatives shall be construed as set forth in this chapter. Words not defined herein shall have the meanings stated in *the Florida Building Code, Building; Florida Building Code, Mechanical; Florida Building Code, Plumbing; Florida Building Code, Fuel Gas*; and *Florida Fire Prevention Code*. Words not defined in these codes shall have the meanings in *Webster's Ninth New Collegiate Dictionary*, as revised. When cited throughout this standard, ASTM and ACI standards refer to the latest editions.

E202 Definitions.

ACTIVE SOIL-DEPRESSURIZATION. The lowering of air-pressure in the soil, relative to the atmospheric pressure immediately above ground level.

ACTIVE SOIL-DEPRESSURIZATION SYSTEM. A system designed to lower the air-pressure in the soil beneath a building, relative to the atmospheric pressure immediately above ground level, by continuously withdrawing air from below a membrane covering the soil. An active soil-depressurization system consists of a pressure distribution manifold, one or more radon vents, an operating fan, and a fan-failure indicator.

ADDITION. An extension or increase in floor area that can be occupied or that exchange air with the conditioned space of the building.

AND/OR. When referring to a choice of two or more provisions of this standard, signifies that use of any one provision is acceptable, and that two or more provisions may also be used together.

APPROVED. Accepted by the building official or other authority having jurisdiction.

AREA. The maximum horizontally projected area of a building or space, measured to the outside surface of the enclosing walls.

AUTOMATIC. Self-acting, providing an emergency function without human intervention, and activated as a result of a predetermined event such as an interruption of air-flow, a change in air-pressure, or the loss of electrical supply.

BACKER ROD. See "Backup."

BACKUP. A compressible material used in the bottom of sealant reservoirs to reduce the depth of the sealant, thus improving its shape factor. Backup also serves to support the sealant against sag or indentation while curing.

BLEACHERS. Tiered or stepped seating facilities without backrests in which an area of 3 square feet (.28 m^2) or less is assigned per person.

BUILDING. Any structure that encloses a space used for sheltering any occupancy. Each portion of a building separated from other portions by a fire wall shall be considered as a separate building.

BUILDING OFFICIAL. The officer or other designated authority, or their duly authorized representative, charged with the administration and enforcement of building codes.

BUTT JOINT. A nonbonded plain, square joint, a keyed joint or a doweled joint between two members, where primarily movement is at right angles to the plane of the joint. Sealant in a butt joint will generally be in tension or compression, but not shear.

CAVITY WALL. A wall built of any combination of materials, so arranged as to provide a vertical air space within the wall.

COMMERCIAL BUILDING. A structure or building classified according to use by the standard building code as occupancy groups: A - Assembly, B - Business, E - Educational, F - Factory Industrial, I - Institutional, M - Mercantile, and R-Residential (except those already covered by the Florida *Standard for Passive Radon-Resistant New Residential Building Construction).*

CONSTRUCTION JOINT. The surface where two successive placements of concrete meet and are to be bonded; reinforcement is not interrupted and tie bars are used as required.

CONTRACTION JOINT. A formed or sawed groove in a concrete structure, extending normal to the surface and to a depth of at least one-fourth the thickness of a concrete element, for the purpose of creating a weakened plane that induces a crack as internal stresses develop due to drying shrinkage.

CONTROL JOINT. See "Contraction joint."

CRAWL SPACE. The unconditioned space between the bottom surface of the lowest floor of a structure and the earth that is created when the lowest floor of the structure spans between structural supports rather than being directly supported by the earth beneath the floor.

CURING. For concrete, the maintenance of a satisfactory moisture content and temperature during its early stages so that desired properties may develop. For sealants, the maintenance of a satisfactory moisture content and temperature while the physical properties of the sealant are changed by chemical reaction.

CURING COMPOUND. A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water, or in the case of pigmented compounds, also to reflect heat so as to provide an opportunity for the concrete to develop its properties in a favorable temperature and moisture environment.

DETERIORATION. The physical manifestation of failure of a material or assembly (e.g., cracking, delamination, flaking, pitting, scaling) caused by environmental or internal autogenous influences during testing or service.

DIFFUSION. The movement of radon from areas of high concentration to areas of low concentration.

ELASTOMERIC SEALANT. A sealant whose macromolecular material returns rapidly to approximately its initial dimensions and shape after substantial deformation by a weak stress and release of the stress.

EMANATION. The gaseous elements produced by and given off from the radioactive disintegration of radium.

EQUILIBRIUM. The condition where the rate of decay of a radioactive parent isotope is exactly matched by the rate of decay of every intermediate daughter isotope.

EXISTING. As applied to a building or structure, one which was erected or permitted prior to the adoption of this standard.

FIELD-MOLDED SEALANT. A liquid or semisolid material molded into the desired shape in the joint into which it is installed.

FOOTING. That portion of the foundation of a structure which spreads and transmits load directly to the piles, or to the soil or supporting grillage.

FOUNDATION WALL. A wall below the first floor extending below the adjacent ground level and serving as a structural support for a wall, pier, column or other structural element.

GASKET. A deformable material clamped between essentially stationary faces to prevent the passage of air through an opening or joint.

GRADE. The top surface of the ground adjoining the exterior of a building.

GRADE BEAM. A reinforced concrete beam, usually at ground level, to form a foundation for the walls of a superstructure.

GRANDSTANDS. Tiered or stepped seating facilities where an area of more than 3 square feet (.28 m^2) is provided for each person.

GRANULAR SOIL. A soil with an air permeability greater than or equal to l0-12 m^2.

GROUT. A mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents.

HIGH-RANGE WATER REDUCER. A chemical admixture capable of reducing the water content of concrete at least 12 percent. This admixture shall conform to ASTM C 494 Type F and/or Type 0.

HOLLOW MASONRY WALL. A wall built of masonry units so arranged as to provide an air space within the wall.

HONEYCOMB. Voids left in concrete due to failure of the mortar to effectively fill the spaces among course aggregate particles.

ISOLATION JOINT. A nonbonded separation between adjoining parts of a structure, usually in a vertical plane, designed to allow relative movement in three directions in order to accommodate differential horizontal or vertical movement without the development of cracks elsewhere in the structure. May be either a butt joint or a lap joint, used to structurally separate the floor slab from other building elements.

KEYED. Fastened or fixed in position in a notch or other recess.

KEYWAY. A recess or groove in one lift or placement of concrete which is filled with concrete of the next placement, providing improved shear resistance at the joint.

LAITANCE. A layer of weak and nondurable material containing cement and fines from aggregates, brought by bleeding water to the outer surface of concrete.

LAP. The length by which one material overlays another at a lap joint.

LAP JOINT. A nonbonded joint in which the materials being joined override each other so that any movement of the materials is primarily parallel to the plane of the joint, putting sealants in shear rather than tension or compression. Formed slab joints that are not attached with a keyway are considered to be lap joints.

MANUFACTURED SANDS. Sands resulting from the crushing of rock, gravel or slag.

MASONRY. Construction composed of shaped or molded units, usually small enough to be handled by one person and composed of stone, ceramic brick or tile, concrete, glass, adobe, or the like.

MASTIC. A sealant with putty-like properties.

MEMBRANE. A flexible, continuous sheet. See also: "Membrane-forming," "wring compound," "Soil-gas-retarder membrane;" "Waterproofing membrane."

MEMBRANE-FORMING CURING COMPOUND. A liquid material that, when applied over the surface of freshly placed concrete, forms a solid, impervious layer which holds the mixing water in the concrete.

MIDRANGE WATER REDUCER. A chemical admixture capable of reducing the water content of concrete from 6 to 15 percent. This admixture shall conform to ASTM C 494 Type A and/or Type F.

NATURAL SANDS. Sands resulting from the natural disintegration and abrasion of rock.

NET-FREE AREA. When referring to foundation vents, the area determined by multiplying the overall width and height of the object and subtracting the total area obstructed by any solid object, such as screen, mesh, louvers, and frame of the vent.

OPEN AIR. When referring to reviewing stands, grandstands and bleachers, indicates a seating facility in which the side toward which the audience faces is without an enclosing wall.

PICOCURIES PER GRAM, pCi/g. a measure of radioactivity corresponding to 0.037 radioactive disintegrations per second per gram of dry weight of a sample.

PICOCURIES PER LITER, pCi/L. a measure of radioactivity corresponding to 0.037 radioactive disintegrations per second per liter of volume.

PLASTICIZER. See "Midrange water-reducer."

POLYETHYLENE. A thermoplastic high-molecular-weight organic compound often used in sheet form as a water-vapor retarder.

POLYURETHANE SEALANT. A building sealant consisting primarily of a polyurethane compound.

POLYVINYL CHLORIDE. A synthetic resin used in the manufacture of pipes and nonmetallic waterstops.

PREFORMED SEALANT. A sealant functionally pre-shaped by the manufacturer so that only a minimum of field fabrication is required prior to installation.

PRESSURE SENSITIVE. Capable of adhering to a surface without the application of additional adhesives when pressed against it.

PSI. Pounds force per square inch.

RADIUM (Ra). A naturally occurring radioactive element resulting from the decay of uranium. For the purposes of this standard, radium applies to Radium-226. It is the parent of radon gas.

RADON. A naturally occurring, chemically inert, radioactive gas. It is part of the Uranium-238 decay series. For the purposes of this standard radon applies to Radon-222; thus, it is the direct decay product of Radium-226.

RADON POTENTIAL. A measure of the potential of soils at a building site for contributing to indoor radon concentrations.

SEALANT. Any material used to seal joints or openings against passage of solids, liquids, or gases.

SHAFT. A vertical opening extending through one or more stories of a building, for utilities, an elevator, dumbwaiter, light, ventilation, plumbing or electrical installation or a similar purpose.

SHAPE FACTOR. The relationship between the depth and width of a field-molded sealant.

SOIL GAS-RETARDER MEMBRANE. A durable, flexible and non-deteriorating material, installed in a continuous sheet to retard the pressure-driven flow of soil gas through elements of a structure.

SOLID REINFORCED MASONRY. Masonry construction in which mortar, grout or concrete completely fills all joints and voids and in which steel reinforcement is embedded in such a manner that the materials act together in resisting forces.

STORY. That portion of a building between the upper surface of a floor and the upper surface of the floor or roof next above.

STRUCTURE. That which is built or constructed. A structure may contain one or more buildings separated by fire-rated construction elements in accordance with prevailing building codes.

SUBGRADE. The soil prepared and compacted to support a structure.

SUPERPLASTICIZER. See “High-range water reducer.”

SUPERSTRUCTURE. All of that part of a structure that is above grade.

TEMPORARY STRUCTURE. A structure which is erected, occupied, and disassembled or otherwise removed from the site within a total time period of 90 calendar days or less.

WATERPROOFING MEMBRANE. A liquid sealing compound (e.g., bituminous and paraffinic emulsions, coal tar cut-backs, etc.) or nonliquid protective coatings (e.g., sheet plastics, etc.) used separately or together in a manner which renders the structural surface to which they are applied essentially impervious to water in either the liquid or vapor state.

WATER-REDUCING ADMIXTURE. A chemical additive to concrete conforming to ASTM C 94 capable of producing a reduction in mixing water or increase in flowability without causing undue set retardation or entrainment of air in the mortar or concrete.

WATERSTOP. A diaphragm used across a joint as a sealant, usually manufactured specifically to prevent the passage of water through joints in concrete structures.

WORKING LEVEL (WL). A measure of radioactive exposure equal to the total quantity of radon decay products in one liter of air that will result in the ultimate emission of 1.3 × 105 MeV (million electron volts) of energy from alpha particles. In perfect equilibrium, 1 WL equals 100 pCi/L (picoCuries per liter). It is often assumed that the air inside buildings is not in equilibrium, and that only half the radon daughters are moving freely in the air, while half are attached to dust or building surfaces. When this condition exists, an equilibrium ratio of 0.5 is said to exist. At an equilibrium ratio of 0.5, 1 WL = 200 pCi/L. For purposes of this standard, 1 WL is defined as equal to 200 pCi/L.

ZONE. That portion of a building in which the HVAC system is controllable from a single point.

CHAPTER E301
CONSTRUCTION REQUIREMENTS FOR PASSIVE CONTROLS

E301 General. Construction to these standards will limit radon entry points through building floors, walls, and foundations and will limit mechanical depressurization of buildings, which can enhance radon entry. Structural radon barriers are primarily intended to stop the pressure-driven flow of soil gas through unsealed cracks and openings in the foundation and/or floor and into the building. Barriers can also be effective in controlling the diffusion of radon through materials and the emanation of radon from materials. An acceptable degree of redundancy and reliability is achieved only when these components are implemented as part of an integrated system of radon-resistance as prescribed by this standard. All structures shall be isolated from the soil by an approved structural barrier as defined by the applicable portions of this standard. No crack, joint, duct, pipe, conduit, chase or other opening in the building foundation or floor shall be allowed to connect soil gas to a conditioned space or to the interior space of an enclosed space that is either adjacent to, or connected to, a conditioned space.

E302 Soil gas-retarder membrane.

E302.1 Membrane materials. Acceptable soil gas-retarder membranes shall consist of a single layer of polyethylene, not less than 0.006-inch (6 mils) thick with a maximum perm rating of 0.3. Polyvinyl chloride (PVC), ethylene propylene diene ter polymer (EPDM), neoprene or other nondeteriorating, non-porous material may be used instead of polyethylene, provided the installed thickness of the alternate material has greater or equal tensile strength, resistance to water-vapor transmission, resistance to puncture, and resistance to deterioration determined in accordance with ASTM E 154. The membrane shall be placed to minimize seams and to cover all of the soil below the building floor.

E302.2 Tape. Tape used to install the soil-gas retarder shall have a minimum width of 2 inches (51 mm) and shall be pressure sensitive vinyl or other non-deteriorating pressure sensitive tape compatible with the surfaces being joined. Paper tape and/or cloth tape shall not be used for these purposes.

E302.3 Mastic. Mastic used to install the soil-gas retarder shall be compatible with the surfaces being joined, and shall be installed in accordance with the manufacturer's recommendations for the materials, surface conditions and temperatures involved. Mastic may be used to join sections of membrane to one another or to elements of the building foundation, or to seal penetrations in the membrane.

E302.4 Installation. The soil-gas retarder shall be placed under the entire soil-contact area of the floor in a manner that minimizes the required number of joints and seams. Care shall be taken to prevent damage to the membrane during the construction process. In buildings incorporating the subslab portions of an active soil-depressurization system, the soil-gas retarder serves an important second purpose: to prevent mastic, cement or other materials from blocking the pressure distribution manifolds or pits.

E302.5 Seams. Seams between portions of the soil-gas retarder shall maintain a minimum of 12 inches (305 mm) of lap when concrete is placed. This may be accomplished by securing the lapped edges of the membrane with tape or mastic or using larger unsecured overlaps prior to placing concrete.

E302.6 Slab edges and joints. The soil-gas retarder shall fully cover the soil beneath the building floor. Where the slab edge is cast against a foundation wall or grade beam, the soil-gas retarder shall contact the foundation element, and shall not extend vertically into the slab more than one half of the slab thickness.

E302.7 Penetrations. At all points where pipes, conduits, reinforcing bars or other objects pass through the soil-gas-retarder membrane, the membrane shall be fitted to within $^1/_2$ inch (12.7 mm) of the penetration and sealed to the penetration. When penetrations occur within 24 inches (610 mm) of a soil-depressurization-system mat or pit, the gap between the penetrating object and the soil-gas retarder shall be taped closed. When necessary, to meet this requirement, a second layer of the membrane, cut so as to provide a minimum 12-inch (305 mm) lap on all sides, shall be placed over the object and shall be sealed to the soil-gas retarder with a continuous band of tape.

E302.8 Punctures, cuts and tears. All damaged portions of the soil-gas-retarder membrane within 24 inches (610 mm) of any portion of a soil-depressurization-system mat or pit shall be sealed with tape or with a patch made from the same or compatible material, cut so as to provide a minimum 12-inch (305 mm) lap from any opening, and taped continuously about its perimeter.

E302.9 Mastics. Mastic may be used to join sections of soil-gas retarder to one another or to elements of the building foundation, or to seal penetrations in the soil-gas retarder, provided that mastic is kept at least 24 inches (610 mm) from any portion of a soil-depressurization-system mat or pit. Only tape may be used to seal the soil-gas-retarder membrane within 24 inches (610 mm) of a soil-depressurization-system mat or pit.

E302.10 Repairs. Where portions of an existing slab have been removed and are about to be replaced, a soil-gas-retarder membrane shall be carefully fitted to the opening, and all openings between the membrane and the soil closed with tape or mastic. Special care must be exercised to assure that mastic does not enter any portion of a soil-depressurization system located beneath the slab.

E303 Concrete floors in contact with soil gas.

E303.1 General. Concrete slabs supported on soil or spanning over exposed soil, that are used as floors for conditioned space or enclosed spaces adjacent to or connected to conditioned spaces, shall be constructed in accordance with the following provisions of Section E303.

E303.2 Concrete for slabs.

E303.2.1 Compressive strength. Design strength for all concrete mixes used in the construction of slab-on-grade floors shall be a minimum of 3,000 psi (21 MPa) at 28 days and shall be designed, delivered and placed in accordance with ASTM C 94.

E303.2.2 Shrinkage control. In order to limit the uncontrolled cracking of floor slabs, the concrete mix design, placing practices, and curing practices prescribed in this section shall be followed. All concrete slabs-on-grade or slabs spanning above exposed soil shall be designed, placed, finished, and cured in accordance with local governing codes and applicable portions of ACI 318, *Building Code Requirements for Reinforced Concrete*; ACI 302, *Guide for Concrete Floor and Slab Construction*; and if fiber-reinforced concrete is used, the recommendations of the ACI Committee 544, *State of the Art Report on Fiber Reinforced Concrete*. ACI 302 and 544 may not be incorporated by reference for design.

E303.2.3 Mix design. Mix design for all concrete used in the construction of slab-on-grade floors shall specify a maximum design slump not to exceed 4 inches (102 mm). On-site slumps shall not exceed 5 inches (127 mm) provided that the total water added to the mix, including plant, transit, and site added water, does not exceed the total following parameters:

1. For mixes using only natural sands, water content shall not exceed 275 pounds per cubic yard of concrete.
2. For mixes using manufactured sands, water content shall not exceed 292 pounds per cubic yard of concrete.

E303.2.4 Slump and workability. For concretes that do not contain midrange or high-range water reducers, concrete slump measured at the point of placement in accordance with ASTM C 172, shall not exceed 5 inches (127 mm). For concretes designed and mixed containing mid-range or high-range water reducers conforming with ASTM C 494, slump measured at the point of placement in accordance with ASTM C 172, shall not exceed 7 inches (178 mm) for mid-range and 8 inches (203 mm) for high-range water reducers.

E303.2.5 Hot weather placing and finishing. All concrete shall be placed and finished in accordance with the provisions of ACI 301, *Specifications for Structural Concrete for Buildings*. When necessary, provision for wind breaks, shading, fog spraying, sprinkling, ponding or wet covering with a light colored material shall be made in advance of placement, and such protective measures shall be taken as quickly as concrete hardening and finishing operations will allow.

E303.2.6 Curing. Concrete floors shall be cured by one of the means described below and shall not be subjected to loading until the architect or engineer has determined the slab to be structurally adequate for the loads imposed.

1. Concrete floor slabs shall be cured by covering the entire slab surface for a period of seven days with clean, ponded water.
2. Concrete floor slabs shall be cured by covering the entire slab surface for a period of seven days with a continuous mist or spray of clean, potable water.
3. Concrete floor slabs shall be cured by covering the entire slab surface for a period of seven days with an impermeable sheet material conforming to ASTM C 171.
4. Concrete floor slabs shall be cured by covering the entire slab surface with a liquid membrane-forming compound that conforms with ASTM C 309. Curing compounds shall be compatible with materials specified in Section E303.3.1.

E303.3 Sealing of construction joints, penetrations, cracks, and other connections.

E303.3.1 Sealants. Sealants shall be selected and installed in compliance with ASTM C 920, *Standard Specification for Elastomeric Joint Sealants,* and ASTM C 1193, *Standard Guide for Use of Joint Sealants.*

1. Sealant materials shall be compatible with the materials they join, including curing compounds and admixtures, and with materials that will be applied over them, including floor finishing materials.
2. Field-molded sealants shall be installed in sealant reservoirs proportioned, cleaned of laitance and prepared in accordance with the manufacturer's recommendations. For elastomeric sealants, this generally requires the installation of a bond breaker or backer rod.
3. When the installed sealant is not protected by a finished floor or other protective surface, it shall be suitable to withstand the traffic to which it will be exposed.
4. Waterstops shall be preformed from polyvinyl chloride or other noncorrosive material and shall be selected and installed in compliance with ACI 504R

E303.3.2 Joints. All joints between sections of concrete floor slabs, between the floor slab and a wall or other vertical surface, or between a section of floor and another object that passes through the slab, shall be sealed to prevent soil gas entry in accordance with the provisions of this section. Joint design depends upon the amount and type of movement that the joint must withstand. Ideally, sealing should occur as late in the construction process as possible. No portion of any joint shall be covered or rendered inaccessible unless the seal has first been inspected and approved by the building official. All such joints shall be sealed prior to the structure being certified for occupancy.

1. Butt joints. All nonbonded butt joints shall be sealed to prevent radon entry using an elastomeric sealant or a waterstop specified above. The sealant reservoir shall be sufficiently large to prevent failure of the sealant or waterstop, but in no case shall the sealant reservoir be less than $^1/_4$ inch by $^1/_4$ inch (6.4 mm by 6.4 mm) in cross section
2. Lap joints. All nonbonded lap joints shall be sealed with either a field-molded or preformed elastomeric sealant or with a flexible waterstop as specified above. The lap joint shall be sufficiently large to prevent failure of the sealant or waterstop, but in no case shall the sealant reservoir be less than $^1/_2$ inch by $^1/_2$ inch (12.7 mm by 12.7 mm) in cross section.
3. Isolation joints. All nonbonded isolation joints shall be sealed with either a field-molded or preformed elastomeric sealant or with a flexible waterstop as specified above. Isolation joints shall be sufficiently large to prevent failure of the sealant or waterstop, but in no case shall the sealant reservoir be less than $^1/_2$ inch by $^1/_2$ inch (12.7 mm by 12.7 mm) in cross section.
4. Control or contraction joints. May be used to limit unplanned cracking of floor slabs. In locations where continued movement of the slab portions can be reasonably expected, flexible

sealants must be installed in reservoirs complying with the requirements of above section on butt joints, or a flexible waterstop must be used.

5. Construction joints. All bonded construction joints shall be sealed to prevent radon entry using either a rigid or an elastomeric sealant or a waterstop as specified above. Where movement of the joint is not prevented by continuous reinforcing and tie bars, flexible sealants must be installed in reservoirs complying with the requirements of above section on lap joints, or a flexible waterstop must be used.

E303.3.3 Cracks. All cracks in concrete slabs supported on soil or spanning over exposed soil, that are used as floors for conditioned space or enclosed spaces adjacent to or connected to conditioned spaces, shall be sealed against radon entry in accordance with the provisions of this section and Section E303.3.1. Ideally, sealing should occur as late in the construction process as possible.

1. Cracks greater than $^1/_4$ inch (6.4 mm) wide; all cracks that exhibit vertical displacement; all cracks that connect weakened zones in the slab such as vertical penetrations or re-entrant corners; and, all cracks that cross changes in materials or planes in the structure, shall be sealed with a flexible field-molded elastomeric sealant installed in accordance with above section on isolation joints.
2. Cracks greater than $^1/_{16}$ inch (1.6 mm) in width, that do not meet any of the conditions described in Item 1 above, shall be enlarged to contain a sealant reservoir not less than $^1/_2$ inch by $^1/_4$ inch (12.7 mm by 6.4 mm) in cross-section along the entire length of the crack; and shall be sealed with a flexible, field-molded elastomeric sealant installed in accordance with above section on butt joints.
3. Cracks less than $^1/_{16}$ inch (1.6 mm) in width, that do not meet any of the conditions described in Item 1 above, may be left unsealed.

E303.3.4 Stakes, pipe penetrations and other small objects. All objects that pass through the slab shall be sealed gas tight. A sealant reservoir, appropriately dimensioned to accommodate any differential movement between the object and the concrete, shall be formed continuously around the object, and the joint shall be sealed with a field molded elastomeric sealant as prescribed for isolation joints and in accordance with the provisions of Section E303.3.1. Where pipes or other penetrations are separated from the concrete by flexible sleeves, the sleeve shall be removed to provide bonding of the sealant to the object. Where stakes are used to support plumbing, electrical conduits or other objects that will penetrate the slab, the stakes shall be solid, non-porous and resistant to decay, corrosion and rust. Special care must be taken to avoid honeycombing between multiple or ganged penetrations.

1. Large utility service openings through the slab shall be sealed gas-tight. For slab-on-grade construction, this can be accomplished by fully covering the exposed soil with a vapor-retarder membrane, covered to a minimum depth of 1 inch with an elastomeric sealant. Alternatively, the opening may be closed with an expansive concrete or hydraulic cement to within $^1/_2$ inch (12.7 mm) of the top of the slab, and the remaining $^1/_2$ inch (12.7 mm) filled with an elastomeric sealant. When the opening connects to a crawlspace, the opening shall be closed with sheet metal or other rigid impermeable materials and sealed with an elastomeric sealant compatible with the materials and conditions.
2. For openings made through existing slabs, they must be sealed to meet the appropriate provisions of this section. If the opening is partially repaired with concrete, any resulting crack shall be sealed in accordance with the Section E303.3.3.
3. Any sump located in a habitable portion of a building and connecting to the soil, either directly or through drainage piping, shall be fined with a gasketed lid. The lid shall be attached so as to provide a gas-tight seal between the sump and the access space above.

E304 Walls in contact with soil gas.

E304.1 General. Walls separating below-grade conditioned space from the surrounding earth or from a crawlspace or other enclosed volume with an exposed earth floor shall be isolated from the soil by an approved structural baffler as described in Section E302 of this standard. Foundation walls consisting of cavity walls, or constructed of hollow masonry products or of any material in such a way as to create an air-space within the wall, shall be capped at the floor level of the first finished floor they intersect. The cap shall be either at least 8 inches (203 mm) of solid concrete or concrete filled block, or a cap that provides airflow resistance at least equal to the adjacent floor. No crack, honeycomb, joint duct, pipe, conduit chase or other opening in the wall shall be allowed to connect soil gas to a conditioned space or to an enclosed space adjacent to or connected to a conditioned space.

E304.2 Materials. Walls governed by the provisions of this section shall be constructed of reinforced concrete, or solid reinforced masonry construction.

E305 Buildings with crawl spaces.

E305.1 General. For the purpose of this standard, buildings with crawl spaces include all buildings with the floor supported above grade.

E305.1.1 Reinforced concrete floor systems. A reinforced concrete floor constructed over crawl spaces shall conform to all applicable provisions of Section E304.

E305.1.2 Wood-framed floor systems. Wood-framed floors spanning over soil that are used as floors for conditioned space, or enclosed spaces adjacent to or connected to conditioned spaces, shall be constructed in accordance with the provisions of this section.

E305.2 Materials. Wood-framed floors constructed over a crawl space shall be constructed of American Plywood Association (APA) certified tongue-in-groove plywood, and otherwise comply with Paragraph 4.1.2 of Appendix C to Chapter 13 of the *Florida Building Code, Building*. Oriented structural board shall not be an acceptable substitute material.

E305.3 Utility penetrations. All penetrations through the floor, including but not limited to plumbing pipes and wiring, shall be fully sealed to the floor structure with approved sealant materials as per Section E303.3.1. Large service openings through the slab, such as beneath bath tub drains, shall be sealed gastight. Where large openings are created, sheet metal or other rigid materials shall be used in conjunction with sealants to close and seal the openings.

E305.4 Vertical joints. All vertical joints between the subfloor and foundation wall or the subfloor and any vertical plane of the building which extends from the crawlspace to the top of the subfloor shall be sealed with an approved sealant (see Section E303.3.1).

E305.5 Doors and service openings. Doors, hatches or removable closures of any kind that can create an opening in the floor-plane should be avoided, but when required, shall be gasketed and installed with a latch or other permanent fastening device.

E305.6 Other radon-entry paths. All openings which connect a crawlspace and construction cavities, such as the space between wall studs, hollow masonry or precast concrete units, or floor and ceiling planes, shall be closed and sealed with an approved sealant (see Section E303.3.1).

E305.7 Crawl space ventilation. Crawl spaces shall be passively ventilated or shall be constructed with an active soil-depressurization system in compliance with Chapter 4. No portion of an air distribution system shall pass through a crawlspace.

E305.7.1 Required ventilation. Crawl spaces shall be ventilated by openings through the perimeter wall connecting to the exterior of the foundation. Required vents shall have a combined net free area not less than 1 square inch (.000645 m^2) per 1 square foot (.0929 m^2) of crawl space, and shall conform to the following conditions:

1. Openings shall be distributed uniformly around the outside walls of the crawl space.
2. Vents shall be fitted with corrosion and decay-resistant wire mesh or grilles with openings not less than $^1/_4$ inch (6 mm) nor more than $^1/_2$ inch (12.7 mm) in size. Vents shall not be fitted with operable louvers, dampers, or other closure mechanisms.
3. Plumbing located in a ventilated crawlspace shall be protected from freezing with insulation and/or heat tape.

E305.7.2 Prohibited uses. Crawl spaces shall not be used as an air-duct or plenum or to house any duct or fan that is part of a heating, ventilating or air-conditioning system.

E306 Space conditioning systems and ventilating.

E306.1 General. All heating, ventilating and air-conditioning systems shall be designed, installed, inspected and maintained in accordance with ANSI/ASHRAE 62-1989, *Ventilation for Acceptable Indoor Air Quality*, Chapter 13 of the *Florida Building Code, Building,* and with the provisions of this section. Construction to the provisions of this section will limit radon entry points through mechanical depressurization of buildings, which can enhance radon entry. Additionally, ventilating systems shall be designed to meet all applicable codes and the provisions of this section for use of outside air of low radon concentration.

E306.2 Condensate drains. All joints in condensate piping shall be solvent welded, soldered, or otherwise connected in a leakproof and gas-tight manner. Condensate drains shall be trapped and terminate in the building sewer or outside the building, a minimum of 6 inches (152 mm) above finished grade. If the condensate piping penetrates a floor or wall separating enclosed space from the soil or from a crawl space, the penetration shall be sealed in accordance with the applicable provisions of Chapter 3. The condensate drain piping shall not terminate in a return plenum.

E306.3 Other piping. When any piping penetrates a floor or wall separating enclosed space from the soil or from a crawl space, the penetration shall be sealed in accordance with the applicable provisions of Chapter 3. In the case of insulated piping, the insulation must be removed at the point of the seal and required seal must be made between the pipe and the building structure. Sealant must be compatible with the materials and anticipated operating temperatures. Piping shall not terminate in a return plenum.

E306.4 Plumbing and wiring chases. Wherever piping or wiring is installed in a chase that is at any point in contact with the soil or a crawl space, the chase shall be sealed to the floor or wall where it first enters the structure, in accordance with the applicable portions of Chapter 3. Piping contained in such a chase shall be sealed to the chase at the interior plane of that floor or wall. No portion of any chase shall terminate in a return air duct or plenum. Where it is impractical or prohibited by another code to seal wiring into an electrical chase or conduit, the chase shall comply with all applicable portions of Chapter 3 or the conduit shall be entirely fabricated of gas-tight components and materials.

E307 Air distribution systems.

E307.1 Air distribution systems. Any air duct, plenum, fan enclosure, or fan that is part of a building's heating, ventilating or air-conditioning system shall be completely isolated from the soil gas by a structural barrier complying with the provisions of Chapter 3. Heating, ventilating, and air conditioning systems supplying spaces that have floors or walls in contact with soil or soil gas shall be designed to minimize air-pressure differences and eliminate negative pressures, that cause significant flow of soil gas through the structural barrier and into the building. Return ducts, plenums, and air handlers shall not be located in a crawl space.

E307.2 Exhaust fans, hoods, equipment, and appliances. For each zone, the required volume of outside ventilation air shall be equal to or greater than the combined volume of air capable of being exhausted by all exhaust fans, hoods, equipment, and appliances installed in the zone. This amount may not be reduced by use factors unless devices are wired and switched in a manner that prevents their simultaneous operation.

E307.3 Combustion air ducts. Ducts that provide combustion air to fuel-burning appliances and equipment shall be completely isolated from the soil-gas by a structural barrier complying with the provisions of Chapter 3.

CHAPTER E401
ACTIVE SOIL-DEPRESSURIZATION SYSTEMS

E401 General. A soil-depressurization system maintains a lower air pressure in the soil directly beneath the building floor and foundation than exists within the building. This not only draws radon away, but also causes the direction of the airflow through any possible failure in the structural barrier to be out of the building and into the soil-depressurization system. Soil depressurization systems may be installed beneath concrete slabs supported directly on the soil, or beneath the soil gas-retarder membrane in crawl spaces.

E401.1 Prohibited uses. Soil-depressurization systems components may not extend beneath areas that are required to be depressurized by other codes for the protection of public health, for example rooms containing general anesthesia, pathogens, or poisonous chemicals. Soil depressurization systems may be installed beneath rooms that are required to be depressurized for other reasons, such as toilets and kitchens.

E402 System components. An active soil-depressurization (ASD) system is comprised of the following components: pressure distribution system porous media or manifolds; a soil cover; one or more vents; a suction fan; and a system failure indicator.

E402.1 Pressure distribution media or manifolds. A wide variety of means can be utilized to extend the low-pressure zone across the entire area beneath the structure. Acceptable means include synthetic ventilation mats, a system of perforated pipe, and an air-permeable gravel layer. Different types of pressure distribution media may be used in the same system, provided each complies with the installation requirements of this chapter. Pressure distribution media must be installed is such a way as to assure that they are never blocked by water.

1. Ventilation mats shall have a soil contact area of at least 216 square inches (0.14 m^2) per lineal foot and provide a cross-section profile of at least 9 square inches (.006 m^2).
2. Perforated pipe may be used to construct pressure extension manifolds. These pipes may be installed directly under the soil cover or in gravel or a similar porous medium that provides an adequate airflow connection between the pipe and the subsoil and that protects the pipe from becoming blocked by soil.
3. Continuous gravel layers of at least 4 inches (102 mm) thick are an acceptable pressure distribution medium, provided they completely cover the area of soil to be depressurized.

E402.2 Soil cover. In slab-on-grade construction, the soil cover consists of the soil gas-retarder membrane and the concrete slab. In crawl spaces, the concrete slab may be omitted, providing the soil gas-retarder membrane will not be subjected to wear and damage due to required maintenance procedures. In all instances, the soil gas-retarder membrane shall be fully sealed to the radon vents in accordance with the provisions of Section E302.

E402.3 Radon vents. Radon vents are gas-tight pipes that carry the soil gas to an area above and away from the building. Radon vent pipes shall be of a material approved by the governing local building code for plumbing vents.

E402.4 Suction fans. Suction fans create the critical pressure difference between the subslab and indoors. Suction fans shall be designed for continuous operation. Fan performance is determined by the soil characteristics, the airflow characteristics of the pressure distribution system, and the system layout, and shall comply with the airflows and operating pressures determined by the system design, as determined using the large-building active soil-depressurization model, or with criteria below for alternate compliance method. The computer model program is available through the Department of Business and Professional Regulation, Codes and Standards Office, 1940 N. Monroe St., Suite 90A, Tallahassee, Florida, 32399-0772.

E402.5 Fan-failure indicator. Each soil-depressurization system shall have a failure indicator labeled with the words "RADON REDUCTION SYSTEM FAN-FAILURE INDICATOR" mounted so as to be conveniently visible to the building occupants. The fan-failure indicator may be either a visual device consisting of a light of not less than $^1/_5$ footcandle (2 lux) at the floor level, or an alarm that produces a minimum 60 db audible signal. The indicator shall be made to operate automatically when the pressure inside any radon vent pipe fitted with an operable fan is less than 0.40-inch water column (100 pascals) lower than the air pressure inside the building.

E403 ASD system design requirements.

E403.1 General. All ASD systems must comply with a design shown by the large-building active soil-depressurization model to be capable of maintaining a 0.02-inch (5 pascal) pressure differential over 90 percent of the slab or crawlspace area.

E403.2 Ventilation mat systems. Mat systems may be designed and installed in accordance with a design shown by the large-building active soil-depressurization model to be capable of maintaining a 5-pascal pressure differential over 90 percent of the slab area or with Section 503.2.2.

E403.2.1 Installation. Radon ventilation mats shall be installed immediately prior to placing the soil gas-retarder membrane, to reduce the chance for soil to enter and block the mat. Mats shall be arranged in a pattern that provides at least two possible flow paths from any point on the mat to a radon vent pipe. Mats shall be placed with the filter material facing the compacted soil. Where sections of mat join, a minimum 6-inch (152 mm) long section of filter material at the end of one of the mats shall be loosened and the other piece of mat inserted between the loosened filter material and the first section of mat. The mats will be pressed tightly together at this lap and mechanically attached together with hog rings or metal pins driven through the mat and into the soil. Wire ties, which will puncture or tear the soil gas-retarder membrane, shall not be used to join the mats. When properly joined, the filter material will extend continuously across the joint and the full cross-sectional area of the mat will be preserved across the splice.

E403.2.2 Alternate compliance method. Systems installed on sand or granular soil, can demonstrate compliance by meeting the following design limits:

1. Mats shall be located at least 15 feet (4572 mm) and not more than 25 feet (7620 mm) from the outside edge of the floor.
2. Mats shall be spaced not more than 50 feet (15 240 mm) on center.
3. No portion of a building floor shall be isolated from a mat by a construction feature, such as an internal footing, grade beam, foundation wall, or other obstacle having a depth greater than the exterior foundation walls.
4. No portion of a building floor shall be more than 35 feet (10 668 mm) from a mat.
5. Mats shall be run parallel to the longest slab dimension unless obstructed by a construction feature, and arranged in a pattern that provides at least two possible flow paths from any point on the mat to a radon vent pipe.

E403.2.3 Radon vent connection. The radon vent pipe shall join to the mat in a manner that does not restrict the full air-flow capacity of the pipe. Depending upon the thickness and effective net-free area of the ventilation mat, this may require enlarging the diameter of the vent pipe at the connection with a suitable flange, or increasing the net-free area of the mat by installing additional layers of mat or a layer of gravel beneath the connection point. The soil gas-retarder membrane shall be fully sealed to the radon vents in accordance with the provisions of Section 302.

E403.3 Perforated pipe systems. Perforated pipes shall be of a material approved by the governing local building code for foundation drainage, and sized according to the air-flow estimated from the large-building active soil-depressurization model. Where perforated pipes are installed in gravel meeting ASTM D 448, numbers 4 or 5 gravel, with not more than 5 percent passing a $^{3}/_{8}$ inch (10 mm) screen.

E403.3.1 Installation. Perforated pipe pressure distribution manifolds shall be installed only after the installation of all other utilities has been completed and immediately prior to the soil gas-retarder membrane. Pipes shall be installed with a row of perforations located at the bottom of the pipe in order to allow condensate to drain from the system. Pipes shall be arranged in a pattern that provides at least two possible flow paths from any point in the system to a radon vent pipe. Separate sections of pipe shall be solvent welded or mechanically fastened together.

E403.3.2 Radon vent connection. The radon vent pipe shall join to the perforated pipe with a fitting that allows for the fill air-flow capacity of the vent pipe. The soil gas-retarder membrane shall be fully sealed to the radon vents in accordance with the provisions of Section E302.

E403.4 Continuous gravel layer systems. Gravel used as the pressure distribution medium shall be installed only after the installation of all other utilities has been completed, and immediately prior to the soil gas-retarder membrane. Where regions of gravel are isolated from one another by interior foundation elements, separate suction points shall be provided in each region, or regions shall be interconnected with pipes run horizontally through the obstruction. The size and number of such pipes shall be sufficient to provide at least two-times the anticipated airflow. In no case shall fewer than two pipes be used to interconnect one gravel area with another. These pipes shall be separated by a horizontal distance not less than one-half the length of the boundary between the connecting gravel areas.

E403.4.1 Radon vent connection. The radon vent pipe shall join to the gravel layer with a "T" fitting that allows for the full airflow capacity of the vent pipe from either side of the "T." The fitting shall be installed with two arms in the gravel and a single arm connected to the radon vent pipe. The soil-gas-retarder membrane shall be fully scaled to the radon vents in accordance with the provisions of Section 302.

E403.5 Radon vent pipe installation. Radon vent pipes shall be solvent welded or otherwise joined to create a gas-tight connection from the soil-suction point to the vent termination point. They shall be sloped a minimum of 1/8 inch (3 mm) per foot in a manner that will drain all rain and condensate back to the soil, and shall be supported in compliance with regulations for plumbing vents.

E403.5.1 Labeling. All portions of the radon vent pipe not permanently encased in a wall or chase shall be labeled to prevent accidental misuse. Labels shall consist of a pressure sensitive 2 inch (51 mm) yellow band with the words "RADON REDUCTION SYSTEM" printed in black letters at least 1 inch (25 mm) in height. These labels shall be placed on every visible portion of the vent pipe at a spacing of not more than 3 feet (914 mm). The labels shall be placed so as to be visible from any direction.

The size of vent pipes shall be determined by application of appropriate engineering principles, based on airflow rates predicted with the large-building active soil-depressurization model. For systems that comply with the alternate compliance method, Section E403.2.2, and are installed in buildings with straight runs of vent pipes no more than 50 feet (15 240 mm) in height, the required number and size of vent pipes may be determined as follows:

1. For up to 100 linear feet (30 480 mm) of ventilation mat use one 2-inch (51 mm) diameter pipe.
2. For up to 200 linear feet (60 960 mm) of ventilation mat use one 3-inch (76 mm) diameter pipe, or two 2-inch (76 mm) diameter pipes.
3. For up to 400 linear feet (121 920 mm) of ventilation mat use one 4-inch (102 mm) diameter pipe, or two 3-inch (76 mm) diameter pipes, or four 2-inch (30 480 mm) diameter pipes.

E403.5.2 Terminals. Radon vent pipes shall terminate with a rain cap, installed above the roof of the structure, and shall be located in accordance with existing codes for toxic or noxious exhausts. If not specifically addressed or applicable, vent pipes shall be terminated in locations that minimize human exposure to their exhaust air, such that the location is:

1. At least 12 inches (305 mm) above the surface of the roof;
2. At least 10 feet (3048 mm) from any window, door, or other opening (e.g., operable skylight or air intake) to conditioned spaces of the structure; and
3. Ten feet (3048 mm) from any opening into an adjacent building.

The total required distance [10 feet (3048 mm)] shall be measured either directly between the two points or be the sum of measurements made around the intervening obstacles. If the discharge point is within two feet of elevation of the opening into conditioned space, the distance [10 feet (3048 mm)] shall be the horizontal distance between the points.

E403.6 Suction fans. Soil-depressurization system fans shall be designed to maintain the following minimum air-pressure differences at the lower opening of the radon vent pipe as compared to the air pressure of the conditioned space above:

1. For systems using ventilation mats, 0.5 inch (0.52 kPa) water column.
2. For systems using perforated pipe, 0.5 inch (0.52 kPa)water column.
3. For systems using continuous gravel layers, 1.0 inch (0.2488 kPa) water column.

E403.6.1 Fan sizing. Soil-depressurization systems that comply with the alternative compliance method, Section E403.2.2, and sizing, Section E403.5.2, may comply by sizing the fan as follows:

1. For up to 100 lineal feet (30 480 mm) of ventilation mat the fan shall be rated for 50 cfm (24 L/s) at 1-inch (30 480 mm) water column.
2. For 100 to 200 lineal feet (30 480 mm to 60 960 mm) of ventilation mat, the fan shall be rated for at least 100 cfm (30 480 mm) at 1-inch (30 480 mm) water column.
3. For 200 to 400 lineal feet (60 960 mm to 121 920 mm) of ventilation mat, the fan shall be rated for at least 175 cfm (83 L/S) at 1-inch (0.2488 kPa) water column.