Florida Standard for Radon-Resistant New Commercial Building Construction

January 23, 1996

State of Florida
Florida Department of Community Affairs
Radon Program
2555 Shumard Oak Blvd
Tallahassee, FL 32399-2100

James F. Murley, Secretary

TABLE OF CONTENTS

CHAPTER ONE

GENERAL

101 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".

102 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.

103 Scope

103.1 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 multi-family residential buildings of three or fewer stories above grade and those identified in Section 104.3. 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.

103.2 Additions When the cost of an addition to an existing building exceeds 50% 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 104.

104 Compliance

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

104.2 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 the current edition of the "Florida Energy Efficiency Code for Building Construction".

(2) Use of methods described in Chapters 3 and 4 of this standard.

104.3 Exemptions All buildings described below in items (1) through (5) are exempted from compliance with this standard. Buildings described in item (6) are exempted from compliance with Sections 306 and 307, 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, and

(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, and

(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 (5%) 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.

104.4 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 TWO

DEFINITIONS

201 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 Standard Building Code, Standard Mechanical Code, Standard Plumbing Code, Standard Gas Code, Standard Fire Prevention Code, or the current edition of the "Florida Energy Efficiency Code For Building Construction". 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.

202 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 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 non-bonded 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).

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.

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.

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.

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.

FIELD-MOLDED SEALANT - a liquid or semi-solid 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.

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 is provided for each person.

GRANULAR SOIL - a soil with an air permeability greater than or equal to lO^{-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%. This admixture shall conform to ASTM C494 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 non-bonded 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 non-bonded 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.

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.

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.

MID-RANGE WATER REDUCER - a chemical admixture capable of reducing the water content of concrete from 6 - 15%. This admixture shall conform to ASTM C494 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 mid-range water-reducer.

POLYETHYLENE - a thermo -plastic 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 preshaped 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.

SUEGRADE - 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.

WATER-REDUCING ADMIXTURE - a chemical additive to concrete conforming to ASTM C94 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.

WATERPROOFING MEMBRANE - a liquid sealing compound (e.g., bituminous and paraffinic emulsions, coal tar cut-backs, etc.) or non-liquid 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.

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 1.3×10^5 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 THREE

CONSTRUCTION REQUIREMENTS FOR PASSIVE CONTROLS

301 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.

302 Soil-Gas-Retarder Membrane

302.1 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 non-deteriorating, 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.

302.2 Tape Tape used to install the soil-gas retarder shall have a minimum width of 2 inches 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.

302.3 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.

302.4 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 sub-slab 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.

302.5 Seams Seams between portions of the soil-gas retarder shall maintain a minimum of 12 inches 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.

302.6 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 the slab thickness.

302.7 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 ½ inch of the penetration and sealed to the penetration. When penetrations occur within 24 inches 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 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.

302.8 Punctures, Cuts and Tears All damaged portions of the soil-gas-retarder membrane within 24 inches 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 lap from any opening, and taped continuously about its perimeter.

302.9 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 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 of a soil-depressurization-system mat or pit.

302.10 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.

303 Concrete Floors in Contact with Soil-Gas

303.1 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 303.

303.2 Concrete for Slabs

303.2.1 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 at 28 days and shall be designed, delivered and placed in accordance with ASTM C 94.

303.2.2 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.

303.2.3 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 four (4) inches. On-site slumps shall not exceed five (5) inches, 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.

303.2.4 Slump and Workability For concretes that do not contain mid-range or high-range water-reducers, concrete slump measured at the point of placement in accordance with ASTM C 172, shall not exceed 5-inches. 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 for mid-range and 8-inches for high-range water reducers.

303.2.5 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.

303.2.6 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 7 days with clean, ponded water.

(2) Concrete floor slabs shall be cured by covering the entire slab surface for a period of 7 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 7 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 303.3.1.

303.3 Sealing of Construction Joints, Penetrations, Cracks, and Other Connections

303.3.1 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 non-corrosive material and shall be selected and installed in compliance with ACI 504R

303.3.2 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 non-bonded butt joints shall be sealed to prevent radon entry using an elastomeric sealant or a waterstop as 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 ¼-inch by ¼-inch in cross-section

(2) **Lap joints.** All non-bonded 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 ½-inch by ½-inch in cross-section.

(3) **Isolation joints.** All non-bonded 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 ½-inch by ½-inch 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.

303.3.3 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 303.3.1. Ideally, sealing should occur as late in the construction process as possible.

(1) Cracks greater than ¼-inch 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 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 ¼-inch x ¼-inch 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 in width, that do not meet any of the conditions described in item (1) above, may be left unsealed.

303.3.4 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 303.3.1. 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 ½ inch of the top of the slab, and the remaining ½ inch 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 303.3.3.

(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.

304 Walls in Contact with Soil-Gas

304.1 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 302 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 of solid concrete or concrete filled block, or a cap that provides air-flow 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.

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

304.3 Waterproofing Walls governed by the provisions of this section shall be constructed with a continuous waterproofing membrane applied

(1) either to the exterior surface from the top of the footing to not less than 6 inches above the finished grade, or where the wall separates interior space and a crawlspace; or

(2) from the top of the footing to the bottom of the floor above.

304.3.1 Application The waterproofing membrane shall be applied in accordance with the applicable local building code and shall be sealed to the top of the footing so as to waterproof the joint between the footing and the wall. When installed in compliance with Section 304.3 Item (2), the membrane shall be attached to the bottom of the floor above to fully seal the joint between the floor and the wall.

304.3.2 Utility Penetrations All below-grade utility penetrations through walls in partial or full contact with the soil shall be closed and sealed with an approved sealant material (see Section 303.3.1). This seal shall be made on both faces of the wall. Where conduits or ducts do not provide a continuous and gas-tight separation from the soil, the end of the conduit or duct must be sealed in accordance with the provisions of Section 303.3.1 to prevent soil-gas entry.

304.4 Doors and Service Openings Doors, hatches, or removable closures of any kind that can create an opening between the interior and a crawlspace should be avoided, but when required, shall be gasketed and installed with a latch or other permanent fastening device.

305 Buildings with Crawl Spaces

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

305.1.1 Reinforced Concrete Floor Systems A reinforced concrete floor constructed over crawl spaces shall conform to all applicable provisions of Section 303.

305.1.2 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.

305.2 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 the 1993 Energy Efficiency Code for Building Construction. Oriented structural board shall not be an acceptable substitute material.

305.3 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 303.3.1. Large service openings through the slab, such as beneath bath tub drains, shall be sealed gas-tight. Where large openings are created, sheet metal or other rigid materials shall be used in conjunction with sealants to close and seal the openings.

305.4 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 303.3.1).

305.5 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.

305.6 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 303.3.1).

305.7 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 trough a crawlspace.

305.7.1 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 per 1 square foot 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 nor more than ½ inch 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.

305.7.2 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.

306 Space Conditioning Systems and Ventilating

306.1 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, the current "Florida Energy Efficiency Code For Building Construction", 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.

306.2 Condensate Drains All joints in condensate piping shall be solvent welded, soldered, or otherwise connected in a leak-proof and gas-tight manner. Condensate drains shall be trapped and terminate in the building sewer or outside the building, a minimum of 6 inches 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.

306.3 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.

306.4 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.

307 Air Distribution Systems

307.1 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.

307.2 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.

307.3 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 FOUR

ACTIVE SOIL-DEPRESSURIZATION SYSTEMS

401 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 air-flow 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.

401.1 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.

402 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.

402.1 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 per lineal foot and provide a cross-section profile of at least 9 square inches.

(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 air-flow connection between the pipe and the sub-soil and that protects the pipe from becoming blocked by soil.

(3) Continuous gravel layers of at least 4-inches thickness are an acceptable pressure distribution medium, provided they completely cover the area of soil to be depressurized.

402.2 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 302.

402.3 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.

402.4 Suction Fans Suction fans create the critical pressure difference between the sub-slab and indoors. Suction fans shall be designed for continuous operation. Fan performance is determined by the soil characteristics, the air-flow characteristics of the pressure distribution system, and the system layout, and shall comply with the air-flows 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 Community Affairs, Codes and Standards, 2740 Centerview Drive, Tallahassee, Florida, 32399-2100, telephone (904) 487-1824.

402.5 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 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.

403 ASD System Design Requirements

403.1 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% of the slab or crawlspace area.

403.2 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% of the slab area or with Section 503.2.2.

403.2.1 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 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.

403.2.2 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 and not more than 25 feet from the outside edge of the

floor.

2) Mats shall be spaced not more than 50 feet 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 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.

403.2.3 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.

403.3 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% passing a 3/8-inch screen.

403.3.1 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.

403.3.2 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 302.

403.4 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 air-flow. 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.

403.4.1 Radon Vent Connection The radon vent pipe shall join to the gravel layer with a "T" fitting that

allows for the full air-flow 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.

403.5 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 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.

403.5.1 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 yellow band with the words "**Radon Reduction System**" printed in black letters at least 1 inch in height. These labels shall be placed on every visible portion of the vent pipe at a spacing of not more than 3 feet. The labels shall be placed so as to be visible from any direction.

403.5.2 Sizing The size of vent pipes shall be determined by application of appropriate engineering principles, based on air-flow rates predicted with the Large-Building Active Soil-Depressurization Model. For systems that comply with the Alternate Compliance Method, Section 403.2.2, and are installed in buildings with straight runs of vent pipes no more than 50 feet in height the required number and size of vent pipes may be determined as follows:

1) For up to 100 linear feet of ventilation mat use one 2-inch diameter pipe.

2) For up to 200 linear feet of ventilation mat use one 3-inch diameter pipe, or two 2- inch diameter pipes.

3) For up to 400 linear feet of ventilation mat use one 4-inch diameter pipe, or two 3- inch diameter pipes, or four 2-inch diameter pipes.

403.5.3 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 above the surface of the roof;

(2) at least ten feet from any window, door, or other opening (e.g., operable skylight or air intake) to conditioned spaces of the structure; and

(3) 10 feet from any opening into an adjacent building.

The total required distance (ten feet) 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 (ten feet) shall be the horizontal distance between the points.

403.6 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 inches water column.

2) For systems using perforated pipe, 0.5 inches water column.

3) For systems using continuous gravel layers, 1.0 inches water column.

403.6.1 Fan Sizing Soil-depressurization systems that comply with the Alternative Compliance Method, Section 403.2.2, and Sizing, Section 403.5.2, may comply by sizing the fan as follows:

1) For up to 100 lineal feet of ventilation mat the fan shall be rated for 50 cfm at 1-inch water column.

2) For 100 to 200 lineal feet of ventilation mat, the fan shall be rated for at least 100 cfm at 1-inch water column.

3) For 200 to 400 lineal feet of ventilation mat, the fan shall be rated for at least 175 cfm at 1-inch water column.