THE DRAFT, FIRST EDITION, FLORIDA STANDARD FOR RADON-RESISTANT BUILDING CONSTRUCTION

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The Florida Department of Community Affairs is required by statutory mandate to develop a building construction standard for radon resistant buildings. That standard is to be reviewed by the Florida Legislature, which will then determine how it is to be adopted as a building code. This paper presents the second version of the first edition of those standards for which administrative rule making was attempted. At this time (Fall 1991), the final version of the standard has not been adopted. The standard was developed from a core of recommended criteria submitted by a select committee of state university system researchers, the modifications to that core provided by the Florida Radon Research Program's (FRRP) standards criteria committees, and recommendations of the Florida Coordinating Council on Radon Protection. The first two years' research projects were directed to providing information for this first edition of the standard. Longer term research of the FRRP is directed toward the development of a more comprehensive standard for construction of radon resistant buildings. The first edition of the standard provides two compliance options for residential buildings. The first option requires measures to improve the performance of floors as barriers to radon entry, measures to decrease natural and mechanically induced pressure differentials which enhance radon entry, and a post construction indoor radon test to demonstrate compliance with the state indoor radon exposure standard. The second compliance option requires implementation of the improved barriers and pressure differential reduction measures and the installation of an active sub-slab depressurization system (slab-on-grade houses), an active sub-membrane depressurization system (off-grade floor houses) or a crawl-space mechanical ventilation system.

DRAFT

Florida Standard

For

Radon-Resistant

Building Construction

March 1991

INTRODUCTION

PURPOSE AND LIMITS OF USE OF THESE BUILDING STANDARDS

Radon is a radioactive gas which occurs naturally in soils. It has been found in high concentrations in some areas of many states, including Florida. Radon can rise from the ground and accumulate in buildings. Its radioactive decay products can cause lung cancer when breathed.

The following building standards have been developed in accordance with Section 553.98, Florida Statutes, to decrease the exposure to indoor radon concentrations in newly constructed buildings.

Principal Approaches for Radon Resistance in Building Design, Construction and Operation

This building standard addresses three principal approaches to limiting radon accumulation in buildings through prevention of its entry:

1. Radon control using the building structure as a gas barrier.

2. Radon control by lowering the air pressure in the soil beneath the building relative to the indoor air pressure of the building.

3. Radon control by separating the building and source with a ventilated region of outside air.

The application of the construction standards contained herein do not guarantee that indoor radon concentrations will be reduced to a certain specific level. These standards are based on the most recent available data, although it is recognized that more research is needed. Scientific research and data collection on radon is continuing and may result in different conclusions, acceptable radon concentration levels, and abatement techniques. The methods and techniques set forth in these standards are for discretionary use as an aid in improving indoor air quality though radon reduction.

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CHAPTER 1

GENERAL

Provisions in the following chapters and sections shall constitute and be known as and may be cited as the Florida Standard For Radon-Resistant Building Construction, hereinafter referred to as "this standard."

101 Intent

101.1 General This standard shall apply to design and construction of buildings as defined in Section 102 "Scope" in order to enable control of human exposure to indoor radon and its progeny.

101.2 Limits This standard is intended to improve indoor air quality with respect to radon. These standards are based on the principle of limiting radon concentrations to a four picocuries per liter level which is accepted as meeting the "not to exceed" .02 working level standard established by the Florida Department of Health and Rehabilitative Services, hereinafter referred to as HRS, and authorized by Section 404.056, Florida Statutes.

102 Scope

102.1 Applicability The provisions of this standard shall apply to the construction of new residential buildings and additions to or renovations of existing residential buildings.

102.2 Existing Buildings When the cost of renovation exceeds 50% of the current value of the building, the entire building must meet the requirements for new buildings in Section 103.2. Buildings having a change of occupancy to residential classification must meet the requirements for new buildings. Exception to this can be made, where shown by pre-construction test, conducted in accordance with Chapter 5 of this standard, that radon does not exist above the HRS standard and no alteration, modification or addition is made to floor and foundation components during construction.

103 Compliance

103.1 General The standard provides different paths by which compliance can be determined. The compliance options include:

(1) Passive mitigation with a post-construction/pre-occupancy test, and
(2) Passive mitigation combined with active mitigation by mechanical systems.

103.2 New Buildings and Additions All new residential buildings and additions to existing residential buildings

shall at a minimum meet one of the following compliance options of this standard:

(1) **Passive Mitigation** (a) Compliance with all parts of Chapter 3 and; (b) a post construction/pre-occupancy indoor radon test, conducted according to Chapter 5, which demonstrates that each residential unit meets the radon exposure standard established by the Florida Department of Health and Rehabilitative Services.
(2) **Passive Plus Active Mitigation** Compliance with all parts of Chapters 3 and 4 of this standard.

103.3 Exemptions Exempt buildings are as follows:

(1) Buildings of occupancy classifications not listed in Section 102.1 Applicability, and
(2) Residential buildings built on piers or pilings that are elevated above grade a minimum of 6 feet and which comply with all requirements of Section 306.

CHAPTER 2

DEFINITIONS

201 General

For the purposes of this code, certain abbreviations, terms, phrases, words and their derivatives shall be set forth in this chapter. Where terms are not defined therein, they shall have the meaning as noted in the applicable locally adopted code. Words not defined in any locally adopted code shall have the meanings in Webster's Ninth New Collegiate Dictionary, as revised.

202 Definitions

AGGREGATE - crushed stone, stone, or other inert material or combinations thereof having hard, strong, durable pieces.

ADDITIONS - An extension or increase in conditioned floor area of a building or structure.

AIR CHANGES - [per hour (ach)] - the number of times within 1 hour that the volume of air inside a building would nominally be replaced, given the rate at which outdoor air is infiltrating the building. If a building has 1 ach, it means that all of the air in the building will be nominally replaced in a 1-hour period.

AIR DISTRIBUTION SYSTEM - For the purposes of this standard air distribution system components include ducts, plenums, air handlers, furnaces, single package air conditioners, etc.

AIR PERMEABILITY (sub-slab) - a measure of the ease with which soil gas and air can flow underneath a concrete slab.

AUTHORIZED GOVERNMENTAL AGENCIES - as relates to testing required by this standard; the Florida Department of Community Affairs, the Florida Department of Health and Rehabilitative Services, and local enforcement agencies.

AUTOMATIC - self-acting, operating by its own mechanism when activated by some personal influence, as for example, a change in current, pressure, temperature or mechanical configuration.

BOND BEAM - in masonry construction, a solid beam that ties the structure together around its perimeter and acts as a diaphragm flange.

CAULKS AND SEALANTS - those materials which will significantly reduce the flow of gases through small openings in the building shell. Among those used are:

Urethane - a crystaline ester-amide used as a gelatinizing agent for cellulose acetate or cellulose nitrate. A component of polyurethane used in making flexible and rigid foams, elastomers, and resins for coatings and adhesives.

Epoxy - a thermosetting resin characterized by adhesiveness, flexibility and resistance to chemicals and used chiefly as a coating or adhesive.

Polysulfide rubber - a synthetic rubber characterized by impermeability to gases and used in adhesives, binders and sealing compositions and in coatings.

CEMENTITIOUS MATERIAL - including natural cements, hydraulic limes, slag cements, and granulated blast-furnace slag.

CONDITIONED FLOOR AREA - the horizontal projection (outside measurements) of that portion of space which is conditioned directly or indirectly by an energy-using system.

CONDITIONED SPACE - all spaces which are provided with heated and/or cooled air or which are maintained at temperatures over 50°F during the heating season, including adjacent connected spaces separated by an uninsulated component (e.g. basements, utility rooms, garages, corridors).

CONTRACTION JOINT - formed, sawed, or tooled groove in a concrete slab to create a weakened plane and regulate the location of cracking resulting from drying and thermal shrinkage (also sometimes called control joints).

CRAWL SPACE - an area beneath the living space in some houses, where the floor of the lowest living area is elevated above grade level. This space (which generally provides only enough head room for a person to crawl in), is not living space, but often contains utilities.

DEPRESSURIZATION - in houses, a condition that exists when the air pressure inside the house is slightly lower than the air pressure outside or the soil gas pressure. The lower levels of houses are essentially always depressurized during cold weather, due to the buoyant force on the warm indoor air (creating the natural thermal stack effect). Houses can also be depressurized by winds and by appliances which exhaust indoor air.

ELASTOMERIC - that property of macromolecular material of returning rapidly to approximately the initial dimensions and shape, after substantial deformation by a weak stress and release of stress.

HIGH RANGE WATER REDUCER - a water reducing admixture capable of producing large water reduction or great flowability without causing undue set retardation or entrapment of air in mortar or concrete (also sometimes called superplasticizer).

HVAC - heating, ventilating and air conditioning.

INFILTRATION BARRIER - a product or system designed to limit the free passage of air through a building envelope component (wall, ceiling or floor). Such products and systems may be continuous or non-continuous discrete elements which are sealed together to form a continuous barrier against air infiltration.

MITIGATE - make less severe, reduce, relieve.

OCCUPANCY - the purpose for which a building or part thereof is used or intended to be used. For the purposes of determining changes of occupancy for this code, the occupancy shall be considered the major occupancy group designations established by the locally adopted building code.

OUTSIDE AIR - air taken from the outdoors and, therefore, not previously circulated through the system.

PARGET - to cover or coat a wall for damp-proofing protection.

PICOCURIE (pCi) - a unit of measurement of radioactivity. A curie is the amount of any radionuclide that undergoes exactly 3.7×10^{10} radioactive disintegrations per second. A picocurie is one trillionth (10^{-12}) of a curie, or 0.037 disintegrations per second.

PICOCURIE PER LITER (pCi/l) - a common unit of measurement of the concentration of radioactivity in a gas. A picocurie per liter corresponds to 0.037 radioactive disintegrations per second in every liter of air.

RADIUM (Ra) - a naturally occurring radioactive element resulting from the decay of uranium. It is the parent of radon.

RADON - a naturally occurring, chemically inert, radioactive gas. It is part of the uranium - 238 decay series, it is the direct decay product of radium - 226.

REMOTE SPACE - a space isolated from the main conditioned area of a building by intermediate non-conditioned spaces.

RESIDENTIAL BUILDING - residential occupancies which include single-family and multifamily buildings that are three or fewer stories above grade. Hotels, motels and other transient occupancies are considered non-residential buildings for the purpose of this standard.

SLUMP - A measure of the relative consistency of stiffness of fresh concrete mix.

SOIL DEPRESSURIZATION SYSTEM - a system designed to withdraw air below the slab through means of a vent pipe and fan arrangement

(active) or a system designed to lower sub-slab air pressure by use of a vent pipe to the outside but relying solely on convective air flow of upward air in the vent (passive).

SOIL GAS - gas which is always present underground, in the small spaces between particles of the soil or in crevices in rock. Major constituents of soil gas include nitrogen, water vapor, carbon dioxide, and (near the surface) oxygen. Since radium-226 is essentially always present in the soil or rock, trace levels of radon-222 will exist in the soil gas.

SOIL GAS RETARDER - a concrete slab; polyvinylchloride (PVC), ethylenepropylene diene terpolymer (EPDM), neoprene, cross laminated HDPE or other flexible sheet material; or other system of materials placed between the soil and the building for the purpose of reducing the flow of soil gas into the building.

STACK EFFECT - the upward movement of building air when the weather is cold, caused by the buoyant force on the warm building air. Building air leaks out at the upper levels of the building, so that outdoor air (and soil gas) must leak in at the lower levels to compensate. The continuous exfiltration upstairs and infiltration downstairs maintain the stack effect air movement, so named because it is similar in principle to hot combustion gases rising up a fireplace or furnace flue stack.

SUB-SLAB MEMBRANE - A sheeting material placed under the slab and over the slab base which retards the flow of soil gas to the slab's lower surface. Typically the sub-slab moisture barrier forms a sub-slab membrane, but it may also be a special purpose product.

SUPERPLASTICIZER - see High Range Water Reducer.

VENTILATION - the process of supplying or removing air, by natural or mechanical means, to or from any space. Such air may or may not have been conditioned.

VENTILATION AIR - that portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

VENTILATION RATE - the rate at which outdoor air enters the building, displacing building air. The ventilation rate depends on the tightness of the building shell, weather conditions, and the operation of appliances (such as fans) influencing air movement. Commonly expressed in terms of air changes per hour (ach), or cubic feet per minute.

WATER COLUMN - a term used to describe air pressure. Part of a water gauge.

WATER GAUGE - an instrument for measuring a moderate air pressure hydrostatically as in a ventilating system usually expressed in inches of height.

CHAPTER 3

MINIMUM STRUCTURAL AND MECHANICAL CONSTRUCTION REQUIREMENTS

301 General

This chapter provides minimum design and construction criteria for passive mitigation of radon entry into residential buildings. Construction to these standards will limit radon entry points through buildings' floors and foundations and will limit mechanical depressurization of buildings which can enhance radon entry. Passive mitigation is believed to be effective up to certain, as yet unidentified, levels of radon in soil gases under buildings. For buildings over soils above those levels additional actions are required. Buildings shall comply with all provisions of this chapter applicable to the floor system, space conditioning system and ventilation system types incorporated in their construction.

302 SUB-SLAB AND SOIL COVER MEMBRANES

A membrane shall consist of a minimum 6 mil single layer of non-corroding, non-deteriorating polyethylene or equivalent placed to minimize seams and to cover all of the soil below the building floor. The membrane shall be cut in cross shape for pipes or other penetrations; the membrane shall extend to within 1/2 inch of all pipes or other penetrations. All seams of the membrane shall be lapped at least 12 inches. Punctures or tears in the membrane shall be repaired with the same or compatible material.

303 FLOOR SLAB-ON-GRADE BUILDINGS

303.1 General

All concrete slabs supported on soil and used as floors for conditioned space or enclosed spaces connected or adjacent to a conditioned space shall be constructed in accordance with the provisions of Section 302 and this Section.

303.2 Concrete for Slabs

303.2.1 Mix Design Mix designs for all concrete used in the construction of slab on grade floors shall specify a slump not to exceed 4 inches. Total water added to the mix (including plant, transit and site added water) shall not exceed:

(1) For Mixes Using Natural Sands - 275 pounds per cubic yard or the amount required to achieve a maximum 4 inch slump, whichever is less.

(2) For Mixes Using Manufactured Sands - 292 pounds per cubic yard or the amount required to achieve a maximum 4 inch slump, whichever is less.

303.2.2 Workability For concrete used in the construction of slab on grade floors, the following shall apply for concrete poured on site:

(1) Slumps of concrete, as measured on site at the point of discharge from the delivery vehicle, shall not exceed 4 inches except where high range water reducing admixtures are used. On site addition of water shall be in compliance with ASTM C94 and in no case shall exceed the amount required to achieve the maximum 4 inch slump and the limitations of Section 303.2.1 of this standard.

(2) High range water reducing admixtures shall be utilized to achieve the slumps in excess of 4 inches. Water in excess of the limitations of Section 303.2.1 of this standard shall not be used to achieve the slump in excess of 4 inches. Slumps of concrete containing high range water reducing admixtures shall not exceed 8 inches.

303.3 Slab Design

303.3.1 Contraction Joints Contraction joints should be constructed in concrete slabs-on-grade in areas known to have significant potential for radon in the soil gas. Contraction joints should be constructed at intervals not greater than 15 feet in each direction and placed in a way that the ratio of the slab sides of the resultant panels should not exceed 1.5 to 1. Contraction joints should also be located at re-entrant corners, such as the inside corner of L or U shaped slabs and where an abrupt change in thickness of the slab occurs. Contraction joints are not necessary in post-tensioned slabs.

Contraction joints shall be constructed by placement of crack inducers at the bottom surface of the slab or by saw cuts or other means of slotting at the slab's upper surface. Where contraction joints are induced at the slab bottom surface, the crack inducer should extend into the slab at least 1/2 thickness. Contraction joints shall be sealed against radon entrance with waterstops; waterstops shall be placed at the top of the soil gas retarder before the construction of the slab according to Section 303.5.1 and shall be embedded in the concrete, thus inducing and sealing the contraction joints. Waterstops shall be positively joined to provide a continuous seal. Contraction joints constructed at the slab's upper surface shall be formed in during the slab pour using premolded joint product or by saw cuts after the slab is poured. The recesses should be a minimum of 1/4 to 1/3 of the slab thickness. Contraction joints installed by the sawcut method should be installed within 4 to 6 hours after

placement of the concrete. Contraction joints installed by proprietary sawcut methods having demonstrated success with lesser contraction joint depths and/or earlier sawcutting times shall be allowed. The joints shall be sealed using approved sealants according to 303.5.1.

303.3.2 Slab Reinforcement Slabs-on-grade shall be reinforced by steel reinforcing bars at re-entrant corners such as inside corners of an L-shaped slab and at rectangular openings or penetrations greater than 6 inches outside. Re-entrant corners shall have two pieces of #4 reinforcing bar 36 inches long placed diagonal to the corner 12 inches apart with the first bar placed 2 inches from the corner. Openings shall have four pieces of #4 reinforcing bar placed diagonal to the corners with each bar extending a minimum of 15 inches past the intersection with the adjacent bar. All reinforcement shall be appropriately positioned in the upper third of the slab. If reinforcing mesh is used in slabs it should be cut at the contraction joint. If fiber reinforcement is used, such fibers shall comply with ASTM C-1116, "Standard Specifications For Fiber-Reinforced Concrete and Shotcrete". Their use in construction shall be in accordance with the practice recommended by the fiber manufacturers and the ACI Committee 544, "State of the Art Report on Fiber Reinforced Concrete".

303.3.3 Slab Edge Detail Slabs and foundations shall be constructed using the slab edge detail which provides the minimum vertical edge joint and is consistent with other construction constraints such as terrain. Monolithic slab construction should be used where possible. Only the following slab edge detail options may be used:

(1) Thickened Edge Monolithic - The sub-slab membrane (soil gas retarder) shall extend beyond the outside face of the slab edge.
(2) Stem Wall Capped by Slab - The sub-slab membrane shall be laid between the stem wall and slab and shall extend to the outer surface of the stem wall. The stem wall shall be sealed either by (a) a solid masonry unit placed immediately underneath the slab, or (b) a thickened slab edge forming a minimum 8 inch thick perimeter beam.
(3) Slab Poured Into Stem Wall - Where concrete blocks are used as slab forms the slab shall be poured onto the stem wall and extend to the inside surface of the block outer face in one of the following ways: (a) using solid header Blocks with a solid base of 4 inch minimum thickness as stem wall caps, the sub-slab membrane shall be placed over the solid base of the cap block and shall not extend up its vertical face, and the concrete shall be placed against the vertical face to form a continuous and solid stem wall cap of minimum 8 inch thickness; or (b) using a bond beam or lintel block or a header block, the sub-slab membrane shall be drawn to and turned down along the inside surface of the stem wall, and the concrete shall be placed against the outside face and into the cores of the header/lintel block, forming a continuous and solid stem wall cap of minimum 8 inch thickness.

303.4 Slab Construction Practices

303.4.1 Backfill Compaction Backfill shall be compacted to a relative compaction of 90 percent in accordance with ASTM D698 Standard Proctor Density Test.

303.4.2 Curing Concrete slabs shall be continuously cured for a minimum of 7 days. Curing shall be accomplished with one of the following procedures:

(1) moist curing by means of ponding, fog spray or wet burlap;
(2) moisture retention by means of impermeable sheet materials conforming with ASTM C171; or
(3) liquid membrane forming compound conforming with ASTM C309.

Curing compounds shall be compatible with materials specified in Section 303.7.2.

303.4.3 Loading Loading or use of the slab shall be delayed for a minimum of 48 hours after pouring. When the slab is used for material storage after the mandatory delay period, caution should be used to prevent impact loading.

303.5 Sealing of Joints, Penetrations and Cracks in Slabs

303.5.1 Contraction Joints Where occurring, contraction joints shall be constructed as per 303.3.1 and sealed against soil-gas entry by either: (a) for bottom surface induced joints, the use of approved waterstops of width not less than 6 inches made of material that is impermeable to air passage and shaped as an inverted T-split ribbed waterstop, or (b) for top surface induced joints, the use of an approved sealant (see Section 303.7) applied according to the manufacturer's instructions. (Note: most sealants require the concrete to be cured and dried.)

303.5.2 Penetrations

303.5.2.1 Stake Penetrations The use of grade or support stakes which penetrate the sub-slab membrane should be avoided. Permanent and/or temporary concrete blocks or screed chairs shall be used when practical.

Where stakes are used to support plumbing, electrical conduits or other objects which penetrate the slab, they shall be sealed to the slab in accordance with Section 303.7.2 and they shall be solid or have the upper end sealed tightly by installation of an end cap designed to provide a gas-tight seal. Such stakes shall be of non-porous material resistant to decay, corrosion and rust.

303.5.2.2 Large Work Spaces Where large work spaces are formed into a slab, such as beneath a bath tub drain, the slab shall be reinforced according to Section 303.3.2 and the exposed soil shall be fully covered with a solvent based plastic roof cement or other approved material to a minimum depth of 1 inch.

303.5.2.3 Pipe Penetrations Pipes shall be in contact with the slab along the slab's depth by casting the concrete tightly against the pipe. Where pipes are jacketed by sleeves they shall be sealed by one of the following methods:

(1) have the joint between the sleeve and the slab sealed with an appropriate joint sealant, as in Section 303.5.2.4, and the pipe sleeve sealed by prefabricated boots placed on the top of the sleeve, or

(2) formation of a slot in the slab around the pipe and casting with an approved sealant from the slab to a point above the sleeve.

(3) pipes and wiring penetrating the slab through chases or conduit shall be sealed by placing an approved sealant between the pipe or wiring and chase or conduit. Plastic sheath, foam or

insulation material shall not be used alone around pipes or conduit for sealing purposes.

303.5.2.4 Vertical Joints Through Slabs Vertical joints through slabs including but not limited to joints in dropped panels shall be formed with a recess of not less than 1/4 inch by 1/4 inch and sealed with an approved sealant. Exception: Vertical joints between the slab and header/lintel blocks used as forms (see Section 303.3.3(3)(b)). An approved sealant (see Section 303.7) shall be applied according to the manufacturer's instructions. (Note: most sealants require the concrete to be cured and dried.)

303.5.3 Cracks Cracks with widths less than 1/32 inch need not be sealed. Cracks with widths between 1/32 and 1/16 inch shall be repaired by the application of an elastomeric material capable of withstanding at least 25 percent extension. The elastomeric material shall extend at least 4 inches beyond the length and width of the crack.

Cracks with widths larger than 1/16 inch shall be routed to a recess with minimum dimensions of 1/4 inch by 1/4 inch and sealed with an approved sealant.

303.6 Sealing Walls Framed walls placed on slabs on grade shall be sealed or gasketed to the slab. Penetrations for electrical receptacle and switches, wiring, plumbing, etc. in the interior surface of the concrete block walls shall be sealed.

303.7 Approved Sealant Material

303.7.1 Waterstops Material shall be preformed from plastic or other noncorrosive material and shall be of the flat ribbed or base seal type of waterstop. Waterstops shall be impermeable to soil-gas.

303.7.2 Sealants Acceptable polyurethane, polysulfide and epoxy caulks and sealants shall conform with ASTM C920-87 "Standard Specifications for Elastomeric Joint Sealants" and ASTM C962-86 "Standard Guide for Use of Elastomeric Joint Sealants." Sealant material and the method of application shall be compatible with curing compounds, admixtures and floor finishing materials; withstand light traffic; be impermeable to soil-gas; and have an allowable extension and compression of at least 25 percent with 100 percent recovery. Sealants shall be applied to dried and cured concrete in accordance with manufacturers' instructions. Soil-gas impermeable backer rods may be used to support sealants in cracks and joints.

Sealants shown to have equivalent adhesion and durability may be used as alternate materials.

304 SLAB-BELOW-GRADE CONSTRUCTION

304.1 General For the purposes of this standard, slab-below-grade construction is defined as any habitable space with the finished floor below finished grade at any point.

304.2 Slab Construction Slabs shall have a sub-slab membrane in conformance with Section 302, and shall be placed in accordance with Section 303.

304.3 Sealing Walls

304.3.1 Walls Below Grade Walls surrounding slab-below-grade space shall be constructed with a continuous waterproofing membrane applied to the outside surface from the top of the footing to finished grade. This membrane should be sealed to the top of the footing to completely seal the joint between the footing and the wall.

304.3.2 Utility Penetrations All utility penetrations through walls in partial or full contact with the soil, shall be closed and sealed with an approved material on the interior and exterior faces of the wall.

304.3.3 Hollow Cavity Walls Below grade hollow walls in contact with the soil shall be fully sealed by solid concrete blocks, a concrete bond beam, or other approved means above finished grade.

The interior surface of hollow walls in contact with the soil and bounding conditioned space shall be pargetted and coated using cementitious or elastomeric coatings from floor to the cap block level required by this Section.

304.4 Sumps

Any sump located in a habitable portion of a building, or in an enclosed space directly attached to a portion of a building, shall be covered by a lid. An air tight seal shall be formed between the sump and lid and at any wire or pipe penetrations.

305 OFF-GRADE FLOOR BUILDINGS WITH CRAWL SPACE

305.1 General For the purposes of this standard, off-grade floor buildings with crawl spaces include all buildings with floor supported above grade which do not meet the requirements of Section 306.

305.2 Reinforced Concrete Floors Reinforced concrete floors constructed over crawl spaces shall conform to all applicable provisions of Section 303.

305.3 Wood Framed Floors Wood framed floors constructed over crawl spaces shall include an air infiltration barrier in compliance with the "Florida Energy Efficiency Code for Building Construction", 1991, sections 903.2(f)2 and 903.2(g)1b(1). Radon resistance is dependent upon strict compliance with the following provisions of that code:

305.3.1 Penetrations All penetrations through the subfloor, including but not limited to plumbing pipes, wiring and ductwork, shall be fully sealed with an approved caulk. Where large openings are created (such as at bath tub drains), sheet metal or other rigid materials shall be used in conjunction with sealants to close and seal the opening; and

305.3.2 Vertical Joints Any vertical joint between the subfloor and foundation wall or the subfloor and any vertical plane of the building, which extends from the crawl space to the top of the subfloor, shall be sealed with an approved sealant or caulk.

305.4 Sealing Walls and Doors Penetrations from the crawl space into wall cavities shall be fully sealed with an approved caulk or sealant. When a door is located in a wall between a crawl space and the conditioned space, it shall be fully weatherstripped or gasketed.

305.5 Closing and Sealing Other Paths Any openings which connect a crawl space and the space between floor or ceiling joists, wall studs, or any other cavity adjoining conditioned space shall be closed and sealed.

306 ELEVATED BUILDINGS

306.1 General For the purposes of this standard, elevated buildings (typically found in flood plain and coastal zone areas), are those supported substantially off-grade by pilings, poles or other supports over an unenclosed area which satisfy all of the following:

306.1.1 Vertical Separation A minimum of 6 feet vertical separation between the soil and the bottom side of the sub-floor at all points under conditioned spaces; and

306.1.2 Perimeter The perimeter of the building from the ground plane to the lower surface of the floor shall be totally open for ventilation, except for the occurrence of enclosures complying with Section 306.1.4; and

306.1.3 Soil Contact Points All pilings, posts or other supports shall be solid, or if hollow shall be capped or sealed; and

306.1.4 Enclosures Enclosures of any kind, including chases, storage rooms, elevator shafts and stairwells, etc., that connect between the soil and the remainder of the structure shall be

sealed at the surface of the soil with a construction complying with the sealing provisions of this chapter and shall have a soil contact area of less than 5% of the total building floor area.

307 COMBINATION FLOOR SYSTEMS BUILDINGS

307.1 Floor System Construction Where slab-on-grade, slab-below-grade, crawl space or elevated building construction are combined in one structure, the provisions for each construction type shall be met.

307.2 Walls A wall located between a crawl space and habitable space shall be designed and constructed in compliance with the "Florida Energy Efficiency Code for Building Construction", 1991, 903.2(g), and the provisions of the applicable Sections 303 through 306 of this standard.

308 SPACE CONDITIONING SYSTEMS (HVAC)

308.1 Equipment Rooms and Enclosures

308.1.1 Garage Ventilation Garages containing air distribution system equipment and clothes dryers shall be vented to the outdoors, but not to the attic, by non-closing air transfer openings. These openings should be sized to not less than 100 square inches for each dryer. Vents are not required if a dryer is located in the garage not containing an air handler. Combustion heating devices shall be provided with outside air for combustion and dilution in accordance with local codes for confined spaces. These provisions for combustion air are in addition to the venting requirements listed above.

308.1.2 Garage Floor and Wall Sealing Cracks and joints in floor slabs of garages containing air distribution system equipment shall be sealed in accordance with Sections 303.5, 303.6 and 303.7.

308.1.3 Crawl Spaces Return ducts, return plenums, and air handlers shall not be located in crawl spaces. Crawl spaces shall not be used for supply or return plenums.

308.1.4 Condensate Drains, Piping and Wiring Chases Condensate drain pipe joints shall be sealed (chemical weld, soldered, etc.) gas tight and shall terminate outside the building perimeter at a height of at least 6 inches above the finished grade ground level. A portion of the condensate pipe shall drop a minimum of two pipe diameters below the height of the condensate outlet, or a trap shall be installed to prevent suction of outdoor air into the air handler. Chases through which the condensate and refrigerant lines run shall not terminate in the return sections of the air distribution system. Where chase lines terminate within the house or garage, they shall be sealed.

308.1.5 Air Handler Clearance A minimum 8 inch clearance from adjacent walls and floors shall be provided for access to air distribution system components located in a closet, utility room, garage, attic, or other enclosed space. When enclosed by walls on three sides, clearance shall be 8 inches minimum at the back and on one side, and 14 inches on the other side.

308.2 Air Distribution Systems

308.2.1 Sealing All ducts and plenums shall be made airtight, constructed and installed in accordance with the "Florida Energy Efficiency Code for Building Construction", 1991. Where rigid fibrous glass ductboard is used, the seal must be on the foil air barrier side of the ductboard.

308.2.2 Return Plenums and Ducts Return air shall be separated from any floor that is in contact with the soil or a crawl space, by a plenum or duct fabricated in compliance with Section 308.2.1 and all local codes. Construction of the return plenum or duct shall provide a continuous air barrier that completely separates the depressurized plenum or duct from adjacent building components including but not limited to floors, walls, chases, enclosures, etc.

The support platform shall not be used as a return plenum. Where the support platform provides a protective enclosure for a duct, one side shall have a removable panel or door to provide access for inspection and/or repair of the duct and duct-to-air handler connection. Ducts shall carry the return air from the return grills or return plenums to the air handler and shall have a positive airtight seal to the air handler. A closet shall not be used as a return plenum.

308.2.3 Return Grill Connection The return pathway from the return grill shall be a part of the return duct or plenum and shall have a continuous air barrier along its boundary. Where the return pathway passes through a wall cavity, the cavity shall be sealed around the duct in all directions to prevent the leakage of air into the return air stream.

308.2.4 Location of Returns Return ducts and plenums shall not be located in crawl spaces (see Section 308.1.5) nor below concrete slab on grade floors. Where a door closes off a conditioned portion of the building from the space containing the distribution system's primary return, the enclosed room or rooms shall have provision for return air transport, by means of return ducts, transfer grills, transfer ducts, door undercuts, or other applications. If return ducts are provided to individual rooms, they shall be sized to carry the same air flow as the supply ducts. Return ducts and transfer openings shall be sized in accordance with Air Conditioning Contractors of America or Sheet Metal and Air Conditioning Contractors National Association, Inc. sizing guidelines.

308.2.5 Crossing Zones Where zones can be separated by door closure, supply air from one zone should not be provided to portions of the building which are in another zone. Where such zone crossovers are unavoidable provisions shall be made for a properly sized return to match the crossover supply.

Supply air shall not be provided to remote spaces, such as remote storage or utility rooms, without provision for an equal amount of return air or makeup air to the system. Supply air shall not be provided to garages and workshops from systems serving main living areas. Such spaces when conditioned, shall have a separate space conditioning system.

308.2.6 Supply Box The junction of supply boxes to supply registers shall be sealed and secured. Boxes shall be secured by straps pressing the box down to the register. The connection between supply boxes and the sheet rock shall be sealed. All seals shall be made with mastic or mastic plus fabric.

308.3 Supply Ducts and Plenums Supply ducts and plenums shall not be located below concrete slab on grade floors.

308.4 Exhaust Fans

308.4.1 Bathroom Fans Bathroom exhaust fans shall be controlled by an independent switch. Manually operated timers should be used as applicable.

308.4.2 Kitchen Fans Kitchen exhaust fans shall be controlled by their own switches independent of other appliances.

308.4.3 Attic Fans Attic exhaust fans shall be installed with unobstructed vent areas in accordance with the minimum areas prescribed by their manufacturer. In no case shall effective open areas be less than the minimum area prescribed by the manufacturer.

CHAPTER 4

SYSTEMS FOR ACTIVE RADON MITIGATION

401 General

This chapter provides design and construction criteria for active radon mitigation systems. Active mitigation systems in conjunction with passive mitigation construction is currently recognized as being reliable in the mitigation of radon in buildings. Buildings built on slabs on grade shall comply with all requirement of Section 402. Buildings built on off grade floors shall comply with all requirements of either Section 403 or Section 404.

402 SUB-SLAB DEPRESSURIZATION SYSTEMS

402.1 General These systems apply to residential buildings with floor types identified by Sections 303 or 304 of this standard. The operating soil depressurization system shall maintain under the entire building a pressure less than the indoor air pressure by strict adherence to the requirements of Sections 402.2 and 402.3 and 402.4, and either 402.5, 402.6, or 402.7 as appropriate.

402.2 Suction Fans

402.2.1 Rating The ratings specific to system type shall apply (see Sections 402.5.4, 402.6.4, 402.7.4).

402.2.2 Fan Suction shall be provided by a fan, rated for continuous operation and having thermal overload with automatic reset features.

402.2.3 Seal The suction fan shall be designed and manufactured to provide an air-tight seal between the inlet and outlet ducts and the fan housing. The fan housing must remain air-tight at air pressure equal to the rated maximum operating pressure.

402.3 Alarm The soil depressurization system shall include a system failure alarm which shall be either a visual device, (a light of not less than 1/5 footcandle at the floor level) conveniently visible to building occupants, or a device that produces a minimum 60 db audible signal.

402.4 Vents

402.4.1 Material Piping material shall be of any type approved by locally adopted codes for plumbing vents.

402.4.2 Grade The vent piping shall have a minimum slope of 1/8 inch per foot in order to drain any condensation back to soil beneath the sub-slab membrane. The system shall be designed and installed so that no portion will allow the excess accumulation of condensation.

402.4.3 Terminals Vent pipes shall be terminated above the roof and at least 10 feet from any operable openings or air intake or other air distribution system equipment and directed away from any operable openings or air intakes.

402.4.4 Labeling All exposed components of the soil depressurization system shall be labeled "Soil Gas System" to prevent accidental damage or misuse. Labels shall be on a yellow band, two inches wide and spaced three feet apart on all components.

402.5 Depressurization Systems in Sands or Granular Soils / Suction Pit Design

Depressurization systems in sands or other granular soils (known to have an air permeability greater than or equal to 10^{-12} m^2) at least 8 inches deep shall meet the requirements of Sections 402.2, 402.3, 402.4, 402.5.1, 402.5.2, 402.5.3 and 402.5.4.

402.5.1 Arrangement A minimum number of suction points shall be equally distributed as follows:

(1) A maximum of 1300 square feet per suction point; and
(2) Each suction point shall be located not less than 6 feet or more than 18 feet from the perimeter; and
(3) Multiple suction points shall be located within 36 feet of each other.

402.5.2 Pits Suction point pits shall conform to one of the following designs:

(1) A hemispherical open pit at least 22 inches in diameter and 11 inches deep, with a cover of 1/2 inch minimum thickness pressure treated plywood or other decay-resistant material, installed below the soil-gas barrier; or
(2) A pit at least 32 inches in diameter and 16 inches deep filled with 1 inch or larger washed gravel and covered by the soil-gas barrier; or
(3) A manufactured ventilation mat having a minimum net suction area in contact with the soil of 10 square feet, installed below the sub-slab membrane.

402.5.3 Pipe Size Suction pipe shall be a minimum of 2 inches in diameter and shall be carried full size through the roof.

402.5.4 Fan Rating Each suction fan shall be rated for not less than 10 cfm at 5 inch water column.

402.6 Depressurization Systems in Sands or Granular Soils / Continuous Ventilation Mat(s) Design

Depressurization systems in sands or other granular soils (known to have an air permeability greater than or equal to 10^{-12} m^2) at least 8 inches deep and utilizing a continuous ventilation mat shall meet the requirements of Sections 402.2, 402.3, 402.4, 402.6.1, 402.6.2, 402.6.3 and 402.6.4.

402.6.1 Arrangement Suction points shall be equally distributed as follows:

(1) The suction point should be centrally located along the length of each unconnected strip of mat; and
(2) Mat strips should be oriented along the central axis of the longest dimension of the slab; and
(3) A minimum of one strip shall be used for slabs having widths up to 50 feet (Additional strips should be added for each additional slab width of up to 50 feet width.); and
(4) The mat strip shall extend to not closer than 6 feet of the inner stemwall at both ends of the building; and
(5) A separate suction point and fan shall be installed for each 100 feet linear length of ventilation mat.

402.6.2 Ventilation Mat Ventilation mat shall have a minimum of 216 square inches of suction area per lineal foot.

402.6.3 Pipe Size Suction pipe shall be a minimum 3 inch diameter and shall be carried full size through the roof.

402.6.4 Fan Rating Suction fans must be capable of developing minimum flows of at least 100 cfm, at 1 inch water column pressure.

402.7 Depressurization Systems in 1 Inch Average Aggregate Fill

Depressurization systems in aggregate shall meet the requirements of Sections 402.2, 402.3, 402.4, 402.7.1, 402.7.2, 402.7.3 and 402.7.4.

402.7.1 Arrangement Suction points shall be equally distributed and centrally located with a maximum of 2500 square feet floor area per suction point.

402.7.2 Aggregate Aggregate shall be equal to or larger than the following: 100% passing a 2 inch grate; 90 to 100% passing a 1-1/2 inch grate; 20-55% passing a 1 inch grate; 0-15% passing a 3/4 inch grate; and 0-5% passing a 3/8 inch grate. The aggregate shall form a continuous layer which is a minimum of 6 inches deep.

402.7.3 Pipe Size Suction points shall be connected to the depressurization fan by a minimum 3 inch diameter riser and shall

begin with a "tee" fitting, or another approved means that provides for air flow from the gravel layer.

402.7.4 Fan Rating Suction fans must be capable of developing flows of at least 100 cfm at 1 inch water column pressure.

403 SUB-MEMBRANE DEPRESSURIZATION SYSTEMS

403.1 General These systems apply to residential buildings with floor types identified by Section 305 of this standard. The operating soil depressurization system shall maintain under the entire building a pressure less than the indoor air pressure by strict adherence to the requirements of Sections 402.2, 402.3, 402.4, 403.1, 403.2, 403.3, and 403.4. Soil cover membranes shall meet the criteria of Section 302 of this standard. For unenclosed crawl spaces only, the membrane shall be protected from wind uplift in accordance with locally adopted codes.

403.2 Sub-Membrane Systems on Sands or Granular Soils / Suction Pit Design Sub-membrane soil depressurization systems of suction pit designs covering sand or other granular soils at least 8 inches deep (known to have an air permeability $\geq 10^{-12}$ m^2) shall meet the requirements of Sections 402.2, 402.3, 402.4 and 402.5.

403.3 Sub-Membrane Systems on Sands or Granular Soils / Continuous Ventilation Mat(s) Design Sub-membrane soil depressurization systems of continuous ventilation mat design on sands or granular soils at least 8 inches deep shall meet the requirements of Sections 402.2, 402.3, 402.4 and 402.6.

403.4 Sub-membrane Systems on 1 inch or Larger Aggregate Fill Sub-membrane suction systems covering a minimum 6 inch deep layer of aggregate having a 1 inch average diameter stone shall satisfy the requirements of Sections 402.2, 402.3, 402.4 and 402.7.

404 CRAWL SPACE VENTILATION SYSTEMS

404.1 General These systems apply to residential buildings with floor types identified by Section 305 of this standard.

404.1.1 Ventilation Rate One or more electrically driven ventilation fans shall be installed to cause not less than 3 air-changes per hour in the space exposed to the soil by blowing outside air into or drawing crawl space air from the central region of the crawl space.

404.1.2 Vents Screened vents connecting the crawl space with outside air shall be sized according to locally adopted codes and shall not be equipped with closures of any kind, and shall be distributed equally about the perimeter wall.

404.1.3 Soil Connection Foundation walls and piers or other intermediate supports that intersect the floor plane shall be solid across the entire horizontal section at a point above the ground plane.

404.1.4 Plumbing Plumbing located in the crawl space shall be adequately protected from freezing by insulation or means other than restriction of ventilation air.

404.1.5 Floor Sealing The floor must be sealed in accordance with Section 304 of this standard.

CHAPTER 5

TESTING FOR MITIGATION EFFECTIVENESS

501 GENERAL

This chapter establishes testing and test data interpretation criteria for determining compliance with this standard. The Florida Department of Health and Rehabilitative Services (HRS) standard establishes "not to exceed" limits for exposure to radon progeny in terms of annual average working levels (.02 WL). This chapter provides relationships between short term (measurements less than one year duration) measured radon concentrations and annual average progeny concentrations for compliance determination.

502 PROCEDURE

502.1 Contractors All tests will be performed by radon test contractors certified by the HRS.

502.2 Test Methods and Compliance Criteria

502.2.1 General Test Procedures Testing shall be conducted according to the procedures in the appropriate sections of EPA 520/1-89-009, "Indoor Radon and Radon Decay Product Measurement Protocols" (US EPA, 1989).

502.2.2 Acceptable Devices The following combinations of test devices and applicable test periods are approved. In each case the device shall be operated according to the appropriate Section of EPA 520/1-89-009.

(1) Continuous radon monitor - 48 hours to 1 year
(2) Electret-Ion Chambers (High Sensitivity Electret) - 72 hours to 28 days with provision that test is valid only if final electret voltage is greater than 200 volts
(3) Electret-Ion Chamber (Low Sensitivity Electret) - 14 days to 1 year with provision that test is valid only if final electret voltage is greater than 200 volts
(4) Charcoal Canister (open face) - 48 to 72 hours
(5) Charcoal Canister (diffusion barrier) - 5 to 10 days

502.2.3 Compliance Criteria The building will be in compliance with the standard if the short term concentration, determined by approved testing, is less than the value in Table 5.1. If multiple measurements are made, the average of those measurements shall be used to determine compliance.

The values in Table 5.1 have been determined to assure with 80% confidence that the annual average radon concentration does not exceed four picocuries per liter. The four picocuries per liter level is accepted as meeting the "not to exceed" .02 working level standard established by the Florida Department of Health and Rehabilitative Services.

Table 5.1 Compliance Criteria for One Radon Measurement

Device	Measurement Period	Concentration (pCi/l)
Continuous Radon Monitor	47 hr. to 120 hr.(5 days)	3.2
	5 days to 10 days	3.4
	11 days or longer	3.5
Electret-Ion Chambers (High Sensitivity)	5 days to 10 days	3.0
	11 days or longer	3.3
Electret-Ion Chambers (Low Sensitivity)	14 days to 25 days	2.9
	26 days or longer	3.3
Charcoal Canister (open face)	47 hr. to 73 hr.	3.0
Charcoal Canister (barrier)	5 days to 10 days	3.1
