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NATIONAL STANDARD OF CANADA
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Radon mitigation options for existing buildings

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CAN/CGSB-149.12-2024

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Radon mitigation options for existing buildings

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Translation of this National Standard of Canada was conducted by the Government of Canada.

Preface

This National Standard of Canada CAN/CGSB-149.12-2024 supersedes CAN/CGSB-149.12-2017 (R2023), *Radon mitigation options for existing low-rise residential buildings*.

This is the second edition of National Standard of Canada CAN/CGSB-149.12.

Compliance with this standard will not guarantee that specific indoor radon concentrations will be attained.

This standard has been developed to apply to Canadian environments. While it may be appropriate for other jurisdictions, users outside of Canada are responsible for assessing its applicability.

This standard does not apply to radon control measures that have been installed prior to the effective date of this standard.

Changes since the previous edition

There have been several changes to CAN/CGSB-149.12-2017 (R2023). They are as follows:

- The scope of the standard has been expanded to existing buildings, not just low-rise residential buildings. For further details, see 1.1 for a statement on building applicability.
- The standard provides two technical solutions for reducing radon levels in existing buildings. These two are as follows:
  - Active soil depressurization – the preferred method for reducing radon levels in existing buildings.
  - Ventilation – an alternative method for reducing radon levels that may be more feasible when active soil depressurization is not possible for a particular building.

Note: Sealing of potential entry points is considered a prerequisite for both of the above methods. Sealing alone is not considered a standalone radon mitigation method.

As a result of the above changes, the title, introduction and scope of the standard have been modified.

- A more comprehensive step-by-step description of fan-sizing and system design has been included.
- Terms and definitions, normative references and bibliography have been updated and expanded.
- The order of content featured in the sections of the active soil depressurization section standard were rearranged to better reflect the order of construction of a radon control system.
- The pipe standards references have been updated to reflect current National Building Code requirements and to add specific marking requirements for pipe products made specifically for radon gas.

The following definitions apply in understanding how to implement this National Standard of Canada:

- "shall" indicates a **requirement**;
- "should" indicates a **recommendation**;

- "may" is used to indicate that something is **permitted**;
- "can" is used to indicate that something is **possible**, for example, that an organization is able to do something.

Notes accompanying clauses do not include requirements or alternative requirements. The purpose of a note accompanying a clause is to separate explanatory or informative material from the text. Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

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Introduction

Background

Radon is a radioactive gas that is a decay product of uranium, and is found everywhere in rocks and soil. Radon gas that emanates from rock can move through the pore spaces between granular particles in the ground into enclosed spaces like buildings, where it can accumulate to high levels. Through inhalation, this increases the long term risk of lung cancer for occupants.

Indoor radon gas concentrations depend on the radon gas infiltration rate and the rate at which diluting outdoor air enters the building. The rate at which soil gas containing radon enters a building depends on:

- the radon concentration in the soil gas;
- the resistance of the ground to gas movement, which is affected by bedrock type, soil type and structure, soil moisture, and freezing;
- the building foundation design and construction;
- openings in the building envelope where it is in contact with the soil; and
- the pressure differences between the building and the soil.

To determine the radon gas concentrations inside a building, Health Canada recommends that a long-term radon test be conducted during the heating season. Long-term tests are used to determine the average annual radon gas concentration. Long-term tests should also be conducted following any renovation work.

Health Canada recommends that remedial measures be undertaken in a building whenever the average annual radon concentration exceeds 200 Bq/m^3 (Becquerel's per cubic metre) in the normal occupancy area[1].

Purpose and intent

The purpose of this National Standard of Canada is to provide technical solutions for the mitigation of radon gas infiltration into existing buildings from the ground.

Radon mitigation of existing buildings is a complex task, associated with many variables. These technical solutions are therefore intended for use by qualified practitioners, such as radon mitigation professionals certified under the Canadian ─ National Radon Proficiency Program (C-NRPP).

Note: In this standard, references to C-NRPP or approval by C-NRPP “or equivalent” refer to equivalent organizations or individuals that provide a radon proficiency program recommended by Health Canada.

The standard also provides guidance suitable for voluntary action and for use by professional training and certification programs. Organizations such as the C-NRPP provide information and training on radon gas control and mitigation for existing buildings.

The standard focuses on mitigation through reduction of radon gas infiltrating into an existing building from the ground. It also includes ventilation strategies to sufficiently reduce radon gas concentrations in occupied spaces. Included are details for communication testing, fan sizing, material/product selection and installation guidance for an active soil depressurization (ASD) system and post-installation testing of an ASD. Guidance when using ventilation to mitigate radon gas is also included.

The structural configuration and integrity of each existing building is unique. The guidance and requirements in this standard provide principles to reduce radon gas concentrations as low as reasonably achievable (ALARA). In addition, building codes vary across Canada, depending on the location and time of construction: these codes may have required the construction of a building to facilitate post-construction mitigation of indoor radon gas. If a long-term radon test demonstrates that radon gas concentrations are above the 200 Bq/m^3 radon guideline in a building equipped with such measures, the completion, activation, or repair of preventive measures that have not reduced radon to below the guideline in a building after occupancy is considered mitigation and is addressed in this standard.

Radon mitigation options for existing buildings

1 Scope

This National Standard of Canada provides details on two types of radon mitigation system that can be selected based on the conditions present in and around an existing building[1].

Active soil depressurization (ASD) systems[2] – ASD systems utilize a fan to create negative pressure on the soil side relative to the interior of the building and exhaust the radon-laden soil gas to the outdoors where it is rapidly diluted. ASD systems can provide a reduction of indoor radon gas concentrations of approximately 90% or more when systems are properly designed and installed by certified professionals. ASD is the preferred method of reducing radon in a building, when practical and installed according to this standard and best practices. It has been shown to be able to reduce radon levels significantly and it is simple and easy to maintain.

Ventilation systems – Reduction of radon gas concentrations in a building can also be achieved through dilution of indoor air using balanced ventilation systems as provided by example systems such as a heat recovery ventilator (HRV) or an energy/enthalpy recovery ventilator (ERV). Balanced ventilation systems in airtight buildings have been shown to reduce indoor radon gas concentrations by an average of 20 to 50%. Ventilation can be used as a supplemental option or in certain circumstances, where ASD systems are not practical. Ventilation effectiveness can be influenced by several factors of building use and can decline in effectiveness if not properly maintained, and therefore should include a system where radon levels are continuously monitored.

When applying either mitigation technique, sealing of the slab and other entry points for radon gas is necessary.

Units of measurement – Quantities and dimensions used in this standard are provided in units from the International System of Units (SI units). Imperial equivalents may be shown in brackets, if applicable.

1.1 Application to building types

The technical provisions for radon mitigation in this standard originate from the successful application of the standard to single family dwellings. There exist known instances where the technical principles of this standard have been applied to other National Building Code of Canada (NBC) part 9 building types (e.g., semi-detached homes, townhomes, other low-rise buildings) and schools. Therefore, under certain conditions, the technical principles in this standard may be applicable to buildings other than single family dwellings.

Buildings are to be considered as systems. Where a building includes two or more buildings/units that share a common foundation without footings or structural features that prevent airflow across the full foundation, work to reduce indoor radon gas concentrations should be undertaken to reduce concentrations as low as reasonably achievable in all buildings/units. However, the mitigation techniques should include accessing each building unit and proper labeling in all units. In such cases where access to each building/unit is restricted due to lack of permission, radon mitigation should be done to limit its impact to only the buildings/units that are accessible. The standard includes a communication test that will determine the effectiveness of an ASD system prior to installation. If this test indicates that any basic system may not be effective, the principles included in the standard can provide guidance for designing effective radon control solutions for non-typical buildings.

This standard is not intended to provide an acceptable solution to every type of building; rather the technical principles included in this standard can provide base requirements for designing radon mitigation solutions for non-typical buildings. Further guidance regarding radon mitigation standards for schools and large buildings is provided in ANSI/AARST RMS-LB 2018 with 12/20 revisions entitled *Radon Mitigation Standards For Schools and Large*

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[1] For this standard and CAN/CGSB-149.11, an existing building is considered a building which has been completed and is either currently occupied or ready for occupancy.

[2] In CAN/CGSB-149.11, ASD systems are considered a Level 3 system. CAN/CGSB-149.11 references this standard for details on the installation of a Level 3 system.

Buildings. Guidance regarding radon mitigation standards for multifamily buildings is provided in ANSI/AARST RMS-MF 2014 entitled *Radon Mitigation Standards for Multifamily Buildings.*

1.2 Limitation

The application of the requirements found in this standard cannot guarantee radon reduction neither below the Canadian radon guideline nor can it predict a desired post-mitigation radon concentration. Factors such as complex building configuration, building deterioration or accessibility issues may impair the application of some requirements and may reduce their efficiencies.

This standard provides a communication test, system design and installation instructions, and acceptable materials and product specifications to optimize the capacity of the mitigation system to reduce indoor radon gas concentrations.

This standard is specific to radon gas infiltrating into a building from the ground.

1.3 Exclusions

This standard does not address the mitigation techniques for radon from water and construction materials (see Annex C).

The radon gas control measures presented in this standard may not be appropriate for the mitigation of radon gas in new buildings (see CAN/CGSB-149.11, *Radon control options for new buildings*).

This standard does not address the control and mitigation of radon gas in all types of buildings. Additional details may be required for the installation in specific building types or building configurations (for example, application of this standard to some large buildings may not be appropriate).

Note: Work is typically undertaken, solely or in combination, by registered professionals possessing expertise in reducing radon gas ingress, C-NRPP certified practitioners/specialists or those permitted by the authority having jurisdiction.

This standard does not address mitigation techniques that involve depressurization of inaccessible crawl spaces.

The testing and evaluation against this standard may require the use of materials and/or equipment that could be hazardous. This standard does not purport to address all the safety aspects associated with its use. Anyone using this standard has the responsibility to consult the appropriate authorities and to establish appropriate health and safety practices in conjunction with any applicable regulatory requirements prior to its use.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this National Standard of Canada. The referenced documents may be obtained from the sources noted below.

Note: The contact information provided below was valid at the date of publication of this standard.

An undated reference is to the latest edition or revision of the reference or document in question, unless otherwise specified by the authority applying this standard. A dated reference is to the specified revision or edition of the reference or document in question.

2.1 Canadian General Standards Board

CAN/CGSB-51.34-2022 – *Polyethylene sheet for use in building construction – Material specification*

CAN/CGSB-149.11-2024 – *Radon control options for new buildings*

2.1.1 Contact information

The above may be obtained from the Canadian General Standards Board. Telephone: 1-800-665-2472. E-mail: ncr.cgsb-ongc@tpsgc-pwgsc.gc.ca. Web site: www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.

2.2 CSA Group

CAN/CSA-B70 – *Cast Iron soil pipe, Fittings, and Means of Joining*

CAN/CSA-B181.1 – *ABS Drain, Waste, and Vent Pipe and Pipe Fittings*

CAN/CSA-B181.2 – *PVC Drain, Waste, and Vent Pipe and Pipe Fittings*

CAN/CSA-B182.1 – *Plastic Drain and Sewer Pipe and Pipe Fittings*

CAN/CSA-B182.2 – *PSM type PVC Sewer Pipe and Fittings*

CAN/CSA-C22.2 No. 113-10 – *Fans and Ventilators*

CAN/CSA-F300:22 – *Residential Depressurization*

2.2.1 Contact information

The above may be obtained from the CSA Group, Standards Sales. Telephone: 416-747-4044 or 1-800-463-6727. Web site: https://www.csagroup.org/.

2.3 ASTM International

ASTM A312/A312M – *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A403/A403M – *Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings*

ASTM B88 – *Standard Specification for Seamless Copper Water Tube*

ASTM B306 – *Standard Specification for Copper Drainage Tube (DWV)*

ASTM C834 – *Standard Specification for Latex Sealants*

ASTM C920 – *Standard Specification for Elastomeric Joint*

ASTM F628 – *Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe With a Cellular Core*

ASTM F3128 – *Standard Specification for Poly(Vinyl Chloride) (PVC) Schedule 40 Drain, Waste, and Vent Pipe with a Cellular Core*

2.3.1 Contact information

The above may be obtained from ASTM International. Telephone: 1-877-909-2786. Web site: https://www.astm.org/.

2.4 American Society of Mechanical Engineers (ASME)

ASME B16.9 – *Factory-Made Wrought Buttwelding Fittings*

ASME B16.23 – *Cast Copper Alloy Solder Joint Drainage Fittings: DWV*

ASME B16.29 – *Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings—DWV*

ASME B36.19M – *Stainless Steel Pipe*

2.4.1 Contact information

The above may be obtained from ASME. Telephone: 1-800-843-2763. Web site: https://www.asme.org/.

2.5 Other radon references

National Research Council of Canada – *National Building Code of Canada 2020: Part 9*

National Research Council of Canada – *National Plumbing Code of Canada 2020*

ANSI/AARST RMS-LB-2018 Rev. 12/20 – *Radon Mitigation Standards For Schools and Large Buildings*

ANSI/AARST RMS-MF-2014 – *Radon Mitigation Standards for Multifamily Buildings*

BNQ 3624-115 – *Polyethylene (PE) Pipe and Fittings for Soil and Foundation Drainage*

2.5.1 Contact information

The National Research Council of Canada documents, the *National Building Code of Canada 2020: Part 9* and *National Plumbing Code of Canada 2020* may be obtained from National Research Council. Telephone: 1-800-672-7990 or 1-613-993-2463. Email: CONSTPubSales-Ventes@nrc-cnrc.gc.ca.

National Building Code: Web site: https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/national-building-code-canada-2020. An electronic version of the 2020 NBC is now available for free download at: https://doi.org/10.4224/w324-hv93.

National Plumbing Code: Web site: https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/national-plumbing-code-canada-2020. An electronic version of the 2020 NBC is now available for free download at: https://doi.org/10.4224/2ehs-dp68.

The document ANSI/AARST RMS-LB-2018 Rev. 12/20 – *Radon Mitigation Standards For Schools and Large Buildings* may be obtained from here: https://webstore.ansi.org/standards/aarst/ansiaarstrmslb2018rev1220.

The document ANSI/AARST RMS-MF-2014 – *Radon Mitigation Standards for Multifamily Buildings* may be obtained from here: https://webstore.ansi.org/standards/aarst/ansiaarstrmsmf2014.

The document BNQ 3624-115 – *Polyethylene (PE) Pipe and Fittings for Soil and Foundation Drainage* may be obtained from BNQ. Telephone: 418-652-2238 or 1-800-386-5114. Web site: https://www.bnq.qc.ca/en.

3 Terms and definitions

For the purposes of this National Standard of Canada, the following terms and definitions apply.

active soil depressurization (ASD)
group of radon control systems involving ASD fan-powered soil depressurization, including, but not limited to, the most common variant known as sub-slab depressurization (SSD), as well as other related techniques, such as sub-floor depressurization, sub-membrane depressurization (SMD) (e.g., in a crawl space), block-wall depressurization, sump pit and drain tubing/tile depressurization. This ASD fan-powered soil depressurization is used to draw radon-bearing soil gas away from the foundation and safely exhaust it outdoors before it can enter a building.

Note: ASD is the most effective way to reduce high radon levels in an existing building, with reductions of 90% or more being possible.

air changes per hour (ACH)
rate that the volume of air in a building or room is exchanged with air from the outside.

Note: To calculate fan-assisted ACH in a house, divide the flow rate through the ASD fan (expressed as air volume per hour) by the volume of the house (make sure volume is expressed in same base units).

as low as reasonably achievable (ALARA)
internationally recognized guiding practice used in radiation protection.

Note: ALARA indicates that radiation doses be reduced to as low a level as practical, with economic and social factors being considered. For additional information on ALARA please see:

a) https://api.cnsc-ccsn.gc.ca/dms/digital-medias/REGDOC-2_7_1__Radiation_Protection_2021.pdf/object;

b) https://apps.who.int/iris/handle/10665/42973.

ASD fan
type of fan that is designed and approved by the manufacturer for continuous duty and for use in an ASD radon reduction (mitigation) system.

backdrafting
reverse flow of outdoor air into a building through the barometric damper, draft hood, burner unit, or fire box, as a result of chimney blockage or a pressure differential greater than can be drawn by the chimney.

Note: Backdrafting can cause the products of combustion (i.e., odour, smoke, toxic gases, particulates) from fuel-fired appliances to be spilled back into the interior of a building. Cold backdrafting occurs when the chimney is acting as an air inlet, but there is no burner operation. Hot backdrafting occurs when the hot flue gas products are prevented from exhausting by flue reversal. Also called flow reversal.

balanced ventilation
mechanical ventilation system in which separate, balanced fans exhaust stale indoor air and bring in outdoor air in equal amounts.

Note: Balanced ventilation often includes heat recovery or heat and moisture recovery.

becquerels per cubic metre (Bq/m^3)
SI unit of measure for the concentration of radioactivity in a volume of air.

Note: One becquerel is one radioactive disintegration per second. The American unit that measures radioactivity is picoCuries per litre (pCi/L). 37 Bq/m^3 = 1 pCi/L.

blower door
device comprised of an adjustable speed fan, a calibrated flowmeter and a pressure differential meter designed to pressurize or depressurize a building.

Note: Blower doors are used to measure the air or leak-tightness of buildings. By determining the air flows through this fan required to achieve different degrees of building pressurization and depressurization, the blower door permits determination of the tightness of the building envelope shell.

building
structure used or intended to be used for supporting or sheltering any use or occupancy.

Note: For the purpose of this standard "occupancy" means "the normal occupancy area is defined as any area occupied by an individual for more than 4 hours per day." As prescribed by Health Canada: https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html.

Canadian – National Radon Proficiency Program (C-NRPP)
national radon certification program used by laboratories, and radon measurement and mitigation professionals in Canada.

Note: C-NRPP may provide designations to individuals or companies that have met qualification requirements or are authorized by a certification program to provide radon laboratory, measurement or mitigation services.

Canadian radon guideline level
indoor radon concentration at which mitigation is recommended, which was set at 200 Bq/m^3, as established by Health Canada in 2007.

Note 1: *Canada Gazette* Part I, June 9th 2007: https://gazette.gc.ca/rp-pr/p1/2007/2007-06-09/pdf/g1-14123.pdf.

Note 2: For more information, see Annex A.

communication testing
process whereby diagnostic pressure measurements of the under slab area are taken in order to properly determine pressure field extension in order to size an ASD fan for a radon mitigation system.

Note: Properly sizing an ASD mitigation system includes determining the type of ASD fan(s) to be used, ASD fan location, and number of required suction points.

continuous duty (motor)
motor that can continue to operate within the motor insulation temperature limits after it has reached normal operating temperature.

continuous radon monitor (CRM)
radon measurement instrument that continuously samples for radon and counts alpha particles or ions as the radon decays.

Note: These counts are stored and usually available for processing and display or printing. Continuous radon monitors use scintillation cells and photomultiplier tubes, ionization chambers, or solid-state silicon detectors.

crawl space
shallow space between a floor of a building and the ground beneath.

Note: The crawl space can have a height ranging from an order of centimetres to meters (few inches to several feet), hence the origin of the term "crawl". The crawl space may or may not be ventilated to the outdoors.

cubic feet per minute (CFM)
measure of volume of a fluid (liquid or gas) flowing within a fixed period of time.

Note: Conversion is 1 CFM = 0.472 Litre per second (L/s).

depressurization
negative pressure induced in one area relative to another.

Note: In a building during cold weather, the lower levels experience a form of depressurization as a result of the stack effect (buoyant forces acting on the warm air). The air pressure within the soil outdoors and under the building is also often higher than that in the basement, which also acts to draw soil gas into the building because of the differences in pressure.

design suction
suction required in the soil gas collection plenum or soils under slab to reduce the average typical wintertime across-slab pressure difference to sufficiently control radon ingress and maintain indoor radon concentrations below 200 Bq/m^3.

diagnostic tests
procedures that typically include communication tests used to identify or characterize conditions under, beside and within buildings that could contribute to radon entry or elevated radon levels or that could provide information regarding the performance of a radon mitigation system.

drainage tubing/tile depressurization (DTD)
variation of ASD where the gas permeable layer underneath the floor slab is depressurized by applying suction on the drainage tubing/tile that runs either outside or inside of the foundation.

entry points
openings in the foundation floors, walls or services (e.g., conduit, pipe etc.) in contact with the soil, which allow soil gas to enter.

exfiltration
unintended flow of indoor air out of the building through openings (e.g., holes or cracks) in the building envelope.

exhaust fan
fan installed such that it draws indoor air out of the building (but not an ASD fan).

Note: Exhaust fans may cause outdoor air and soil gas to infiltrate at other locations in the building to compensate for the exhausted air.

footing(s)
concrete, stone or wood base that supports a foundation wall or load bearing wall and is used to distribute the weight of the building or a portion of the building over the soil or the sub grade underlying the building.

gas permeable layer
layer of gas permeable material installed under the soil gas barrier that facilitates a negative pressure field (depressurization) to extend from the suction point to the foundation walls and footings. (Examples of gas permeable material include granular material and manufactured products providing gas permeability).

Note: An efficient gas permeable layer permits a radon control system to draw radon laden soil gas from the entire sub-slab area. Typical void ratios in the gas permeable layer are in the range of 35 to 40%.

grade (above or below)
lowest of the average levels of finished ground adjoining each exterior wall of a building.

Note: It is not necessary to consider localized depressions in the determination of average levels of finished ground.

heat recovery ventilator (HRV) / Energy/enthalpy recovery ventilator (ERV)
packaged ventilation appliance (consisting of supply and exhaust air fans and motors, a heat recovery core, filters and controls) that provides supply and exhaust ventilation and transfers heat between the exhaust and supply airstreams to reduce ventilation-related space conditioning energy use.

Note: Energy/enthalpy recovery ventilators (ERV) are HRVs that also control/exchange humidity.

infiltration
unintended movement of outdoor air or soil gas (e.g., via flow or diffusion) into a building.

joist
one of a series of horizontal or inclined structural members used to span an open space typically supporting floors, ceilings or roofs, often between beams that subsequently transfer loads to vertical members.

litres per second (L/s)
measure of the volume of a fluid (liquid or gas) flowing within a fixed period of time.

Note: Conversion is 1 L/s = 2.119 CFM.

manometer/micromanometer
sensitive differential air pressure indicating device used to determine very small pressure differences across a boundary.

Note: Generally reads in units of Pascal (Pa) or Inches Water Column (WC).

passive vertical radon stack
feature of building construction whereby a full-height vertical pipe run passes through heated and/or insulated portions of the building with the inlet originating beneath the basement floor slab and the outlet terminating above the roofline for the purpose of using the stack effect to depressurize the sub-slab space to exhaust radon containing soil gas without the use of a fan.

Note: The passive radon stack allows one to exploit the natural stack effect within a building in order to draw radon containing soil gas from beneath the slab and expel it to the outdoors. Research has demonstrated that passive vertical radon stacks have reduced indoor radon gas concentrations by 40 to 90%[2-8], as compared to an active radon control system which can yield radon reductions of 90% or more. A passive vertical radon stack is readily converted to an active system by the installation of an ASD fan, following appropriate diagnostic measurements to confirm the system design.

post-mitigation radon level
radon gas concentration in air expressed in becquerels per cubic metre (Bq/m^3) in a particular area or space (e.g., inside a building) as measured by a radon testing device that is approved by C-NRPP or equivalent after radon mitigation work has been performed.

Note: The radon level should be reduced to ALARA levels but at a minimum to below the Canadian guideline value of 200 Bq/m^3.

pre-mitigation radon level
radon gas concentration in air expressed in becquerels per cubic metre (Bq/m^3) in a particular area or space (e.g., inside a building) as measured by a radon testing device that is approved by C-NRPP or equivalent ideally during the heating season prior to radon mitigation work.

pressure field extension
spatial extension of the area of reduced pressure that occurs under a slab, membrane/soil gas barrier or sub-floor when an ASD fan ventilates at one or more distinct points.

radon
naturally occurring radioactive element that is a gas at standard temperature and pressure.

Note: Technically, the term “radon” can refer to any of a number of radioactive isotopes having atomic number 86. In this document, the term is used to refer specifically to the isotope radon-222, the primary longest lived isotope present inside buildings. Radon-222 is directly created by the decay of radium-226, and has a half-life of 3.82 days. Chemical symbol: Rn222.

radon level
radon gas concentration in air expressed in becquerels per cubic metre (Bq/m^3) in a particular area or space (e.g., inside a building) as measured by a radon testing device that is approved by C-NRPP or equivalent.

Note: C-NRPP approved long-term radon testing devices are commonly used to determine the average annual radon level in a building and if mitigation is required. An up to date list of C-NRPP approved long-term radon testing devices can be found at: https://c-nrpp.ca/approved-radon-measurement-devices/.

radon mitigation
act of repairing or altering a building in whole or in part for the purpose of reducing the concentration of radon in the indoor atmosphere.

radon mitigation/control system
system, component, design, or installation for reducing radon concentrations in the indoor air of a building.

radon mitigator
individual who is accredited by C-NRPP or equivalent, who reduces indoor radon concentrations, and is experienced in radon mitigation.

Note: In Canada, the C-NRPP accredits and maintains lists of mitigation professionals/companies that have met qualification requirements or are accredited to provide radon laboratory measurement or mitigation services.

radon rough-in system
foundational system that aims to reduce infiltration of radon gas into a building and facilitates the future addition of more efficient and effective mitigation systems consisting of, but is not limited to, the following: gas permeable layer, soil gas collector, suction point, soil gas barrier and a rough-in pipe connected to the suction point below the soil gas barrier at one end, terminating either inside or outside of the building at the other, where it is capped, labelled and sealed.

radon rough-in pipe (extended)
pipe (including fittings and solvent cement) that connects to the soil gas collection system through the slab (or equivalent) and soil gas barrier extending fully through the building envelope, penetrating to the outside where it is capped, labelled and sealed.

Note: The pipe does not have an ASD fan to actively move the soil gas, however it is ready for an ASD fan to be added once a radon measurement shows that activation is necessary.

radon rough-in pipe (stub)
pipe (including fittings and solvent cement) that connects to the soil gas collection system through the slab (or equivalent) and soil gas barrier with a height above the finished floor of no less than 300 mm (12 in.) and is labelled and sealed with an airtight cap.

slab
layer of concrete that commonly serves as the floor of any part of a building whenever the floor is supported on a foundation or is in direct contact with the underlying granular materials or soil.

slab on grade
type of building construction where one or more portions of the foundation feature a concrete slab resting directly on the ground below it.

soil gas
gas that is always present underground, in the small pore spaces between particles of soil or in crevices inside rock and consists mostly of air with some components from the soil (such as radon and water vapour).

soil gas barrier
continuous layer installed in order to reduce the infiltration and diffusion of soil gas into a building.

Note: A soil gas barrier is often made of polyethylene, but other more radon-specific barrier materials are available (e.g., spray foam).

soil gas collection plenum
constructed enclosure for collecting radon and other soil gases, typically from under a floor slab or membrane.

soil gas collection system
a collection of components providing for a gas permeable conduit that can consist of granular material, solid pipe, perforated pipe, sub-slab ventilation panels, geotextile matting, a suction pit or suction cage for collecting soil gas from within a soil gas collection plenum and connecting to the exhaust pipe system (e.g., radon rough-in pipe, passive vertical radon stack, ASD fan pipe system).

stack effect
vertical movement of air as a result of differences in indoor-outdoor air density that arise from indoor-outdoor temperature differentials which increase the buoyancy of the indoor air relative to that of the outdoor air.

Note: The buoyant force driving the stack effect increases with building height and indoor-outdoor temperature differential. In cold climates, the stack effect tends to cause air and soil gas to infiltrate the lower portions of the building and exfiltrate through the upper portions.

sub-membrane depressurization (SMD)
radon mitigation technique designed to maintain lower air pressure in the space under a soil gas barrier membrane by use of an ASD fan drawing soil gas from beneath the membrane. This technique is often used in crawl spaces.

sub-slab depressurization (SSD)
radon mitigation technique designed to maintain lower air pressure under a floor slab, relative to the building interior above it.

Note: SSD can be either active or passive. A passive system uses the natural stack effect to draw air from the soil gas collection system below the floor slab. An active SSD system uses an ASD fan to draw the soil gas.

suction cage
component that is intended by the manufacturer to maintain a void space in the gas permeable layer for use in a soil gas collection system.

suction pit
cavity dug out from fill and/or native soil or created by a suction cage beneath the floor slab, by which the radon rough-in pipe (via the soil gas collection system) draws soil gas from this pit.

suction point
location on the floor where the radon rough-in pipe penetrates the sub-floor to connect to the soil gas collection system.

sump
watertight tank/cavity that receives the discharge of drainage water from a subdrain or foundation drain and from which the discharge flows or is ejected into drainage piping by pumping.

Note: Water is often directed into the sump by drainage tubing around the inside or outside of the footings.

sump pump
pump, usually electrically operated, used to remove water which collects in a sump.

ventilation rate
rate of infiltration/exfiltration of air through a building envelope via leaks or openings. The *natural* ventilation rate typically refers to the infiltration/exfiltration of air through unintended leaks or openings in the building envelope. Whereas the *mechanical* ventilation rate, the intended rate of air exchange, is the balanced exchange of air, typically measured in units of air changes per hour (ACH), litres per second (L/s) or cubic feet per minute (CFM).

Note: The ventilation rate depends on the tightness of the building envelope, weather conditions, and the operation of appliances (such as exhaust) influencing air movement commonly expressed in terms of air changes per hour. The ventilation system of a building (e.g., HRV) should be designed to balance exhaust and supply air flows.

water column (WC)
conventional pressure measurement expressed in terms of a height of a column of water rather than in pressure per unit area and typically used to express differential pressure. Water column is often measured using a manometer (e.g., Utube) and is determined by the difference in height of two columns of water exposed to different pressures.

Note: The units of water column are often expressed in the non-SI pressure unit of Inches of Water Column (WC). 249 Pa (pascal) = 25.4 mm water column (1 in. water column).

4 Symbols, acronyms and abbreviated terms

The following abbreviations and acronyms are used in this National Standard of Canada.

ABS	Acrylonitrile-butadiene-styrene
ACH	Air changes per hour
ALARA	As Low As Reasonably Achievable
ASD	Active soil depressurization
ASTM	ASTM International, formally known as the American Society of Testing and Materials
Bq/m^3	Becquerels per cubic metre
CFM	Cubic feet per minute
CGSB	Canadian General Standards Board
C-NRPP	Canadian ─ National Radon Proficiency Program
CRM	Continuous radon monitor
CSA	CSA Group, formerly known as Canadian Standards Association
DTD	Drainage tubing/tile depressurization
DWV	Drain, waste and vent
EPDM	Ethylene Propylene Diene Monomer
ERV	Energy/enthalpy recovery ventilator

FPTRPC	Federal Provincial Territorial Radiation Protection Committee
GSG	Galvanized Sheet Gauge
HDD	Heating degree day
HRV	Heat recovery ventilator
PFE	Pressure field extension test
PVC	Poly Vinyl Chloride
RMS	Radon mitigation system
SD	Sump depressurization
SDSD	Sump and drainage system depressurization
SMD	Sub-membrane depressurization
SSD	Sub-slab depressurization
WC	Water column
WHO	World Health Organization

5 Mitigation by active soil depressurization

Mitigation by active soil depressurization (ASD) can be achieved through the following:

a) Sub-slab depressurization (SSD) – see Section 5;

b) Sub-membrane depressurization (SMD) – see 5.6;

c) Sump and drainage system depressurization (SDSD) – see 5.7.

Mitigation may also be achieved through balanced ventilation with the use of a heat recovery ventilator (HRV) or energy/enthalpy recovery ventilator (ERV) (see Section 6). However, when practicable, the ASD technique is the preferred choice for radon mitigation. SSD, SMD and SDSD systems depressurize the ground in contact with the building by a pressure differential calculated specifically for it. Table 1 lists the typical types of radon mitigation used based on foundation floor type.

Table 1 — Types of radon mitigation based on foundation floor type

Foundation Floor type	Type of Radon Mitigation
Concrete slab[a]	SSD SDSD Balanced ventilation (HRV/ERV)
Dirt floor crawl space[b]	SMD Balanced ventilation (HRV/ERV)
Combination – Slab and dirt floor crawl space	SSD SMD SDSD Balanced ventilation (HRV/ERV)

[a] Includes wood foundations with a concrete slab floor type
[b] Includes wood foundations with a sleeper or suspended floor type

5.1 Fan characteristics

5.1.1 As specified by the manufacturer, the ASD fan used shall be intended for continuous duty for use in a radon mitigation system.

5.1.2 As specified by the manufacturer, the ASD fan used shall meet the requirements of CSA-C22.2 No. 113 or equivalent U.S. or Canadian product standards.

Note: Compliance with U.S. or Canadian product Standards is typically indicated by the manufacturer through use of one of the following certifications: cUL, CSA, cULus or cCSAus.

5.1.3 The ASD fan shall have a minimum three-year warranty against factory defect.

5.1.4 The ASD fan shall be compatible with the nominal internal diameter of the pipe used as determined by 5.2.1.1.

5.1.5 The combined area of all gaps or openings of the ASD fan housing shall not exceed a total area of a single 3.17 mm (0.125 in.) diameter hole which would result in a maximum 0.425 m^3/h (0.25 CFM) leakage at 375 Pa (1.5 in WC pressure).

5.2 Pipe and fittings

5.2.1 The following are the minimum requirements for permitted pipe used in the construction of an ASD system.

5.2.1.1 Pipes with a nominal internal diameter no less than 100 mm (4 in.) shall be used except as stated in 5.2.1.2.

5.2.1.2 Pipes with a nominal internal diameter less than 100 mm (4 in.) may only be used if the following criteria are met and documented as part of the building-owner package:

a) The system design determines that the air flow at the suction point(s) is low enough that air moving through pipe with a nominal internal diameter less than 100 mm (4 in.) does not create additional noise.

b) The use of a pipe with a nominal internal diameter less than 100 mm (4 in.) does not:

   1) require the use of a more powerful ASD fan or higher setting on a variable speed ASD fan;

   2) create an unacceptable pressure drop in piping system.

Note: As a general rule of thumb, air speeds in piping above 3.56 m/s (700 ft/min) can create noise that can be heard from occupied levels of a building.

5.2.1.3 The pipe material shall be resistant to the service environment and shall comply with 5.2.2.

5.2.1.4 All Polyvinyl Chloride (PVC), PVC cellular core, Acrylonitrile-butadiene-styrene (ABS) and ABS cellular core pipes installed completely or in part above grade shall comply with Schedule 40 specifications.

Note: Where possible, radon pipe should have a different colour or identifying mark than Drain, Waste and Vent (DWV) piping. Additional information on Schedule 40 pipe can be found in ASTM E1465 and ANSI/AARST CCAH and clause 7.1.7.3 of this standard.

5.2.1.5 Piping runs along the inside of hollow walls or partitions located within 43 mm (1.75 in.) of the wall/partition surface shall be protected against physical damage and puncture at wall plates, supporting members within walls or joist cavities, and any other framing members by the use of No. 16 Galvanized Sheet Gauge (GSG) (1.59 mm) plates or sleeves. The protective plates or sleeves shall be located where piping passes through notches or holes in these framing members. This provision shall not apply to piping that passes directly through walls or partitions.

Note: For example, where a horizontal pipe run passes through a hole or notch in a stud, a protective plate would be placed on the stud such that neither the stud or the section of pipe passing through, in-front or behind it could be penetrated by a nail or screw entering from the wall/partition surface.

5.2.1.6 Where pipe passes through a fire separation, it shall meet the requirements of the applicable building or fire code.

5.2.1.7 Horizontal pipe runs shall be minimized and when used shall be sloped for drainage of condensate to the ground by being installed with at least a 1% slope to return water to the soil or according to Table 2.

Note: Radon vent pipes should be installed without depressions (traps) in which moisture can collect. If a depression (trap) is installed, a continual drainage system is necessary to drain condensate to the soil.

5.2.1.8 Where horizontal pipe runs are necessary, pipes shall be supported as required by the local plumbing code for DWV piping.

Table 2 — Recommended pipe gradient at various flow rates

Nominal Pipe Size ID (mm)	Flow Rate (L/s)	Recommended Gradient
100	10	1:100
100	25	1:50
100	50	1:30

5.2.1.9 All joining materials and practices shall be in accordance with the applicable plumbing code and the manufacturers installation instructions.

Note: Relevant Safety Data Sheet should be consulted before using glues, cements, primers, solvents, etc.

5.2.1.10 The piping shall not block doorways, windows and/or access to switches, controls, electrical boxes or equipment requiring maintenance.

5.2.1.11 Pipes shall be insulated where located in unconditioned spaces or when located outdoors, with the following two exceptions.

a) The outdoor section of a sidewall discharge, above roof discharge or gable end discharge (see 5.3) exhaust pipe having fan located either indoors or in unconditioned space if not longer than 30 cm (1 ft).

b) Buildings located in geographic areas for which the heating degree day (HDD) value is 3999 or lower.

5.2.1.12 Portions of the pipe passing through unconditioned space (e.g., an attic) shall be insulated with a minimum of R4 (0.70 RSI) insulation with a vapour barrier applied to the exterior of the insulation.

5.2.2 Acceptable pipe and fitting specifications

Where the pipe material conforms to one of the following standards, it shall be deemed to comply with 5.2.2 of this standard.

5.2.2.1 Pipe and fittings shall conform to the following standards for above and below ground use as outlined in Table 3.

Table 3 – Product standards for piping and fittings and their materials

Product Standard	Material	Permitted for above or below ground use (Yes/No)	
		Above ground	Below ground
ASTM F628	Cell core ABS pipe	Yes	Yes
ASTM F3128[a]	Cell core PVC pipe	Yes	Yes
CSA B181.1	ABS pipe and fittings	Yes	Yes
CSA B181.2	PVC pipe and fittings	Yes	Yes
CSA B182.1	ABS, PP, PVC pipe and fittings	No	Yes
CSA B182.2	PVC pipe and fittings	No	Yes
ASME B36.19M	Stainless steel pipe	Yes	Yes
ASTM A312/A312M	Stainless steel pipe	Yes	Yes
ASME B16.9	Stainless steel fittings	Yes	Yes
ASTM A403/A403M	Stainless steel fittings	Yes	Yes
CSA B70	Cast iron pipe and fittings	Yes	Yes
ASTM B306 M Hard	Copper pipe	Yes	No
ASTM B306 DWV	Copper pipe	Yes	No
ASTM B88 K & L hard temper	Copper pipe	Yes	Yes
ASTM B306 K & L hard temper	Copper pipe	Yes	Yes
ASME B16.23	Copper fittings	Yes	Yes
ASME B16.29	Copper fittings	Yes	Yes

[a] In accordance to the *National Plumbing Code*, ASTM F3128 is permitted below ground only in residential buildings containing 1 or 2 dwelling units and row houses that do not exceed 3 storeys in height.

5.2.2.2 Where used, solid or perforated corrugated high-density polyethylene (HDPE) tubing should comply with BNQ-3624-115, and shall be resistant to the service environment and be used for below ground use only.

5.2.2.3 Pipes and fittings described in 5.2.2 shall be joined with products meeting the requirements of the respective pipe manufacturer.

5.2.2.4 Primer shall be applied where required.

5.3 Mitigation system termination and clearances

5.3.1 An ASD system shall terminate and discharge to the outdoors at one of the following three discharge type locations:

a) Rooftop: where the ASD fan is typically installed in a nearby unconditioned space or attached garage.

b) Gable-end: where the ASD fan is typically installed in a nearby unconditioned space or attached garage.

c) Side-wall discharge near ground level: where the ASD fan is typically installed in a basement or attached garage.

Note: Cost, possible indoor pipe layout, space availability, and requirement to respect discharge clearance distances (see 5.3.5) may impact the selected location of the exhaust discharge point. Above roof discharge typically passes vertically through the roof but lateral and vertical gable discharge may also be acceptable to avoid penetrating the roof.

5.3.2 An above-ground discharge from a short pipe near ground level at right angles to the wall (side-wall discharge) shall be favoured in cold weather areas.

5.3.3 Where an ASD system terminates and discharges via the roof top or gable end, the ASD fan should be located at the highest building level (including any unconditioned spaces).

Note: In buildings such as residential dwellings, the highest level (including any unconditioned spaces) could be an attic.

5.3.4 In all discharge types, the end of the discharge pipe shall be protected by a low pressure drop stainless steel mesh with 10 mm to 12.5 mm openings, or by a product providing equivalent performance. When using a product other than metal mesh it shall have equivalent airflow performance.

5.3.5 Clearances outside the building (all systems)

5.3.5.1 The three termination and discharge locations in 5.3.1 shall comply with the clearance distances specified in Table 4.

5.3.5.2 The termination and discharge of the system shall not:

a) be located where it may cause hazardous frost or ice accumulation on building surfaces or any adjacent property surfaces;

b) be located directly above a walkway or paved driveway;

c) be located where it could be buried or obstructed by snow clearing or landscaping operations.

5.3.5.3 Discharging no less than 1 m (3.3 ft) under a veranda, porch, deck or balcony should only be applied if the veranda, porch, deck or balcony is fully open on a minimum of two sides.

Table 4 – Table of clearances required for the exhaust end of an ASD mitigation system

Locations	Required minimum clearances (m)	Suggested clearances (m)
Clearance from a mechanical air supply inlet	1.8	3
Clearance from a permanently closed window	0.3	1
Clearance from an openable window	1	2
Clearance from a door that may be opened	0.3	1

Locations	Required minimum clearances (m)	Suggested clearances (m)
Clearance from a door that has an openable window	1	2
Clearance from outside corner	0.3	0.3
Clearance from inside corner (outlet of pipe shall not face inside corner)	1	1
Clearance above paved sidewalk or paved driveway located on public property	2.1	2.1
Clearance from a veranda, a porch, a deck, or a balcony	0.3	1
Vertical clearance above grade	0.3	1
Vertical clearance below soffits or from any attic venting component	1	1
Horizontal clearance from an area below the discharge where there is a risk of injury from ice falling	1	2
Horizontal clearance from the vertical line (from the ground to the roof) aligned with a natural gas relief valve termination	1	1
Horizontal clearance from the vertical line (from the ground to the roof) aligned with a propane relief valve termination	1	1
Note: The selection of the outlet point should be made considering maximal available clearances from building openings and from outdoor occupancy areas.		

5.3.5.4 The pipe shall not be located where the discharged air and moisture will directly strike surfaces on the property or adjacent properties.

Note: This is to prevent ice accumulation, frost or water damage on those surfaces.

5.3.5.5 Clearances specific to rooftop discharge

When an above roof discharge option is installed, the suction pipe runs vertically upwards through the conditioned space and the ASD fan is typically located at the highest building level (including any unconditioned spaces).

5.3.5.5.1 Where the discharge pipe comes into contact with the roof, it shall discharge vertically outdoors above the roof.

5.3.5.5.2 The pipe outlet shall not penetrate the roof in a roof valley.

5.3.5.5.3 The pipe outlet should not be installed in snow drift areas of flat roofs.

5.3.5.6 Clearances specific to gable end discharge

An active radon mitigation system may discharge through the gable of the highest building level (including any unconditioned spaces).

5.3.5.6.1 The pipe shall be located where the discharged air and moisture does not directly strike surfaces on the property or adjacent properties.

Note: This is to prevent ice accumulation, frost, or water damage on those surfaces.

5.3.5.6.2 The pipe for a gable ended discharge shall discharge horizontally with a minimal length of 50 mm (2 in.) and a maximum length of 150 mm (6 in.) protruding beyond the plane of the vertical structure.

5.3.5.7 Clearances specific to side-wall discharge

The exhaust-end of the extended rough-in pipe located outside the building, shall extend a minimum of 100 mm (4 in.), from the finished surface on the exterior of the building.

5.4 Pre-existing radon control measures

5.4.1 Assessing pre-existing radon control measures (without a fan)

5.4.1.1 A visual inspection of the building shall be conducted to identify any pre-existing radon control measures intended to facilitate sub-slab soil depressurization.

5.4.1.2 CAN/CGSB-149.11-2024, *Radon control options for new buildings* shall be consulted when performing a visual inspection to assist in identifying whether any radon control measures intended to facilitate sub-slab soil depressurization are present. These measures may be visually identified by their components above the finished floor of the lowest level of the building. They may include one of the following:

a) Radon rough-in system: visually identifiable as a capped and labelled pipe stub above the finished floor of the lowest level. In buildings with crawl spaces a labelled and sealed soil gas barrier may also be visible.

b) Extended radon rough-in system: visually identifiable as a pipe run between the finished floor of the lowest level and the outside of the building where it penetrates through a side-wall or rim-joist. The portion of the pipe run inside the building should be labelled. The portion of the pipe outside the building should be capped.

c) Passive (soil depressurization) vertical radon stack: visually identifiable as a vertical pipe run between the finished floor of the lowest level and the outside of the building where it penetrates through the roof or gable end above the roof line. The portion of the pipe run inside the building should be labelled as specified in CAN/CGSB-149.11, clause 8.1.6.2. Portions of the pipe run located in unconditioned spaces should be insulated.

Note: CAN/CGSB-149.11 describes the installation of the three measures listed above.

5.4.1.3 If pre-existing radon control measures intended for SSD are identified in the building, assessment of these measures and their current condition both below and above the floor shall be done to determine if they can be used for completion of a SSD system.

5.4.1.4 Below finished floor: performance of pre-existing non-active radon control measures

5.4.1.4.1 If a pre-existing radon control measure is identified as one of those listed in 5.4.1.2, a pressure field extension test (PFE) (or communication test), as outlined in 5.5.2, shall be conducted to test the performance of the soil gas collection system located below the finished floor.

5.4.1.4.2 Where components of the system located below the finished floor do not, or cannot, be modified to afford adequate pressure field extension across the soil gas collection plenum as determined by a PFE communication test outlined in 5.5.2, the below floor components of the system should be abandoned. Abandoning may be achieved by capping any piping in connection with the sub-floor soil gas collection system. Abandoned components, if not removed, should be labelled to indicate that the component is not in use.

5.4.1.4.3 Where components of the system, or a modified system, located below the finished floor provide adequate pressure field extension across the soil gas collection plenum as determined by a PFE communication test as outlined in 5.5.2, and are to be used in a SSD system, this standard shall be applied with the exception of 5.5.3 (excavation of a suction pit).

Note: Depending on the type of pre-existing radon control measure, a PFE communication test may require cutting or uncapping of the pipe on the pre-existing system.

5.4.1.5 Above finished floor: compliance with CAN/CGSB-149.11-2024, *Radon control options for new buildings*

Where a pre-existing radon control measure is identified as one of those listed in 5.4.1.3, CAN/CGSB-149.11 shall be consulted as follows.

5.4.1.5.1 Where a radon rough-in system is identified, components of the system located above the finished floor shall be assessed for compliance, and if required modified to comply, with all applicable clauses of Sections 7.1.2.2 and 7.1.2.4 of CAN/CGSB-149.11.

5.4.1.5.2 Where an extended radon rough-in system is identified, components of the system located above the finished floor shall be assessed for compliance, and if required modified to comply, with all applicable clauses of sections 7.1.2.3 and 7.1.2.4 of CAN/CGSB-149.11.

5.4.1.5.3 Where a passive vertical radon stack is identified, components of the system located above the finished floor shall be assessed for compliance, and if required modified to comply with all applicable clauses of section 7.2 of CAN/CGSB-149.11. A positive pressure test shall be performed to ensure pipes and fittings are gas tight.

Note 1: The standard air pressure test consists of pressurizing the passive vertical radon stack sealed at both ends to 35 kPa (5 psi). The pressure is maintained for 15 minutes and the pipe system is inspected for pressure loss by conducting a soap test on each joint.

Note 2: The word “applicable” in 5.4.1.5.1, 5.4.1.5.2 and 5.4.1.5.3 refers to clauses in sections of CAN/CGSB-149.11 that concern components of the system located above the finished floor of the lowest level in these building.

5.4.1.5.4 Where components of the system located above the finished floor fail (or cannot be modified) to comply with CAN/CGSB-149.11, these components shall be abandoned. Abandoning shall be completed either by:

a) Removing the non-compliant components and, if applicable, repairing any and all penetrations through walls, floors, ceilings, the roof or the building envelope.

b) Isolating the non-compliant components. For example, a non-compliant pipe-run can be isolated by cutting all sections of pipe from compliant portions of the system, capping all open ends of the non-compliant portion of the pipe, and labelling the pipe as abandoned at each end and at least every 1.8 m (6 ft) where accessible.

5.4.1.5.5 Where components of the system located above the finished floor comply with CAN/CGSB-149.11, and are to be used in a SSD system, this standard shall be applied.

5.4.2 Retrofitting of a pre-existing radon control measures (with a fan)

5.4.2.1 Where a pre-existing ASD system (i.e., a pre-existing system with an ASD fan) is present in the building. The following investigation shall be carried out to diagnose and correct high radon levels:

a) Review documentation regarding current radon levels and existing system design (such as radon test reports, building owner leave-behind package provided by C-NRPP professional or other documentation).

b) Identification of system malfunctions, deviations from existing system design, adjustments to system components (e.g., dampers, ASD fan speed change and ASD fans).

c) Inspection of functionality of system components (e.g., fan connected/running, exhaust, pipe supports and connections, piping leak test, etc.).

d) Sealing of all accessible entry points that were not sealed or where sealing had failed.

e) Communication test to verify pressure field extension.

5.4.2.2 Correction of system failures or fan sizing issues shall be done in accordance with requirements in this standard.

5.4.2.3 Confirmatory short-term and long-term radon tests shall be conducted to confirm the success of the retrofit work. Updated documentation regarding the system design and confirmatory radon testing shall be provided to the building owner once the work is complete.

5.5 Sub-slab depressurization

When building structure/characteristics permit it (e.g., poured concrete basement or slab on grade), sub-slab depressurization (SSD) is typically the most effective radon reduction system and should be the first choice when selecting a radon mitigation system (RMS).

Depending on the age or history of the building, pre-existing radon control measures may already be in the building. Assessment of any pre-existing radon control measures for SSD is required prior to installation of an ASD system.

5.5.1 Sealing entry points

Closing entry points increases ASD radon reduction efficacy and minimizes energy consumption by minimizing the loss of conditioned (i.e., heated or cooled) air and potentially reducing the number of required suction points and fan size.

5.5.1.1 Entry points that may compromise the pressure field extension of a communication test (5.5.2) shall be sealed.

5.5.1.2 Sealants shall conform to the ASTM C834 or ASTM C920 standards or shall be compatible with the materials being sealed as described by the manufacturers.

5.5.1.3 Where an entry point compromises pressure field extension, but sealing may be impractical or demand a high cost, the potential of this to reduce the degree of radon reduction attainable and to increase heating or cooling energy costs should be discussed with the building owner.

5.5.1.4 Sumps shall be provided with rigid lids that are hermetically sealed with a gasket or silicone caulking, or are mechanically fastened as required in 5.7. Any penetrations through the lid shall be sealed. Where the sump basin penetrates the slab, it shall be sealed with a compatible sealant. A sump pit also serving as a floor drain should use a cover equipped with a water trap and be embedded in the concrete to facilitate water drainage.

5.5.1.5 Sump lids shall be made of durable plastic or other rot-resistant rigid material, designed to resist removal by children, to permit airtight sealing and resealing and to support the weight of a 70 kg (154 lb) person standing on the cover.

5.5.1.6 Floor drain, condensate drain, and foundation drain openings shall be sealed to prevent the entry of soil gas but not impede function of the drain.

5.5.1.7 All openings through the floors and walls, or portions thereof, in contact with soil for plumbing fixtures, accessible penetrations, including access openings should be sealed to prevent the infiltration of soil gas.

Note: Special attention should be paid to basement tubs and showers as many of these have not been sealed to allow for final adjustments when fixtures are installed. Plumbing fixtures such as tubs and showers can be frequently found to have openings which can allow soil gas to enter the building.

5.5.1.8 If the space under tubs and showers or other fixtures, items or things is accessible and has been found to have openings to soil, these shall be sealed.

5.5.1.9 Other accessible penetrations through foundation walls shall be sealed with appropriate materials.

Note 1: These penetrations can include under furnaces, geothermal piping etc.

Note 2: Areas requiring sealing can be identified through air pressure measurements during the communication test or through other diagnostic measurements such as smoke testing.

5.5.1.10 Hollow masonry foundation walls should have their open top courses sealed to prevent soil gas traveling. Where accessible, hollow blocks with open tops under windows and doors should also be sealed.

5.5.1.11 Hollow blocks should be tested for air permeability and if prone to leaks shall be face sealed to prevent air from moving from within the cores to the interior of the building.

5.5.2 PFE communication test of sub-slab environment

5.5.2.1 A PFE communication test shall be used to determine the number of suction points and the ASD fan size needed for an effective ASD system. A scheme of the communication testing results shall be documented and provided in the building owner radon mitigation system package (see 7.2).

5.5.2.2 The location of any sub-slab plumbing piping, electrical conduits or other services shall be identified beforehand to avoid damaging them during the communication test.

Note 1: Similar precautions should be used when piercing or coring through any wall, ceiling or surface to avoid hitting any hidden gas pipe, electrical wire, water pipe or other service.

Note 2: The presence of radiant heating piping under the slab also requires precautions be taken when conducting a communication test. Thermal imaging may be used to determine radial piping location. Refer to *Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractor*s[9], Health Canada, 2010, ISBN: 978-1-100-18472-2 for tutorial on the communication test.

Note 3: If uncertainty exists with regards to the location of hidden services in walls or the subsurface, consider retaining a locate professional to assist or utilize professional scanning equipment such as ground penetrating radar.

5.5.2.3 Where a sump exists, the communication test should be carried out with a temporary cover over the sump sealed to the floor. In many cases, the best location for the suction point may be found near the sump.

5.5.2.4 At a candidate location for a suction point, core a hole for the installation of the suction pipe.

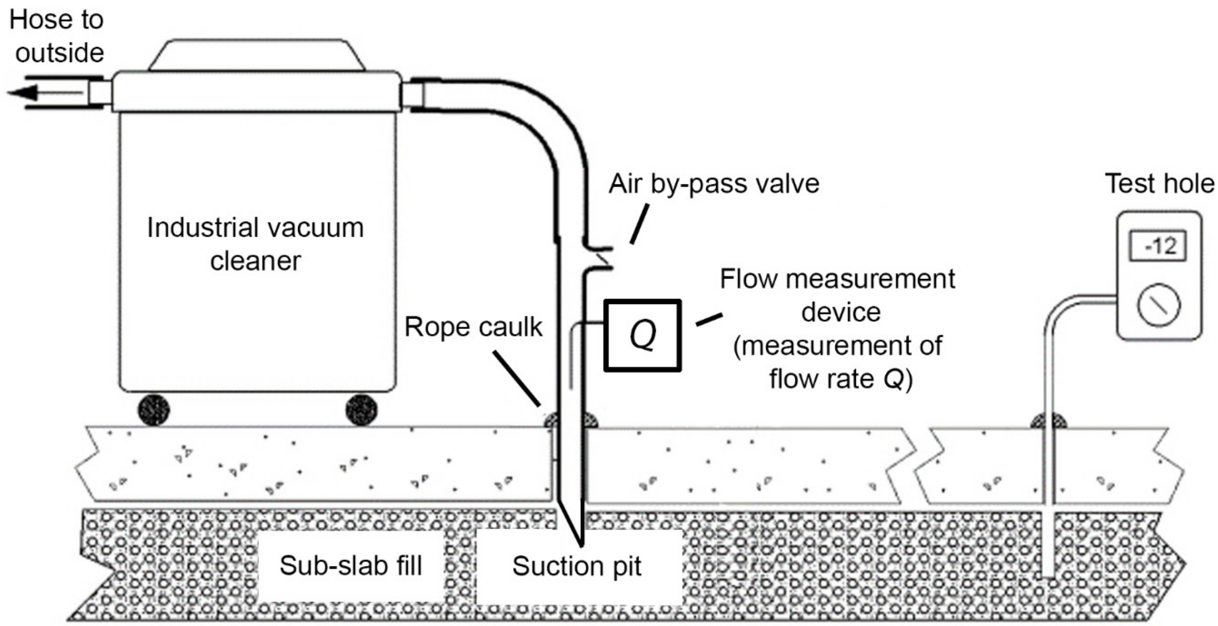
Note: Typically, the diameter of the hole will be 2.5 cm (1 in.) greater than the diameter of the intended pipe to be used.

5.5.2.4.1 A suction pit may not be required if a pre-existing sub-floor soil gas collection system is identified and found to pass a communication test (see 5.5.2).

5.5.2.4.2 A suction pit of radius approximately 25 cm (0.8 ft) and depth of 15 cm (0.5 ft) shall be excavated at the confirmed suction point. See Figure 1 for an illustrative example.

Note: Increasing suction pit size may help improve the communication under the slab where subfill material shows high resistance to air movement. A smaller suction pit is acceptable in low resistance subfill material such as clean aggregate.

Figure 1 — Sub-slab communication and flow test



5.5.2.5 To ensure adequate pressure field extension, small test holes 8-10 mm (5/16 in.) in diameter through the slab and into the sub-slab fill shall be made using a drill at the corners/edges of the soil gas collection plenum, at least 2040 cm (8-16 in.) from the foundation to avoid the footings.

Note 1: In finished areas, take care to remove flooring or finishing in such a way that it can be put back without damaging.

Note 2: Additional test holes may be required between the suction point location and the soil gas collection plenum corners/ edges as part of validating the pressure field extension.

Note 3: If drilling through finished flooring materials, investigate the materials for asbestos content and follow applicable provincial, territorial or federal procedures for material classification and disturbance.

5.5.2.6 Suction shall be applied to the hole (made in 5.5.2.4) using a vacuum cleaner (or equivalent). At each test hole a pressure reading with the vacuum turned on and off shall be recorded using a micromanometer.

Note: In an enclosed building, when suction is applied to the hole, drawing air from the sub-floor space, the discharge side of the vacuum should be vented to the outside of the building to protect occupants from elevated radon levels drawn in from suction.

5.5.2.7 If there is a pressure change (in response to applied suction) at each test hole, the proposed suction point location is feasible.

5.5.2.8 If there is no pressure change at some holes, an investigation to determine why should be performed. Application of 5.5.2 can be repeated until a suitable location for a suction pit or suitable locations for multiple suction pits is confirmed.

Note: Investigation can include identifying construction features beneath the slab such as footings which are a barrier to airflow and subsequent pressure changes or it can include identifying gaps or openings in the foundation which are allowing sufficient air leakage to overcome the build-up of negative pressure (i.e., suction) across the soil gas collection plenum.

5.5.2.9 If no suitable location for a suction pit is confirmed, alternative mitigation options should be considered.

5.5.3 System design and ASD fan sizing

Several measurable and calculable parameters are required to size an ASD fan for an effective and efficient ASD system. Application of 5.5.3 determines these parameters sequentially as follows:

- 5.5.3.1 Design suction pressure, P_{DSuc} (Pa);
- 5.5.3.2 Design airflow, Q_D (L/s);
- 5.5.3.3 Pit design pressure, P_{DPit} (Pa);
- 5.5.3.4 Dynamic piping resistance, P_{DPipeR} (Pa);
- 5.5.3.5 Outdoor vs. indoor pressure difference, $P_{Out\text{-}In}$ (Pa);
- 5.5.3.6 Total system resistance, P_{Total} (Pa).

Note: Units for each parameter are denoted in parentheses.

5.5.3.1 Design suction pressure (P_{DSuc})

5.5.3.1.1 The natural pressure, P_N (Pa), between the conditioned space and the sub-floor environment, at each test hole shall be measured by completing the following steps:

a) Close all exterior doors and windows in the building.

b) Measure and record the air pressure at each test hole drilled during the communication test (see 5.5.2), without air being mechanically drawn from the suction point location. Record the highest reading across all test holes, P_N^{MAX} (Pa).

Note 1: If there is no pressure differential at some holes look for air leaks through the floor near or between the suction point and test hole, then temporarily seal them (duct tape or rope caulk/putty). If still no pressure differential, choose a different location to drill a test hole.

Note 2: If there is significant pressure differential in one test hole and none in another, this could indicate that the footing divides the sub-slab space into two or more sections and more than one suction point may be needed to cover the floor slab.

5.5.3.1.2 The value of P_N^{MAX} determined in 5.5.3.1.1 shall be multiplied by a temperature adjustment factor (*AF*) (see Table 5) to obtain a value for the design suction pressure change, P_{DSuc} (Pa) ($P_{DSuc} = P_N^{MAX} \times AF$).

Table 5 — Design suction temperature adjustment factors

Adjustment factor (*AF*) for design suction based on outdoor temperature			
Exterior temperature (*T*) during test	Winter climate zone		
	Mild <4000 HDDs	Moderate 4000-5999 HDDs	Severe >6000 HDDs
$T > 0$ °C	2.0	2.2	2.5
$-10 < T \leq 0$ °C	1.4	1.5	1.6
$-20 < T \leq -10$ °C	1.0	1.0	1.2
$T \leq -20$ °C	1.0	1.0	1.0

Note: HDD values can be obtained from: https://climateatlas.ca/map/canada/hdd_2030_85#.

5.5.3.2 Design airflow (Q_D)

The design airflow, Q_D (L/s) is the airflow required to achieve the design suction pressure (P_{DSuc}) at the test hole most resistant to a change in pressure when air is mechanically drawn from the suction point location.

5.5.3.2.1 A flow measurement device attached to the vacuum nozzle between the vacuum and the suction pit, shall be used to measure and record the observed vacuum flow rate, *Q* (L/s).

Note 1: Flow measurement devices can be:

a) An orifice plate;

b) A pitot tube;

c) Hot-wire anemometer;

d) Vane anemometer;

e) Choke or bypass in the hose, to measure two flow rates;

f) Other suitable device

Note 2: Nozzle calibration on the device used should be checked against a standard flow device in free air.

Note 3: Unit conversion: 1 CFM = 0.472 L/s.

5.5.3.2.2 Air shall be mechanically extracted from the suction point/pit location such that the pressure within the suction pit is 250 Pa. While under suction, the pressure at each test hole (while under suction), P_S shall be measured and recorded.

Note: If a suction pit has been created as in 5.5.3, the suction pit will be directly below the suction point. However, if designing a system for a pre-existing radon rough-in system, the sub-slab void space (suction pit equivalent) may or may not exist depending on the type of soil gas collector installed. Where solid pipe is used for the soil gas collector, the void space will often be located towards the center of the slab.

5.5.3.2.3 For each test hole, the change in pressure, ΔP shall be computed as the difference between the natural pressure at the test hole, P_N (see 5.5.3.1.1) and the pressure measured while under suction, P_S (see 5.5.3.2.2) i.e., $\Delta P = P_N - P_S$. Record the smallest value of ΔP across all test holes, ΔP^{MIN}.

Note: The value of ΔP^{MIN} corresponds to the *weakest* test hole, often the test hole furthest away from the suction point location if a suction pit has been created. Where a pre-existing radon rough-in system is being used, the location of the weakest test hole may be close to the edge of the concrete slab if a solid pipe has been used for the sub-slab soil gas collector.

5.5.3.2.4 Using the parameters determined in 5.5.3.1.2 (P_{DSuc}), 5.5.3.2.1 (*Q*) and 5.5.3.2.3 (ΔP^{MIN}) the design airflow, Q_D shall be computed as follows: $Q_D = Q \times (P_{DSuc} / \Delta P^{MIN})$.

5.5.3.3 Pit design pressure (P_{DPit})

The pit pressure, P_{Dpit} (Pa), is one of three pressures that the ASD fan in an ASD system must overcome.

5.5.3.3.1 Where a suction pit has been excavated as in 5.5.3, or a sub-slab void space has been determined to be present, the pressure of the pit/void space as in 5.5.3.3 shall be calculated and accounted for in the system design.

5.5.3.3.2 For a test hole located 25 cm from where the suction point meets the pit, the change in pressure in the pit, ΔP_{Pit} shall be measured and recorded using the same method as outlined in 5.5.3.2.3.

5.5.3.3.3 Using the parameters determined in 5.5.3.2.1 (Q), 5.5.3.2.4 (Q_D) and 5.5.3.3.2 (ΔP_{Pit}) the design pit pressure, P_{DPit} shall be computed as follows: $P_{DPit} = \Delta P_{Pit} \times (Q_D / Q)^2$.

5.5.3.4 Dynamic piping resistance, P_{DPipeR}

Pipe runs will naturally resist airflow, the dynamic piping resistance, P_{DPipeR} (Pa) is one of three pressures that the ASD fan in an ASD system must overcome. Each component of the pipe run (e.g., elbows, tee fittings, etc.) contributes to the total pipe resistance. The dynamic piping resistance accounts for both this resistance and the design airflow, Q_D of the ASD system.

5.5.3.4.1 The total pipe resistance, P_{Pipe} (Pa) of an ASD system shall be computed as the sum of the contributions of the pipe run and its components as outlined in Table 6.

Table 6 – Resistance contribution of components in a pipe run of an ASD system

Component	Resistance contribution
Piping length	0.25 Pa / m
90° elbow	1.0 Pa / elbow
45° elbow	0.5 Pa / elbow
Tee fitting	1.0 Pa / tee fitting
Cavity/void space material	0.0 Pa if empty 2.0 Pa if space backfilled with granular material (or equivalent)
Rodent guard	3.0 Pa
Muffler	1.0 Pa

5.5.3.4.2 Using the parameters determined in 5.5.3.2.4 (Q_D), the velocity of air, V (m/s) in the piping of the ASD system shall be computed as follows: $V = (Q_D / 1000) / (3.1416 \times (R_{Pipe})^2)$, where R_{Pipe} (m) is the radius of the pipe.

Note 1: The factor (Q_D / 1000) converts Q_D from units of L/s to m^3/s.

Note 2: The term 3.1416 is pi (π) to 4 decimal places.

5.5.3.4.3 Using the value of V determined in 5.5.3.4.2, the velocity pressure, P_V (Pa) shall be computed as follows: $V_P = 0.6 \times V^2$

5.5.3.4.4 Using the parameters determined in 5.5.3.4.1 (P_{Pipe}) and 5.5.3.4.3 (V_P) the dynamic piping resistance, P_{DPipeR} shall be computed as follows: $P_{DPipeR} = P_{Pipe} \times V_P$.

5.5.3.5 Outdoor vs. indoor pressure difference, $P_{Out\text{-}In}$

5.5.3.5.1 The differential pressure arising from the stack effect between ground level outside the building and indoors, just above the slab floor, $P_{Out\text{-}In}$ (Pa) is one of three pressures that the ASD fan in an ASD system shall overcome. An ASD system should be designed to overcome the maximum of this pressure difference. This factor is intended to address the pressure from the outside of the building that attempts to enter though the termination end of an ASD system located near ground level due to the stack effect in the building.

5.5.3.5.2 A value of the maximum pressure difference across the below-grade building envelope, $P_{Out\text{-}In}$ shall be determined based on building type and the termination location of the ASD system.

Note: Recommendations for this value for some building types are provided in Annex F. For more information on the stack effect, see https://nrc-publications.canada.ca/eng/view/object/?id=598b8655-d03a-4779-b59e-d140cf8549a8.

5.5.3.6 Total system resistance, P_{TOTAL}

Using the parameters determined in 5.5.3.3 (P_{DPit}), 5.5.3.4 (P_{DPR}) and 5.5.3.5 ($P_{OUT\text{-}IN}$) the total system resistance, P_{TOTAL} (Pa) shall be computed as follows: $P_{TOTAL} = P_{DPit} + P_{DPR} + P_{Out\text{-}In}$.

5.5.3.7 Fan sizing

Fan curves supplied by ASD fan manufacturers shall be used to determine which ASD fan will best achieve the design airflow (Q_D) and pressure drop to overcome the total system resistance (P_{TOTAL}).

Note: Unit conversions which may be useful when consulting fan curves:

a) 1 CFM = 0.472 L/s;

b) 1 in. H_2O = 249.09 Pa.

5.6 Sub-membrane depressurization

In buildings without a concrete slab but with accessible sub floor areas with exposed soil or granular material (e.g., buildings with crawl spaces) a barrier can be added in order to install an active soil depressurization system known as a sub-membrane depressurization (SMD). This type of system provides a cavity above exposed soil to depressurize and reduce indoor radon concentrations.

5.6.1 In buildings without a concrete slab, perforated piping or porous material like granular material shall be placed over the soil, if not already present. Then a flexible air barrier membrane meeting the requirements of Type 2 CAN/CGSB-51.34-2022 0.22 mm (10 mil) thick polyethylene shall be installed on top, with all joints, penetrations and terminations sealed. The ASD fan suction pipe shall be installed so that the opening of the pipe is below the air barrier material and sealed in place to act as the gas collector.

Note: The intention of having the piece of perforated pipe or granular material under the membrane is to ensure that a volume or headspace is created under the membrane which acts as a soil gas collector and can be effectively depressurized rather than acting as a vapour barrier.

5.6.2 The membrane material shall be durable enough to withstand foot traffic during installation without damage. In areas with high foot traffic, thicker sheeting and/or protective mats shall be installed when and where appropriate and where crawl spaces are used for storage or frequent entry is required for maintenance of utilities.

Note: Several examples of membranes that have been used for this application are listed below in order of resistance. This is not meant to be an exhaustive list of possible solutions. The crush strength should be considered if an area has foot traffic or is used for storage. Air barrier membranes should be made of a material meeting the requirements of the applicable building or fire code.

- 0.08 mm (3 mil) or 0.15 mm (6 mil) two ply laminated high density polyethylene; laminated high density;
- polyethylene reinforced with a polyester or fibreglass scrim;
- polyolefin reinforced with nonwoven textile;
- up to 1 mm (40 mil) polypropylene or Ethylene Propylene Diene Monomer (EPDM) sheets or membranes which are approved for indoor use.

5.6.3 Air barrier membranes shall be made of a material meeting the requirements of local codes and *National Fire Code*.

5.6.4 The membrane material should be available in large sheets to limit the number of joints or overlaps needed.

5.6.5 If the membrane is damaged during installation, it shall be repaired immediately.

5.6.6 Appropriate joining tape should be installed according to the manufacturer's instructions.

5.6.7 Seams where sheets of the membrane overlap shall be lapped by 300 mm (12 in.), sealed using a manufacturer's approved method such as caulked and taped.

Note: Pipe and corner flashings are also available for use with thicker membranes such as polypropylene or EPDM.

5.6.8 The membrane should run no less than 100 mm (4 in.) up each wall and be fixed and sealed to the foundation walls using manufacturer approved adhesives or spray foams. The membrane shall be secured in place with decay and insect resistant battens fixed with fasteners compatible with the foundation materials. Figure 2 illustrates how the membrane is installed and attached to the wall.

Note 1: Uncover and remove any materials which may come between the membrane and the wall to ensure that the membrane is fastened directly to the exterior wall.

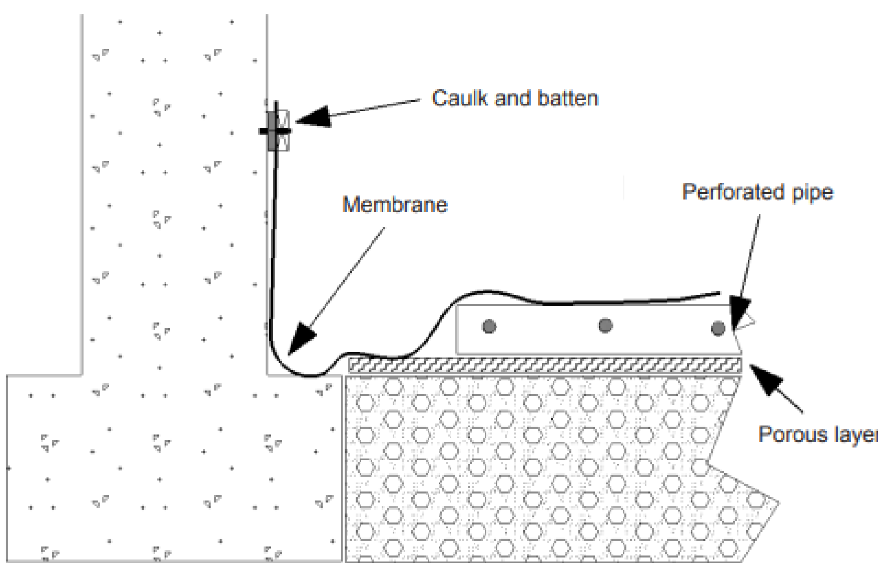
Note 2: Wood under the membrane may rot and so wood should not be left under the membrane.

5.6.9 Ensure compatibility of caulking and construction adhesives with the membrane material and their tolerance to dirt on the wall surface, as described by manufacturers.

5.6.10 The quality of the seal to the wall shall be visually inspected, and a leak survey should also be carried out with appropriate leak detection techniques. Any leak found shall be sealed/repaired before sizing the permanent fan.

5.6.11 Penetrations through the membrane, and any tears in the membrane shall be sealed to reduce the amount of air drawn from the building.

Figure 2 — Membrane/wall detail



5.6.12 Where there are supports or pipes in the space, the membrane shall be slit to pass around these items and the seams shall be sealed effectively (caulked with a compatible adhesive caulk) and shall be lapped at least 300 mm (12 in.) and taped. Alternatively, a collar shall be fitted around each penetration and attached and sealed (caulked) to the penetration. The membrane shall then be sealed (caulked) to the collar.

Note: Collar may be cut from the membrane material.

5.6.13 If water is likely to collect on top of the membrane, it shall be fitted with drainage at the low points that does not interfere with efficient depressurization and is resistant to soil gas infiltration.

5.6.14 Where the suction point penetrates through the membrane, it shall be caulked to form an airtight seal.

Note 1: This is generally achieved using either roof soil stack flashings (one under the membrane and one above the membrane) or using a manufactured top hat unit.

Note 2: Roof soil stack flashing and top hat units used to connect the suction pipe to the membrane are commonly made of vinyl or Ethylene-Propylene-Diene-Terpolymer.

5.6.15 Piping shall be brought out through the membrane and shall be connected to a fan to discharge the collected soil gas and radon outdoors.

5.6.16 Requirements for fan characteristics (5.1), pipe fitting and specifications (5.2) and system termination and clearances (5.3) shall apply.

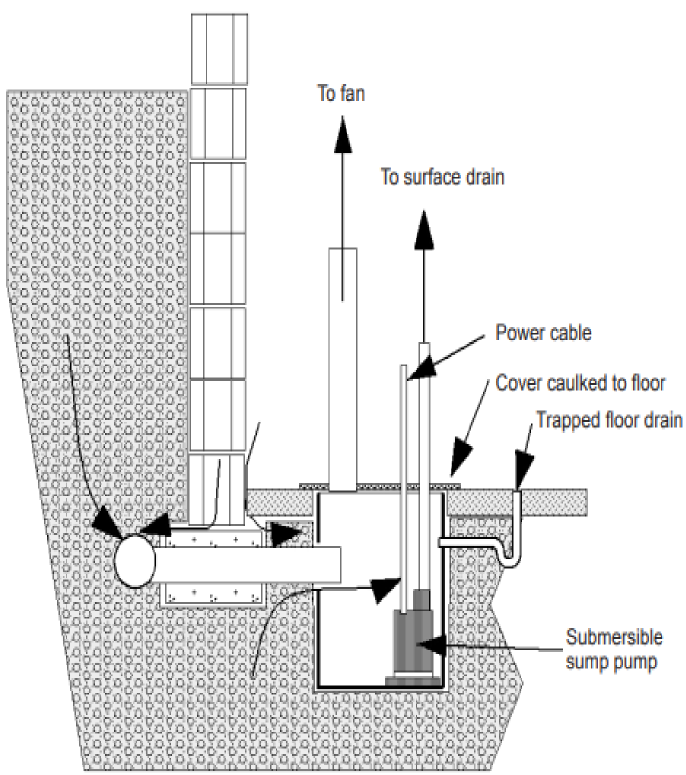
5.6.17 Requirements for sealing entry points (5.5.1) with the exception of slab sealing or sump sealing shall apply.

5.6.18 Requirements for system design (above the membrane) and fan sizing (5.5.4) shall apply as well as fan and electrical installation (5.8).

5.7 Sump and drainage system depressurization

5.7.1 A building equipped with a ground water drain system (weeping tile) may be mitigated for radon by applying suction to the drainage tubing or sump if communication tests determine this technique provides adequate depressurization to the sub-slab area. Figure 3 illustrates sump depressurization (SD).

Figure 3 — Sump exhaust installation



5.7.2 A ground water drainage system connected to a sump basin inside the building shall be sealed with a cover that allows a connection to an exhaust fan, while still allowing water to enter the sump and be pumped away.

5.7.3 The sealed sump cover shall be strong enough to support a 70 kg (154 lb) person standing on the cover.

Note: Specialized plastic “radon sump covers“, and complete “radon sump basins”, with these connections built into the sump lid and liner, can be commercially purchased or fabricated. If the sump is suitable for radon extraction, then such products will ensure the sump maintains a pressure field extension to the soil.

5.7.4 The sealing of the sump cover shall be airtight, serviceable and resealable.

5.7.5 The sump cover should incorporate a view port or allow access to permit observation of conditions within the sump pit.

5.7.6 If exhaust piping is connected to the sump cover, the piping shall be installed so that it can readily be reconnected and resealed to permit sump pump maintenance.

Note: Gas tight couplers may be used to allow the ASD piping to be easily disconnected from the sump lid to facilitate maintenance of the sump area.

5.7.7 Penetrations of sump covers for electrical wiring or for a water discharge pipe from a submersible water pump shall be designed to permit airtight sealing around them using rubber grommets or appropriate caulking.

5.7.8 A sump pit also serving as a floor drain should use a cover equipped with a floor drain and be embedded in the concrete to facilitate water drainage.

5.7.9 Selected floor drain types being connected to the sump shall be resistant to soil gas infiltration and to soil depressurization.

Note: Commercially available gas tight drains are available.

5.7.10 An ASD fan should be connected to the covered sump basin through the side openings in the sump basin instead of through the sump lid to collect soil gas from the weeping tubing/tile system, and to draw soil gas from the sub-slab environment.

5.7.11 To make sure the ASD fan is not drawing air from downspouts or window wells drained to the weeping tile, downspouts should be re-routed to discharge at ground level away from the building and the connections closed. Window well drains cannot be closed without a risk of basement flooding and should be either equipped with a mechanical trap resistant to depressurization while at the same time allowing water drainage; or by covering the drain openings with filter cloth and sand to reduce airflows but still allow water to drain. This increased air restriction due to filter cloth or sand shall not compromise water drainage.

5.7.12 To prevent freezing the ground in winter, inspection shall be performed to ensure the system does not draw large amounts of outdoor air into the ground.

5.7.13 Requirements for fan and pipe installation and layout and communication testing in 5.1 also apply.

5.7.14 Requirements for fan characteristics (5.1), pipe fitting and specifications (5.2) and system termination and clearances (5.3) shall apply.

5.7.15 Requirements for sealing entry points (5.5.1) shall apply.

5.7.16 Requirements for system design and fan sizing (5.5.4) shall apply as well as fan and electrical installation (5.8).

5.8 ASD Fan installation: location and electrical

5.8.1 ASD Fan installation: location

5.8.1.1 ASD Fan and piping shall not be located outdoors except for buildings located in geographic areas where the heating degree day (HDD) value is 3999 or lower.

Note: Climatic variations exist in each area and each site should be considered independently.

5.8.1.2 ASD fans shall be installed as per the manufacturers instructions and shall provide for proper condensation drainage. If condensation drainage is not integral to the ASD fan housing, a condensation by-pass shall be installed which diverts condensation within the discharge pipe away from the ASD fan.

Note: ASD fans are typically installed on vertical piping.

5.8.1.3 The ASD fan shall be connected to the piping according to the manufacturer's instructions. Flexible couplers shall be used to provide proper sealing, vibration dampening and a service break for fan replacement.

Note: A typical installation utilizes flexible plumbing couplers that hold the ASD fan and prevent contact between the ASD fan and pipe, thereby reducing noise due to vibration.

5.8.1.4 Once the ASD fan is installed, a leak test shall be performed on the ASD fan seams and couplings holding the ASD fan onto the pipe on the pressurized part of the system (under positive pressure) using a typical soap test method with the ASD fan running. Any observed leaks shall be sealed.

5.8.2 Fan installation: electrical

5.8.2.1 Wiring and electrical components shall comply with applicable electrical codes.

5.8.2.2 The ASD fan electrical disconnect shall be located less than or equal to 1.8 m (6 ft) from the ASD fan and within line of sight of the ASD fan.

5.9 Leak test

5.9.1 A leak test of the system shall be required unless the ASD fan installation meets one of the following conditions:

a) The ASD fan is mounted outdoors, in an unconditioned space or in an attached garage.

b) The ASD fan and all critical seams are under negative pressure or housed in a negative pressure enclosure that exhausts/vents to the outdoors.

5.10 Labelling

5.10.1 Where a leak test is performed, a label shall be applied to the ASD fan. The label shall contain the following information:

"This system has been tested for leaks during installation. Please note that physical damage or aging may result in leakage which can increase indoor radon levels. You are advised that your system should be routinely inspected. To verify continued performance, an additional long-term radon measurement should be made within two years of the system activation, and at five-year intervals thereafter. Radon levels should also be retested after ventilation/ air circulation equipment changes or renovations to the building." « Ce système a fait l'objet d'un test d'étanchéité lors de l'installation. Veuillez noter que les dommages physiques ou le vieillissement peuvent entraîner des fuites susceptibles d'augmenter les niveaux de radon à l'intérieur des habitations. Nous vous conseillons d'inspecter régulièrement votre système. Pour vérifier la continuité des performances, une mesure supplémentaire du radon à long terme doit être effectuée dans les deux ans qui suivent la mise en service du système, puis tous les cinq ans.

Les niveaux de radon doivent également être mesurés de nouveau après toute modification de l'équipement de ventilation/circulation de l'air ou toute rénovation du bâtiment. »

5.10.2 Where a leak test is performed, a label shall show the date the leak test was completed.

5.11 Fan monitoring

5.11.1 A system performance indicator shall be installed to monitor the ASD fan performance by indicating the suction pressure or soil gas flow in the stack piping, and shall be installed indoors in a location which can be read, or in the case of an audible alarm heard by the occupants of the building.

Note: U-tube manometers are generally used as the system performance indicator due to their low cost, availability, and dependability. Other system performance indicators are possible such as magnehelic pressure gauges, flow gauges, micromanometers, etc.

5.11.2 The start-up system pressure shall be clearly marked on a durable label (see Section 7).

Note: The term "start-up system pressure" refers to the suction vacuum level achieved when the ASD fan is running at the time the system is first activated.

5.12 Post installation PFE verification

As built pressure field extension shall be determined/verified by measuring the pressure change (in response to applied suction) at each test hole after the completion of the system installation to ensure design pressure, P_{DS} is achieved by the selected fan.

6 Mitigation by ventilation

Installation of an ASD system should always be the preferred choice of achieving lower indoor radon gas concentrations. However, when building structure, configuration and/or use prevent radon reduction by active soil depressurization, ventilation methods may be considered. This standard addresses only ventilation methods intending to dilute radon to acceptable levels. Although some crawl space and/or subfloor exhaust ventilation scenarios are plausible mitigation techniques for preventing radon infiltration into occupied space, this standard does not address those scenarios. Guidance on these exhaust scenarios may be found in the Health Canada publication entitled *Reducing Radon Levels in Existing Homes : A Canadian Guide for Professional Contractors*[9].

6.1 Heat recovery ventilators and energy/enthalpy recovery ventilators

Heat recovery ventilators (HRVs) and energy/enthalpy recovery ventilators (ERVs) are most effective in buildings that are relatively airtight. It is recommended that HRVs and ERVs be installed for the purpose of radon reduction only in instances where a known or predicted radon reduction could be expected by increasing ventilation to lower radon levels.

Note 1: Some HRV/ERV models may not be able to meet the specific criteria outlined in this standard to reduce radon levels to acceptable levels.

Note 2: Further information on the requirements for performance, installation and application and performance verification of mechanical ventilation systems for residential buildings can be found in CAN/CSA-F326-M91 – *Residential Mechanical Ventilation Systems*. For commercial systems, further information on how ventilation can be used to achieve acceptable indoor air quality can be found in ANSI/ASHRAE 62.1.

Note 3: The airtightness of an existing building will vary based on construction year and whether any retrofits have been performed to improve airtightness. A common measure of airtightness is ACH50 (air changes per hour at 50 Pa). For example, recent research into existing buildings such as residential dwellings in Canada indicate that, on average, when installed, HRVs feature in dwellings with ACH50 values of 3 or below[10].

6.1.1 Where an HRV or ERV system is already installed in the building and is intended to be reconfigured for radon reduction, section 6.1 of this standard shall apply.

6.1.2 To optimize the conditions for the HRV or ERV system to achieve radon reduction, requirements for sealing entry points (5.5.1) shall apply.

6.1.3 HRVs and ERVs shall be installed, balanced, and commissioned according to the manufacturer's instructions and applicable building codes.

6.1.4 Installation shall aim for a neutral balanced system and shall avoid exhaust equipment that produces large negative pressures as this may increase the radon infiltration rate into the building.

6.1.5 The total existing ventilation [air changes per hour (ACH)] shall be determined considering existing mechanical ventilation. The initial air leakage rate of the building shall be determined (for example, by conducting a blower door test) when sizing a new HRV or ERV to estimate how much radon reduction can be anticipated from the additional ventilation brought about by installing the HRV or ERV. The cost of heating and cooling shall be calculated. The proposed implementation of an HRV or ERV solution for reducing indoor radon levels should not conflict with good ventilation practice.

Note: In some cases, attempting to reduce high radon levels by using an HRV may result in impractical mechanical ventilation rates which would make such a system relatively expensive to operate. Building codes affecting building ventilation may be consulted.

6.1.6 HRVs and ERVs installed specifically for radon reduction or existing ventilation units reconfigured for radon reduction should generally exhaust air from the part(s) of the building where the highest radon concentrations were measured (or are expected) and bring outdoor air into the most occupied space of the building.

6.1.7 HRV and ERV systems shall use separate ducted intake and exhaust ports.

6.1.8 The outdoor air intake shall be no less than 1.8 m (6 ft) from the exhaust outlet.

Note: Ideally the air intake should be no less than 3.05 m (10 ft) from the exhaust outlet.

6.1.9 The HRV or ERV shall be able to operate continuously to maintain constant dilution of indoor radon levels. In the case of buildings occupied for specific hours of the day, the HRV or ERV should be able to be timed to operate and control indoor radon below action levels during occupied hours.

Note: Some HRV and ERV models offer a self-monitoring of airflow and fault indicator display which provide a supplemental monitoring level that should be considered for radon mitigation purposes.

6.1.10 The HRV's or ERV's cross-leakage from exhaust to supply airflow shall not exceed 2%.

Note: Cross-leakage data are available from: https://www.hvi.org/.

6.1.11 HRVs and ERVs installed specifically for radon reduction shall not have a defrost cycle that increases building depressurization.

Note: Depending on the model, the ERV/HRV may not be exchanging air when in defrost mode, achieving no radon reduction. When an existing HRV/ERV system is to be reconfigured for radon reduction, if its defrost cycle depressurizes the building, a diagnostic assessment using a continuous radon monitor (CRM) to determine average radon levels during occupied hours is recommended to determine if they are acceptable.

6.1.12 HRVs and ERVs installed specifically for radon reduction shall not have a recirculation option enabled as a mode from the remote controllers.

Note: When an existing HRV/ERV system is to be reconfigured for radon reduction and the system has a recirculation option enabled, a diagnostic assessment using a CRM to determine average radon levels during occupied hours is recommended to determine if they are acceptable.

6.1.13 The HRV or ERV drain system shall have a P-trap installed and be kept filled with water. The drain tube shall not be drained directly under the slab into the subfill material.

6.1.14 In HRV or ERV installations that are not integrated with an air handler, supply and return vents in the interior shall be located a minimum of 3.66 m (12 ft) apart, or as far apart as building size may allow it.

6.1.15 The exterior intake and exhaust vents shall be positioned to avoid blockage by snow or leaves.

6.1.16 During installation of a HRV or ERV system, it shall verified that the incoming and outgoing airflow is balanced to ensure that the system does not create a negative pressure within the building, as this may increase the radon infiltration rate into the building.

6.1.17 During installation of a HRV or ERV system, the building owner or occupant shall be informed that periodic filter replacement and inlet grill cleaning are necessary (typically every three months) to maintain a balanced airflow. This information as well as information on maintenance and system operation shall be included in any documentation left to the building owner or occupant.

6.1.18 Following installation of an HRV or ERV system or the reconfiguration of an existing system for radon reduction, a CRM should be used to continuously monitor radon levels in the building.

Note: Changes to the HRV/ERV balancing can quickly impact radon levels in the building. A CRM will provide a visual indicator of potential changes to HRV/ERV balancing.

7 Labelling, marking and information package

7.1 Labelling

Labels serve the purpose of identifying the radon control system to someone performing future work in the building. They also identify the system to the building occupants who may be unaware of radon and/or its control options. There are eight label types (7.1.7): (1) air barrier membrane labels, (2) pipe labels, (3) ASD fan labels, (4) sump labels, (5) active system start-up pressure labels, (6) radon maintenance, (7) information labels and (8) HRV/ERV labels.

7.1.1 Labels shall be water resistant.

Note: CSA-C22.2 No. 0.15:15 and UL 969 are two standards detailing permanent adhesive labels intended for use indoors or outdoors on application surfaces.

7.1.2 Labels shall be in both official languages.

7.1.3 Labels shall be applied to clean dry surfaces and otherwise well adhered.

7.1.4 Labels shall use lettering that is in a contrasting colour to the background.

7.1.5 Labels shall clearly indicate the system is only intended for the removal of radon gas from below the flooronground.

7.1.6 Labels shall be applied immediately following installation of a radon mitigation system.

7.1.7 ASD radon mitigation system component labels

7.1.7.1 Where an air barrier membrane is used (see 5.6), a label shall be located on the membrane in a prominent location and shall state, in both official languages: “This is a component of a radon reduction system. Do not tamper with or disconnect. For information related to radon, visit https://www.canada.ca/radon” and « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter. Pour plus d’information sur le radon, consultez le site https://www.canada.ca/radon ».

Note: A sufficient number of labels should be used when the soil gas barrier covering can be prominently viewed from multiple locations that may not be in line of sight of a single label.

7.1.7.2 Piping for the mitigation system located in the interior of the building, labelling shall state, in both official languages: “This is a component of a radon reduction system. Do not tamper with or disconnect. For information related to radon, visit https://www.canada.ca/radon”and « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter. Pour plus d’information sur le radon, consultez le site https://www.canada.ca/radon ». The labels shall be applied every 1.8 m (6 ft) or at a change in direction. The labels shall be applied before wall cavities are closed (where applicable).

7.1.7.3 Where pipe manufactured specifically for radon mitigation is used for the radon rough-in piping in the interior of the building, it shall be a contrasting colour to other pipe and marked with the following, in a print with contrasting colour, at 1.8 m (6 ft) intervals:

a) “Soil Gas Venting”;

b) Pipe size;

c) “Sch 40”;

d) Manufacturer’s production information;

e) Certification marks.

7.1.7.4 Where sumps are installed and used as an inlet for an ASD system, the sealed sump pit cover shall be provided with durable labelling containing the following information in both official languages: “This is a component of a radon reduction system. Do not tamper with or remove sump cover except for situations where the sump area requires servicing. Re-seal the sump pit (and re-install ASD piping connections and turn fan back on) after servicing” and « Composant d’un système d’atténuation du radon. Ne pas modifier ou enlever le couvercle de puisard, sauf dans le cas où le secteur du puisard a besoin d’entretien. Resceller le puisard (et raccorder la tuyauterie de la DAS et remettre le ventilateur en fonction) après l’entretien ».

7.1.7.5 ASD fans shall be labelled “This is a component of a radon reduction system. Do not tamper with or disconnect” and « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ».

7.1.7.6 Where a fan and any system performance device is installed on a circuit breaker, the circuit breaker shall be labelled “ASD fan and monitor” « Ventilateur de DAS et moniteur ».

7.1.7.7 Where a fan has an electrical disconnect instead of a cord and plug, it shall also be labelled.

7.1.7.8 The initial suction pressure shall be clearly marked within visual range (to a maximum 30 cm (1 ft) distance) of the system pressure gauge. The monitor device shall have durable labelling that states, in both official languages, “This is a component of a radon reduction system. Do not tamper with or disconnect” and « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ».

The labelling shall describe how an occupant or building owner should read the gauge, and when and who to call for servicing. Description may vary with each device. The label shall also include bilingual wording “This gauge measures differential pressure in Pascals or [Inches WC], it does not measure radon.” « Ce manomètre mesure la pression différentielle en pascals (ou en pouces CE), mais il ne mesure pas la concentration de radon ».

Note: Differential pressure monitoring devices used in ASD systems are typically U-tube manometers or digital manometers which may have display scales in Pascals or inches of WC.

7.1.7.9 When used, a radon surveillance device should be clearly labeled, in both official languages, “This is a component of a radon reduction system. Do not tamper with or disconnect” and « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ».

7.1.7.10 When used, electrical radon surveillance devices should be connected on a separate electric circuit than that of the ASD fan. It shall describe how an occupant or building owner should read the monitor, and when and how calibration and maintenance is required. This description may vary with the device.

Note: If the radon surveillance device indicates a long term (three months or more) average radon level higher than 200 Bq/m^3 (5.4 pCi/L), Health Canada’s guideline recommends that steps should be taken to reduce the radon levels in the building.

7.1.7.11 The radon mitigation system shall also be provided with one mitigation system label for the purpose of informing the occupant or building owner. The label shall be located on an exposed and visible part of the system and shall be written in both official languages. Soil depressurization and HRV/ERV labels shall follow the formats shown below:

Radon mitigation system – The ASD fan should NEVER be turned off. Type: Active soil depressurization system Installer’s name: Company: Company address: Telephone number: Applicable certification identification: Date of installation: Suction pressure: __________ in _______ Pascal or “WC”. Additional radon information available on https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/radon.html or at 1-833-723-6600.

Système d’atténuation du radon — Le ventilateur de DAS ne devrait JAMAIS être éteint. Type : Système de dépressurisation active du sol Nom de l’installateur : Entreprise : Adresse de l’entreprise : Numéro de téléphone : Numéro de certification applicable : Date de l’installation : Pression d’aspiration : __________ en ______ Pa ou po CE Consultez le https://www.canada.ca/fr/sante-canada/services/securite-et-risque-pour-sante/radiation/radon.html ou composez le 1-833-723-6600 pour en savoir davantage sur le radon.

Radon mitigation system — The HRV/ERV should NEVER be turned off. Type: Ventilation Installer’s name: Company: Company address: Telephone number: Applicable certification identification: Date of installation: Determined to increase ventilation by: _____________ Air change(s) per hour. Additional radon information available on https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/radon.html or call 1-833-723-6600.

Système d’atténuation du radon — Le VRC/VRE ne devrait JAMAIS être éteint. Type : Ventilation Nom de l’installateur : Entreprise : Adresse de l’entreprise : Numéro de téléphone : Numéro de certification applicable : Date de l’installation : Réglé de façon à augmenter la ventilation de : __________________ renouvellement(s) d’air par heure. Consultez le https://www.canada.ca/fr/sante-canada/services/securite-et-risque-pour-sante/radiation/radon.html ou composez le 1-833-723-6600 pour en savoir davantage sur le radon.

7.2 Building owner/occupant radon mitigation system package

The building owner or occupant shall be provided with a documentation package that includes the following:

a) a copy of the appropriate information label outlined in 7.1.7.11;

b) all manuals for the installed systems, including any mitigation system monitoring devices and fans, if applicable;

c) all radon test data for the property, if applicable;

d) the installed fan's estimated annual energy consumption, and the projected cost of such energy, if applicable;

e) recommended inspection and retest schedule;

f) scheme of the communication testing results and other applicable diagrams.

8 Inspection

8.1 System mechanical checks after installation

8.1.1 When the mitigation system is first activated, the seals and joints should be checked for leaks and loose connections and vibration noises: any omissions or defects should be addressed. A label on the system listing the date that the system was activated shall include suggested maintenance check re-test intervals.

8.1.2 In soil depressurization, the suction pressure in the piping recorded by the U-tube manometer shall be noted on the label for comparison with the system maintenance check.

8.2 Buildings containing natural draft or other non-sealed combustion appliances

8.2.1 No radon mitigation system shall interfere with combustion gas exhaust from natural draft or other nonsealed combustion appliances.

8.2.2 Where the building contains natural draft or other non-sealed combustion appliances, an F300 depressurization test shall be performed after installation of the radon system.

Note 1: The radon system may be required to be turned on as part of the F300 test.

Note 2: The CSA Residential depressurization F300 standard addresses the determination of building depressurization level and provides corrective measures to mitigate excessive levels of building depressurization.

8.2.3 If the F300 depressurization test fails with the radon system turned on, the test shall be repeated to determine if the radon system is the source of failure for the test.

Note: Proper fan sizing, sealing of entry points for soil depressurization, and ensuring balanced ventilation systems all serve to minimize the risk of backdrafting of natural draft combustion appliances.

8.2.4 If the radon system is a source of failure for the F300 depressurization test, the radon system shall be made inoperable to the building owner and occupant until the issue can be resolved.

8.2.5 If the F300 depressurization test fails with the radon system turned on or off, an information sheet and carbon monoxide (CO) monitor should be left with the occupant or building owner.

Note: It is recommended that any combustion appliance or venting system found to be noncomplying with the F300 test be brought into compliance.

8.2.6 The radon mitigation system shall not be placed into service (i.e., activated for use by occupant) until any and all potential backdrafting issues have been resolved.

9 Testing

9.1 Post-installation testing

9.1.1 Long-term radon measurement devices shall be approved by the C-NRPP or equivalent.

Note 1: An up to date list of C-NRPP approved long-term radon test devices can be found at: https://c-nrpp.ca/approved-radon-measurement-devices/.

Note 2: C-NRPP periodically reports on the performance of digital radon monitors available to Canadian consumers. These devices can be used by consumers to conduct a long-term test. The most recent report, which includes guidelines for using digital radon monitors, can be found here: https://c-nrpp.ca/wp-content/uploads/2023/10/Digital-Device-Report-Oct-2023.pdf.

9.1.2 Short-term radon measurement devices shall be approved by C-NRPP or equivalent.

9.2 Short-term post-mitigation radon test

9.2.1 No sooner than 24 h and no later than one month after the radon system is activated, a short-term radon test shall be carried out with the system operating to demonstrate initially that the mitigation has been successful.

9.2.2 The short-term radon test shall be no shorter than 48 h in duration and shall use an approved radon testing device.

Note: Short-term radon tests can typically last between 2 to 7 days.

9.2.3 The short-term radon test shall be conducted under closed building conditions.

9.2.4 After completion of a short-term radon test, a long-term radon test (see 9.3) shall be conducted in the first heating season.

9.3 Long-term post-mitigation radon test

Health Canada recommendations for radon mitigation are based on the results of a long-term radon test. Long-term tests typically have a duration of 3 months (or longer) and are conducted in the normal occupancy area of the lowest occupied level of a building. The effectiveness of the mitigation system is based on the long-term radon concentration measurement made in this same location by the test.

9.3.1 The need for a long-term post-mitigation radon test to be conducted during the heating season shall be communicated to the building owner or occupant.

9.3.2 The long-term (three months) post-mitigation radon test shall be made in the same location as the premitigation radon measurement.

9.3.3 The building owner or occupant shall be advised that system troubleshooting or additional remedial actions may be required if a long-term post-mitigation radon test indicates concentrations above 200 Bq/m^3 (5.4 pCi/L).

Note 1: See Annex A for typical radon reductions. Radon concentrations should be reduced to as low as reasonably achievable (ALARA). An effective mitigation system keeps radon concentrations low provided there are no changes in the soil, building, or systems. To verify continued performance, an additional long-term radon measurement should be made within two years of the system activation, and at five-year intervals thereafter. If the building or any unoccupied area/room have a change of use, or is altered or extended, a long-term test should be carried out in the normal occupancy area of the lowest lived in level of the building.

Note 2: Health Canada radon test guidance:

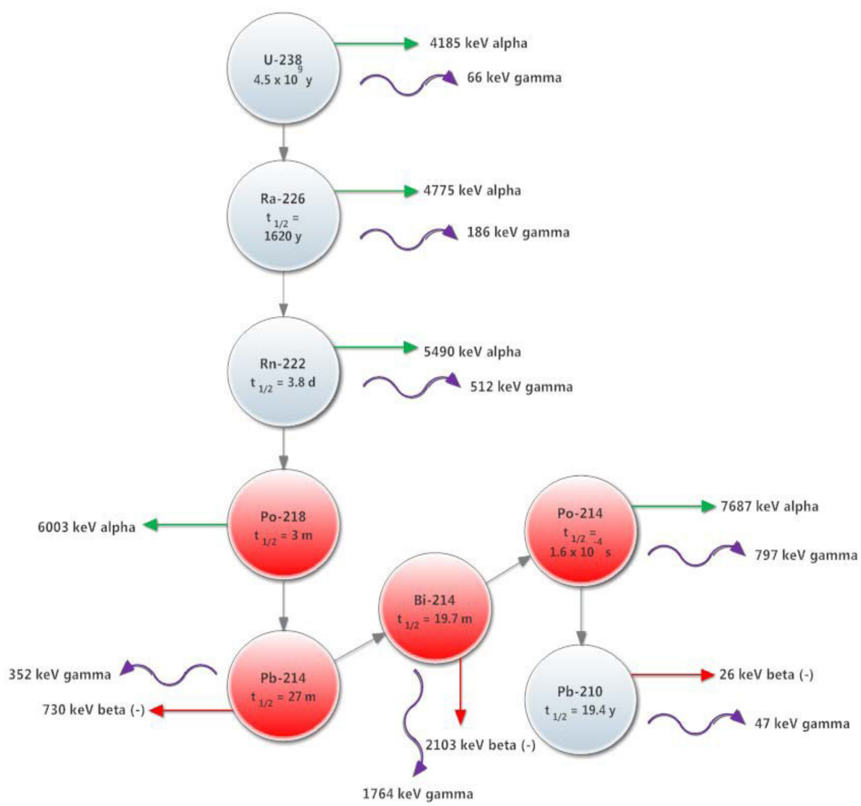
- Guide for Radon Measurements in Residential Dwellings (Homes): https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html
- Guide for radon measurements in public buildings: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/radiation/guide-radon-measurements-public-buildings-schools-hospitals-care-facilities-detention-centres.html

Annex A
(informative)
General information on radon

What is radon?

Uranium is a naturally occurring radioactive element that is present everywhere in rocks and soil. The radioactive decay of uranium produces radium, which in turn decays to radon. Radon is a colourless and odourless inert gas that is chemically inert, but radioactive (see Figure A.1). As it is a gas, it can move easily through bedrock, soil and ground water; either escaping into the outdoor air or infiltrating into a building. All soil contains uranium, so radon is present in all types of soil. Radon that moves from the ground into the outdoor air is rapidly diluted to low concentrations and is not a health concern. However, inside a building, radon can accumulate to a high concentrations and become a long term health concern. While the health risk from radon exposure below the Canadian (Health Canada) guideline is small, there is no level that is considered risk free.

Figure A.1 – The uranium decay chain



Note: Figure A.1 courtesy of Physics Solutions Inc.

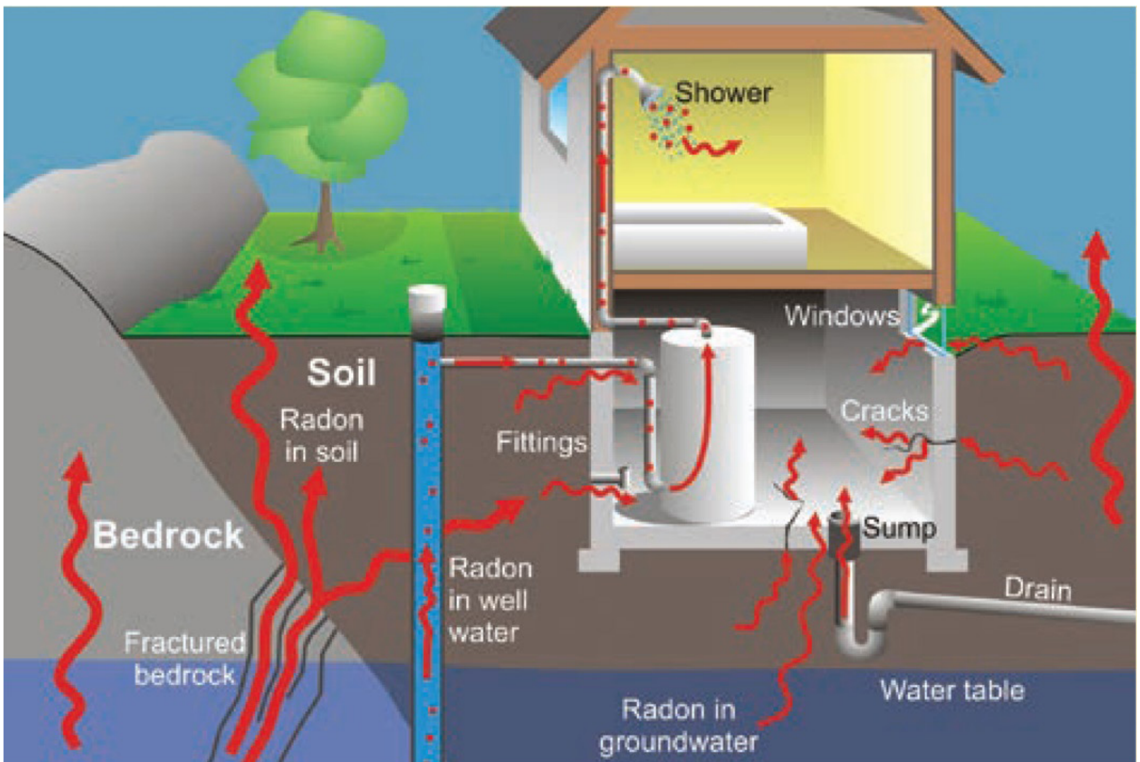
How does radon enter a building?

The air pressure inside a building is usually lower than in the soil surrounding the foundation. This difference in pressure draws in gases, including radon, through openings in the foundation where it is in contact with the ground. This includes construction joints, gaps around service pipes and support posts, floor drains and sumps, cracks in foundation walls and in floor slabs, and openings in concrete block walls.

In some areas, radon in the water supply can contribute to the indoor air radon concentration in the building. In such cases, radon dissolves in the water as it travels through rocks and soils. This situation is generally associated with ground water and thus is more likely to affect well water sources rather than surface waters used for most municipal water supplies. Large volumes of water are used for showers, washing etc., and when agitated, radon, if present in the water, can be released into the air. However, the health risk associated with radon dissolved in water is not from drinking the water, but from breathing the air into which radon has been released.

Potential radon gas entry points are illustrated in Figure A.2.

Figure A.2 – Radon entry points



"Reproduced with the permission of Natural Resources Canada 2008, courtesy of the Geological Survey of Canada."

Although high radon concentrations are associated with some geological formations, the combinations of soil type, building type and foundation type from one location to another mean that radon potential maps are poor indicators of the indoor radon gas concentration in any individual building. Even similar buildings next to each other can have very different average radon concentrations. The only way to know if a building has a high radon level is to measure the radon concentration using a long-term radon test (three-month test) that is approved by C-NRPP or equivalent.

Why is radon gas exposure a health hazard?

The only known health risk associated with exposure to radon is an increased risk of developing lung cancer. The risk of developing lung cancer depends on:

a) The smoking habits of the exposed person;

b) The average radon concentration in the building;

c) The length of time a person is exposed.

Health Canada estimates a non-smoker exposed to elevated levels (i.e., 800 Bq/m³) of radon over a lifetime has a 1 in 20 chance of developing lung cancer. The combined effects of radon exposure and smoking tobacco significantly increase the risk of lung cancer (tobacco leaves also uptake radioactive Po-210 from the soil). If a smoker is exposed to the same elevated level of radon over a lifetime, the risk increases to a 1 in 3 chance.

When a radon atom decays, it emits an alpha particle and produces new elements, called “radon progeny”. Unlike radon, the radon progeny (also referred to as radon decay products or radon daughters) are solids.

When alpha particles hit an object, such as a cell, their energies are transferred to that object, resulting in damage. Human skin is thick enough that the alpha particles cannot penetrate to more vulnerable tissues beneath, but if you breathe in radon or its progeny, the alpha particles they emit can damage unprotected and sensitive bronchial and lung tissues, which can then lead to lung cancer.

Originally, the estimate of lung cancer risk from radon exposure was based on exposures to high concentrations found in uranium mines, and the risk from lower concentrations typically found in buildings was uncertain. However, recent residential studies have confirmed that even exposure to the lower radon concentrations found in buildings carries a lung cancer risk[11, 12]. The time between exposure and the onset of the disease is usually many years (the average age of onset for lung cancer is age 60). Unlike smoking, besides lung cancer, exposure to radon does not cause other diseases or respiratory conditions nor does it produce symptoms such as coughing or headaches.

Radon guideline

Beginning in 2005, Health Canada collaborated with the Federal Provincial Territorial Radiation Protection Committee (FPTRPC) to review the health risk from exposure to radon. The risk assessment was based on new scientific information and was the subject of a broad public consultation. Using the risk assessment and feedback obtained from the public consultation, the Government of Canada updated its guideline for exposure to radon in indoor air in 2007[1]. This updated guideline provides advice that is more broadly applicable and more protective than the previous FPTRPC guideline.

The current Government of Canada guideline for exposure to radon in indoor air is:

- Remedial measures should be undertaken in a building whenever the average annual radon concentration exceeds 200 Bq/m³ in the normal occupancy area.

- The higher the radon concentration, the sooner remedial measures should be undertaken.

- When remedial action is taken, the radon level should be reduced to a level or concentration as low as practicable.

- The construction of new buildings should employ techniques that will minimize radon entry and facilitate post-construction radon removal should this subsequently prove necessary.

For more information about radon and the Guideline, visit the Health Canada Website: https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/radon.html or call 1-833-723-6600.

Annex B
(informative)
Radon mitigation system information package for building owners

The below information What is radon?, What are the health effects of radon?, and How can radon get into a building? are based on content from *Reducing Radon in Existing Homes: A Canadian Guide for Professional Contractors, Health Canada, 2010*[9].

What is radon?

Uranium is a naturally occurring radioactive element that is present everywhere in rocks and soil. The radioactive decay of uranium produces radium, which in turn decays to radon. Radon is a colourless and odourless gas that is chemically inert, but radioactive (see Figure A.1). As it is a gas, it can move easily through bedrock, soil and ground water; either escaping into the outdoor air or infiltrating into a building. All soil contains uranium, so radon is present in all types of soil. Radon that moves from the ground into the outdoor air is rapidly diluted to low concentrations and is not a health concern. However, inside a building, radon can accumulate to high concentrations and become a long term health concern. While the health risk from radon exposure below the Canadian (Health Canada) guideline is small, there is no level that is considered risk free.

What are the health effects of radon?

Exposure to high levels of radon in indoor air results in an increased risk of developing lung cancer. The risk of cancer depends on the level of radon and how long a person is exposed to those levels.

How can radon get into my building?

The air pressure inside your building is usually lower than in the soil surrounding the foundation. This difference in pressure (also known as the stack effect) draws air and other gases, including radon, from the soil into your building.

Radon can enter a building any place it finds an opening where the building contacts the soil: cracks in foundation walls and in floor slabs, construction joints, gaps around service pipes, support posts, window casements, floor drains, sumps or cavities inside walls.

Do I have a radon reduction system?

Yes if your building has been constructed with:

a) Radon rough-in system: visually identifiable as a capped and labelled pipe stub above the finished floor of the lowest level.

b) Extended radon rough-in system: visually identifiable as a pipe run between the finished floor of the lowest level and the outside of the building where it penetrates through a side-wall. The portion of the pipe run inside the building should be labelled. The portion of the pipe outside the building is capped.

c) Passive (soil depressurization) stack: visually identifiable as a vertical pipe run between the finished floor of the lowest level and the outside of the building where it penetrates through the roof or gable. The portion of the pipe run inside the building should be labelled. Portions of the pipe run located in unconditioned spaces should be insulated.

d) Active soil depressurization (ASD) system — A radon mitigation system designed to maintain lower air pressure under a floor slab (or a crawl space membrane, from within a sump pit, or within block walls) by using a fan and piping to draw radon from below a floor slab (or crawl space membrane, sump pit, or block walls) and exhaust it outdoors where it is rapidly diluted.

e) An HRV or ERV system expressly installed or an existing HRV or ERV re-configured for the purposes of reducing indoor radon levels.

Is there system maintenance?

Your radon system has been labelled in various locations, such as pipe, air barriers, and electrical panels and ASD fans, if applicable. DO NOT ALTER OR DISCONNECT any of these components.

Pipe

Inspect all exposed piping for damage at least once per year.

Membranes

The exposed membrane, used in crawl spaces, if applicable, should be inspected at least once per year for tears, cuts, or leaks in its seals, and any damage should be repaired as soon as is reasonably possible. The radon reduction system can have its performance reduced if damage to the membrane results in air leakage. Whenever there is an object resting on the membrane, check to ensure the membrane is protected from damage.

Sump pit

For sump pits, if applicable, an active (fan driven) radon reduction system can have its performance reduced if the sump pit cover is not tightly sealed. An unsealed sump cover may result in conditioned air from inside the building being removed instead of radon soil gas only being removed from beneath the slab as intended, which can in turn increase the risk of depressurizing the building. The sump cover's condition should be inspected at least once per year to ensure the integrity of its seals. This includes checking if gaskets are in good condition, and mechanical fasteners are installed to hold the cover in place. When repairing or replacing caulking, a removable type of caulk should always be used to seal the cover. If the sump basin requires maintenance, restore it to the original condition immediately after completing the work.

Foundation

Foundation settling, renovations (including openings associated with plumbing), or additions to your building can alter the radon concentrations in your building. You should test your building for radon after any of the above.

Water traps (floor drains)

Water traps or other devices should be fitted for drains to control sewer/soil-gas entry. Where water traps are installed, they should be refilled at least once per month to replace evaporated water.

Continuous radon monitors (professional-grade)

Where certified professional-grade continuous radon monitors are used as part of a maintenance inspection to ensure the system is maintaining low radon levels in a building, they should be sent for recalibration every two years at least one week before the calibration certificate expires.

System pressure gauge

Active radon reduction systems (Level 3) have a system pressure gauge that indicates the pressure in the piping system created by the ASD fan. The initial pressure should have been marked by the system installer. You should regularly check the gauge, at least once per month, to ensure the system is operating properly. If the gauge indicates a substantial change from the original marked pressure, or if it reads zero pressure, your radon reduction system may not be working properly, and you should call for service. This gauge measures suction pressure in Inches Water Column; it does not measure radon.

ASD fans

ASD fans for active systems should never be turned off; if turned off, the system will no longer function as intended. ASD fan replacement will vary depending on the location of the building and where the ASD fan is installed. For example, ASD fans installed in basements are typically easier to replace than those installed in attics. ASD fan replacement should be completed by a trained individual holding C-NRPP designation. Fan options and pricing can vary.

HRV/ERV system filters

The air filters in these systems require regular cleaning or maintenance in order for these systems to continue to function as designed. For example, ERV and HRV ventilation systems need periodic filter replacement and inlet grill cleaning (typically every three months) to ensure that their radon reduction capacity will be maintained. Plugged inlet filters or grills may lead to increased negative pressure in the building which may increase the radon infiltration rate into the building.

Should I retest for radon?

Health Canada recommends that buildings be tested for a minimum of three months, ideally between October and April. Your building should be tested after mitigation is completed and should be subsequently re-tested every two years. Testing is easy and inexpensive. Radon testing can be easily carried out by the building owner or occupant using special detectors available from commercial businesses, home improvement stores, some municipalities, and many provincial lung associations. These devices are simply placed in your building, exposed to indoor air for a specified period of time and then returned to the company to be analyzed. Other businesses may send a trained technician to your building to do the testing for you. For a list of service providers, you may also contact the Canadian — National Radon Proficiency Program (C-NRPP) at 1-800-269-4174 or contact Health Canada at:

Radiation Health Assessment Division – Health Canada
775 Brookfield Road, A.L. 6302D
Ottawa, Ontario K1A 1C1
1-833-723-6600
radon@hc-sc.gc.ca

Where can I learn more?

Visit the Health Canada Web site https://www.canada.ca/radon for more information on radon and testing your building.

Annex C
(informative)
Typical radon reductions associated with different mitigation techniques

The level of radon reduction achieved using various mitigation techniques is subject to several contributing factors. The World Health Organization (WHO) Radon Handbook (2009)[13] indicates that typical radon reductions range from 10 to 30% for sealing entry points, 30 to 70% for increasing ventilation mechanically when properly sized for radon reduction, and from 50 to 90% or more reduction in radon levels for active techniques, such as ASD. The nature of the Canadian climate may decrease the typical reduction in radon levels achieved for mitigation via ventilation.

Annex D
(informative)
Radon from water and construction material

This National Standard of Canada describes reducing radon in existing buildings where the radon in air originates in the soil surrounding and beneath the building. Radon can enter a building via two other mechanisms primarily.

Radon concentrations in municipally treated water systems are usually extremely low due to a combination of water treatment methods and delays in water treatment processing and distribution. Radon concentrations in well water can be significant depending on the source, but again, it requires extremely high radon concentrations dissolved in well water to appreciably impact indoor radon gas concentrations. A general rule of thumb used in the radon profession is that one requires roughly 10,000 times the radon in water concentrations per cubic metre of water (i.e., 2,000,000 Bq/m³ radon in water) before radon in water is likely to impact the indoor radon gas concentrations significantly. Radon concentrations in water this high are a rare occurrence, but can happen occasionally in private or community wells. If the air of a building supplied with groundwater tests above 200 Bq/m³, testing for radon levels in water should be considered. Radon in water test kits are commercially available. Radon mitigation from the soil should be performed first as it is usually the main contributor to high indoor radon levels. Depending on the results of the post-mitigation radon test for indoor radon gas concentrations, it may be necessary to also mitigate radon from water in order to reduce radon gas levels inside a building.

Radon can be dissolved in well water that enters the building from the distribution piping. When a faucet is opened, radon dissolved in the water will outgas into the air. This can happen for example during periods when occupants are showering, washing dishes, or doing laundry. Generally speaking, this radon outgassing is a very small contributor to indoor radon levels.

Well water systems having high radon concentrations can be treated in several ways in order to remove radon from the water before it can outgas inside a building. The main techniques used today are aeration (to displace radon) or treatment with granulated activated carbon (to trap radon). Both techniques require consideration of the overall composition of the water source to prevent clogging or fouling of these treatment systems, and the concentrations of radon in the water. Aeration is the preferred treatment technique for removing high concentrations of radon from well water.

Treatment with activated carbon requires consideration of long-term storage and disposal of the cartridges as gamma emitting radioactive radon decay products may buildup on the filter. This may require shielding of the cartridge, or mounting the cartridge outdoors or in an uninhabited part of the basement to reduce exposure of occupants to gamma radiation. Depending on the concentration of radon in the water and the length of time the granulated activated carbon filter is used, spent cartridges may require specialized hazardous waste disposal.

The other potential source of radon entering a building can originate in the materials of construction, depending on the concentration of radium-226 (the immediate parent of radon-222) present in the material. Radon can emanate from materials such as concrete, drywall, tiles, or granite countertops. Again, the contribution made by materials of construction to indoor radon gas concentrations in Canada is generally very small. Health Canada performed a study of radon emanation from a number of the most popular tiles and granite countertops sold into Canada and found that these were unlikely to contribute significantly to indoor radon levels[14].

Health Canada also performed a small study on emanation of radon from aggregate samples from various Canadian sources and found that these generally would be small contributors to indoor radon gas concentrations[15].

Annex E
(informative)
Outdoor soil depressurization systems

E.1 Outdoor fan with above roof discharge

Apart from the mild Canadian weather conditions in regions where the heating degree day (HDD) value is 3999 or lower, the performance of an outdoor soil depressurization system discharging above the roof with uninsulated fans and piping cannot be ensured. The main factors that may increase the risk of icing problems in winter time are:

- cold temperature (heating degree days);
- soil moisture: Elevated soil moisture is more likely to increase system icing issues;
- exhaust flowrates: A lower exhaust flow rate allows more time for moisture to condense and to freeze;
- electric power interruption frequency: Electric power interruption may impair the draining of condensation from within the ASD fan rotor. Below the freezing point, ice formation may freeze-up internal parts of the ASD fan thereby preventing it from starting up again after electrical power has been restored.

Installation of a pressure alarm device should be considered to detect major obstructive icing issues.

- A moisture condensation bypass should be installed to extend fan life.
- Fans should be sized in accordance with this Standard.

A radon mitigator should consider these parameters before making a decision to install an outdoor mitigation system. The ASTM E2121 standard addresses outdoor fan and piping installation.

E.2 Outdoor fan at above ground level with a downblast discharge

In northern countries such as Finland and the Czech Republic, mitigation solutions also include outdoor downblast exhaust fans discharging above ground level through the body of the ASD fan. The outdoor exhaust through the downblast fan could be used for various types of soil depressurization. This type of installation is less likely to encounter obstructive icing due to the fact that long outdoor pipe runs discharging above the roof are not required.

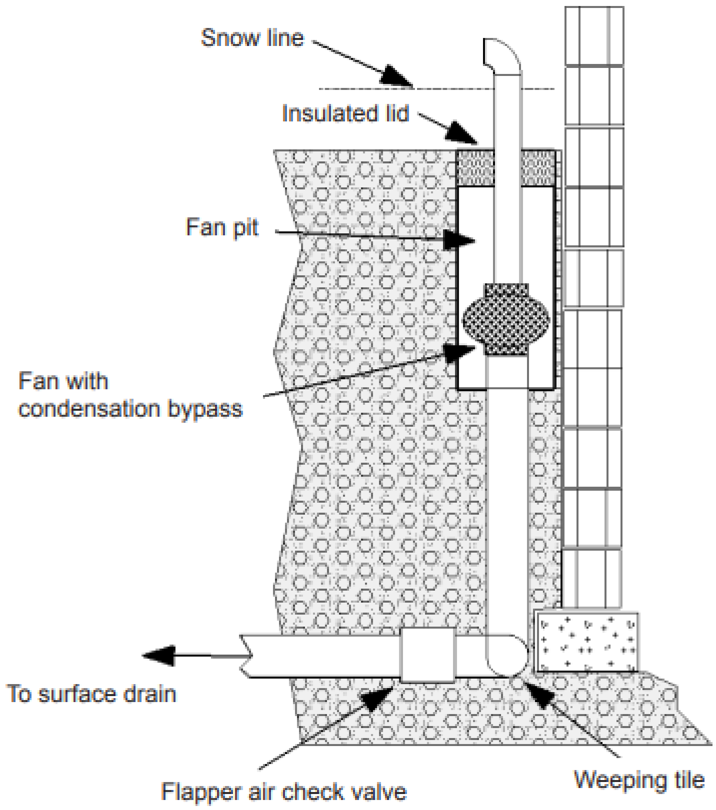
This outdoor installation option would allow the creation of a sump underneath the slab that can be connected to piping that runs along the foundation. The downblast fan connects to the piping to allow suction across the subslab area.

All parts of the systems are outside of the building envelope.

The ASD fan should be installed vertically. An enclosure or box, resistant to weather and moisture should be used to cover the outdoor fan. Access to the ASD fan is via the bottom which is left opened. Fans should be sized in accordance with this standard.

E.3 Soil depressurization through exterior perimeter foundation drains

Figure E.1 — Drainage tubing exhaust



E.3.1 Even if the exterior perimeter foundation drain (weeping tile) is not brought into a sump but rather discharges by gravity to the surface of a sloping site, it can still be used to achieve soil depressurization by attaching a fan directly to the weeping tile.

E.3.2 This installation should be considered when communication tests demonstrate the potential feasibility of this technique.

E.3.4 An uninsulated above ground outdoor fan should only be considered in regions where the heating degree day (HDD) value is 3999 or lower.

Note: Fan may be placed in a protective insulated enclosure with an exhaust pipe above the snow line. Refer to E.1 for outdoor fan installation.

E.3.5 Exterior underground fan installation for weeping tile depressurization

With the exception of houses being mitigated in regions where the HDD value is 3999 or lower, fans should be placed underground in a pit to prevent freezing in the ASD fan and the condensate bypass drain. An interior fan power indicator, or an electrical pressure switch connected to a light or pressure alarm should be installed to warn that the ASD fan is not operating. A tube connected to a manometer inside the building should not be used as water vapour may freeze in a cold section of the tube and give erroneous readings.

E.3.5.1 The water discharge pipe(s) must be trapped to prevent surface air from entering the system and reducing the suction while still allowing water to drain. This trap should be below the frost line.

E.3.5.2 Requirements for pipe selection, fan and pipe installation and layout, discharge clearances, fan sizing, and communication testing from this standard also apply.

Annex F
(informative)
Pressure difference across below-grade envelope

The differential pressure arising from the stack effect between ground level outside the building and indoors, just above the slab floor, $P_{Out\text{-}In}$ (Pa) is one of three pressures that the ASD fan in an ASD system must overcome. An ASD system should be designed to overcome the maximum of this pressure difference. Shown in Table F.1 below are recommended values for some building types.

Table F.1 — Building outdoor-indoor pressure differences (stack effect)

Maximum pressure difference across below-grade building envelope (Pa)			
Building type	**Mild winter <4000 HDDs**	**Moderate winter 4000-5999 HDDs**	**Severe winter >6000 HDDs**
Slab on grade (no chimney)	1	2	3
Slab on grade (chimney)	3	4	5
1 or 2 storey (no chimney)	4	5	6
1 or 2 storey (chimney)	8	9	10
3 storey (no chimney)	7	8	9

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Other useful resources

ANSI/AARST CCAH – *Reducing Radon in New Construction of One & Two Family Dwellings and Townhouses.* Available from: https://webstore.ansi.org/standards/aarst/ansiaarstccah2020.

ANSI/ASHRAE 62.1 – *Ventilation and Acceptable Indoor Air Quality.* Available from: https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

ASTM E1465 – *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings* (withdrawn 2017). Available from: https://www.astm.org/.

ASTM E2121 – *Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings.* Accessible à l'adresse suivante : https://www.astm.org/.

CAN/CSA-F326-M91 – *Residential Mechanical Ventilation Systems.* Available from: https://www.csagroup.org/.

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