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National Standard of Canada

Radon mitigation options for existing low-rise residential buildings

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Radon mitigation options for existing low-rise residential buildings

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Introduction

Radon is a radioactive gas which is a decay product of uranium, and is found everywhere in rocks and soil. Radon moves easily through bedrock and soil and either escapes into outdoor air where it is rapidly diluted, or into enclosed spaces like homes, where it can sometimes accumulate to high levels, which increases the long-term risk of lung cancer for occupants.

The risk of developing lung cancer depends on:

1. the smoking habits of inhabitants;

2. the length and intensity of the cumulative exposure of an individual (to indoor radon) in the buildings where they spend most of their time.

NOTE There are other lung cancer risk factors such as socio-economic, behavioral, occupational, biological and environmental.

The combined effects of radon exposure and smoking tobacco can significantly increase the risk of lung cancer. Although the exposure to radon gas indoors and in occupational settings has been associated with an increased risk of developing lung cancer, there is not sufficient evidence in the published literature for the association with other diseases[1].

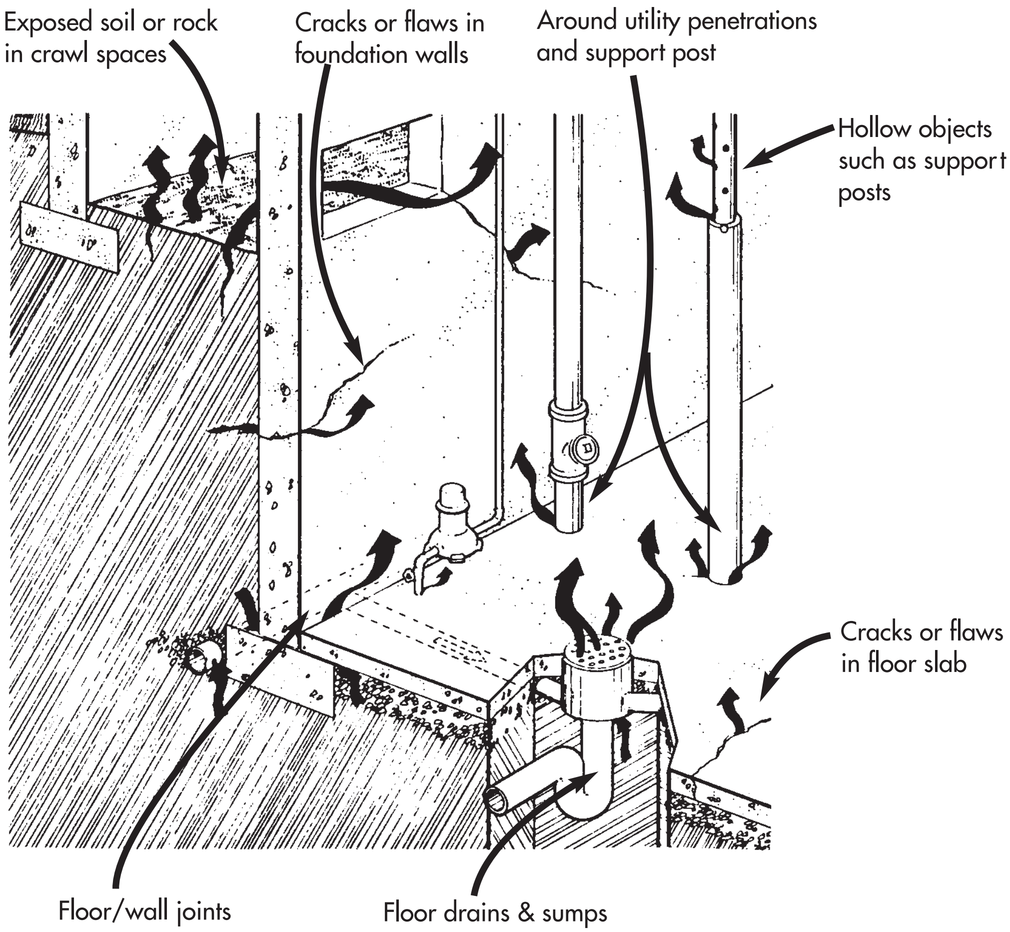
Due to a difference in air pressure between the inside of a building and the soil surrounding the foundation, soil gases, including radon may enter through openings in the foundation such as construction joints, gaps around service pipes and support posts, floor drains and sumps, cracks in foundation walls and in floor slabs, and openings in concrete block walls.

Mitigation of existing homes with high levels of radioactive radon gas is a complex task, associated with many variables. It is recommended that radon mitigation be performed by a knowledgeable, specially trained radon mitigator such as a Canadian – National Radon Proficiency Program (C-NRPP) certified radon mitigator.

Radon is soluble in water and affects well water sources rather than surface waters which are more commonly used for municipal water supplies. When large volumes of water are used for domestic purposes, the radon dissolved in the water outgasses into the air. The health risk associated with radon dissolved in water is not from drinking the water, but from breathing the air into which the radon gas has been released.

Potential entry routes for radon are illustrated in Figure 1.

[1] You can consult the World Health Organization (WHO) Radon handbook, September 2009 [viewed 2017-07-13]. Available from <http://www.who.int/ionizing_radiation/env/radon/en/index1.html>



NOTE 1 The only way to know if a home has a high radon concentration is to measure the radon concentration.

NOTE 2 Figure has been taken from Health Canada, Radon Reduction Guide for Canadians, May 2014.

Figure 1 — Potential entry points of radon in foundation walls and poured concrete floors

In 2007 the Government of Canada in conjunction with the Federal Provincial Territorial Radiation Protection Committee updated its guideline for exposure to radon in indoor air after a broad public consultation process which was based on new scientific information on health risk from indoor radon exposure.

The current Government of Canada Guideline for radon in indoor air is:

- Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 becquerels per cubic metre (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 value as low as practicable.
- The construction of new dwellings should employ techniques that will minimize radon entry and will 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/environmental-workplace-health/radiation/radon.html#wb-info or call 1-800-O-Canada.

Radon detection techniques and reduction system types

Indoor radon levels can fluctuate over time. The variability is due to the combination of radon inflow from the soil and the home's ventilation rate.

The radon concentration in soil gas depends on the concentration of uranium and radium in the soil beneath and around the building. Indoor radon concentration depends on the radon supply rate and the rate at which diluting outdoor air enters the building. The rate at which soil gas containing radon enters a building (radon supply rate, Bq per hour) depends on:

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

In addition to short-term variations in indoor radon concentrations around the monthly average radon value, the monthly average itself varies from season to season, with the highest values usually occurring during winter months. Because of these variations, a measurement duration of at least three months during the heating season will generally provide a conservative estimate of the annual average.

If the result of the long-term measurement is greater than 200 Bq/m³ (5.4 pCi/L), Health Canada recommends that remedial action be undertaken. A short-term measurement of two to seven days is only acceptable as a rapid indication of radon concentration, for example, as an initial check on the success of a mitigation system installation. As it may not represent the actual long term average radon concentration, short-term testing should always be followed up with a long term test. The results of a short-term radon test should never be used to assess the need for radon mitigation in a house.

While the health risk from radon exposure below the Canadian guideline decreases as the concentration is reduced, no level can be considered risk free. It is the choice of each homeowner to decide what level of radon exposure they are willing to accept.

The mitigation method chosen is influenced by the initial radon concentration test results, the degree of radon reduction desired by the homeowner, the building type, and the costs associated with the method. How the basement or foundation area is used by a homeowner can affect their expectations of the installation appearance and the cost.

Mitigation of high levels of radon gas in a home may be accomplished using two basic methods. Either high levels of radon are kept from entering the building, or the radon which has already entered the home is diluted with outdoor air.

An established method of keeping radon from entering a building is active soil depressurization (ASD). ASD systems utilize a fan to create a negative pressure on the soil side relative to the interior of the building and thus exhaust the radon-laden soil gas to the outdoors where it is rapidly diluted. Typical radon reductions associated with different mitigation techniques are presented in Annex A.

The effectiveness of ASD in combination with sealing soil gas entry routes for radon control has been extensively proven, and the system typically does not significantly increase building energy usage when it is well-designed and operated, therefore ASD should always be the first choice for reducing radon levels. ASD systems require little maintenance, function well for many years with an average fan life expectancy up to ten years, and typically reduce radon levels from 50 to 99%. Occasional replacement of the fan ensures the functionality of the system far into the future. The family of ASD systems consist of several different methods depending on the building construction.

Buildings that have a fully poured concrete floor slab use sub-slab depressurization (SSD) and buildings that have exposed soil or other native materials use sub-membrane depressurization (SMD). Sump depressurization (SD), drain tile depressurization as well as block-wall depressurization are variants on soil depressurization where a depressurization fan is connected to a sump pit, drain tile network, or cavities of a block wall structure respectively to reduce radon levels. In SSD systems, the mitigation contractor cores through the existing concrete floor and connects to the gas permeable layer. The mitigation contractor then installs piping running to the outside of the building, and connects a radon fan inline into the piping system. The fan and piping depressurize the gas permeable layer and exhaust radon-laden soil gas outdoors. A variation of this technique, called sump depressurization uses a fan to draw from a previously covered, existing sump basin typically having weeping tile inside the foundation walls.

In SMD, the mitigator creates a soil gas collection plenum between the soil and the building such as in an exposed soil crawl space by installing a membrane that is tightly sealed to the foundation walls and around all penetrations. The mitigator then installs piping to the outside of the home, as well as a radon fan inline into this piping system. The fan depressurizes the soil side of the membrane and exhausts radon-laden soil gas outdoors. SMD can also be coupled with a SSD system.

Reducing radon through dilution is typically achieved through the installation of heat recovery ventilators (HRV) or energy recovery ventilators (ERV). A blower door test is required to estimate the natural ventilation rate of the building. This natural ventilation rate is then used to calculate HRV or ERV sizing for a given or desired level of radon reduction. Equally balanced flow rates for the inlet and outlet of the system and system maintenance are paramount. HRVs and ERVs that are sized for radon reduction may achieve radon reductions of 20-50% but there is an ongoing energy penalty associated with these systems.

Multifamily/semi-detached dwelling concerns

Buildings are to be considered as systems. Many townhouse complexes or semi-detached buildings share a common foundation and this is the typical pathway for radon gas entry into the building. Therefore, radon mitigation of this style of construction needs to consider the building in its entirety.

As much as is feasible, the building should also be considered as a whole for initial radon testing, consequently, all dwellings should be tested simultaneously. In the case of a single building being occupied by several owners or tenants, all or several owners or tenants should be advised of the detected radon issue. In this case, the mitigator may often need to access all basement levels of the building as well as other levels to perform diagnostics, and to ensure that the mitigation system does not cause adverse health impacts or damage due to backdrafting of combustion appliances, or possible cold weather concerns such as freezing of foundation footings. Multifamily, semi-detached and condominium buildings also present challenges in terms of installation, operation and maintenance costs of a radon mitigation system (RMS). It is beyond the scope of the present standard to determine how occupants and owners will address radon mitigation in these situations, but this may directly impact the selection of the mitigation technique.

If all basement sections are not accessible to a mitigator, sealing and increasing the ventilation rate can be achieved in a certain section of a building with minimal risk of adverse impacts in the other inaccessible sections. The outcome of either sealing or increasing ventilation as standalone mitigation techniques for reducing radon levels can vary greatly.

Some guidance on mitigation for multifamily buildings is addressed in the ANSI/AARST standard RMS-MF 2014 entitled *Radon Mitigation Standards for Multifamily Buildings*[2].

[2] This publication is available from <https://aarst-nrpp.com/wp/store/>

Mitigation of buildings equipped with preventive measures

In Canada, various preventive measures against soil gas infiltration have been described in different building codes, other guidance (Leadership in Energy and Environmental Design (LEED) residential, municipal programs, etc.) as well as in CAN/CGSB-149.11 *Radon control options for new construction in low-rise residential buildings*[3]. After a long term radon test demonstrates that radon concentrations are above the radon Guideline in a building equipped with preventive measures, completing, activating or retrofitting any preventive measures that failed to reduce radon to below the guideline in a dwelling after occupancy is considered mitigation and is addressed in this standard.

Limitations:

This standard is not a substitute for building code regulations currently in effect. It is the responsibility of the contractor to ensure that they comply with the applicable health, safety and building code standards. Local codes and regulations take precedence in the event of a discrepancy with the present standard. Annex B *Radon mitigation system information package for homeowners* offers valuable data to consult as required.

The application of the requirements found in this standard cannot guarantee radon reduction neither below the Canadian radon guideline nor below any 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.

Units of measure:

Quantities and dimensions in this standard are given in metric units with imperial equivalents, mostly obtained through soft conversion, given in parentheses to the closest imperial rounded value, for convenience. The metric unit is regarded as being official in the event of dispute or unforeseen difficulty arising from the conversion.

[3] CGSB standard to be published at a later date.

Radon mitigation options for existing low-rise residential buildings

1 Scope

This National Standard of Canada (NSC) addresses system design and installation requirements for radon mitigation in existing low-rise residential buildings (see 3.37).

This standard provides diagnostic methods, design and installation instructions, and acceptable materials and product specifications, to maximize the radon reduction capacity of the system.

This standard is specific to radon gas emanating from soil gas sources. This standard does not address specific mitigation techniques for radon from other sources (see Annex C).

The scope of this NSC may include but is not limited to provision of requirements, specifications, guidelines and characteristics that can be used consistently to ensure that materials, products, processes and services used in the radon mitigation of existing low-rise residential buildings are fit for their purposes.

This standard is intended to support Canadian regulation and may be used to support operational compliance for radon certification/qualification programs or to assist in preventing deceptive practices in the marketplace.

The testing and evaluation of a product against this standard may require the use of materials and/or equipment that could be hazardous. This document 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 addresses provided below were 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 Standards Association (CSA)

B149.1-05 — *Natural gas and propane installation code* (withdrawn)

B149.1-10 (R2015) — *Natural gas and propane installation code*

CAN/CSA B181.1-96 — *ABS drain, waste, and vent pipe and pipe fittings* (withdrawn)

CAN/CSA B181.2-M87 — *PVC drain, waste, and vent pipe and pipe fittings* (withdrawn)

CAN/CSA B182.1-M92 — *Plastic drain and sewer pipe and pipe fittings* (withdrawn)

C22.2 No. 100-14 — *Motors and generators*

C22.2 No. 113-12 — *Fans and ventilators* (withdrawn)

F300-13 — *Residential depressurization*.

2.1.1 Source

The above may be obtained from the Canadian Standards Association, Standards Sales, 178 Rexdale Boulevard, Toronto, Canada M9W 1R3. Telephone 1-800-463-6727 or 416-747-4044.

2.2 Underwriters' Laboratories of Canada (ULC)

ULC S636-08 — *Standard for type BH gas venting systems*

CAN/ULC-S741 — *Standard for Air Barrier Materials — Specification*.

2.2.1 Source

The above may be obtained from the Department Underwriters' Laboratory of Canada, 7 Crouse Road, Toronto, Canada M1R 3A9, Telephone 416-757-3611.

2.3 ASTM International

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

ASTM F891 – Standard *Specification for Coextruded Poly (Vinyl Chloride) (PVC) Plastic Pipe With a Cellular Core.*

2.3.1 Source

The above may be obtained from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, U.S.A., telephone 610-832-9585, fax 610-832-9555, Web site www.astm.org, or from IHS Markit, 200-1331 MacLeod Trail SE, Calgary, Alberta T2G 0K3, telephone 613-237-4250 or 1-800-267-8220, fax 613-237-4251, Web site www.global.ihs.com.

3 Terms and definitions

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

3.1
active soil depressurization (ASD)
group of radon mitigation systems involving fan-powered soil depressurization, including but not limited to the most common variant called sub-slab depressurization, and other related techniques such as sub-membrane depressurization, (ex. crawl space depressurization) block-wall depressurization, and weeping tile depressurization.

NOTE ASD is considered to be the method of choice in residential buildings to reduce high radon levels, with radon reductions of 90% or higher being possible.

3.2
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 air changes per hour in a house, divide the flow rate through the fan (expressed as air volume per hour) by the volume of the house (make sure volume is expressed in same base units).

3.3
as low as reasonably achievable (ALARA)
internationally recognized guiding practice employed 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 http://nuclearsafety.gc.ca/pubs_catalogue/uploads/G129rev1_e.pdf and http://apps.who.int/iris/handle/10665/42973

3.4
ASD fan
type of fan that is designed and approved by the manufacturer for continuous duty and for use in an ASD system.

3.5
backdrafting
reverse flow of outdoor air into a building through the barometric damper, draft hood or 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 (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.

3.6
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.

3.7
band joist
board with the same width as the floor joist that rests on its thinnest dimension on top of the sill plate around the perimeter of the dwelling.

NOTE Band joist is also called header joist, header plate, or rim joist, the ends of the floor joists are nailed into the header joist that maintains spacing between the floor joists.

3.8
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 radon is pCi/L. 37 Bq/m^3 = 1 pCi/L

3.9
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 Blowers 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 dwelling pressurization and depressurization, the blower door permits determination of the tightness of the building envelope shell.

3.10
Canadian – National Radon Proficiency Program (C-NRPP)
national program used by laboratories, measurement and mitigation professionals in Canada.

NOTE Canadian – National Radon Proficiency Program (C-NRPP) may provide designation to individuals or companies that have met qualification requirements or are authorized by a certification program to provide radon laboratory, measurement or mitigation services.

3.11
Canadian radon guideline
indoor radon concentration at which mitigation is recommended, which was set at 200 Bq/m^3, as established by Health Canada's radon guideline in 2007 (Canada Gazette Part I, June 9, 2007).

3.12
shrinkage gap (cold joint)
contact joint between the foundation wall and the basement slab or the parts of a slab that were poured at different times.

3.13
communication testing
typical process whereby a radon mitigator makes diagnostic pressure measurements of the under slab area in order to properly size an ASD mitigation system.

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

3.14
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. CR monitors use scintillation cells and photomultiplier tubes, ionization chambers, or solid-state silicon detectors.

3.15
crawl space
shallow space between the lowest floor of a house and the ground beneath.

NOTE The crawl space can have a height ranging from a few inches to several feet (hence the origin of the term "crawl"). The crawl space may or may not be ventilated to the outdoors.

3.16
cubic feet per minute (CFM)
measure of the volume of a fluid (liquid or gas) flowing within a fixed period of time.

NOTE Conversion: 1 cfm = 0.472 Litre per second [L/s].

3.17
depressurization
negative pressure induced in one area relative to another.

NOTE In a dwelling during cold weather, the lower levels experience depressurization due to the stack effect, causing the air pressure in the lowest levels of the building to become lower than the air pressure of the soil beneath the building, resulting in air being drawn into the building through leakage points.

3.18
design suction
suction needed in the fill at the slab edge to reduce the winter-time across-slab pressure difference to at least zero.

3.19
diagnostic tests
procedures that typically include communication tests used to identify or characterize conditions under, beside and within dwellings that could contribute to radon entry or elevated radon levels or that could provide information regarding the performance of a radon mitigation system.

3.20
drainage tubing depressurization (DTD)
variation of ASD where the gas permeable layer underneath the floor slab is depressurized by applying suction on the drainage tubing which runs either outside or inside of the foundation.

NOTE Also known as drain tile depressurization.

3.21
dwelling
single room or series of rooms of complementary use, operated under a single tenancy including individual guest rooms in boarding houses, rooming houses and dormitories — operated as a housekeeping unit, used or intended to be used by one or more persons and usually containing cooking, eating, living, sleeping and sanitary facilities.

NOTE This definition is based on the definition of dwelling unit in the *2015 National Building Code*, but excludes any residential spaces in motels, hotels, and business and mercantile occupancies.

3.22
entry points
openings in the foundation floor or walls in contact with the soil, which allow soil gas to enter.

3.23
entry routes
pathways by which soil gas can flow into a building.

3.24
exfiltration
unintended flow of indoor air out of the dwelling through holes or cracks in the building envelope.

3.25
exhaust fan
fan installed such that it draws indoor air out of the dwelling.

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

3.26
footing(s)
concrete or stone or wood base which supports a foundation wall and is used to distribute the weight of the building over the soil or the sub grade underlying the building.

3.27
french drain
water drainage technique installed in basements of some dwellings during initial construction.

3.28
gas permeable layer
layer of gas permeable material installed under the basement sub-slab membrane which allows a negative pressure field to extend from the suction point to the foundation walls and footings.

NOTE An efficient gas permeable layer permits a radon mitigation system to draw radon-laden soil gas from the entire sub-slab area.

3.29
grade (above or below)
lowest of the average levels of finished ground adjoining each exterior wall of a building.

NOTE Localized depressions need not be considered in the determination of average levels of finished ground.

3.30
habitable space
any enclosed space that residents use or could reasonably adapt for use as living space within the dwelling.

3.31
heat exchanger
device which transfers heat from a warm to a cooler medium, normally by conduction.

3.32
heat recovery ventilator (HRV)
packaged ventilation appliance consisting of supply and exhaust air fans and motors, a heat recovery core, filters and controls which provides supply and exhaust ventilation and transfers heat between the exhaust and supply airstreams to reduce ventilation-related space conditioning energy use.

NOTE Energy recovery ventilators are HRVs that also handle humidity.

3.33
HVAC system
heating, ventilating, and air conditioning system for a building.

NOTE This system generally refers to a centralized heating source with or without an air conditioning system that uses forced air as the heating medium within the building.

3.34
infiltration
unintended movement of outdoor air or soil gas into a dwelling.

3.35
joist
one of a series of horizontal or inclined wood members, usually 50 mm (2 in.) nominal thickness, used for support in floors, ceilings or roofs.

3.36
litres per second (L/s)
measure of the volume of a fluid (liquid or gas) flowing within a fixed period of time.

NOTE Conversion: 1 Litre per second [L/s] = 2.119 cubic feet per minute (cfm).

3.37
low-rise residential building
building three storeys or less, having a building footprint area not exceeding 600 m^2.

3.38
manometer (micro-manometer)
sensitive differential air pressure indicating device used to determine very small pressure differences across a boundary.

NOTE Generally reads in units of Pa.

3.39
passive vertical radon stack
feature of dwelling construction whereby a full-height vertical pipe run is installed within the dwelling 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 dwelling in order to draw radon containing soil gas from beneath the slab and expel it to the outdoors. This technique generally leads to radon reductions of less than 50% as compared to an active radon mitigation system which can yield radon reductions of 90% or more. A passive 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.

3.40
post-mitigation radon level
radon concentration measured within the habitable space of the dwelling as a result of a long-term radon test (three months/ 90+ days) conducted after radon mitigation work has been performed.

NOTE The radon level should be reduced to ideally below the Canadian guideline value of 200 Bq/m^3, and in fact to ALARA levels. For most dwellings, it may be possible to reduce the radon level to below 100 Bq/m^3 (2.7 pCi/L). It is recognized that it may not be possible to reduce radon levels below 100 Bq/m^3 (2.7 pCi/L) in all homes by following the best practices outlined in this standard. The 3-month test is ideally conducted during the heating season to give a conservative estimate of the radon reduction achieved.

3.41
pressure field extension
spatial extension of the area of reduced pressure as occurs under a slab when a mitigation fan ventilates at one or more distinct points.

3.42
pre-mitigation radon level
radon concentration measured within the occupied space of the home as determined by a long-term radon test, ideally during the heating season.

3.43
radon
only naturally occurring radioactive element which is a gas.

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 dwellings. Radon-222 is directly created by the decay of radium-226, and has a half-life of 3.82 d. Chemical symbol: Rn-222.

3.44
radon mitigation
act of repairing or altering a building or building design for the purpose in whole or in part of reducing the concentration of radon in the indoor atmosphere.

3.45
radon mitigator
qualified individual who reduces indoor radon concentrations, and is experienced in radon mitigation.

NOTE In Canada, the Canadian – National Radon Proficiency Program (C-NRPP) maintains lists of mitigation professionals/ companies that have met qualification requirements or are authorized to provide radon laboratory measurement or mitigation services

3.46
radon mitigation system
system, component, design or installation for reducing radon concentrations in the indoor air of a dwelling.

3.47
rough-in
installation of all parts and materials of an ASD system that needs to be completed prior to the placement of concrete, prior to the closure of building cavities, and prior to the installation of finish materials.

3.48
slab
layer of concrete which commonly serves as the floor of any part of a dwelling whenever the floor is supported on a foundation or is in direct contact with the underlying soil.

3.49
slab on grade
type of building construction where the bottom floor of a house is a slab which is at grade level on any side of the building.

3.50
smoke tube
small tube, several inches long, which releases a small stream of inert smoke when a bulb at one end of the tube is compressed.

NOTE Smoke tube may be referred as smoke pencil. Can be used to visually define bulk air movement in a small area, such as the direction of air flow through small openings in slabs and foundation walls.

3.51
soil gas
gas which is always present underground, in the small spaces between particles of the soil or in crevices inside the rock and consists mostly of air with some components from the soil (such as radon and water vapour).

3.52
soil gas barrier
continuous membrane installed in order to reduce the flow of air containing radon gas into a dwelling.

NOTE A soil gas barrier is often made of polyolefin, but other more radon-specific membranes have been developed. Other types of soil gas proof continuous layers of material are also possible.

3.53
soil gas collector
gas permeable conduit constructed of gravel, perforated pipe or geotextile matting for collecting radon and other soil gases from within a soil gas collection plenum and connecting the plenum to the ASD pipe system.

3.54
stack effect
vertical movement of air due to differences in indoor-outdoor air density that increases the buoyancy of the indoor air relative to that of the outdoor air. This difference occurs as a result of differences in indoor-outdoor temperature.

NOTE The buoyancy forces driving stack effect increase with building height and temperature difference. In cold climates, stack effect tends to cause air to leak into the bottom of a building and out of the top.

3.55
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 air from beneath the membrane. The technique is quite often used in crawl spaces.

3.56
sub-slab depressurization (SSD)
radon mitigation technique designed to maintain lower air pressure under a floor slab.

NOTE An ASD fan is installed in the radon system piping that draws air from below the floor slab.

3.57
suction pit
cavity dug out from fill and soil beneath the floor slab. The sub-slab exhaust pipe draws air from this pit.

3.58
suction point
location where the soil gas collector is connected to the ASD system piping.

3.59
sump
watertight tank 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

3.60
sump pump
pump, usually electrically operated, used to remove water which collects in a sump.

3.61
ventilation rate
rate of movement of outdoor air through a building's exterior envelope via intended leaks or openings, both inward and outward (infiltration and exfiltration).

NOTE Ventilation is commonly expressed in units of air changes per hour, litres per second, or cubic feet per minute.

3.62
water column (WC)
differential pressure measurement made using the difference in height of two columns of water; one connected to a higher pressure and one to a lower pressure.

NOTE The units of water column are often expressed in the non-SI pressure unit of inches of water column (WC). 249 Pa = 25.4 mm water column [1 in. water column].

4 Abbreviations and acronyms

The following abbreviations and acronyms are used in this standard:

ABS	Acrylonitrile-butadiene-styrene
ACH	Air changes per hour
ALARA	As low as reasonably achievable
ASD	Active soil depressurization
ASTM	American Society of the International Association for Testing and Materials
Bq/m^3	Becquerels per cubic meter
CFM	Cubic feet per minute
CGSB	Canadian General Standards Board
C-NRPP	Canadian – National Radon Proficiency Program
CRM	Continuous radon monitor

CSA	Canadian Standards Association
DTD	Drainage tubing/ Drain tile depressurization
DWV	Drain, waste and vent
EPDM	Ethylene Propylene Diene Monomer
ERV	Energy Recovery Ventilator
HRV	Heat Recovery Ventilator
HVAC	Heating, ventilating and air conditioning system for a building
LEED	Leadership in Energy and Environmental Design
NRPP	National Radon Proficiency Program (NRPP American)
NSC	National Standard of Canada
PVC	Poly Vinyl Chloride
RMS	Radon mitigation system
SD	Sump depressurization
SDR	Standard Dimension Ratio
SMD	Sub-membrane depressurization
SSD	Sub-slab depressurization
ULC	Underwriters' Laboratories of Canada
WC	Water column
WHO	World Health Organization

5 Active soil depressurization methods

5.1 Mitigation by sub-slab depressurization

When house structure/characteristics permit it, sub-slab depressurization (SSD) is usually the most effective radon reduction system, and should be the first choice when selecting a radon mitigation system (RMS).

NOTE For the SSD to be efficient, all accessible holes, cracks and openings should be sealed as part of the work.

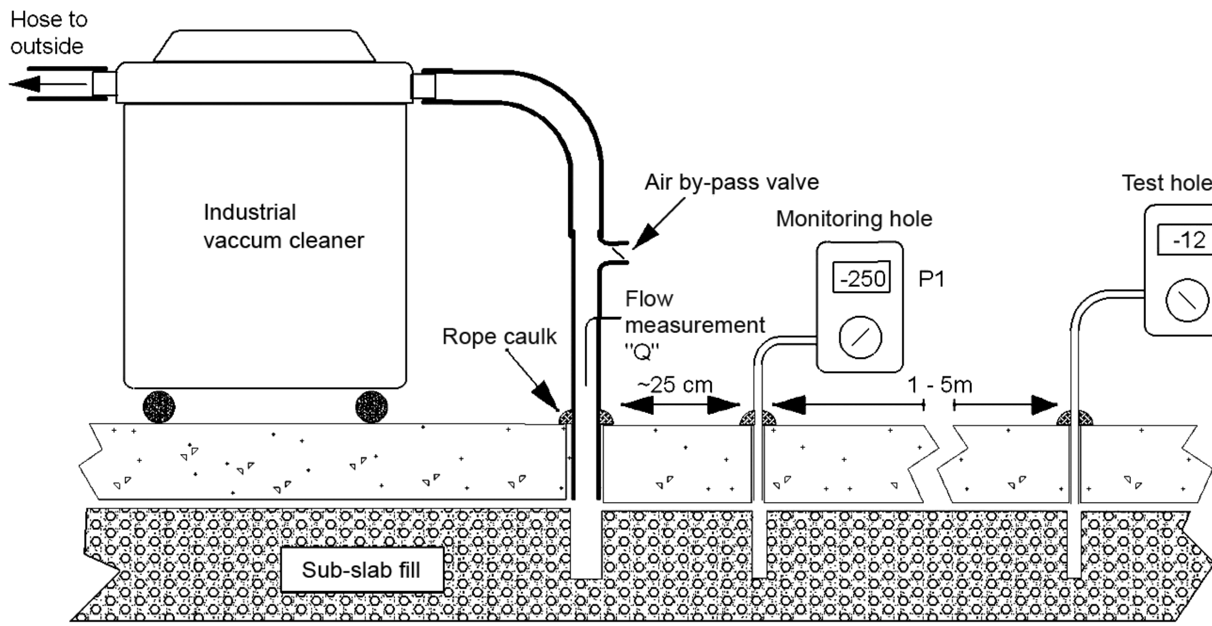
5.1.1 Feasibility test prior to installation

A "pressure field extension test" (i.e. communication test) shall be used to determine the number of suction points and the fan size needed for an effective system. A scheme of the communication testing results shall be documented and provided in the Homeowner radon mitigation system package (see 7.2).

a) Identify layout of any sub-slab plumbing piping and of any electrical conduits beforehand to avoid hitting those; and

b) Probe the fill to a depth of 15-20 cm to ensure that drilling deeper does not hit a plumbing pipe or a water supply line, once the drill breaks through the slab. See Figure 2 for the test layout concept.

NOTE 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.



NOTE 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 Contractors*, Health Canada, 2010, ISBN: 978-1-100-18472-2 for tutorial on the communication test.

Figure 2 — Sub-slab communication and flow test

5.1.2 Excavation of the suction pit

A suction pit shall be excavated at the selected suction point.

NOTE Typically, a suction pit has a radius of approximately 25 cm (0.8 ft.) and a depth of 15 cm (0.5 ft.) Increasing suction pit size may help improve the communication under the slab where sub fill material shows high resistance to air movement. A smaller suction pit is acceptable in low resistance sub fill material such as clean aggregate.

5.1.3 Sealing entry routes

Closing entry routes increases SSD efficiency from both a radon reduction and an energy consumption standpoint. All accessible entry routes should be sealed to increase the efficiency of the ASD system and to reduce associated heating and cooling energy costs. Entry routes which may compromise pressure field extension shall be sealed. Should an entry route strongly compromise pressure field extension in a finished basement, 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.

NOTE In addition, large losses of conditioned air may also present a risk of combustion appliance back drafting.

5.1.3.1 Sumps shall be provided with rigid lids that are hermetically sealed with a gasket or silicone caulking, or are mechanically fastened as required in 5.3. 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.

5.1.3.2 Floor drains, condensate drains, and foundation drains shall be designed and installed to prevent the entry of soil gas.

5.1.3.3 Openings through the slab for plumbing fixtures shall be sealed to the penetrations to prevent the ingress of soil gas.

5.1.3.4 Other penetrations through the slab, including access openings, shall be sealed to prevent the ingress of soil gas.

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

5.1.4 Pipe and fitting specifications

5.1.4.1 Piping of 100 mm (4 in.) nominal internal diameter shall be the first choice, while 75 mm (3 in.) nominal internal diameter pipe should only be used in low flow situations.

NOTE Partial sections of 75 mm (3 in.) nominal internal diameter may also be used to facilitate routing up through the attic and in a finished building.

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

5.1.4.3 Pipe shall not block access to areas requiring maintenance or inspection, except where airtight removable couplings are provided for pipe removal and replacement.

5.1.4.4 The following are the minimum requirements for permitted pipe used in the construction of soil gas collector and suction points.

a) The pipe material shall be resistant to the service environment or shall comply with 5.1.4.10

b) PVC pipes installed completely or in part above grade shall comply with Schedule 40 specifications regarding wall thickness, inside and outside diameters.

c) Specific colours for pipes are not required.

NOTE Refer to section 7 for labelling requirements.

5.1.4.5 Piping runs inside hollow walls or partitions within 43 mm (1.75 in.) of the surface shall be protected against physical damage and puncture at the joists, studs, and plates by the use of No. 16 GSG (1.59 mm) plates or sleeves. This provision shall not apply to piping that passes directly through walls or partitions.

5.1.4.6 Horizontal pipe runs should be minimized as permitted by the pipe design layout.

5.1.4.7 Above ground piping shall be attached to the structure of the building using appropriate hangers or straps. Horizontal pipe shall be supported at least every 1.8 m (6 ft) and vertical pipe shall be supported at least every 3 m (10 ft).

5.1.4.8 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 discharge exhaust pipe having fan located either indoors or in the attic if not longer than 30 cm (1 ft).

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

5.1.4.9 Horizontal pipes above and below ground shall be installed with at least a 1% slope to return water to the soil or in accordance with Table 1.

Table 1 — Recommended piping gradients

Nominal pipe size (ID) mm	Recommended gradient		
	@10 L/s	@25 L/s	@50 L/s
100	1/100	1/50	1/30

5.1.4.10 Acceptable pipe and fitting specifications

Where the pipe material conforms to one of the standards mentioned in a) to h) below, it shall be deemed to comply with 5.1.4 of this standard.

a) PVC flue gas venting pipe and fittings shall meet the requirements of ULC S636 and all pipe, fittings and cement shall come from one manufacturer and the cement shall conform to manufacturer's specifications and be adequate for the application conditions.

b) PVC Drain, Waste and Vent (DWV) pipe and fittings shall meet the requirements of CSA B181.2. Cement shall meet manufacturer's specifications and be adequate for the application conditions.

c) Pipe materials shall conform to ASTM F891, CAN/CSA-B181.1 or ASTM F628.

d) The application of glues, cements, priming materials and pipe materials shall be selected according to the manufacturer's requirements for the applicable site conditions and service environment. All pipes, fittings, primer and cement products used in the same soil collector and suction point system shall be compatible.

e) Primer shall be applied where required.

f) PVC drain sewer pipe shall meet the requirements of CSA B182.1 and shall conform to SDR35 specifications. Fittings shall be made of PVC and conform to the requirements of CSA B182.1. Pipes and fittings shall be joined with PVC solvent cement meeting manufacturer's specification and application conditions. The above-mentioned pipe and fittings are only certified for below grade installation and shall not be used above grade unless specified by a local authority.

g) Other types of piping not mentioned in this standard shall meet or exceed the minimum performance criteria specified in 5.1.4.4 a) b) and c).

h) When pipe passes through a fire rated wall or ceiling, the base of its penetration on its fire rated side shall be fitted with an intumescent collar to maintain its fire resistance.

5.1.5 Fan and piping

5.1.5.1 Piping where installed in unconditioned cold or warm environments shall be insulated and protected to minimize freezing inside of the pipe and condensation outside of the pipe.

5.1.5.2 Fan characteristics

In-line centrifugal fans specifically designed or designated by the manufacturer for radon mitigation shall be used. The radon fan used shall meet the product safety requirements in accordance with CSA C22.2 No. 113 and the motor shall comply with the applicable requirements of CSA C22.2 No. 100. The motor shall be approved by the manufacturer for 100% duty cycle. The radon fan seams and enclosure openings other than the inlet and outlet ports, shall be sealed so that the combined area of all gaps or openings of the 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 0.12 L/s (0.25 cubic foot per minute (cfm)) leakage at 375 Pa (1.5 in. water column (WC)) pressure.

5.1.5.3 A fan shall be installed so that the flow is vertical, so that any condensation in the system drains through the fan.

NOTE When the fan is installed outdoors, a condensation by-pass may be installed to collect and divert condensation in the discharge pipe around the fan.

5.1.5.4 To prevent noise, vibrations and leakage, the fan shall be connected to the piping with flexible PVC couplers that hold the fan away from both ends of the pipe. The suction pipe inside the house shall be sloped so that condensate passing through the fan can drain back to the sub-slab fill. Avoid dips or low spots in the piping so that condensate does not accumulate.

5.1.6 Electrical installation

5.1.6.1 Wiring shall be properly sized. According to fan electrical configuration, the fan shall be either doubly insulated or grounded. It shall comply with the relevant electrical codes, and electrical components shall be CSA or ULC listed.

5.1.6.2 The fan disconnect switch or plug should be within visual range (to a maximum 1.8 m (6 ft) distance) of the fan.

NOTE Disconnect refers to the possibility of a service switch or receptacle.

5.1.7 Fan monitoring

Each fan-powered system shall have a device to monitor fan performance.

NOTE A U-tube manometer is commonly used as an indicator that the mitigation system is working. The manometer is filled with a liquid and indicates a differential pressure between the building interior and the suction part of the pipe. A digital manometer can also be used to indicate a differential pressure between the building interior and the suction part of the pipe.

5.1.8 Mitigation system termination

Depending on the fan location, the termination of a soil depressurization exhaust can either be located:

a) at low level lateral discharge usually passing through the rim-joist at right angles for a fan installed indoors in the basement or in an attached garage.

b) above roof line level where the fan is typically installed in the attic or in an attached garage.

NOTE Cost, possible indoor pipe layout, space availability, and requirement to respect discharge clearance distances (see 5.1.8.2) 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 passing through sensitive roof material.

5.1.8.1 In all discharge types, a protective screen should be installed at the end of the pipe. When used, the screen shall be made of low pressure drop stainless steel mesh.

5.1.8.2 Minimal clearances for all types of radon discharges

Adapted from CSA B149.1 (2005 and 2015).

Clearances from radon discharge should follow suggested minimal clearances and shall follow required minimal clearances listed in Table 2.

a) A vent shall not terminate where it may cause hazardous frost or ice accumulation on building surfaces or any adjacent property surfaces;

b) A vent shall not terminate directly above a sidewalk or paved driveway that is located between two single family dwellings and that serves both dwellings;

c) The clearance for an openable window should also be applied for rooms that are occupied more than 4 h a day;

d) Discharging no less than 100 cm (3.3 ft) under veranda, porch, deck, or balcony should be considered only if veranda, porch, deck, or balcony is fully open on a minimum of two sides.

Table 2 — Clearances from radon discharge

Locations	**Suggested clearances m**	**Required minimal clearances m**
Clearance to a mechanical air supply inlet	3	1.80
Clearance to permanently closed window	1	0.30
Clearance to an openable window	2	1
Clearance from a door that may be opened	1	0.30
Clearance from a door that has an openable window	2	1
Clearance to outside corner	0.30	0.30
Clearance to inside corner	1.0	0.30
Clearance above paved sidewalk or paved driveway located on public property	2.10	2.10
Clearance above grade- from a veranda, a porch, a deck, or a balcony	1	0.30
Vertical clearance below soffits or from any attic venting component	1	1
Horizontal clearance from an area directly below the discharge where there is a risk of injury from ice falling	2	1
NOTE The selection of the exhaust point should be made considering maximal available clearances from building openings and from outdoor occupancy areas.		

5.1.8.3 Provisions for an above roof discharge

When an above roof discharge option is installed, the suction pipe runs vertically upwards through the conditioned space and the fan is located in the attic.

NOTE Recommended minimum effective thermal resistance of the pipe passing through the attic is 2.46 $m^2 \cdot K/W$ or R14.

5.1.8.3.1 The discharge pipe penetrating the roof shall discharge vertically above the roof line.

NOTE The outdoor section of a vertical discharge location should be located after considering the likelihood of snow accumulation or condensation icing in the vicinity of the discharge pipe.

5.1.8.3.2 Outdoor fan installation shall only be considered in regions where the heating degree day (HDD) value is 3999 or lower. Since local climatic variations exist, each area should be considered independently. See Annex D for information on outdoor fan installations.

NOTE A condensation bypass may extend the fan life in outdoor installations by reducing the impact from accumulation of moisture.

5.1.8.3.3 Refer to 5.1.8.4.1.4 and 9.2 for short term and long term post-mitigation measurement requirements.

5.1.8.4 Provisions for a horizontal sidewall discharge

An above-ground discharge from a short pipe near ground level at right angles to the wall should be favoured in the following circumstances:

a) cold weather areas

b) elevated soil moisture levels

c) low exhaust flow rates.

NOTE The above-mentioned circumstances either alone or in combination have been observed to increase above roof line discharge icing issues.

The short outdoor section of a sidewall discharge exhaust pipe should be located to avoid snow accumulation blocking the discharge pipe.

5.1.8.4.1 Requirements for rim-joist lateral discharge with fan in the basement

5.1.8.4.1.1 Indoor fan selection criteria

The mitigator shall use a sealed fan designed for radon mitigation having the following characteristics.

The radon fan used shall meet the product safety requirements in accordance with CSA C22.2 No. 113 and the motor shall comply with the applicable requirements of CSA C22.2 No. 100. The motor shall be approved by the manufacturer for 100% duty cycle. The radon fan seams and enclosure openings other than the inlet and outlet ports, shall be sealed so that the combined area of all gaps or openings of the fan ousing shall not exceed a total area of a single 3.17 mm (0.125 in.) diameter hole which would result in a maximum 0.12 L/s (0.25 (cfm)) leakage at 375 Pa (1.5 in. WC pressure).

5.1.8.4.1.2 Indoor fan location

The fan should be installed in a non-occupied part of the building such as a mechanical room or unfinished part of the basement.

5.1.8.4.1.3 Leak test

Any fan, fitting and pipe assemblies under positive pressure shall not contribute to indoor radon levels. The installer shall check each connection, fan joint and system component subject to fan-induced positive pressure while under normal operating pressure with either a liquid bubble solution or a leak-detection device to locate any source of a leak. The installer shall seal any detected leak in a manner recommended by the component manufacturer and retest. Fans requiring bubble leak testing or fans installed outdoors shall meet the requirements of CSA 22.2 No. 113 for outdoor use.

Leak test exception: Radon fans mounted outdoors, in attics or attached garages, or radon fans with all critical seams under negative pressure or housed in a negative pressure enclosure shall not require a leak test.

5.1.8.4.1.4 Post-mitigation testing

The radon mitigator shall conduct a short-term test or arrange for one to be carried out, after a system is activated to demonstrate initially that the mitigation has been successful. A short-term radon measurement of a duration no shorter than 48 h using an approved radon testing device shall be performed no sooner than 24 h after activation, while the system is operating, but within the first month of system activation to assess system effectiveness. Upon verification of the short-term test, the homeowner shall be advised to do a long-term test using an approved radon testing device. A re-test should be performed every two years with a long-term radon testing device.

The radon testing device shall be approved by the Canadian – National Radon Proficiency Program (C-NRPP), the National Radon Proficiency Program (NRPP American) or an equivalent.

NOTE Post-mitigation testing may also include a radon surveillance device to continuously monitor indoor radon. For additional radon testing information, please see the Health Canada website at https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html

5.1.8.4.1.5 Indoor fan system labelling

After completion of the leak test, a label shall be applied to the radon fan by the installer. The label shall contain the following information:

"The Installer has tested this system 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 and your radon levels retested every two years or after major structural, or ventilation/air circulation equipment changes to your home."

« L'installateur a soumis ce système à un essai d'étanchéité durant son installation. Veuillez noter que tout dommage matériel ou vieillissement pourrait provoquer une fuite qui, à son tour, pourrait faire augmenter la concentration de radon dans l'air intérieur. Il vous est conseillé d'inspecter régulièrement votre système et de mesurer la concentration de radon tous les deux ans ou après des modifications importantes apportées à la structure, à l'équipement de ventilation ou au système de circulation d'air de votre habitation. »

The installer shall also indicate the date of mitigation on the label.

5.1.8.5 Gable discharge through the attic

An active radon mitigation system may discharge through the attic gable provided the installation conforms to the clearances listed in Table 2.

5.1.8.5.1 Minimal clearances for all types of radon discharges in 5.1.8.2 shall also be followed.

5.1.8.5.2 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.

5.1.8.5.3 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.

5.1.8.5.4 The pipe shall be installed in such a position that it shall not be covered with snow or other materials from adjacent roofs and gutters.

5.1.8.5.5 Refer to 5.1.8.4.1.4 and 9.2 for short-term and 9.3 for long-term post-mitigation measurement requirements.

5.1.9 System sizing

5.1.9.1 Sizing the system fan

Fans should be sized to produce the required flows and pressures to effectively reverse the flow of soil gas from inside to outside of the house as a function of the house size, slab condition, and sub-slab fill material.

5.1.9.2 Building pressure differences

Table 3 shows differential pressure arising from the stack effect between ground level outside the house and indoors just above the floor slab for Canadian climatic conditions. Soil depressurization should be achieved by a fan drawing more soil gas from beneath the slab than the house can draw, making the sub-slab pressure lower than the house pressure, thus reversing the flow.

Table 3 — Building exterior-interior pressure differences (Stack effect)

Maximum pressure difference across below-grade building envelope Pa			
House 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
3 storey (chimney)	13	14	15
NOTE Data from NHC-15-187-1997 CMHC *Estimating the concentrations of soil gas pollutants in housing* (page 7).			

5.1.9.3 Seasonal effects

The impact of seasonal variation on system design should be considered when sizing an ASD fan by multiplying the design suction pressure by the corresponding seasonal adjustment factor found in Table 4.

Table 4 — Design suction temperature adjustment factors[4]

Suggested adjustment factor for design suction versus exterior temperature			
Exterior temperature during test	**Winter heating degree days**		
	Mild <4000 HDDs	**Moderate 4000-5999 HDDs**	**Severe >6000 HDDs**
>0 °C	2.0	2.2	2.5
0 to -10 °C	1.4	1.5	1.6
-10 to -20 °C	1.0	1.0	1.2
< -20 °C	1.0	1.0	1.0

[4] If Data from Health Canada Document *Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors* 2010, page 22. ISBN : 978-1-100-18472-2.

5.1.9.4 Piping system pressure drop

The pressure drop associated with the pipe layout should be considered when sizing the fan.

NOTE See Health Canada document *Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors* for pressure drops associated with the pipe layout.

5.1.9.5 System testing

A communication test shall be performed after the completion of the system to ensure pressure field extension is achieved by the selected fan.

NOTE Precautions should be taken to ensure the fan is not drawing air from window wells draining to the weeping tile or by exposed foundations

5.1.10 Sub-slab depressurization and sumps

A SSD system with a suction point near a covered sump may also collect soil gas from the weeping tile via these connections.

5.1.10.1 The sump basin shall be covered, and sealed as described in 5.1.3.1.

5.1.10.2 The feasibility study 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.

5.2 Mitigation by sub-membrane depressurization

5.2.1 In dwellings without a concrete slab, perforated piping or porous material like large clean aggregate shall be placed over the soil. Then a flexible air barrier membrane meeting the requirements of CAN/ULC-S741 shall be installed on top, with all joints, penetrations and terminations sealed. The 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 aggregate 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.

5.2.2 In areas with high traffic, thicker sheeting and protective mats shall be installed when 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 National Fire Code[5].

- 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] Codes Canada publications can be ordered from the National Research Council of Canada Virtual Store at https://www.nrc-cnrc.gc.ca/eng/virtual_store/index.html or you can place your order by email at CONSTPubSales-Ventes@nrc-cnrc.gc.ca, by phone at 1-800-672-7990 or 1-613-993-2463, by fax at 1-613-952-7673 or by mail at Publication Sales, National Research Council Canada, 1200 Montreal Road, Building M-23A, Ottawa, Ontario K1A 0R6.

5.2.3 The membrane shall be attached to the foundation walls and sealed using manufacturer approved adhesives. Seams where sheets overlap shall be lapped by 300 mm (12 in.). Penetrations through the membrane, and any tears in the membrane shall be sealed to reduce the amount of air drawn from the house.

5.2.4 The piping used shall meet the requirements specified in 5.1.4. The piping shall be brought out through the membrane and shall be connected to a fan to discharge the collected soil gas and radon outdoors.

5.2.5 The membrane material shall be strong enough to withstand the traffic during installation without damage, and be available in large sheets to limit the number of joints or overlaps needed.

5.2.6 Any damage to the membrane during installation shall be repaired immediately.

5.2.7 Appropriate joining tape should be installed according to the manufacturer's instructions. Pipe and corner flashings are also available for use with thicker membranes such as polypropylene or EPDM.

5.2.8 The membrane should run no less than 100 mm (4 in.) up each wall and be fixed to the foundation wall using manufacturer approved adhesives, and secured in place with decay and insect resistant battens fixed with fasteners compatible with foundation materials.

5.2.9 Compatibility of caulking and construction adhesives with the membrane material and their tolerance to dirt on the wall surface, as described by manufacturers shall be ensured.

5.2.10 Horizontal seams shall be overlapped by 300 mm (12 in.) and caulked and taped.

5.2.11 Figure 3 illustrates how the membrane is installed and attached to the wall.

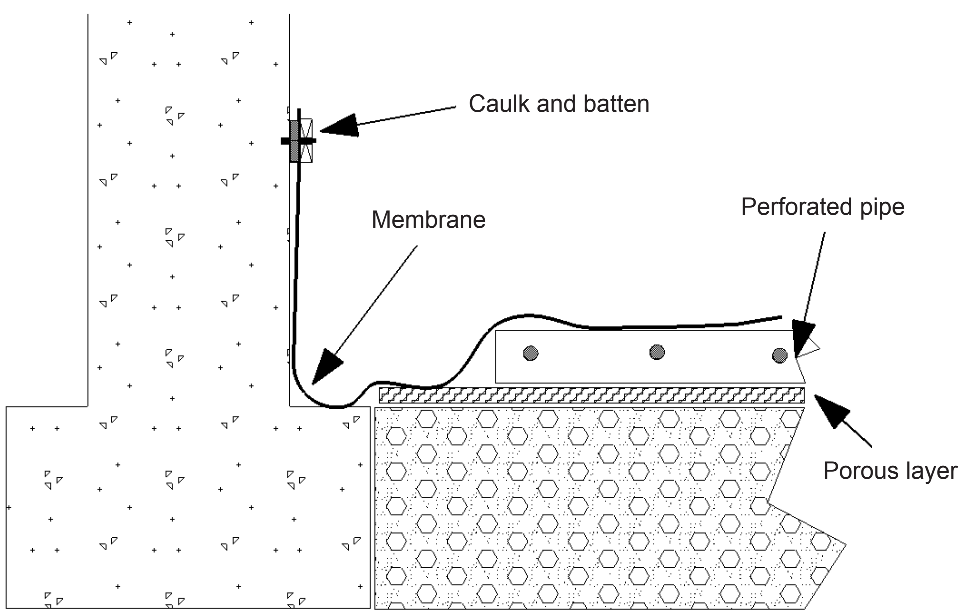


Figure 3 — Membrane/wall detail

5.2.12 When there are supports or pipes in the space, the membrane shall be slit to pass around these items and the seams shall be caulked with an adhesive caulk and shall be lapped at least 300 mm (12 in.) and taped.

5.2.13 A collar shall be fitted around each penetration and attached and caulked to the penetration. The membrane shall then be caulked to the collar.

NOTE Collar may be cut from the membrane material.

5.2.14 If water is likely to collect on the membrane, it shall be fitted with drainage that does not interfere with efficient depressurization at the lowest locations that are likely to become wet.

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

5.2.16 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.

5.2.17 Requirements for pipe selection, installation layout, and fan sizing in 5.1 shall also apply.

5.2.18 All requirements described in 5.1 (see 5.1.3.2 to 5.1.8.5) shall also apply to 5.2 with the exception of the slab sealing and communication testing requirements.

5.3 Mitigation by sump and drainage system depressurization

5.3.1 A house equipped with a ground water drain system (weeping tile) may be mitigated for radon by applying suction to the drainage tubing or sump if diagnostic tests determine this technique provides adequate depressurization to the sub-slab area. Figure 4 illustrates sump depressurization (SD).

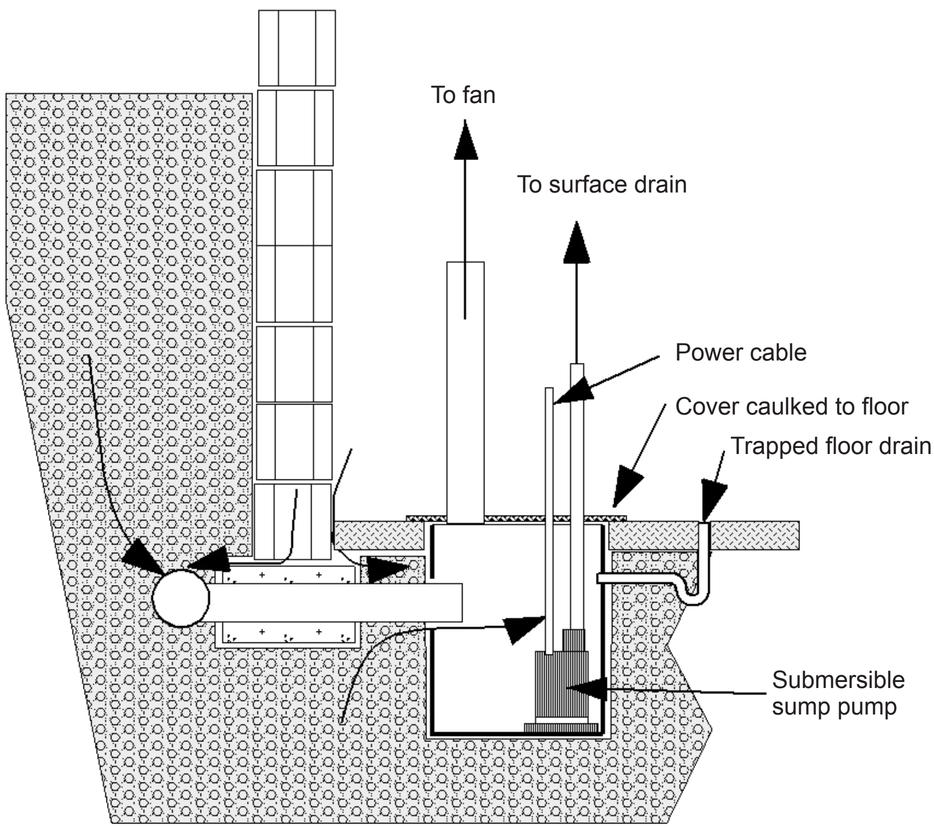


Figure 4 — Sump exhaust installation

5.3.2 A ground water drainage system connected to a sump basin inside the house 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.

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

5.3.4 The sealing of this cover shall be airtight and serviceable.

5.3.5 Covers should incorporate a view port or allow access to permit observation of conditions within the sump pit.

5.3.6 If exhaust piping is connected to the sump cover, consideration should be given to facilitate removal of the cover for 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.

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

5.3.8 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.

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

5.3.10 An exhaust fan should be connected to the covered sump basin to collect soil gas from the weeping tile system, and to draw air from the sub-slab aggregate through the side openings in the sump basin.

5.3.11 To make sure the 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 house 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.

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.

5.3.12 Requirements for pipe selection, fan and pipe installation and layout, fan sizing, and communication testing in 5.1 also apply.

5.4 Completion, activation or retrofitting of preventive measures

Various preventive measures applied at the time of construction of a residential building are described in CAN/CGSB-149.11[6]. The National Building Code, various provincial building codes, and other guidance (LEED residential, municipal programs, etc.) may also contain information on various radon preventive measures.

5.4.1 Basic preventive measures

Basic preventive measures completed at the time of the construction include various measures to minimize radon infiltration and to facilitate its mitigation. This includes sealing of all entry points, use of a soil gas barrier (air barrier) over a gas permeable layer and includes a rough-in connection for a future SSD system.

[6] CGSB standard to be published at a later date.

5.4.1.1 All requirements in 5.1 (see 5.1.3.2 to 5.1.8.4), including diagnostic testing, shall apply to 5.4 prior to activating a rough in system.

5.4.1.2 Completion of such measures into a full active SSD system shall follow the applicable requirements in 5.1.

5.4.2 Passive vertical radon stack

This preventive measure consists of a full vertical pipe running upwards from beneath the slab, up through the inside of the building shell, and venting above the roof.

5.4.2.1 A positive pressure test shall be performed before activating an existing passive stack to ensure pipes and fittings are sealed.

NOTE The standard air pressure test consists of pressurizing the passive stack sealed at both ends to 5 psi (34.5 kPa). The pressure shall be maintained for 15 min and the pipe system shall be inspected for pressure loss by conducting a soap test on each joint.

5.4.2.2 Completion of such measures into a full ASD system consists of adding a fan to the piping. Requirements of 5.1 (see 5.1.3.2 to 5.1.8.4), including diagnostic testing, shall apply to the activation of a passive system.

5.4.3 Retrofitting of a full active soil depressurization system

To correct high radon levels, the following investigation shall be carried out:

a) Determination of system malfunctions or adjustments in fan sizing

b) Inspection of functionality of system components (fan connected/running, exhaust, welding, piping leak test.)

c) Sealing of all accessible entry points that were not sealed or had deteriorated

d) Pressure field extension verification.

Correction of system failures or fan sizing issues shall be done in accordance with requirements in 5.1.

6 Other mitigation methods

6.1 Mitigation by ventilation methods

When building structure, configuration and/or use prevent radon reduction by 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.*

6.1.1 Heat recovery ventilators and energy recovery ventilators

6.1.1.1 Heat recovery ventilators (HRVs) and energy recovery ventilators (ERVs) are most effective in homes that have low natural ventilation rates or are relatively airtight. HRVs and ERVs should be used only in instances where a known or predicted radon reduction could be expected by increasing ventilation to lower the radon levels. These ventilation systems should only be selected when modest radon reductions are needed, since they typically only tend to provide modest radon reductions.

6.1.1.2 When used, HRVs and ERVs shall be installed, balanced, and commissioned according to the manufacturer`s instructions and applicable building codes.

NOTE Ensure that the heat or energy exchanger core material does not compromise radon reduction by allowing radon diffusion through it between intake and the exhaust streams.

6.1.1.3 Installation shall aim for a neutral balanced system. Avoid exhaust equipment that produces large negative pressures as this may increase the radon infiltration rate into the dwelling.

6.1.1.4 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 by using a blower door test to determine sizing of a new HRV or ERV and how much radon reduction can be anticipated from the additional ventilation brought about by installing an 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 very expensive to operate. Building codes affecting building ventilation may be consulted.

6.1.1.5 HRV and ERV installed specifically for radon reduction or existing 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.

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

6.1.1.7 The outdoor air intake shall be at least 1.83 m [6 ft] from the exhaust outlet and ideally at least 3.05 m [10 ft] from the exhaust outlet.

6.1.1.8 The HRV or ERV shall be able to operate continuously to maintain constant dilution of indoor radon levels.

6.1.1.9 The HRV or ERV fan motor(s) shall be equipped with maintenance free rolling-element bearings or better.

6.1.1.10 The HRV's or ERV's cross-leakage from exhaust to supply airflow shall be less than 2 %. Internal leakage data are available on HVI[7] .

6.1.1.11 The HRV or ERV defrost cycle shall not increase building depressurization.

6.1.1.12 The HRV or ERV shall not have a recirculation option enabled as a mode from the remote controllers.

6.1.1.13 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.

6.1.1.14 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.

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

6.1.1.16 Contractors installing HRV or ERV systems shall verify 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 dwelling.

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[7] http://www.hvi.org/index.cfm.

6.1.1.17 Contractors shall inform building owners 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 the documentation.

6.2 Sealing entry points in the slab

Sealing of entry points is not a stand-alone method for radon reduction. Closing entry routes should be performed to improve the performance of fan-driven mitigation systems.

NOTE Conventional building construction has several foundation openings. These are the shrinkage gap where the floor slab meets the foundation wall of house for poured concrete basement walls, the gaps around the sanitary and water pipes, house supports, penetrating shrinkage cracks in the concrete floor and unsealed sump pits.

6.2.1 Sumps shall be provided with rigid lids that are sealed with a gasket, removable caulking or are mechanically fastened. A sump pit also serving as a floor drain should use a cover equipped with a floor drain and embedded in the concrete to facilitate water drainage

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

6.2.3 Penetrations through the sump lid shall be sealed. Where the sump basin penetrates the slab, it shall be sealed with a compatible sealant.

6.2.4 Floor drains, condensate drains, and foundation perimeter drains (French drain) should be retrofitted to control the loss of building air by the mitigation system.

6.2.5 All openings through the slab for plumbing fixtures, accessible penetrations through the slab, including access openings and penetrations through foundation walls should be sealed to prevent the ingress 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.

6.2.6 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.

7 Labelling, marking and information package

7.1 Labelling

Durable labels shall be provided. Labels shall clearly indicate the system is only intended for the removal of radon gas from below the floor-on-ground. The labels serve the purpose of identifying the radon control systems for future work by radon professionals, identifying the systems to contractors who may mistakenly use the system for other purposes, and identifying the systems to homeowners who may be unaware of radon and/or its control options. All labels shall be composed of lettering that is in a contrasting colour to the background. A homeowner radon mitigation system package shall be provided to occupants by the contractor.

7.1.1 Radon mitigation system component labels

There are seven label types: air barrier membrane labels, pipe labels, fan labels, sump labels, active system start-up pressure labels, and radon maintenance and information labels. All applicable labels in 7.1.1.1 to 7.1.1.7 shall be provided in both official languages and applied immediately after installation of a mitigation system.

7.1.1.1 Air barrier membrane labels

For residences with ground covering sealed membranes, such as crawl spaces, a label shall be located in a prominent location and shall state, “This is a component of a radon reduction system. Do not tamper with or disconnect." « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ».

7.1.1.2 Pipe labels

The piping for the radon control systems located in the interior of the building shall be identified with the label “This is a component of a radon reduction system. Do not tamper with or disconnect.” « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ». The label 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.

7.1.1.3 Sump labels

Where sumps are installed, sump basin covers shall be provided with a durable label, “This is a component of a radon reduction system. Do not tamper with or disconnect.” « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ».

7.1.1.4 Fan labels

Radon fans shall be labelled “This is a component of a radon reduction system. Do not tamper with or disconnect.” « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ». The circuit breakers for the fan and any system failure warning device shall be labelled “Radon fan and monitor.” « Ventilateur de radon et moniteur ». For fans that have an electrical disconnect instead of a cord and plug, it shall also be labelled.

7.1.1.5 Active system start-up pressure label

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 a durable label that states “This is a component of a radon reduction system. Do not tamper with or disconnect.” « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ». The label shall describe how a homeowner should read the gauge, and when and who to call for servicing. Description may vary with each device. The label shall also include 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.

7.1.1.6 Radon surveillance device labels

When used, a radon surveillance device should be clearly labeled with a label that states “This is a component of a radon reduction system. Do not tamper with or disconnect.” « Composant d’un système d’atténuation du radon. Ne pas modifier ou démonter ». When used, electrical radon surveillance devices should be connected on a separate electric circuit than that of the fan. It shall describe how a homeowner should read the monitor, and when and how calibration and maintenance is required; this description may vary with the device. If the radon surveillance device indicates a long term 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.

7.1.1.7 Radon maintenance and information labels

The radon control system shall also be provided with one mitigation system label for the purpose of informing the homeowner. The label shall be located on an exposed and visible part of the system. Soil depressurization and ventilation labels shall follow the following formats:

Radon mitigation system — The 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 __________"WC".

Additional radon information available on www.healthcanada.gc.ca/radon or call 1 800 O-Canada (1-800-622-6232), TTY – 1-800-926-9105

Système d'atténuation du radon — Le ventilateur ne devrait JAMAIS être éteint.

Type : Système de dépressurisation active du sol

Nom de l'installateur :

Compagnie :

Adresse de la compagnie :

Numéro de téléphone :

Numéro de certification applicable :

Date de l'installation :

Pression d'aspiration__________po CE

Consultez le www.santecanada.gc.ca/radon ou composez le 1 800 O-Canada (1-800-622-6232), ATS – 1-800-926-9105 pour en savoir davantage sur le radon.

Radon mitigation system — It 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 www.healthcanada.gc.ca/radon or call 1 800 O-Canada (1-800-622-6232), TTY – 1-800-926-9105

Système d'atténuation du radon — Il ne devrait JAMAIS être éteint.

Type : Ventilation

Nom de l'installateur :

Compagnie:

Adresse de la compagnie :

Numéro de téléphone :

Numéro de certification applicable :

Date de l'installation :

Réglé de façon à augmenter la ventilation de :

__________________ changement(s) d'air par heure

Consultez le www.santecanada.gc.ca/radon ou composez le 1 800 O-Canada (1-800-622-6232), ATS – 1-800-926-9105 pour en savoir davantage sur le radon.

7.2 Homeowner radon mitigation system package

The homeowner shall be provided with a documentation package that includes the following:

a) A copy of the appropriate information label outlined in 7.1.1.7;

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 contractor shall verify the integrity of seals and joints, check for loose connections and vibration noises, and rectify any omissions or defects found. The contractor shall place a label on the system listing when it was activated, and the suggested re-test intervals.

8.1.2 In soil depressurization, the suction pressure in the piping shall be read on the U-tube manometer and noted on the label by the contractor, for comparison when the system fan is serviced.

8.1.3 No RMS shall interfere with combustion gas exhaust from natural draft combustion appliances. In the event that natural draft or other non-sealed combustion appliances are installed in the home:

a) The contractor shall recommend that a qualified person inspect the natural draft combustion or other non-sealed combustion appliances and venting systems for compliance with local codes, and

b) The RMS shall not be activated until the potential backdrafting issue has been investigated and resolved.

NOTE Proper fan sizing, sealing of entry routes for soil depressurization, and ensuring balanced ventilation systems, all serve to minimize the risk of backdrafting of natural draft combustion appliances. The CSA *Residential depressurization* F300-13 standard addresses the determination of building depressurization level and provides corrective measures to mitigate excessive levels of building depressurization. The contractor should also recommend that any combustion appliance or venting system, found to be noncomplying, be brought into compliance.

9 Testing

9.1 Post-installation testing

9.1.1 Long-term radon measurement devices shall be approved by Canadian – National Radon Proficiency Program (C-NRPP) or equivalent.

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

9.2 Short-term post-mitigation radon test

The radon mitigator shall conduct a short-term test or arrange for one to be carried out, after a system is activated to demonstrate initially that the mitigation has been successful. A short-term radon measurement of a duration no shorter than 48 h using an approved radon testing device shall be performed no sooner than 24 h after activation, while the system is operating, within the first month of system activation. The test shall be conducted under closed house conditions and may be as short as two to seven days in duration. A long-term measurement shall be also performed to confirm the effectiveness as described in 9.3.

NOTE A post-mitigation short-term radon concentration that is lower than the initial pre-mitigation value (reduced from 50 to 99% for ASD and 30 to 70 % for ventilation) suggests a successful mitigation. If the short-term result is greater than or equal to the initial measurement value, troubleshooting of the mitigation strategy should be undertaken.

9.3 Long-term post-mitigation radon test

The Health Canada recommendations for radon mitigation are based on the long-term radon concentration (as determined by a three-month test) in the normal occupancy area of the lowest lived-in level of the home. The true effectiveness of the mitigation system is based on the long-term radon concentration measurement made in this same location.

9.3.1 The contractor shall outline the need for a long-term post-mitigation measurement to be made during the heating season by the homeowner or an independent tester.

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

9.3.3 The contractor shall advise the homeowner 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 See Annex A for typical radon reductions. Radon concentrations should be reduced to as low as reasonably achievable (ALARA), generally well under 100 Bq/m3 (2.7 pCi/L). An effective mitigation system keeps radon concentrations low provided there are no changes in the soil, building, or system. To verify continued performance, an additional long-term radon measurement should be made within two years of the system activation, and at two-year intervals thereafter. If the building has a change of use, 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 home.

Annex A
(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) indicates that, typical radon reductions range from 10 to 30% for sealing entry routes, 30 to 70% for increasing ventilation mechanically when properly sized for radon reduction, and from 50 to 99% 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 B
(informative)

Radon mitigation system information package for homeowners

B.1 What is radon?

Radon is a radioactive gas that occurs naturally when the uranium in soil and rock breaks down. It is invisible, odourless and tasteless. When radon is released from the ground into the outdoor air, it is diluted and is not a concern. However, in enclosed spaces, like homes, it can sometimes accumulate to high levels, which can be a risk to the health of occupants.

B.2 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 lung cancer depends on the level of radon and how long a person is exposed to those levels.

B.3 How can radon get into my home?

The air pressure inside your home is usually lower than in the soil surrounding the foundation. This difference in pressure draws air and other gases, including radon, from the soil into your home.

Radon can enter a home any place it finds an opening where the house 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.

B.4 Do I have a radon mitigation system?

Yes, if your house has been constructed with

a) Passive stack — A full-height vertical pipe run installed within the dwelling with the inlet originating beneath the basement floor slab and the outlet terminating above the roofline for the purpose of passively venting soil gas to the outdoors.

b) ASD system — A **RMS** 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.

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

B.5 Is there system maintenance?

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

Pipe
Multiple times per year, inspect all exposed piping for damage.

Membranes
The plastic membrane, if a SMD system was installed, should be inspected multiple times per year for tears, cuts, or leaks in its seals, and any damage should be repaired as soon as is reasonably possible. The radon mitigation 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, the radon mitigation system can have its performance reduced if air is leaking from it. The sump cover's condition should be periodically inspected 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, or additions to your home can alter the radon concentrations in your home. You should test your home for radon after any of the above.

Water traps
Water traps or other devices should be fitted with drains to control sewer/soil-gas entry. Where water traps are installed, they should be refilled periodically to replace evaporated water.

Continuous radon monitor
Continuous radon monitors require calibration and maintenance. Consult the manual or call the manufacturer for more information on your particular device. The Canadian radon guideline action level is 200 Bq/m^3 (5.4 pCi/L). If the monitor indicates levels significantly higher than the result from the long-term post-mitigation test, the continuous radon monitor or mitigation system should be investigated.

The manual for the continuous radon monitor should be provided to the homeowner.

System pressure gauge
Active radon mitigation systems have a system pressure gauge that indicates the pressure in the piping system created by the radon fan. The initial pressure should have been marked by the system installer. You should regularly check the gauge to ensure the system is operating properly. If the gauge indicates a substantial change (a 20% or more difference from the original marked pressure), or if it reads zero pressure, your radon mitigation system may not be working properly and you should call for service. ***This gauge measures pressure in Inches WC, it does not measure radon.***

Fans
Radon fans for active systems should NEVER be turned off; if turned off, the system no longer functions as intended. The lifespan of a radon fan varies, with an average life expectancy up to ten years. Radon fan replacement cost is only a small fraction of the initial whole system installation costs.

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 home which may increase the radon infiltration rate into the building.

Horizontal discharge
If your radon mitigation system discharges outside through a side wall, it is important not to have any occupancy area (ex. picnic table, children's play areas or pet's cages) within 2 m (6.6 ft) of the exhaust.

B.6 Should I retest for radon?

Health Canada recommends that homes be tested for a minimum of three months, ideally between October and April. Your home 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 homeowner using special detectors available from commercial businesses, home improvement stores, some municipalities, and many provincial lung associations. These devices are simply placed in your home, 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 home 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 Protection Bureau
775 Brookfield Road,
Ottawa, Ontario Canada K1A 1C1
613-954-6647
radon@hc-sc.gc.ca

B.7 Where can I learn more?

Visit the Health Canada website at www.healthcanada.gc.ca/radon or call 1-800-O-Canada (1-800-622-6232), TTY – 1-800-926-9105 for more information on radon and testing your home.

Health Canada publishes a booklet called *Radon Reduction Guide for Canadians* that provides information on radon, testing for radon, and reducing high levels of radon. For a free copy, visit Health Canada's website.

NOTE When you sell the house, this information package should be left with the house for reference by the new owners.

Annex C
(informative)

Radon from water and construction material

In some areas, radon is brought into the building dissolved in well water.

This national standard describes reducing radon in construction where the radon in air originates in the soil surrounding and beneath the home. Radon can enter a building via two other mechanisms primarily.

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

Radon levels 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 levels in well water can be significant depending on the source, but again, it requires extremely high radon levels dissolved in well water to impact indoor radon levels appreciably. A general rule of thumb used in the radon profession is that it requires radon in water concentrations of 10,000 Bq/m^3 to add 1 Bq/m^3 of radon to the air of a typical residential home. As an example, 2,000,000 Bq/m^3 radon in water could be expected to add 200 Bq/m^3 (5.4 pCi/L) to the air. This radon in water concentration is a rare occurrence, but can happen occasionally in private or community wells. If the air of a dwelling supplied with groundwater tests above 200 Bq/m^3 (5.4 pCi/L), testing for radon levels in water should be considered. Radon in water test kits are commercially available. Depending on the results, it may be necessary to mitigate for radon from the soil, the water, or from both, in order to obtain an acceptable radon reduction in air.

Well water systems having high radon levels can be treated in several ways in order to remove radon from the water before it can outgas into a home. 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 source water to prevent clogging or fouling of these treatment systems, and the levels of radon in the water. Aeration is the preferred treatment technique for removing high levels 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 are captured in 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 levels of radon in 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 radium-226 levels (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 levels 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[8].

Health Canada also recently 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 levels[9].

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[8] Radon Exhalation From Building Materials for Decorative Use, Chen, J. et. al., Journal of Environmental Radioactivity, Volume 101, Issue 4, April 2010, Pages 317–322.

[9] Radon Exhalation From Sub-Slab Aggregate Used in Home Construction in Canada, Bergman,L. et. al., Radiation Protection Dosimetry, doi:10.1093/rpd/ncv320, May 2015, Pages 1- 6.

Annex D
(informative)

Outdoor soil depressurization systems

D.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 fan rotor. Below the freezing point, ice formation may freeze-up internal parts of the 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 5.1.9.
- Sections 6, 7 and 8 should also be followed.

A radon mitigator should consider these parameters before making a decision to install an outdoor mitigation system. The ASTM E2121[10] standard addresses outdoor fan and piping installation.

D.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 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 sub-slab area.

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

The 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 fan is via the bottom which is left opened. Fans should be sized in accordance with 5.1.9.

[10] ASTM E2121 — Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings.

D.3 Soil depressurization through exterior perimeter foundation drains

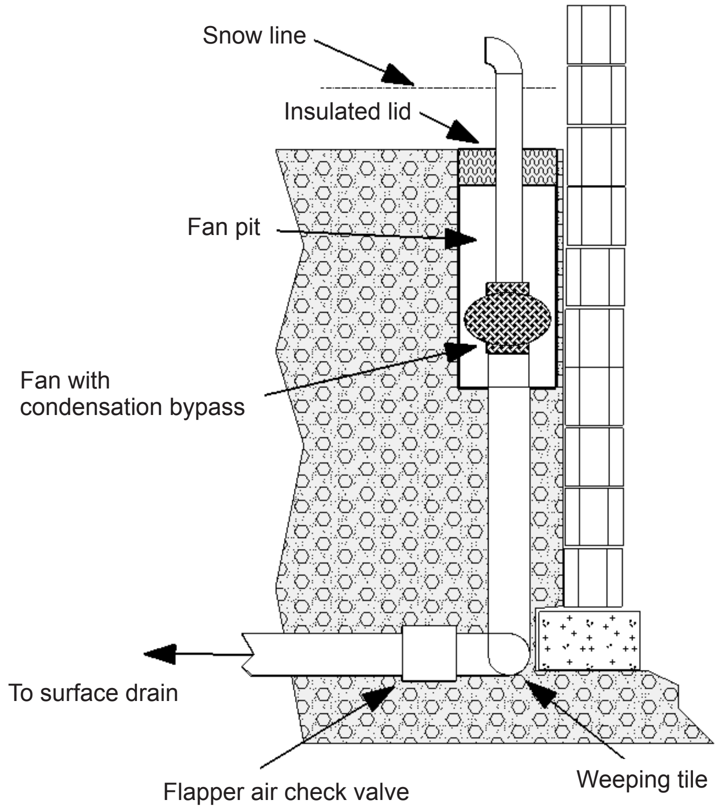

Figure D.1 — Drainage tubing exhaust

D.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.

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

D.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 D.1 for outdoor fan installation.

D.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 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 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.

D.3.5.1 The water discharge pipe(s) shall 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.

D.3.5.2 Requirements for pipe selection, fan and pipe installation and layout, discharge clearances, fan sizing, and communication testing from 5.1 also apply.

Bibliography

[1] Health Canada. *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*, Revised 2011 [viewed 2017-10-26]. Available from <https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/pubs/contaminants/norm-mrn/norm-mrn-eng.pdf >

[2] Canada Mortgage and Housing Corporation (CMHC). *Research Highlight: Assessment of Natural Ventilation for Canadian Residential Buildings*. Technical Series 08-100, February 2008 [viewed 2017-07-13]. Available from <https://www.cmhc-schl.gc.ca/odpub/pdf/65903.pdf>

[3] Canada Mortgage and Housing Corporation (CMHC). *Research Highlight: Fixing Houses with High Radon — A Canadian Demonstration*. Technical Series 08-105, June 2008 [viewed 2017-07-13]. Available from <https://www.cmhc-schl.gc.ca/odpub/pdf/66063.pdf>

[4] Canada Mortgage and Housing Corporation (CMHC). *Research Highlight: Testing Oil-fired Appliance Depressurization Spillage*. Technical Series 07-109, March 2007 [viewed 2017-07-13]. Available from <https://www.cmhc-schl.gc.ca/odpub/pdf/65365.pdf>

[5] Canada Mortgage and Housing Corporation (CMHC). *Research Highlight: Laboratory Depressurization Test for Residential Gas Appliances*. Technical Series 05-111, October 2005 [viewed 2017-07-13]. Available from <https://www.cmhc-schl.gc.ca/odpub/pdf/64806.pdf>

[6] Canada Mortgage and Housing Corporation (CMHC). *Research Highlight: Laboratory Depressurization Test for Residential Gas Appliances — Part 2*. Technical Series 08-103, June 2008 [viewed 2017-07-13]. Available from <https://www.cmhc-schl.gc.ca/odpub/pdf/65961.pdf>

[7] Health Canada. *Guide for Radon Measurements in Residential Dwellings (Homes)* [viewed 2017-07-13]. Available from <https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html>

[8] Heath Canada. *Radon: Is it in your home?* [viewed 2017-07-13]. Available from <https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/radiation/radon-your-home-health-canada-2009.html>