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Radon mitigation options for existing low rise residential buildings

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Introduction (Informative)

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 accumulates to high concentrations in homes where it increases long term risk for lung cancers.

The risk of developing lung cancer mainly depends on:

1. The smoking habits of inhabitants
2. The average radon concentration in the building
3. The length of time a person is exposed

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. (World Health Organization (WHO) radon handbook 2009 http://www.who.int/ionizing_radiation/env/radon/en/index1.html)

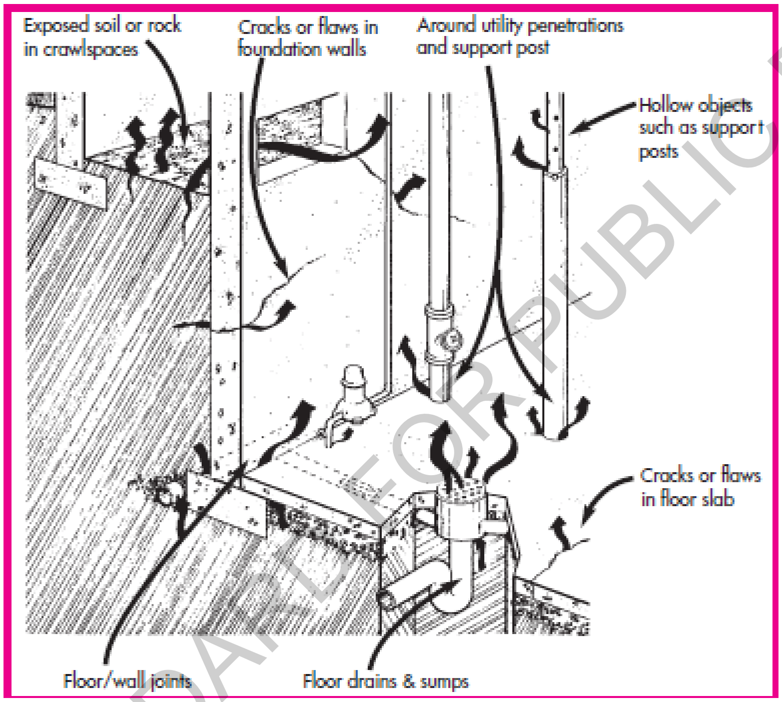
Due to a difference in air pressure between the inside of a building and the soil surrounding the foundation, soil gases, including radon enter through openings in the foundation such as construction joints, gaps around service pipes and support posts, floor drains and sumps, cracks in foundation walls 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 will outgas 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 pathways and routes of exposure to Radon are illustrated in Figure 1.

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



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

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 meter (Bq/m³) in the normal occupancy area.
- The higher the radon concentration, the sooner remedial measures should be undertaken.
- When remedial action is taken, the radon level should be reduced to a level or concentration as low as practicable.

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

For more information about radon and the Guideline, visit the Health Canada Website: www.healthcanada.gc.ca/radon 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 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 (ventilation rate, air changes per hour). 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 around the monthly average 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 3 months (preferably during the heating season) to 12 months is recommended by Health Canada to give a good estimate of the annual average radon exposure.

If the result of the long-term measurement is greater than 200 Bq/m^3, Health Canada recommends that remedial action be undertaken. A short term measurement of 2 to 7 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. Short term tests should neither be used to determine the level of risk from indoor radon exposure nor if the house needs radon mitigation.

While the health risk from radon exposure below the Canadian Guideline is small there is no level that is 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 required radon concentration reduction, 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. Expected radon reductions associated with different mitigation techniques are presented in Annex A.

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 should always be the first choice for reducing radon levels. ASD systems 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. ASD systems require little maintenance, function well for many years (typical lifetime is 10-20 years), and typically reduce radon levels up to 99%. The family of ASD systems consist of several different methods depending on the building construction.

Buildings that have a fully poured concrete floor use sub-slab depressurisation (SSD) and buildings that have exposed soil or other native materials use sub-membrane depressurisation (SMD). Sump depressurization, drainage tubing depressurization as well as block-wall ventilation are also methods associated with soil depressurization. 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 depressurisation (SD) uses a fan to draw from a previously covered, existing sump basin 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 crawlspace 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 needed 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 may be an ongoing energy penalty associated with these systems.

Multifamily/Semi-Detached Dwelling Concerns

Buildings are to be considered as systems. Many town house 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. 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 will 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, and cold weather concerns such as freezing of foundations. Multifamily, semi-detached and condominium buildings also represent challenges in terms of installation, operation and maintenance costs of a radon mitigation system. It is beyond the scope of the present standard to determine how the communication and agreement should occur between occupants and owners but this will 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 in reducing radon levels can vary greatly.

Mitigation of buildings equipped with preventive measures

In Canada, various preventive measures against soil gas infiltration have been described in different construction codes as well as in CGSB's 149-11 (Radon Control Options for New Construction in Low Rise Residential) standard. After a long term radon test demonstrates that radon concentrations are above the 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, "The Radon reduction system information package for homeowners" offers valuable data to consult as required.

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 definition)

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 proposed 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 homes are fit for their purposes.

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 standard. 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 method. A dated reference is to the specified revision or edition of the reference or document in question. However, parties to agreements based on this method are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

2.1 Canadian Standards Association (CSA)

CSA B149.1 2005 and 2010 — *Natural gas and propane installation code*

CAN/CSA 181.1-96 — *ABS drain, waste, and vent pipe and pipe fittings*

CAN/CSA 181.2-M87 — *PVC drain, waste, and vent pipe and pipe fittings*

CAN /CSA 181.2-M92 — *Plastic drain and sewer pipe and pipe fittings.*

CSA-C22.2 NO. 113-12 - Fans and ventilators

CSA- C22.2 NO. 100-14 - Motors and generators

2.1.1 Source

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

2.2 Underwriters' Laboratories of Canada (ULC)

ULC-S636-08 – *Standard for type BH gas venting system.*

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 F891 – *Specification for coextruded poly (Vinyl Chloride) (PVC) plastic pipe with cellular core*

ASTM F628-*Specification for acrylonitrile-butadiene-styrene (ABS) schedule 40 plastic drain, waste, and vent 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 Canada, 1 Antares Drive, Suite 200, Ottawa, Ontario K2E 8C4, telephone 613-237-4250 or 1-800-267-8220, fax 613-237-4251, e-mail gic@ihscanada.ca, Web site www.ihs.com.

3 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply.

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

NOTE ASD is considered the method of choice to reduce high radon levels in a building, with reductions of 90 % being typical.

3.2

air changes per hour (ACH)

the rate at which the air inside a house escapes or is forced out and replaced by outdoor air.

NOTE To calculate fan-assisted air changes per hour in a house, divide the capacity of the fan (expressed as air volume per hour) by the volume of the house (make sure volume is expressed in same base units). Also referred to as ventilation rate.

3.3

as low as reasonably achievable (ALARA)

an 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

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

3.5

backdrafting

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

NOTE Backdraftng causes smell, smoke or toxic gases to escape 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 fresh outdoor air in equal amounts;

NOTE balanced ventilation often includes heat recovery or heat and moisture recovery.

3.7

band joist

a 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 meter (Bq/m^3)

the SI unit of measure for the concentration of radioactivity in a volume of air.

NOTE One Becquerel is one radioactive disintegration per second.

3.9

blower door

a device comprised of a calibrated, adjustable speed fan and a calibrated air pressure monitor; designed to be mounted in an existing doorway of 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)

the 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

the 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 9th 2007).

3.12

chemical smoke

a "smoke-like" vapour used for detecting air currents, often generated from a chemical reaction (e.g. titanium tetrachloride and air)

3.13

cold joint

the contact joint between the foundation wall and the basement slab or the parts of a slab that were poured at different times.

3.14

continuous radon monitors (CRM)

a 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, ion changers, or sold-state silicon detectors.

3.15

communication testing

the 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.

3.16

crawl space

a foundation type having an open area beneath the habitable space of a building that typically has either a concrete slab or an earthen floor.

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 ventilated to the outdoors.

3.17

cubic feet per minute (CFM)

a measure of the volume of a fluid (liquid or gas) flowing within a fixed period of time.

NOTE CONVERSION: 1 cfm = 0.472 Liters per second [L/s]

3.18

depressurisation

a 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 (buoyant forces acting on the warm air). The air pressure within the soil outdoors is also often higher than that in the basement which also acts to draw soil gas into the dwelling

3.19

design suction

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

3.20

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.

3.21

drainage tubing

a perforated drainpipe at footing level around the exterior perimeter of a house. Part of the ground water management system.

3.22

drainage tubing depressurization (DTD)

a variation of ASD where the gas permeable layer underneath the floor slab is depressurized by applying suction on the drainage tubing either on the outside or inside of the foundation.

3.23

dwelling

a 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 2010 National Building Code, but excludes any residential spaces in motels, hotels, and business and mercantile occupancies.

3.24

entry points

openings through the flooring and walls where the dwelling contacts the soil, and allows soil gas to enter.

3.25

entry routes

pathways by which soil gas can flow into a building

3.26

exfiltration

the unintended movement of indoor air out of the dwelling through cracks in the building envelope.

3.27

exhaust fan

a 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.

3.28

footing(s)

a 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.

3.29

french drain

a water drainage technique installed in basements of some dwellings during initial construction.

3.30

gas permeable layer

the layer of gas permeable material installed under the basement sub-slab membrane which facilitates 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 reduction system to draw radon laden soil gas from the entire sub-slab area.

3.31

grade (above or below)

the 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.

3.32

habitable space

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

3.33

heat exchanger

a device used to transfer heat from one stream to another.

NOTE It is also known as heat recovery ventilators (HRVs) or energy recovery ventilators (ERVs) for those systems that also handle humidity in the air streams. In air-to-air heat exchangers for residential use, heat from exhausted conditioned indoor air is transferred to the incoming outdoor air, without mixing the two streams.

3.34

heat recovery ventilator (HRV)

also known as an air-to-air heat exchanger. Energy recovery ventilators are HRVs that also handle humidity.

3.35

HVAC system

the 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 heating medium within the building.

3.36

infiltration

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

3.37

joist

any of the parallel horizontal beams set from wall to wall to support the floor or ceiling.

3.38

low rise

buildings 3 storeys or less in building height, having a building area not exceeding $600m^2$.

3.39

manometer

a differential pressure indicating device used for radon diagnostic purposes to test pressure field extension under a concrete slab.

NOTE Generally reads in units of Pa or in inches of water column (in WC)

3.40

mitigation

the 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.

3.41

mitigator

a qualified individual who reduces indoor radon concentrations, and is experienced in radon remediation.

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

3.42

mitigation system

any system, component, design or installation designed to reduce radon concentrations in the indoor air of a dwelling.

3.43

passive vertical radon stack

a 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 a fan-powered active radon stack technique which yields radon reductions of 90-95%. This passive technique only works intermittently compared to the active technique which works continuously as long as the fan is operating. A passive stack is easily converted to an active system by the installation of an ASD fan in-line.

3.44

post-mitigation radon level

the radon concentration measured within the habitable space of the dwelling as a result of a long-term radon test (3-month/ 90+ days during the first heating season) conducted after radon mitigation work has been performed.

NOTE The radon level should be reduced to below the Canadian guideline value of 200 Bq/m^3 and in fact to ALARA. For most dwellings, it will be possible to reduce the radon level to below 100 Bq/m^3. It is recognized that it may not be possible to reduce radon levels below 100 Bq/m^3 in all homes by following the best practices outlined in this standard.

3.45

pressure field extension

a spatial extension of a variation in pressure as occurs under a slab when a mitigation fan ventilates at one or a few distinct points.

3.46

pre-mitigation radon level

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

3.47

radon

the 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.

3.48

rough-in

the 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.

3.49

slab

a layer of concrete which commonly serves as the floor of any part of a dwelling whenever the floor is in direct contact with the underlying soil.

3.50

slab on grade

a 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.

3.51

smoke tube

a 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.

3.52

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).

3.53

soil gas barrier

a continuous polymeric membrane installed in order to retard the flow of radon containing soil 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 layer of material are also possible.

3.54

soil gas collector

a 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.

3.55

stack effect

a phenomenon caused by gravity where warm air rises in a house and exfiltrates through the upper half of the house, causing infiltration through the lower half of the house.

3.56

sub-membrane depressurisation (SMD)

a 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.

3.57

sub-slab despressurisation (SSD)

a 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.

3.58

suction pit

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

3.59

suction point

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

3.60

sump

a pit through a basement floor slab, designed to collect water and thus avoid water problems in the basement.

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

3.61

sump pump

a pump to move collected water out of the sump pit, to an above grade discharge remote from the house.

3.62

ventilation rate

the rate of movement of outdoor air through a building's exterior envelope via leaks or intended openings, both inward and outward (infiltration and exfiltration). Ventilation is commonly expressed in units of air changes per hour, litres per second, or cubic feet per minute

3.63

water column (WC)

a 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, usually expressed in inches"

4 Active soil depressurisation methods

4.1 Mitigation by sub-slab depressurization

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

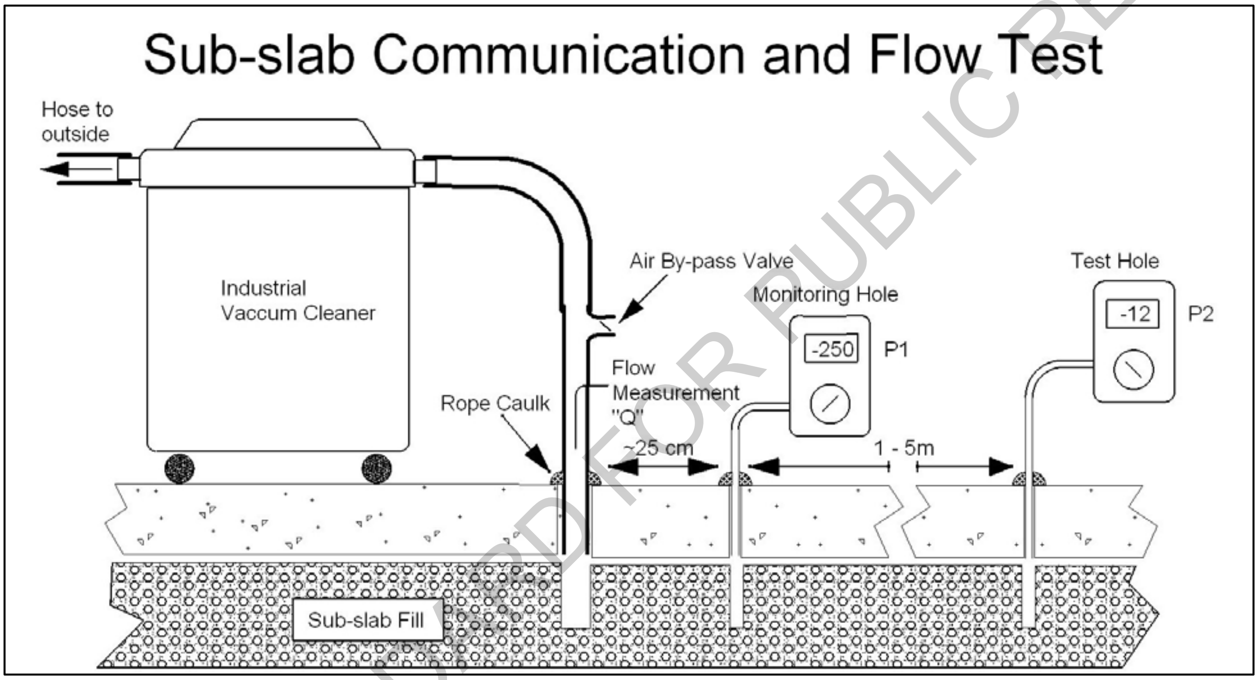
4.1.1 Feasibility test prior to installation

A "pressure field extension test" (i.e. communication test) should be used to determine the number of suction points and the fan size needed for an effective system.

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

— Probe the fill to a depth of 15-20 cm to ensure that drilling deeper will 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.

Figure 2 -Sub-slab Communication and Flow Test



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 communication test.

4.1.2 Sealing entry routes

Closing entry routes increases sub-slab depressurization 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 penalties. Entry routes which may compromise pressure field extension shall be sealed.

4.1.2.1 Sumps shall be provided with rigid lids that are hermetically sealed with a gasket or silicone caulking, or are mechanically fastened as required in section 4.3. 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 embedded in the concrete to facilitate water drainage.

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

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

4.1.2.4 Other penetrations through the slab, including access openings, shall be designed and installed to prevent the ingress of soil gas.

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

4.1.3 Pipe and fitting specifications

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

NOTE Partial section of 76.2 mm (3 inch) diameter may also be used to facilitate routing up through the attic and in a finished building.

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

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

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

4.1.3.4.1 The pipe material shall be resistant to the service environment or shall comply with **4.1.3.11**

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

4.1.3.4.3 Specific colours for pipes are not required.

NOTE radon pipe should have a different color than pipes used for drain, waste and venting.

4.1.3.5 Where pipe is installed in the cavity of a wood-frame or steel-frame wall, the top and bottom of the frame where the pipe passes shall have hidden steel shield plates installed to protect the pipe.

4.1.3.6. Horizontal pipe runs shall be minimized.

4.1.3.7 Where horizontal pipe runs are necessary, pipes shall be supported as per pipe manufacturer instructions.

4.1.3.8 Pipes shall be installed so as to minimize exposure to cold temperature and shall be insulated where located in unconditioned space.

4.1.3.9 Horizontal pipes above and below ground shall be installed with at least a 1% slope to return water to the soil or according to Table 1 as shown.

Pipe Size	Recommended Gradient		
	@10 L/s	@25 L/s	@ 50 L/s
100 mm	1/100	1/50	1/30

4.1.3.10 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.

4.1.3.11 Acceptable pipe and fitting specifications

Where the pipe material conforms to one of the following standards, it shall be deemed to comply with Clause 4.1.3 of this standard.

4.1.3.11.1 PVC Flue Gas Venting pipe and fittings shall meet the requirements of ULC S636 and all pipe, fittings and cement must come from one manufacturer and the cement shall conform to manufacturer's specification and be adequate for the application conditions.

4.1.3.11.2 PVC Drain, Waste and Vent (DWV) pipe and fittings shall meet the requirements of CSA B181.2 and have a Flame Spread Rating not greater than 25 (as per ULC S102.2). Cement shall meet manufacturer's specification and be adequate for the application conditions.

4.1.3.11.3 Pipe materials shall conform to one of the following standards: ASTM F891 Specification for coextruded poly (vinyl chloride) (PVC) plastic pipe with a cellular core or CAN/CSA B181.1 ABS drain, waste, and vent pipe and pipe fittings or ASTM F628 Specification for acrylonitrile-butadiene-styrene (ABS) schedule 40 plastic drain, waste, and vent pipe with a cellular core.

4.1.3.11.4 Pipes and fittings described in **4.1.3.11.3** shall be joined with products meeting the requirements of the respective pipe manufacturer.

4.1.3.11.5 Primer shall be applied where required by the pipe manufacturer.

4.1.3.11.6 PVC Dwelling Drain Sewer Pipe shall meet the requirements of CSA B182.1 and shall conform to DR35 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. This pipe and fittings are only certified for below grade installation and shall not be used above grade unless specified by a local authority.

4.1.3.11.7 Other types of piping not mentioned in this standard shall meet or exceed the minimum performance criteria specified in Clauses 4.1.3.4.1 and 4.1.3.4.2

4.1.4 Fan and piping

4.1.4.1 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.

4.1.4.2 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 ofCSA-C22.2 No. 100 for motors having 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" diameter hole which would result in a maximum 0.12 L/s [0.425 m3/hr] 0.25 cubic foot per minute (cfm) leakage at [375 Pa] 1.5" water column (WC) pressure.

4.1.4.3 A fan shall be installed so that the flow is vertical, so that any condensation in the system will drain through the fan.

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

4.1.4.4 To prevent noise, vibrations and leakage, the fan shall be connected to the piping with rubber 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 will not accumulate.

4.1.5 Electrical installation

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

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

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

4.1.6 Fan monitoring

Each fan-powered system shall have a u-tube manometer to monitor fan performance. 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 in pressures from inside the pipe to the air in the home.

4.1.7 Mitigation system termination

Depending on fan location, the two levels of soil depressurisation exhaust terminations possible are:

- low level lateral discharge usually passing through the rim-joist for a fan installed indoors in the basement and
- above roof line level when the fan is typically installed in the attic.

NOTE Cost, possible indoor pipe layout, space availability, respect of discharge clearances (4.1.7.2) will impact exhaust discharge selected location. Above roof discharge typically pass vertically through the roof but lateral and vertical gable discharge may also be acceptable to avoid passing through sensitive roof material.

4.1.7.1 In all discharge types, a protective screen should be installed at the end of the pipe. When used, the screen shall not restrict the flow

4.1.7.2 Minimal clearances for all types of radon discharges

Adapted from CSA-B149.1 Natural Gas and Propane Installation Code 2005 and 2010.

Clearances should follow suggested and shall follow required as per Table 2.

Table 2 Clearances from radon discharge

Locations	Suggested minimal clearances (meter)	Required minimal clearances (meter)
Clearance to a mechanical air supply inlet	3	1.80
Clearance to permanently closed window	1	0.30
Clearance to a bedroom window	2	1
Clearance from a door that may be opened	1	0.30
Clearance to outside corner	0.30	0.30
Clearance to inside corner	0.30	0.30
Clearance above paved sidewalk or paved driveway located on public property	2.10	2.10
Clearance above grade, veranda, porch, deck, or 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 fall.	2	1

- A vent shall not terminate where it may cause hazardous frost or ice accumulations on building surfaces or any adjacent property surfaces;
- A vent shall not terminate directly above a sidewalk or paved driveway that is located between two single family dwellings and serves both dwellings;
- The clearance for a bedroom window should also be applied for rooms that are occupied more than 4 hours a day;
- Discharging no less than 100 cm 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.

NOTE The selection of the exhaust point should be made considering maximal available clearances from building openings and from outdoor occupancy areas.

4.1.7.3 Provisions for an above roof discharge

An internal suction pipe shall be installed with a fan located in the attic space if the building configuration allows for it.

4.1.7.3.1 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.

4.1.7.3.2 Outdoor fan installation shall only be considered in ASHRAE's Climate Zone 5. Since local climatic variations exist, each area should be considered independently. See Annex D for information on outdoor fan installations.

NOTE Fan life in outdoor installations discharging above roof, may be extended through the installation of a condensation bypass that may reduce the internal moisture stress.

4.1.7.3.3 Refers to sections 4.1.7.4.1.4 and 8.2 for short term and long term post mitigation measurement requirements

4.1.7.4 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:

- cold weather areas
- elevated soil moisture levels
- low exhaust flow

NOTE Those above mentioned circumstances stand alone or in combination have been observed to increase above roof line discharge icing issues

4.1.7.4.1 Conditions for rim-joist lateral discharge with fan in the basement:

4.1.7.4.1.1 Indoor fan selection criteria:

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 for motors having 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" diameter hole which would result in a maximum [0.425 m3/hr] 0.25 cubic foot per minute (cfm) leakage at [375 Pa] 1.5" WC pressure.

4.1.7.4.1.2 Indoor fan location

4.1.7.4.1.2.1 Fan locations

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

4.1.7.4.1.3 Leak test

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.

4.1.7.4.1.4 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 hours using an approved radon testing device shall be performed no sooner than 24 hours after activation, while the system is operating, but within the first month of system activation to access 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 2 years with a long-term radon testing device.

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

NOTE Post mitigation testing may also include radon surveillance device to continuously monitor indoor radon. These devices are listed by C-NRPP as home radon alarms. *For additional testing information please see the Health Canada website:* www.hc-sc.gc.ca

4.1.7.4.1.5 Indoor fan system labelling

After completion of the Leak Test, a label shall be applied by the Installer to the radon fan. 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 2 years or after major structural, or ventilation/air circulation equipment changes to your home**."

4.1.7.5 Gable discharge through the attic

The active radon reduction systems may discharge through the attic gable provided the installation conforms to the clearances in Table 2 of section 4.1.7.2.

4.1.7.5.1 Minimal clearances for all types of radon discharges section 4.1.7.2 shall also be followed.

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

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

4.1.7.5.3 The pipe for a gable ended discharge shall discharge horizontally with a minimal length of 50 mm protruding beyond the plane of the vertical structure and a maximum length protruding of 150 mm.

4**.1.7.5.4** The pipe shall be installed in such a position that it will not be covered with snow or other materials from adjacent roofs and gutters.

4.1.7.5.5 Refers to sections 4.1.7.4.1.4 and 8.2 for short term and long term post mitigation measurement requirements

4.1.8 System sizing

4.1.8.1 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.

4.1.8.2 Building pressure differences

Table 3 shows differential pressure from the stack effect between ground level outside the house and just above the floor slab for Canadian 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**	**Moderate Winter**	**Severe Winter**
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

Data from CMHC Estimating the Concentrations of Soil Gas Pollutants in Housing 1997

4.1.8.3 Seasonal effects

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

Table 4 –Design Suction Temperature Adjustment Factors (from Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors, Health Canada, 2010, ISBN : 978-1-100-18472-2)

Suggested Adjustment Factor for Design Suction versus Exterior Temperature			
Exterior Temperature during Test	Winter Climate Zone		
	Mild	Moderate	Severe
>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

4.1.8.4 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 to pipe layout

4.1.8.5 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 drained to the weeping tile or by exposed foundations

4.1.9 Sub-slab depressurization and sumps

A sub-slab depressurization system with a suction point near a covered sump will also collect soil gas from the weeping tile via these connections.

4.1.9.1 The sump basin shall be covered, and sealed as described in 4.1.2.1

4.1.9.2 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.

4.2 Sub-membrane depressurization

4.2.1 In dwellings without a concrete slab, a flexible air barrier membrane over perforated piping or porous material like large clean aggregate, should be placed on the soil and should ensure the fan suction is distributed to the edges of the membrane and hence acts as the gas collector.

NOTE Perforated piping under the membrane used to create the void space may be of various diameter and wall thickness.

4.2.2 In areas with high traffic, thicker sheeting and protective mats shall be installed when crawlspaces are used for storage or frequent entry is required for maintenance of utilities.

NOTE Examples of membranes that may be used are listed in order of resistance. The crush strength should be considered if an area has foot traffic or is used for storage. Air barrier membrane should be made of a material meeting the requirements of the National Fire Code .

- 0.08 mm 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 polypropylene or Ethylene Propylene Diene Monomer (EPDM)sheets as used in roofing.

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

4.2.4 The piping used shall meet 4.1.3.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.

4.2.5 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.

4.2.6 Any damage during installation shall be repaired immediately.

4.2.7 Appropriate joining tape should be use according to the manufacturer instructions, and pipe and corner flashings are available for polypropylene and EPDM.

4.2.8 The membrane should run no less than 100 mm up each wall and be caulked to the wall, and secured in place with decay and insect resistant battens fixed with fasteners compatible with foundation materials.

4.2.9 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 followed.

4.2.10 Horizontal seams shall be overlapped by 300 mm caulked and taped.

4.2.11 Figure 3 and Figure 4 illustrate how the membrane is installed and attached to the wall.

Figure 3 Membrane Installation

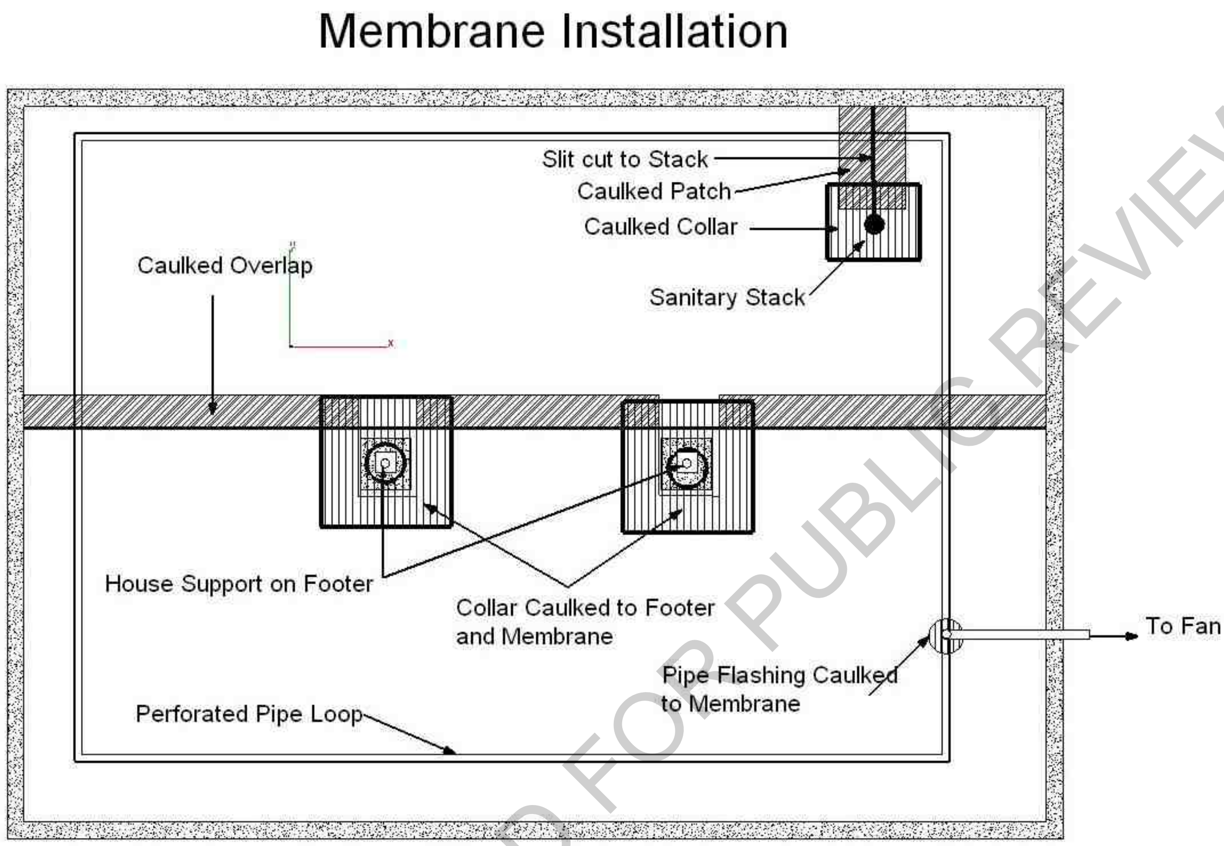
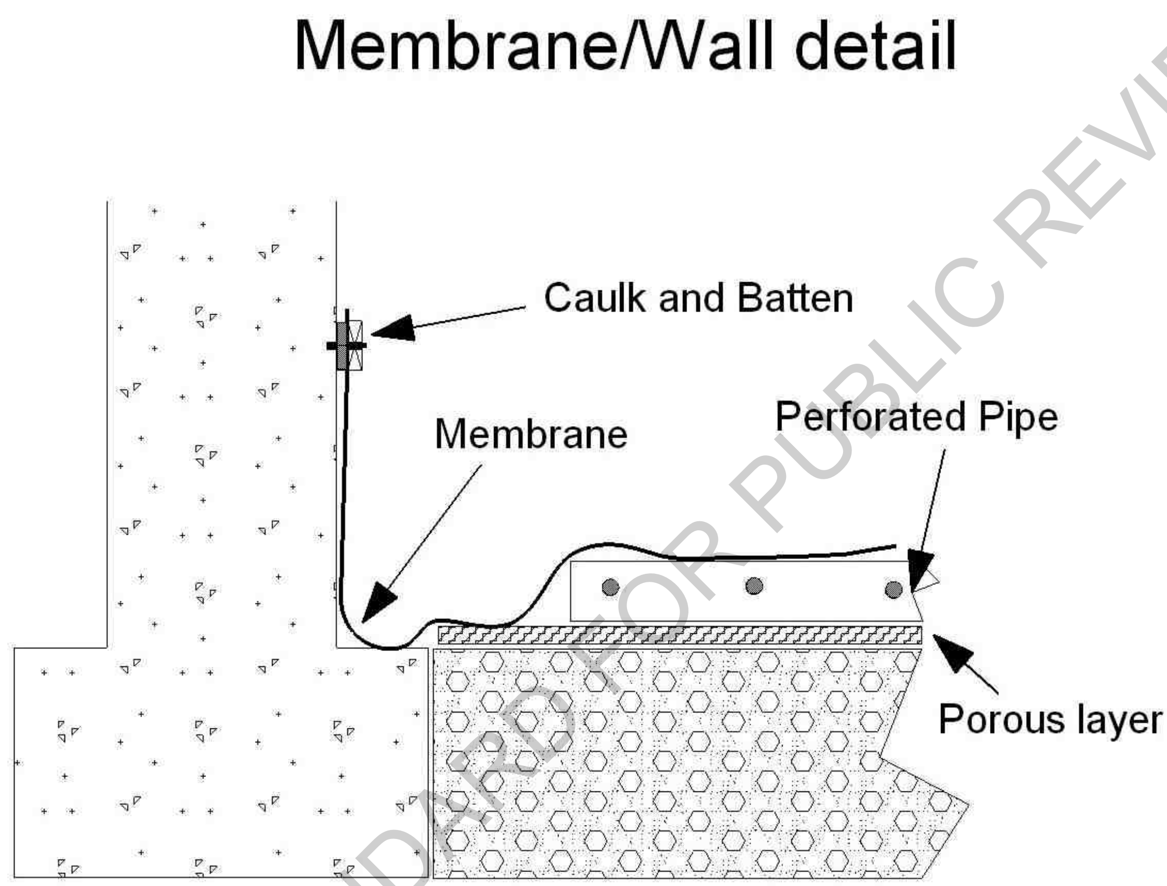


Figure 4 Membrane/Wall detail



4.2.12 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 and taped.

4.2.13 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

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

4.2.15 Where the suction point penetrates through the membrane, it shall be sealed; material such as two vinyl roof soil stack flashings under the membrane and one above the membrane shall be caulked to form an airtight seal.

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

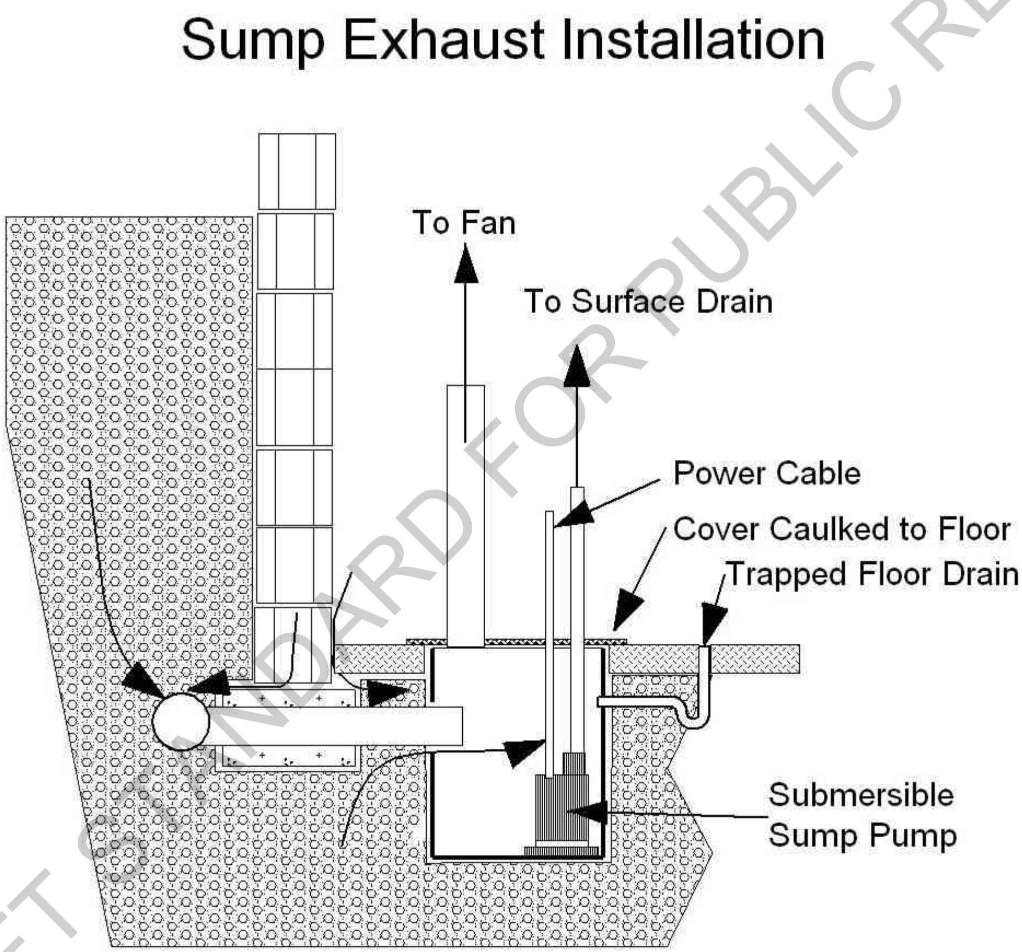
4.2.17 Requirements for pipe selection, installation layout, and fan sizing from section 4.1. shall also apply.

4.2.18 All requirements described in section 4.1 (4.1.2.2 to 4.1.7.4) shall also apply to section 4.2 with the exception of the slab sealing and communication testing requirements.

4.3 Mitigation by sump and drainage system depressurization

4.3.1 A house equipped with a ground water drain system (weeping tile) that is not saturated with water may be mitigated for radon by applying suction to the drainage tubing. This should only be considered if a large fraction of the basement perimeter is covered by the drain system. Figure 5 illustrates sump depressurisation.

Figure 5: Sump Exhaust Installation



4.3.2 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.

4.3.3 The hermetically sealed sump cover shall be strong enough to support a 70 kg person standing on the cover. Specialised commercially available plastic “radon sump covers“, and complete “radon sump basins”, with these connections built into the sump lid and liner can be fabricated.

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

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

4.3.6 If exhaust piping is connected to the sump cover, the piping should include rubber couplings to ease removal of the cover for sump pump maintenance.

4.3.7 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.

4.3.8 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.

4.3.9 Selected Floor Drain types being connected to the sump shall be resistant to soil gas infiltration and to soil depressurisation.

4.3.10 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.

4.3.11 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 depressurisation while at the same time allowing water drainage; or by covering the drain openings with filter cloth and sand which will reduce airflows but still allow water to drain.

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.

4.3.12 Requirements for pipe selection, fan and pipe installation and layout, fan sizing, and communication testing from section 4.1 also apply

4.4 Completion, activation or retrofitting of preventative measures.

Various preventive measures applied at the construction of the building are found in the national building code, provincial building codes, construction programs, volunteer certifications and are also described in CGSB 149-11 standard.

4.4.1 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 entry points and use of a soil gas barrier over a gas permeable layer and could include a rough-in connection for a future SSDS.

4.4.1.1 Initial communication testing should be performed to ensure the rough–in is communicating with the sub-slab gas-permeable layer prior to completing the pipe layout.

4.4.1.2 Completion of such measures into a full active SDS shall follow the applicable requirements in section 4.1.

4.4.2 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 through the roof.

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

4.4.2.2 Completion of such measures into a full active SDS consists of adding a fan inline to the piping. It shall follow applicable requirements in section 4.1.

4.4.3 Retrofitting of active soil depressurisation system

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

- Determination of system malfunctions or fan size adjustments
- Inspection of functionality of system components (fan connected/running, exhaust, welding, piping leak test.)
- Sealing of all accessible entry points that were not sealed or had deteriorated
- Pressure field extension verification

Correction of system failures or fan sizing issues shall be done according to Section 4.1 requirements.

5 Other mitigation methods

5.1 Mitigation by ventilation methods

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

5.1.1 Heat recovery ventilators and energy recovery ventilators

5.1.1.1 Heat Recovery Ventilators (HRVs) and Energy Recovery Ventilators (ERVs) should only be selected when other types of mitigation solutions preventing radon entry are not applicable since they typically only tend to provide modest radon reductions. Heat Recovery Ventilators (HRVs) and Energy Recovery Ventilators (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.

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

NOTE HRV technology is preferred over ERVs' as radon gas could possibly transfer with water vapor particles.

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

5.1.1.4 The initial ACH of the house shall be determined by using a blower door test to determine sizing of a new HRV or ERV and how much expected radon reduction can be anticipated from the installation of the additional ventilation brought by a new HRV or ERV. The cost of heating and cooling energy penalties shall also be calculated. In some cases, it may result in impractical mechanical ventilation rates which would make such a system very expensive to operate.

5.1.1.5 HRV and ERV installations should exhaust air from the part(s) of the building where the highest radon concentrations were measured (or are expected) and bring fresh air into the most occupied space of the building.

5.1.1.6 HRV and ERV systems shall use two separate intake and exhaust ports.

5.1.1.7 The fresh air intake should be located at 3.05 m (10 feet) from the exhaust outlet but shall be at least at 1.83 m (6 feet) from the exhaust outlet.

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

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

5.1.1.10 The HRV's or ERV's internal leakage rate from exhaust to supply airflow shall be less than 2 %.

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

5.1.1.12 Each floor or enclosed room susceptible to any radon entry shall have a supply and return grill with balanced ventilation.

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

5.1.1.14 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 under the slab.

5.1.1.15 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 feet) apart.

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

5.1.1.17 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.

5.1.1.18 Contractors shall inform building owners that periodic filter replacement and inlet grill cleaning are necessary (typically every 3 months) to maintain a balanced airflow . This information shall also be included in the documentation.

5.1.1.19 An inclined manometer should be installed across the intake filter to indicate the need for filter cleaning or replacement.

5.2 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. The shrinkage gap where the floor meets the wall of house with poured concrete basement walls, the gaps around the sanitary and water pipes, house supports, penetrating shrinkage cracks in the concrete floor and ground water control drainpipe into a sump.

5.2.1 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

5.2.2 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 person standing on the cover.

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

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

5.2.5 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.

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

6 Labelling, marking and information package

6.1 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 reduction system package shall be provided to occupants by the contractor.

6.1.1 Radon reduction 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 shall be applied immediately after installation of a mitigation system.

6.1.1.1 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 damage the membrane or disconnect the system”.

6.1.1.2 Pipe labels

The piping for the radon control systems located in the interior of the building must be identified with the label “This is a component of a Radon Reduction System. Do not tamper with or disconnect”. The label shall be applied every 1.8m or at a change in direction. The labels shall be applied before wall cavities are closed.

6.1.1.3 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”.

6.1.1.4 Fan labels

Radon fans shall be labelled “This is a component of a Radon Reduction System. Do not tamper with or disconnect”. The circuit breakers for the fan and any system failure warning device shall be labelled “Radon Fan and Monitor”. For fans that have an electrical disconnect instead of a cord and plug, it shall also be labelled.

6.1.1.5 Active system start-up pressure label

The initial suction pressure shall be clearly marked within visual range (to a maximum 30 cm 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". The label shall describe how a homeowner should read the gauge, and when and who to call for servicing. Description will vary with each device. The label shall also include wording "***This gauge measures pressure in Inches Water Column, it does not measure radon*** *"*.

6.1.1.6 Radon surveillance device labels

When used, 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" it shall describe how a homeowner should read the monitor, and when and how calibration and maintenance is required; this description will vary with the device. If the radon surveillance device indicates long term level average higher than 200 Bq/m^3, Health Canada's guideline recommends that steps should be taken to reduce the radon levels in the building."

6.1.1.7 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 depressurisation and ventilation labels shall follow the following formats:

Radon Reduction System

Radon System Specification: CGSB ______

Type: Active soil depressurisation Radon Reduction System

Status: System Operational

Upgrade Option: Please consult a professional radon mitigator.

Description: An active soil depressurization system has been designed, installed, and is operating in this building. The fan should NEVER be turned off.

System Monitoring: The radon system pressure gauge should be read periodically. The gauge displays vent stack suction pressure, which indicates the system's performance. The initial pressure was __________''WC".

Ensure to have the system inspected if the suction pressure falls to "0"or under the initial pressure reading as this indicates system malfunctions.

Radon Testing: This system has been installed to the industry's best practices. However, for various reasons, radon levels may still be elevated. Test the building for radon during the first winter after installation using a long-term radon test (3 to 12 months). The building should be tested for radon every 2 years, or as recommended by Health Canada.

Also, retest the building for radon whenever there has been a change in ownership, of heating, cooling or ventilation equipment, or after renovations or additions have been completed.

Radon Testing Interpretation: If radon test results are above 200 Bq/m^3 , contact a certified radon mitigator as soon as is reasonably possible to determine further mitigation options. Contact Health Canada for more information – contact information is provided below.

Installer's Name:

Company:

Company Address:

Company Telephone Number:

Applicable Certification Identification:

Date of Installation:

Signature:

Additional Radon Information: Visit the Health Canada Website 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 your reduction system

Radon Reduction System

Radon System Specification: CGSB ______

Type: Ventilation

Status: System Operational

Maintenance and upgrade Option: Please consult a professional radon mitigator. This system should be serviced / checked annually by qualified c-NRPP personnel or equivalent to maintain protection levels

Description: A ventilation system has been designed, installed, and is operating in this building. It should NEVER be turned off. It was calibrated to increase ventilation by:

__________________ Air change(s) per hour

_________________ Equally balanced intake and exhaust air flows – L/s or cfm

Energy Penalty : Increased ventilation provided by this system to dilute indoor radon concentration will increase heating costs.

Heat penalty calculation provided [yess] [no]

OWNER WARNING: Refer to manufacturer's ventilation system manual for recommended system maintenance

Radon Testing: This system has been installed to the industry's best practices. However, for various reasons, radon levels may still be elevated. Test the building for radon during the first winter after installation using a long-term radon test (3 to 12 months). The building should be tested for radon every 2 years, or as recommended by Health Canada.

Also, retest the building for radon whenever there has been a change in ownership, of heating, cooling or ventilation equipment, or after renovations or additions have been completed.

Radon Testing Interpretation: If radon test results are above 200 Bq/m^3 , contact a certified radon mitigator as soon as is reasonably possible to determine further mitigation options. Contact Health Canada for more information – contact information is provided below.

Installer's Name:

Company: **Company Address:**

Company Telephone Number:

Applicable Certification Identification:

Date of Installation:

Subsequent service date:

Signature:

Additional Radon Information: Visit the Health Canada Website 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 your reduction system

6.2 Homeowner radon reduction system package

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

1. A copy of the appropriate information label outlined in 6.1.1.7;
2. All manuals for the installed systems, including the continuous monitor and fans, if applicable;
3. All radon test data for the property, if applicable;
4. The installed fan's estimated annual energy consumption, and the projected cost of such energy, if applicable.
5. Recommended inspection and retest schedule
6. Applicable Diagrams

7 Inspection

System Mechanical Checks after installation

7.1 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.

7.2 In soil depressurisation, the suction 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.

7.3 In presence of natural draft combustion appliances, any radon mitigation system shall not interfere with combustion gas exhaust.

NOTE Proper fan sizing and sealing entry routes for soil depressurisation and balanced outlet inlet ventilation system will minimise any interference with combustion gas exhaust.

8 Testing

8.1 Post installation testing

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

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

8.2 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 hours using an approved radon testing device shall be performed no sooner than 24 hours 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 2 to 7 days in duration. A long-term measurement shall be also performed to confirm the effectiveness as described in section 8.3.

NOTE The first 24 hours after the fan is being turned on allows the house ventilation to remove the radon and are not representative of post-mitigation radon concentration. The average radon concentration is indicative of the mitigation system's performance. Interpretation of the results will be easier if the location of the post-mitigation measurement is the same as the pre-mitigation measurement location. If the short term concentration is shown to be low, (<100 Bq/m^3), the system may be effective.

8.3 Long- term post mitigation radon test

The Health Canada recommendations for radon mitigation are based on the long-term radon concentration 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.

8.3.1 The Contractor shall outline the need for a long-term post-mitigation measurement to be made during winter by the homeowner or an independent tester.

8.3.2 The measurement shall be made in the same location as the pre-mitigation measurement.

8.3.3 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/m3.

NOTE Interpretation of the results is easier if the post mitigation measurement is made in the same location as where the original long-term pre-mitigation test was conducted. See annexe A for expected radon reduction. Radon concentrations should be reduced to as low as reasonably achievable, generally well under 100 $Bq/m^{3.}$ An effective mitigation system will keep 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
Expected 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 Organisation (WHO) Radon Handbook (2009) indicates that, typical radon reductions will range from 10 to 30% for sealing entry routes, 30 to 70% for increasing ventilation mechanically when properly sized for radon reduction, and up to a 99% reduction in radon levels for active techniques, such as active soil depressurization. The nature of the Canadian climate may decrease the typical expected reduction range on ventilation type systems. Additionally there is an energy penalty associated with increasing ventilation in Canada's winter cold climate.

Annex B
Informative
Radon reduction 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 you and your family.

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 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 reduction system?

Your house has been constructed with:

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

Active soil depressurisation system

A radon mitigation system designed to maintain lower air pressure under a floor slab by using

a fan and piping to draw from below the floor slab.

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 applicable, 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 reduction system can have its performance reduced if damage to the membrane results in air leakage. Whenever there is an object resting on the membrane, check to ensure the membrane is protected from damage.

Sump Pit
For sump pits, if applicable, the radon reduction 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 for drains to control sewer/soil-gal entry. Where water trap 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/m3 ; if the monitor indicates levels are higher than 200 Bq/m3, steps should be taken to reduce the radon levels in the building.
The manual for the continuous radon monitor should be provided to the homeowner.

System Pressure Gauge
Active radon reduction 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 reduction system may not be working properly and you should call for service.
This gauge measures pressure in Inches Water Column, it does not measure radon.

Fans
Radon fans for active systems should NEVER be turned off; if turned off, the system will no longer function as intended. The lifespan of a radon fan varies between five to ten years. Radon fans can cost $200-$300 to replace.

<u>Horizontal Discharge</u>
If your radon reduction 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 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 post-mitigation and should be subsequently tested every 2 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 will 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 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 will give you more information on radon, testing for radon, and reducing high levels of radon. For a free copy, visit Health Canada's website.

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 will outgas 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 one requires roughly 10,000 times the radon in water concentrations per m3 of water (i.e. 2,000,000 Bq/m3 radon in water) before radon in water is likely to impact the radon in air concentrations significantly. 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 Becquerels per cubic meter (Bq/m3), 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 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.

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. Please see: **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**

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. Please see: 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 depressurisation systems

D-1 Outdoor fan with above roof discharge

Apart from the mild Canadian weather conditions in Climatic Zone 5, the performance of an outdoor soil depressurisation system discharging above the roof with uninsulated fans and piping cannot be ensured. The main factors that will increase the risk of icing problems in winter time are:

- Cold temperature (heating zones or 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 condensate and to freeze.
- Electric power interruption frequency: Electric power interruption will 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 back again after electrical power has been restored.

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

- A moisture condensation bypass should be installed to extend fan life
- Fans should be sized accordingly to section 4.1.8.
- Section 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. ASTM-E-2121 standard addresses the installation of 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 all types of soil depressurisation. This type of installation is less likely to encounter obstructive icing in the absence of long uninsulated outdoor exhaust piping discharging above the roof.

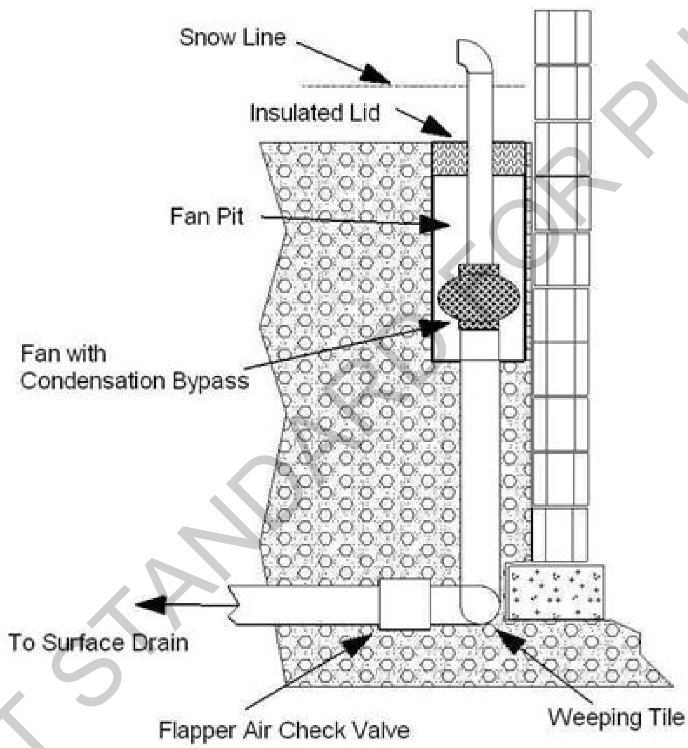
This outdoor installation option would allow the creation of a sump underneath the slab that can be connected to piping that runs along the foundation. The down blast fan connects to the piping to allow suction across the sub slab area.

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

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 according to section 4.1.8.

D-3 Soil depressurisation through exterior perimeter foundation drains

Figure 6 Drainage tubing exaust



D3.1 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 depressurisation by attaching a fan directly to the weeping tile.

D3.2 This installation should only be considered if a large fraction of the basement perimeter is covered by the drain system.

D3.4 An uninsulated aboveground outdoor fan should only be considered in Climate Zone 5.

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.

D3.5 Exterior underground fan installation for weeping tile depressurisation

With the exception of houses being mitigated in climate Zone 5**,** 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.

D3.5.1 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.

D3.5.2 Requirements for pipe selection, fan and pipe installation and layout, discharge clearances, fan sizing and communication testing from section 4.1 also apply.

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