Diagnostic testing, installation and confirmation sampling for active vapor mitigation systems in single-family residential buildings

Purpose

The purpose of this document is to provide guidelines on best practices for conducting pre and post-mitigation diagnostic testing, installation and confirmation sampling for active vapor mitigation systems (active systems). For the purposes of this document, an active system refers to a system equipped with an electrically powered fan(s). Active systems may include one or a combination of the following; sub-slab depressurization systems, sub-membrane depressurization systems (for building areas without slabs) and/or block foundation wall depressurization systems. Each of these systems relies on actively depressurizing the soil gas beneath and/or surrounding the foundation of a building.

An important distinction is that active systems are installed to mitigate vapor intrusion risks to a specific building and are not intended to act as a remediation system to clean-up soil vapor contamination. Ongoing source-area or site-wide remediation may likely be taking place concurrently via other remedial technologies (i.e. soil vapor extraction, air sparge, pump and treat) to address site-wide contamination.

Application

Diagnostic testing is required for pre-installation (selecting system components), installation and post-installation monitoring of active mitigation systems installed to address vapor intrusion risk to existing inhabited buildings. Diagnostic testing prior to mitigation system installation (pre-mitigation) is required to ensure the system is effectively installed based on the specifics of each building including; construction (full basement, slab-on-grade, crawl spaces), sub-slab soil type, moisture conditions, air tightness of the building, number/construction of combustion and exhausting appliances. Pre-mitigation diagnostic testing assists in selecting the appropriate number and locations of suction points to achieve pressure field extension across the entire slab. Diagnostic testing after mitigation system installation (post-mitigation) and confirmation sampling are required to ensure the system is operating as required to protect occupants of the building from vapor intrusion.

These guidelines are generally intended for installing active systems in single-family residential homes with conventional foundation systems. Additional considerations should be evaluated for larger multi-unit residential, commercial and industrial buildings and/or buildings with more complex heating, ventilating and air conditioning (HVAC) systems, and buildings with complex foundation systems (pilings, grade beams, piers, multiple foundations, multiple level foundations, etc.).

Pressure differential requirements

Active systems prevent vapor intrusion into indoor air by creating a pressure differential between the indoor air space and the air space directly beneath the floor slab, floor membrane and/or outside the foundation wall. Minnesota Pollution Control Agency (MPCA) has established pressure differential requirements that must be met to ensure the active system is operating effectively to prevent vapor intrusion into the building.

The following default pressure differential criteria for active systems (pre and post-mitigation) have been established based on seasonal conditions and with all exterior windows and doors closed and all indoor combustion appliances and exhaust fans operating:

- three pascals during winter conditions (November 1st through March 31st)
- five pascals during non-winter conditions (April 1st through October 31st)

Winter conditions were established based on average ambient outdoor temperatures requiring heating of indoor air and the likelihood of frost in the subsurface soils.

Additional information regarding pressure differential requirements during pre and post-mitigation diagnostic testing is described below.

Contractor certification requirements

The MPCA recommends only qualified persons trained in performing the requirements and duties described herein should conduct the work. Contractors performing pre and post-mitigation diagnostic testing and active system installation for single family residences should be currently certified by either the National Radon Proficiency Program (NRPP) or National Radon Safety Board (NRSB) for installation of active systems. Contractors must also have current certification for Occupational Safety and Health Administration (OSHA) forty hour Hazardous Waste Operations and Emergency Response (HAZWOPER) to conduct pre and post-mitigation diagnostic testing and mitigation system installation. MPCA also recommends that mitigation contractors complete training on chemical vapor intrusion mitigation. The Midwest Universities Radon Consortium offers a two day course on vapor intrusion mitigation.

Pre-mitigation diagnostic testing

Prior to installation of an active system, diagnostic testing should be performed to assist in determining the following system information: number and placement of suction points, size of system piping, sizing of vent fan, tightness to the floor slab and evaluating the overall effectiveness of the system to provide adequate protection of the building occupants from vapor intrusion. Pre-mitigation testing includes collection of pressure field extension (PFE) measurements. PFE measurements are obtained by measuring the pressure differential between the indoor air space and the air space directly beneath the floor slab, floor membrane and/or outside the foundation wall.

Pre-mitigation diagnostic testing should be conducted in accordance with Section 3 of U.S. Environmental Protection Agency (EPA) 1993. Pre-mitigation diagnostic testing measurements, building floor plan and system information should be recorded on Attachment A – Pre-mitigation Diagnostic Testing Checklist. Following is a summary of procedures for conducting pre-mitigation diagnostic testing.

1. Prepare a floor plan (to-scale, with north arrow) of the lowest level of the building including any crawl spaces and floor-slab additions of different elevations (if present) prior to any diagnostic testing for system installation. This includes foundation and footing locations.
2. Conduct backdraft testing on all combustion appliances inside the building. Procedures for checking combustion appliance backdrafting can be found in section 11.5 of EPA, 1993. If backdraft conditions are identified, notify the building occupants and the building owner immediately. DO NOT conduct pre-mitigation diagnostic testing or commence with mitigation system installation until all backdraft conditions have been corrected. A heating, ventilation and air conditioning (HVAC) contractor should evaluate and correct any backdraft conditions and verify proper appliance installation and performance.
3. Confirm the locations of any underground utilities beneath or within the floor slab with the property owner and/or hire a utility locating contractor to identify and mark the utilities prior to drilling through the floor slab.
4. Seal potential vapor intrusion points in the floor (e.g. gaps, cracks, cold joints, utility penetrations) to the extent practical.

5. All suction points and proposed system piping locations should be confirmed with the property owner prior to installation.
6. Select a suitable location for a suction point based on building layout and utilities and property owner approval and make a hole in the concrete floor slab to open communication with the soil space beneath the floor slab.
7. The diameter of the suction point hole should correspond to the type of diagnostic testing equipment you are using (shop-type vacuum, radon fan, etc.).
8. Connect the suction source (shop-type vacuum, radon fan, etc.) to the suction point and seal against the floor slab.
9. The vacuum applied at the suction point should generally be similar to the vacuum developed by the fan that is selected for use in the building. Therefore, if using a shop-type vacuum you may need to reduce the vacuum by bleeding in fresh air.
10. Make sure that the exhaust from the shop-type vacuum or radon fan is vented to the outside to prevent vapor emissions into the building.
11. Drill ¼ inch to ½ inch diameter PFE test holes in the floor slab with a masonry drill bit. One PFE test hole should be installed within approximately one foot of the suction hole to measure applied vacuum pressure.
12. One PFE test hole should be completed in each quadrant of the floor slab (minimum of four PFE points for a 1,000 square foot or less foundation) and at distances as far from the suction point as practicable based on building construction, above and below ground utility lines and/or obstructions. Buildings with foundations larger than 1,000 square feet should be tested at a rate of one PFE point for every additional 250 square feet.
13. Conduct the PFE diagnostic testing with all natural draft appliances (older non-high efficiency furnaces, stove/range hoods, clothes dryers, bathroom fans, etc.) operating and all windows and exterior doors closed to provide "worst case" conditions.
14. Measure the pressure differential between the area below the floor slab and the indoor air space above the floor slab at each PFE test hole using a micromanometer.
15. Measure the air flow from or into the vacuum to assist in proper selection of the fan size for the active system.
16. The pre-mitigation PFE diagnostic testing should demonstrate a pressure differential at each PFE test point that is greater than the following default pressure differential criteria:
    - three pascals during winter conditions (November 1st through March 31st)
    - five pascals during non-winter conditions (April 1st through October 31st)
17. Additional suction points and/or adjustments to the suction point (e.g. removal of soil, increasing vacuum) may be needed to obtain the required PFE across the building footprint.
18. The results of the pre-mitigation system PFE diagnostic testing are necessary to assist in selecting the active system components including: determining the correct fan size, number of suction points and diameter of the suction/vent piping.
19. The PFE test points should be left in place and used for post-mitigation diagnostic testing where appropriate. The PFE test points should be temporarily sealed with an air tight cap between diagnostic tests and final sealed (remove sampling insert and backfill hole with cement) upon completion of testing to prevent vapor intrusion from the sub-slab into the living space.
20. Pre-mitigation diagnostic testing results should be documented on Attachment A and included with the final Property Summary Report (PSR).
21. In the event that the building has existing combustion appliances that draw room air from inside the building and a direct source of make-up air from outside the building is not present, make-up air to the

combustion appliance room should be installed prior to conducting pre-mitigation diagnostic testing. Providing outside make-up air for combustion appliances significantly reduces the potential for backdrafting in addition to reducing the potential for vapor intrusion into the building. Modifications to combustion appliances, including providing make-up air, may require a permit.

22. Any building construction/reconstruction work must be completed in accordance with all State and local building codes and regulations. All elements of any mitigation system installed must meet with all State and local building codes and regulations, as well.

Active system installation

Active mitigation systems should be installed in general accordance with the most current versions of American Society for Testing Materials (ASTM) and EPA technical documents (ASTM, 2013, ASTM, 2009, EPA, 1993, EPA 1994a, 1994b, 1994).

Active system installation information should be recorded on Attachment B – Active System Installation Checklist. Following is a summary of active system installation methods and procedures:

1. All active systems should be installed to avoid creation of other health, safety and environmental hazards to building occupants including but not limited to; backdrafting combustion appliances, constricting or blocking building exits with pipe runs or degradation of fire rated assemblies with pipe and/or cable penetrations. All elements of any mitigation system installed must meet with all State and local building codes and regulations.
2. If the contaminants of potential concern (COPC) include flammable or explosive compounds (i.e. petroleum compounds), the active system must be intrinsically safe.
3. Special safety considerations, which are not included in this document, are required if methane is a COPC. If methane is a COPC, please contact MPCA staff to discuss further safety considerations prior to system installation.
4. The placement of all suction points and piping should be confirmed with the property owner prior to installation of the active system.
5. A minimum of one suction point should be installed in each level (e.g. multi-level basements, crawl spaces, etc.) and in each area where there is a building addition or the foundation would restrict the air flow from one area to another.
6. PFE diagnostic testing should be conducted prior to installation of the active system to evaluate PFE across the building footprint and determine how many suction points are required.
7. If the required pressure differential is not achieved at all PFE test points, additional suction pits, higher vacuum fans, additional fans, or alternative vapor mitigation techniques should be employed.
8. Install schedule 40 polyvinyl chloride (PVC) pipe (typically three inch or four inch diameter based on site-specific conditions) or MPCA approved equivalent to connect the suction point(s) to the fan(s).
9. The fan(s) should be located in an unconditioned space like the attic or garage and should not be located outside (if possible) where it will be exposed to the elements.
10. If the stack piping and/or fan(s) need to be located outside, they should be chased and insulated to reduce the potential for condensation and frost build-up.
11. The circuit breaker box should indicate which breaker the active system electrical supply is connected to.
12. If the rated electricity requirements of a radon mitigation system fan exceed 50% of the circuit capacity into which it will be connected, or if the total connected load on the circuit (including the radon vent fan) exceeds 80% of the circuit's rated capacity, a separate, dedicated circuit shall be installed to power the fan.
13. The stack discharge should be located a minimum of 10 feet from any building openings to prevent vapor re-entrainment.

14. The discharge height of the stack should be a minimum of two feet above the roof line.
15. The exhaust discharge should be vertical with no elbows or deflectors.
16. Active system piping should have labels identifying it as vapor mitigation system piping, and should have flow direction arrows on the piping in all visible locations on each floor/level.
17. A manometer should be installed in a visible and accessible location on at least one suction point stack/riser associated with each fan so the system performance can be monitored.
18. A label should be placed in a visible location on the stack/riser containing the manometer. The label should contain the following information:
    - active system installer's name, telephone number and NRPP or NRSB certification number
    - initial vacuum reading on the manometer upon active system installation
    - active system installation date
    - fan model
19. Active system installation activities and diagnostic testing results should be recorded on Attachment B and included in the final PSR.

Post-mitigation diagnostic testing

Post-mitigation diagnostic testing should be conducted after installation of the active system to confirm that the system is operating properly to provide the required PFE throughout the building footprint and to determine if any adjustments to the system are required.

Post-mitigation diagnostic testing should be conducted in accordance with Section 11 of EPA, 1993. Post-mitigation diagnostic testing measurements, building floor plan and system information should be recorded on Attachment C – Post-mitigation Diagnostic Testing Checklist. Following is a summary of the procedures to be followed for conducting post-mitigation diagnostic testing after installation of an active system.

1. With the active system running and all internal combustion appliances and exhaust fans operating, the post-mitigation PFE diagnostic testing should demonstrate a pressure differential at each PFE test point that is greater than the following default pressure differential criteria:
    - three pascals during winter conditions (November 1st through March 31st)
    - five pascals during non-winter conditions (April 1st through October 31st)
2. A minimum of four PFE test points should be measured for residential buildings with a foundation size of 1,000 square feet or less. Additional PFE test points are required for larger buildings (>1,000 ft^2) or where there are multiple levels or additions which would have separate foundations or crawl spaces. PFE test points should be located radially surrounding the suction pit(s). At least one PFE test point should be located at the maximum distance from all suction points within the building footprint.
3. Conduct PFE testing with all combustion appliances and natural draft appliances (older non-high efficiency furnaces, stove/range hoods, bathroom fans, etc.) operating and all windows and doors closed to provide "worst case" conditions.
4. The PFE test points installed during the pre-mitigation diagnostic testing can be re-used for post-mitigation diagnostic testing; however, additional PFE test points may be required to confirm PFE across the floor slab and/or membrane and the PFE test points need to be temporarily sealed between tests to prevent vapor intrusion to the building. Upon completion of the post-mitigation PFE diagnostic testing, the PFE test points need to be sealed to prevent vapor intrusion to the building.
5. Conduct smoke testing along interior floor cracks and wall joints while active system is operating to check for air leakage.
6. Conduct backdraft testing on all combustion appliances while the active system, all combustion appliances and vent fans are running to ensure backdraft conditions were not created within the building due to the installed active system. This is a critical step from a health and safety standpoint. If backdrafting conditions

are observed, the active system must be turned off until the backdrafting condition is corrected. Report any backdrafting to the building owner and document the conditions. If the backdraft condition is not corrected, building occupants may be at risk from carbon monoxide poisoning. Procedures for checking combustion appliance backdrafting can be found in Section 11.5 of EPA, 1993.

7. Diagnostic testing results should be documented on a field checklist form (Attachment C) and included with the final PSR.

Post-mitigation confirmation sampling

Upon completion of active system installation, confirmation sub-slab, indoor air and ambient outdoor air sampling is required to evaluate whether the active system is operating effectively to prevent vapor intrusion into the building above the intrusion screening values.

Post-mitigation confirmation sampling information should be recorded on Attachment D – Post-mitigation Confirmation Sampling Checklist. Procedures for conducting post-mitigation confirmation sampling after installation and post-mitigation diagnostic testing include:

1. Post-mitigation confirmation sampling consists of collecting concurrent sub-slab, indoor air and ambient outside air samples and collecting follow-up PFE diagnostic testing. Concurrent collection of these samples will assist in distinguishing indoor air contaminants resulting from vapor intrusion versus those originating from other background contaminant sources.
2. Regardless of seasonal conditions, post-mitigation confirmation sampling is required after installation of the active system and confirmation of post-mitigation PFE diagnostic testing. Post-mitigation confirmation sampling should be conducted after a one week (seven calendar days) equilibration period and must be completed within 30 days after active system installation.
3. If the post-mitigation confirmation samples are not collected in winter conditions, a second round of post-mitigation confirmation sampling during winter conditions is required to evaluate system performance under worst-case conditions.
4. Indoor air samples and outside ambient air samples should be collected over a twenty-four hour period. Both indoor air and ambient outdoor air sampling require the use of individually certified clean canisters.
5. Sub-slab samples should be collected with a canister equipped to collect the sample at a maximum flow rate of 200 milliliters (ml)/minute and the canister should be individually certified clean by the analytical laboratory.
6. Indoor ambient air samples should be collected from the basement or lowest level near suspected vapor entry points (if present) to assess the worst-case vapor intrusion to the building.
7. The sample collection point should be located in the breathing zone, approximately three to five feet above the floor.
8. Collection of one concurrent sub-slab sample and paired indoor air sample is required per 1,000 square feet of building footprint or for every section of a building separated by footings or foundations.
9. All confirmation samples should be analyzed using EPA Method TO-15 (full scan) by a fixed base Minnesota Department of Health certified laboratory for the full Minnesota Soil Gas List compounds. The use of other analytical methods will require prior MPCA staff approval.
10. Follow-up PFE diagnostic testing should also be completed at the same locations as the test points completed for post-mitigation PFE diagnostic testing upon system installation.

References

ASTM, 2013, E2121-13, Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings, ASTM International, West Conshohocken, Pennsylvania, 13 pp.

ASTM, 2009, E1465-09, Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings, ASTM International, West Conshohocken, Pennsylvania, 24 pp.

EPA, 1994a, Radon Prevention in the Design and Construction of Schools and Other Large Buildings, Third Printing with Addendum, June 1994, EPA Document: EPA/625/R-92/016, EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, 50 pp.

EPA, 1994b, Radon Mitigation Standards, Revised April 1994, EPA Document: EPA/402-R-93-078, EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, 24 pp.

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EPA, 1993, Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems, October 1993, EPA Document: EPA/625/R-93/011, EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, 329 pp.