MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

NORTHEAST REGIONAL OFFICE

GUIDELINES FOR THE DESIGN, INSTALLATION, AND OPERATION OF SUB-SLAB DEPRESSURIZATION SYSTEMS

DECEMBER 1995

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1.0 INTRODUCTION

This guidance document addresses the design, installation, and operation of sub-slab depressurization (SSD) systems. Its purpose is to provide technical insight and guidance to regional staff involved in the oversight of response actions where these systems are being considered, proposed, designed, and/or operated.

SSD systems are a proven, effective, and economical means for intercepting subsurface vapors that would otherwise infiltrate into a structure of concern. These systems have been successfully installed and operated in residential, commercial, and school buildings throughout Massachusetts.

Site-specific performance standards and monitoring requirements are typically set forth by DEP in a response action approval letter, or, in the case of a state funded response action, a Task Assignment or bid document. Generally, such approval or specifications should be predicated/contingent upon satisfying the design, operational and performance standards outlined in this document. Parties proposing to deviate from such standards should fully document the necessity and implications of their approach.

2.0 STATEMENT OF THE PROBLEM

Volatile Organic Compounds (VOCs) in soil and groundwater tend to partition or volatilize into the vapor phase, fill the interstitial (void) spaces of the soil, and subsequently migrate in the vapor phase via diffusive and/or advective forces towards an area of lower concentration or pressure, along the underground pathway(s) of least resistance.

In undeveloped areas, migration of vapor-phase contaminants is towards the ground surface and into the ambient air. The presence of a building or other subsurface structure, however, can provide an alternative advective or diffusive "sink". Underpressurization within a building (relative to the ambient atmosphere) can create a significant negative pressure differential between the building/basement air and the surrounding soil, and induce the advective transport of vapor-phase contaminants towards and into the structure.

There are a number of factors which can and do lead to building underpressurization:

- thermal differences between indoor air and the surrounding soils;
- wind and barometric changes;
- "stack effects" of chimneys and flues;
- the operation of exhaust fans/vents; and
- negative pressures created by the use of combustion air in gas and oil furnaces.

The existence of a frost layer tends to exacerbate vapor phase intrusion during winter months, by temporarily eliminating the ground surface/ambient-air transport pathway. This is also when combustion furnaces will be in operation, and when household ventilation will be at a minimum. While buildings with basements are most at risk, vapor phase intrusion may also occur within slab-on-grade structures.

Johnson and Ettinger[1] have postulated that diffusion is the predominant vapor-phase transport mechanism at release source areas, but that advective transport generally predominates in the areas adjacent to and near buildings. It is generally believed that most vapor-phase intrusion occurs via cracks in masonry foundations (as opposed to diffusion through concrete). Of particular concern are the small perimeter cracks that generally develop in poured concrete foundations at the intersection of the footing/wall/slab. Other problematic entry points include the annulus space around incoming utility pipes, as well as shear, settling, or shrinking cracks that can develop over time within the walls or slab.

The mechanisms that create pressure differentials are complex and temporally variable. The magnitude of building underpressurization that can be created by these mechanisms has been reported to be in the range of 1 to 50 Pa.[2] This underpressurization leads to a "pressure coupling" effect on surrounding soils, producing a measurable decrease in soil gas pressures, thus resulting in a pressure gradient and advective flow. This pressure coupling is highly variable and site-specific; although usually most significant within 1 or 2 meters of a structure, measurable effects have been reported up to 8 meters from building structures.[2,3] Although seasonal changes in vadose zone moisture content will influence soil/air permeability in near-surface soils (less than 1 meter below grade), Garbesi et. al. have reported that soil moisture and permeability conditions remain reasonably constant at depth, and that little seasonal change in pressure-coupling effects will be observed in structures with full basements.[4]

> Extremely small pressure differences are significant in the evaluation of soil gas intrusion. The typical pressure measurement unit is the Pascal (Pa).
>
> 1 Pa = 0.004 inches water column
>
> 1 inch of water column = 0.036 psi
>
> Special gauges are needed to measure such pressure differentials. A magnehelic gauge is capable of measuring as little as 0.5 - 1.0 Pa.

3.0 DETERMINING THE NEED FOR AN SSD SYSTEM

An SSD system should be considered at any structure where indoor air quality is being compromised by a subsurface environmental source, and where the design and/or construction of the foundation structure is, or can be made, relatively air-tight. This includes buildings without foundation slabs, provided it is feasible to pour a slab, or place an impermeable liner over the earthen subgrade.

Before pursuing this option, however, **it is essential that conclusive evidence exist documenting the presence of a subsurface VOC source and/or migration pathway**. Where appropriate, this effort should include investigations to identify possible source/source areas, and source control or mitigation measures.

3.1 Ruling Out Extraneous Sources and Pathways

Odors in buildings are frequently the first sign of a potential environmental problem which may be best addressed by the installation of an SSD system. However, there are a number of other possible explanations for these odors that must be first investigated and eliminated from consideration, including:

- Leaks from natural gas/propane piping;
- Backdrafting from furnaces/chimneys;
- Paints, sealers, pesticides, or other chemical products applied, used, or stored at the structure; or
- Sewer gases from improperly constructed or maintained drain lines (including sump pumps).

Where appropriate, local building, plumbing, and/or fire departments should be consulted. Any (recent) use of a chemical product or building material should be investigated and evaluated.

3.2 Indoor Air/Soil Gas Sampling

To confirm the presence of an environmental source and pathway, two actions should be taken:

- A PID and/or FID unit should be used to scan typical soil gas entry points into a foundation (cracks, annulus spaces, sumps). If a sump is present, an attempt should be made to obtain and test a groundwater sample (make sure to pump out stagnant water first).

- One or more soil gas samples should be obtained from beneath the slab of the impacted building, in areas where positive responses were obtained on the PID unit, and/or areas most likely to be impacted by VOC vapors. In buildings with finished basements, attempts should be made to locate these test probes in utility rooms or other unobtrusive areas.

3.3 Source Location and Mitigation

An attempt should be made to identify the source of the VOC problem, to mitigate the effects of the release, and/or facilitate SSD design and operation. Common efforts and considerations include the following:

- At buildings experiencing petroleum odors, all fuel oil storage tanks should be evaluated, both USTs and ASTs. The feed line between the tank and furnace is often a source of releases to the subsurface; the building owner should be directed to contract the services of a qualified heating oil firm to air test this line.

- Gasoline stations, dry cleaners, and automotive repair facilities are the most common sources of VOC releases. In surveying surrounding establishments, consider topography, presumed groundwater flow direction, and land use between the suspected sources and impacted buildings. Use a PID and/or FID meter to scan drainage and other subsurface utilities. Note that open (grassed) areas allow the infiltration of precipitation/runoff, and formation of a "fresh water lens" over a contaminated groundwater plume. These lenses can effectively prevent the off-gassing of dissolved VOCs at-depth. Conversely, paved/impervious/sloping areas provide minimal infiltrative benefits, and tend to promote water-table plume migration and vapor-phase partitioning and buildup.

4.0 PURPOSE/OBJECTIVE OF SSD SYSTEM

The purpose of an SSD system is to create a negative pressure field directly under a building and on the outside of the foundation (in relation to building ambient pressure). This negative pressure field becomes a "sink" for any gases present in the vicinity of the structure. VOCs caught in the advective sweep of this negative pressure field are collected and piped to an ambient air discharge point.

Note that an SSD system is not intended to remediate the soil or groundwater beneath a building. Its design objective is to prevent soil gases from infiltrating the building. Ideally, the extent of depressurization and soil gas removal should be kept to a minimum, to minimize energy, handling, and/or off-gas treatment costs. This is why these systems are most appropriately termed "depressurization" systems, rather than "ventilation" systems.

Even though site remediation is not a design objective, it is in fact an ancillary effect and benefit. Specifically, by venting soil gases contaminated by VOCs, an SSD system facilitates the mass removal of contaminants from subsurface media. Moreover, every cubic foot of vented soil gas has to be replaced by a cubic foot of air, resulting in an influx of oxygen into contaminated areas, which may facilitate the aerobic biodegradation of contaminants.

The significance of this remediation "bonus" is site dependent, a function contaminant type, location, mass, and SSD flow rate. While perhaps most beneficial at residential sites contaminated by a leaking fuel oil tank (limited extent of contamination; directly below slab; aerobically degradable contaminants), in most cases SSD systems will not have an appreciable impact on site contaminant levels.

5.0 DESCRIPTION OF THE SSD SYSTEM

A sub-slab depressurization system basically consists of a fan or blower which draws air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes. One or more holes are cut through the building slab so that the extraction pipe(s) can be placed in contact with subgrade materials, in order for soil gas to be drawn in from just beneath the slab. In some cases the system may require horizontal extraction point(s) through a foundation wall, although in most cases the pressure field from an extraction point in the slab will extend upward adjacent to the foundation walls. A schematic diagram of a typical residential SSD system is presented in Figure 1.

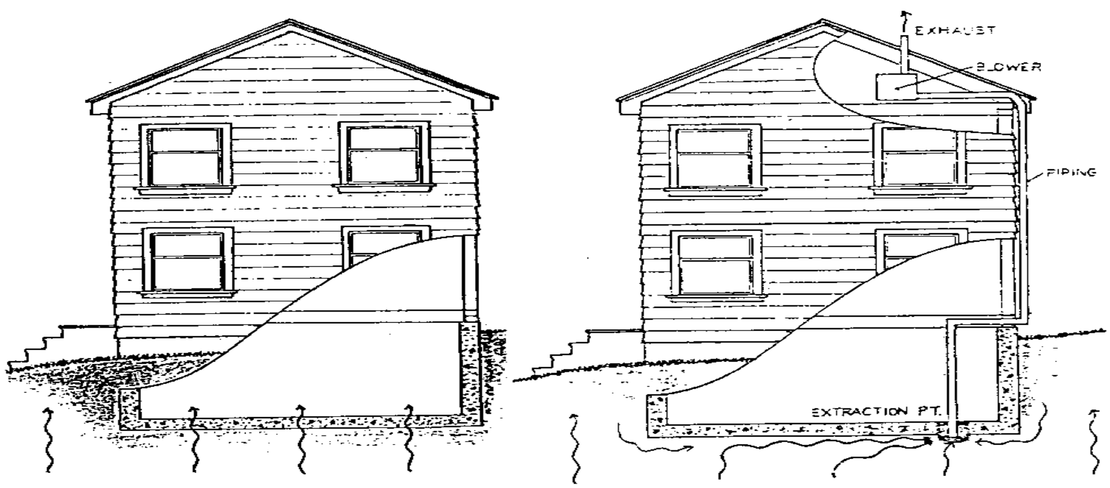


Figure 1 - Schematic Diagram of Typical Residential SSD System

SSD systems are generally categorized as "Low Pressure/High Flow" or "High Pressure/Low Flow". Site conditions dictate which system is most appropriate.

Some buildings have pervious fill/soil materials beneath the slab. Soil gas/air movement through such materials is rapid, and only a slight vacuum will create high flowrates. In such cases, the SSD system should utilize a low pressure/high flow fan. Other building slabs are underlain by less pervious materials, and common fan units will not be able to draw the appropriate level of vacuum. In these cases, a high pressure/low flow blower unit is required, capable of creating high vacuum levels.

Low Pressure/High Flow systems generally use 4 inch diameter piping; High Pressure/ Low Flow systems generally use 1.5 or 2 inch diameter piping. This piping is generally run from the extraction point(s) through an exterior wall to the outside of the building. The piping is connected to a fan/blower, which is mounted either on the outside of the building or in the attic. Placement of the fan/blower in this manner ensures that a pressurized discharge pipe is not present within occupied spaces (in case of leakage). Exhaust piping is run so that the discharge is above the roof line. Figures 2, 3, and 4 are photographs of typical residential SSD systems.

6.0 DESIGN AND INSTALLATION OF SSD SYSTEMS

All SSD systems should be designed in conformance with standard engineering principles and practices. As the work will likely be conducted in close proximity to building inhabitants, safety concerns are a priority. Attempts should be made to minimize noise, dust, and other inconveniences to occupants. Attempts should also be made to minimize alterations in the appearance of the building, by keeping system components as discretely located as practicable.

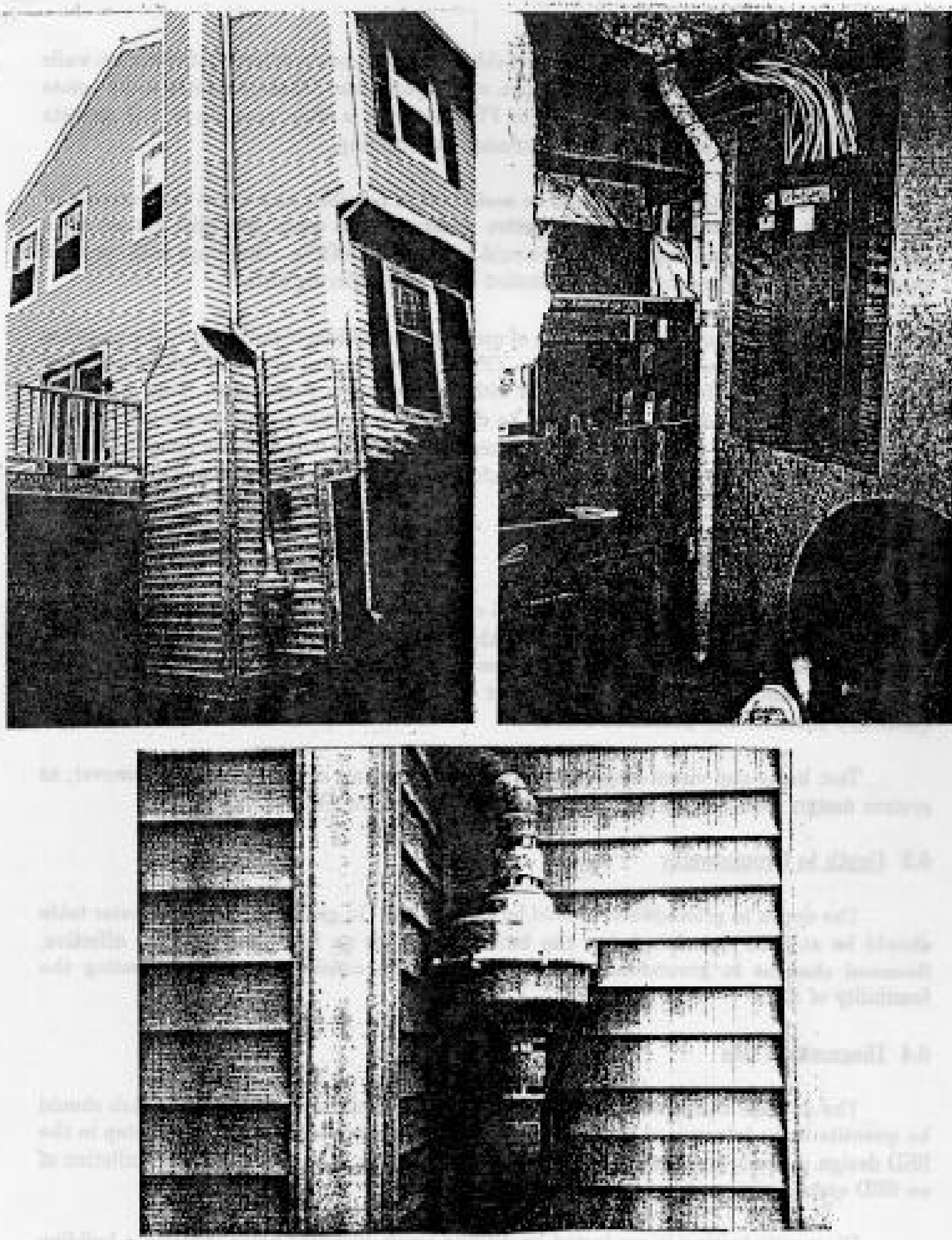
The installation of an SSD system should be conducted under the direct supervision of a competent professional with specific experience in building vapor mitigation, site remediation, and/or environmental engineering practices. There are many firms which specialize in installing SSD systems for residential radon mitigation, as the same processes described above apply to the intrusion of radon into buildings. BWSC/NERO encourages the use of firms which are listed by the EPA Radon Contractor Efficiency Program. An updated list of these contractors can be obtained by contacting the Massachusetts Department of Public Health.

The following sections describe the most important aspects of SSD system design and installation.

6.1 <u>Inspection of Building Foundation</u>

An inspection of the building foundation should be conducted, with particular attention paid to identifying all potential entry routes for VOC contaminated soil gases, such as cracks in concrete walls or slabs, gaps in fieldstone walls, construction joints between walls and slabs, annulus space around utility pipes, open sumps, etc. These potential entry points should be surveyed with a portable PID or FID meter; it is often possible to find discrete "hits" at particular points where vapor intrusion is occurring.

All possible entry routes should be sealed off, if possible, to prevent the entrance of soil gas, and enhance the sub-slab negative pressure field when the SSD system is in operation. Sealing/caulking materials should not contain VOC's. Buildings with no slabs should have an impermeable barrier installed before considering SSD.



Figures 2, 3, 4: Photographs of SSD System Components

A particularly problematic feature of commercial and school buildings is the presence of floor drains in lavatories and other areas. Often, the water seal within the plumbing "trap" of these drains is ineffective, as the water either leaks out or evaporates. This provides a vehicle for soil gases and/or sewer gases to discharge into these areas (especially true in lavatories with fans or vents which create a negative pressure within these rooms). In such cases, efforts should be made to periodically add water to these traps, or to install a "Dranjer" type seal.

6.2 Sub-Slab Materials

Knowledge/information on the fill/soil conditions beneath the slab is desirable. Small diameter test holes can be drilled through the slab at various representative locations to collect sub-slab material for visual inspection. Test holes should be installed above the groundwater table and should not be deeper than one foot. A general evaluation of the material's permeability should be made.

Test holes and visual inspection of sub-slab materials are not essential, however, as system design is based primarily on the results of pressure testing.

6.3 Depth to Groundwater

The depth to groundwater should be ascertained. In general, the groundwater table should be at least 6 inches below the building slab for an SSD system to be effective. Seasonal changes in groundwater elevation should be considered when evaluating the feasibility of SSD.

6.4 Diagnostic Tests

The air flow characteristics and capacity of the material(s) beneath the slab should be quantitatively determined by diagnostic testing. This is the most important step in the SSD design process, and should always be performed prior to the design and installation of an SSD system.

Diagnostic testing is conducted by drilling small diameter holes through a building slab, applying a vacuum to one hole, and measuring pressure drops at surrounding test holes. The procedure is analogous to conducting a pump test to gauge aquifer properties and zone of influence. Most reputable and experienced SSD installation contractors have developed empirical (and proprietary) means to conduct and evaluate diagnostic tests. It is not necessary that complete details of this test be provided to DEP, as long as overall task and project performance standards are met (i.e., that upon installation and operation of the final system, a negative pressure field is documented beneath all impacted areas).

Within this context, several comments and recommendations are offered:

- The objective of diagnostic testing is to investigate and evaluate the development of a negative pressure field, via the induced movement of soil gases beneath the slab. This information is in turn used to determine whether a Low Pressure/High Flow or High Pressure/Low Flow system is necessary, and to determine the number and location of needed system extraction points.

- Two means are used to monitor and document the development of a negative pressure field: pressure testing and smoke testing. Pressure testing provides a direct and quantitative means to measure a negative pressure field. However, in cases where very pervious fills/subsoils are present, large volumes of air can be moved with relatively little pressure drop, undetectable by even the most sensitive gauge. In these cases, the creation of a negative pressure field can be verified by smoke tests, which demonstrate the (downward) advection of smoke (air) into the ground (i.e., through the slab).

- Generally, the diagnostic extraction hole should be at least 3/4 inches in diameter; the test holes 3/8 to 5/8 inches in diameter.[5] Test holes should be placed at representative locations, such that the size of the effective pressure field under the slab may be evaluated. Typically, a "shop vac" unit is used to pump soil gas from the extraction hole; the pressure drop and flow rate at this extraction point should be monitored and recorded. Pressure drops at the test holes should be measured quantitatively with a pressure gauge (e.g., a magnehelic gauge). A pressure drop of less than 0.5 Pa (0.002" of water) is generally not considered significant.

- Extraction and observation holes should be placed in the most unobtrusive locations possible; utility rooms and closets in a finished basement are good choices. Care must be taken to avoid damaging subslab utilities or conduits; the oil feed line to a furnace is of particular concern. The discharge from the extraction hole should be vented to the outside air. Following the test, the diagnostic extraction and test holes should be sealed with a portland cement grout, although at least 1 or 2 holes should remain unsealed until after installation of the final SSD system, in order to provide points to demonstrate establishment of a negative pressure field.

- For larger buildings, such as commercial buildings and school buildings, more extensive and involved sub-slab diagnostics are essential. Structures such as utility tunnel floors and walls, crawl spaces, internal continuous footings, and/or frostwalls should be considered in the diagnostic evaluations, as they can impede air flow.

- Atmospheric pressure may be of importance at sites where diagnostic testing indicates marginal negative pressure readings. In such cases, barometric pressure data should be obtained and reviewed for the day of testing, and previous several days. A trend of rising barometric pressure tends to promote advection of air into the ground, which may be falsely interpreted as a negative pressure field created during diagnostic tests. Where concern exists in this regard, the testing should be repeated during a time of falling barometric pressures.

6.5 Location and Construction of Extraction Points

Final system extraction points should be properly located, based upon pressure/smoke test results, to ensure a sub-slab negative pressure field under the entire building. For most private residences, especially one to four family houses, only one or two extraction holes should be needed, unless anomalous conditions (e.g. very impermeable sub-slab material) exist. High Pressure/Low Flow blowers should be used at sites with impervious subsoils, to minimize the number of extraction points necessary.

Extraction points are constructed by drilling or cutting holes through the building slab, making sure that any vapor barriers are breached and the sub-slab materials are encountered. Wherever practicable, extraction points and piping should be placed in the most unobtrusive locations, particularly in residential dwellings with finished basements.

A 10 to 20 inch diameter pit should be excavated at the extraction point(s), to a depth of about 10 inches. Crushed stone is then backfilled around the extraction pipe, and the extraction hole is then patched around the piping using mortar or non-shrink grout, to insure a good seal. There are two important advantages gained by such a pit:

- Bonnefous et. al.[3] have reported that a pit of this nature can "dramatically" improve and extend the pressure field beneath a slab; and

- water vapor condensation within the piping system (a particular concern during winter at sites with external discharge piping runs) can be readily infiltrated back into the subsoil, minimizing effects on soil gas extraction.

As a final note, care should be taken to ensure that extraction points/pits intercept the thin void zone that typically exists directly beneath poured slabs. Specifically, differential settlement over time typically creates a series of interconnected void spaces beneath concrete slabs. While the extent and significance of these voids in transmitting soil gases is highly site-dependent, it makes sense to use every advantage possible.

6.6 Fan and Piping Design

The type of sub-slab material and pressure field characteristics, as determined by diagnostic tests, should determine the type of fan or blower to be used for the SSD system.

Generally, one of two types of units will be specified:

- **Low Pressure/High Flow** - The most common application, used at sites with relatively permeable subsoils, where only low vacuum is needed to produce a negative pressure field beneath impacted areas. Generally, an in-line centrifugal fan unit is used. These units are simple, quiet, inexpensive ($100 -$200), and consume only about 100w of power (the same amount as a 100w light bulb). Typically, these units are capable of inducing 0 - 4 inches of water vacuum, while moving 50 to 300 cubic feet per minute (cfm) of air. [5,6]

- **High Pressure/Low Flow** - Required at sites with impervious subsoils (fine sands/silts/tills). Generally, a regenerative blower unit is required to produce the needed level of vacuum - typically 5 to 30 inches of water. At this vacuum level, only 5 to 30 cfm of air is moved. Regenerative blowers are relatively expensive ($300 - $500), and require around 300w of power to run. Regenerative blowers can produce a high-pitch whine, which may not be suitable for residential applications without appropriate soundproofing.[5,6]

Fans and blowers are designed and specified on the basis of flow vs pressure. In any given unit, flow is proportional to pressure (or vacuum). The greater the flowrate, the less pressure (or vacuum) that can be maintained. Manufacturers provide information of this nature in tabular and graphical form; an example of tabular data for a centrifugal fan is presented in Figure 5, an example of a performance curve for a regenerative blower unit is presented in Figure 6. A fan or blower selected for a site must have performance characteristics suited (or optimally suited) for the application in question.

Four inch diameter schedule 40 PVC piping is generally used for Low Pressure/High Flow systems; 1.5 - 2 inch diameter schedule 40 PVC for High Pressure/Low Flow system. Aluminum "downspout" conduit can be used in lieu of PVC, in cases where building owners wish to make the piping as discreet as possible.

Maximum Pressure	Watts	Typical CFM vs Static Pressure WC 1.0"	1.5"	2.0"	2.5"	3.0"	3.5"	4.0"
2.0" WC	55-80	82	58	5				
2.6" WC	55-90	92	77	45	10			
3.4" WC	60-120	93	82	60	41	18		
4.2" WC	60-140	95	87	80	70	57	30	10

Figure 5 - Centrifugal Fan Performance Characteristics

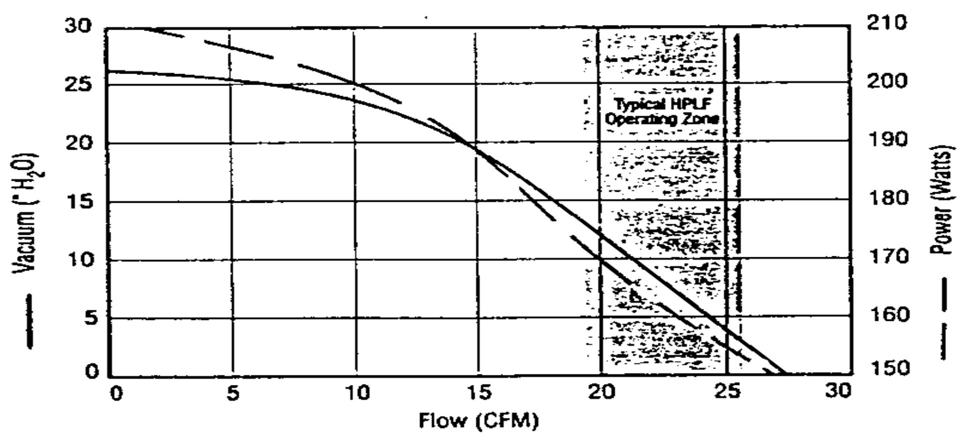


Figure 6 - Regenerative Blower Performance Curve

However, the aluminum conduit is more susceptible to condensation freezing in winter. All piping should be installed with a positive pitch back to the extraction point, to ensure that any condensation is directed back to the extraction sump, or some other moisture collection/discharge point.

Generally, the fan/blower and discharge piping (all piping after the fan) should be kept outside the building. The discharge piping contains VOCs under positive pressure during system operation, and in the event of a failure could leak contaminated soil gases into the building, if kept inside. For SSD systems with a fan/blower outside the building, condensate control devices may be necessary in the cold months and the fan must be weather-proofed. If the fan/blower is inside the building, it must be as near as possible to the outside to minimize the amount of discharge piping inside the building. Fans installed in the attic must either be able to sustain the heat in the summer or provisions for fan cooling must be made.

Units installed in residential buildings must be designed, installed, and operated in a manner that minimizes noise and vibration. This is a particular concern for regenerative blowers and/or units installed in an attic. Special insulation and/or mounting hardware may be necessary in such applications. Attic units should be located as far from sleeping areas as possible.

6.7 System Gauges and Alarms

At a minimum, an in-line pressure gauge or manometer must be installed on every unit. The gauge or manometer must have a clearly marked line or lines showing minimum acceptable vacuum levels. A simple manometer is depicted in Figure 7.

Where appropriate, in addition to a manometer or gauge, a visible and/or audible alarm should be considered, indicating loss of system vacuum or power. In all cases, clear instructions, with the name and phone number of a person to be contacted in such event, should be visible at the extraction points.

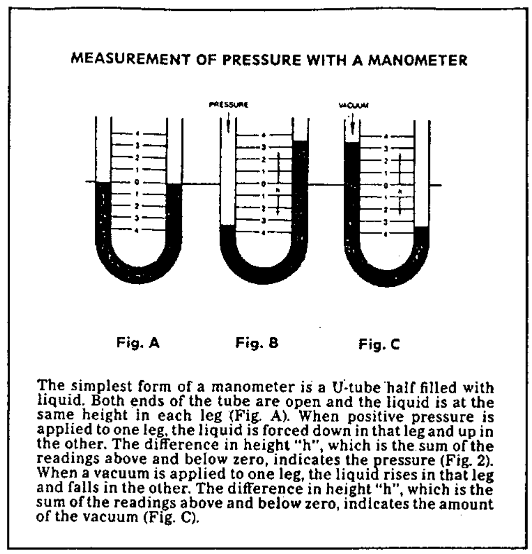


Figure 7 - Simple U-Tube Manometer

6.8 Backdrafting

Consideration should be given to the possible occurrence of a flue-gas "backdrafting" situation in a building equipped with an SSD system. Specifically, oil/gas furnaces and wood stoves/fireplaces vent combustion gases to the ambient air, typically by directing the gases up a chimney.

While some newer high-efficiency furnaces use a fan to create a positive discharge to the ambient air, most furnaces rely upon the development of a natural "draft", in which the flue gases rise up the chimney due to thermal density differences. Backdrafting can theoretically occur if negative pressures within a building are stronger than the density differential which drives the combustion gases up the chimney. In such cases, potentially deadly combustion gases (e.g., carbon monoxide) could be discharged into the building.

In some extreme cases, the operation of an SSD system could increase the depressurization level of a basement to a point where backdrafting could occur. This is most likely to happen in an energy efficient ("tight") home, particularly where significant SSD short-circuiting is occurring (via cracks in slab or leak in extraction piping).

The USEPA has recommended the following procedures to investigate and evaluate the possibility of backdrafting[7]:

(1) Close all windows and doors, both internal and external.
(2) Open all HVAC supply and return air duct vents/registers.
(3) Close fireplace and wood stove dampers.

(4) Turn on all exhaust and air distribution fans and combustion appliances EXCEPT the appliance being tested for backdrafting.

(5) Wait 5 minutes.

(6) Test to determine the indoor/outdoor pressure differential in the room where the appliance being tested in located. If the pressure differential is a negative 5 Pascals or more, assume that a potential for backdrafting exists.

(7) To begin a test for actual spillage of flue gases, turn on the appliance being tested. (If the appliance is a forced air furnace, ensure that the blower starts to run before proceeding.)

(8) Wait 5 minutes.

(9) Using either a smoke tube or a carbon dioxide gas analyzer, check for flue gas spillage near the vent hood.

(10) Repeat steps (4) through (9) for each natural draft appliance being tested for backdrafting. Extreme or unusual weather conditions need to be considered in evaluating data.

If a backdrafting potential is identified, the SSD system should not be installed or operated until a qualified HVAC contractor corrects drafting problems. In addition to improvements in appliances and flues, make-up air can be ducted from the outside to provide for combustion and drafting. Generally, 6 inch diameter duct work should be adequate for single family residential homes.

As an added level of comfort, a carbon monoxide detector should be considered for any home where an SSD system is installed, and where backdrafting is a possibility.

6.9 Other Considerations

- The presence of a sump in a basement can provide a significant "short circuiting" vehicle to the establishment of a subslab negative pressure field. In such cases, an air tight cover should be installed over the sump; if a sump pump is present, the cover should be equipped with appropriate fittings or grommets to ensure an air tight seal around piping and wiring, and the cover itself should be fitted with a gasket to ensure an air-tight seal to the slab while facilitating easy access to the pump. Note that it is also possible to use the sump as a soil gas extraction point (where appropriate); a number of manufacturers make equipment for just such applications.

- At buildings where establishment of a negative pressure field is difficult, steps can be taken to improve the effectiveness of the SSD system by reducing the degree of underpressurization occurring within the basement. These include:

    * Ducting make-up air from outside the building for combustion and drafting; and/or

    * Overpressurizing the basement by using fans to direct air from the rest of the building into the basement, or an air/air heat exchanger to direct outside air into the basement.

- Issues regarding piping routes, fan location, vibration and noise concerns, etc., should be discussed with the building owners and occupants. The local municipal Building Department should also be contacted to determine if any permits are required.

- Electrical work for the fan installation will generally require the utilization of a licensed electrician. At locations where extremely high concentrations of combustible VOCs are expected, explosion-proofed equipment should be used.
- Start-up of the system should not occur until several hours after the extraction hole has been grouted, to allow the grout to cure. Otherwise, the fan/blower could draw moisture from the wet grout and cause the patch to shrink and crack.

7.0 PERFORMANCE STANDARDS

The contractor designing and installing the SSD system should be required to guarantee and demonstrate that the system will effectively prevent the intrusion of VOCs into the building. The specific requirements for demonstrating that performance standards have been met can be set on a case by case basis. There are two levels of performance standards for SSD systems:

7.1 <u>Confirmation of Pressure Field</u>

The primary performance standard which should be used to confirm effective SSD system operation is the demonstration of a negative pressure field which extends under the entire slab. Pressure and/or smoke testing at representative/"worst case" test holes after system startup should provide sufficient information to demonstrate the presence of a negative pressure field. After the pressure field is confirmed following system start-up, monitoring of the in-line manometer or other pressure gauge should be an adequate indicator of satisfactory system operation.

7.2 <u>Indoor Air Quality Monitoring</u>

The creation of an effective sub-slab negative pressure field should necessarily result in the reduction of VOC concentrations in the indoor air within the building. After SSD system startup, indoor air quality sampling data should be collected to confirm that concentrations of VOCs in indoor air are reduced (e.g. to levels below typical indoor background levels). Generally, this confirmatory monitoring should be done 2 to 4 weeks after system startup.

Subsequent to this initial evaluation, consideration should be given to conducting one additional indoor air sampling effort during the "worst case" months of January or February (unless, of course, the initial evaluation is conducted during these months). This is especially true if non-winter SSD negative pressure conditions were marginal.

If indoor air quality data continues to indicate elevated concentrations of VOCs, further evaluation would be necessary to determine if (1) the SSD system is functioning properly, but "background" air concentrations in the building exceed published guidelines, or (2) the SSD system requires modification or expansion. To make such a determination, it is necessary to look carefully at the indoor air data (e.g., if the VOC levels are higher in the 1st floor than in the basement, the likely source is not from a subsurface vapor discharge), as well as building conditions, SSD system parameters, subslab pressure readings, and soil gas data. "Short-circuiting" problems are of particular concern, where cracks, holes, sumps, or annulus spaces in the building foundation/slab disrupt a negative pressure field.

Once an adequate demonstration of SSD system effectiveness has been made, as long as an adequate negative pressure in maintained at the extraction point(s), indoor air quality should be acceptable. For single family residential structures, it is generally not necessary to institute a regular or long term indoor air monitoring program, although periodic checks (every 2-5 years) are advisable. More frequent and/or systematic monitoring programs are advisable for larger and more complex buildings, such as schools.

8.0 REPORT SUBMITTALS

Requirements for deliverables will be made on a case by case basis. Time lines for submittal of status reports for Release Abatement Measures (RAMs) and Immediate Response Actions (IRAs) are set forth in 310 CMR 40.0400. Interim Deadlines may be set for certain deliverables, in accordance with 310 CMR 40.0167, in cases where more frequent monitoring is necessary. In general, the following reports regarding SSD system design, installation, startup, and monitoring should be submitted for adequate documentation.

8.1 Initial Design Report

A report detailing the SSD system design should be submitted to DEP for approval or presumptive approval prior to commencement of SSD system installation. This report should be prepared after the inspection of the building foundation and diagnostic tests. The design report should contain the following: a description of the building foundation; the methods used in diagnostic testing; the results of the diagnostic tests; and system design plans including equipment specifications and the location of system components.

8.2 Final Installation Report

A report detailing the SSD system installation and operation should be submitted to DEP/NERO after system startup. This report should generally include the following: a plan or sketch outlining the locations of all system components and vacuum monitoring points; a brief account of field operations associated with the SSD system installation and startup; initial post-startup smoke/pressure test data and flow rate readings from the extraction and monitoring points; a description of backdraft evaluation and documentation that a backdraft situation is not occurring; and post-startup indoor air testing data.

8.3 Periodic Monitoring Reports

Depending on the details surrounding the particular case, frequent periodic monitoring (e.g. monthly or quarterly) may be necessary to document SSD system operation in accordance with performance standards. Note that in general, SSD systems installed at residences do not require regular monitoring. Monitoring reports on SSD systems should generally include: smoke/pressure test data and flow rate readings; laboratory and screening results of indoor air and/or discharged vapor samples (if conducted); and any problems/changes made to the SSD system.

9.0 OFF-GAS CONTROLS

In accordance with DEP Policy #WSC-94-150, off-gas control systems are not required for SSD systems, provided that the system will emit less than 100 pounds/year of VOCs and will not cause air pollution/odor problems in the surrounding area. A graphical relationship between VOC concentrations, system flowrate, and yearly emission flux is presented in Figure 8, to aid in evaluations of this nature.

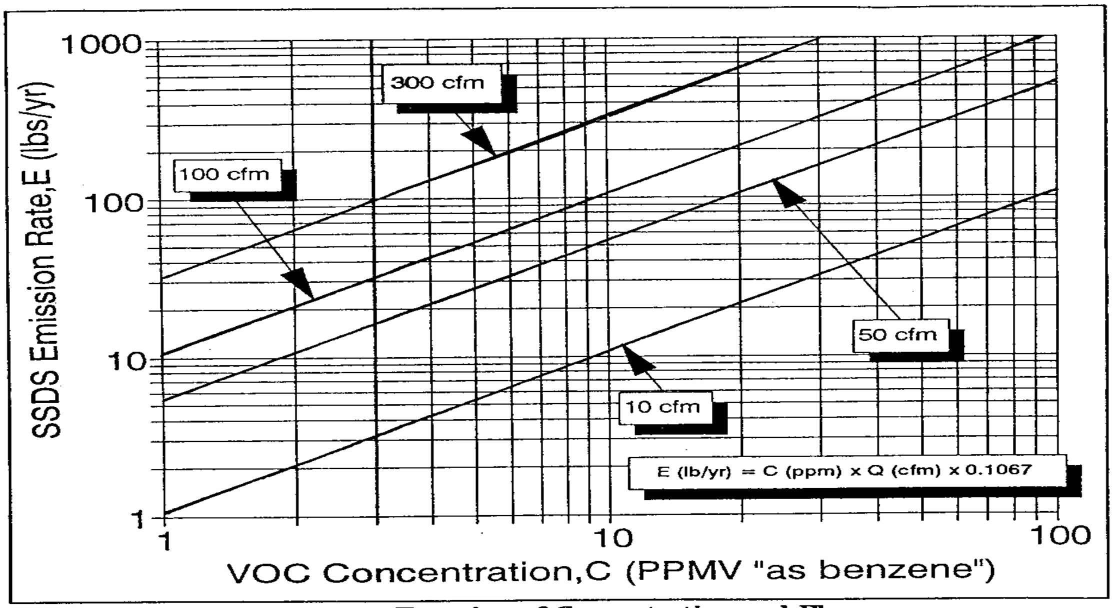


Figure 8: Emission Flux as a Function of Concentration and Flow

10.0 REFERENCES

The following documents have been cited in this report, and should be consulted for additional information and insight:

1. Johnson, Paul C. and Ettinger, R.A. "Heuristic Model for Predicting the Intrusion Rate of Contaminated Vapors Into Buildings", ES&T, 1991, 25, 1445-1452.

2. Nazaroff, W.W. et. al., "Experiments on Pollutant Transport from Soil into Residential Basements by Pressure-Driven Airflow", ES&T, 1987, 21, 459-466.

3. Bonnefous, Y.C., et. al., "Field Study and Numerical Simulation of Subslab Ventilation Systems", ES&T, 1992, 26, 1752-1759.

4. Garbesi, K., et. al., "Soil Gas Entry Into an Experimental Basement: Model Measurement Comparisons and Seasonal Effects", ES&T, 1993, 27, 466-473.

5. Crawshaw, D.A., and Crawshaw, G.K., "Migration of Elevated VOC Concentrations in Buildings Arising From Contaminated Groundwater", Proceedings of HMC, Hazardous Materials Research Institute, September, 1990.

6. Pelican Environmental Corporation Product Literature, 1990.

7. USEPA, "Radon Mitigation Standards", EPA 402-R-93-078, October 1993.