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Standard Practice for Active Soil Gas Sampling in the Vadose Zone for Vapor Intrusion Evaluations¹

This standard is issued under the fixed designation D7663; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Purpose*—This practice covers standardized techniques for actively collecting soil gas samples from the vadose zone beneath or near dwellings and other buildings.

1.2 *Objectives*—Objectives guiding the development of this practice are: (1) to synthesize and put in writing good commercial and customary practice for active soil gas sampling, (2) to provide an industry standard for soil gas sampling performed in support of vapor intrusion evaluations that is practical and reasonable.

1.3 This practice allows a variety of techniques to be used for collecting soil gas samples because different techniques may offer certain advantages for specific applications. Three techniques are presented: sampling at discrete depths, sampling over a small screened interval, and sampling using permanent vapor monitoring wells.

1.4 Some of the recommendations require knowledge of pressure differential and tracer gas concentration measurements.

1.5 The values stated in SI units shall be regarded as standard. Other units are shown for information only.

1.6 This practice does not address requirements of any federal, state, or local regulations or guidance, or both, with respect to soil gas sampling. Users are cautioned that federal, state, and local guidance may impose specific requirements that differ from those of this practice.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with

professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM practice is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title means only that the document has been approved through the ASTM consensus process.

2. Referenced Documents

2.1 *ASTM Standards*:²

- D653 [Terminology Relating to Soil, Rock, and Contained Fluids](#)
- D854 [Test Methods for Specific Gravity of Soil Solids by Water Pycnometer](#)
- D1356 [Terminology Relating to Sampling and Analysis of Atmospheres](#)
- D1946 [Practice for Analysis of Reformed Gas by Gas Chromatography](#)
- D2216 [Test Methods for Laboratory Determination of Water \(Moisture\) Content of Soil and Rock by Mass](#)
- D2487 [Practice for Classification of Soils for Engineering Purposes \(Unified Soil Classification System\)](#)
- D3404 [Guide for Measuring Matric Potential in Vadose Zone Using Tensiometers](#)
- D4696 [Guide for Pore-Liquid Sampling from the Vadose Zone](#)
- D4700 [Guide for Soil Sampling from the Vadose Zone](#)
- D5088 [Practice for Decontamination of Field Equipment Used at Waste Sites](#)
- D5092 [Practice for Design and Installation of Groundwater Monitoring Wells](#)
- D5314 [Guide for Soil Gas Monitoring in the Vadose Zone](#)
- D5466 [Test Method for Determination of Volatile Organic Chemicals in Atmospheres \(Canister Sampling Methodology\)](#)
- D5504 [Test Method for Determination of Sulfur Compounds](#)

¹ This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence

D6196 Practice for Selection of Sorbents, Sampling, and Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air

D6725 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers

E741 Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

E2024 Test Methods for Atmospheric Leaks Using a Thermal Conductivity Leak Detector

F1815 Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Athletic Field Rootzones

3. Terminology

3.1 This section provides definitions and descriptions of terms used in or related to this practice. A list of acronyms and a list of symbols also are included. The terms are an integral part of this practice and are critical to an understanding of the practice and its use.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *active sampling, n*—a means of collecting a gas-phase substance that employs a mechanical device such as a pump or vacuum assisted critical orifice to draw air into or through a sampling device.

3.2.2 *adsorption, n*—a physical process in which molecules or gas, of dissolved substances, or of liquids adhere in an extremely thin layer to the surfaces of solid bodies with which they are in contact.

3.2.3 *ambient air, n*—any unconfined portion of the atmosphere; open air.

3.2.4 *attenuation factor (a), n*—ratio of indoor air concentration to soil-gas concentration for a given compound.

3.2.5 *background level, n*—the concentration of a substance that is typically found in ambient air (for example, due to industrial or automobile emissions), indoor air (for example, from building materials or indoor activities) or the natural geology of an area.

3.2.6 *blank sample, n*—a sample that is intended to contain none of the analytes of interest and which is subjected to the usual analytical or measurement process to establish a zero baseline or background value. Blank samples are named according to their type and use (for example, field blank, trip blank, equipment blank, reagent blank).

3.2.7 *contaminant, n*—substances not normally found in an environment at the observed concentration.

3.2.8 *dead volume, n*—the total air-filled internal volume of the sampling system.

3.2.9 *duplicate samples, n*—two samples taken from and representative of the same population and carried through all steps of the sampling and analytical procedures in an identical manner.

3.2.10 *effective porosity, n*—the amount of interconnected void space (within intergranular pores, fractures, openings, and the like) available for fluid movement: generally less than total porosity.

3.2.11 *equipment blank, n*—a sample of the gas which is used to purge the sampling equipment between uses. Sampling equipment blanks are used to check the cleanliness of sampling devices and the thoroughness of the cleaning procedure.

3.2.12 *field blank, n*—unused media carried to the sampling site, exposed to sampling conditions (for example, connected to the sampling lines) and returned to the laboratory and treated as an environmental sample. Field blanks are used to check for analytical artifacts or background contaminants or both introduced by sampling and analytical procedures.

3.2.13 *fracture, n*—a break in the mechanical continuity of a body of rock or soil caused by stress exceeding the strength of the rock or soil. Includes joints and faults.

3.2.14 *free product, n*—organic contaminants in the liquid (“free” or non-aqueous) phase.

3.2.15 *ground water, n*—the part of the subsurface water that is in the saturated zone.

3.2.16 *liquid phase, n*—contaminant residing as a liquid in vadose zone pore space, often referred to as “free product.”

3.2.17 *moisture content, n*—the amount of water lost from a soil upon drying to a constant weight, expressed as the weight per unit weight of dry soil or as the volume of water per unit bulk volume of the soil.

3.2.18 *passive sampling, n*—a means of collecting an airborne substance that depends on gaseous diffusion, gravity, or other unassisted means to bring the sample to the collection surface of sorbent.

3.2.19 *partitioning, n*—the act or process of distributing a chemical among different phases or compartments.

3.2.20 *perched aquifer, n*—a lens of saturated soil above the main water table that forms on top of an isolated geologic layer of low permeability.

3.2.21 *permeability, n*—the ease with which a porous medium can transmit a fluid under a potential gradient.

3.2.22 *preferential pathway, n*—a migration route for chemicals of concern that has less constraint on gas transport than the surrounding soil. Preferential pathways may be natural (for example, vertically fractured bedrock where the fractures are interconnected) or man-made (for example, utility conduits, sewers, dry wells).

3.2.23 *porosity, n*—the volume fraction of a rock or unconsolidated sediment not occupied by solid material but usually occupied by liquids, vapor, or air, or combinations thereof. Porosity is the void volume of soil divided by the total volume of soil.

3.2.24 *purge volume, n*—the amount of air removed from the sampling system prior to the start of sample collection. This is usually referred to in number of dead volumes.

3.2.25 *reagent blank, n*—sample of one or more reagents used in a given analysis.

3.2.26 *saturated zone, n*—the zone in which all of the voids in the rock or soil are filled with water at a pressure that is greater than atmospheric. The *water table* is the top of the *saturated zone* in an unconfined aquifer.

3.2.27 *semi-volatile organic compound (SVOC), n*—organic compounds with boiling points typically in the range 240-260 to 380-400 °C with polar compounds in the higher range.

3.2.28 *soil gas, n*—vadose zone atmosphere. Soil gas is the air existing in void spaces in the soil between the groundwater table and the ground surface.

3.2.29 *soil moisture, n*—the water contained in the pore spaces in the vadose zone.

3.2.30 *sorbent sampling, n*—the collection of an air sample via removal of chemicals from a gas by passing the gas through or allowing it to come in contact with a sorptive medium. The chemicals are subsequently desorbed for analysis.

3.2.31 *sub-slab vapor sampling, n*—the collection of vapor from the zone just beneath the lowest floor slab of a building.

3.2.32 *tracer, n*—a material that can be easily identified and determined even at very low concentrations and that may be added to other substances to enable their movements to be followed or their presence to be detected.

3.2.33 *tracer gas, n*—a gas used with a detection device to determine the rate of air interchange within a space, or between spaces.

3.2.34 *trip blank, n*—clean, unused sampling media that is carried to the sampling site and transported to the laboratory for analysis without having been exposed to sampling procedures.

3.2.35 *vadose zone, n*—hydrogeological region extending from the soil surface to the top of the principal water table. Perched ground water may exist within this zone.

3.2.36 *vapor intrusion, n*—the migration of a volatile chemical(s) from subsurface soil or water into an overlying or nearby building.

3.2.37 *volatile organic compound (VOC), n*—organic compounds with boiling points typically ranging from a lower limit between 50 °C and 100 °C, and an upper limit between 240 °C and 260 °C, where the upper limits represent mostly polar compounds.

3.2.38 *water table, n*—the top of the saturated zone in an unconfined aquifer.

3.3 Acronyms and Abbreviations:

3.3.1 *BLS*—Below Land Surface (also known as below ground surface [bgs])

3.3.2 *HDPE*—High density polyethylene tubing

3.3.3 *OD*—Outer Diameter

3.3.4 *PEEK*—Polyetheretherketone

3.3.5 *PTFE*—Polytetrafluoroethylene

3.3.6 *ppbv*—part-per-billion on a volume basis

3.3.7 *PRT*—post-run tubing

3.3.8 *QC*—Quality Control

3.3.9 *SVOC*—Semi-Volatile Organic Compound

3.3.10 *TO*—Toxic Organic

3.3.11 *USEPA*—United States Environmental Protection Agency

3.3.12 *VOC*—Volatile Organic Compound

3.4 Symbols

3.4.1 Variables (typical units)

3.4.1.1 *C* = concentration (ppbv, µg/m³, %)

3.4.1.2 *C_{DL}* = detection limit concentration (µg/m³)

3.4.1.3 *d* = diameter (cm)

3.4.1.4 *L* = length (cm)

3.4.1.5 *M* = mass (µg)

3.4.1.6 *n* = number of data points

3.4.1.7 *Q* = flow rate (cm³/min)

3.4.1.8 *t* = time (min)

3.4.1.9 *V* = volume (cm³)

3.4.1.10 *X_{MW}* = molecular weight of compound *X* (g/mol)

3.4.1.11 *α* = attenuation coefficient or factor (dimensionless)

3.4.1.12 *ΔP* = change in pressure (Pa)

3.4.1.13 *τ* = residence time (min)

3.5 Superscripts

3.5.1 — = mean value

3.6 Subscripts

3.6.1 *i* = pertaining to compound, time, or location *i*

4. Summary of Practice

4.1 This practice describes the active collection of soil gas samples from soil pore spaces in the vadose zone or in fill material directly under building slabs to determine the concentration of volatile organic compounds (VOCs). Three techniques are presented: (1) sampling at discrete depths, (2) sampling over a small screened interval, or (3) sampling using permanent vapor monitoring wells with one or more screened intervals. For sampling at a given depth, options include (i) a short stainless steel probe installed in a small diameter hole drilled through building slab, (ii) disposable drive tips and post-run tubing (PRT), or (iii) installation of sampling points using tubing placed into a borehole and sealed in place with clay or other packing material. Several different combinations of equipment and materials can be used to actively collect soil gas samples, and this practice is intended to allow all methods that typically result in representative and reproducible samples. Other techniques for assessing soil vapor concentrations exist (for example, passive sampling), but are outside the scope of this practice. The design of soil gas sampling programs (for example, the number and location of samples necessary to characterize a site) also is outside the scope of this practice. **Table 1** summarizes the key design aspects for the most common techniques. Examples of various installation approaches are shown in **Fig. 1**.

4.2 *Choice of Technique*—In choosing a technique for collecting and measuring soil gas concentrations, the user should consider the study objectives, site geology, chemicals of interest, target concentrations, type of building and its construction, potential for preferential pathways to be present, potential for long-term or repeat sampling, the comparative capabilities of the techniques, and the complexity of the equipment and procedures.

TABLE 1 Comparison of Installation Options for Soil-Gas Sampling

Topic	Direct-Push Options			Probe or Well with Annular Seal ^A
	Sub-Slab Probe	Drive Point	Screened Interval	
Installation method	Hammer drill and 5 – 15 cm stainless-steel tube	Direct-push rig with sacrificial drive point	Direct-push rig with sacrificial drive point	Hollow-stem auger, direct push with coring
Typical minimum sampling depth BLS (m)	Bottom of slab	1.5	1.5	1.5
Typical length of sampling depth interval (cm)	None ^B	2.5–5	15 –30	Can be customized to any length. Typically at least 15 cm
Type of seal ^C	Clay, cement, wax, PTFE tape	Gasket at bottom of rods. Clay cap at ground surface	Clay layer directly above screened interval	Clay throughout the borehole annulus
Potential for dilution of sample by ambient air ^D	Low	Low	Very low	Very low
Typical purge volume	3 void volumes	3 void volumes	3 void volumes	3 void volumes
Potential for dilution of sample by soil gas from depths other than the sampling depth interval	Low	Moderate	Very low	Very low
Potential for smearing ^E	Very low	Low	Moderate	Low
Potential for plugging between uses	Very low	Moderate	Low	Low
Suitability for multiple uses	Seals may lose integrity over time	Not typically used more than once	Not typically used more than once	Suitable for multiple uses

^AThe type of wells described here have a screened interval that is isolated from the remainder of the monitoring well and connected to the ground surface via small-bore tubing. The use of traditional groundwater monitoring wells for soil-gas monitoring is possible if the screened interval extends up into the vadose zone, but such wells will have a relatively large dead space volume and therefore require purging of relatively large gas volumes.

^BSample is drawn from the preferentially permeable materials beneath the slab. The thickness of permeable materials varies and may not be known for a given site.

^CThe term “clay” here refers to use of applied material such as hydrated bentonite and not native in-situ material.

^DAll sampling options have an equal probability of ambient air dilution due to leaking fittings or tubing in the portion of the sampling train above the ground surface.

^EScreened interval or pipe opening may become plugged during installation due to smearing of soil.

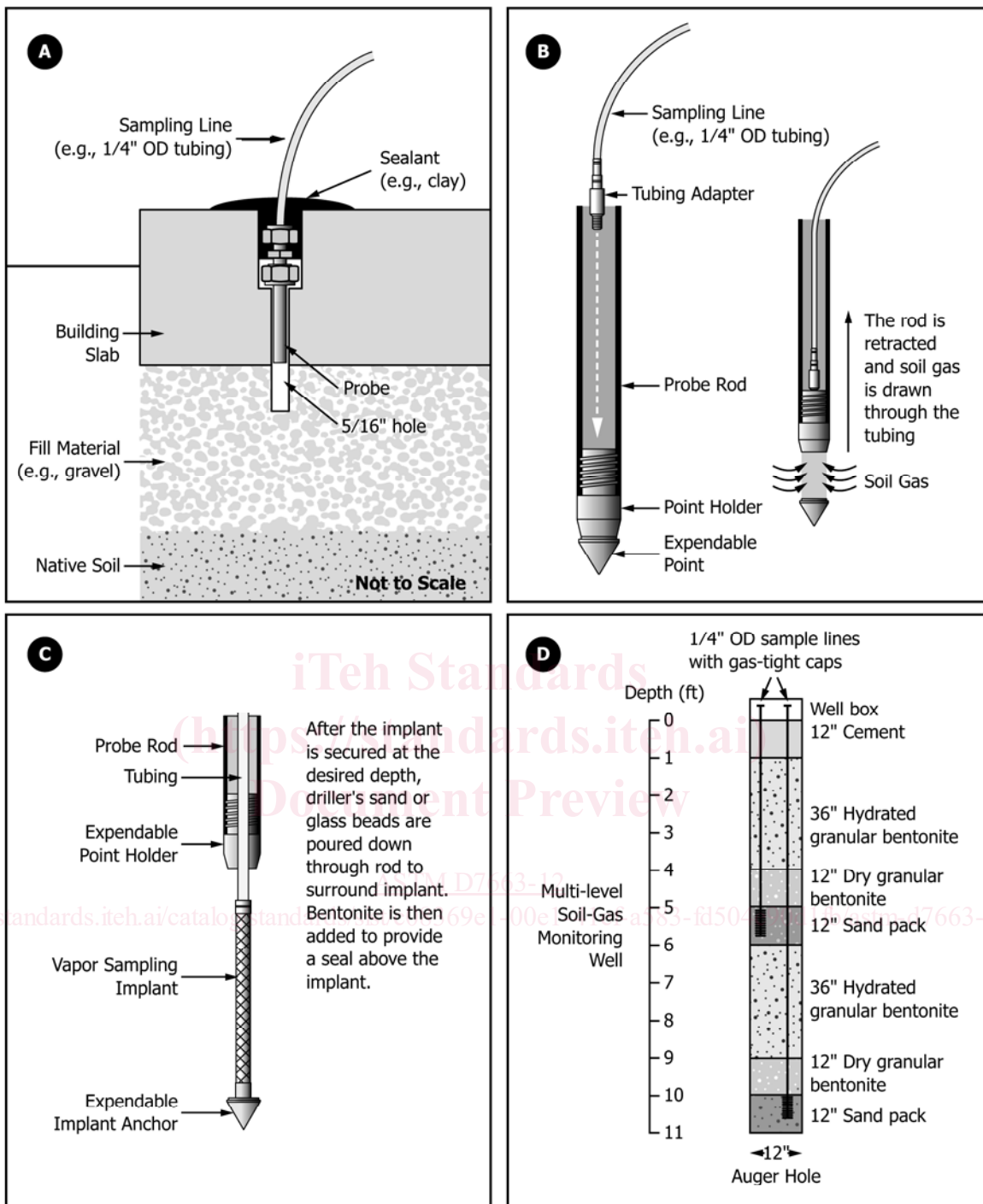


FIG. 1 Illustration of Various Installation Options: A—Sub-Slab Probe, B—Direct-Push Drive Point, C—Direct-Push Screened Interval, and D—Well with Annular Seal

5. Significance and Use

5.1 Soil-gas sampling results can be dependent on numerous factors both within and outside the control of the sampling personnel. Key variables are identified and briefly discussed below. Please see the documents listed in the Bibliography for more detailed information on the effect of various variables.

5.2 Application—The techniques described in this standard practice are suitable for collecting samples for subsequent analysis for VOCs by US EPA Method TO-15, US EPA Method TO-17, Test Method D5466, Practice D6196, or other VOC methods (for example, ISO 16017-1, US EPA Methods TO-3 and TO-12). In general, off-site analysis is employed

when data are needed for input to a human health risk assessment and low- or sub-ppbv analytical sensitivity is required. On-site analysis typically has lesser analytical sensitivity and tends to be employed for screening level studies. The techniques also may prove useful for analytical categories other than VOCs, such as methane, ammonia, mercury, or hydrogen sulfide (See Test Method D5504).

5.3 Limitations:

5.3.1 This method only addresses collection of gas-phase species. Less volatile compounds, such as SVOCs, may be present in the environment both in the gas phase and sorbed onto particulate matter, as well as in liquid phase. In soil gas, the gas-phase fraction is the primary concern. In other potential sampling locations (for example, ambient or indoor air), however, sampling for the particulate phase fraction may also be of interest.

5.3.2 The data produced using this method should be representative of the soil gas concentrations in the geological materials in the immediate vicinity of the sample probe or well at the time of sample collection (that is, they represent a point-in-time and point-in-space measurement). The degree to which these data are representative of any larger areas or different times depends on numerous site-specific factors.

5.4 *Effect of Purging of Dead Space*—If a soil gas probe is to be sampled soon after installation, the gas within the probe and any sand pack will consist mostly of atmospheric air. This air must be purged before soil gas that is representative of the geologic materials can be obtained. If the probe has previously been sampled, it may be possible to collect a representative sample after a smaller volume of gas is purged, but the volume of gas in the probe tubing or pipe must be purged at a minimum. It is recommended that a minimum of three (3) dead volumes be purged from the sampling system immediately prior to sample collection. Larger purge volumes typically are not necessary to achieve stable readings and should be avoided for shallower probes or if the potential exists that the additional purging will affect the partitioning of the VOCs in the subsurface. Larger purge (and sample collection) volumes can result in migration of soil gas from locations some distance from the sampling probe. Preferential pathways within the soil may exist and so the uncertainty associated with the origin of the soil gas will tend to increase with increasing purge (and sample) volumes. The data, however, should still be representative of how VOCs will migrate in these subsurface conditions.

5.5 *Effect of Sampling Rate*—The faster the rate of sampling, the larger the pressure differential (that is, vacuum) that is induced at the point(s) where soil gas enters the sampling system. The relationship between the flow rate and the vacuum is primarily dependent on the gas-permeability of the subsurface materials. This pressure differential has the potential to affect the partitioning of the VOCs in the subsurface if the VOCs exist in two or more phases (for example, free phase, dissolved phase, gas phase, sorbed onto soil particles) at or near the sampling depth (for example, within 1 m of the

sample probe³). Sampling at relatively high rates (for example, >200 mL/min) has the potential to introduce a positive bias to the results (that is, make the results more conservative). The magnitude of any such bias is believed to be at most a factor of two. If the sampling depth is not near the source of the vapors, faster sampling rates (or larger sampling volumes) are not expected to have a significant effect on data quality.

5.6 *Effect of Induced Vacuum*—If desired, the induced vacuum can be limited by some upper bound value (for example, 2500 Pa [10 in. of water column]). The induced vacuum, however, is dependent on variables such as soil moisture as well as length and internal diameter of sampling line that may not be under the control of the user. Most significantly, the use of an upper limit for induced vacuum may preclude the use of preset flow control devices that allow unattended sample collection into evacuated canisters.

5.7 *Effect of System Volume and Length of Tubing*—The system volume should be relatively small to minimize the volume of dead space that must be removed prior to sampling. In practice, this typically means that 0.32 or 0.64-cm ($\frac{1}{8}$ or $\frac{1}{4}$ -in.) OD tubing is used for shallow probes. For deeper probes (for example, ≥ 10 m), larger diameter installations may be preferable to minimize potential for plugging over time. Larger diameter probes and tubing also may be needed for large volume sub-slab sampling. The length of any tubing used in the above-ground sample collection train also should be kept to a minimum. If the ambient air temperature is less than the bulk soil temperature, condensation may form in the above-ground sampling lines and remove polar compounds from the sample stream. The potential is greater if excess tubing is present, so the length of tubing extending from the probe or well to connect to the sampling device should be kept to a meter or less. When the ambient temperature is less than the soil gas temperature, collecting samples at or near the maximum obtainable flow rate for a given location will minimize the potential for condensation.

5.8 *Effect of Connections and Fittings*—The number of connections and fittings also should be kept to a minimum, as these represent potential points for leaks to occur. If possible, all connections should be made above ground and visually inspected. For direct push approaches, this requires that slotted drive caps and pull caps be used, to allow the tubing connection to the PRT adapter or implant to be made above ground prior to probe installation. All fittings shall be leak checked prior to use (See 7.3.1).

5.9 *Effect of Annular Seal*—Soil gas probes installed in an augered or cored hole with a thick slurry of bentonite and water in the borehole annulus above the sand pack have the least risk of atmospheric air leakage down the borehole annulus or cross-communication of soil gas between different intervals

³ Hartman, B., B.A. Schumacher, J. Zimmerman, D.S. Springer, R.J. Elliott, and M.C. Rigby. Results from EPA Funded Research Programs on the Importance of Purge Volume, Sample Volume, Sample Flow Rate and Temporal Variations on Soil Gas Concentrations, *Proceedings of Vapor Intrusion: Learning from the Challenges*, Sponsored by the Air & Waste Management Association (AWMA). Providence, RI. September 26-28, 2007