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Environmental Programs
Engineering & Technology Division

Standard Operating Procedure

for

INSTALLATION OF VADOSE ZONE MONITORING WELLS FOR VAPOR SAMPLING AND MOISTURE MONITORING

APPROVAL SIGNATURES:

Subject Matter Expert:	Organization	Signature	Date
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Responsible Line Manager:	**Organization**	**Signature**	**Date**
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1.0 PURPOSE AND SCOPE

This standard operating procedure (SOP) states the responsibilities and describes the process for installing monitoring wells into the unsaturated zone (vadose zone) for the extraction and sampling of subsurface pore gas and vapor and for monitoring subsurface moisture conditions for the Los Alamos National Laboratory (LANL) Waste and Environmental Services Division (WES). This procedure is applicable for sampling subsurface gas/vapor using EP-ERSS-SOP-5074 “Sampling Subsurface Vapor”. This procedure is applicable for moisture monitoring per EP-ERSS-SOP-5040 “Subsurface Moisture Measuring Using a Neutron Probe”. For the installation of groundwater wells refer to EP-ERSS-SOP-5032. This procedure integrates the criteria of the Quality Assurance Plan for the Environmental Programs, hereinafter referred to as the Quality Assurance Plan.

2.0 BACKGROUND AND PRECAUTIONS

2.1 Background

Vadose zone monitoring wells are installed for a variety of purposes and care should be used in choosing an appropriate well design to meet the data quality objectives of the investigation. For example, wells are often installed as part of an initial investigation to define the nature and extent of contamination and to determine further monitoring or corrective measure needs. Also, a well may be installed for long-term monitoring to meet regulatory requirements. Therefore, multiple well designs are possible and a site specific work plan should outline the specific data needs and vadose zone well design requirements. It is recommended that this procedure be referred to during the development of a site specific work plan. This procedure is applicable to the installation of three classes of vadose zone systems: 1) multiport gas/vapor monitoring wells utilizing stainless-steel tubing; 2) multiport gas/vapor monitoring systems using FLUTe™ membranes; and 3) moisture monitoring boreholes for use with a neutron moisture probe.

2.2 Well Design Criteria

This procedure is used in conjunction with an approved Site-Specific Health and Safety Plan (SSHASP). The following is a list of critical issues that should be addressed in developing the site specific work plan and monitoring well design. This list may not be complete or applicable to all situations.

- Refer to Attachment 1 and 2 (Section 7) for typical well designs and the general specifications for well construction materials.
- Determine data needs – that is, what analytes or parameters (e.g., moisture, VOCs, tritium, natural/introduced gas/vapor phase tracers) will be measured.
- Determine the monitoring requirements:
    - is there a regulatory driver defining the methods and monitoring duration/interval?
    - is the purpose to define nature and extent, characterize the hydrogeology or to test a remediation technology?
    - Will well be used for short-term screening or long-term monitoring
- Select the drilling methods that support the data needs and well design (e.g., hollow stem auger (HSA), sonic, air rotary, or other more appropriate drilling methods). Avoid using drilling mud or fluids near monitoring intervals.

- Determine the well materials compatible with the data needs and monitoring requirements (e.g., casing, tubing, sampling port/screen).
- Determine the desired radius of influence of the monitoring (important for borehole diameter requirements, filter pack dimensions and interval distance between ports).
- Select well completion technique. Will well be cased or open hole? Will sampling system consist of stainless steel tubing and ports or FLUTe membranes?
- Select number of sampling ports and port locations.
- Determine the filter pack composition, grain size, gradation and thickness.
- Determine the filter pack seal composition and thickness.
- Determine the surface casing type, dimensions, seal and protection.

3.0 EQUIPMENT AND TOOLS

This list may not be complete or applicable to all situations.

Drill rig and accompanying equipment	Tape measure, weighted borehole sounding tape, adequate to reach bottom of borehole
Tremie pipe	Fieldbook/logbook
Well materials (e.g., casing, cap, tubing, sample ports)	Calculator
FLUTe™ liners and installation canister	Potable water supply (to hydrate bentonite)
Power for FLUTe™ (line power or solar)	Silica sand (filter pack)
Bentonite (pellets, chips or powder)	

4.0 STEP-BY-STEP PROCESS DESCRIPTION

4.1 Vapor/Gas Monitoring Well Installation – Installing Permanent Stainless Steel Multiport Monitoring

Field Team Leader/ Site Geologist / Driller	1.	Refer to Attachment 1 (Section 7) for a typical well design and the specifications for well construction materials (i.e., tubing and screen type, size and gage, filter pack, borehole seal).
	2.	Attachment 1 requires that sampling system materials arrive from the manufacturer clean and free of contamination. **Alternatively,** all equipment can be decontaminated prior to installation, and rinsate samples shall be collected to document the thoroughness of this decontamination.

Field Team Leader/ Site Geologist / Driller (cont.)	3.	Per requirements of the work plan, install surface casing. This may occur prior to or after advancing the borehole.
	4.	Refer to work plan for sample port locations (depths below ground surface) and the number of ports.
		NOTE: Work plan may require borehole screening/collection of analytical samples using down-hole inflatable packers to determine the final well design and port locations
	5.	Use lengths of tubing as long as practical, in terms of cost and handling in the field, to minimize the number of unions.
	6.	Cut tubing using tubing cutter or saw. Ensure that cut surfaces are at 90 degrees, flat and free of burrs. Ensure that tubing interior is free of cuttings and burrs.
	7.	Connect sample port/screen and tubing lengths with Swagelock® stainless-steel unions or equivalent. Follow the manufacturer instructions for properly seating these unions to prevent leaks.
	8.	If practical, locate tubing unions such that they are not within the filter pack of other sampling intervals.
	9.	Prior to well installation, measure (sound) the total borehole depth and record in log book. Measurements should be accurate to within 0.5 ft.
	10.	Calculate volume of all well construction/backfill materials (e.g., bentonite and sand) to be used for each interval. Base calculation on borehole diameter or caliper log (if available). Caliper logging is recommended for installation into open boreholes.
	11.	Record lot number and collect a sample of each type of well construction/ backfill material.
	12.	Add bentonite (pellets, chips or powder) and hydrate using potable water to the first sampling interval. Note, in some boreholes a cement plug at the bottom may be necessary to provide borehole stability for well construction. Measure (accuracy to within 0.5 ft) and record the depth. Record the volume of bentonite added. • Pour several feet of dry bentonite into the hole, add potable water (use of a tremie is required) to hydrate, wait ~10 minutes, repeat.
	13.	Add dry silica sand (sand pack) to the desired depth of the sampling port (or base of sampling screen). Measure (accuracy to within 0.5 ft) and record the depth. Record the volume of sand added.

Field Team Leader/ Site Geologist / Driller (cont.)	14.	Lower the sample port and tubing to desired depth – measure and record. This depth should correspond to the top of the sand pack in the borehole. Ensure that the length of tubing and depth to sand pack agree to within 0.5 ft. Do not kink tubing during installation.
	15.	Immediately cap the sampling tube with a stainless steel cap. This prevents introduction of sand and bentonite into the tubing.
	16.	Ensure that the sample tubing is labeled near the top, indicating the port number and sampling depth below ground surface. Color-coded tape or brass tags may be used to designate multiple ports in a single borehole.
		NOTE: The tubing should be labeled, not just the cap. The label should include the port number and depth below ground surface with units indicated (m or ft).
	17.	Add additional silica sand to the predetermined depth to the top of the sand pack. Measure and record depth. Record the volume of sand.
		NOTE: Additional intervals of finer silica sand may be added above and below sampling sand pack to minimize migration of hydrated bentonite into sand pack.
	18.	Add bentonite and hydrate to the next sampling interval. Measure and record the depth. Record the volume of bentonite. ▪ **Note:** In situations where long intervals exist between sampling ports, the site-specific work plan **may** allow the use of borehole cuttings or a mix of cuttings and bentonite. The cuttings may require characterization in terms of contaminants prior to use. **If** this is allowed, at least 3.3 ft (1 meter) of hydrated pure bentonite should be used above and below a sampling port to ensure a seal.
	19.	Repeat steps 12-18 until all sample ports are installed.
	20.	Install wellhead cap to secure tubing and label cap with port numbers, complete well pad, surface casing and locking cover as specified in work plan. Install protective posts if required to prevent vehicle damage to well head. Well completion may be flush-mounted or above grade, and may require engineering design.

4.2 Vapor/Gas Monitoring Well Installation – Installing FLUTe™ Multiport Membranes

Field Team Leader/ Site Geologist/ Driller	1.	Refer to Attachment 2 (Section 7) for a typical well design and the FLUTe™ specifications (i.e., tubing type, size; membrane material and thickness; sample spacer material).
	2.	Verify that FLUTe™ membrane construction meets the design specification for the well provided to the manufacturer (e.g., length, diameter, number and location of ports, port spacer dimension, membrane material, tubing material and well head design).

Field Team Leader/ Site Geologist / Driller (cont.)	3.	The ports will be labeled on the wellhead by the manufacturer. Ensure that the port number corresponds to the correct port depth (refer to manufacturer as-built documentation).
	4.	Measure (sound) the borehole depth prior to installation and record (accuracy to within 0.5ft). Ensure the borehole has not sloughed.
		NOTE: **IF** significant sloughing has occurred prior to membrane installation **THEN** membrane modification or borehole cleaning may be required.
	5.	Install the membrane and well head following the manufacturer's instruction (or under the direction of FLUTe™ technicians).
	6.	Install solar panel and battery or utilize line power to run membrane pump.
	7.	Maintain membrane air-pressure to manufacturer's specification to ensure borehole and sampling port seal.

4.3 Moisture Monitoring Well Installation – Choosing Drilling Method and Casing Type

Field Team Leader/ Site Geologist	1.	Consult site specific work plan on the drilling method most appropriate for well type. The following are some considerations: ▪ For moisture monitoring a consistent diameter is ideal, and HSA or sonic drilling methods work best in volcanic tuff or other materials. ▪ **Caution:** If air-rotary methods are used, weak zones such as surge deposits and weakly consolidated zone may blow out creating an irregular borehole diameter. ▪ If air-rotary methods are used, then an in-line filtration and dewatering system must be utilized. ▪ Irregular diameter boreholes, if not identified, will adversely impact the calibration process. **If possible** caliper or video log boreholes prior to use or casing installation. In the case of unstable holes, this will not be possible. ▪ Large diameter boreholes limit the effectiveness of the neutron probe. Boreholes should not be >12 in. in diameter.
	2.	Open holes will work well for moisture monitoring using a neutron probe if the well is sealed at the surface. However, use of an open hole is only feasible in materials that are well indurated and support an open hole. In situations where holes are unstable and/or the risk of losing a probe is unacceptable, casing must be used.
	3.	Aluminum, PVC and steel may be used as access casing/tubing for moisture monitoring wells. Each will impact the calibration differently (see section on probe calibration). The diameter of the casing will depend on the application. ▪ If installing casing down the drill string, use the largest diameter possible to minimize the annular space between the casing and borehole wall. Consult the driller for size limitations. When removing the drill string the annular space may collapse or remain partially open.

Field Team Leader/ Site Geologist (cont.)		• Do not add materials (sand, bentonite, cuttings or cement) into the annular space – these will alter the native moisture conditions and hydraulic conditions around the casing.
	4.	Some applications warrant the use of 2 in. diameter access tubing. Examples include shallow borings using hand-augers or hand operated mechanical auger into soil, fill or bedrock. In this case the tubing is driven into the hole after drilling. An example of this application is installation of monitoring tubes into landfill covers.
	5.	Ensure that a surface seal is installed that prevents precipitation and runoff from entering the borehole. ▪ In the case of an open borehole, install surface casing with a cover. The cover should seal well enough to prevent inhalation and exhalation due to barometric and temperature changes to prevent downhole moisture changes. ▪ Access tubing should have a bentonite surface seal and a sealing cap to prevent any precipitation from entering the borehole annulus and tube.
	6.	A FLUTe™ membrane may also be used to seal and stabilize the hole. Moisture logging can be done by first removing the membrane, or by logging down the center of the inflated membrane using an airlock. Note that the membrane will slightly alter the calibration if it is in place during measurements (see 4.4 step 3).

4.4 Moisture Monitoring Well Installation – Calibration

Field Team Leader/Site Geologist	1.	During drilling, subsurface samples should be collected for laboratory moisture content analysis. The sampling interval should be given in the site-specific work plan. ▪ The interval should adequately represent each geologic unit of interest encountered.
	2.	After the well installation is complete, log the hole on one-foot intervals using a neutron moisture probe, following EP-ERSS-SOP-5040.
	3.	Correlate the counts from the neutron probe to the laboratory-determined moisture content to compute a calibration curve. ▪ Note: Calibration curves for each type of well will be needed – that is, wells with the same diameter and casing type, including a FLUTe membrane if neutron logging will be conducted within the membrane. ▪ Using data from multiple wells of the same construction at a given site will result in more representative calibration curves. ▪ It is recommended that separate calibration curves be computed for geologic units with different composition – e.g., Bandelier Tuff, Puye Formation, Cerros del Rio Basalt.

Field Team Leader/ Site Geologist (cont.)	4.	In the case where an access tube is installed into fill/soil/bedrock and samples cannot be obtained for accurate moisture determination, several options exist. ▪ Use an applicable built-in calibration for the probe. For example a linear calibration is built in for 2 in. aluminum tubing. This will work for most geologic materials, and although it is not site specific, it will provide excellent precision for tracking temporal variations in moisture. ▪ Obtain a calibration from other sites that are using the same access tube configuration.

4.5 Monitoring Well As-built Preparation

Field Team Leader/Site Geologist	1.	Prepare an as-built drawing and report of the monitoring well – refer to Attachment 1 and 2 for example drawings.
	2.	For multiport stainless steel wells, the drawing (see Attachment 1) and report should include at a minimum: ▪ Borehole depth ▪ Borehole diameter ▪ Geology ▪ Port identification (e.g., number and depth) ▪ Tubing inside diameter, type and wall thickness ▪ Tubing union types, number and location for each sample port tube, thread compound material (if applicable) ▪ Port/screen type, dimensions and design including a blow-up inset of the port ▪ Filter pack thickness for each port ▪ Location of port/screen in filter pack ▪ Sand pack type (e.g., #10-20 silica sand) ▪ Bentonite type (composition and form -chips, pellets, powder) ▪ Thickness of bentonite intervals ▪ Surface casing and cap (material, depth and diameter) ▪ Surface casing grout/cement ▪ Subsurface logs (e.g., video, gamma, caliper)
	3.	For FLUTe™ membranes, the drawing (see Attachment 2) and report should include at a minimum: ▪ Borehole depth ▪ Borehole diameter ▪ Geology

Field Team Leader/ Site Geologist (cont.)		▪ Port identification (e.g., number and depth) ▪ Tubing material, inside diameter and wall thickness ▪ Membrane material and thickness ▪ Port spacer material and length ▪ Blow-up inset of port design ▪ Well-head design ▪ Inflation method (e.g., air) ▪ Surface casing and cap (material, depth and diameter) ▪ Surface casing grout/cement ▪ Subsurface logs (e.g., video, gamma, caliper)
	4.	For moisture monitoring wells, the drawing and report should include at a minimum: ▪ Borehole depth ▪ Borehole diameter ▪ Geology ▪ Access tubing/casing type inside diameter and wall thickness ▪ Surface casing and cap (material, depth and diameter) ▪ Surface casing grout/cement ▪ Well-specific neutron probe calibration
4.6 Records Management		
Field Team Leader/ Site Geologist	1.	Maintains and submits records and/or documents generated to the Records Processing Facility according to EP-DIR-SOP-4004, Records Transmittal and Retrieval Process.

5.0 DEFINITIONS

HSA – Hollow Stem Auger

6.0 PROCESS FLOW CHART

N/A

7.0 ATTACHMENTS

Attachment 1: Typical Specifications and Design for Stainless-Steel Multiport Pore-Gas Wells

Attachment 2: Typical Specifications and Design for FLUTe™ Multiport Pore-Gas Wells

8.0 REVISION HISTORY

Revision No. *[Enter current revision number, beginning with Rev.0]*	Effective Date *[DCC inserts effective date for revision]*	Description of Changes *[List specific changes made since the previous revision]*	Type of Change *[Technical (T) or Editorial (E)]*
0	8/18/10	New Document	T/E
1	9/14/10	Replaced Attachment 1	T

ATTACHMENT 1	
EP-DIR-SOP-10001-1 TYPICAL SPECIFICATIONS AND DESIGN FOR STAINLESS-STEEL MULTIPORT PORE-GAS WELLS	Records Use only Los Alamos NATIONAL LABORATORY EST. 1943

All materials must be new and free of contamination. Organic based lubricants must not be used during construction or installation.

Tubing: Grade T316 seamless stainless steel; 0.25 in. O.D; ≥0.028 in. wall thickness; chemically cleaned and passivated (e.g., ASTM G93 Level A requirement for nonvolatile residue). The maximum available lengths may be manufacturer specific.

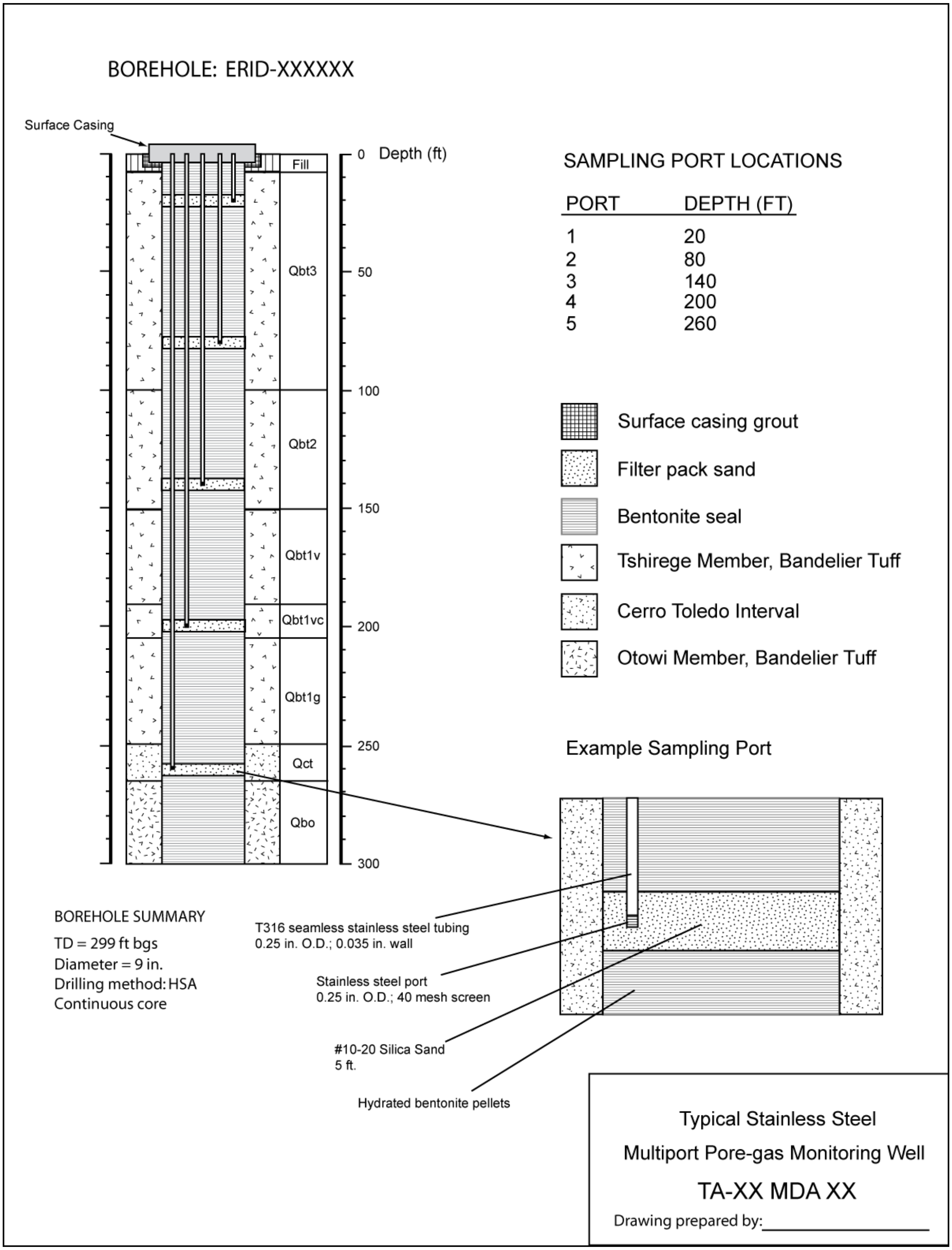
Unions and caps: Swagelock® stainless steel unions and caps for 0.25 in. O.D. tubing; clean and oil free (e.g., ASTM G93 Level C).

Sample port/screen: The port/screen shall be T316 stainless steel and compatible with the gradation of the sand pack. (See below.) For example: 0.25 in. O.D. Swagelock® Mud Dauber vent protector with 40 mesh (0.420 mm) screen.

Filter pack (sand pack): Use well-sorted (poorly graded) and rounded sand that is clean, inert, and siliceous and compatible with the screen slot size in-use (e.g., has a larger diameter than the screen slot size). Use sand that has a gradation that will allow less than 10% of filter-pack material to pass through the screen slots. For example: #10-20 sand is compatible with a maximum 0.030 in. (0.760 mm) screen slot.

Bentonite Seal: Use bentonite chips, bentonite pellets, or crushed, granular bentonite. The pellets should have a minimum purity of 90% montmorillonite and a minimum dry bulk density of 75 lb/ft^3

ATTACHMENT 1 (CONT.)



ATTACHMENT 2	
EP-DIR-SOP-10001-2 TYPICAL SPECIFICATIONS AND DESIGN FOR FLUTE™ MULTIPORT PORE-GAS WELLS	Records Use only Los Alamos NATIONAL LABORATORY EST. 1943

All materials must be new and free of contamination. Organic based lubricants must not be used during construction or installation.

FLUTe™ membrane construction: Liners are manufactured to the length of the hole and the diameter plus one-half inch. Liners have been made over 18 inches in diameter at a significant extra charge. A minimum diameter is about 3 inches.

FLUTe™ membrane material: Urethane coated nylon fabric. Air driven systems are generally of either 210 denier or 400 denier liners. 400 denier liners are recommended for sand filled systems or liners lowered into the hole or casing.

Sample spacer construction: Spacers surround the circumference of the membrane at the desired sampling depth. The length of the spacer can be variable and is generally 12 inches.

Sample spacer material: A filter fabric of polyester, LDPE (low density polyethylene) mesh, and an inner layer of a diffusion barrier of a foil/poly laminate.

Sample tubing: The tubing can be either nylon or polyvinyl-dene fluoride (PVDF). PVDF is a Teflon like material with very low absorption recommended for sampling VOCs. Nylon is appropriate for sampling tritium or non-sorbing gases/vapor (e.g, CO_2). Sampling tubing is 0.25 in. O.D. by 0.177 in. I.D., unless otherwise specified.

Wellhead: The wellhead can be customized to the borehole surface completion configuration. Generally, the wellhead is constructed of schedule 40 PVC and designed to slip over the borehole surface casing. The sample tubing and sampling ports are fixed to the wellhead and labeled.

Liner inflation method: Liners can be inflated/sealed with either air or sand. However, it is strongly recommended that only air-inflated liners be used for pore gas monitoring wells. Air filled liners require a small air pump at the surface.

Power: Air filled liners require a small air pump at the surface. This can be powered by line power or a solar system. Multiple monitoring wells proximal to one another may be powered by one solar system.

ATTACHMENT 2 (CONT.)