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SEAMISTTM

INNOVATIVE TECHNOLOGY SUMMARY REPORT

demonstrated at

**U.S. Department of Energy Sites:
LLNL, LANL, SRS, SNL, Hanford, ORNL,
WIPP other Federal and Commercial Sites**

prepared for

U.S. Department of Energy
Office of Environmental Management
Office of Technology Development

August 1995

U.S. Department of Energy

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SECTION 1

SUMMARY

Technology Description

SEAMIST has been demonstrated and deployed as an innovative tool to better access the subsurface for characterization and monitoring of contaminants in both vertical and horizontal boreholes. The technology has been developed by industry with assistance from DOE's Office of Technology Development to ensure it meets the needs of the environmental restoration market.

SEAMIST:

- consists of an airtight membrane liner pneumatically and/or hydraulically emplaced inside a borehole, simultaneously maintaining the integrity of the borehole and permitting collection of contaminant samples from the subsurface at discrete depth intervals;
 - is simple in concept and relatively inexpensive to use; yet, it provides quality samples of subsurface chemistry and hydrogeology;
 - lines the borehole temporarily or permanently, preventing the borehole from collapsing, limiting movement of air into the subsurface, and preventing fluid flow into and within the borehole (limits vertical mixing);
 - acts as a downhole support platform for sampling devices and instrumentation: sampling can be accomplished using sampling ports with attached tubes running back to the surface, using absorbent collectors, or in situ measurement devices; instrumentation can be towed through the borehole while making measurements (e.g. a neutron logging tool can be used to measure soil moisture content);
- can be used in horizontal, vertical, enlarged, constricted, and curved holes;
- has been demonstrated both above and below the water table;
- is emplaced into a borehole using a pneumatic pressure/canister system containing the membrane liner attached to a tether; the liner is installed by progressive eversion; positive pressure is supplied to maintain the integrity of the borehole using either air, sand, water, or grout;
- can be retrieved by simply reversing the reel direction and maintaining constant pressure inside the canister;
- can be used for decontamination of ducting using stripcoat saturated duct liner materials and as a support platform for certain robotic applications (see Appendix B);
- liner can be made of a wide variety of impermeable materials, including plastic tubular films and laminates; and
- has significant advantages over baseline technologies that it competes with in some instances and in other instances there is no known competitive technology.

SEAMIST liners:

- cost less than \$1000 for several-hundred-foot lengths;
- can be most cost-effective when requirements call for more than one characterization technology to be used within a single borehole; and
- can be greater than three times more cost-effective than conventional lysimeters when attempting to collect pore fluid samples from the unsaturated zone.

Figure 1: Components of the SEAMIST system.

Technology Status

- SEA and Eastman Cherrington Environmental teamed with the Department of Energy to advance the application of this technology, called SEAMIST, to the environmental market. The joint industry-government partnership mission was to develop and demonstrate new applications of the SEAMIST technology so that it could be applied cost-effectively to solve environmental restoration problems.
- Field demonstrations of SEAMIST have been conducted at Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratory (SNL), Los Alamos National Laboratory (LANL), Savannah River Site (SRS), Hanford, Oak Ridge National Laboratory (ORNL), the Waste Isolation Pilot Project (WIPP), several federal [Department of Defense (DOD) and Department of Agriculture (DOA)] and industrial sites.
- SEAMIST won an R&D 100 award in 1994.
- The following applications summarize how and where SEAMIST has been demonstrated and deployed in the field:
 - vapor and liquid sampling for radioactive materials at LLNL and ORNL in vertical boreholes and at LANL in both vertical and horizontal boreholes;
 - vapor sampling for VOCs in Tucson, with permeability measurements at SNL, with permeability and vapor pressure measurements at SRS and Sacramento, and for petroleum hydrocarbons in Seattle;
 - vapor and liquid sampling and permeability measurements in horizontal boreholes at LANL and SNL;
 - vapor sampling for VOCs in cased boreholes at Hanford (membrane used to pack off sections);
 - emplacement of monitoring instruments at LANL and LLNL and DOA sites in Nebraska;
 - design for monitoring vapors under a new mixed waste landfill at LANL;
 - monitoring (sampling and pressure measurements) during remediation (bioremediation, air sparging, and thermal enhanced SVE) at SRS and SNL;
 - transport of logging tools and cameras in horizontal and vertical boreholes at SNL and in horizontal boreholes at LANL;
 - inner liner for PVC well casings during steam injection at LLNL;
 - ground water flow sampling to map fractures and flow rates at WIPP;
 - vapor and liquid sampling ports both above and below the water table at March AFB in California;
 - application of strip coat to ducting interiors to immobilize radioactive dust at LANL.
- **Key results:**
 - Several different applications of the technology to solve environmental management problems;
 - Relatively widespread use of the technology considering its stage of development.
- The original patent was developed by Science and Engineering Associates (SEA). The technology is commercially available from Eastman Cherrington Environmental (ECE). ECE purchased the patent and trademark for SEAMIST from SEA (Patent No. 5176207). ECE owns all commercial applications covered by the patent plus all underground installations at government facilities.

Contacts**Technical**

Numerous technical contacts exist at many DOE sites. See Appendix A for table describing applications in more detail.

Carl Keller, Eastman Cherrington Environmental, (505) 983-3199.
Bill Lowry, Science Engineering Associates, (505) 983-6698.

Management

Jim Wright, DOE Plumes Focus Area Manager, (803) 725-5608.

Patent/Licensing Information

Carl Keller, Eastman Cherrington Environmental, (505) 983-3199.

SECTION 2

TECHNOLOGY DESCRIPTION

Technology Schematic

Figure 2: SEAMIST system deployment sequence.

- SEAMIST consists of the hole liner composed of a tubular fabric called an impermeable membrane, a tether that gathers the bottom of the membrane and extends up the center of the hole to a reel, in a canister, at the surface.
- The impermeable membrane lines the drillhole, is pressed against the hole wall by a modest internal pressure (1-3 psi), and can carry instruments into the hole (e.g., thermocouples, absorbent pads, fiber optic sensors, tubings, electrodes, etc).
- Larger instruments that can "see" through the membrane can be carried into the hole on the tether (e.g. gamma logs, neutron logs, resistance logs, TV cameras, etc.).
- The impermeable membrane is emplaced down the hole by eversion at speeds of approximately 20 to 50 feet/minute. If the system is later removed from the subsurface, the membrane is wound onto the reel by inversion. Thus, there is no cross contamination of absorbent pads or sensors as the membrane is removed.
- The interior of the membrane is isolated from the exterior, except where ports and tubing allow access to the geologic medium.
- Numerous materials have been used as liners. Urethane-coated polyester has been most versatile. HDPE, vinyl-coated polyester and nylon, and fluoropolymer have been used as membranes.
- Liner materials should be selected on the basis of cost, durability, fabrication ease, impermeability, and chemical compatibility.
- SEAMIST can be used in open and cased boreholes.
- For long-term installations, the lined borehole can be filled with air, water, sand, or grout. Filling the borehole with water and sand can be viewed as a temporary situation where the water or sand can later be removed. Because the membrane system supports the borehole wall, casing and backfill is not required. Because the hole filling material is located inside the liner, there is no contamination of the geologic medium with hole-filling material (as there is when grouting wells).

System Configuration and Operation

- A variety of applications for the technology are described in this section.

Figure 3: Absorbent pad emplacement design.

- Absorbent pads can be affixed to the outside of the impermeable liner to be used as collectors for unsaturated zone vapors and fluids at discrete depths. As the membrane everts, it is pressed against the hole wall in a specific location. Wall pore fluids are wicked into the pad, if the capillary tension in the absorber is greater than that of the geologic medium. The fluid absorbed is only that of the unique wall position contacted. Upon removal of the impermeable liner, the absorbent pads are rolled inside, thus are completely protected from any contact with the hole wall or with other pads.
- The absorbent collector system requires removal of the liner so that the pads can be analyzed for concentrations of various contaminants or amount of water present.
- Absorbent material can completely cover the SEAMIST liner from top to bottom of the borehole. A continuous map of the subsurface at that location can then be obtained.
- Absorbent material need not be in contact with the pore liquid because some pore liquid can be absorbed from the vapor phase.
- Electrical resistance measurements inside the pads indicate moisture uptake.
- Absorbent collector materials tested include Waterlock G405 and D212, Debrisan, polypropylene, surgipad, filter paper Whatman #42, cotton cosmetic pads, cellulose sponge, polyester and silica flour.

Figure 4: Pore gas port sampling system.

- Flexible gas or liquid sampling tubes are connected to the interior of the impermeable membrane. The subsurface is accessed at a particular depth through a port that penetrates the membrane. The tubes run from the port opening to the ground surface, where samples can be extracted for field or laboratory analysis or sensors can be emplaced down the tubes.
- Gas samples from a particular depth are removed by drawing a partial vacuum on the sampling tube. Gas from the pore space at that depth is withdrawn while the pore pressure is lowered. This pulls the membrane more tightly against the borehole wall, ensuring a good seal between port locations.
- The amount of gas removed is proportional to the volume of the subsurface being sampled.
- The gas sample can be collected at the surface or a carbon filter can be emplaced over the port. Use of a filter removes the uncertainty of adsorbing contaminants in the plastic tubing but requires removal of the liner to do the analysis (similar to the absorbent pad application).
- Permeability measurements can be made with minor modification of the port design (see Appendix B).

Figure 5: Towing of logging tools.

- If a logging sonde is directly attached to the membrane, it can be transported down the hole as the liner is installed. As the membrane is emplaced, using air pressure above the water table or water pressure below the water table, the logging tool moves within the lined hole.
- The ability to tow the sonde is especially helpful in horizontal boreholes or in crooked vertical holes.
- Cameras can be used in association with clear liners.
- Benefits include less probability of loss of equipment downhole because the instrumentation is installed within a supported borehole.
- SEAMIST can be used below the water table. The membrane is emplaced with water for this application. Pore fluid is drawn from the annulus outside the membrane, through the port to the surface via a pump lowered on a tether. Multiple horizons can be sampled. The purge volume is the tubing volume only.
- Pressure transducers can be attached at each port to monitor the head.
- **Operational Requirements**
- SEAMIST can be emplaced rapidly by one technician. Membrane insertion can proceed as quickly as 20 to 50 ft/min.

SECTION 3

PERFORMANCE

Demonstration Overview

Many applications of SEAMIST have been tested in the field. Each demonstration or application is further described in Appendix A.

Emplacement Performance

- Tests have been performed on the membranes for strength, weld quality, borehole seal quality, eversion/inversion ability, and chemical compatibility. The quality of the seal is so site-specific it cannot be generalized. Experience to date has been good, however.
- If rough walls are expected, a transparent membrane can first be used with a TV camera to determine the quality of the seal. Different types of membrane materials have been tested to better seal rough walls. For example, the membrane may be covered with soft foam (open or closed cell) or the material may be felted.
- Tracer gas tests and flow measurements are conducted to determine if the seal is satisfactory.

Sampling Performance

- Sampling can be accomplished using ports with tubing or with absorbent pads.
- When using absorbent pads, liquid is easily absorbed from a soil of high saturation (low tension) and vapor is more easily absorbed from a soil of low saturation (dry media). Absorbers have been shown to collect moisture from soils with capillary tensions much greater than one bar, well beyond the operating limit of suction lysimeters and tensiometers.
- Dan Stephens and Associates have completed tests on a variety of absorbent materials (10) to wick fluids.
 - Factors examined include amount of liquid absorbed under various matric potentials, rate of absorption and degree of sample dilution caused by hygroscopic uptake of water vapor.
 - Highly absorbing compounds such as Waterlock and Debrisan retained most water (1.69 - 7.4 at 1 -15.7 bars matric potential)
 - Moisture analysis uptake rates for absorbent pads (using laboratory samples) ranged from 2.5 to 31.2 hrs; field rates depend upon matric potential and unsaturated hydraulic conductivity of soil (generally slower than laboratory tests).
- Tests have been conducted to determine tubing collapse thresholds as a function of temperature, tubing size, and material while pulling gas at a partial vacuum.

Monitoring/Characterization Performance

- Physical sensors [pressure (on surface and downhole), temperature (2 types), and hydrologic matric potential (3 devices)] and four chemical sensors [(adsorbent resistive sensors, gore-sorbers (absorbent charcoal), colorimetric indicator-tubes and litmus paper)] were successfully emplaced and monitored at two elevations at the Chemical Waste Landfill at SNL.
- At LLNL fluid samples removed using tubing ports showed the same activity of tritium as absorbent pad samples and both were similar to data obtained from pore water extracted from cores. When sampling for VOCs, tubing port data contained about 70% of that determined from in situ samples. Also, moisture content data were equivalent (log vs samples).
- Downhole characterization technologies demonstrated via SEAMIST include x-ray spectrometry (radionuclides), x-ray fluorescence (metals), neutron activation (metals, neutron logging (moisture), and cross hole em and seismic tomography.
- A comparison of SEAMIST to Geoprobe for soil vapor measurements showed similar results.
- Performance of SEAMIST sensor systems is limited by the sensors available and their maturity.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Technology Applicability

- The optimum application of SEAMIST technology will be at sites where:
 - 1) multiple characterization technologies are needed and can be implemented using the SEAMIST platform;
 - 2) contamination is relatively deep (greater than 50 ft) and boreholes can be maintained open long enough for emplacement;
 - 3) there is a need for depth-discrete measurements either for initial site characterization or monitoring, especially that required during remediation.

Alternative Technologies

- Alternative technologies include multiple driven well points and gas-sampling probes for shallow applications, multiple monitoring wells for deeper applications, the Westbay sampling system or equivalent, lysimeters, and soil coring and analysis.
- No one alternative technology has the capability to provide all features of the SEAMIST system.
- For many applications there is no technology that duplicates SEAMIST capabilities.
- To obtain multiple depth-discrete liquid or vapor samples, most alternative technologies require multiple boreholes, which of course, add significantly to the cost.
 - Competitive technologies, such as driven well-points and driven gas-sampling probes, will always be more cost-effective. However, they have practical limitations of very shallow depths. SEAMIST becomes more cost-effective as the depth of investigation increases beyond that where driven installation systems can be used. At depths greater than 50 feet or at shallower depths in hard or rocky media, SEAMIST becomes very cost competitive.
 - SEAMIST can be compared with the Westbay multipoint sampling system. Costs for installation of SEAMIST are much less than those for the Westbay system.
- Comparison of SEAMIST to straddle packers shows that SEAMIST provides a more continuous seal over a range of depths. The probability of a leak is thus reduced.
- When the performance of SEAMIST is compared to a grouted annulus, the quality of the grout job is critical. SEAMIST measurement ports can be used in conjunction with a grout seal to detect leaks.
- SEAMIST's major advantage when comparing it to the competition is that one borehole can provide samples at multiple discrete depths at a relatively low cost. If sampling ten discrete depth locations is desirable, only one SEAMIST borehole is required, whereas driving of ten well points would be required.

SECTION 5

COST

Introduction

Information in this section was prepared from data provided by many DOE sites that have successfully used the technology as well as from the technology vendor Eastman Cherrington to the Los Alamos National Laboratory (LANL), tasked to perform technology cost analysis as an independent team for the DOE Office of Environmental Management Office of Technology Development (EM-50).

- The LANL cost analysis was not meant to be an exhaustive review of all applications of the SEAMIST system, but a selection of five representative comparisons that provide a good review of the strengths and concerns of the technology.
- To fairly evaluate the innovative technology, baselines were examined in the most advantageous light as possible. The lowest cost values for baseline technologies were used if a range of costs was provided.

Cost Comparison

- Because SEAMIST is a very versatile system for characterization and monitoring of the subsurface, the cost comparison section looks at five different scenarios. Many other applications of the technology are possible and have been tested.
- Some applications of SEAMIST do not have a baseline technology for comparison. These applications were not considered for this analysis.
- The cost of a system is very sensitive to material requirements. For example, a gas permeability system does not require Teflon tubing whereas a vapor-sampling system often does.
- The scenarios examined attempt to look at monitoring for a broad range of contaminants from VOCs to radioactive contaminants (such as tritium) in a broad range of sample types (such as pore gas and pore fluids).
- **Scenario 1** is a system designed to obtain VOC samples from twelve 100-ft-deep vadose zone boreholes, monitored monthly for one year.
 - The SEAMIST system consists of ten equally spaced sampling ports connected to Teflon tubes that terminate at an external sampling array, for each borehole.
 - The SEAMIST membrane is installed and packed with sand to be left in place for the 12-month monitoring period. Samples are collected monthly.
 - The baseline system uses PVC casing with 10 ports connected to 10 PVC tubes, grouted in place at specific depths, and terminating to a ground-level sampling array, for each borehole.

Table 1: Vapor sampling for VOCs in 12 vertical boreholes

SEAMIST	Cost (\$)	BASELINE	Cost (\$)
Materials & supplies		Materials & supplies	
Membrane	12,600	PVC casing	4,850
Teflon tubing	6,600	Bentonite/seals	2,600
Ports	1,080	Port assemblies	390
Basepipe		PVC tubing	9,600
assembly with tether	1,800	Sand packing	1,360
Sand	60	Well vaults	9,600
Manufacturing labor technician	3,020	Sampling array w/valves	6,000
Indirect costs		Installation & set-up	
Manufacturing overhead		Drill boreholes incl.	
and G & A	6,290	mobilize/demobilize	18,000
Installation and set-up		Labor to construct	65,300
Drill boreholes incl.			
mobilize/demobilize	18,000		
Labor to install	2,400		
Equipment rental			
(air pump, etc.)	150		
Total costs	52,000	Total costs	117,700

- **Scenario 2** obtains VOC samples under a shallow (<25 ft) contaminant plume (200 ft wide by 500 ft long) in the vadose zone. Samples are collected monthly.
 - The SEAMIST system is installed within four 500-ft horizontal boreholes 25 ft below ground. Each liner has ten ports.
 - The baseline system uses 40 soil vapor probes implanted at a 25 ft depth. Probes are implanted with a commercially available vapor probe system.
 - It is assumed that the soil is stable and can withstand drilling of a horizontal borehole into which the membrane can then be emplaced.
 - If the measurements were to be made under a surface structure, the baseline system would not be possible. The soil vapor probe system would then be used in a horizontal borehole and costs would be equivalent to those of the SEAMIST system. The cost of the SEAMIST system is highly dependent upon horizontal drilling costs, which are decreasing rapidly as the technology becomes more commonly used.

Table 2: Vapor sampling for VOCs in horizontal vs vertical boreholes

SEAMIST	Cost (\$)	BASELINE	Cost (\$)
Materials & supplies		Materials & Supplies	
Membrane	25,200	Vapor probe system	
Teflon tubing	13,000	Punch system	
Ports	360	w/shaft sections	16,900
Basepipe		Gas connector	20
assembly with tether	600	Vapor probes and anchors	360
Manufacturing labor technician	1,000	Teflon tubing	3,600
Indirect costs		Packing sand	30
Manufacturing		Surface cap assemblies	480
overhead and G & A	10,040	Bentonite	30
Installation and set-up		Installation & set-up	
Drill boreholes		Labor to install and setup	6,400
mobilize/demobilize	117,800		
Labor to install	1,600		
Equipment rental			
(air pump, etc.)	3,360		
Total costs	172,960	Total costs	27,820

- **Scenario 3** obtains samples of nonvolatile contaminants from pore fluids in the vadose zone. The site is contaminated with SVOCs, PCBs, pesticides, and/or PAHs. Samples are collected monthly.
 - SEAMIST employs 12 100-ft vertical boreholes with ten equally spaced absorbent wicking pads. The liner is removed monthly, outfitted with fresh absorbent collectors, and emplaced.
 - Baseline has 12 vertical lysimeter stacks. Each stack consists of 10 equally spaced pressure-vacuum lysimeters.
 - Baseline requires that the soil matrix will allow vacuum pressures required for collecting fluid samples.

Table 3: Pore-fluid sampling for non-volatile contaminants

SEAMIST	Cost (\$)	BASELINE	Cost (\$)
Materials & supplies		Materials & supplies	
Membrane	12,600	Lysimeters	35,400
Absorber assemblies and pads	3,600	Bentonite/seals	1,450
Basepipe assembly with tether	1,200	Teflon tubing	43,200
Manufacturing labor		Clamps	170
Engineer	530	Sampling array with valves	6,000
Technician	340	Well vaults	9,600
Indirect costs		Vacuum equipment with battery (x10)	5,750
Manufacturing overhead and G & A	4,600	Installation & set-up	
Installation and set-up		Labor to install and set up	6,400
Drill boreholes mobilize/demobilize	18,000	Sampling	
Labor to install	1,600	Mobilize/demobilize (2 technicians)	14,520
Equipment rental (air pump, etc.)	3,360	Sampling lysimeters	106,560
Sampling			
Windscreen	2,000		
Labor	23,000		
Materials	12,960		
Total costs	83,790	Total costs	272,200

- **Scenario 4** involves taking soil moisture measurements under a low-level radioactive land disposal pit using four stable 250-ft blind horizontal boreholes.
 - The SEAMIST case has liners emplaced in each of the boreholes so that a neutron logging tool can be pulled through the borehole under the pit.
 - The baseline uses aluminum casing through which the logging tool is pulled in each of the boreholes.
 - The SEAMIST advantage includes the potential use of wicking pads to collect samples of pore fluids, whereas the aluminum casing may provide a better platform for later remediation.

Table 4: Soil moisture measurements underneath a low-level radioactive land disposal pit

SEAMIST	Cost (\$)	BASELINE	Cost (\$)
Materials & supplies		Materials & supplies	
Membrane	480	Aluminum casing	18,240
Basepipe assembly		Neutron logging tool	4,300
with cable attachment	100	Cable 350-ft	
Neutron logging tool	4,300	with marking and collar	1,380
Cable 350-ft		Laptop computer	
with markings	1,300	with accessories	4,230
Laptop computer		Installation & Set-up	
with accessories	4,230	Drill cont. borehole incl.	
Indirect costs		mobilize/demobilize	109,000
Manufacturing		Labor to obtain	
overhead and G & A	150	measurements	9,600
Installation and set-up			
Drill boreholes			
mobilize/demobilize	102,650		
Labor to obtain			
measurements	9,600		
Equipment rental			
(air pump, etc.)	50		
Membrane disposal	1,040		
Total costs	123,900	Total costs	147,250

- **Scenario 5** involves the integration of scenarios 1 and 3: vapor and pore fluid sampling. This type of application demonstrates the cost-effectiveness and versatility of SEAMIST. The SEAMIST system can do both functions within the same borehole at a cost of \$98,690. The baseline would require two separate systems requiring the cost as presented in Tables 1 and 3 for a total of \$389,900.

Cost Summary

- When contamination is deep, SEAMIST is 56% more cost-effective than using ports in casing.
- SEAMIST used with absorbent pads has been shown to be three times more cost-effective than conventional lysimeters.
- If SEAMIST substitutes for conventional casing, up to 90% of the costs can be saved if more than one characterization/monitoring technology is required.
- Costs for the SEAMIST liner material range from <\$10/ft to \$100/ft.
- Costs of the canister air pump range from \$2000 to 5000.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

- No special permits are required to install SEAMIST systems. Regulatory approval is generally required to drill boreholes in the subsurface. Information on the SEAMIST system should be submitted to the proper regulatory agencies when the drilling request is submitted.
- No additional NEPA review is required over that already completed for drilling of the boreholes.

Regulatory Advantage

- The SEAMIST technology may be viewed as better by the regulators because fewer boreholes are required.

Safety, Risks, Benefits, and Community Reaction

Worker Safety

- Health and safety issues for the installation of SEAMIST are essentially equivalent to those for the conventional drilling technology used at a particular site. There are no additional requirements or issues.

Community Safety

- SEAMIST does not cause the routine release of contaminants.
- No unusual safety concerns are associated with SEAMIST emplacement or operation activities.

Environmental Impacts

- Environmental impacts are minimal. The SEAMIST system covers the wellhead and takes up relatively little space. The major benefit is that it reduces the number of wells required.

Socioeconomic Impacts and Community Perception

- SEAMIST has a minimal economic or labor-force impact.
- The general public has limited familiarity with SEAMIST.

SECTION 7

LESSONS LEARNED

■ Implementation Considerations

- Design the system to meet your site-specific needs. This can help keep costs low.
- The number and kinds of characterization and monitoring technologies required at a particular site will control the selection of the SEAMIST technology as a platform.

■ Technology Limitations/Needs for Future Development

- Currently the major limitation is that the borehole must remain open long enough for the system to be emplaced. SEAMIST cannot be used at some sites. The liner does not seal well in horizons that contain large cobbles. Future development should focus on an emplacement-while-drilling system.
- There is no real limitation to the size of the borehole in which SEAMIST is to be emplaced.
 - SEAMIST has been installed in a hole as small as that produced by a cone penetrometer to a depth of 80 ft. SEAMIST can be installed in cone-penetrometer holes after the drill string is removed only if the borehole does not collapse.
 - SEAMIST has also been installed in holes as small as 1 in. and as large as 24 in. diam.
- Absorbent collectors applied to measure capillary tensions are plagued by the question of how long until equilibrium is reached. Electrical monitoring can assist with improving our knowledge of what is happening in the subsurface.
- Absorbent collectors can be used to obtain fluid samples in reasonable volumes and times from many, but not all, soils. They are not generally appropriate below the water table because borehole fluids become mixed as the liner is emplaced. However, application of the technology at sites with extremely low permeability units to monitor water flow, such as at WIPP, is appropriate.

■ Technology Selection Considerations

- The application of SEAMIST as a platform to transport logging tools, especially those that contain radioactive materials, in horizontal or rough vertical boreholes assures much greater likelihood of a successful run without loss of logging equipment.
- A system has been designed to monitor pore fluids below landfills (either old or new). In addition to its monitoring role, it can be used to remedy small leaks by a variety of methods (heat can be applied to evaporate the leachate or it can be frozen). SEAMIST can be combined with thermal or cryogenic remediation systems.
- It is less expensive to remove the SEAMIST liner and grout the borehole than it would be to drill out the casing in a hole and then grout.
- SEAMIST can be used to emplace electrodes for geophysical tomography measurements.
- SEAMIST tubing ports could be used to inject fluids into specific horizons in the subsurface. Applications where this might be desired include injection of tracers or nutrients to stimulate microorganisms to degrade contaminants in place.
- SEAMIST is relatively inexpensive, reliable, and easy to install. It allows access to multiple sampling points in a single borehole.
- SEAMIST is being used for other applications such as decontamination of ducting in aboveground facilities, subsurface permeability measurements, and a progressive borehole packer system (Appendix B).

APPENDIX A

SUMMARY OF SEAMIST APPLICATIONS

Summary of SEAMIST™ Field Applications					
APPLICATION	DESCRIPTION	CLIENT	SITE	PERIOD OF USE	CONTACT
Tritium plume monitoring	Two systems installed at Lawrence Livermore National Laboratory, CA are continuing to track the movement and concentrations of a tritiated water plume (both vapor and liquid water sampling to 40 ft).	Lawrence Livermore National Laboratory	Lawrence Livermore National Laboratory	May 1991-Present	Barbara Mallon Lawrence Livermore National Laboratory
Carbon tetrachloride monitoring	Two emplacement systems with disposable membrane liners are in use at Hanford, WA. in a carbon tetrachloride plume monitoring program. The membranes pack off the cased borehole while sample tubing to the bottom draws the vapor sample.	Westinghouse	Hanford	Feb. 1992-Present	Virginia Rohay WHC
Fracture flow mapping and rate measurement	SEAMIST membranes coated with liquid indicating and wicking layers mapped and measured brine flows (grams per day) underground at Waste Isolation Pilot Project, NM.	Sandia National Laboratory	WIPP	January 1992	Lee Jenson Sandia National Laboratory
Tritium and VOC sampling	SEAMIST system transported vapor sampling tubes and absorbent collectors 230 ft horizontally beneath an old radwaste landfill at Los Alamos.	Los Alamos National Laboratory	Los Alamos National Laboratory	April 1992	Steve McLin Los Alamos National Laboratory
Sandia National Laboratory - Integrated demonstrations	<ul style="list-style-type: none"> • Demonstrated capability to transport logging tools and cameras in horizontal boreholes up to 230 ft long, 1.75 to 4 in. diam. • Performed gas sampling and permeability measurements in two 11.5 in., 110 ft deep boreholes immediately after auguring in the Chemical Waste Landfill. • Installed three 110 ft borehole liners to support holes during logging. 	Sandia National Laboratory	Sandia National Laboratory	Spring through Fall 1992	John Stormont Sandia National Laboratory
Vapor sampling/permeability measurements	Three membranes were instrumented and installed at the Savannah River Site in July 1992 for soil vapor, vapor pressure, and permeability measurements in the remediation demonstration project. Maximum depth is 130 ft with ten sampling elevations per membrane.	Westinghouse	Savannah River Site	July 1992 (Continuing for up to 2 years)	Carol Eddy Westinghouse Savannah River Company
Neutron logging tool transport	SEAMIST membrane was used to tow a neutron moisture logging tool in horizontal boreholes underneath radwaste landfill in Los Alamos. Typically, four holes (200-250 ft long) were logged in one day, with data taken every 2 ft.	Los Alamos National Laboratory	Los Alamos National Laboratory	August 1992	Steve McLin Los Alamos National Laboratory
Vapor sampling	Vapor sampling SEAMIST system with nine sampling points was installed to 90 ft deep for long-term monitoring.	Danial B. Stephens & Associates, Inc.	Tucson	Sept. 1992	Jeff Forbes (DBS&A)
Borehole liners	SEAMIST liners installed after holes drilled to support/seal holes while long-term monitoring system is designed (8.5 ft diameter, 100 ft deep).	Lawrence Livermore National Laboratory	Lawrence Livermore National Laboratory	Sept. 1992	Joe Iovenitti Weiss & Associates
High pressure borehole liners	Two Kevlar reinforced SEAMIST membranes were installed to a maximum depth of 155 ft, then filled with water inside cased wells to prevent collapse of the PVC casing during steam injection remediation experiments.	Lawrence Livermore National Laboratory	Lawrence Livermore National Laboratory	Oct. 1992	Robin Newmark Lawrence Livermore National Laboratory

APPENDIX A

SUMMARY OF SEAMIST APPLICATIONS

Summary of SEAMIST™ Field Applications					
APPLICATION	DESCRIPTION	CLIENT	SITE	PERIOD OF USE	CONTACT
Borehole liner	One SEAMIST liner was installed after hole drilled to support/seal hole while long-term monitoring system is designed (8.5 diam, 90 ft deep).	Argonne/ Dept. of Agriculture	Utica, Nebraska	Oct. 1992	John Walker Argonne National Laboratory
Sandia National Laboratory - integrated demonstration	Installed gas sampling tubing to 393 ft in a horizontal borehole of 4 in. diam.	Sandia National Laboratory	Sandia National Laboratory Albuquerque	Fall 1993- Fall 1994	Cecelia Williams
Monitor fuel oil plume position	Monitor the position of the plume via closely spaced soil vapor sampling ports in a vertical hole.	Hart Crowser, Seattle, Washington	Swedish Hospital	May 1993 to present	Chad Armour
Characterize the site and map contamination	Install SEAMIST in numerous boreholes to sample pore vapor for VOC's and to emplace other monitoring instruments	Los Alamos National Laboratory	Mixed waste landfill site, Los Alamos, NM	Fall 1993 to present	Don Krier
Monitoring under new mixed waste landfill	The SEAMIST system is a critical part of the landfill monitoring design being developed for a mixed waste disposal facility.	Los Alamos National Laboratory	Mixed waste landfill site, Los Alamos, NM	Prototype testing in 1994	Robert Crowley
Stabilization of contamination in ducting	SEAMIST is being used to apply strip coat to the interior of ducting to immobilize hazardous dust (e.g., U&Pu)	Los Alamos National Laboratory	Old plutonium facility	Spring 1994 to present	Dan Stout
Monitoring of soil vapor extraction	Nine vertical SEAMIST systems with 10 vapor sampling ports to 80 ft used for pressure, permeability, and concentration monitoring.	Kleinfelder	Sacramento Army Depot, California	March 1994 to present	Randy Wheeler
Mapping of contamination at radioactive waste site	Installation, in a 4.5 in. diam. mole hole, of an absorbent covering on SEAMIST	Oak Ridge National Laboratory	Oak Ridge WAG6	August 1994 to present	
Monitoring of a radioactive waste landfill	Use of SEAMIST in tunnels built in trenches below low level radioactive waste landfill to monitor for leachate migration.	Los Alamos National Laboratory	TA-54, Pit 39	Sept. 1994 to present	Bill Purtyman
Sampling at discrete levels below the water table	Installation of SEAMIST with water and vapor sampling ports. The water table is at 40 ft below the surface.	Weiss Associates	March AFB, Riverside, CA	Being Installed	Joe Iovenitti
Permeability measurements	Use of SEAMIST in 60 ft deep hole for measurement of permeability and changes during thermal enhanced vapor extraction.	Sandia National Laboratory	TA-3, Chemical Waste Landfill	July 1994 to present	Jim Phelan
Tritium plume measurement	Installation of absorbers on SEAMIST membrane to 300 ft for wicking of water in vadose zone.	Los Alamos National Laboratory	TA-33	August 1994 to present	Jake Turin

OTHER TECHNOLOGY APPLICATIONS

Figure 6: Permeability measurement geometry.

- To add the capability of making permeability measurements to the gas sampling port design described above, a thin spacer (screen or netting) is attached to the outside surface of the membrane to produce a highly permeable annulus.
- A separate capillary tube is used to measure the pressure at the gas port. The gas flow rate is also measured, allowing a direct calculation of one-dimensional effective gas permeability.
- Two membranes can be installed, one from each end, in a continuous horizontal borehole to be used as a straddle packer system. Samples are collected from the borehole section located between the two membranes.

Figure 7: Progressive packer system.

APPENDIX B

OTHER TECHNOLOGY APPLICATIONS

Figure 8: Strip-coat membrane emplacement in a duct using a guide tube.

- Both reel and linear hose canisters can be used to emplace the liner. The linear canister is more likely to be used for decontamination and decommissioning (D&D) applications.

APPENDIX C

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This report was prepared by:

**Colorado Center
for
Environmental Management**

999 18th Street, Suite 2750
Denver, Colorado 80202
Contact: Dawn Kaback
(303) 297-0180 Ext. 111

in conjunction with:

Oak Ridge National Laboratory

P.O. Box 2003
Oak Ridge, Tennessee 37831
Contact: Kathryn Lowe
(303) 966-3430

Assistance was provided by

**Millgard Environmental Corporation
Geo-Con**