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7. Abstract

Fancher, J. D. and J. N. Fisler, 1994, *PAWS and Multisorbent Arrayed Sampler Integrated Test Plan*, WHC-SD-EN-TP-045, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

This Integrated Test Plan describes the field demonstrations of two sampling systems for characterization of volatile organic compounds in the vadose zone. The two systems are portable acoustic wave sensor and the multisorbent arrayed sampler.

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This integrated test plan (ITP) describes field demonstrations of two Portable Acoustic Wave Sensor (PAWS) systems and the multisorbent arrayed sampler for collection of samples of volatile organic compounds (VOC) in the vadose zone (see Appendix A). All activities of the field demonstrations will comply with this plan.

The field demonstrations conducted under this ITP involve using the PAWS downhole probe for in situ monitoring in 4-, 6-, and 8-in-dia vadose zone wells with an aboveground system for comparison analysis of gas samples pushed to the surface from the in situ probe (to compare to the in situ sensor data). The demonstration of the multisorbent arrayed sampler will involve 4-in-dia vadose and groundwater monitoring wells. There will also be a dual deployment of both the PAWS and the multisorbent arrayed sampler in the same well simultaneously. This dual deployment will utilize an 8-in-dia well.

The field demonstrations described in this ITP are being conducted as part of the VOC-Arid ID, one of several U.S. Department of Energy (DOE) integrated demonstrations designed to support the testing of emerging environmental management and restoration technologies. The purpose of the VOC-Arid ID is to identify, develop, and demonstrate technologies that may be used to characterize, remediate, and/or monitor arid or semiarid sites containing VOC (e.g., carbon tetrachloride) with or without associated metal and radionuclide contamination. This demonstration will focus on the carbon tetrachloride contamination found in the 200 West Area of the Hanford Site (Figure 1).

1.2 BACKGROUND

This integrated demonstration will test two different types of sampling systems for detection of VOC. A description of the individual devices is provided in the following sections.

1.2.1 PAWS

The PAWS technology consists of a surface acoustic wave (SAW) sensor utilizing a sorbent coating to detect chlorinated hydrocarbons and other VOC. The instrument measures the velocity and attenuation of the wave as chemical species are sorbed into the coating. Efforts to date have resulted in the development and field demonstration of a portable instrument that can detect and measure isolated chlorinated compounds in the vapor phase from 10 ppm to 100,000 ppm in a continuous mode. In addition, a downhole (borehole) monitor with associated packers and purge system has been developed and field

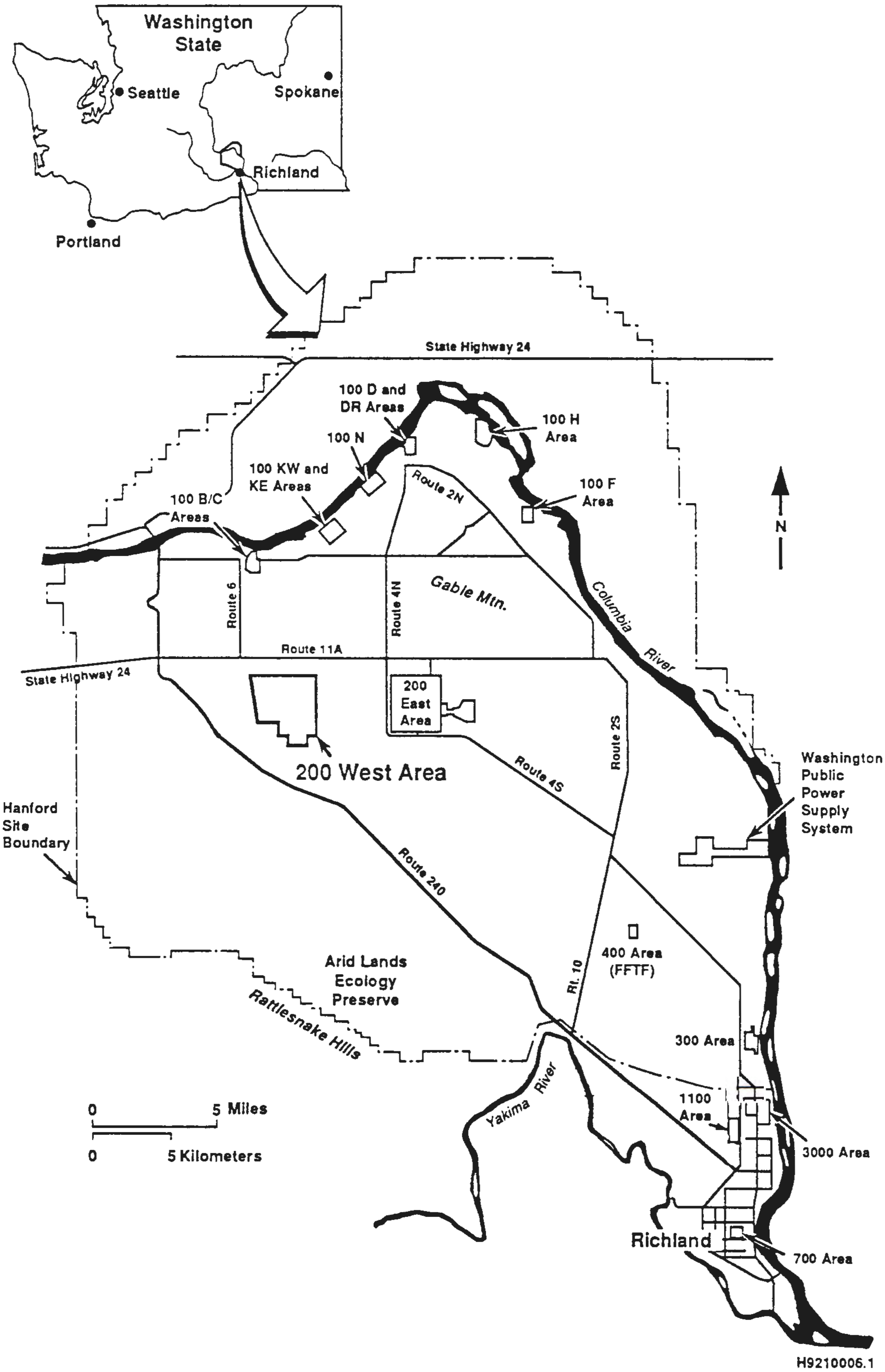


Figure 1. Hanford Site Map and Location of the 200 West Area.

demonstrated. These systems have been shown to have the following advantages: (1) rapid (few second) and reversible responses enabling real-time analysis, (2) accurate analysis for monitoring isolated species (within 2% of baseline instruments during the last field demonstration), (3) wide dynamic range, (4) stable calibrations (within 3% over a 50-day test), (5) easy to transport, set-up, and use, (6) low maintenance, and (7) inexpensive.

The baseline technique for these PAWS field demonstrations is analysis of grab samples by gas chromatography. This was chosen since it is the most common and accepted technique for site characterization and monitoring of off-gas streams. Comparisons with other techniques being used at the Hanford Site (e.g., Brüel and Kjær photoacoustic IR analyzer and Transducer Research Odyssey systems) will also be performed.

1.2.2 Multisorbent Arrayed Sampler

The multisorbent arrayed sampler utilizes multisorbent cartridges in a downhole sampler to collect samples for a broad range of VOC. These cartridges, filled with solid sorbents such as Tenax (a trademark of Enka Research Institute), have been used for a number of years for ambient air sampling. Studies performed at Oak Ridge National Laboratory (ORNL) and elsewhere have demonstrated that packing multiple solid sorbents sequentially in tubes could extend the range of VOC that could be collected and retrieved quantitatively. Carbonaceous sorbents offer several important advantages over polymer-based species (e.g., Tenax), the most important being minimization of artifacts from degradation of the sorbent material during thermal desorption. More recent pilot studies at ORNL suggested that such multisorbent traps could retain VOC even in very high humidity environments, such as those likely to be encountered in the vadose zone.

Conventional approaches to the acquisition of a soil-gas sample at depths of more than a few feet involve the implantation of a tube, and withdrawal of a soil-gas sample to the surface. Advantages of using the multisorbent sampler for collection of VOC samples include: (1) Extraction of the small volume of sample required by the multisorbent sampler will prevent disturbing the sub-surface equilibrium, and gas withdrawn in the cartridges will be representative of that present in the soil, (2) elimination of significant losses of organic vapors through permeable tubing, such as Teflon (a trademark of E.I. duPond de Nemours & Company), especially when the length of tubing involved is considerable. Even in non-porous tubing, organic vapors may adsorb on or react with tubing surfaces, or dissolve in water vapor condensed on the walls of the tubing.

The baseline technology for the multisorbent arrayed sampler is the acquisition of a soil-gas sample at depth by the implantation of a tube, and withdrawal of a soil-gas sample to the surface. Previous comparisons of these baseline samples have included comparison of multisorbent samples with grab soil-gas samples analyzed with a gas-chromatograph.

1.3 SITE SETTING

Field testing will be conducted mainly in the vicinity of three carbon tetrachloride disposal sites (216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib) (Figure 2).

The upper geologic unit of the 200 West Area consists of two facies: (1) coarse-grained sand and granule to boulder gravel from which matrix is commonly lacking, and (2) fine- to coarse-grained sand and silt that commonly display normally graded rhythmites a few centimeters to several decimeters thick. In general, this unit is composed of approximately 50% sands and gravels, 45% cobbles, and 5% boulders. This unit ranges in thickness from 6 m to greater than 60 m in the 200 West Area. It is underlain by 1.5 to 18 m of silts and fine sands, which in turn are underlain by another gravel unit.

Carbon tetrachloride vapor concentrations observed throughout the 200 West Area in 1991 ranged from less than detectable to several hundred parts per million per volume (ppmv) in the unsaturated zone. Observed concentrations are highest in the vicinity of, and west of, three sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) where carbon tetrachloride was discharged to the soil column (Figure 2). However, the observed vapor concentrations may vary with time and appear to be influenced by fluctuations in the barometric pressure (DOE-RL 1991). Carbon tetrachloride breakdown products, chloroform and methylene chloride, have also been observed in soil samples in trace amounts. Other substances that have been identified, in trace amounts, in at least one soil sample from the 200 West Area include: benzene, fluoromethane, 1,1-dichloroethylene, trans-1,2-dichloroethylene, trichlorofluoromethane, methyl isobutyl ketone, and toluene (DOE-RL 1991).

Many of the liquid waste streams discharged to the soil column in the 200 West Area since 1944 contained radionuclides. The primary radionuclide components of the aqueous and organic liquids discharged to the three carbon tetrachloride disposal sites were plutonium and americium. The plutonium contamination extends approximately 30 m beneath the 216-Z-1A Tile Field (Figure 2); the lateral spread is limited within a 9-m-wide zone around the perimeter of the tile field. Other radionuclides, such as radioactive isotopes of cesium, cobalt, hydrogen, iodine, strontium, and technetium have been discharged to the soil column beneath the 200 West Area. In addition, radon gas occurs naturally in Hanford soils.

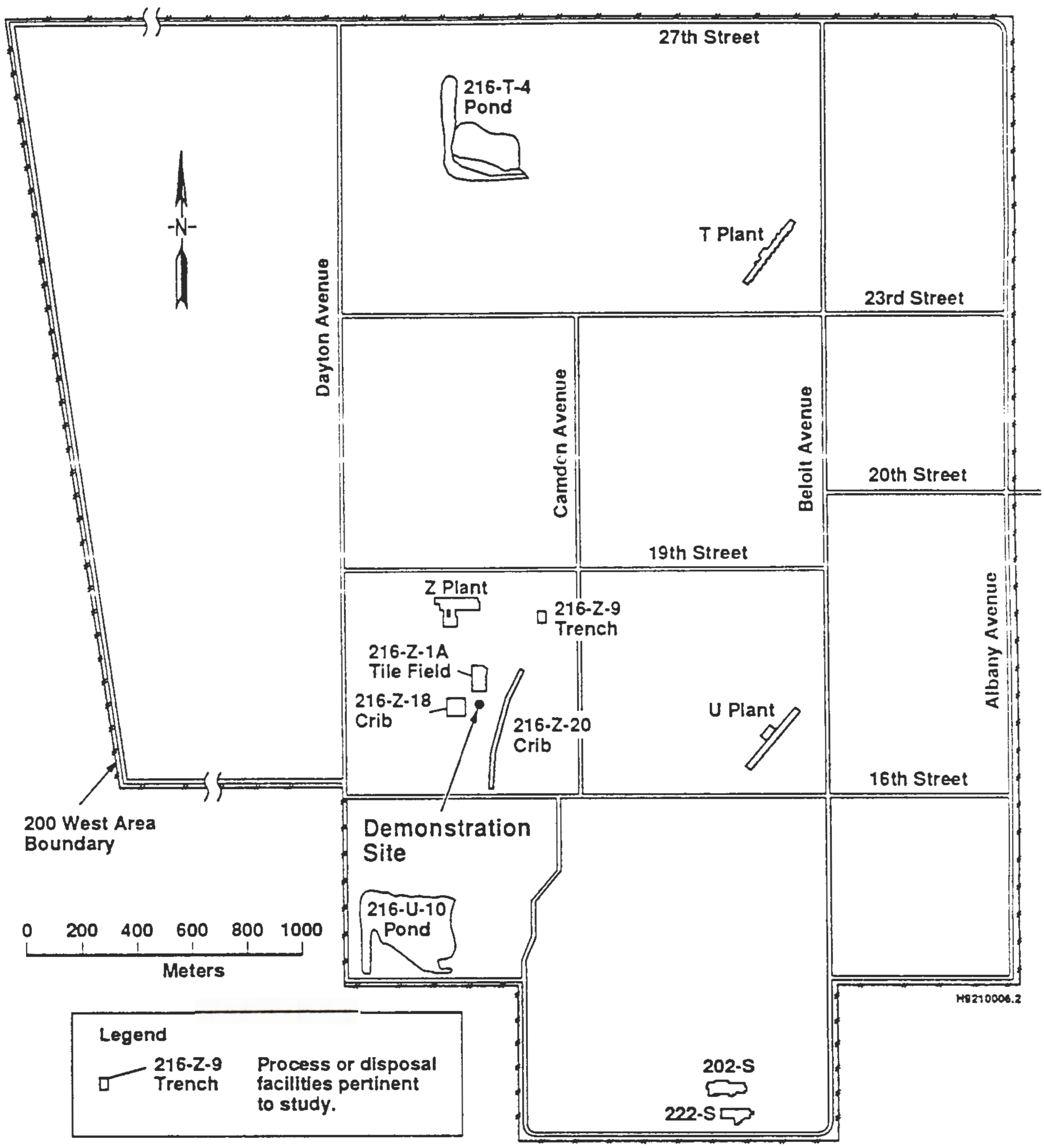


Figure 2. Map of the 200 West Area and Demonstration Site.

2.0 TECHNOLOGY DESCRIPTIONS

2.1 PAWS

The monitoring systems being developed in this project utilize surface acoustic wave (SAW) sensors. A schematic of a SAW sensor is shown in Figure 3. A quartz substrate containing two interdigitated transducers is coated with an absorptive polymer film. Application of an alternating voltage to the input transducer generates a strain field in the underlying quartz due to its piezoelectric properties. This strain field launches a surface acoustic wave that travels along the substrate, interacting with the polymer overlayer, before being converted back into an electrical signal by the output transducer. The wave/film interaction results in a perturbation of the wave propagation properties, specifically the wave velocity, v, and the wave attenuation, α (i.e., rate of wave diminution with distance). This sensitivity to thin film properties makes SAW devices ideally suited for the development of chemical sensors to monitor gas and vapor species.

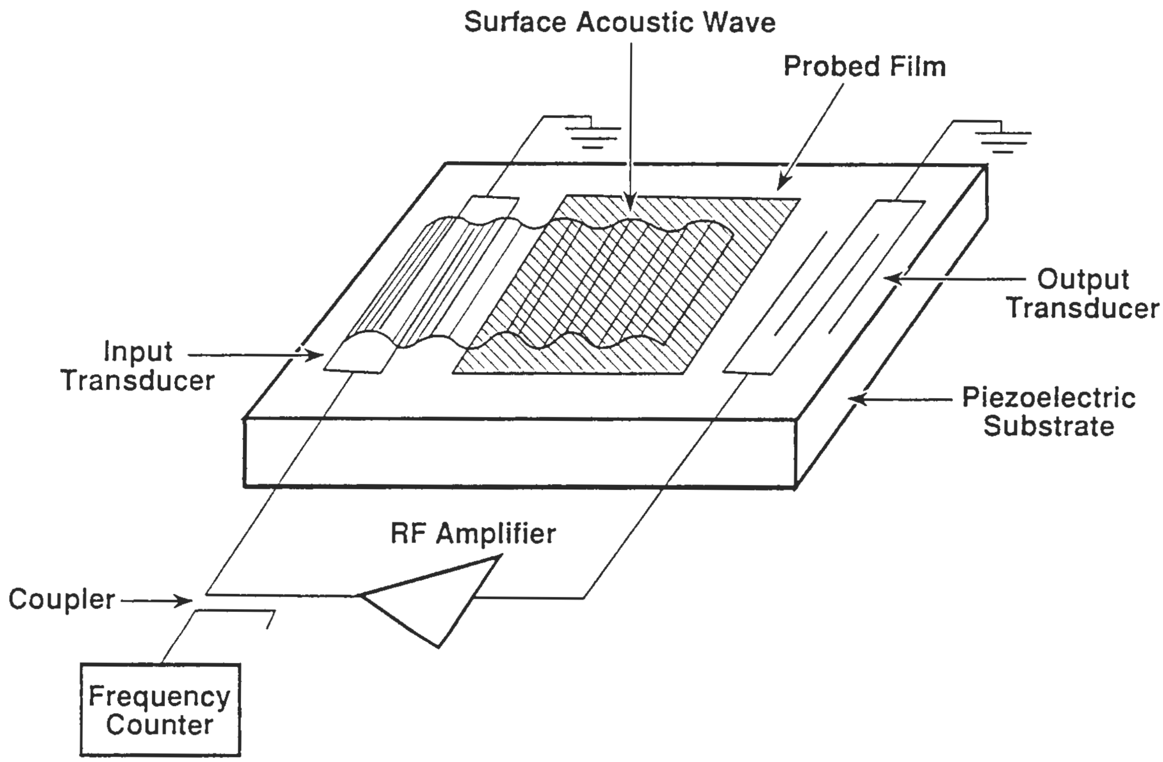


Figure 3. Schematic of SAW Sensor with Absorptive Polymer Coating.

Using viscoelastic polymer films, it has been demonstrated that by simultaneously monitoring both velocity and attenuation from a single device, the identity of an isolated molecular species as well as its concentration can be determined. A significant advantage of this dual output technique is that it provides chemical discrimination based on differences between species in the modification of film properties such as mass and viscoelasticity. For example, for several polymers tested (e.g., polyisobutylene), this molecular recognition capability tends to discriminate on the basis of the liquid density of the absorbing species. This makes these films ideally suited for discriminating relatively high density chlorinated hydrocarbons (1.4 to 1.6 g/ml) from lower density nonchlorinated species (0.6 to 1.0 g/ml).

In practice, these two responses are measured by using the SAW device as the feedback element of an oscillator circuit. In this configuration, relative frequency changes ($\Delta f/f$ where f is frequency) are proportional to relative velocity changes ($\Delta v/v$), enabling a frequency counter to be used to monitor velocity. Wave velocity can be resolved to an accuracy of approximately 0.01 ppm (1 Hz noise out of 97 MHz operating frequency). Insertion loss can be evaluated by measuring the power level after the SAW device using a detector to convert the RF power to a DC voltage. Noise levels as low as 0.0004 dB have been measured using this technique.

By utilizing elastomeric polymers (e.g., polyisobutylene) as the absorptive layers for these sensors, the rapid diffusional properties result in rapid (few second) and reversible sensor responses. This enables the sensors to be used on-line or in situ to continuously monitor concentration with time. The reversibility of the absorption enables sensor baseline to be evaluated on line by periodically removing the chemical from the gas stream using a stream of chemical free ambient air. To minimize humidity differences between sample and baseline gases, the sample gas is brought to ambient humidity using a Nafion (a trademark of E.I. dupont de Nemours & Company) membrane dryer tube. This technique also prevents condensation of water in the sensor system when analyzing high humidity downhole samples. Minimum detection limits for typical chlorinated hydrocarbons are approximately 2 to 10 ppmv using this ambient air/Nafion membrane method to evaluate baseline. Calibration coefficients have been shown to be very stable (within 3% over a 50-day test) and both laboratory and field demonstration data indicate high accuracy, especially at higher concentrations (agreement with the Brüel and Kjær analyzer during the last field demonstration was within 2%).

2.1.1 The Basic Sensor System

The basic PAWS system, shown schematically in Figure 4, consists of two SAW devices contained in a test case and configured with appropriate oscillator circuitry, data acquisition and control electronics, and environmental sampling. The system can be configured with a single, polymer-coated device in the test case acting as an independent sensor or dual coated devices with one being the sensor and the other acting as a reference. When using reference devices, each SAW component is part of a separate oscillator with the sensing device exposed to the chemical while the reference is isolated. The resultant frequency from the sensor oscillator is mixed with the reference frequency to obtain a difference frequency that is partially compensated for temperature-induced baseline drift.

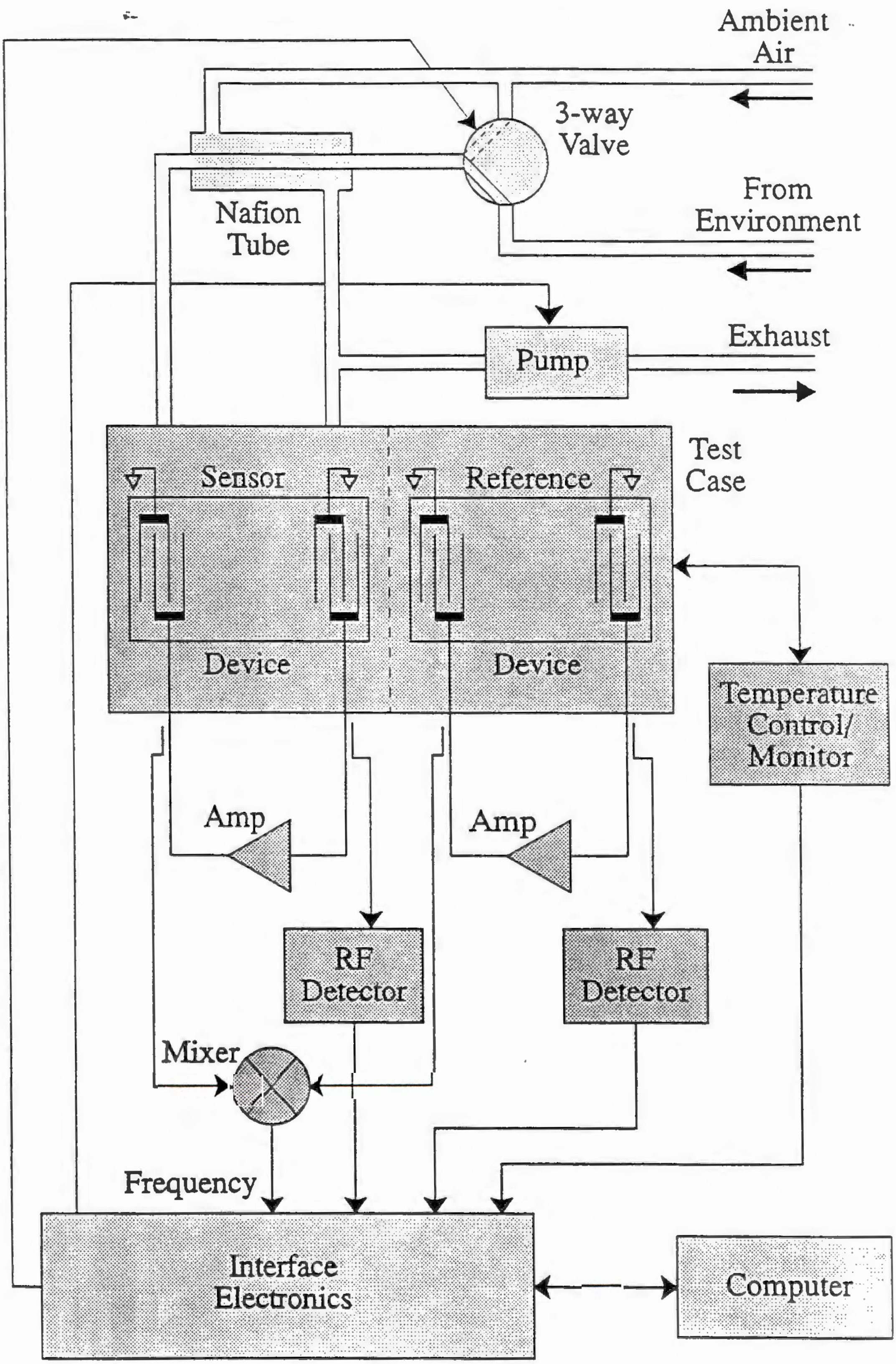


Figure 4. Schematic of the Portable Acoustic Wave Sensor (PAWS) System.

The sensor device is challenged with known concentrations of the chemical of interest to determine the calibration coefficient. Both wave velocity and attenuation for the device are measured. Either response can be used to determine chemical concentration while the ratio of responses can be used to verify the identity of an isolated chemical species.

Elements of the RF oscillator electronics are high-gain, low-noise amplifiers, a low-pass filter, impedance matching for the SAW transducers, and couplers to remove RF signals for frequency and power measurements. Since the viscoelastic properties used to obtain the two independent device responses also change with temperature, thermal control is required to overcome the resulting temperature sensitivity. Thermal stability is provided by an electronic feedback system to control temperature fluctuations in the test case and frequency mixing to remove (to first order) temperature-dependent response in the two similar devices. Accurate temperature monitoring is possible from resistance measurements directly on the SAW devices or from thermistors in the test case. Bridge circuits convert resistance into voltage for measurement. All components of the oscillator electronics, the thermal management and measurement system, and the device test case are integrated onto two PC-boards.

The standard PAWS environmental sampling system consists of a pump to move the gaseous species across the sensor, a Nafion membrane tube, and a three-way solenoid valve. The Nafion membrane tube is configured so that the sample gas goes through the inside of the Nafion tube while ambient air is passed in countercurrent flow on the outside of the Nafion (the Nafion tube is contained in a larger diameter Teflon tube). The selective permeation of water over VOC enables this system to be used to bring the sample gas to ambient humidity without altering the contaminant concentration. The three-way solenoid valve is used to periodically direct ambient air to the sensor to purge the sensor of the contaminant and reestablish sensor baseline (i.e., sensor response at zero concentration). System stability (i.e., drift rate) dictates how often the sensor baseline must be reevaluated.

Data acquisition and system control is provided by a digital electronic board and computing system linked via a serial interface. The digital board contains (1) a frequency counter to monitor oscillation or mixed frequency, (2) multiplexed 16-bit analog-to-digital conversion for measuring up to eight voltages from RF detectors and temperature sensors, (3) digital outputs (maximum of eight) used to activate relays for pump power and solenoid valve switching, (4) a control microprocessor and associated RAM programmed for single command data acquisition of all relevant parameters, and (5) a serial communications port capable of either RS-232 or RS-422 protocol. A DOS-based computer is used to communicate with the digital electronic board, analyze the data, and display the pertinent parameters in real-time. The system, which uses a simple set-up routine, automatically turns on pumps and scrubbers, acquires and stores data, computes chemical concentrations based on frequency shifts and the related calibration coefficients, and analyzes frequency to attenuation ratios. A small notebook computer is adequate for PAWS system implementation.

2.1.2 The PAWS Aboveground System

For aboveground monitoring, the SAW sensor and oscillator circuitry, data acquisition and control electronics, environmental sampling hardware, and associated power conditioners are housed in a single modular package with a total volume of approximately 0.4 ft^3.

Communication to a notebook computer uses an RS-232 serial interface since drive requirements are small. The power conditioning enables any 12 V power source, including a battery (e.g., car battery) for those sites where AC line power is not available, to be used to power the PAWS module. A battery enabling at least 8 hr of remote operation is included in the module.

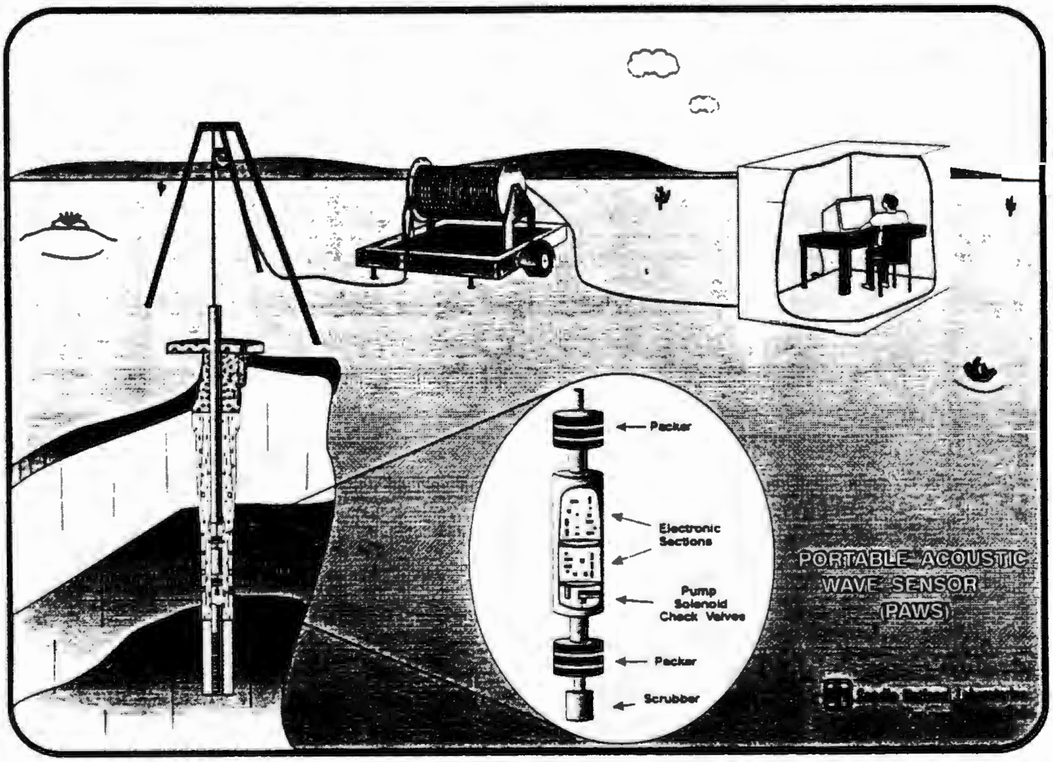
Gas inlet and outlet ports with 1/8-in. Swagelok (a trademark of the Swagelok Company) connections are provided on the front of the module. Exhaust following chemical detection can be recirculated back into the original gas stream, treated to remove the contaminant (e.g., with GAC), or released to the atmosphere as appropriate. Onsite verification of the sensor calibration is possible through use of bottled gases containing calibrated concentrations. Comparisons to other measurement techniques, such as grab sampling and GC analysis, are possible through simple plumbing reconfiguration.

2.1.3 The In Situ System for Vadose Zone Monitoring Wells

The PAWS downhole system is illustrated in Figure 5. The probe, constructed so that it can be placed into 4-in. and larger wells, houses the same components as the aboveground PAWS module (Section 2.1.2) except the battery. RF oscillator electronics and data acquisition/control electronics are placed in separate, shielded compartments within the probe to reduce interference during measurements. Environmental sampling and power conditioning hardware are contained in a third isolated section as well as being put into available spaces in the other two sections. This sampling system is configured to enable a portion of the sample gas to be pulled to the surface using a Teflon or stainless steel tube and a pump at the surface. The probe superstructure consists of a 2.5-ft-long anodized aluminum cylinder with the three isolated internal regions. An anodized aluminum cover protects the electronic components. Access to the well environment is achieved with a port at the bottom of the probe that contains a frit to prevent particulate contamination inside the chamber.

Packers are attached above and below the main section and are sealed against the well by application of 25 to 50 psi on a gas line from the surface. The bottom packer can be separated from the main section using a long gas line and tether to enable longer sections of screened wells to be packed off. The pressurized line from the surface has a quick connect to the probe while a pressure regulated 12 V pump is used to inflate the packers. The gas handling equipment also contains a purge system consisting of a pump attached to a fritted port above the bottom packer, a one-way valve, and a port that exits the probe above the top packer.

Figure 5. Application of the PAWS Downhole Probe for In Situ Analysis.



A small purge pump can be housed in the main probe section or a larger pump can be housed in a separate section that is connected to the main probe by a gas line (to go to the vent above the top packer), a pair of wires for power, and a tether. Having a separate section enables higher capacity pumps to be used for larger diameter wells. This separate purge pump section can be used to push 20 L/min or more out of the well to purge the well prior to analysis. If desired, this flow can be sent to the surface with a 3/8-in. Teflon tube for comparison analysis at the surface. Alternatively, a pulling purge pump at the surface can be attached to remove the size restriction on the pump.

The probe is lowered into the well using a portable tripod, a winch, and a braided cable. Connections to the computing system and power supply at the surface use a cable containing four twisted shielded pairs. The serial communication between the probe and the up-hole computer requires use of the RS-422 interface as long line lengths may be necessary. Both RS-232 and RS-422 interface capabilities are designed into the data acquisition electronics.

2.2 MULTISORBENT ARRAYED SAMPLER

The multisorbent arrayed sampler (Figure 6) consists of a cylindrical stainless steel assembly housing an array of 13 micro-miniature solenoid valves in a mounting structure to accept six multisorbent traps connected into the system via standard 1/4-in tube fittings. As mounted in the body, solenoid valves are connected to each end of each trap for isolation or sampling as desired. The outlet of each trap is connected (via a solenoid valve) to a common sample conduction manifold. A pump at the surface draws an accurately metered sample of air through any selected trap via the manifold. An additional solenoid valve is used in the sampler head to provide for rapid direct evacuation of the residual air in the vicinity of the sampler prior to sampling through a trap if such is deemed appropriate.

The system may also be used to draw soil-gas samples directly to the surface. Each end of the sampler body is fitted with an inflatable donut-shaped bladder that acts as a packer to secure the body at any given vertical location in a well. The sampler body is connected to a control assembly at the surface by 250 ft of composite cable. This assembly contains all the necessary electrical and pneumatic circuitry to deploy and activate the sampler body. Pressure and vacuum gages, a 0 - 500 mL/min mass flowmeter, power supplies, as well as all necessary switches and valves are contained in a compact 17x21x8-in portable case.

The control assembly requires 120 V electrical power, a source of low pressure nitrogen or other inert gas, and a source of moderate vacuum. The latter is provided by a small portable diaphragm pump. At a site without permanent electrical power, a small AC generator can be substituted. An additional independently inflatable packer, which will hang about 15 ft below the sampler body, will be used to isolate the well screened intervals.

3.0 DEMONSTRATION OBJECTIVES AND MEASURES OF SUCCESS

3.1 DEMONSTRATION OBJECTIVES

3.1.1 PAWS

The test objectives for the field demonstration of the PAWS downhole system for carbon tetrachloride are presented below.

1. Determine system ease of use by both experienced and novice operators.

   A. Determine ease of system transport to site and set-up.

   B. Identify training requirements for use by new operator.

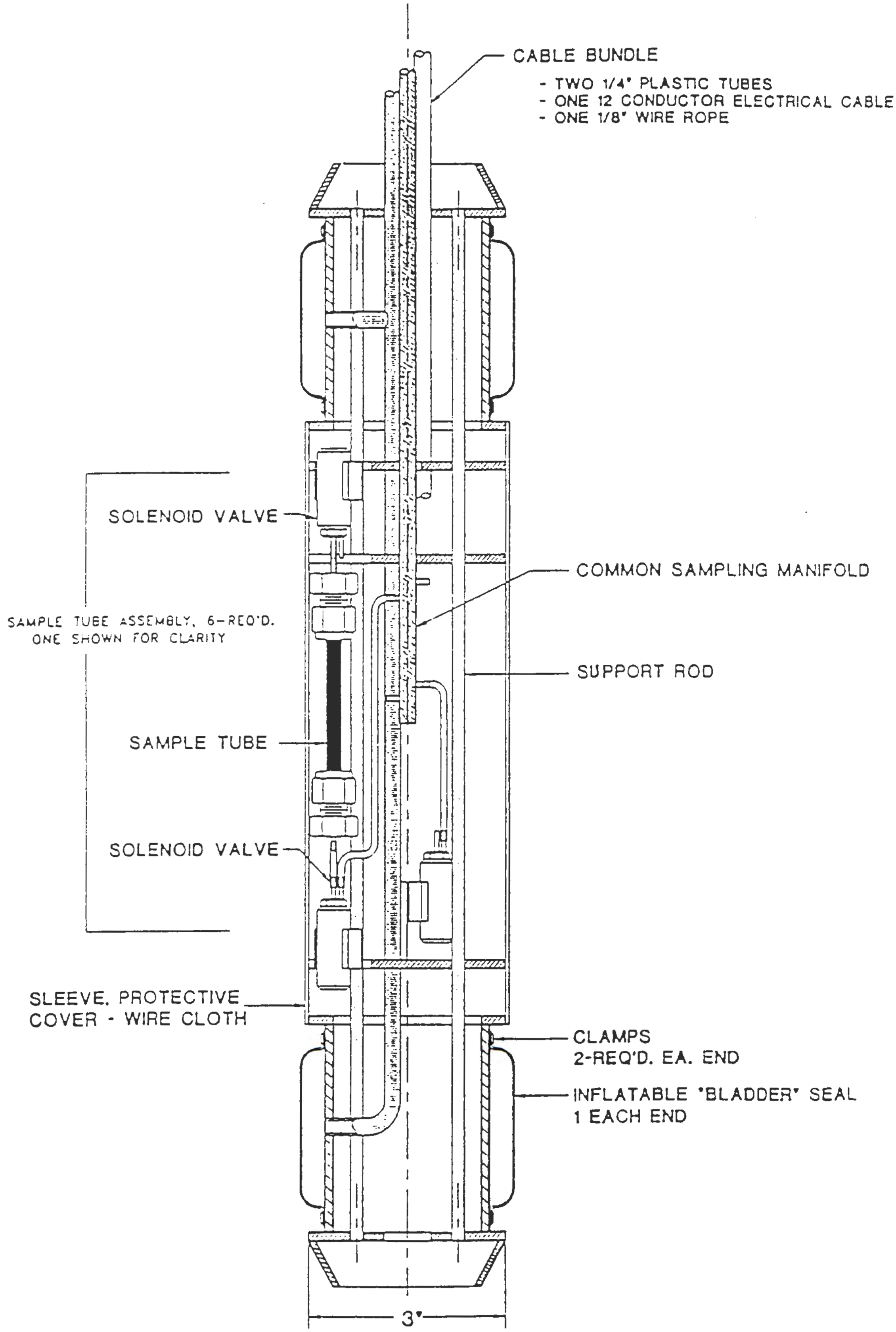


Figure 6. Schematic of the Multisorbent Arrayed Sampler.

C. Evaluate complexity of set-up and operation.

D. Identify problems with lowering the probe into the target monitoring wells to the depths of interest.

2. Evaluate downhole system effectiveness for monitoring of carbon tetrachloride concentrations, especially regarding the advantages provided by the in situ capability and the ability to meet the needs of potential uses (e.g., field screening, regulatory compliance):

   A. Compare carbon tetrachloride concentrations from the PAWS downhole system with recent measurements from the same wells and with gas samples pushed from the well during the PAWS field test to determine advantages of in situ analysis. For joint tests with the arrayed sampler, compare concentrations with those determined with aboveground analysis of samples taken at similar times with the sampler.

   B. Estimate minimum detection limit based on noise levels and accuracy of baseline evaluation using the nafion membrane system.

   C. Determine accuracy of carbon tetrachloride measurement.

3. Evaluate system reliability.

4. Determine system response time and identify maximum time limits between baseline evaluations.

5. Determine costs of materials for the prototype and estimate a final manufacturing cost.

6. Determine time required to perform a downhole measurement.

3.1.2 Multisorbent Arrayed Sampler

The test objectives for the field demonstration of the multisorbent arrayed sampler for collection of vadose zone VOC are presented below.

1. Determine sampler reliability and operational problems.

2. Determine ease of use.

3. Determine and document infrastructure and physical requirements.

4. Determine sampler performance.

5. Determine ease of decontamination.

6. Evaluate cross contamination potential of the sampler.

7. Determine, after two field trials, if the sampler is ready for full deployment.

8. Determine operational time, maintenance problems, and the time required to cycle the system.

9. Evaluate the sampler's compatibility with both vadose zone vapor extraction wells (slotted screen) and groundwater monitoring wells (wire wrapped screen).

10. Compare concentrations of VOC collected on sorbent cartridges with those determined in-situ with downhole version of PAWS.

3.2 DEMONSTRATION PARAMETERS

3.2.1 PAWS

The following demonstration parameters will be recorded to address stated demonstration objectives (numbers correspond to objectives in Section 3.1.1):

1. A. Record time and materials required to prepare system for transport. Document transportation requirements. Record time for initial system set-up onsite.

   B. Record time required to train new operator in the use of the system including set-up for a new well, operation of the sensor software, and removal of probe from a well. Record any problems encountered when system operated by novice user.

   C. Document steps required for system set-up and operation.

   D. Record any problems with lowering the probe into the target monitoring wells to the depths of interest.

2. A. Record carbon tetrachloride concentrations vs. time from the downhole system, the aboveground PAWS system, and any onsite baseline analysis. Collect periodic grab samples for post test analysis by the PAWS systems and onsite analytical instrumentation. Obtain meteorological data during the time of the test. Obtain previous measurements in each well and the method used for these previous measurements. For joint tests with the arrayed sampler, record time and PAWS carbon tetrachloride concentration when samples are

taken with the arrayed sampler. After aboveground analysis of these samples, record chemical species and concentrations detected from the samples.

B. Collect data for the downhole probe when sampling contaminant free ambient air and when sampling various humidity air samples (laboratory tests) to determine maximum errors in baseline analysis. Measure noise levels during a long baseline cycle during a well test.

C. Record agreement between downhole probe and other systems (aboveground PAWS and onsite instruments) when sampling a previously collected grab sample.

3. Record any problems encountered with the system. Include the nature of the problem, the time required to fix the problem, and any modifications that could prevent or minimize the impact of this problem in the future.

4. Record system response times based on initial challenge with chemical gas after the baseline evaluation cycles. Record sensor drift rates based on long baseline evaluation cycles to eliminate the possibility of concentration changes occurring during the test.

5. Document components required for system and the current cost of these components. For specially designed electronics and hardware, document cost of current prototypes and estimate of cost if designed for manufacturability.

6. Record time required to remove probe from one well, move to a new well, lower probe into well, pack off desired region, and achieve effective sensor operation (e.g., achieve stable device temperature).

3.2.2 Multisorbent Arrayed Sampler

The following demonstration parameters will be recorded to address the demonstration objectives above (numbers correspond to objectives in Section 3.1.2):

1. Document sampler's reliability noting operational difficulties after the sampler has been deployed in at least three wells.

2. Document number of people required for deployment and time required for deployment in single person and two person deployments.

3. Record the pressure drop on the gas supply regulator and volumetric data for the gas supply cylinder. Record time required to assemble and disassemble the portable enclosure (usually a backpacking dome tent) to change out sorbent traps and house

tools. The difficulties, if any, with moving the enclosure from well to well will be documented.

4. Document sampler performance by comparing apparent concentrations of vadose zone contaminants collected on sorbent traps and concentrations measured with on-site monitoring equipment (e.g., HaloSnif (a trademark of Pacific Northwest Laboratory), B&K Model 1302, and/or direct sampling ion trap mass spectrometer [DSITMS]) if available. Real time data acquired through the exhaust port of the sampler will be compared with sorbent trap samples returned to the laboratory for analysis.

5. If sampler becomes contaminated, document the time and quantity of materials required for sampler decontamination.

6. Cross contamination of the sampler will be determined by first acquiring a sample in a high concentration well, then by acquiring samples sequentially in wells when vadose zone levels of contaminants are expected to be stable. The sorbent analysis data will later be compared to determine the level of cross contamination.

7. Document the current state of development after two field deployments by determining the extent to which the objectives of the field trials were met and the overall performance of the sampler during those trials.

8. Record the time necessary to perform various sampler operations, including time required to replace used sorbent tubes with fresh traps. Document and photograph any mechanical failures that occur on the first field trial. These will be rectified prior to the second field trial.

9. Deploy the sampler in both groundwater monitoring wells (headspace collection) and vapor extraction wells, and document any operational problems.

10. Document the vadose zone soil-gas concentrations determined in-situ with the PAWS and from samples collected with the arrayed sampler, by co-deploying the downhole PAWS system and the arrayed sampler.

3.3 SAMPLING AND ANALYTICAL PROCEDURES

3.3.1 PAWS

Grab samples will be obtained by filling Tedlar (a trademark of E.I. dupont de Nemours & Company) bags from the gas line leading from the downhole probe. The time when the sample is taken will be recorded and sampling will be taken when the downhole measurement indicates that the concentration is stable with time (if possible). Analytical instrumentation for grab sample analysis should have an accuracy of 2% (at least for concentration over 100 ppm) and be calibrated over a range that includes the measured concentration. Preferably, the systems should be precalibrated from 10 to 30000 ppm to cover the expected concentration range of interest. Similar requirements are needed for on-line analysis instruments (e.g., the Brüel and Kjær analyzer has previously shown itself to be able to meet these requirements).

3.3.2 Multisorbent Arrayed Sampler

The multisorbent traps used in the sampler are constructed according to ORNL Standard Operating Procedures (Appendix B), using 6 mm OD (4 mm ID) stainless steel tubing, 76 mm in length. To fabricate the traps, the tubing lengths are plugged at the downstream end with ca. 15 mm of silanized glass wool and then filled with a 14 mm length each of three specified carbonaceous adsorbents. Another silanized glass wool plug is inserted in the upstream end. The traps are treated prior to use by thermal desorption in batches of 15 on a manifold using helium (high-purity helium passed through an oxytrap) flowing counter to the sampling direction at 50 mL/min. The traps are heated to 386 °C for 3 hr.

Prior to shipment to a site for sampling, each trap is spiked with a bolus of vapor containing known quantities of three surrogate standard species (hexafluorobenzene, d8-toluene, and d5-bromobenzene), according to ORNL Standard Operating Procedure. Quantities of these surrogates remaining on the traps upon their return to ORNL for analysis provides an indication of the stability of the VOC retained on the traps following collection, sample transport, and storage prior to analysis.

The multisorbent traps are routinely analyzed using thermal desorption gas chromatography with flame ionization detection, according to Standard Operation Procedure AC-MM-1-003156. Alternatively, the traps can be analyzed using thermal desorption gas chromatography/mass spectrometry (GC/MS) or by thermal desorption DSITMS, either in the field or in the laboratory.

4.0 REGULATORY COMPLIANCE

This section identifies the regulatory compliance requirements for this field demonstration. The major requirements for the demonstration are derived from the National Environmental Policy Act (NEPA); CERCLA; and the Resource Conservation and Recovery Act (RCRA). Because of the limited nature of residuals from this demonstration, no requirements under the Clean Air Act, Clean Water Act, or other federal or state environmental laws are specifically applicable.

4.1 NEPA

The NEPA, 42 USC 4321 et seq., is the basic federal charter for protecting the nation's environment and ensures that federal agencies such as DOE give appropriate consideration to environmental impacts in their decision making.

On December 4, 1992, DOE determined that characterization and environmental monitoring activities on the Hanford Site fit within a typical class of action currently available for categorical exclusion (CX) in Subpart D of the DOE NEPA implementing procedures, 10 CFR 1021.

On April 30, 1992, DOE determined that VOC-Arid ID sensor development and demonstration activities fit within a typical class of action currently available for a CX in Subpart D of the DOE NEPA implementing procedures, 10 CFR 1021. Each of the technologies to be demonstrated in this test is either specifically discussed in the information bulletin supporting the CX approval or similar in its minimal environmental impacts to the technologies that are specifically discussed and clearly within the range of impacts assumed in DOE's CX approval. Accordingly, no further NEPA compliance documentation is required for demonstration of the sensor technologies as part of this test.

4.2 CERCLA

The field demonstrations will be conducted at the site of the expedited response action (ERA) (which is a CERCLA removal action), in coordination with the ERA, and are expected to provide data that is useful to the ERA.

4.3 WASTE DISPOSITION

Subtitle C of RCRA, 42 USC 6921-6939b, establishes a comprehensive program to regulate newly generated hazardous waste. Administered by Ecology and EPA, RCRA Subtitle C requirements are contained in Chapter 173-303, Washington Administrative Code (WAC), and in 40 CFR Parts 260 through 272, and apply to the generation, accumulation, treatment, storage, and disposal of hazardous waste. No solid, hazardous, or mixed wastes are expected to be generated by this test. In the event such wastes are generated, they will be managed in accordance with applicable RCRA requirements, including environmental investigations instructions (EII) 4.2, Interim Control of Unknown, Suspected Hazardous, and Mixed Waste (WHC 1988a).

4.4 CULTURAL RESOURCES REVIEW

A cultural resources review was performed at the carbon tetrachloride site and it was determined to have no historic properties.

5.0 HANFORD COMPLIANCE

This section identifies Hanford Site institutional compliance areas for these field demonstrations.

5.1 SAFETY

Activities under this ITP will be governed by the existing site-specific health and safety plan for the test site.

5.2 QUALITY ASSURANCE

All work on the Hanford Site is subject to the requirements of DOE Order 5700.6C, Quality Assurance (DOE-RL 1991), which establishes broadly applicable quality assurance (QA) program requirements.

To ensure that the field demonstration activities are consistent with DOE-RL (1991), all work will be performed in compliance with WHC (1988b) and with applicable procedures outlined in the QA program plan, (WHC 1990). This plan describes the various plans, procedures, and instructions that will be used by Westinghouse Hanford Company (WHC) to implement the requirements of DOE-RL (1991).

The objective of the test plan and the appendices is to ensure that the data obtained and the conclusions drawn are sufficiently accurate and reliable to support decisions associated with the evaluation of the demonstrations.

5.3 TRAINING

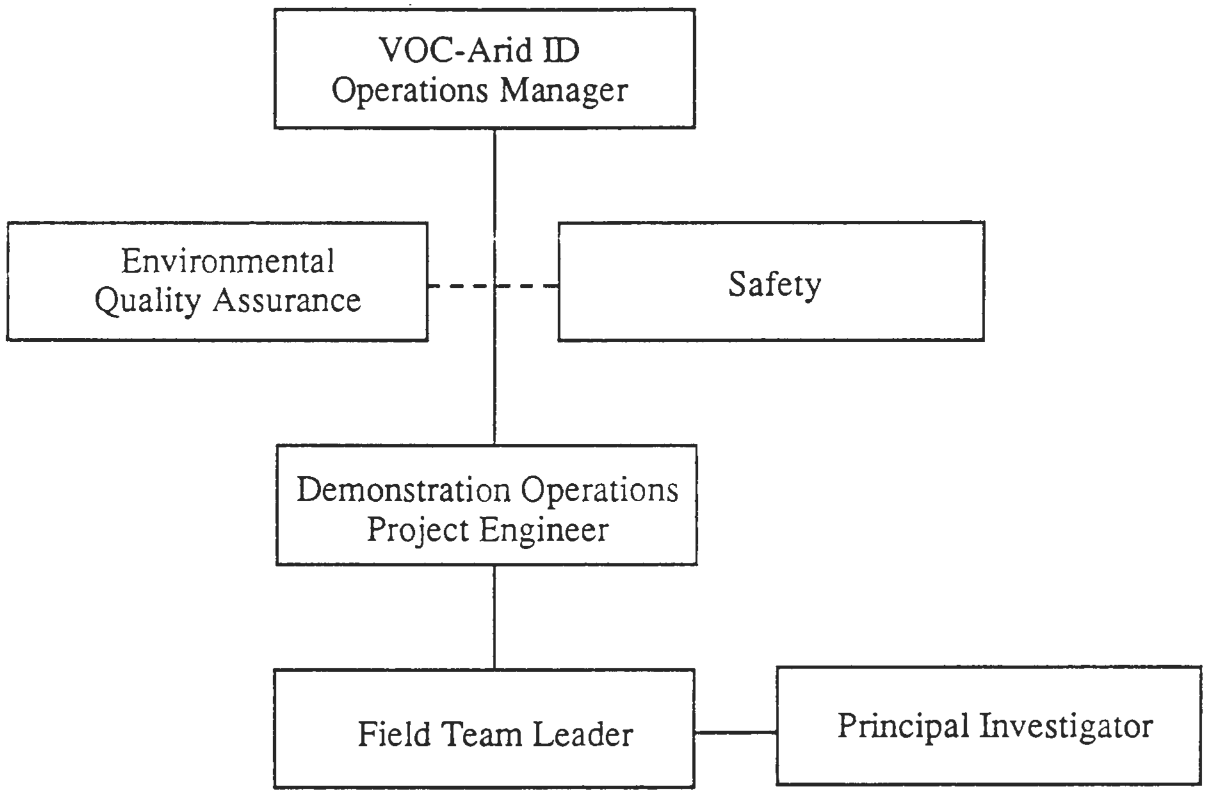
With the exception of high carbon tetrachloride concentrations, no special health and safety considerations are expected. Standard training, including the Occupational Safety and Health Administration (OSHA) training for personnel working at hazardous waste sites (40-hr hazardous waste worker training), participation in a medical surveillance program, plus all relevant training required to be on the Hanford Site, will be required for any personnel entering an exclusion zone. Should conditions warrant the use of supplied air, appropriate training (e.g., equipment and mask fit) and qualifications will be required.

Safety training requirements are listed in the site-specific health and safety plan. Security requirements are consistent with those needed for visitor access to the test site.

6.0 ORGANIZATION AND RESPONSIBILITIES

This field test will be performed by the demonstration operations group working with the principal investigators. Organization for the field demonstration is shown in Figure 7. General responsibilities and specific responsibilities for the field demonstrations follow.

Figure 7. Field Demonstration Organization Chart.



6.1 DEMONSTRATION OPERATIONS

Demonstration operations is responsible for site characterization, engineering and conduct of field demonstrations, and regulatory and DOE/Hanford compliance for field demonstration activities.

6.2 PROJECT ENGINEER/SCIENTIST

The project engineer/scientist is assigned to each technology. Responsibilities of each project engineer/scientist include:

- Provide host site interface to principal investigators for respective technology

- Produce ITP for technology demonstration in coordination with the principal investigator and field team leader
- Provide engineering field designs to adapt technology to field conditions
- Ensure site preparation and equipment installation for field demonstration
- Ensure that field demonstrations are accomplished in a safe and controlled environment and in accordance with releases ITP
- Participate in data evaluation and demonstration reports including lessons learned.

6.3 FIELD TEAM LEADER

The field team leader will be assigned for each field activity. Responsibilities of each field team leader include:

- Support the project engineer/scientist in preparation for field demonstrations
- Direct and control the field activities in accomplishing field demonstrations
- Ensure that field demonstrations are accomplished in a safe and controlled environment
- Participate in data evaluation and demonstration reports including lessons learned.

6.4 PRINCIPAL INVESTIGATOR

The principal investigator will:

- Ensure that the demonstration objectives are met
- Conduct the testing through coordination with the field team leaders
- Provide all equipment to be tested
- Provide personnel to set up the equipment, perform the test, and analyze the results
- Prepare a performance evaluation report that reviews the results of the testing related to each objective.

6.5 SITE SAFETY OFFICER

The site safety officer is responsible for the generation of the site-specific health and safety plan. The site safety officer has the final authority with regard to safety related issues in the field. Personnel are obligated to conduct activities in a safe and professional manner. The site safety officer will make periodic site visits to assure compliance with the site-specific health and safety plan.

7.0 DESCRIPTION OF TASKS AND PROCEDURES

Demonstration sites will be restored after the field demonstrations. Restoration will include removal of demonstration related equipment and temporary services not necessary for other activities either ongoing or anticipated at the test site.

7.1 PAWS

Field activities include testing of the downhole probe for in situ monitoring in vadose zone monitoring wells. The description of tasks describes the sequence in which the tests will be performed.

At least six wells with one or more screened intervals in the vadose zone will be selected from the list in Appendix C by the project engineer and field team leader prior to initiation of the field demonstration. These wells should have carbon tetrachloride as the major contaminant. At least one well each with diameters of 4-, 6-, and 8-in. should be selected. In addition, at least one well with multiple screened intervals (e.g., one of the new monitoring wells drilled in FY92) should be chosen to test the systems ability to monitor screened intervals that are not at the bottom of the well.

To prevent any possibility of radioactive contamination of the probe during this test, wells outside of radiologic controlled areas will be utilized. If possible, baseline information from previous grab sample analysis on concentrations of carbon tetrachloride and the various co-contaminants in the selected wells should be provided to the principal investigator prior to testing. In addition, comparison testing (e.g., based on access to the Brüel and Kjær analyzer or a gas chromatograph for analysis of samples pushed to the surface by the probe) during the field demonstration is needed to verify the accuracy of the acoustic wave sensor.

A detailed procedure for the actual field tasks is provided in Appendix A. This downhole in situ test will involve the system described in Section 2.1.3. This system will be calibrated in the Sandia National Laboratory (SNL), Albuquerque, New Mexico, and then disassembled for transport to the Hanford Site. Upon arrival at the Hanford Site, the major components (e.g., probe and packer module, cabling and plumbing, computer and power supplies) will be reassembled. Assembly includes attaching the purge pump section (if used) and packers to the main probe section, attaching the electrical and gas connections to the probe using the quick connections, and attaching the electrical cable to the power supply box and to the RS-232 to RS-422 converter attached to the computer.

The well will be opened and tested for contaminant concentrations above the action level in the vicinity of the well. If needed, personnel working near the well head will put on protective gear. The tripod will be set up over the well and the probe will be attached to the cabling of the winch system and lowered into the well to the desired depth. The gas line will be attached to the air compressor and the packers will be inflated to seal off a section of the well. The sensor system will be activated and monitoring initiated. If and when desired, the purge system will be activated and operated for sufficient time to purge the gas in the well bore. Monitoring during and after these purges will be performed to monitor the rise in contaminant concentration and the final concentration value. For some runs, a gas sample will be pulled to the surface for comparison with the in situ analysis. After completion of the test cycle, the packers will be deflated and the probe will either be moved to a new depth (for wells with multiple screened intervals) or will be removed from the well and prepared for testing in a new well.

After completion of all tests, the probe will be surveyed for contamination and, if declared free of contamination, disassembled and prepared for transport back to SNL. The results of the test will be documented in a data package describing the activities and basic test results.

7.2 MULTISORBENT ARRAYED SAMPLER

The first field deployment of the multisorbent arrayed sampler will focus on the determination of mechanical performance and sampling reproducibility. Following that visit, the sampling system will be modified as required. The second field deployment will focus on the validation of the modified system performance, as well as a demonstration of the sampler's ability to collect useful data.

These demonstrations will be used in wells where minimal radioactive contamination is expected, and where VOC co-contaminants are present. The latter may include chloroform, other VOC, or species resulting from the action of indigenous bacteria on contaminants such as lard, a small fraction of which may be volatile.

The operation of the sampler is as follows: The sampler is lowered into a well, and the packers are inflated. The isolated zone is then evacuated through the sampler's exhaust channel, if appropriate. After permitting equilibrium conditions to be achieved, one to six samples are collected on the on-board sorbent traps. The packers are then deflated, and the sampler moved to another location within the well. The process is repeated until up to six samples are acquired. The packers undergo final deflation, and the sampler extracted from the well. The used traps are removed, fresh traps installed, and the sampler redeployed. Time "in-hole" can range from 20 min to 4 hr (or more), depending on the data needs.

The sampler is intended for use in at least two scenarios. In the first, where relatively large concentrations of contaminants exist (ppm levels), the sampler can be employed to collect samples so small (10 - 20 mL) that there is essentially no disturbance of the subsurface equilibrium. This is especially important in strata of low porosity. In another scenario, where porosities are higher, the sampler can be used to concentrate very large samples of soil-gas. Typically, such a capability would be important when very strict regulatory levels have been imposed. For example, if 1 ng of carbon tetrachloride can be sorbed on a trap and accurately quantified, then collection of soil-gas at the rate of 200 mL/min for 8 hr on a single trap would permit the observation of carbon tetrachloride concentrations of 2 parts-per-trillion. In general, the capabilities of the sampler are such that it may be useful in a number of scenarios, or concentration ranges.

On the first field trials the primary emphasis will be placed on three 4-in-dia monitoring wells. Two of these are vapor extraction wells, while the third is a groundwater monitoring well. One test will involve acquiring six samples at one location in the low level well, moving to a high level well, and acquiring six samples at one location, and returning to the low concentration well and collecting another six samples. This test will be used to assess sampling reproducibility and cross contamination. Another two tests will involve collection of two samples from each of three locations in both a high level and low level well. A fourth test will involve removal of the lower "dangling packer" and collection of headspace in a water well and operation of the water alarm system.

7.3 CO-DEPLOYMENT OF PAWS AND MULTISORBENT ARRAYED SAMPLER

In order to conduct comparisons of the arrayed sampler with the PAWS system, the two systems will be co-deployed in the same 8-in-dia well during the first field trial of the arrayed sampler. In order to conduct the co-deployment, the independent packer from the arrayed sampler will be removed, making the sampling unit about 3.5 ft long. Next, the lower packer from the PAWS system will be lowered into the 8-in-dia well. (An 8-in-dia well is to be used, so that there will be enough space for the control cables from the sampler to be routed around the packers of the PAWS system without undue compression). Next, the arrayed sampler body will be lowered into the well. Finally, the downhole PAWS will be lowered into the well, and the packers inflated.

Because of the developmental nature of both technologies, it is inappropriate to use one of these systems as the "reference" and the other as the test system. Instead, each system will be used to gather as much data as possible while the other system is in operation. A minimum of two specific tests will be conducted. A static mode test will be performed, where multiple sorbent cartridge samples will be acquired while the PAWS system is operating with minimal soil-gas being removed from the packed interval. A dynamic mode test will also be performed, whereby the packed interval will be evacuated over a specified period of time, such that the concentration of soil-gas VOC in the isolated well volume will be forced to change. Six sequential samples at different time points will be acquired and subsequently analyzed. Concentrations of VOC in the soil-gas, as determined using the two different technologies will be compared.

8.0 SITE SERVICES REQUIREMENTS

Access to one of the mobile site support trailers with batteries for 12 V DC power and line power or a generator for 110 V AC power and compressed air or nitrogen is required for this demonstration. Use of an organic vapor monitor or other portable instrument will be required to monitor contaminant concentrations in the vicinity of the wells. Since the concentrations in the vicinity of the wells may be high enough to prevent safe operation by personnel, access to protective equipment including a source of supplied air will be needed during the field demonstration. Access to the Brüel and Kjær analyzer (preferred choice) or a gas chromatograph for analysis of samples sent to the surface by the probe will be needed for comparison to the in situ results. At least one onsite person will be required to help with moving the trailer, accessing the wells, and monitoring for contamination levels in the environment.

If a portable generator is used it should be placed a minimum of 50 m from the work location (downwind, if practical) to reduce noise, and more importantly, airborne contamination from exhaust and unburned fuel.

9.0 DEMONSTRATION SCHEDULE

The task/milestone schedule for these demonstration are:

1. Field demonstration of the PAWS and multisorbent arrayed sampler in Hanford wells is currently planned for the week of May 16, 1994. The demonstration will run approximately 1 wk.

2. The respective principal investigator will provide project engineers and the VOC-Arid technology coordinator with separate (PAWS and multisorbent arrayed sampler) summaries of demonstration results, a data package of measurements taken to measure the objectives, and a lessons learned letter regarding demonstration operations support by June 20, 1994.

3. The PAWS principal investigator will provide the VOC-Arid technology coordinator with a performance evaluation report in accordance with guidance by August 19, 1994. A revised report based on review comments (to be provided by October 19, 1994) will be provided by November 18, 1994.

4. A second demonstration of the multisorbent arrayed sampler in Hanford wells is currently planned for the week of July 18, 1994. The demonstration will run approximately 1 wk.

5. The multisorbent arrayed sampler principal investigator will provide the project engineer and the VOC-Arid technology coordinator with a final summary of demonstration results, a data package of measurements taken to measure the objectives, and a lessons learned letter regarding demonstration operations support by August 10, 1994.

10.0 REFERENCES

DOE-RL, 1983, Quality Assurance, DOE-RL Order 5700.1A, U. S. Department of Energy, Richland Field Office, Richland, Washington.

DOE-RL, 1991, Expedited Response Action Proposal (EE/CA & EA for 200 West Area Carbon Tetrachloride Plume, DOE/RL-91-32, Draft B, U.S. Department of Energy, Richland Field Office, Richland, Washington.

WHC, 1988a, Environmental Investigations and Site Characterization Manual, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.

WHC 1988b, Quality Assurance, WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.

WHC 1990, Environmental Engineering, Technology, and Permitting Function Quality Assurance Program Plan, WHC-EP-0383, Environmental Engineering Group, Westinghouse Hanford Company, Richland, Washington.

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Maskarinec, M. P., C. K. Bayne, R. A. Jenkins, L. H. Johnson, and S. K. Holladay, 1992, Stability of Volatile Organics in Environmental Soil Samples - Final Report, ORNL/TM 12128, November, 1992, Available from the National Technical Information Service, Springfield, VA 22161

APPENDIX A

PROCEDURE FOR PAWS MONITORING IN VADOSE ZONE WELLS

Operation of the PAWS downhole probe will be done in accordance with the following procedure:

1. Transport probe, purge pumps, packers, cable, gas lines, air compressor, power supply (if needed), and computer to the Hanford Site.

2. Reassemble the probe including the purge pump section and the packers.

3. Make electrical connections between the computer and the power supplies and the probe pigtail cable. If operating on a car or other battery (expected mode), attach the computer power cord and the probe power lines to the battery. If operating with a generator, plug in the computer and power supply to the generator and start up the generator. Turn on the computer and initiate the software routine.

4. Electrically connect the probe to the spooled power cable and connect the gas line for the packers. Connect the probe to the support cable from the winch.

5. If comparison testing with aboveground instrument(s) is to be performed, attach the 1/8-in. stainless steel tube to the sample line or the 3/8-in. Teflon tube to the purge pump exhaust.

6. Open the well to be tested and monitor the air concentrations in the vicinity to determine if concentrations are above action limits. If levels are too high, personnel working in the vicinity of the well will put on protective gear. Place the portable tripod with winch over the well and manually place the probe into the top of the well so that it is suspended from the support cable.

7. Using the winch, lower the probe into the well to the desired depth. The electrical and gas lines will be fed manually while the winch lowers the probe.

8. Attach the main probe power cable to the pigtail cable. Supplying power to the probe will turn on the sample pump.

9. Attach the air compressor to the gas line of the probe and pressurize to 30 psi to set the packers. If comparison testing with an aboveground PAWS system, attach the sample tube from the probe to the PAWS system and to any other on-line instruments (e.g., Brüel and Kjær). If directed by the field team leader, a carbon-based scrubber canister will be attached to all lines being exhausted to collect the contaminant.

10. For wells where a pre-purge value is to be determined, the sensor system will be operated prior to purging.

11. Operating the sensor system involves setting up the parameters for the run (e.g., scrub time, number of cycles, calibration coefficient) in the software, initiating the run and noting the concentration values determined during the run, and plotting out the results upon completion of the run. Runs will be repeated if necessary.

12. When comparison testing is being performed, the aboveground PAWS system will be run simultaneously with the in situ system. Gas samples will be drawn at known times for analysis by gas chromatography by onsite personnel or the Brüel and Kjær instrument will be used on-line.

13. Using the aboveground switch, turn on the pump that purges the packed off region. Pump long enough to pull at least two well volumes from the well. The sensor system will be operated (see step 11) during the purge to monitor in real-time the changes in contaminant concentration with volume purged.

14. The sensor system will be operated after purging (see step 11) to determine the contaminant concentration in the formation.

15. Disconnect the main electrical cable from pigtail cable. Release the pressure on the line to deflate the packers and then disconnect the gas line from the air compressor.

16. Repeat steps 7 to 15 for each of the well depths to be tested.

17. When testing on a given well is complete, pull the probe up using the winch while manually respooling the electrical and gas lines. Disconnect the electrical cable, the gas line, and the winch line from the probe.

18. Move the various components to a new well and repeat steps 5 to 17 for each well to be tested. If changing well diameters from a 4 to 6 in. or larger well (or vice versa), the packers will need to be changed.

19. After testing is completed, have the probe and associated hardware tested for contamination.

20. Prepare system hardware for transportation back to SNL or for transfer to Hanford environmental restoration personnel.

APPENDIX B

MULTISORBENT ARRAYED SAMPLER OPERATIONS PROCEDURES

Operation of the multisorbent arrayed sampler will be done in accordance with the following procedure:

1. Transport the sampler, purge pumps, cable, gas lines, and regulators to the Hanford Site.

2. Reassemble the sampler and load with six fresh multisorbent traps.

3. Make electrical connections between the switch control equipment and the power supplies and the sampler cable.

4. Electrically connect the sampler to the spooled cable and connect the gas line for the packers.

5. If comparison testing with aboveground instrument(s) is to be performed, attach the Teflon or other tube to the sampler line exhaust.

6. Open the well to be sampled and monitor the air concentrations in the vicinity to determine if concentrations are above action limits. If levels are too high, personnel working in the vicinity of the well will put on protective gear. Manually place the sampler into the top of the well so that it is suspended from the support cable.

7. Lower the sampler into the well to the predetermined depth.

8. Inflate the packers using the cylinder of nitrogen. The regulator on the cylinder is affixed with a bleed valve to ensure the packers do not over-inflate.

9. Once a decision is made to acquire a sample, the switch controlling the solenoid valves which isolate one of the six traps is thrown, and the vacuum source control valve is moved from a bypass to a sampling position.

10. The time is noted, and the flow rate through the vacuum line (and through the trap) is recorded by the operator.

11. When an adequate volume has been collected on the trap, the solenoid valves are closed, and the sampling flow routed to bypass.

12. Up to six separate samples on separate traps can be taken utilizing steps 9, 10, and 11 before the sampler must be returned to the surface, and fresh traps loaded into the system.

13. Release the nitrogen pressure to deflate the packers.

14. When testing on a given well is complete, disconnect the electrical cable and pull the sampler to the surface.

15. Move the various components to a new well and repeat steps 2 to 14 for each well to be sampler.

16. After sampling is completed, have the sampler and associated hardware surveyed for contamination.

17. Prepare the sampler for transportation back to Oak Ridge.

The following procedures relating to manufacture and analysis of sorbent tubes for the multisorbent arrayed sampler will be followed for this demonstration:

ORNL, 1993, Procedure for Manufacturing Single and Multi-Carbon Sorbent Traps, Standard Operating Procedure AC-OP-300-0907.

ORNL, 1993, Measurement of Volatile Organic Compounds by Thermal Desorption and Gas Chromatography, Standard Operating Procedure AC-MM-1-003153.

APPENDIX C

WELLS FOR PAWS AND MULTISORBENT ARRAYED SAMPLER MONITORING

The following is a list of wells for the PAWS and multisorbent arrayed sampler test (Table C-1). Also included is a map showing well locations see Figure C-1.

Table C-1. Wells for PAWS and Multisorbent Arrayed Sampler Monitoring

Well	Diameter (in.)	Completion (ft)
W15-6	6	Perforated 175 to 300
W15-9	4 (liner)	Perforated 186 to 189
W15-22	4	Screened 198.5 to 219.8
W15-82	8	Perforated 73 to 88
W15-85	8	Perforated 83 to 98
W15-95	8	Perforated 83 to 98
W15-216	4	Two Screens: 70 to 80, 175 to 185
W15-217	4	Screen: 106 to 121
W15-218	4	Two Screens: 98.5 to 113.5, 180.5 to 195.5
W15-219	4	Two Screens: 87 to 102, 167 to 182
W15-220	4	Two Screens: 80 to 95, 155 to 170
W18-2	8 (w/6-in. screen)	Perforated 200 to 278, screen: 205 to 254.5
W18-6	6 (linear)	Perforated 190 to 278
W18-9	6 (w/5-in. screen)	Perforated 180 to 218, Screen: 182 to 212
W18-12	6 (w/5-in. screen)	Perforated 180 to 218, Screen: 194 to 214
W18-24	4	Screened 205.5 to 235.5
W18-85	6	Open at Bottom: 150
W18-86	6	Open at Bottom: 150
W18-153	8	Open at Bottom: 110
W18-157	8	Open at Bottom: 110
W18-246	4	Two Screens: 120 to 130, 165 to 175
W18-247	4	Two Screens: 119 to 129, 162 to 172
W18-248	4	Screen: 123 to 138
W18-249	4	Screen: 122 to 137

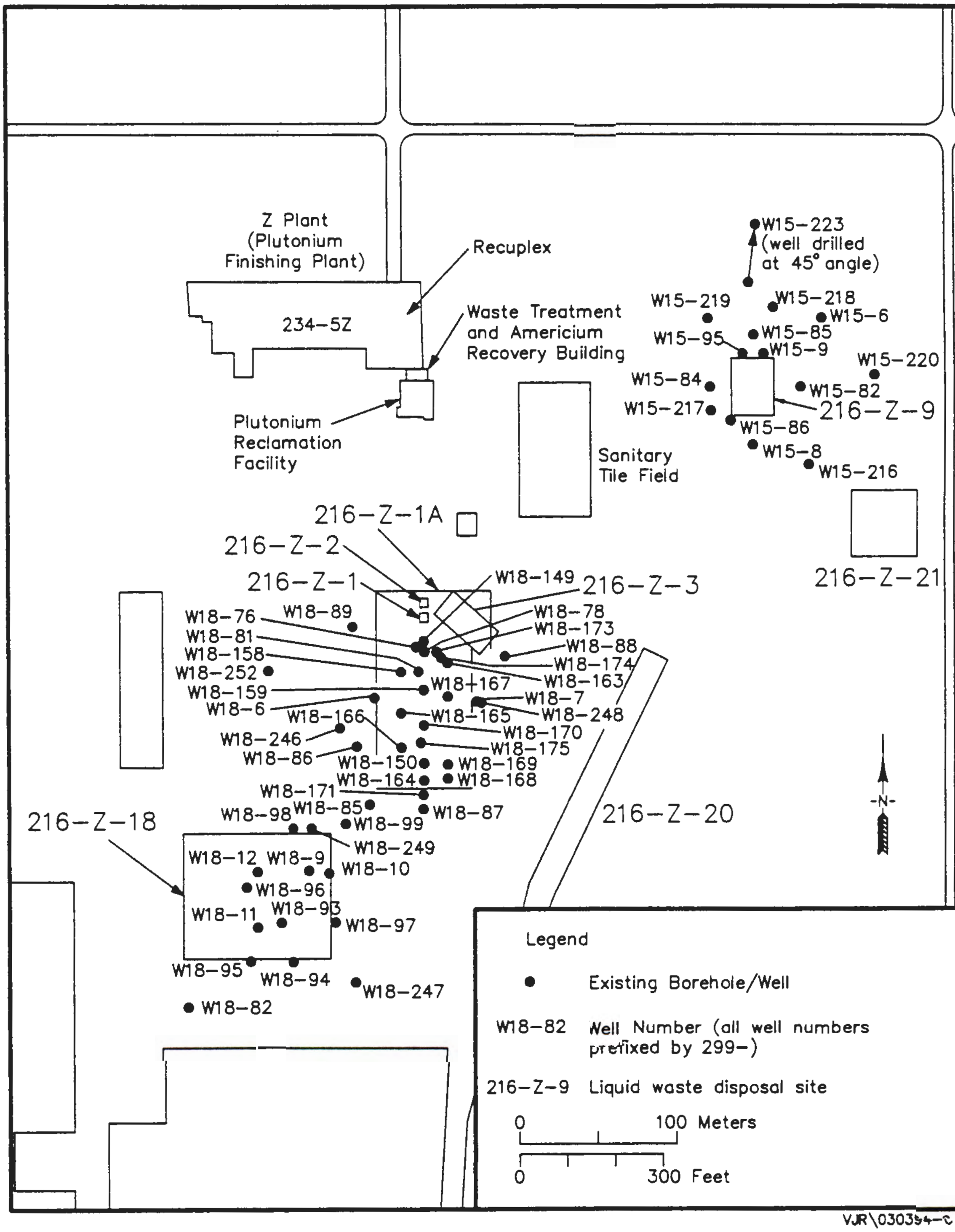

Figure C-1. Well Field.

INFORMATION RELEASE REQUEST

Date Received: 5/12/94 08

Reference: WHC-CM-3-4

Complete for all Types of Release

Purpose		ID Number (include revision, volume, etc.)
[] Speech or Presentation	[] Reference	WHC-SD-EN-TP-045, Rev. 0
[] Full Paper (Check only one suffix)	[x] Technical Report	List attachments.
[] Summary	[] Thesis or Dissertation	
[] Abstract	[] Manual	
[] Visual Aid	[] Brochure/Flier	
[] Speakers Bureau	[] Software/Database	Date Release Required
[] Poster Session	[] Controlled Document	5/9/94
[] Videotape	[] Other	

Title: Integrated Test Plan for the Demonstration of the PAWS and Multisorbent Arrayed Sampler

Unclassified Category: UC-

Impact Level: Q

New or novel (patentable) subject matter? [X] No [] Yes
If "Yes", has disclosure been submitted by WHC or other company?
[] No [] Yes Disclosure No(s).

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