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INNOVATIVE TECHNOLOGY
Summary Report

Surface Acoustic Wave/Gas Chromatography System for Trace Vapor Analysis

Industry Programs

Prepared for
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INNOVATIVE TECHNOLOGY
Summary Report

Surface Acoustic Wave/Gas Chromatography System for Trace Vapor Analysis

OST Reference # 282

Industry Programs

Demonstrated at
U.S. Department of Energy Sites:
Savannah River Site, South Carolina
Idaho National Engineering
and Environmental Laboratory, Idaho
Hanford Site, Washington

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Technology Description

Surface Acoustic Wave/Gas Chromatography (SAW/GC) provides a cost-effective system for collecting real-time field screening data for characterization of vapor streams contaminated with volatile organic compounds (VOCs). The technology was developed by the Amerasia Technology Corporation supported by the U.S. Department of Energy (DOE) Office of Science and Technology (OST) through its Industry Program at the Federal Energy Technology Center (FETC). A new company, Electronic Sensor Technology (EST), was incorporated to manufacture, distribute, and market the Model 4100 SAW/GC.

Problem

There is a need to quickly analyze a large number of samples during site characterization. The Model 4100 can be used in a field screening mode to produce chromatograms in 10 seconds. This capability allows a project manager to make immediate decisions and avoid the long delays and high costs associated with analysis by off-site analytical laboratories. The Model 4100 will not replace a reference laboratory, but instead provides a cost-effective means of quickly analyzing a large number of samples during site characterization and minimizes the number of “clean samples,” i.e., those below threshold contamination levels, that need to be analyzed.

How it Works

The Model 4100 SAW/GC shown in Figure 1

- is based on gas chromatography (GC) and surface acoustic wave (SAW) technologies;
- consists of the following two components connected with an umbilical cord:
  - a handheld module containing a piezoelectric surface acoustic wave sensor, a capillary gas chromatograph, an air pump, and a six-way GC valve;
  - a support module, which supplies the helium gas and the electrical power and incorporates a laptop computer;

Figure 1. Model 4100 SAW/GC.

- can be used for sampling vapor streams from environmental characterization and monitoring applications, remediation waste streams, processing applications that include food and medical analyses, and other monitoring applications such as workplace monitoring;

- has specific environmental applications, including air monitoring, stack emissions monitoring, underground storage tank monitoring, soil and ground water characterization, and screening of hazardous workplaces;

- is fast, portable, rugged, and can detect compounds at the parts per billion (ppb) level using extremely low-volume samples.

- should be considered for field monitoring and characterization if there is a need

  - to make in situ measurements;
  - to make decisions in real time, i.e., 8 hours or less;
  - to reduce fixed laboratory costs; or
  - to identify and characterize contaminant hot spots instead of sampling an entire site.

A sample chromatogram is shown in Figure 2.

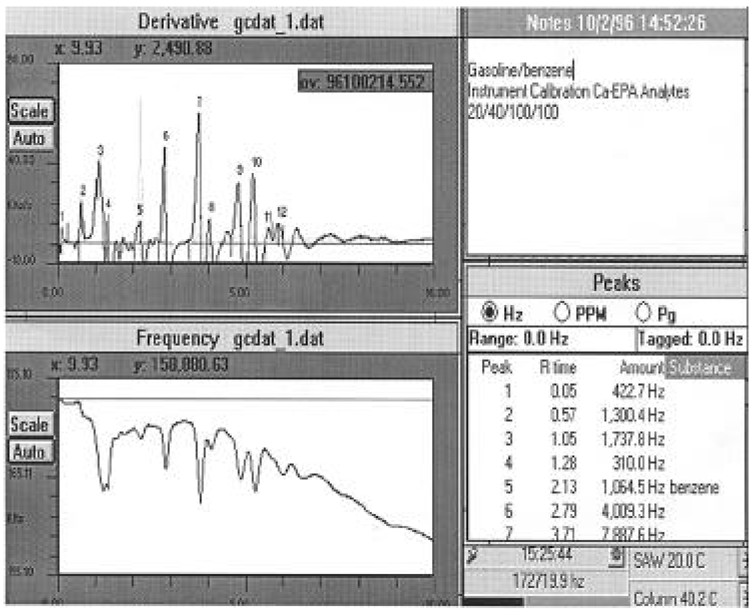

Figure 2. Representative chromatogram showing the use of Model 4100 in field mode to analyze soils near a leaking underground fuel tank (LUFT).

Advantages over the Baseline

When compared to using a stationary analytical laboratory, this technology reduces the likelihood of losing VOCs during sample handling, transport, and holding; there is no problem with holding time requirements; and the per sample cost is less.

In comparison to other portable analytical instruments, this technology has greater sensitivity than many similar instruments and has a lower capital cost.

Technology Status

The Model 4100 SAW/GC has been demonstrated and evaluated at a number of DOE sites (Savannah River Site [SRS], Lawrence Berkeley National Laboratory [LBNL], Hanford, and Idaho National Engineering and Environmental Laboratory [INEEL]) to verify its performance under a number of different applications.

The Model 4100 SAW/GC is currently under evaluation by the California Environmental Protection Agency (Cal EPA) Technology Certification Program. This process requires the review of all quality control aspects in the field, operation, and manufacture. Initial certification focuses upon the following compounds:

- cis-dichloroethylene (cis-DCE)
- chloroform (CF)
- carbon tetrachloride (CT)
- trichloroethylene (TCE)
- tetrachloroethylene (PCE)
- tetrachloroethane (1,1,2,2-TCA)
- benzene (B)
- ethylbenzene (EB)
- toluene (T)
- o-xylene (O-X)

Specific and defensible performance claims will be available when certification is completed. Cal EPA certification is expected in 1998. Cal EPA certification is accepted currently by all state, county, and municipal agencies in California and by five other states: New York, Massachusetts, New Jersey, Illinois, and Pennsylvania.

- The SAW detector shows a large dynamic range and is linear over a wide range of concentrations (Figure 3).

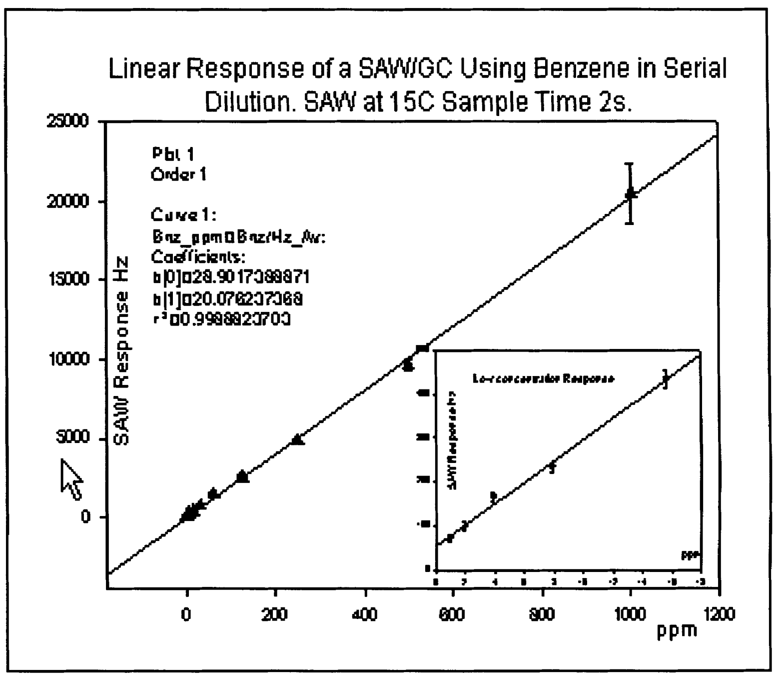

Figure 3. Representative chromatogram of benzene samples generated during Cal EPA certification.

- The r^2 for this calibration curve was found to be 0.9998.
- The dynamic range for this calibration at a 2-second sample time was 450 ppb to 1,100 parts per million (ppm).

Commercial Availability

The Model 4100 SAW/GC is commercially available at this time from EST, which holds a U.S. patent (number 5,289,715) for the technology. The computer programs controlling the Model 4100 are proprietary and restricted. This includes all algorithms for peak detection and signal processing.

Contacts

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Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference # for SAW/GC is 282.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall System Description

- The Model 4100 SAW/GC instrument couples a piezoelectric surface acoustic wave (SAW) sensor and a capillary gas chromatograph (GC) with a dynamic particle/vapor sampling interface. The instrument comprises two parts: (1) a head assembly containing the capillary column, the six-port valve, oven trap, and SAW detector; and (2) a support chassis containing the helium carrier gas, laptop computer, and the thermoelectric processors. The unit is 14 by 20 by 10 inches and weighs only 35 pounds. The components are housed in a shock-mounted field-portable fiberglass carrying case.

- Samples are introduced to the Model 4100 using a Tedlar bag or by direct injection. A needle attached to the nose of the instrument is used to puncture the septum of the Tedlar bag and approximately
5 milliliters of sample is injected for one analysis (Figure 4).

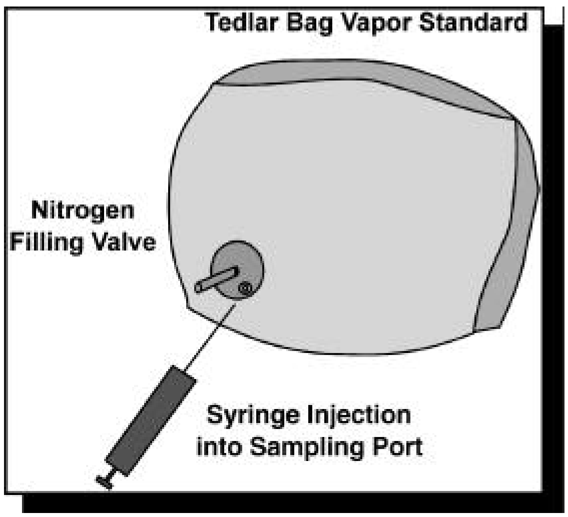

Figure 4. Tedlar bag.

- The instrument is controlled by proprietary software that allows the operator to select or develop a method, program various component temperatures, and automatically record the data for future recall.

- The system uses a two-position, six-port GC valve to switch between sampling and injection modes (Figure 5).

  – In the sample position, headspace vapor is first passed through an inlet preconcentrator or water trap and then through the inlet, valve, and loop trap. The loop trap concentrates the suspect compounds. At the same time, helium carrier gas passes through the alternate ports of the valve to a capillary column, impinging on the surface of a temperature-controlled SAW resonator.

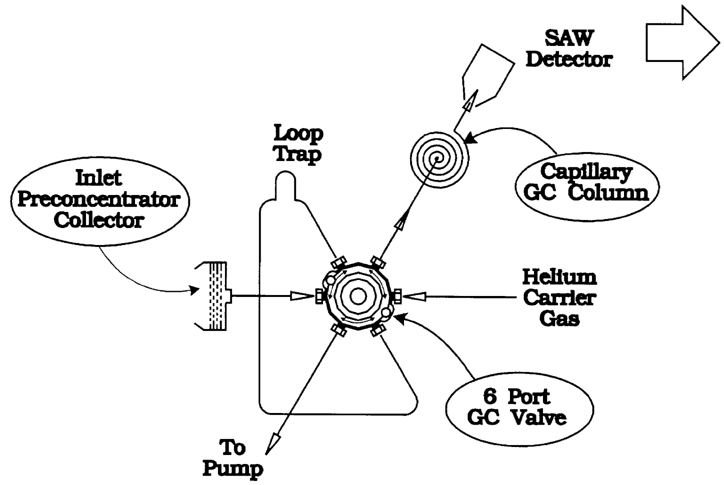

Figure 5. System diagram.

- When the valve trap is switched into the injection position, the flow of helium carrier gas is reversed through the column, and the loop trap is rapidly heated to 200 °C causing the release of the contaminants to the head of the GC column. The temperature of the GC column is linearly ramped to approximately 125 °C over 10 seconds causing the VOCs to separate as they travel down the column.

- As the contaminants pass through the GC column, they are separated. As the resolved analytes strike the surface of the resonant SAW sensor, they cause the resonant frequency of the crystal to change. The frequency shift is recorded and the concentration level of the compound is calculated in ppb or picograms.
  - The adsorption to the surface of the resonator causes a change in the characteristic frequency of the piezoelectric crystal. The adsorption efficiency for a given compound is dependent on the crystal temperature.
  - By operating the crystal at different temperatures using the system software, the crystal can be made specific for given materials based on the vapor pressure of the material.
  - The SAW sensor determines the mass density of the compound and reports it to the database maintained in the 486 laptop computer.
  - To obtain a conventional chromatogram plot of retention time, the derivative of frequency versus time is calculated. A representative chromatogram with a peak identification table is shown in Figure 6.

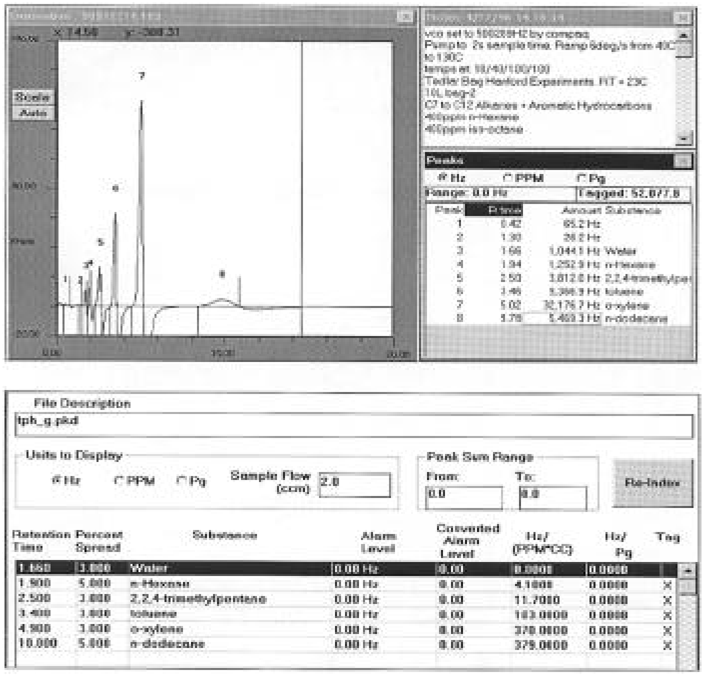

Figure 6. A 20-second chromatogram with a peak identification table.

- In the leaking underground fuel tanks (LUFT) configuration, a useful set of standards is the alkane hydrocarbons homologous series from C_6-C_{12}.

- A peak identification table shows alkanes and aromatic hydrocarbons.

* Several standard compounds are used for contaminant identification. The Model 4100 identifies the unknown compounds through comparison with the many chemical signatures stored in the database. For screening analyses, benzene is needed to establish retention time reference. For quantitative results at the ppm level in real time, additional standards can be run before field screening to determine a scaling factor for compounds.

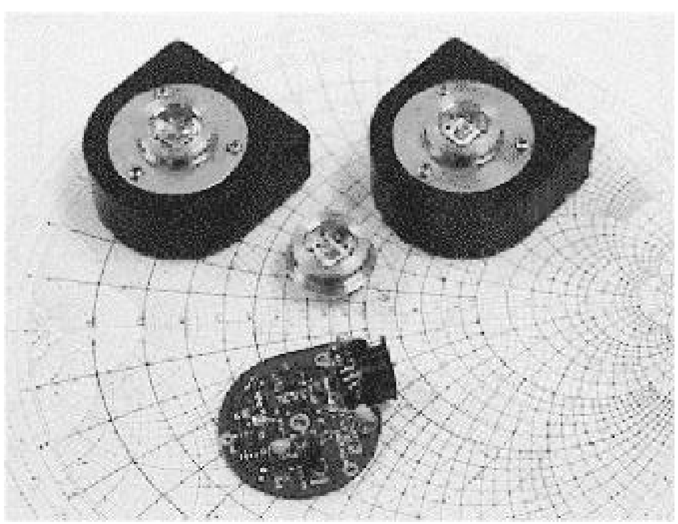

Figure 7. Photo of the Surface Acoustic Wave (SAW) detector.

- SAW sensors are quartz crystals having patterned electrodes that allow a high-frequency (60-1000 MHz) surface acoustic wave to be maintained on their surface.

  – The crystal frequency is dependent on the spacing of the electrode pattern, the crystal temperature, and the condition of the surface. Because the electrode pattern of a given SAW crystal is fixed, the frequency of the SAW sensor is dependent on the material adsorbed onto the quartz surface.

  – The innovative feature of the SAW resonator is that the temperature of the SAW sensor can be programmed using a thermoelectric cooling/heating module bonded under the SAW crystal.

  – In this configuration, the detector displays a wide dynamic operational range, up to six orders of magnitude. This dynamic range is not found in other detectors.

  – The thermoelectric module is controlled by the computer, maintaining the SAW crystal at temperatures between 20 and 200° C. Lower temperatures can be obtained by cascading thermoelectric coolers. The SAW resonator can be cooled during the analysis time when the materials are eluting from the column, thus ensuring that materials will adsorb onto the SAW surface.

  – At the end of the injection cycle, the SAW can be heated to temperatures greater than 150°C to boil off materials from the previous injection, thus cleaning the SAW surface for the subsequent analysis. This feature makes it unique among existing detectors.

- During development of the technology, a quality control plan was implemented. This plan called for the use of Underwriters Laboratory-approved wiring for safety and thermal imaging of the column and oven to optimize performance while minimizing cold spots. The instrument was reduced in size and weight by 50 percent. Significant changes were made to the electronic and mechanical design to reduce power consumption while increasing sensitivity.

- The system is simple to operate and can be used safely by properly trained technicians. Technicians should complete 16 hours of basic training provided by the vendor.

PERFORMANCE

Laboratory Testing

Laboratory testing first established ideal minimum detection levels for selected target compounds (Table 1). Representative compounds typical of those found at hazardous waste sites were tested using two different GC columns.

Table 1. Measurement range of Model 4100 for selected compounds.

Analyte	Minimum (ppb)	Maximum (ppb)
Carbon Tetrachloride (CT)	70	100,195
cis-Dichloroethylene (DCE)	110	186,420
Chloroform (CF)	65	182,351
Trichloroethylene (TCE)	10	74,926
Tetrachloroethylene (PCE)	3	17,965
1,1,2,2-Tetrachloroethane (TCA)	1	6,256
Benzene (B)	45	106,711
Toluene (T)	4	29,276
Ethylbenzene (EB)	2	98,263
O-Xylene (o-X)	2	6,465

A typical display screen presenting both visual and numerical data results is shown in Figure 8.

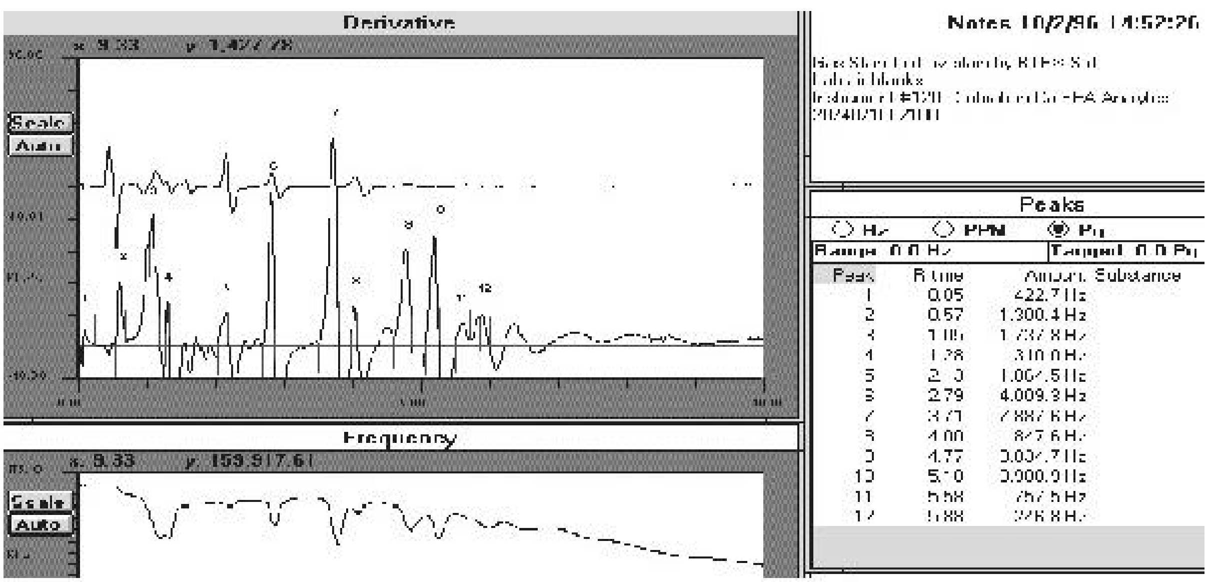

Figure 8. Chromatogram displaying screen presenting visual and numerical data results.

The instrument was able to characterize and separate a calibrated mixture of TO-14 compounds (a U.S. Environmental Protection Agency [EPA] standard mixture of 39 compounds for air quality sample analysis) in 20 seconds. Figure 9 displays the result of such an analysis.

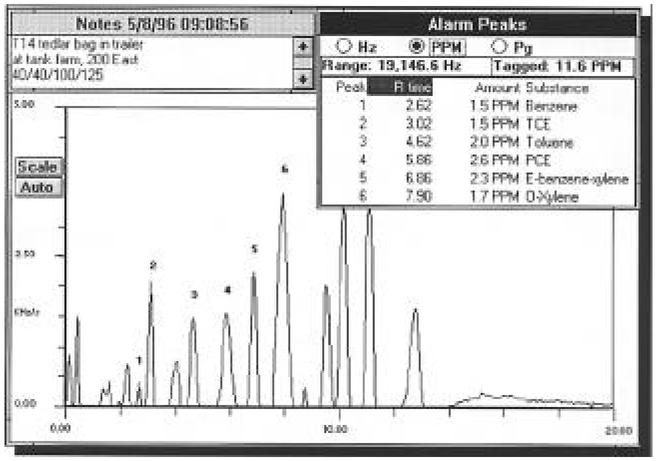

Figure 9. TO-14 analysis with optional peak tagging.

Demonstrations and Evaluations

- Field testing of the SAW/GC was first performed in M-Area at SRS in 1995. Testing was done on water, soil, and gas samples. The performance of the SAW/GC prototype was validated with results obtained with an on-site Hewlett Packard gas chromatograph. The comparison showed that results agreed within 20 percent. This evaluation documented that the Model 4100 could identify and quantify the presence of VOCs, specifically TCE and PCE. Figure 10 shows results of analysis of gas samples from the headspace of contaminated wells.

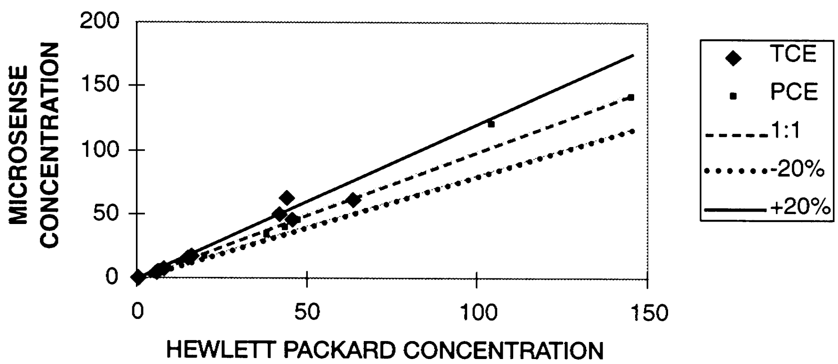

Figure 10. Verification of the Surface Acoustic Wave/Gas Chromatography (SAW/GC) with the Savannah River Site (SRS) gas chromatograph. Measurement units are ppm.

- At LBNL in February 1996, the Model 4100 was used for characterization of soil gas and ground water with PCE and TCE at the ppb levels. Samples were collected from wells fitted with septum lids designed to accumulate soil gas. The Model 4100 demonstrated its ability to speciate contaminants in real time. Instrument calibration and compound identification was provided by preparing a 1 liter tedlar bag with the analytes at a 1 ppm concentration level.

- In April 1996, the Model 4100 was demonstrated at DOE's INEEL to perform vapor monitoring in wells surrounding the Radioactive Waste Management Complex (RWMC) and ground water monitoring at the Test Area North (TAN) (Figure 11).

  – At the first site, the Central facility in the RWMC, the Model 4100 was evaluated as a well headspace monitor. Forty tedlar bags from 20 wells (samples were collected at different depths within a well) were analyzed in approximately one hour for carbon tetrachloride, chloroform, and TCE. Accuracy over the range of 20–500 ppm was validated by more than 10 calibration runs. Samples were also collected directly from the sampling port at the wellhead for field analysis, thus removing the need and cost of tedlar bags.

Figure 11. Sampling a well head at Idaho National Engineering and Environmental Laboratory, Idaho.

- At the second site, the Ground Water Treatment Facility (GWTF) at TAN, the Model 4100 successfully detected DCE, TCE and PCE at the ppb level. Figure 12 displays a chromatogram of the analytes of interest at the GWTF.

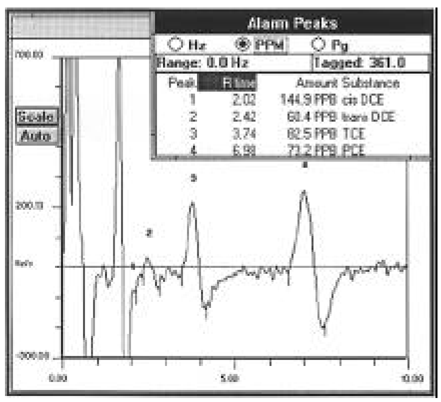

Figure 12. Chromatogram of Ground Water Treatment Facility analytes of interest.

- During May 1996, demonstrations were conducted at the DOE Hanford Site, in both the 200 Area West and the 200 Area East. Samples were collected from the headspace of tanks containing mixed wastes (Figure 13). Both tedlar bags and summa canisters were used for sample collection. Two instruments with different columns were demonstrated first in the laboratory and then in the field.
  - Typically, the samples are collected and sent to a laboratory for analysis of hydrocarbons by GC/mass spectrometry(MS) using an EPA method for TO-14 compounds.
  - For this demonstration, the samples were analyzed using standards supplied by the laboratory. Total hydrocarbon content was determined by summation of the individual components. The Model 4100 reduced the time required for an individual sample analysis from 50 minutes using a GC/MS in the lab to two minutes using the Model 4100 in the field.

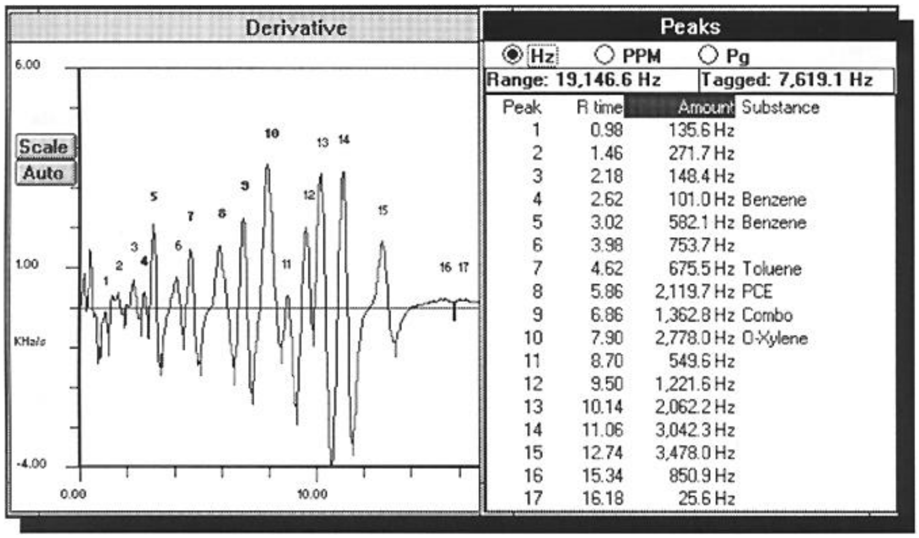

Figure 13. Chromatogram of tank farm analytes of interest.

- The Model 4100 SAW/GC was tested at the Cal EPA Hazardous Materials Laboratory, Berkeley, California, for specificity and sensitivity toward dioxins, furans, and polychlorinated biphenyls (PCBs) (Figure 14). Because these compounds have vapor pressures of 5–12 orders of magnitude less than VOCs, the SAW was modified to operate at significantly higher temperatures to ensure uniform evaporation. Target detection limits were established at the ppm level by using calibrated amounts of the subject compounds (EPA-prepared solvent solutions with contaminant concentrations ranging from 0.1 to 50 ppm).
    - The instrument was able to detect these compounds at the 0.1- ppm level. Subsequent experiments using real samples of fly ash containing dioxins and PCBs showed that the instrument was sensitive to 5 picograms over a sampling time of 10 seconds.

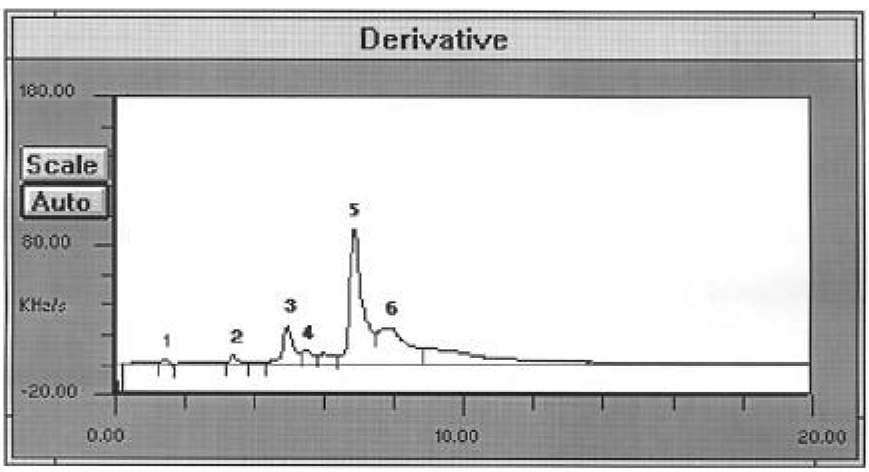

Figure 14. Response to dioxin-dibenzofurans mixture.

- The Model 4100 SAW/GC was demonstrated at a Chicago Refinery to identify and quantify carbon scrubber efficiency in the containment of VOCs. The Model 4100 accurately detected benzene and toluene at the inlet and outlet to the scrubber (Figure 15).

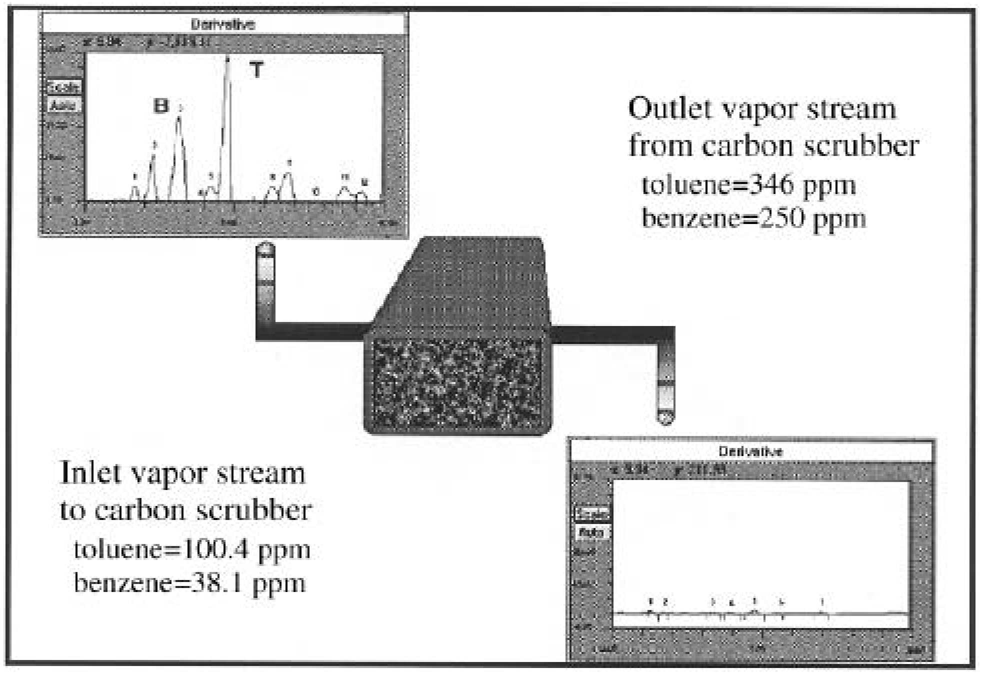

Figure 15. Volatile organic compounds detected at the inlet and outlet of a carbon scrubber.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

- The specific problem targeted for this technology is quantitative field analysis of non-polar compounds, generally solvents and PCBs, at hazardous waste sites. The technology is especially effective at waste sites where historical information is available on the expected contaminant suite and concentration. SAW/GC can be used for site characterization and monitoring, and remediation waste stream (e.g., off gas) monitoring. The technology can be used on liquid and vapor samples.

- The SAWS/GC technology can also be used for other applications such as:

  – environmental monitoring of chemical processes, fugitive emissions, and Occupational Safety and Health Administration/Clean Air Act (OSHA/CAA) materials;

  – industrial monitoring including continuous emissions monitoring (CEM) of stack emissions, particle chemical processes, and other processes;

  – detection of contraband, drugs, explosives, and lethal chemicals for law enforcement and the military;

  – workplace monitoring for environmental health and safety.

- It is not expected that field screening with the Model 4100 will replace laboratory analysis, but it can be used to significantly reduce the number of samples sent off site for more expensive laboratory analysis.

- Field screening with the Model 4100 allows collection of large data sets because of the relatively low cost of analyzing additional samples. Collection of a large number of replicate quantitative measurements at a low cost allows for a more robust statistical evaluation of the analytical results.

Competing Technologies

- In Section 5, Cost, the technology is compared with two baseline scenarios:

  – The first comparison is to a stationary analytical laboratory using Resource Conservation & Recovery Act (RCRA) protocols.

    The standard method for analysis of soil and ground water samples is to package and document the sample according to EPA handling and chain-of-custody requirements and to ship the samples to a commercial laboratory for analysis. Laboratory analyses are done using procedures defined by the EPA in document SW-846.

  – The second comparison is with other portable analytical instruments, including GC and GC/MS.

- Analyses by a commercial laboratory on a per sample basis are significantly more expensive than field screening.

- Field analysis of samples minimizes problems associated with potential loss of VOCs during sample handling, transport, and holding.

- Field analysis of samples eliminates problems associated with holding time requirements.

- Many other portable field instruments are commercially available, but most are not comparable because either they do not adequately speciate contaminants or they do not have adequate sensitivity (e.g., Fourier transform infrared, fluorescence, Raman, simple surface acoustic wave spectroscopy, solid state sensors on a chip, photoionization detectors, electron capture detectors, flame ionization detectors, and immunoassay test kits).

- The performance of field portable GC/MS instruments is comparable with the Model 4100, but capital costs for GC/MS units are approximately three times as expensive.

SECTION 5

COST

Introduction

In 1992, the Los Alamos National Laboratory (LANL) compared the cost of analysis for VOCs in soil, water, and gas samples by commercial laboratory and by six different field instruments (Henricksen and Booth, 1992). The study concluded that field sampling and analysis of VOCs offers substantial savings above a certain threshold number of samples per year (on the order of 100 samples per year). They documented a factor-of-five reduction in cost per sample using field screening methods over commercial laboratory analysis. They compared six field screening instruments, several of which are comparable in performance to the Model 4100. The cost decision for selection of the field screening devices was driven by capital cost of the instrument and supporting equipment, because the annual operating costs of the six methods was relatively constant. The capital costs, in 1992 dollars, ranged from $42K to $166K while the estimate of annual operating expenses ranged from $147K to $159K.

Discussion

A direct comparison of the Model 4100 with the results obtained from the LANL study is not possible for the following reasons. First, due to lack of operating experience, reliable estimates of the operating cost for the EST SAW/GC are not available. A rough estimate was obtained from the vendor and is included below. Second, the LANL report was written in 1992 and is priced in 1992 dollars. While it is reasonable to escalate operating costs to 1997 dollars, it is not reasonable to escalate hardware prices because they typically do not increase. Most often, the equipment manufacturer releases a new version of the instrument with improved capabilities and at an increased price.

The following analysis summarizes capital and operating cost estimates for the Model 4100 instrument. It is very important to note that a rather robust operational scenario (Scenario 1) for the equipment was used. This includes the cost of two technicians and a vehicle to support the use of the instrument. In most DOE applications, personnel and vehicles are available and are currently assigned to sampling and analysis tasks. The cost of implementation in this case is much less than estimated here and is shown as Scenario 2. This scenario was chosen so that the operational costs can be compared with the other instruments in the referenced LANL report. In fact, the report showed that operational costs for the selected field screening instruments are very similar. Because a price was not available from the vendor, the estimated capital price of $44,000 is based on similar technology used in the security industry.

Model 4100 capital cost estimate, 1997 dollars

	Scenario 1	Scenario 2
Instrument	$44,000	$44,000
Training and User Support Kit	$2,000	$2,000
Vehicle*	$20,000	
Total	$66,000	$46,000

SAW/GC operating cost estimates, 1997 dollars

	Scenario 1	Scenario 2
Two full-time technicians*	$139,200	
Trap	$350	$350
Helium carrier gas 99.9995%	$740	$740
VOC offgas treatment	$1,000	$1,000
GC column	$4,000	$4,000
Maintenance contract	$2,500	$2,500
Other consumables	$2,500	$2,500
Vehicle operation*	$3,560	$3,560
Admin overhead	$7,420	$7,420
Total	$161,270	$22,070

*Sponsoring organizations at SRS, INEEL, and Hanford currently have technicians and vehicles in place within the organization. The cost of the technicians and vehicle is included to allow comparison with the following instruments.

The following is a summary of the LANL data for detectors summarized in Table 5 (pp. 35–36) of the LANL report. The escalation to 1997 dollars is a compounded 3.1 percent per year, and no attempt was made to re-price the instruments evaluated in the report.

Table 2: LANL estimates of capital and operating costs for six methods of VOC analysis in the field

INSTRUMENT	CAPITAL COST 1992 dollars	OPERATING COST 1992 dollars	OPERATING COST 1997 dollars*
Direct Sampling Ion Trap Mass Spectrometer (DSITMS)	$111,525	$148,674	$172,460
LANL GC/MS w/ITMS	$142,725	$149,571	$173,500
Hewlett Packard 5890 GC w/5971A MSD	$78,947	$151,170	$175,357
VIKING SPECTRA TRAK 620	$165,575	$158,541	$183,910
PHOTOVAC GC w/PID	$42,010	$146,823	$170,315
SENTEX GC w/AID/ECD	$42,645	$147,862	$171,520

*Assumes 3.1 percent per year escalation rate 1992-1997.

Estimated operating costs for all instruments including the Model 4100 are very similar. A detailed discussion of the performance characteristics of the instruments is contained in the LANL report. In summary, the DSITMS, the GC/MS, and the Model 4100 can detect most compounds of interest at the low ppb level in real time. The Sentex instrument requires preconcentration to routinely detect at the ppb level, and in real time, can only detect at the ppm level. The Photovac can detect from ppm to low ppb for some compounds but in real time only at the ppm level.

Conclusions

- The LANL study clearly documents a significant cost savings (a factor-of-five) when field screening instruments are used for analysis of VOCs in ground water and sediments, reducing the number of samples sent to commercial labs for analysis.
- The LANL study shows that field screening technology selection decisions are driven by the capital cost of the instrument, because annual operating costs are relatively similar for different instruments.
- The only commercially available analytical instruments that provide unambiguous compound identification with ppb levels of sensitivity utilize mass spectrometric techniques.
- The cost comparison of the Model 4100 to mass spectrometric techniques is very favorable (capital costs of Model 4100 ~ 30 percent of mass spectrometer).

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

- Although field screening methods, such as the Model 4100 SAW/GC, generally provide rapid, high-quality, compound-specific data with minimal instrument maintenance and operating cost, procedures and application for their use are not generally as well documented as the EPA reference methods.
- A significant effort must be made by technology developers to acquire regulatory acceptance for new field methods.
- Secondary waste stream generation is the same or slightly reduced with the use of the Model 4100 over baseline methods.
- Field analysis of samples minimizes problems associated with potential loss of VOCs during sample handling, transport, and holding.
- Field analysis of samples eliminates problems associated with holding time requirements
- Chain-of-custody requirements do not apply because samples are not transported.

Safety, Risks, Benefits, and Community Reaction

Worker Safety

- The system is simple to operate and can be used safely by properly trained technicians. Technicians are required to complete 16 hours of basic training.

Community Safety

- Field analysis of samples minimizes risks posed by sample handling, transport, and holding.

Environmental Impact

- None

Socioeconomic Impacts and Community Perception

- Use of the technology will have minimal impact on the labor force and the economy of the region.

SECTION 7

LESSONS LEARNED

Implementation Considerations

- The site manager must work with regulators to assure acceptance of the data collected. The pending Cal EPA Certification will assist in this acceptance.
- Field screening is not expected to replace laboratory analysis, but can be used to significantly reduce the number of samples sent off site.

Technology Limitations and Needs for Future Development

- The Model 4100 will not distinguish constituents that elute from the GC column at the same time. Careful choice of GC columns, taking into consideration anticipated constituents, will eliminate this problem.
- The Model 4100 is an excellent choice for robust field screening of non-polar compounds. Baseline GC/MS may provide better speciation in some settings, but capital costs are approximately three times as much.

Technology Selection Considerations

- Field screening methods, such as the Model 4100 SAW/GC, have the potential to provide rapid, high-quality, compound-specific data with minimal instrument maintenance and operating cost when compared to EPA reference methods. These methods should be used in conjunction with laboratory analysis of a subset of samples for verification of the technology’s performance.
- The accuracy of the Model 4100 SAW/GC usually derives from the fact that an expected suite and concentration of contaminants at DOE sites are generally known. Field screening using the Model 4100 can provide very good data where there is historical information to serve as a guide.
- Field screening methods allow collection of a large data set at a low cost, consistent with the well-documented statistical approaches in exploration geochemistry.

APPENDIX A

REFERENCES

Henriksen, A.D. and S.R. Booth, 1992, *Cost Effectiveness of an Innovative Technology for VOC Detection: The Direct Sampling Ion Trap Mass Spectrometer*, LA-UR 92-3527, Los Alamos National Laboratory.