INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0497

Long Range Alpha Detection for Component Monitoring

Deactivation and Decommissioning
Focus Area

Prepared for
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INNOVATIVE TECHNOLOGY
Summary Report

Long Range Alpha Detection for Component Monitoring

OST/TMS ID 2382

Deactivation and Decommissioning
Focus Area

Demonstrated at
321-M Fuel Fabrication Facility
Savannah River Site
Aiken, South Carolina

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 whether 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://ost.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

The IonSens™ Cut Pipe Monitor is an application of the Long Range Alpha Detection method of measuring alpha emitting contamination on surfaces of materials. The monitor provides a method of measuring alpha contamination in areas that are inaccessible to the hand probe and smear baseline, but accessible to the flow of ambient air. While the costs of surveying items using the baseline technology varies with item complexity and surface area, measurement time of the IonSens™ system is the same for all items regardless of surface area or complexity. Therefore, the IonSens™ system provides cost savings when monitoring large or complex items and multiple items during single measurement cycles. The cost for monitoring a single item with the IonSens™ monitor was $8.49 versus $3.30 for the baseline. For multiple items, cost savings begin with three items per cycle and increase thereafter. The cost drops to $1.70 per item if five items are monitored in a single measurement cycle. Items with surfaces inaccessible to the baseline technology are normally managed as low level radioactive waste. One measurement cycle, costing approximately $8.49, can preclude the disposal of several cubic feet of waste, which costs $106.00/ft^3 (SRS disposal rates).

Technology Summary

Problem

Many items (pipe, tools, fluorescent light bulbs, small equipment, etc.) in contamination areas may not become contaminated with radioactive materials during their normal use. These items eventually become low level radioactive waste unless they are proven to be free of contamination. For unrestricted release from a contamination area, these items must receive radiological surveys to prove radioactive contamination is not present on any surface of the item. For items in areas with alpha contamination, this becomes difficult because of the very short range and poor penetration of alpha radiation. Contamination on inaccessible surfaces, such as the internal surfaces of small diameter pipe, cannot be measured, and therefore the surfaces cannot be released for recycle or clean landfill disposal.

The Long Range Alpha Detection (LRAD) technology provides an alternative method for measuring alpha emitting contamination on surfaces that are accessible to ambient air. BNFL Instruments, Inc., developed and produced the IonSens™ monitoring system based on the principles of the LRAD technology.

How It Works

When air is exposed to alpha radiation, ionized air molecules are generated. The IonSens™ system collects the ions on a collector grid and measures the number of ions produced by the radiation. The number of ions produced is proportional to the amount of contamination present on the monitored surface. The system can measure contamination on any surface that has access to an unrestricted air flow.

The IonSens™ system consists of three basic units: an input filter, a component measurement chamber, and a detector unit. Air is drawn through the input filter and measurement chamber containing the component under inspection by a fan located inside the detector unit. The air passes over the surfaces of the component. Ions produced by any alpha contamination present are drawn into the collection grid. The resultant voltage change on the collection grid is measured and converted to the amount of contamination on the surface. The air is expelled through a HEPA filter.

Figure 1. IonSens™ Cut Pipe Monitor

A personal computer controls the detector unit and contains software that guides the operator through the system operation. The simple and straightforward operation makes the system easy to use by non-technical personnel. Figure 1 shows the equipment setup for the 321-M demonstration.

Potential Markets

The technology has potential for use at any DOE or commercial facility that has alpha producing radionuclides and the need to release suspect contaminated tools and materials.

Advantages Over the Baseline

The IonSens™ technology has several advantages over the manual hand probe and smear method usually used for free release surveys. Advantages include:

- Cost reduction for free release surveys
- Provides measurements on surfaces inaccessible to hand probes and smears
- Provides computer printout of measurement data
- Near real time analysis and display of contamination levels
- Shorter measurement times for large items
- Eliminates operator error and inconsistencies associated with baseline

Limitations of the Technology

The technology, as demonstrated, is not effective for the following conditions:

- Beta/gamma contamination
- Components with a surface charge, e.g., plastic materials.
- Surfaces inaccessible to the free flow of air

The IonSens™ monitoring system is used most effectively in the monitoring of components that are candidates for unrestricted release and are known to have contamination levels at or below unrestricted release limits.

Demonstration Summary

The IonSens^{TM} demonstration was held in the 321-M Fuel Fabrication Facility located at the Savannah River Site (SRS) for total of three weeks during the period October 28, 1998 to January 26,1999. The 321-M facility was used to manufacture fuel and target assemblies for irradiation in the site's production reactors. The facility was deinventoried in 1995 and the process area remains a high contamination area contaminated with highly enriched uranium (HEU).

During operation, many miscellaneous items and components were used in the process area but did not become contaminated with HEU. These items are potential candidates for recycle or unrestricted release, but must be proven clean before releasing from the contamination area. Since HEU was the only radionuclide used in the 321-M facility, release limits were based on uranium limits of 1000 dpm/100 cm^2 (transferable) and 5000 dpm/100 cm^2 (total). This level was well within the minimum detection limits of the IonSens^{TM} monitoring system.

In addition to the technology vendor, BNFL Instruments Ltd, the demonstration participants were:

- WSRC Health Physics Technology
- WSRC Radiological Control Operations (RCO)
- Facilities Decommissioning Division (FDD)
- Savannah River Technology Center (SRTC)

Key results

Based on the amortizement assumptions in Section 5, the cost per hour of operation of the IonSens^{TM} equipment is $12.80, or approximately $0.30 per item. When more than three items are monitored in a single measurement cycle, the average cost is lower than the baseline. Single measurements of larger or complex items are normally more cost efficient with the IonSens^{TM} system.

For pipe and similar tubular items that cannot be surveyed using the baseline, the IonSens^{TM} system may eliminate the contaminated waste produced by these items. A single measurement cycle costing $8.49 may save several cubic feet of waste costing $106 per cubic foot for disposal (SRS disposal rates).

One health protection technician may operate the IonSens^{TM} system under normal operating conditions.

The IonSens^{TM} system is best used for monitoring items that are:

- Candidates for free release or clean disposal
- Have surfaces that are inaccessible to hand probing and smears
- Larger items with complex shapes
- Items with surfaces available for free air flow

The IonSens^{TM} system may not be economical for smaller items with surfaces and sizes conducive to hand surveys.

Regulatory/Policy Issues

None.

Availability

From BNFL Instruments, Inc.

Future Plans

Based on the data collected during the demonstration, the IonSens™ system may be used at SRS for free release of components. Until additional production experience is obtained, 10% of items released by the system will be hand surveyed as a verification check. As confidence levels increase, the need for hand surveys will be re-evaluated. When operating software is available to measure contamination levels approaching plutonium release limits, further evaluation will also be made.

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Licensing Information

No licensing or permitting activities were required to support this demonstration.

Web Site

The 321-M LSDDP Internet address is http://www.srs.gov/general/srtech/lstd/index.htm

Other

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about OST programs, technologies, and problems. The OST Reference number for Long Range Alpha Detection for Component Monitoring is 2382.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

Technology Principles of Operation

The demonstration goal was to evaluate the IonSens^{TM} monitoring system technology for releasing suspected clean items from a contamination area. During the demonstration, data were collected that could support use of the IonSens^{TM} system as an alternative method for releasing items as compared to the manual probe and smear method. The probe and smear method is normally used for free release monitoring at SRS.

The LRAD technology was developed at Los Alamos National Laboratories (LANL) and has been demonstrated to be a highly sensitive method of measuring alpha activity. Alpha particles are highly ionizing radiations which lose energy by creating electron/ion pairs in the medium they traverse. In air they have a very short range of approximately 1.6 in. (4 cm). In most gases an energy of approximately 35 electron volts is required to produce an electron/ion pair and thus a typical 5,000,000 eV alpha particle will produce around 150,000 ion pairs. These ions can be collected and measured directly as a current of several femtoamperes (10^{-15} amperes) per becquerel (Bq).

The ions can be transported over a range of several meters in the air current created by using a fan to pass air over the potentially contaminated item to be measured. The air and any ions produced are then transported to a collection grid. The ions collected are attracted to the grid by an electrostatic field and cause a small current flow proportional to the alpha activity present on the item. This method relies on the fact that it takes several seconds for half of the ions in the air to recombine. Contamination in a pipe many meters long can therefore be measured if the airflow is sufficient to transport the ions from the contamination position to the measurement grid within this time.

The technique will not work if the item to be measured has a surface charge, e.g. plastic. The surface charge will tend to attract ions and thus reduce the measured ionization current. Alpha particles must be able to escape from where they are emitted into the air, i.e., not covered by paint, grease or liquid. Alpha particles must also deposit a large fraction of its energy into the air, i.e. cannot be located in very small grooves etc.

System Configuration

The IonSens^{TM} monitoring system consists of three basic units: (1) input filter; (2) measurement chamber; and (3) detector unit. The units are connected together to form a complete monitoring system. The measurement chambers determine the size and shapes of items that can be monitored. Figure 2 shows a schematic of the system with three 6.6-foot (2 m) pipe measurement chambers connected to the detector unit.

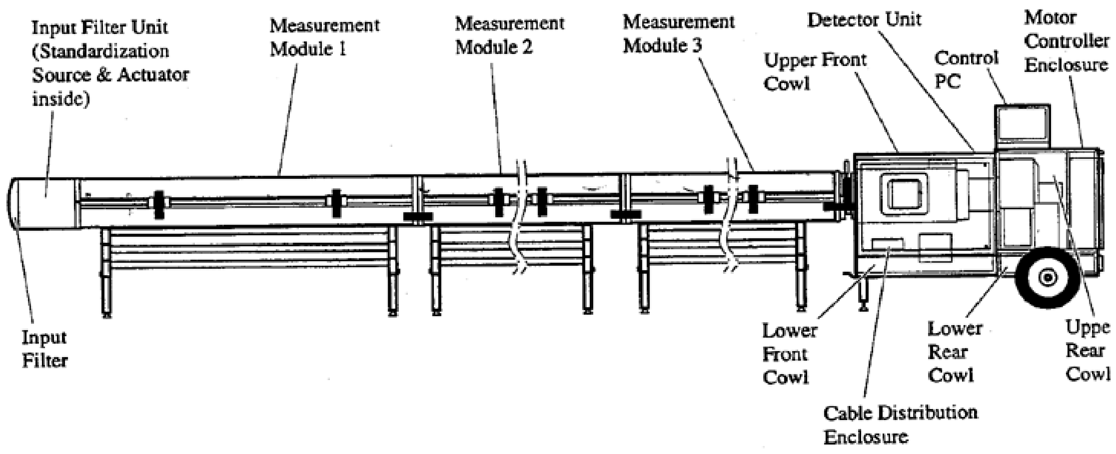

Figure 2. IonSens^{TM} basic units and components.

Air Inlet Filter

Air is drawn into the measurement chamber through an air inlet filter. This removes particulate and dust as well as removing ions from the outside environment. A radioactive source (0.005 micro-curie Am-241) is located in the air inlet filter to provide standardization of the system. During normal operation the source is retracted to a shielded position by an electro-mechanical actuator.

Measurement Chamber

The measurement chamber is the enclosure that holds the item being monitored. The modular system allows items of different configurations to be monitored. The pipe measurement chambers allow insertion of 1, 2, or 3 modules and can monitor pipe sections up to 19.7 ft (6 m) in length. The large item chamber is available for larger complex items other than pipe.

Detector Unit

The detector unit contains the following hardware:

- Ion Detector
- HEPA filter
- Data Processing Electronics
- Iris Seal (Gag Valve)
- Fan Unit
- Control PC

System Implementation

During startup, IonSens^{TM} performs a variety of diagnostic routines to confirm the correct operation of the instrument hardware. During a routine measurement, items are loaded into the measurement chamber and the measurement sequence initiated at the control PC. Each measurement sequence includes a purge to remove residual ions from the system and a background measurement. The total alpha contamination is then measured, compared against classification criteria specified by the operator, and both the total alpha activity and item classification are displayed. The IonSens^{TM} software reports activity in becquerels.

All measurement data is stored on the PC hard disk and can be cross-referenced to a unique serial number or identification of components. A computer printout of measurement date provides survey data for items monitored. For measurement cycles with single items, each item can be traced to its measurement data. For measurement cycles with multiple items, each lot of items can be traced to specific measurement data. See Appendix D for a printout example.

Standardization/Background Measurements

A standardization measurement confirms the correct operability of the instrument hardware. During standardization, the radioactive source in the inlet air filter is exposed while the measurement chamber is empty and allows the efficiency of the system to be checked. An invalid standardization prohibits further item measurements until corrections are made.

A background measurement assures the accuracy and sensitivity of the system by measuring the background ionization of the environment surrounding the system. Both environmental conditions and internal contamination of the instrument may contribute to the background result. If the background is above a preset limit, IonSens™ will prevent any further measurements.

Standardization and background measurements are run periodically in the normal operation of the system and may be prompted by the system software or initiated by the operator.

Software and Electronics

The operating software runs under Microsoft Windows™ NT, and is written to provide the operator with a familiar and user friendly interface. The software includes comprehensive error handling functions and diagnostic facilities to aid system maintenance. Password protection is provided to allow controlled access to system manager functions such as system constants.

Operator Interface

All measurement and control functions are controlled by the operator from the PC. The software guides the operator through background, standardization, and item measurement routines; therefore, IonSens™ is easy to use by non-technical personnel. Item measurements are only allowed to proceed if IonSens™ has valid background and standardization results, and all diagnostic checks are satisfactory. The instrument display panel shows the system status. During measurements, the time remaining and instantaneous activities are displayed.

IonSens™ Cut Pipe Monitor and 208 Large Item Monitor

The cut pipe monitor consists of up to three pipe measurement chamber modules connected together for measuring the internal and external surfaces of pipe up to 19.7 ft (6 m) long. A manually operated iris seal directs the air over both internal and external surfaces or just the internal surface alone. Measuring the ion current with the iris seal open and then with it closed allows an assessment to be made of the total contamination level plus levels on both internal and external surfaces of pipe.

Each pipe chamber module is 6.6 ft (2 m) in length. A cradle system ensures that all pipe diameters are held centrally in the chamber. Practical range of diameters run from 2 in. (5 cm) to 5 in. (12.7 cm); however, the system can be specially calibrated for pipe with diameters as small as 0.5 in. (1.3 cm). Only one 6.6-foot (2 m) measurement chamber was used during the 321-M demonstration. Figure 1 shows a photograph of the cut pipe monitor used in the demonstration.

The 208 Large Item measurement chamber is available for objects other than pipe. The system is designed for larger items and can monitor items with dimensions up to 3.3 ft (1 m) x 3.3 ft (1 m) x 2.6 ft (0.8 m). A turntable is mounted inside the measurement chamber so items can be rotated to expose all surfaces to air flow and improve measurement accuracy.

The large item monitor system configuration and operation is basically identical to the pipe monitor. Figure 3 shows a photograph of the large item monitor.

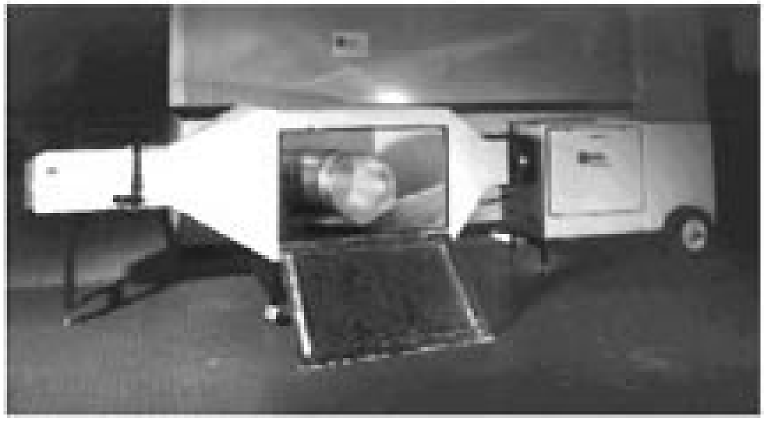

Figure 3. IonSens^{TM} 208 Large Item Monitor

System Operation

System Setup

The setup of the IonSens^{TM} monitoring system is simple and straightforward. The individual units are designed to mate together using alignment pins, locating dowels, and latches. The measurement chambers are positioned on stands and are designed for straight and level operation. Each pipe measurement chamber and stand weighs 99 lbs (45 kg) each and can be lifted and positioned by two people. Each stand has four legs with adjustable feet for leveling.

The detector unit weighs 506 lbs (230 kg) and is mounted on two wheels. The unit can be moved by two people using mounted handles on the front top and sides and a wheeled tug handle. The detector unit connects to the measurement chambers using alignment pins, holes, and latches. The two legs of the detector unit have adjustable feet for leveling the unit with the measurement chambers.

The system operates on 110 Volts and 10 Amps. The Cut Pipe Monitor does not require any additional services for operation. The 208 Large Item Monitor requires a supply of compressed air (100 psi) to operate an internal turntable.

The footprints of the detection unit and measurement chambers are:

One 2-meter pipe measurement chamber	3.3 ft (1 m) x 13.8 ft (4.2 m)
Two 2-meter pipe measurement chambers	3.3 ft (1 m) x 20.7 ft (6.3 m)
Three 2-meter pipe measurement chambers	3.3 ft (1 m) x 27.5 ft (8.4 m)
208 Large Item Monitor	6.9 ft (1.5 m) x 16.4 ft (5 m)

Operational Information

For the 321-M demonstration, the pipe measurement chamber was located in the Contamination Area (CA) and the detector unit was in a Radiological Buffer Area (RBA). This setup allowed the operator to work outside the CA without protective clothing, but required someone in the CA to load and unload the measurement chamber. Under some radiological conditions, the operator may be able to load, unload, and operate the system. Figures 4 and 5 shows the IonSens^{TM} Cut Pipe Monitor used for the demonstration.

Figure 4. IonSens^{TM} setup in RBA and CA

Figure 5. Loading measurement chamber in CA.

The unit should be setup in an area where contamination is unlikely. Items with loose dust and particles should be wiped with a clean lint-free cloth before placing in the measurement chamber. The inside surfaces of the measurement chambers are designed for decontamination and are easily cleaned with wipes and a decontamination solution. Figure 6 shows a typical chamber decontamination.

Figure 6. Measurement chamber decontamination

The internal surfaces of the detector unit that normally come in contact with contaminated air are designed for decontamination. Since the contaminated air passes through a HEPA filter before exiting into the unit enclosure, other surfaces and parts inside the unit enclosure should not become contaminated during normal operations. However, surfaces within the detector unit enclosure would be very difficult to clean if contaminated. Normal operation and maintenance requires opening the enclosure, so it is recommended that the detector unit not be placed in a contamination area.

Contamination can affect both the measurement chamber and the detector unit. A contaminated measurement chamber will cause excessively high background readings and prevent further measurements. Particles that pass into the detector unit may be lodged on the collector plates and cause erroneous readings. The detector unit is easily removed and replaced; however, detector plate decontamination requires more effort. Efficient cleaning of the detector is best done using lint-free wipes, clean compressed air, and a decontamination solution that does not leave residues.

Manpower Skills and Training Requirements

The IonSens^{TM} system is relatively simple to operate. Once the material to be monitored is identified and staged in the area of the equipment, system operation requires an operator and someone to load and unload the measurement chamber. In some cases, one person could operate, load, and unload the system.

A short training period with the vendor is recommended to become familiar with system components and software. A few days of on-the-job training on system trouble shooting, routine maintenance, and system operation should be sufficient. A basic understanding of health physics' practices and personal computers is recommended, but not necessary.

SECTION 3

PERFORMANCE

Demonstration Plan

The demonstration of the IonSens™ Cut Pipe Monitor was performed using components from the contamination area in Building 321-M. The following components were monitored during the demonstration:

- Items with contamination levels <2000 dpm/100 cm^2
- Items that are candidates for free release
- Radioactive alpha sources with known radiation levels

The contamination levels used for the demonstration were the uranium levels for offsite release of process related materials, tools, and equipment. The limits are:

- 1000 dpm/100 cm^2 transferable alpha
- 5000 dpm/100 cm^2 total alpha

The IonSens™ system measures total alpha contamination and does not determine surface area. For demonstration purposes, 1000 dpm was the release limit regardless of surface area. Any item, or batch of items, with total activity level below 1000 dpm was considered for free release.

For demonstration purposes, items cleared for free release by the IonSens™ system were 100% hand surveyed before disposal to confirm the IonSens™ readings. Figures 7 and 8 shows typical items monitored during the demonstration.

Figure 7. Typical small items monitored by the IonSens™ system.

Figure 8. One lot of pipe sections monitored by the IonSens™ system.

Performance Objectives

The primary objective of this demonstration was to evaluate the capabilities and performance of the IonSens^{TM} monitoring system. The elements of the demonstration were:

- Evaluate system as an alternative to hand probes and smears for free release surveys
- Evaluate capabilities for segregating waste into LLW and clean waste categories
- Measure radioactive sources with known radiation levels for accuracy
- Free release materials in support of the 321-M Deactivation Project

Results

Approximately 400 items weighing 2000 lbs (909 kg) were monitored by the IonSens^{TM} system. The sizes and shapes of the items varied, but fit into one section of a 6.6-foot (2 m) pipe measurement chamber. A mesh tray was fabricated to supported items such as hand tools and short tubular pieces that were too small for the chamber's support system. Using this setup, multiple items were monitored during a single measurement cycle to increase throughput and efficiency.

Of the 400 items monitored, approximately 300 items, or 1000 lbs (455 kg), were identified for free release based on uranium free release criteria. The 300 items included approximately 500 lbs (227 kg) of lead with contamination levels below free release levels. A manual free release survey confirmed all items released by the IonSens^{TM} system met free release criteria.

The time required for the IonSens^{TM} Cut Pipe Monitor to perform a measurement is 4.3 minutes. Each measurement includes:

- Purge – 60 seconds
- Background Measurement – 100 seconds
- Measurement of Item – 100 seconds

The purge, background, and measurement times are parameters set by the system software. The operator may change parameters only if a preset password is entered.

Other tasks that are part of the normal operations of the IonSens^{TM} system add to the overall measurement cycle time. The following tasks were considered in determining the average measurement cycle time during the demonstration and are included in the total time in Tables 1 and 2:

- Daily Start Up
- Background measurements
- Standardization measurements
- Empty chamber measurements
- Measurement chamber loading and unloading

Normal maintenance tasks for the equipment during the demonstration consisted of occasional wipe down of the measurement chambers to remove loose particles. The time involved was minimal. The detector plate unit was contaminated once during the demonstration. The troubleshooting and decontamination time was approximately two hours and was not included in determining the average times.

Table 1 represents the average time per item required to monitor items with the IonSens™ system. Some measurement cycles included multiple items.

Table 1. Average Time Required for Measurements

No. of Items	No. of Measurement Cycles	Multiple or Single Items/Cycle	Total Time (min)	Average/Item (min)
239	72	Multiple	509	2.1
164	164	Single	1095	6.7

Table 2 represents the average time of the measurement cycles during the demonstration. The total time includes tasks for normal daily operations as discussed above.

Table 2. Average Time Per Measurement Cycle

No. of Measurement Cycles	Total Time (min)	Average/Cycle (min)
236	1604	6.8

Table 3 represents the time to perform the baseline probe and smear. All of the items represented in Table 3 were previously monitored during the IonSens™ demonstration. None were large items and the average time per item should be considered an absolute minimum.

Table 3. Average Time for Baseline Measurements

No. of Items	Total Time (min)	Average/Item (min)
132	465	3.5

NOTE: Times include report preparation.

For an overall cost evaluation of the IonSens™ system, the following points must be considered:

- Probe and smear costs are dependent on the size of the item and the rate at which the surface can be frisked. The measurement time indicated in Table 3 is for small simple items that can be frisked quickly.

- The measurement time of the IonSens™ system is the same for one item or multiple items, or for a small item or large item, regardless of the configuration or surface area.

- Single item measurement cycles may not appear economical if only the minutes-per-item is considered. The IonSens™ system will be the best method for large complex items or items with surfaces inaccessible to probe and smear.

- Measurement of multiple items at once will reduce the average time and cost per item monitored by the IonSens™ system.

- A small item chamber could be designed especially for small tools and components. The design would increase the number of items that could be monitored in a single measurement cycle, reduce measurement time, and increase sensitivity. This would considerably decrease the unit costs in Section 5.

Accuracy and Precision

During the demonstration sources with known activity were monitored to determine the accuracy and precision of the IonSens™ system. National Institute of Standards and Technology (NIST) traceable standards of 500 dpm and 1000 dpm were measured. The sources were placed in the measurement chamber at the position of the standardization source, or the least sensitivity measurement position. The measurement data in Appendix C reflects the data collected from these source measurements.

The IonSens™ software reports total activity measurements that include standard deviations to reduce the uncertainty of the measurements. The software is set to report the measured activity plus three standard deviations to increase the confidence level of the total activity reported. (The software can be changed to add any number of standard deviations.) The added standard deviations assure the system will overestimate any activity present. This gives confidence that any item classified for free release is definitely free release.

Based on measurements of known sources and hand surveys of monitored items, the minimum detection levels of the IonSens™ equipment as setup for the demonstration was approximately 500 dpm.

See Appendix C for accuracy and precision calculations and data details.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The hand probe and smear method is normally used for measuring alpha contamination. For the free release of materials, 100% of surface area must measured with an alpha scintillation probe to determine the total contamination (fixed and transferable). In addition, the surface area must be smeared to measure transferable contamination. The smears are counted on a calibrated gas flow proportional counter.

Hand probe and smear method disadvantages:

- Many surfaces are inaccessible to probing and smearing. Due to the short range of alpha radiation, probes must be held extremely close to the surface being scanned for an accurate measurement. Both surface configuration and probe size and configuration may limit the surfaces monitored by the probe and smear method.

- The accuracy is dependent on operator technique. Probe scanning speed and distance to the surface being scanned determines the accuracy of the method. Sensitivity decreases markedly when scan speed and distance are increased.

- Probing of many items may become tedious and prone to operator error. It may be difficult to maintain accurate scan speeds and distances after hours of surveying.

Technology Applicability

The IonSens^{TM} system removes the inaccuracies and inconsistencies of probing and smearing. The automated detection process completely eliminates error resulting from operator technique. The detection levels are within the range of the uranium limits identified in Section 3. The limits for other transuranic radionuclides are lower and may be below the detection level of the detector.

The IonSens^{TM} monitoring system measures alpha contamination on any surface accessible to the free flow of air. Measurement times are not dependent on the amount of surface area and are equal for small or large surfaces. A small item [i.e., 2 in. (5 cm) diameter rod, 1 ft (30.5cm) in length] requires the same measurement time as a 18 in. (45.7 cm) diameter valve body. The manhours for probes and smears for the valve body would be much longer than those for the small rod. In general, the IonSens^{TM} system becomes more economical for larger items, or batches of small items.

The IonSens^{TM} monitoring system measures the total alpha contamination present on all surfaces of monitored items. The contamination level reported by the software is a total reading and not a reading per unit area. Calculations of the surface area of items being monitored must be done separately by the operator and is not a capability of the system.

It should be noted that the pipe measurement chambers were designed for pipe sections and not small tools and items. A measurement chamber that would give optimum results for multiple small items could be designed if needed.

The IonSens™ monitoring system is most efficient when used for the following purposes:

- Verifying contamination on surfaces inaccessible to hand probing and smearing but accessible to a free flow of air
- Confirming the lack of contamination on materials that are candidates for free release but must be proven clean
- Larger items where detailed hand probing and smearing requires additional time and number of smears.

Patents/Commercialization/Sponsor

The IonSens is based on the "High Gas Flow Alpha Detector" patent (US # >5514872). The patent was licensed by LANL to BNFL Instruments (BI) for production of instruments such as the IonSens. Additional patents are pending (both in the US and the abroad) covering the IonSens instrument itself as well as detector modifications. All of these pending patents are joint applications between BI and LANL.

The IonSens™ Cut Pipe Monitor and 208 Large Item Monitor are available from BNFL Instruments, Inc.

Other LRAD based methods and equipment are also commercially available.

SECTION 5

COST

Methodology

This cost analysis compares the innovative Long Range Alpha Detection (LRAD) Technology, used to survey alpha activity, to baseline technologies used for radiological surveying at DOE-Savannah River Site (SRS). The innovative technology was deployed for use in surveying 403 items with an approximate total weight of 2000 pounds, for the Large Scale Demonstration and Deployment Project (LSDDP) located at building 321-M. The innovative technology costs are based on the production rates of tasks observed during the LSDDP, for the LRAD. Cost for the alpha baseline technology is derived from the production rates observed during the LSDDP demonstration on 132 items. The baseline data were recorded on site during the LSDDP at building 321-M.

The cost analysis considers only purchase of the innovative technology equipment and contract personnel performing the demonstration; no training costs were required. The analysis includes mobilization, survey activities and demobilization. Mobilization costs include the cost of moving the technology equipment to the work area, removing it from shipping crates, installation of temporary work areas, and equipment setup in the work area. Demobilization includes removal of temporary work areas, decontamination of technology equipment, and disposal of wastes generated by removal of temporary work areas. PPE costs include all clothing, equipment, etc., required for protection of crewmembers during the demonstration. The survey activity cost includes survey of 403 items

Cost Analysis

Data were collected during the demonstration for the cost elements. Survey productivity was measured and unit costs determined on the basis of items surveyed per minute. For each element, detailed costs were determined from the data collected. For labor-intensive activities a production rate was calculated from the performance data.

Labor rates used in the analysis were those in effect for the SRS site labor agreement at the time of the data collection. Crew labor rates are shown on Tables B-2 and B-3. Crews for the various activities were based on the tasks performed. The labor rates included department overhead, but did not include site overheads. Engineering, quality assurance, administrative costs and taxes were also omitted from the analysis. The bare unit costs determined by the analysis can be modified by adding site specific indirect costs to produce a site-specific unit cost that includes indirect costs.

- Equipment costs were based on the cost of ownership. The IonSens^{TM} Cut Pipe Monitor's cost is $123,000.00. The equipment cost includes the detector, one 2-meter pipe measurement chamber and stands, and shipping from England . The large item monitor and additional pipe chambers are extra. No information was collected to determine the projected time of use per year. The following assumptions are made to assign equipment cost dollar figure to the project:

    - expected useful life of the new technology equipment is 10 years;
    - equipment is operated one eight-hour shift per day for 24 weeks a year; and
    - equipment would be used by numerous projects and thus share the cost over the useful life of the equipment.

Based on these assumptions, the extended cost per hour of operation would be $12.80, which translates to an additional equipment cost of approximately $0.30/item to survey.

For each technology, the cost data were entered into an MCACES Gold 5.30 software project database. Supporting databases for labor, equipment and crews were created for the LRAD. Laborers, equipment pieces and crews were added to these supporting databases. The project database was priced from the supporting databases. A hard copy of the complete MCACES Gold 5.30 cost estimate has been provided to the project via the Detailed Cost Report.

For fixed cost elements (independent of the quantity of characterization work), costs were calculated as lump sum costs instead of unit costs. Unit cost elements were based on the quantity of characterization work performed.

A comparison of the unit cost elements is shown in Table 4.

Table 4 Summary Unit Cost Comparison

Long Range Alpha Detection (IonSens™ Cut Pipe Monitor)			**Probe and Smear Survey** (Baseline)		
Cost Element	**Unit Cost**	**Production Rate**	**Cost Element**	**Unit Cost**	**Production Rate**
Monitoring Single Items and Reporting	$8.49/cycle	7min/cycle	Monitoring and Reporting	$3.30/item	3.3 min/item
Multiple Items, 5 items per cycle	$1.70/item	7 min/cycle			

The cost of performing characterization work was found to be lower on the average for the IonSens™ system than hand probing and smearing for multiple items. It should be noted that the costs of hand probing and smearing in Table 4 include small items only. Large or complex items will require higher costs for hand surveys. IonSens™ measurement times for small, large, or multiple items are the same regardless of size, shape, or number. Multiple items can be loaded into the IonSens™ measurement chamber and scanned together, thus lowering the effective cost per item. The cost per item for single item measurements may appear more expensive than the baseline, but the cost of frisking large or complex parts will be higher than indicated while the IonSens™ costs remain the same. The costs for single item measurements must be weighed appropriately. One Health Protection Technician is required both to operate the IonSens™ system and to perform the baseline method. Hand probing and smearing cannot clear small pipe; this new technology would reduce the contaminated waste, and associated cost, resulting from these items.

Figure 9 is a cost comparison for the innovative and the baseline technologies The innovative technology (LRAD) costs are based on the purchase of the equipment. The cost of the capital investment will be shared with numerous projects over a ten year service life as detailed in the cost analysis of this report.

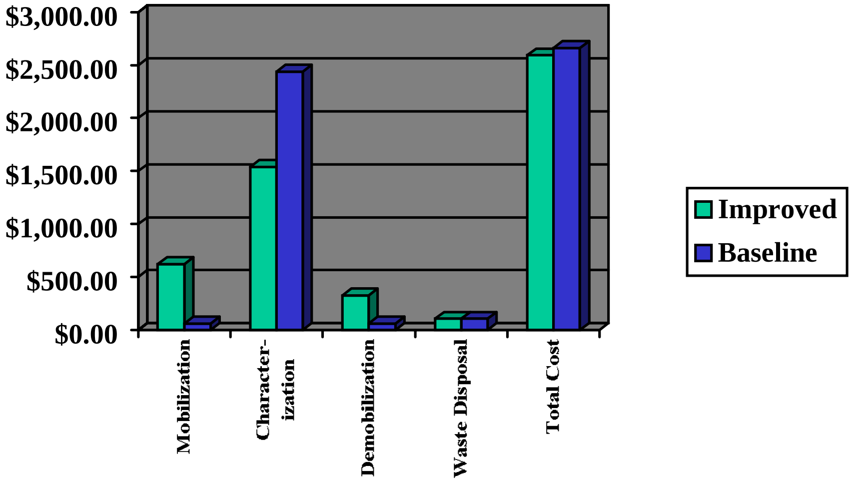

Figure 9. Estimated Cost Summary Based on 500 Items

A breakeven point for the innovative versus baseline technologies is shown in Figure 10. Mobilization, monitoring and demobilization costs were used in preparing the comparison. The breakeven point as shown above for the IonSens™ technology is approximately 400 items when mobilization and demobilization is factored in. It is based on monitoring small items, five items per cycle, that are conducive to hand probes and smears. The breakeven point for larger items and small diameter pipe will be different.

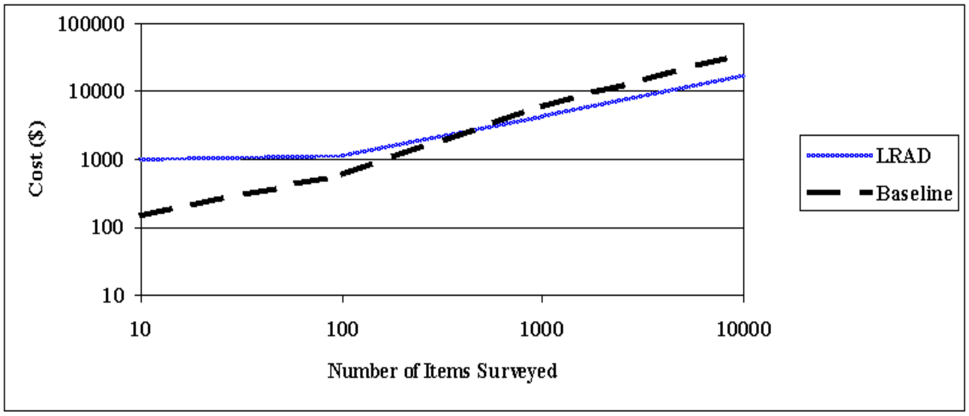

Figure 10. Breakeven Point Analysis

Cost Conclusions

The comparative unit costs for the two technologies for the demonstrated application are (excluding mobilization, demobilization and setup):

Table 5 Summary — Cost Conclusions

	Labor Cost	Equipment Cost	Total Cost
Probe and Smear Method	$3.30/Item	N/A	$3.30/Item
IonSens™ (Bulk Items)	$1.40/Item	$0.30/Item	$1.70/Item
IonSens™ (Single Items)	$7.00/Item	$1.49/Item	$8.49/Item

The innovative technology has a higher production rate than the baseline technology (2.3 times faster than manual alpha surveys). The IonSens™ Cut Pipe Monitor offers cost savings over the baseline alternative for bulk items of characterization work performed during the demonstration. The capital cost of equipment is assumed to be amortized over a ten-year period and adds little cost to the survey per item (approx. $0.30/item or $1.49 per cycle). The IonSens™ system was more costly for equipment, mobilization, and demobilization. The probe and smear method was less costly for equipment (equipment is included in RCO labor rates) but more costly when bulk counting of items and when monitoring cut pipe (which cannot be done manually). The IonSens™ Cut Pipe Monitor would be best suited for clearing pipe and similar tubular items. Note that the probe and smear method cannot scan and clear pipe. The cost for burial of low level waste at SRS is $106.00 per cubic foot. One cubic foot is approximately equal in cost to one multiple survey by the IonSens™ system. Consequently, the IonSens™ system would be beneficial in reducing contaminated waste. Cut pipe and similar objects with inaccessible internal voids could be measured and cleared by the device. If the IonSens™ system was not used, cut pipe would be disposed of by burial and this would be more costly in comparison to the IonSens™ equipment.

The fixed costs for the equipment, mobilization and demobilization were higher for the innovative technology, but the cost to survey bulk items is approximately 50% the cost of hand frisking. The cost to survey a single item with the IonSens™ system may be greater for small items, but the difference decreases when large items are frisked, which require more time for hand surveying. For those items that can be surveyed with the IonSens™ system but not with the hand probe and smear method, several cubic feet of LLW may be eliminated with one monitoring cycle. Here, savings are not limited by the production rate but in releasing items that would otherwise be considered low level waste.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

There are no Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or other regulatory considerations related to this technology.

The use of this technology as an alternative to the baseline technology requires approval by responsible site or facility health physics departments.

Safety Risks, Benefits, and Community Reaction

No issues identified. Additionally, socioeconomic impacts and community perceptions are expected to be positive, as the technology supports waste minimization and reuse/recycle concepts.

SECTION 7

LESSONS LEARNED

Implementation Considerations

The setup and use of the IonSens^{TM} equipment is relatively simple and straightforward. No special services are required for operation. The following should be considered when operating the system:

- The IonSens^{TM} system was not designed to measure contamination levels. There is no benefit of monitoring items with known contamination above release limits. Excessive amounts of transferable contamination may contaminate the measurement chamber and detector unit.

- For demonstration purposes, 1000 dpm was the release limit without regard for the surface area of components being monitored. The conservative view was that any item, or batch of items, with total contamination level less than 1000 dpm was considered clean. The contamination was not identified as a point source or uniformly spread over surface area. For surface areas larger than 100 cm^2, the operator can calculate the surface area and relate to a reading per 100 cm^2 if desired.

- The location of the measurement chamber and detector during operation should be carefully considered. The detector unit should be located where contamination is unlikely since the operator will be removing the detector plate assembly for cleaning and decontamination. Decontamination of the inside of the detector unit may be difficult.

- For production operation, an extra detector plate assembly should be available as a spare. The detector plate unit is sensitive to foreign particles (i.e., lint, dust, contamination, etc.). The unit is easily removed and replaced, but may require time to decontaminate. Clean wipes, decontamination solution, and clean compressed air is recommended for cleaning of the unit.

- If multiple items are monitored, only items with a high degree of certainty that no contamination is present should be monitored. A single contaminated item will reject the entire batch. Then all items will be rejected or each item must be monitored to identify the contaminated item.

- For items where contamination is highly improbable, it is reasonable and practical to put a large number of items per batch through the system to reduce the unit cost of measuring such items.

- The system will only detect contamination on surfaces exposed to the flowing air in the measurement chamber. Items may have areas where air flow is interrupted or blocked. Contamination on these areas will not be monitored.

- Radon will effect the sensitivity level of the system. High radon may raise the sensitivity above acceptable levels. Radon levels did not affect the equipment operation during the demonstration.

- Depending on the radiological conditions where the system is used, one operator may be able to load, unload, and operate the unit. Two operators were used during the demonstration because the equipment was located in two differently classified radiological areas.

Technology Limitations and Needs for Future Development

Limitations of the IonSens^{TM} monitoring are:

- The IonSens^{TM} system measures total contamination on surfaces being monitored. The surface area must be calculated by the operator.
- The minimum sensitivity level may not be low enough for some of the transuranic radionuclides release limits.
- Materials with surface charges, such as plastics, tend to attract ions and thus reduce the measured ionization current.
- Alpha particles will not penetrate paint, grease, or liquid. Items should be free of these materials before monitoring.
- The Cut Pipe Monitor and 208 Large item monitor were not designed to monitor multiple small items and may not give the sensitivity levels required for these items. A small item measurement chamber that would reduce cycle time and improve sensitivity levels can be designed for small multiple items.

Technology Selection Considerations

It may not be economical to monitor any and all items with the IonSens^{TM} system. The technology was designed as a tool for free releasing materials from contamination areas. The system works best on materials with areas inaccessible to hand probes and smears or large items where the baseline technology may require an excessive amount time for each item.

APPENDIX A

REFERENCES

C. Luff, T. Dockray, A. Messenger, and D.W. Macarthur, *Free Release Monitoring of Pipes and Ducts*, Proceedings of WM'97, Tucson AZ, March 2-6 1997.

D. W. Macarthur, K. S. Allander, J. A. Bounds, and J. L. McAtee*, LRAD-Based Contamination Monitoring of Personnel and Equipment,* Nuclear Technology v. 102, p. 270 (1993).

D. W. Macarthur, K. S. Allander, J. A. Bounds, K. B. Butterfield, and J. L. McAtee, *Long-Range Alpha Detector,* Health Physics, Volume 63, Number 3, Page 324 (1992).

D. W. Macarthur, K. S. Allander, J. A. Bounds, and K. B. Butterfield*, Small Long-Range Alpha Detector (LRAD) with Computer Readout*, Los Alamos National Laboratory publication LA-12199-MS (1991).

D. W. Macarthur, K. S. Allander, J. A. Bounds, K. E. Koster, M. Rawool-Sullivan, and S. Rojas, *Alpha Detection for D&D: Results and Possibilities*, Proceedings of ER'95, Denver, CO, August 14-17, 1995.

D. W. Macarthur, K. S. Allander, J. A. Bounds, M. M. Catlett, R. W. Caress, and D. A. Rutherford, *Alpha Contamination Monitoring of Surfaces, Objects, and Enclosed Areas,* IEEE Transactions on Nuclear Science, Volume 40, Number 4, Page 840 (1993) .

D. W. Macarthur, K. S. Allander, J. Koster, M. Rawool-Sullivan, S. Rojas, and L. Sprouse*, Alpha Detection for Characterization of D&D Sites,* Proceedings of the ANS Embedded Topical Symposium on DDER, November 1994.

D. W. Macarthur, M. Rawool-Sullivan and T. Dockray*, Detection of Alpha Contamination inside Pipes*, Proceedings of WM'96, Tucson AZ, Feb 25-29 1996.

D.W. Macarthur, R.D. Gunn, T. Dockray, C. Luff, and F. Gardner, *Unrestricted Release Measurements with Ambient Air Ionization Monitors*, Proceedings of WM'99, Tucson AZ, 1-5 March 1999.

M. Rawool-Sullivan, K. S. Allander, J. A. Bounds, J. E. Koster, D. W. Macarthur, L. L. Sprouse, D. Stout, J. A. Vaccarella, and T. Q. Vu*, Characterization of a D&D Site Using Long-Range Alpha Detectors,* Proceedings of the ANS Embedded Topical Symposium on DDER, November 1994.

R. W. Caress, K. S. Allander, J. A. Bounds, M. M. Catlett, and D. W. Macarthur, *LRAD- Based Airflow Monitors,* Los Alamos National Laboratory publication LA-12742-MS, March 1994.

S. P. Rojas, M. W. Rawool-Sullivan, K. G. Williams, and J. A. Vaccarella, *Alpha Characterization Inside Pipes Using Ion Transport Technology,* Proceedings of WM'95, Tucson AZ, Feb. 26 - March 2, 1995.

T. W. Coffield, Solid Waste – Generator Services, WSRC; telecon with Cecil May, June, 1999.

Westinghouse Savannah River Company, *321-M Large Scale Demonstration and Deployment Project, Demonstration Test Plan, IonSens^{TM} Cut Pipe and 208 Large Item Monitor.*

APPENDIX B

TECHNOLOGY COST COMPARISON

This cost analysis provides a comparison of the IonSens^{TM} Cut Pipe Monitor innovative technology to the baseline technology of manual probe and smear. The costs involved in the demonstration were evaluated to provide realistic costs of both baseline and innovative technologies and are tabulated in Tables B-2 and B-3.

The following assumptions were used in the this cost analysis:

- No engineering, quality assurance, or administrative costs were included.
- The IonSens^{TM} equipment cost includes shipping costs from England, but does not include any procurement or material surcharges.
- Labor rates used in the cost analysis include SRS department overhead; however, do not include site G&A.
- A 10-hour day, four-day week was used during the demonstration.

Improved Technology IonSens^{TM} Cut Pipe Monitor

MOBILIZATION (WBS 331.01)

Move Equipment to Work Area: Includes unloading equipment from truck and moving boxed equipment to work area with a fork lift.

Remove Equipment from Boxes: Includes removing equipment from boxes and installing measurement chamber on its support stand.

Setup Equipment in CA: Includes expansion of the CA as a work location for the equipment, and moving equipment into the CA.

Calibrate Detector: Includes initial standardization, calibration, and background runs.

DECONTAMINATION AND DISMANTLING ACTIVITY (WBS 331.17)

Identify/Survey Items: Includes initial identification of items that are candidates for free release surveys.

Stage Items to Monitor: Includes moving items to an area adjacent to the measurement chamber for convenience of loading and unloading the chamber.

Monitor Staged Items, Load, and Unload Chamber: Includes loading measurement chamber, monitoring items, unloading chamber, placing items in area marked for disposition, and data loading for reports.

Monitor Known Sources, Gather Support Data: Includes additional monitoring of known sources, standardizations, backgrounds, and other data collection to verify and support acceptance of the technology.

Disposal of Material: Includes the movement of monitored items to disposal area or placing in waste containers.

<u>Don/Removal of PPE:</u> Includes the time for workers to don and remove PPE and the total cost of PPE for the duration of the demonstration. Daily material costs for PPE for one worker at SRS are shown in Table B-1.

Table B-1 Daily Personnel Protective Equipment (PPE)

Description	Cost each Time Used	No. Used per day	Cost Per Day
Booties	$1.00	2	$2.00
Coveralls	$5.00	2	$10.00
Gloves	$1.50	4	$6.00
Glove Liners	$0.30	2	$0.60
Rubber Overshoes	$2.00	2	$4.00
Total			**$22.60**

DEMOBILIZATION (WBS 331.21)

<u>Remove Equipment from CA, Wipe Down:</u> Includes the removal of the measurement chamber and stand from the CA. Before removal from the CA, the equipment must be surveyed and decontaminated if necessary. The decontamination of the internal surfaces of the detector unit exposed to contaminated air is included in this activity.

<u>Survey Equipment for Release:</u> Includes the time of RCO to perform free release surveys for removal of equipment from the contaminated area.

WASTE DISPOSAL (WBS 331.18)

<u>Waste Disposal:</u> Includes the disposal of LLW waste created by the use of the innovative technoloogy.

Table B-2. Improved IonSens^{TM} Technology Cost Summary

Work Breakdown Structure (WBS)	Unit Cost (UC)					Other	Total Quanity (TQ)	Unit of Measure	Total Cost (TC)	Crew	Comments
	Labor		Equipment		Total UC						
	Hrs	Rate	Hrs	Rate							
Mobilization (WBS 331.01)									**$ 643.90**		
Move Equipment to work Area	1	$ 128.00	1	$ 6.55	$ 134.55		1	LS	$ 134.55	I Forklift Operator, 2 Shop Mechanic	
Remove equipment from	2	$ 188.00			$ 376.00		1	LS	$ 376.00	3 Mechanics, 1 HP Tech.	
Set up Equipment in CA	0.5	$ 146.69			$ 73.35		1	LS	$ 73.35	2 Mechanic and 1 HP Tech.	
Calibrate Detector	1	$ 60.00			$ 60.00		1	LS	$ 60.00	1 HP Tech	
Decontamination & Dismantling Activity (WBS 331.17)									**$ 2,940.94**		
Identify / Survey items	4	$ 103.35			$ 458.60	$ 45.20	1	LS	$ 458.60	1 Mechanic, 1 HP Tech.	Other Rate is PPE, $22.60/day
Stage Items to Monitor	1	$ 43.34			$ 43.34	$ 22.60	1	LS	$ 65.94	1 Mechanic	Other Rate is PPE, 22.60/day
Monitor staged items, load and unload chamber	0.023	$ 60.00	0.023	$ 12.80	$ 1.70		403	EA	$ 683.58	1 HP Tech	
Monitor known sources, gather support data	10.6	$ 60.00	10.6	$ 12.80	$ 771.68		1	LS	$ 771.68	1 HP Tech	
Disposal of Material	1	$ 43.34			$ 43.34		1	LS	$ 43.34	1 Mechanic	
Don/Removal of Personal Protective	0.8	$ 60.00			$ 48.00	$ 22.60	13	Day	$ 917.80	1 HP Tech	Other Rate is PPE, $22.60/day
Demobliziation (WBS 331.21)									**$ 322.66**		
Remove equipment from CA, Wipe down,	1	$ 144.66			$ 210.66	$ 66.00	1	LS	$ 210.66	1 HP Tech., 2 Mechanics	Other Rate is PPE, $22.60/day
Survey Equipment for release	1.5	$ 60.00			$ 112.00	$ 22.00	1	LS	$ 112.00	1 HP Tech.	Other Rate is PPE, $22.60/day
Waste Disposal (WBS 331.18)									**$ 106.00**		
Waste Disposal					$ 106.00	$ 106.00	1	cu ft	$ 106.00		
Total Cost For The Demonstration									**$ 4,013.50**		

NOTES

1. TC = UC X TQ (where TC = total cost, UC = unit cost, and TQ = total quanity), LS = Lump Sum
2. Labor Rates ar $23.40/hr for Laborer, $43.34/hr for Mechanic, $33.60 Forklift Operator, $60.00/hr for Health Protection (HP) Technician
3. Equipment rates are $12.80/hr for the IonSens equipment, $6.55/hr for 6000# Forklift
4. One HP Technician can operate the IonSens Equipment, during the initial demonstration one HP Tech., one mechanic and one vendor supplied technician were used. To keep cost realistic one HP Tech was used in the cost report.
5. The Table B-1 was generated based on collected data during site demonstration. The data was evaluated and collected to give a good representation of a actual costs for a project.
6. Unit cost and hours for monitoring items are based on 5 items/cycle. The number of items monitored per cycle during the demonstration varied.

Baseline Technology – Hand Probe and Smear

MOBILIZATION (WBS 331.01)

Prepare Instruments/Mobilize to Work Area: Includes daily calibration check of instruments and moving to work area.

DECONTAMINATION & DISMANTLING ACTIVITY (WBS 331.17)

Identify/Survey Items: Includes initial identification of items that are candidates for free release surveys.

Stage Items for Monitoring: Includes moving items to an area suitable for final free release surveys.

Survey Staged Items: Includes the hand probing and smearing of items.

Count Smears/Prepare Reports: Includes the counting of the smears taken during the surveys and preparing the final reports of the surveys.

Disposal of Material: Includes the movement of monitored items to disposal area or placing in waste containers.

Don/Removal of PPE's: Includes the time for workers to don and remove PPE's and the total cost of PPE's.

DEMOBILIZATION (WBS 331.21)

Clear Instruments from Area: Includes probing, smearing, and counting of smears required to remove instruments from the contamination area.

WASTE DISPOSAL (WBS 331.18)

Waste Disposal: Includes the disposal of LLW created by the use of the baseline technology.

Table B-3. Baseline Probe and Smear Cost Summary

Work Breakdown Structure (WBS)	Unit Cost (UC)					Other	Total Quantity (TQ)	Unit of Measure	Total Cost (TC)	Crew	Comments
	Labor		Equipment		Total Unit Cost						
	Hrs	Rate	Hrs	Rate							
Mobilization (WBS 331.01)									**$ 60.00**		
Prepare Instruments/moblize to work area	1	$ 60.00			$ 60.00		1	LS	$ 60.00	1 HP Tech.	Equipment Cost Included in HP Labor Rate
Decontamination & Dismantling Activity (WBS 331.17)									**$ 1,153.08**		
Identify / Survey items	4	$ 103.35			$ 458.60	$ 45.20	1	LS	$ 458.60	1 Mechanic and 1 HP Tech.	Other Rate is PPE, $22.60/day
Stage Items to Monitor	1	$ 43.34			$ 65.94	$ 22.60	1	LS	$ 65.94	1 Mechanic	Other Rate is PPE, $22.60/day
Survey Staged Items	0.034	$ 60.00			$ 2.05		132	EA	$ 270.00	1 HP Tech.	Equipment Cost Included in HP Labor Rate
Count and smears/Prepare Reports	0.028	$ 60.00			$ 1.68		132	EA	$ 222.00	1 HP Tech.	Equipment Cost Included in HP Labor Rate
Disposal of Material	1	$ 43.34			$ 43.34		1	LS	$ 43.34	1 Mechanic	
Don/Removal of Personeal Protective Equipment, (PPE)	0.4	$ 60.00			$ 46.60	$ 22.60	2	Day	$ 93.20	1 HP Tech.	Other Rate is PPE, $22.60/day
Demobliziation WBS 331.21									**$ 60.00**		
Clear Equipment From Area	1	$ 60.00			$ 60.00		1	LS	$ 60.00	1 HP Tech.	
Waste Disposal (WBS 331.18)									**$ 106.00**		
Waste Disposal					$ 106.00	$ 106.00	1	cu ft	$ 106.00		
Total Cost For The Demonstration									**$ 1,379.08**		

NOTES

1. TC = UC X TQ (where TC = total cost, UC = unit cost, and TQ = total quanity), LS = Lump Sum
2. Labor Rates ar $23.40/hr for Laborer, $43.34/hr for Mechanic, $33.60 Forklift Operator, $60.00/hr for Health Protection (HP) Technician

APPENDIX C

TECHNOLOGY ACCURACY/PRECISION DATA

Precision and Accuracy

National Institute of Standards and Technology traceable standards with known alpha activity were used to determine the precision and accuracy of the IonSens™ system. Table C-1 shows the results obtained from measuring a 500 dpm standard as the measured activity in dpm with no uncertainty, the percent difference from the value of the standard, and the upper activity limit including 3 σ uncertainty. Table C-2 shows the results obtained from measuring a 1000 dpm standard as the measured activity in dpm with no uncertainty, the percent difference from the value of the standard, and the upper activity limit including 3 σ uncertainty.

The precision of the system is expressed in terms of Percent Relative Standard Deviation (%RSD) and its accuracy is expressed in terms of average percent difference (%Diff) from the original value of the standard. The precision of the system ranged between 13.17 and 24.36 for results obtained from the 1000 dpm and the 500 dpm standards respectively. The accuracy of the system is expressed in terms of average percent difference (%Diff) from the original value of the standard. The accuracy of the system ranged between 5.97 and 19.25 for results obtained from the 1000 dpm and the 500 dpm standards respectively. Table C-3, shows statistical parameters calculated for both standards. For the 500 dpm standard, the average measured activity was 596.25 dpm with a standard deviation of 145.27, an average percent difference of 19.25, and a percent relative standard deviation of 24.36. For the 1000 dpm standard, the average measured activity was 1059.65 dpm with a standard deviation of 139.58, an average percent difference of 5.97, and a percent relative standard deviation of 13.17.

Overall, the pooled standard deviation for the system is 141.57 and the overall average percent difference is 12.61. The average percent relative standard deviation for the system is 18.77.

Table C-1. Results Obtained From Measuring a 500dpm Standard.

Measurement number using a 500dpm source	Measured Activity in (dpm)	Upper Activity Limit at 3 σ confidence level	Percent Difference
Meas 23	463	840	-7.4
Meas 37	503	1020	0.6
Meas 38	625	1140	25
Meas 39	530	1140	6
Meas 40	468	1020	-6.4
Meas 41	494	960	-1.2
Meas 42	845	1440	69
Meas 43	548	1080	9.6
Meas 44	842	1320	68.4
Meas 45	736	1260	47.2
Meas 46	505	1020	1

Table C-2. Results obtained from measuring a 1000dpm standard.

Measurement number using a 1000dpm source	Measured Activity (dpm)	Upper Activity Limit at 3 σ confidence level	Percent Difference
Meas 27	946	1500	-5.4
Meas 28	888	1500	-11.2
Meas 29	930	1440	-7
Meas 30	927	1440	-7.3
Meas 31	1011	1620	1.1
Meas 32	917	1380	-8.3
Meas 33	1076	1560	7.6
Meas 34	1081	1620	8.1
Meas 35	1088	1620	8.8
Meas 36	898	1500	-10.2
Meas 75	924	1440	-7.6
Meas 76	1027	1500	2.7
Meas 77	1347	1740	34.7
Meas 78	1180	1740	18
Meas 79	1210	1680	21
Meas 80	1202	1860	20.2
Meas 81	1260	1740	26
Meas 82	1256	1800	25.6
Meas 83	997	1440	-0.3
Meas 84	1028	1500	2.8

Table C-3. Statistical parameters calculated for both standards

Standard (dpm)	Average measured Activity	Standard Deviation	Average Percent Difference	%RSD
500	596.27	145.27	19.25	24.36
1000	1059.65	139.58	5.97	13.17
Average	N/A	141.57*	12.61	18.77

* pooled standard deviation

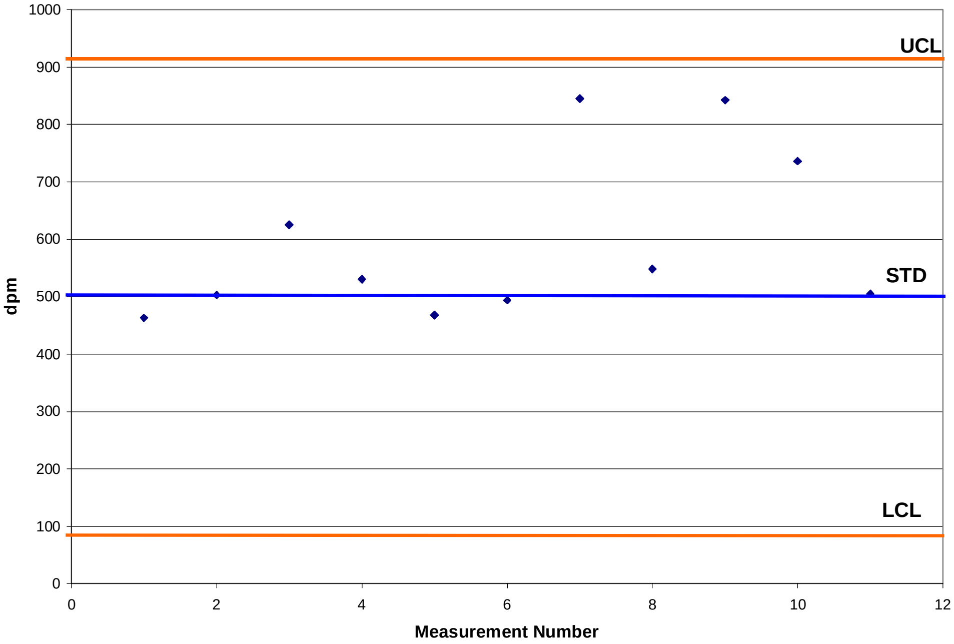

Figure C-1. Precision control chart for the 500 dpm standard

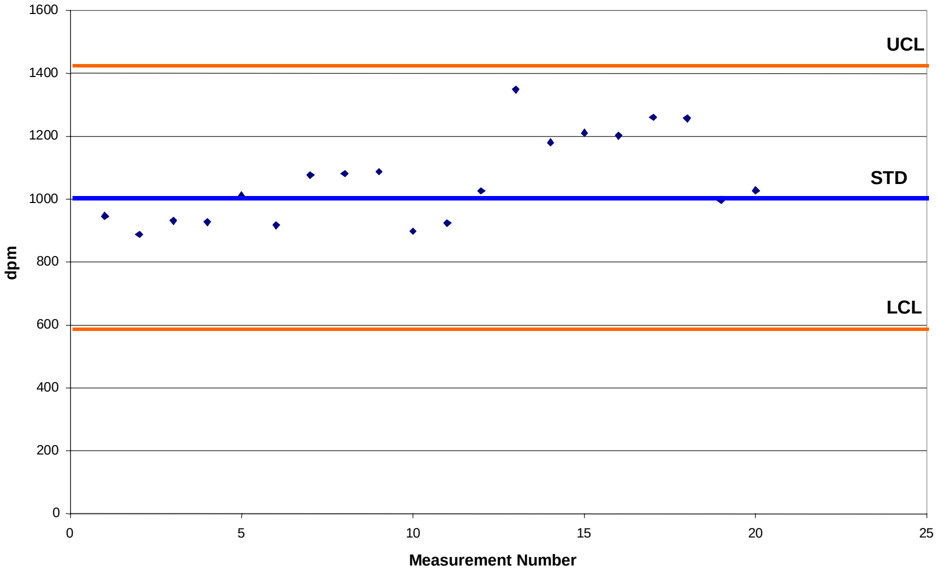

Figure C-2. Precision control chart for the 1000 dpm standard

Limit of Detection

The limit of detection (LOD) depends on the background fluctuations and the efficiency (Eff) of the detector. For the IonSens Pipe Monitor, this is calculated as follows:

$$LOD = n\sqrt{2}\,\frac{\sigma_B}{Eff},$$

Where n is the number of standard deviations used, σ_B is the standard deviation of the background determined during the background measurement routine, and Eff is the efficiency factor of the detector determined during the standardization routine.

The standard error on a measurement is calculated from:

$$\sigma_T = \sqrt{\left(\frac{\sigma_B}{Eff}\right)^2 + \left(\frac{\sigma_M}{Eff}\right)^2}$$

Where σ_M is the standard error on the measurement. If we put a completely clean object into the device,

$$\sigma_M = \sigma_B,$$

Simplifying the equation to:

$$\sigma_T = \sqrt{2}\,\frac{\sigma_B}{Eff}$$

The total activity is calculated as

$$T = \frac{\overline{M} - \overline{B}}{Eff} + n\sigma$$

Where M is the mean of the electrometer readings during a measurement and B is the mean of the electrometer readings during a background measurement.

Given that $n\sigma_T$ = LOD, and that M-B is constrained to positive values, it is clear that for samples which are essentially exempt from any contamination, the system can only report a figure for total activity which is at or above the LOD.

The number of standard deviations, n, used in these calculations is a maintainable constant. It was set at 3 during the IonSens demonstration.

Measurement of Contaminated Pieces

In a real measurement the error on the activity is calculated using the full equation

$$\sigma_T = \sqrt{\left(\frac{\sigma_B}{Eff}\right)^2 + \left(\frac{\sigma_M}{Eff}\right)^2}$$

And the total activity is thus given by

$$T = \frac{\overline{M} - \overline{B}}{Eff} + n\sigma_T$$

The activity displayed by the instrument is therefore an upper limit on the possible activity on the item.

A further cause of a difference between the measured activity and the actual activity is the geometrical uncertainty. The instrument is calibrated as if the activity in the chamber were at the position of the standardization source, the least sensitive measurement position. This is because the instrument cannot give the position of the activity so we have to assume it is located in the worst measurement position.

Therefore we would expect the system to overestimate the activity present. This gives confidence that any item classified as suitable for free release is definitely free release.

APPENDIX D

IONSENS^{TM} DATA REPORT

Pipe Serial Number	meas 12
Date And Time	09:21:07 03/11/98
Measurement Type	Dual Surface
Voltage Mean	0.0310066067442602
Voltage Stand Error	0.00113329131293443
Total Activity	12.6772298198196
Total Activity Stand Error	4.72173348597516
External Activity	0
External Activity Stand Error	0
Internal Activity	0
Internal Activity Stand Error	0
Activity No Stnd Err	3
Number of Modules	1
Classification	Unclassified
PCM/Normal	Normal
Back Date And Time	09:06:25 03/11/98
Stand Date And Time	09:09:30 03/11/98

Pipe Serial Number	meas 13
Date And Time	09:26:34 03/11/98
Measurement Type	Dual Surface
Voltage Mean	0.0283622356376263
Voltage Stand Error	0.000838132758939909
Total Activity	6.35694382769882
Total Activity Stand Error	4.35554171445231
External Activity	0
External Activity Stand Error	0
Internal Activity	0
Internal Activity Stand Error	0
Activity No Stnd Err	3
Number of Modules	I
Classification	Free Release
PCM/Normal	Normal
Back Date And Time	09:06:25 03/11/98
Stand Date And Time	09:09:30 03/11/98

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APPENDIX E

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
BI	BNFL Instruments Limited
BNFL	British Nuclear Fuels Limited
Bq	Becquerel
CA	contamination area
DOE-SR	Department of Energy – Savannah River
FDD	Facilities Decommissioning Division
ft	feet
HEPA	high efficiency particulate air
in.	inches
lbs	pounds
LLW	low level waste
LRAD	Long Range Alpha Detection
LSDDP	Large Scale Demonstration and Deployment Project
PC	personal computer
RBA	Radiological Buffer Area
RCO	Radiological Control Operations
SRS	Savannah River Site
SRTC	Savannah River Technology Center
USACE	U. S. Army Corps of Engineers
WSRC	Westinghouse Savannah River Company