INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0477

# In-Situ Object Counting System

Deactivation and Decommissioning
Focus Area

*Prepared for*
**U.S. Department of Energy**
Office of Environmental Management
Office of Science and Technology

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INNOVATIVE TECHNOLOGY
Summary Report

# In-Situ Object Counting System

OST Reference #2098

Deactivation and Decommissioning
Focus Area

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

*Demonstrated at*
Argonne National Laboratory-East
Argonne, Illinois

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://OST.em.doe.gov under "Publications."

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# SECTION 1

# SUMMARY

## Technology Description

In a decontamination and decommissioning (D&D) project there is need for a gamma-ray identification and assay system to identify radioactive isotopes and to qualitatively determine the amount of radioactive material. This information is used for planning, for monitoring the effectiveness of a decontamination process, and for determining the subsequent disposition of material generated during the D&D process. The In Situ Object Counting System (ISOCS) developed by Canberra, Inc. is a portable, in-situ Germanium based spectroscopy system that is designed to provide information on the type and amount of radioactive material. The ability to provide quantitative information in real time reduces costly delays from off site analysis.

This demonstration was part of the Large-Scale Demonstration Project (LSDP) whose objective was to select and demonstrate potentially beneficial technologies at the Argonne National Laboratory-East's (ANL) Chicago Pile-5 Research Reactor (CP-5). The purpose of the LSDP is to demonstrate that significant benefits can be achieved using innovative and improved D&D technologies when compared to baseline D&D technologies. This demonstration is sponsored by the U.S. Department of Energy's (DOE) Office of Science and Technology's Deactivation and Decommissioning Focus Area (DDFA).

The Canberra ISOCS consists of an ISOCS characterized Germanium detector with portable cryostat; a cart support for holding the detector, lead shielding and collimators; an InSpector portable spectroscopy analyzer; a portable computer with Genie-PC software; and the ISOXSW in situ calibration software. The ISOCS characterized detector is a Germanium detector whose response to a series of point sources surrounding it has been characterized using a Monte Carlo code. The steel-jacketed lead shielding can be mounted around the Germanium detector to provide 1 or 2 inches of shielding from background radiation, and to change the field of view between 30, 90 or 180 degrees. The detector rotates on the cart for alignment with the target. The computer controls the InSpector analyzer and the Genie-PC software provides peak identification, data and error analysis, and sample quality assurance. The ISOXSW software automatically determines the relationship between the radioactive source geometry, the measured count rate, and the amount of radioactive material present using the ISOCS characterized detector data.

Figure 1. ISOCS Germanium Detector, Shield, and Cryostat

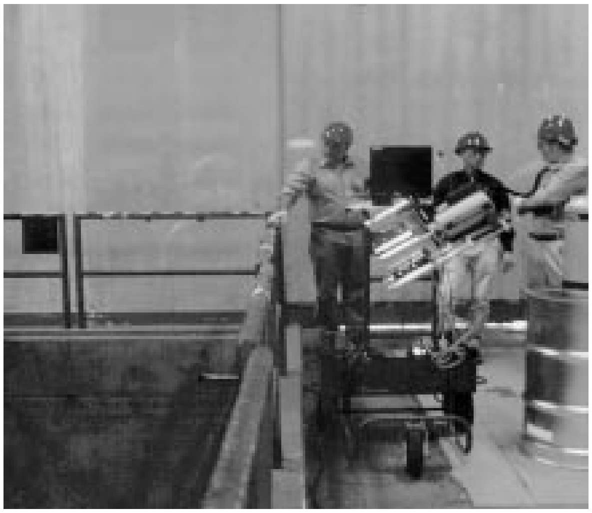

Figure 2. ISOCS Measuring a Pool Wall at the CP-5 Facility

## Technology Status

The purpose of the demonstration was to determine the capabilities and limitations of ISOCS in two areas. The first was as a general purpose, high-resolution gamma ray system for identifying radioactive isotopes. The second was as an in-situ radioactive assay system for determining the radioactive content of a range of containers, objects, and surfaces. The baseline system consisted of Germanium detector system and an off line shielding code or sample collection followed by offsite analysis.

CP-5 is a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research. The reactor had a thermal-power rating of 5 megawatts and was continuously operated for 25 years until its final shutdown in 1979. These twenty-five years of operation have produced activation and contamination characteristics representative of other nuclear facilities within the DOE Complex. CP-5 contains many of the essential features of other DOE nuclear facilities and can be safely utilized as a demonstration facility for the evaluation of innovative technologies for the future D&D of much larger, more highly contaminated facilities.

A Canberra engineer operated the ISOCS system during these tests. ANL personnel from CP-5 and the Environment, Safety, and Health (ESH) Department provided health physics (HP) support. Argonne National Laboratory personnel wrote the test plan and produced a data report describing the information collected. Cost analysis was performed by the U.S. Army Corps of Engineers, and benchmark activities were performed by ICF Kaiser.

## Key Results

The key results of the demonstration are as follows:

- The Canberra ISOCS system performed well during the CP-5 demonstration by successfully obtaining data over a wide range of objects and surfaces. No problems with the system were identified in the three days of tests despite considerable movement and relocation of the device.
- The high-resolution Germanium detector and spectroscopy system were easy to use and the associated databases provided useful information on radionuclide gamma peak identification.
- The ability of the ISOCS system to provide real time, in-situ, non-intrusive assay information on a series of containers compared to the baseline system of making measurements and then performing shielding calculations off line would significantly reduce the time needed in determining the effectiveness of a decontamination process or in deciding how waste materials can be disposed.
- The use of the ISOCS system to assay concrete or soil samples is considerably more efficient compared to collecting samples and having the sample analyzed off site. While not tested directly, the ISOCS system could also be used to analyze the core samples directly.
- Operation of the ISOCS system is relatively simple but some training is required. In addition, the use of the assaying software requires considerable experience in modeling the source distribution.
- The shielding for the Germanium detectors was useful in reducing the effects of background radiation. However, if the gamma rays of interest in the sample to be assayed are the same as those in the background radiation field, there will be an increase in the uncertainty of the measured result. High backgrounds can also lead to long data acquisition times.
- Currently, ISOCS has nine standard geometry templates. Detection limits are approximately 0.002 Bq/g for beta-gamma detection, and 0.02-0.1 Bq/g for alpha detection (for a 15 minute count).

## Contacts

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### Licensing Information

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

The CP-5 LSDP Internet address is http://www.strategic-alliance.org.

# SECTION 2

# TECHNOLOGY DESCRIPTION

## System Configuration and Operation

The In Situ Object Counting System (ISOCS) is a Germanium based gamma-ray spectroscopy system with a built in shielding code that identifies radioactive isotopes and quantitatively assays the radioactive contents of containers, surfaces, and samples. The system is able to simultaneously collect data while performing report calculations real time.

The ISOCS system consists of an ISOCS characterized Germanium detector with a portable liquid-nitrogen cryostat; a push cart for supporting the detector, cryostat, and lead shielding and for aiming the device; a battery or AC powered InSpector portable spectroscopy analyzer; a portable computer with Genie-PC and PROcount software for spectra processing, batch processing and quality assurance; and the ISOXSW in-situ calibration package for determining the relationship between measured counts and source activity. A photograph of the system being used to measure the radiation type and content of an electronic instrument panel is shown in Figure 3. The detector head is positioned inside the lead shielding at lower left of the figure. The cryostat is the cylinder with the Canberra name on it at the upper right. The entire system is mounted on a portable cart, which allows rotation of the detector about a horizontal axis.

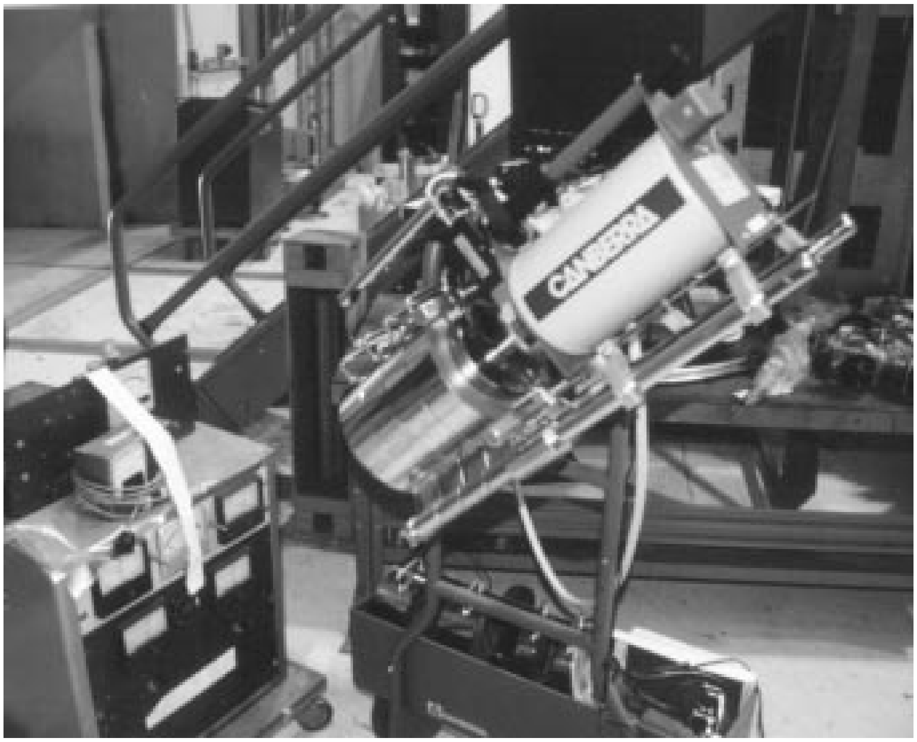

Figure 3. Image of ISOCS analyzing the radioactive content of an electronic instrument panel.

The system measures 132 x 78.7 x 96.5 cm fully assembled. The stand/detector/holder weighs 170 lbs. With the 25 mm shields in place, the system weighs 233 lbs. With the 50 mm shields in place, the system weighs 294 lbs. With both shield sets, the total weight of the system will be 357 lbs. For this demonstration, the shipping weight was 300 lbs. The ISOCS software system currently allows for 9 different survey geometries for various applications. The total survey area is dependent on the geometry used and the geometry parameters. The ISOCS is for stationary measurements only.

The major cost of the system is the Germanium detector which is strongly dependent on the required detector efficiency. In addition, different detectors are required for detecting low-energy gamma rays from TRU waste (energy less than 100 keV) versus those from Cs-137 or Co-60 (energy greater than 100 keV). The cryostat, which contains the liquid nitrogen for cooling, can be sized for 2 to 4 days of cooling. Cool down time is approximately two hours. The cryostat can be operated with the detector either pointing upward or downward but must be emptied and refilled to switch between the two orientations. In ISOCS, detector calibration consists of determining the response function of the detector for a series of point sources positioned at various locations around the detector using a Monte Carlo code. The data for each of these positions is saved in a file associated with the Germanium detector and is used by the ISOXSW software to determine the detector calibration curve.

The lead shielding is packaged as a series of modules with the maximum weight of a module being 16 kg. Each module is steel jacketed and comes in a thickness of 1 or 2 inches. The 1 inch shielding reduces background radiation at 1 MeV by an approximate factor of 7.5, while the 2-inch shielding reduces the background radiation by a factor of 60. There is an end-plate shield between the detector and the cryostat and several different collimators in front of the detector for defining a 30, 90, or 180 degree field of view. Some of the collimator lead surfaces are covered by epoxy paint rather than steel.

The InSpector is a battery powered spectroscopic analysis system that is controlled via a portable computer. The batteries are 6 V NiCd and are equivalent to those used in standard camcorders. Each battery is capable of approximately 1.5 hours of real-time data collection. Dual batteries are used to maintain uninterrupted operation.

The Genie-PC and PROCount-PC software are used to setup system parameters, process the resulting spectra, and maintain a quality assurance record for each collected spectra.

The first four components of ISOCS are relatively standard in any Germanium counting system. The key feature of the ISOCS system that allows in situ analysis is the ISOXSW software package. This software uses the detector characterization data provided by Canberra and a source geometry template to determine the relationship between measured detector counts and the actual source strength. The geometry template defines the source distribution and all other materials in the line-of-sight of the detector. Knowing the location of the source volumes, the attenuation volumes, and the response of the detector to point sources located at the positions of the source volumes allows calculation of the relationship between source intensity and measured count rate as a function of energy.

The ISOXSW software has nine standard geometries. It also has a database of materials and gamma ray attenuation coefficients for use in entering property information. The geometric templates have a wide range of parameters to allow an accurate description of the geometry, but for simple geometries the standard default values can be used. The ability to determine this relationship without complicated measurements or off-line shielding calculations is a key feature of ISOCS

The ISOCS system requires a IBM compatible PC with a math co-processor and a 486DX or higher processor. The software requires either the OS/2 or WIN95 operating system. A key advantage of the system is that data can be collected concurrently while previous reports are analyzed or new calibration curves are calculated.

# SECTION 3

# PERFORMANCE

## Demonstration Plan

In a D&D environment, ISOCS has two distinct uses. In the first use, the system is operated as a high-resolution gamma ray detector that characterizes the type of radioactive isotopes present by analysis of gamma spectra. The second use is as an assaying device that provides real-time quantitative information on the amount of radioactive material present. This quantitative information can be used to monitor, in real time, the effectiveness of D&D cleanup processes or for determining how material generated in the D&D process can be safely disposed. The tests performed in this large scale demonstration examined ISOCS operation in the standard gamma-ray detector system mode, but did not do any comparisons with other spectroscopy systems. The main object of these tests was to evaluate the capability of ISOCS to quantitatively characterize surfaces, containers, and miscellaneous objects in real time.

A wide range of objects and areas were surveyed with ISOCS and a brief summary of the main areas is given in Table 1. Figure 4 shows an example of ISOCS performing a floor survey at the Truck Dock in CP-5. Figure 5 shows the system surveying a hot spot located on a vertical wall.

Table 1. Description of Areas Surveyed

| Name | Type | Description |
|---|---|---|
| Truck Dock | Floor | 400 sq. ft. area |
| 701 Cask | Container | 701 cask containing four 55-gallon drums |
| Small container | Container | Small 5-gallon container filled with miscellaneous radioactive material |
| Pool Wall | Wall surface | Walls of a drained water pool |
| Instrument Panel/Water filter | Small volumes | 3 x 2 x 2 ft Instrument box, and a 2 ft high by 1 foot in diameter water filter. |
| Core Sample | Core | Two concrete core samples approximately 6 inches in diameter |
| Hot Spot | Wall | Small hot spot located on a wall. |

There were two different baselines considered in these tests. The first baseline system uses a high-resolution Germanium system similar to ISOCS but analyzes the radioactive content off line by means of a standard shielding code. For these tests, the comparison was done using the Small Container measurement. The second baseline consisted of obtaining a core sample from a concrete floor and then sending the sample for off-site analysis. In this case, the ISOCS system provided an in situ estimate of the radioactive material versus the core sample method, which typically requires several days before the analyzed data is available.

In these tests it was assumed that the radioactivity in the core sample was distributed within the top surface of the sample. In general, unless there are several gamma-ray lines of different energy it is difficult for ISOCS to determine the distribution of radioactivity as a function of depth with a single measurement. In those cases in which the radioactivity varies as a function of depth, it would be necessary to drill a hole in the concrete and measure the ISOCS response as a function of depth within the hole. It would also be possible to use ISOCS in its sample mode to analyze the concrete from the core sample directly.

Setup of the ISOCS detector and electronics typically requires one to two hours by a technician. A major portion of this setup time is associated with detector cool down. Data collection time depends on source strength and was typically 15 to 25 minutes in these tests. Data acquisition can be performed simultaneously with the analysis of previous samples and summary report generation. The ISOXSW software code was relatively easy to use in modeling the geometry of the source. Since there is considerable judgement required in choosing the parameters involved in the template geometry, this portion of the test should be done by a Health Physicist. If the geometries have been used in the past, then this can be done by a trained technician.

ISOCS output was not available for this demonstration. Included in Figure 4 is a typical output from the ISOCS display.

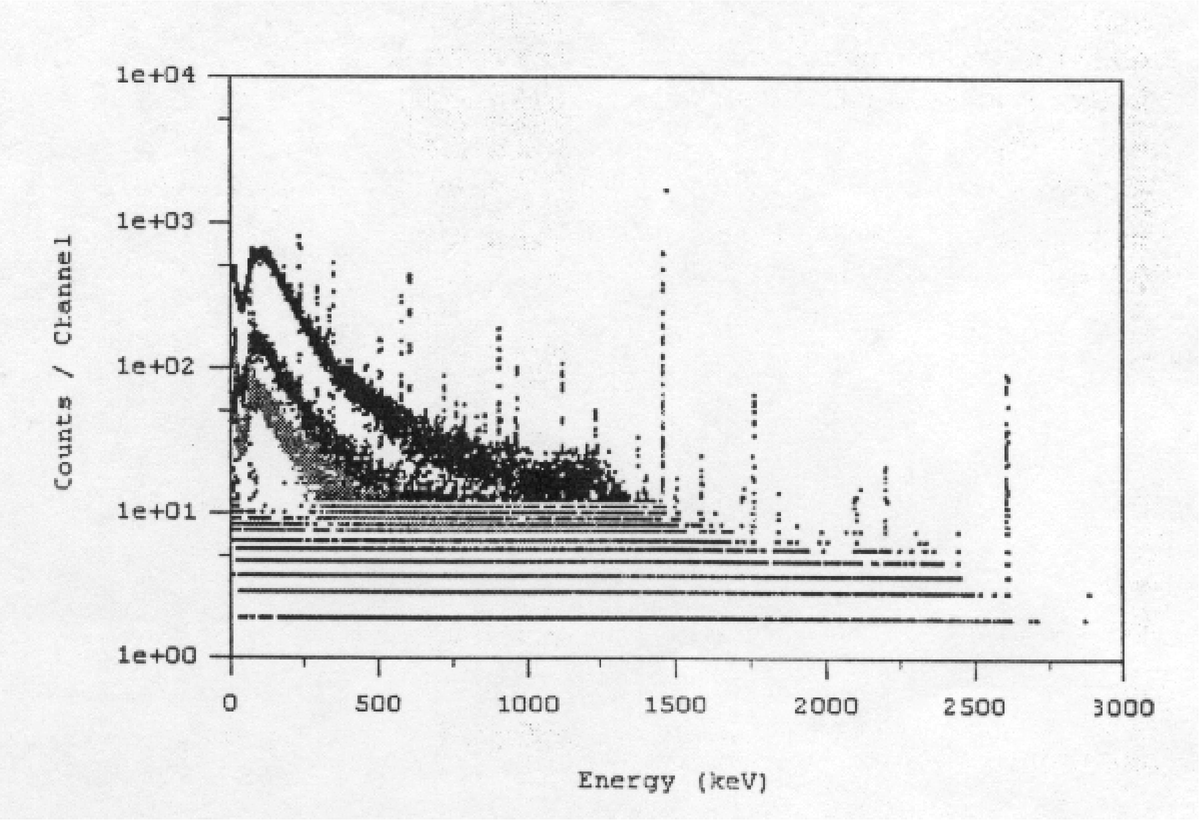

Figure 4. Background Radiation vs. Energy for the ISOCS 50 mm Shields

The peak energy clearly show the channel energies and corresponding radionuclides in a given survey.

In general there was reasonable agreement between the radioactive contents determined by ISOCS as compared to the baseline systems.

A high-resolution Germanium detector system requires a relatively large number of support systems to operate and maintain. In particular there is need for a source of liquid nitrogen for cooling the detector, and a trained operator to perform system setup and data collection. Analysis of the data requires some experience with shielding codes if ISOCS is not used. If ISOCS is used, then the availability of standard geometries reduces the required experience somewhat but there is still a need for considerable judgment. For small tasks it may be cost efficient to hire Canberra to perform the necessary measurements.

The lead shielding surrounding the detectors usually provides an adequate reduction in background radiation reaching the detector. Still if the background radiation is high relative to the area being measured, additional shielding may be required. In the case of the pool wall measurements, a concrete block was used to shield the detector system from the 701 Cask which was in the same room.

There were no mechanical, electrical, or software failures during the tests.

Figure 5.  Survey of a Truck Dock Floor

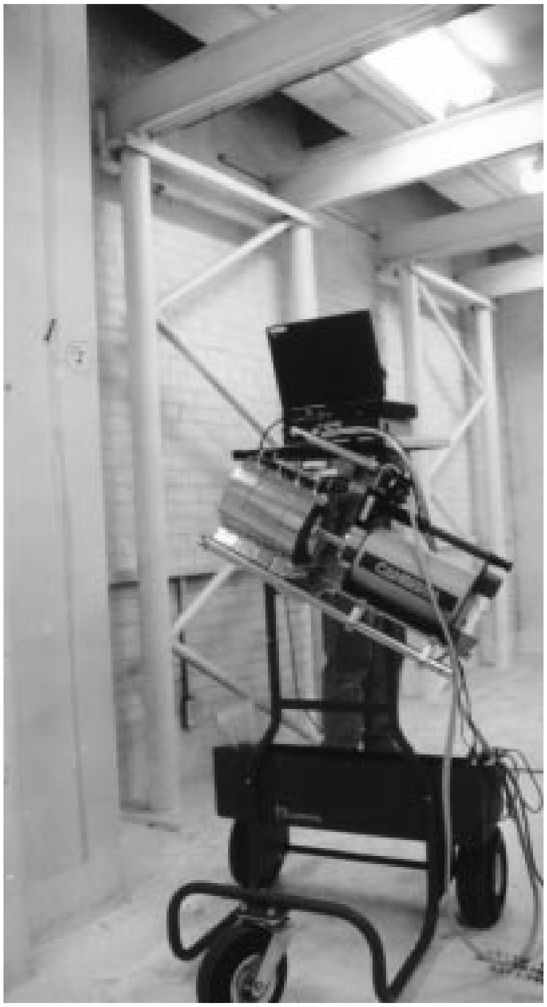

Figure 6.  Survey of Hot Spot on a Wall

## SECTION 4

# TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

## Technology Applicability

Any D&D site that has a need for real-time gamma-ray assay of containers, surfaces, or samples would benefit from the use of the ISOCS system. The major advantage of the ISOCS system is its ability to assay these objects in real time without the typical delay due to off-site analysis. This ability reduces project downtime due to waiting for results. Additionally, the availability of real time information allows for repeated measurements during the decontamination process. This minimizes the amount of unnecessary material removed, resulting in reduced waste volumes and time spent on D&D cleaning processes.

The collimator system gives the system the capability of looking at objects that are otherwise not readily accessible while still providing shielding against background radiation. In particular, objects such as ceilings or pipes that are located overhead can be assayed.

The system can also function as a high resolution Germanium spectroscopy system, so it can provide in situ identification of isotopes. The system is portable and relatively compact so space should not be a major limitation.

## Competing Technologies

The baseline technology is a manual measurement by a trained Health Physicist using a high-resolution Germanium detector and an off-line shielding code, or core and/or sample collection followed by off site analysis. The baseline technologies tend to be slower than the innovative technology, and may be more time intensive, less accurate, or both if a range of geometries is involved. In addition, the data is not available in real time, and does not allow for additional measurements that could clarify the initial data.

Similar, but not identical, competing technologies include the GammaCam™ developed by AIL, Inc., and the three-dimensional, Integrated Characterization and Archiving System developed by Coleman Research Corporation.

# SECTION 5

# COST

## Introduction

This cost analysis compares the relative costs of the innovative technology of the In-Situ Object Counting System (ISOCS) to the baseline technology of sampling with off-site analysis. The information presented will assist D&D planners in decisions about using the innovative technology in future D&D work. This analysis strives to develop realistic estimates that represent D&D work within the Department of Energy (DOE) complex. However, this is a limited representation of actual costs because the analysis uses only data observed during the demonstration. Some of the observed costs will include refinements to make the estimates more realistic such as elimination of costs for Canberra personnel who would not be present during normal work. These are allowed only when they will not distort the fundamental elements of the observed data (e.g., do not change the productivity rates, quantities, and work elements) and work. The Technology Technical Data Report (ANL, 1998) provides additional cost information and is available upon request from the Argonne National Laboratory. The project file contains an Micro Computer Aided Cost Engineering System (MCACES) report.

## Methodology

This cost analysis compares an innovative technology for remote characterization, the In-Situ Object Counting System (ISOCS), against a baseline technology consisting of collecting core sampling and off-site analysis. Both technologies are used to determine radiological conditions. The ISOCS technology was demonstrated at ANL. The cost analysis is based on observed scanning operations using the ISOCS which appear to be representative of typical work.

The manual survey was not demonstrated concurrently. The baseline is developed from previous manual surveys under similar conditions to those of the demonstration. Productivity loss factors (PLFs) and labor, equipment, and production rates were provided by site personnel at ANL or are derived from similar work being performed elsewhere.

The selected basic activities being analyzed originate from the Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure (HTRW RA WBS) and Data Dictionary, USACE, 1996. The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. The ANL indirect expense rates for common support and materials are omitted from this analysis. The overhead and general and administrative (G&A) rates for each DOE site vary in magnitude and in their application. Decision-makers seeking site-specific costs can apply their site's rates to this analysis without having to first "back out" the rates used at ANL. The impact resulting from this omission is judged to be minor since overhead is applied to both the innovative and baseline technology costs. Engineering, quality assurance, administrative costs, and taxes on services and materials are also omitted from this analysis for the same reasons.

The standard labor rates established by ANL for estimating D&D work are used in this analysis for the portions of the work performed by local crafts. Costs for site-owned equipment, such as trucks for transport or Health Physics Technician (HPT) radiological survey equipment, are based upon an hourly government ownership rate that is computed using the Office of Management and Budget (OMB) Circular No. A-94. Quoted rates for the vendor's costs are used in this analysis for performing training of the site's personnel and includes the vendor's G&A, overhead, and fee mark-up costs. Additionally, the analysis uses an eight-hour workday with a five-day workweek. The production rates and observed duration used in the cost analysis do not include "non-productive" items such as work breaks, donning and doffing protective clothing, loss of dexterity (due to cumbersome personal protection equipment (PPE)), and heat stress. These "non-productive" items are accounted for in the analysis by including a Productivity Loss

Factor (PLF). The PLF is a historically based estimate of the fraction of the workday that the worker spends in non-productive activities.

## Cost Data

Information about the costs of equipment purchase, equipment lease, and vendor-provided services are presented in Table 2.

**Table 2. Innovative Technology Acquisition Costs.**

| Acquisition Option | Item | Cost |
|---|---|---|
| Equipment Purchase | ISOCS | $ 75,000 |
| Vendor Provided Service | ISOCS | $10,000 - $20,000 per week (occasionally $30,000/week) |
| Equipment Lease | ISOCS | $ 1,000 to 2,000 per week |

In addition to the purchase price, there will be costs to operate and maintain ISOCS (typical of any Germanium detector system). In particular, there is a need for liquid nitrogen for cooling the detector and a “check source” calibration will need to be performed during the day. These costs are highly dependent on individual project specifics. The range of costs for the vendor provided services reflect these variable costs.

Observed unit costs and production rates for principal components of the demonstrations for both the innovative and baseline technologies are presented in Table 3.

**Table 3. Summary of Unit Costs and Production Rates Observed During the Demonstration.**

| Innovative Technology | | | Baseline Technology | | |
|---|---|---|---|---|---|
| **Cost Element** | **Unit Cost** | **Production Rate** | **Cost Element** | **Unit Cost** | **Production Rate** |
| Survey | $56 / test location | 2 tests per hour | Core Sampling | $140 / sample | 1 sample per hour |

The unit costs and production rates shown do not include mobilization, initial set-up, or other losses associated with non-productive portions of the work (such as suit-up, breaks, etc.). The intention of this table is to show unit costs at their elemental level which are free of site specific factors (such as work culture or work environment influences on productivity loss factors). Consequently, the unit cost for the ISOCS survey is computed by dividing the cost shown for the Set Up and Move, Survey, and the Process Data line items of Table C-1 of Appendix C by the number of samples. The unit cost for the baseline core sampling is computed by dividing the cost shown for the Set Up and Move, Core Sample, Package Sample Transport Analyze and Dispose of Sample line items of Table C-2 of Appendix C. Tables C-1 and C-2 can be used to compute site specific costs by inserting quantities and adjusting the units for conditions of an individual D&D job.

## Summary of Cost Variable Conditions

The DOE complex presents a wide range of D&D work conditions as a result of the variety of site functions and facilities. The working conditions for an individual job directly affect the manner in which D&D work is performed and, consequently, the costs for an individual job are unique. The innovative and baseline technology estimates presented in this analysis are based upon a specific set of conditions or work practices found at CP-5 and are summarized in Table 4. This table is intended to help the technology user identify work differences that can result in cost variances.

**Table 4. Summary of Cost Variable Conditions.**

| Cost Variable | ISOCS | Core Sample and Off-Site Analysis |
|---|---|---|
| Scope of Work | | |
| Quantity and Type | Survey a 2,000 ft$^2$ concrete-floored room at 20 test locations using ISOCS hardware and software. | Collect 20 concrete floor samples from a 2,000-ft$^2$ room using a core drill with a six-inch diameter core bit and analyze off-site. |
| Location | Assumed to be a typical room with a concrete floor that requires a survey. | Assumed to be a typical room with a concrete floor that requires a survey. |
| Nature of Work | Characterization of a concrete floor for planning purposes. Provides standard radiation detection with high-energy resolution. | Characterization of Concrete floor for planning purposes. |
| Work Environment | | |
| Worker Protection | Anti-contamination coveralls with hood. | Anti-contamination coveralls with hood. |
| Level of Contamination | Assumed to be a buffer zone. | Assumed to be a buffer zone. |
| Work Performance | | |
| Acquisition Means | Site personnel with site-owned equipment | Site personnel with site-owned equipment |
| Production Rates | The rate for the survey is assumed to be two tests per hour (i.e., 15 minutes for set up and 15 minutes for measurement, each) for data collection; four tests per hour for data processing; and ten data points per hour for data evaluation. | Core sampling is assumed to require one hour per sample. Four samples are assumed to be packaged per hour. However, the time required for the sample to be shipped off site and analyzed is approximately one week. Faster turn-around time would result in an elevated cost. |
| Equipment and Crew | One D&D worker (@ $33.60/hr) is assumed for setup and operation. One HPT (@ $56/hr) for data analysis. | One D&D worker using one Milwaukee Model 4120-22 core drill with six-inch diameter core bit. One D&D worker to package and send samples. Transportation to off-site lab, and analysis and disposal of samples by off-site lab costs $92 per sample. |
| Work Process Steps | 1• Transport equipment to work area<br>2• Prepare for use<br>3• Set up and move equipment<br>4• Perform surveys<br>5• Process data<br>6• Evaluate data<br>7• Survey and decontaminate equipment<br>8• Transport equipment to storage area | 1• Transport equipment to work area<br>2• Prepare for use<br>3• Set up and move equipment<br>4• Take core samples<br>5• Package samples<br>6• Transport, analyze, and dispose of samples<br>7• Evaluate data<br>8• Survey and decontaminate equipment<br>9• Transport equipment to storage |
| End Product | Characterization of concrete floor area | Characterization of concrete floor area |

## Potential Savings and Cost Conclusions

The innovative technology, the In-Situ Object Counting System (ISOCS), for the conditions stated in Table 4 and assumptions established in Appendix C, is approximately 70% of the cost of the baseline technology for this demonstration. A comparison of the costs for mobilization, characterization, and demobilization for both technologies can be seen in Figure 6.

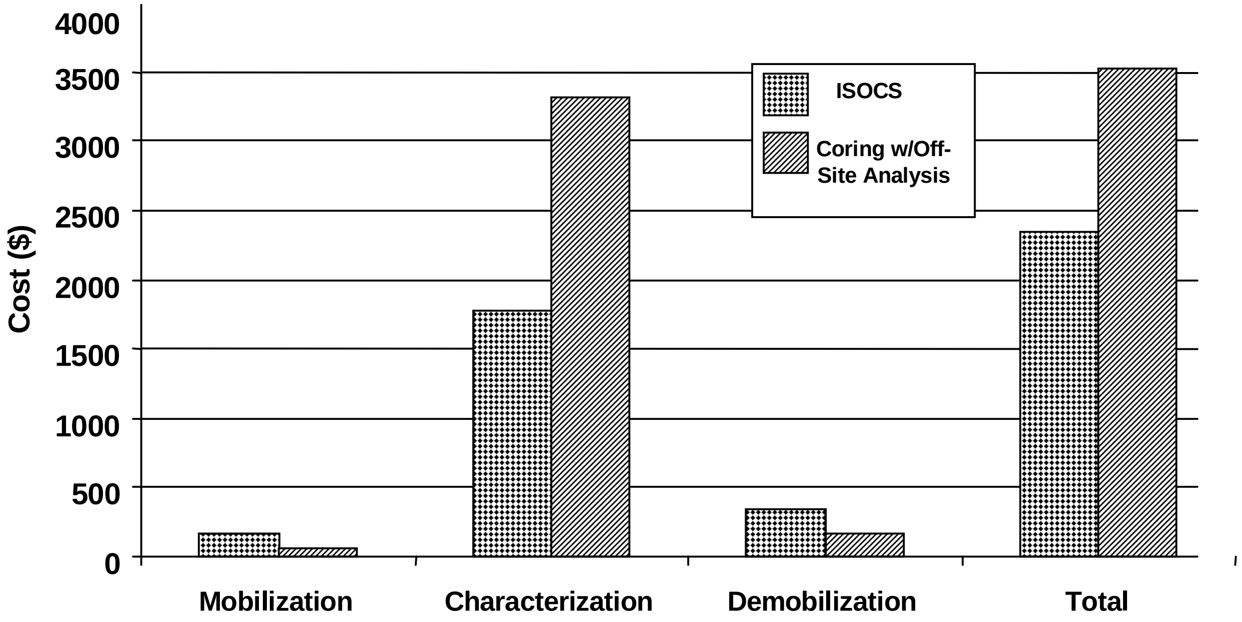

Figure 6. Technology Comparison

The difference in cost between ISOCS and the baseline technology results from ISOCS avoiding the laboratory charge for sample analysis and associated costs for handling/transporting the core samples. For this analysis, the cost for labor and equipment to collect the core samples was not significantly different from the cost for ISOCS to scan each sample [$48/sample (core) vs. $56/sample (ISOCS)]. But for other types of work such as compliance sampling for release the crews and procedures will be different from this analysis and may result in significant cost differences.

This cost analysis does not include costs for training operators to use the ISOCS equipment. This cost was omitted because site personnel may be familiar with the use of gamma spectroscopy hardware and because it would be a one time cost. Qualified operators are essential for ISOCS and proper training may be an important cost consideration. The costs for maintenance of the ISOCS equipment is not considered in this analysis. Finally, the cost of liquid nitrogen may be more substantial than shown in this analysis depending on the individual site.

# SECTION 6

# REGULATORY/POLICY ISSUES

## Regulatory Considerations

The regulatory/permitting issues related to the use of the ISOCS technology at the ANL CP-5 Test Reactor are governed by the following safety and health regulations

- Occupational Safety and Health Administration (OSHA) 29 CFR 1926

| | |
|---|---|
| - 19.26.300 to 19.26.307 | Tools-Hand and Power |
| - 1926.400 to 1926.449 | Electrical - Definitions |
| - 1926.28 | Personal Protective Equipment |
| - 19.26.52 | Occupational Noise Exposure |
| - 1926.102 | Eye and Face Protection |
| - 1926.103 | Respiratory Protection |

- OSHA 29 CFR 1910

| | |
|---|---|
| - 1910.211 to 1910.219 | Machinery and Machine Guarding |
| - 1910.241 to 1910.244 | Hand and Portable Powered Tools and Other Hand-Held Equipment |
| - 19.10.301 to 1910.399 | Electrical - Definitions |
| - 1910.95 | Occupational Noise Exposure |
| - 1910.132 | General Requirements (Personnel Protective Equipment) |
| - 1910.133 | Eye and Face Protection |
| - 1910.134 | Respiratory Protection |
| - 1910.147 | The Control of Hazardous Energy (Lockout/Tagout) |

Disposal requirements/criteria include the following Department of Transportation (DOT) and DOE requirements:

- 49CFR Subchapter C Hazardous Materials Regulation

| | |
|---|---|
| —171 | General Information, Regulations, and Definitions |
| —172 | Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements |
| —173 | Shippers - General Requirements for Shipments and Packagings |
| —174 | Carriage by Rail |
| —177 | Carriage by Public Highway |
| —178 | Specifications for Packaging |

- 10CFR 71 Packaging and Transportation of Radioactive Material

If the waste is determined to be hazardous solid waste, the following Environmental Protection Agency (EPA) requirement should be considered:

| | |
|---|---|
| 40 CFR Subchapter 1 | Solid Waste |

These are the same regulations that govern the baseline technology, excavation and disposal. The waste form requirements/ criteria specified by disposal facilities used by ANL include:

| | |
|---|---|
| • *Hanford Site Solid Waste Acceptance Criteria* | WHC-EP-0063-4 |
| • *Barnwell Waste Management Facility Site Disposal Criteria* | S20-AD-010 |
| • *Waste Acceptance Criteria for the Waste Isolation Pilot Plant* | WIPP-DOE-069 |

The ISOCS system is relatively new in terms of assaying radioactive materials. Thus it will probably be necessary to calibrate the accuracy of the ISOCS system relative to the standard baseline situation for each regulatory agency and for each D&D project. As experience is gained with the use of this technology, the need for bench marking the system should decrease.

The acceptability of the ISOCS data is dependent upon the regulatory body to which, and the specific reasons for which, the data is presented.

## Safety, Risks, Benefits, and Community Reaction

The safety issues with ISOCS are limited to those routinely encountered in an industrial environment. The coolant liquid nitrogen is the major concern in terms of worker safety, but it is not a chemical hazard.

A major benefit is that ISOCS can provide rapid, real time information on the type of isotopes, and the magnitude of a radiological hazard. This allows public health personnel to quickly access the situation and provide the public with fast and accurate information.

## SECTION 7

# LESSONS LEARNED

## Implementation Considerations

The Canberra ISOCS system demonstrated at CP-5 is a well developed and commercially available instrument. During the tests, the Germanium detector and electronic spectroscopy system were moved many times within the facility and no problems were encountered. As configured, the system can work off standard camcorder batteries or 120-VAC. The system requires a source of liquid nitrogen for filling the cryostat that cools the detector system. The lead shielding for reducing background radiation reaching the detector is useful, but additional shielding may be necessary. In general, this system will have problems in providing accurate assay information in high background fields.

## Technology Limitations and Needs for Future Development

The ISOCS system would benefit from the following design improvements:

- Cryostat that can be tilted up or down without refilling

## Technology Selection Considerations

Any large nuclear site can make use of this technology. In its simplest use of isotopic identification, ISOCS can be used to provide characterization information on the type and extent of radioactive material. The ISOXSW software provides the capability of assaying a wide range of containers and surfaces using a set of standard geometrical models. The system can also be used to assay soil or core samples that have been collected and brought to the instrument, or it can make the measurements directly at the site. The ability to do in situ measurements and provide data almost instantaneously would aid decontamination projects in which the status of the decontamination object must be measured as part of the process. In general, ISOCS is not well suited for working in areas with large background radiation fields, if relatively low strength sources must be assayed.

# Appendix A

## REFERENCES

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Strategic Alliance for Environmental Restoration, *CP-5 Large Scale Demonstration Project, Data Report for ISOCS Radiation Imaging System, at CP-5*, Argonne National Laboratory, December 1997.

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# Appendix B

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACE | Activity Cost Estimate (Sheets) |
| AIF | Atomic Industrial Forum, Incorporated |
| ALARA | As Low As Reasonably Achievable |
| ANL | Argonne National Laboratory |
| CF | Cubic Feet (Foot) |
| CFM | Cubic Feet Per Minute |
| COE | Corps Of Engineers |
| D&D | Decontamination And Decommissioning |
| DDFA | Deactivation and Decommissioning Focus Area |
| Decon | Decontamination |
| Demo | Demonstration |
| Demob | Demobilization |
| DOE | Department Of Energy |
| DOE-CH | DOE- Chicago |
| DOE-RL | DOE- Richland |
| Eq | Equal |
| Equip | Equipment |
| ER | Environmental Restoration |
| FCCM | Facilities Capital Cost Of Money |
| FETC | Federal Energy Technology Center |
| $FT^2$ | Square Feet (Foot) |
| $FT^3$ | Cubic Feet (Foot) |
| G&A | General and Administrative |
| H&S | Health And Safety |
| HR | Hour |
| HPT | Health Physics Technician |
| HTRW | Hazardous, Toxic, Radioactive Waste |
| ICT | Integrating Contractor Team |
| ISOCS | In-Situ Object Counting System |
| LF | Lineal Feet (Foot) |
| LLW | Low-Level Waste |
| LS | Lump Sum |
| MB | Magnetic Broom |
| Min | Minute |
| Mob | Mobilization |
| NESP | National Environmental Studies Project |
| OMB | Office of Management and Budget |
| OT | Overtime |
| PCs | Personal Computer |
| PLF | Productivity Loss Factor |

| | |
|---|---|
| PPE | Personnel Protective Equipment |
| Qty (Qnty) | Quantity |
| RA | Remedial Action |
| SAFSTOR | Safe Storage |
| SF | Square Feet (Foot) |
| TC | Total Cost |
| Tech | Technician |
| TQ | Total Quality |
| UC | Unit Cost |
| UCF | Unit Cost Factor |
| UOM | Unit Of Measure |
| WBS | Work Breakdown Structure |
| WPI | Waste Policy Institute |
| YR | Year |

# Appendix C

## TECHNOLOGY COST COMPARISON

This appendix contains definitions of cost elements, descriptions of assumptions, and computations of unit costs that are used in the cost analysis.

## Innovative Technology – In-Situ Object Counting System

### MOBILIZATION (WBS 331.01)

Transport Equipment to Work Area
Definition: ISOCS equipment is transported from the on-site storage location to the work area.

Assumptions: Assumed duration is ½ hour. The duration is consistent with the cost analysis for other similar technologies.

Prepare Equipment for Use
Definition: ISOCS equipment is prepared for use (includes wrapping cables and body with plastic to minimize potential contamination). Also, the equipment is set up for its initial use (i.e., turned on, liquid nitrogen changed or added, computer booted up, etc.).

Assumptions: Crew consists of one HPT for one hour (based on test engineer's judgement).

### CHARACTERIZATION (WBS 331.17)

Liquid Nitrogen
Definition: The ISOCS equipment requires liquid nitrogen to keep it cold so that it operates properly.

Assumptions: Assumed to cost $50 per refill. Equipment is assumed to only need to be filled once. Labor is included under set up.

Set Up and Move Equipment
Definition: The time required for setting up and moving from one survey location to the next.

Assumptions: The duration is assumed to be 15 minutes per location.

Surveys
Definition: Survey of floor area using the ISOCS equipment.

Assumptions: The survey was assumed to be in a 2,000-$ft^2$ room that required 20 samples. The crew was one D&D worker (based on the test engineer's judgement). Each survey location (20 total) required an average of 15 minutes.

Process Data
Definition: This activity includes processing the data from the measurements using the ISOCS software to determine the results of the survey.

Assumptions: This activity requires one Health Physics Technician (HPT) for 15 minutes per measurement.

Evaluate Data
Definition: This activity includes evaluating the data from the output of the ISOCS software to determine the results of the survey.

Assumptions: This task requires two hours for one HPT (i.e., a productivity of ten data points per hour).

Daily Meetings
Definition: This cost element provides for safety/project-planning meetings during the work.

Assumptions: One 15-minute safety/project-planning meeting per day (based on typical practice at ANL).

Personal Protective Equipment
Definition: This cost element provides for the personal protective equipment used during the work activity.

| **Equipment** | **Cost Each Time Used** | **Number Used Per Day** | **Cost Per Day** |
|---|---:|:---:|---:|
| Respirator | $10.00 | 1 | $10.00 |
| Respirator Cartridges | 9.25 | 2 | 18.50 |
| Booties | 0.25 | 4 | 1.00 |
| Tyvek | 3.40 | 4 | 13.60 |
| Gloves (inner) | 0.17 | 8 | 1.36 |
| Gloves (outer pair) | 0.75 | 1 | 0.75 |
| Glove (cotton Liner) | 0.14 | 8 | 1.12 |
| **Total** | | | $46.33 |

The PPE costs are predominantly from the ANL activity cost estimates for 1996 (costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs).

Productivity Loss Factor
Definition: Productivity losses occurring during the course of the work due to PPE changes, ALARA, reach height inefficiencies, etc.

Assumption: Work area is assumed to be a buffer zone (no respirator needed). The survey duration does not account for work breaks or PPE changes. Consequently, these types of costs are estimated and added to the innovative cost in this cost element. The duration of work performed in the controlled area (activities outside the controlled area, such as evaluation of the data, are not included in the computation) is adjusted by a factor of 1.27. This is included to account for these losses (particularly work breaks and suiting up) based on the factors shown below (AIF, 1986):

| | | |
|---|---:|---|
| Base | 1.00 | |
| +Height | 0 | |
| +Rad/ALARA | 0 | (not considered since most work is waiting) |
| +Protective Clothing | 0.15 | |
| Subtotal | 1.15 | |
| X | | |
| Respiratory Protection | 1.00 | (no factor used, losses included in observed times) |
| Subtotal | 1.15 | |
| X | | |
| Breaks | 1.10 | |
| Total | 1.27 | |

## DEMOBILIZATION (WBS 331.21)

Survey and Decontaminate Equipment
Definition: ISOCS equipment is surveyed for contamination and decontamination is performed as needed before transferring back to the on-site equipment storage area.

Assumption: This task requires one HPT for two hours.

Transport Equipment to On-Site Storage Area
Definition: The equipment is transported from the work area to the on-site equipment storage area.

Assumption: The assumed duration is ½ hour.

The activities, quantities, production rates, and costs observed during the demonstration are shown in Table C-1 Innovative Technology Cost Summary.

**Table C-1: Innovative Technology Cost Summary – ISOCS.**

| Work Breakdown Structure (WBS) | Unit Cost (UC) | | | | | | Total Quantity (TQ) | Unit of Measure | Total Cost (TC) note | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | | Equipment | | Other | Total UC | | | | |
| | HRS | Rate | HRS | Rate | | | | | | |
| **MOBILIZATION WBS 331.01** | | | | | | | | **Subtotal** | **$155** | |
| Transport Equipment to Work Area | 0.50 | $56.00 | 0.50 | $47.10 | $0 | $51.55 | 1 | Each | $51.55 | Transferring the ISOCS equipment to the work area by one D&D worker (@ $33.60/hr) requires ½ hour. One trip. |
| Prepare Equipment for Use | 1.00 | $56.00 | 1.00 | $47.10 | $0 | $103.10 | 1 | Each | $103.10 | One HPT for one hour (includes instrument check out, wrapping instrument with plastic sheeting, and initialization). |
| **CHARACTERIZATION WBS 331.17** | | | | | | | | **Subtotal** | **$1,896** | |
| Liquid Nitrogen | 0 | $0 | 0 | $0 | $50 | $50 | 1 | Each | $50 | Includes cost for liquid nitrogen for ISOCS. |
| Set Up and Move Equipment | 0.25 | $56.00 | 0.25 | $47.10 | $0 | $25.78 | 20 | Each | $515.50 | Move equipment to survey location and prepare for next survey. Requires one HPT for 15 minutes for each new location. |
| Surveys | 0.25 | $56.00 | 0.25 | $47.10 | $0 | $25.78 | 20 | Each | $515.50 | Take measurement at each survey location. Crew includes one HPT. |
| Process Data | 0.25 | $56.00 | 0 | $0 | $0 | $ 14 | 20 | Each | $280.00 | One HPT (@ $56/hr) is required for an average of 15 minutes per data set from each location. |
| Evaluate Data | 0.10 | $56.00 | 0 | $0 | $0 | $ 6 | 20 | Each | $112.00 | One HPT evaluates ten data sets per hour. |
| Daily Meetings | 0.25 | $56.00 | 0.25 | $47.10 | $0 | $ 25.78 | 2 | Each | $51.55 | One safety/project-planning meeting (15 min) each morning prior to beginning work attended by one HPT. |
| Personal Protection Equipment | 0 | $0 | 0 | $0 | $46.33 | $46 | 2 | Man Day | $93 | Assumed cost per person per day of $46.33 |
| Productivity Loss Factor | 2.7 | $56.00 | 2.7 | $47.10 | $0 | $278.37 | 1 | Lump Sum | $278.37 | Duration in controlled area X 27% |
| **DEMOBILIZATION WBS 331.21** | | | | | | | | **Subtotal** | **$364** | |
| Survey and Decontaminate Equipment | 2.00 | $56.00 | 2.00 | $47.10 | $106 | $312.20 | 1 | Each | $312.20 | Survey equipment prior to sending to on-site storage area and remove plastic wrap by one HPT for two hours. Other costs include waste disposal of 2 $ft^3$ of low-level waste @ $52.78/$ft^3$. |
| Transport Equipment to On-Site Storage Area | 0.50 | $56.00 | 0.50 | $47.10 | $0 | $ 51.55 | 1 | Each | $51.55 | Manually transport equipment to on-site equipment storage area by one D&D worker. |
| Note: TC = UC * TQ | | | | | | | | **TOTAL:** | **$2,415** | |

# Baseline Technology – Core Sampling with Off-Site Analysis

## MOBILIZATION (WBS 331.01)

Transport Equipment to Work Area
Definition: The equipment is transported to the work area from the on-site equipment storage area.

Assumptions: The effort is assumed to be ½ hour. Electricity is assumed to be available in the vicinity of the sampling location. Therefore, a generator is not required.

Prepare Equipment for Use
Definition: This core drill is prepared for use by wrapping it in plastic to reduce potential contamination.

Assumption: Assume one hour.

## CHARACTERIZATION (WBS 331.17)

Set Up and Move Equipment
Definition: The time required for setting up in one location and moving from one survey area to the next.

Assumptions: The duration is ½ hour per location and the crew is assumed (based on the test engineer's judgment) to be one D&D worker.

Core Samples
Definition: Drilling and collecting a core sample from the concrete floor.

Assumptions: The core sample is six inches in diameter and six inches deep. The total drilling duration is assumed to be ½ hour per core. The crew is assumed to be one D&D worker.

Package Samples
Definition: Packaging the samples for delivery to an off-site analytical laboratory.

Assumptions: Each sample requires 15 minutes to prepare by a D&D worker. Assume that packaging for transport takes place outside of the radiological controlled area.

Transport, Analyze, and Dispose of Samples
Definition: This cost element provides for activities related to the transportation of the samples to the off-site analytical laboratory, analysis of the samples, and disposal costs of the analytical laboratory.

Assumptions: Each sample costs $92 for transportation, analysis, and disposal.

Evaluate Data
Definition: Reviewing the survey results and developing survey reports (including maps of the maximum readings).

Assumptions: This effort requires two hours for one HPT (i.e., a productivity of ten data points per hour).

Daily Meetings
Definition: This cost element provides for safety/project-planning meetings during the work.

Assumption: One 15-minute safety/project-planning meeting per day (based on typical practice at ANL).

Personal Protection Equipment
Definition: This cost element provides for the personal protective clothing used during the work activity.

| Equipment | Cost Each Time Used | Number Used Per Day | Cost Per Day |
|---|---|---|---|
| Respirator | $10.00 | 1 | $10.00 |
| Respirator Cartridges | 9.25 | 2 | 18.50 |
| Booties | 0.25 | 4 | 1.00 |
| Tyvek | 3.40 | 4 | 13.60 |
| Gloves (inner) | 0.17 | 8 | 1.36 |
| Gloves (outer pair) | 0.75 | 1 | 0.75 |
| Glove (cotton Liner) | 0.14 | 8 | 1.12 |
| **Total** | | | $46.33 |

The PPE costs are predominantly from the ANL activity cost estimates for 1996 (costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs).

Productivity Loss Factor
Definition: Productivity losses occurring during the course of the work due to PPE changes, ALARA, reach height inefficiencies, etc.

Assumption: The work area is assumed to be a buffer zone (no respirator required). The survey duration does not account for work breaks or PPE changes. Consequently, these types of costs are estimated and added to the baseline cost in this cost element. The duration of work performed in the controlled area (activities outside the controlled area, such as evaluation of the data, are not included in the computation) is adjusted by a factor of 1.27. This factor is used to account for these losses (particularly work breaks and suiting up) based on the factors shown below (AIF, 1986):

| | | |
|---|---|---|
| Base | 1.00 | |
| +Height | 0 | |
| +Rad/ALARA | 0 | |
| +Protective Clothing | 0.15 | |
| Subtotal | 1.15 | |
| X | | |
| Respiratory Protection | 1.00 | (no factor used, losses included in observed times) |
| Subtotal | 1.15 | |
| X | | |
| Breaks | 1.10 | |
| Total | 1.27 | |

**DEMOBILIZATION (WBS 331.21)**

Survey and Decontaminate Equipment
Definition: Equipment and personnel are surveyed for contamination and decontamination is performed as need for free release.

Assumption: This task requires one HPT for two hours.

Transport Equipment to Storage
Definition: The equipment is transported to an on-site equipment storage area.

Assumption: The effort is assumed to be ½ hour for one D&D worker.

The activities, quantities, production rates, and costs utilized in the baseline are shown in Table C-2: Baseline Technology Cost Summary.

### Table C-2. Baseline Technology Cost Summary – Sampling with Off-Site Analysis

| Work Breakdown Structure (WBS) | Unit Cost (UC) | | | | | | Total Quantity (TQ) | Unit of Measure | Total Cost (TC) note | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | | Equipment | | Other | Total UC | | | | |
| | Hour | Rate | Hour | Rate | | | | | | |
| **Mobilization (WBS 331.01)** | | | | | | | | **Subtotal** | **$60** | |
| Transport Equipment to Work Area | 0.5 | $33.60 | 0.5 | $6.75 | $0 | $20 | 1 | Each | $20 | One trip. Crew of one D&D worker (@ $33.60/hr) plus one Milwaukee core drill with extension cord and six-inch core bit (@ $6.66/hr) and water. |
| Prepare Equipment for Use | 1.0 | $33.60 | 1.0 | $6.75 | $0 | $40 | 1 | Each | $40 | One D&D worker prepares equipment using plastic to reduce potential for contamination. |
| **Characterization (WBS 331.17)** | | | | | | | | **Subtotal** | **$3,367** | |
| Set Up and Move Equipment | 0.5 | $33.60 | 0.5 | $6.75 | $0 | $20 | 20 | Each | $403 | One D&D worker setting up core drill in 20 survey location areas. |
| Core Samples | 0.5 | $33.60 | 0.5 | $6.75 | $0 | $20 | 20 | Each | $403 | One D&D worker takes one concrete core sample from 20 floor locations. |
| Package Samples | 0.25 | $33.60 | 0 | $0 | $0 | $8 | 20 | Each | $168 | One D&D worker prepares concrete core samples for delivery to off-site lab. |
| Transport, Analyze, and Dispose of Samples | 0 | $0 | 0 | $0 | $92 | $92 | 20 | Each | $1,840 | It costs $92 for each of the 20 samples to be shipped, analyzed, and disposed of. |
| Evaluate Data | 0.1 | $56.00 | 0 | $0 | $0 | $6 | 20 | Each | $112 | One HPT evaluates report from off-site laboratory at assumed rate of ten sample results per hour. |
| Daily Meetings | 0.25 | $33.60 | 0.25 | $6.75 | $0 | $10.09 | 3 | Each | $30 | One D&D worker attends a daily meeting for 15 minutes. |
| Personal Protection Equip. | 0 | $0 | 0 | $0 | $46 | $46 | 3 | Man-Day | $139 | PPE cost per person per day of $46.33 |
| Productivity Loss Factor | 6.75 | $33.60 | 6.75 | $6.75 | $0 | $272 | 1 | Lump Sum | $272 | Productivity Loss Factor (adjusts for changes, breaks, respiratory protection, and ALARA; extends radiation controlled area work by 27%) |
| **Demobilization (WBS 331.21)** | | | | | | | | **Subtotal** | **$158** | |
| Survey and Decontaminate Equipment | 2.0 | $56.00 | 2.0 | $6.75 | $13 | $138 | 1 | Each | $138 | One HPT and 1/4 ft$^3$ of low level waste disposal for swipes and plastic @ $52.78/ft$^3$ |
| Transport Equipment to Storage | 0.5 | $33.60 | 0.5 | $6.75 | $0 | $20 | 1 | Each | $20 | One D&D worker returns the equipment to the on-site storage area. |

Note: TC = UC * TQ

**TOTAL** **$ 3,525**