INNOVATIVE TECHNOLOGY
Summary Report

Field Transportable Beta Spectrometer

OST Reference #1853

Deactivation and Decommissioning Focus Area

Demonstrated at
Argonne National Laboratory-East
Argonne, Illinois

MASTER

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

The objective of the Large-Scale Demonstration Project (LSDP) is to select and demonstrate potentially beneficial technologies at the Argonne National Laboratory-East (ANL) Chicago Pile-5 Test Reactor (CP-5). The purpose of the LSDP is to demonstrate that by using innovative and improved deactivation and decommissioning (D&D) technologies from various sources, significant benefits can be achieved when compared to baseline D&D technologies. The overall emphasis of the DOE, Office of Science and Technology (OST), D&D Focus Area is to focus on systems and capabilities that can be used in facility deactivation and ongoing surveillance and maintenance activities with extended application to final facility D&D tasks.

One such capability being addressed by the D&D Focus Area is rapid characterization for facility contaminants. The technology was field demonstrated during the period January 7 through January 9, 1997, and offers several potential benefits, including faster turn-around time, cost reduction, and reduction in secondary waste. This report describes a PC controlled, field-transportable beta counter-spectrometer which uses solid scintillation coincident counting and low-noise photomultiplier tubes to count element-selective filters and other solid media.

The dry scintillation counter used in combination with an element-selective technology eliminates the mess and disposal costs of liquid scintillation cocktails. Software in the instrument provides real-time spectral analysis. The instrument can detect and measure Tc-99, Sr-90, and other beta emitters reaching detection limits in the 20 pCi range (with shielding). Full analysis can be achieved in 30 minutes.

The potential advantages of a field-portable beta counter-spectrometer include the savings gained from field generated results. The basis for decision-making is provided with a rapid turnaround analysis in the field. This technology would be competitive with the radiometric analysis done in fixed laboratories and the associated chain of custody operations.

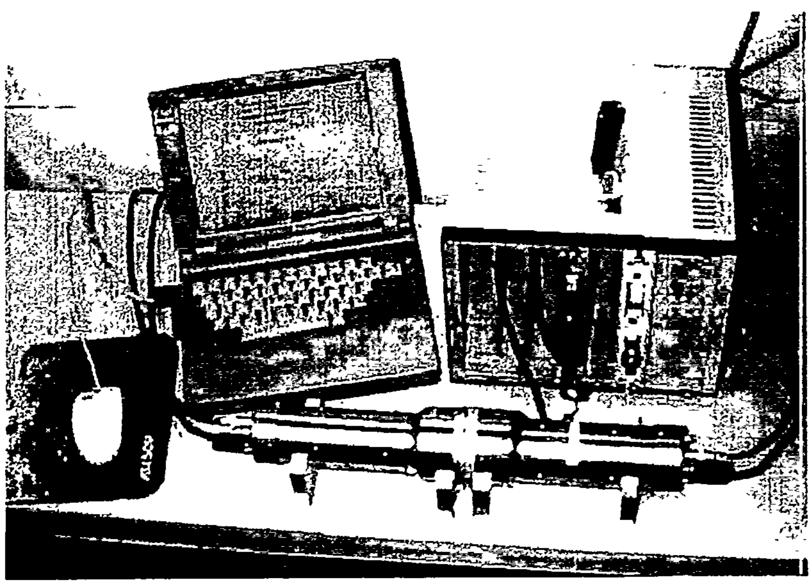

Figure 1. Field transportable beta spectrometer equipment.

Technology Status

The beta counter-spectrometer used for the demonstration was a working prototype, a first generation device. Argonne National Laboratory personnel operated the solid scintillation instrument during the two-day exercise.

The setting for the demonstration was the former CP-5 research reactor. CP-5 was a thermal reactor, fueled with highly enriched uranium, moderated with a heavy-water coolant and was engineered to provide neutron beams for research purposes. The reactor had a thermal-power rating of 5 megawatts and was continuously operated for 25 years with final shutdown in 1979. CP-5 has many of the essential features associated with other nuclear facilities within the U.S. Department of Energy complex, including certain levels of activation and contamination residuals.

Key Results

The key results of the demonstration are as follows:

- The prototype was able to generate quantitative and qualitative data. This was accomplished for sources containing Tc-99, Sr-90, Co-60, and Cs-137 plus two samples containing radioactive material recovered from the CP-5 building.

- The prototype was able to generate data rapidly in a "field" situation. This was accomplished as results were produced within 30 minutes of counting.

- Over the two (2) day demonstration period, 25 separate analytical measurements were made. A total of twenty (20) personnel-hours were spent at the CP-5 including the orientation, unpacking, set up, sample collection, sample processing, measurements, troubleshooting, take-apart, packing, and removal.

Contacts

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Licensing Information

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

Web Site

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

SECTION 2

TECHNOLOGY DESCRIPTION

System Configuration and Operation

The technology is a novel detection device for the qualitative and quantitative measurement of beta-emitters. This is a portable instrument (not hand-held) which uses solid-scintillation, coincident-guarded counting. It employs low-background photomultiplier tubes and low-noise preamplifiers to assay filters, swipes, and other solid media. This dry scintillation technology eliminates the mess and disposal costs of liquid scintillation cocktails. Software in the instrument provides real-time spectral analysis. A schematic representation of the solid scintillation device is given in Figure 2. The technology is intended to reduce the cost and efforts associated with the collection of radio-spectroscopy data and provide decision-makers with quality information in the minimum time possible.

The Dual-Channel, Low-Level Beta Counting System consists of 2 photomultiplier tube/detector units each with 0.125-in. BC-400 plastic scintillators, a high-voltage power supply, 2 preamplifier units with integral amplifier/lower-level discriminator, a NIM signal mixer interface, a notebook or desk-top type (PC) computer and various interconnect cables.

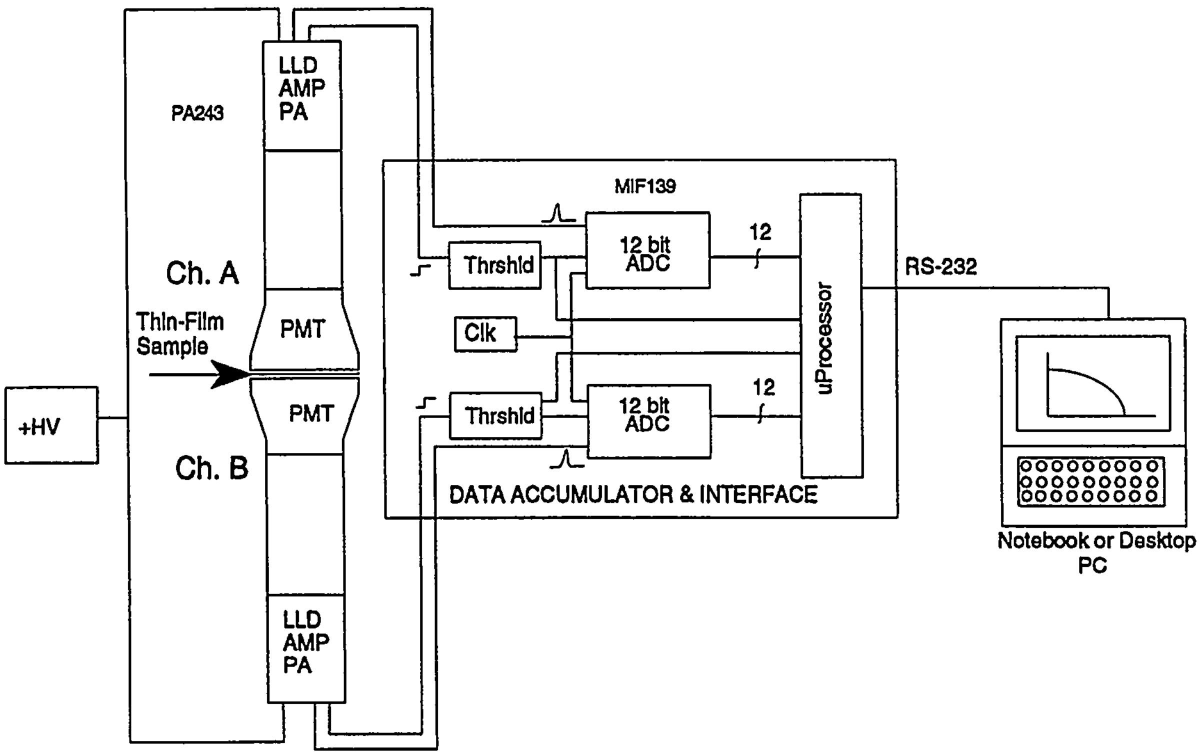

Figure 2. Dual-channel, low-level beta counter block diagram.

Data is accumulated via the interface module. When a scintillation event occurs in one of the detectors, it is amplified and routed to its corresponding Analog-to-Digital Converter (ADC); whereupon, the pulse is converted to a digital signal for processing. The digital signal is routed via parallel data lines to I/O ports on a microprocessor. The lower-level discriminator in the preamp/amplifier unit is set to discriminate against low-level noise and initiates the data analysis and timing sequence in the interface microprocessor. An internal software delay interrupts the pulse analysis for approximately 24 microseconds. During this time, the processor waits for a second pulse to occur. If a pulse occurs during this time, the original pulse and the second pulse are considered coincident and are not analyzed; however, the coincident pulses are stored in memory and are available for analysis. The microprocessor processes the data by building 16-bit words from the received pulses. Each word consists of four information packets: two bits which identify which channel the pulse was detected in, two bits which quantitize the timing between any two pulses (timing being 0 for a single event outside of the 24 microsecond coincident window), and 12 bits allotted for pulse height information (4096 channels). The 16-bit data words are routed as a two character sequence via an RS-232 serial port to a PC serial port where the data is continuously analyzed by software in the PC. A multichannel analyzer (MCA) function in the software is used to display the collected data as spectra on the PC screen.

The instrument can detect beta-emitting nuclides such as Tc-99 and Sr-90 with detection limits in the 20 pCi range (with shielding). Full analysis can be achieved in 30 minutes depending on the background at the site. The instrument occupies approximately 2 ft x 3 ft of floor or bench space and requires 110 VAC or could be configured for battery operation. The instrument is controlled by a portable PC operating in a Windows-95 environment with Visual Basic™ software. Consumables consist of filters, ordinary wipes, materials for physical wiping (swipes) of suspect surfaces, and selective adsorbent discs for recovery of radioactive analytes from waste streams and other contaminated aqueous solutions.

During the CP-5 demonstration (field work on January 6 and January 7, 1997) measurements were conducted on element selective discs containing Tc-99, Sr-90, Cs-137, and Co-60. A surface swipe was obtained from a contaminated area near the former fuel storage pool. A water sample (1-gallon) was taken from the fuel storage pool and passed through a cesium selective membrane disc.

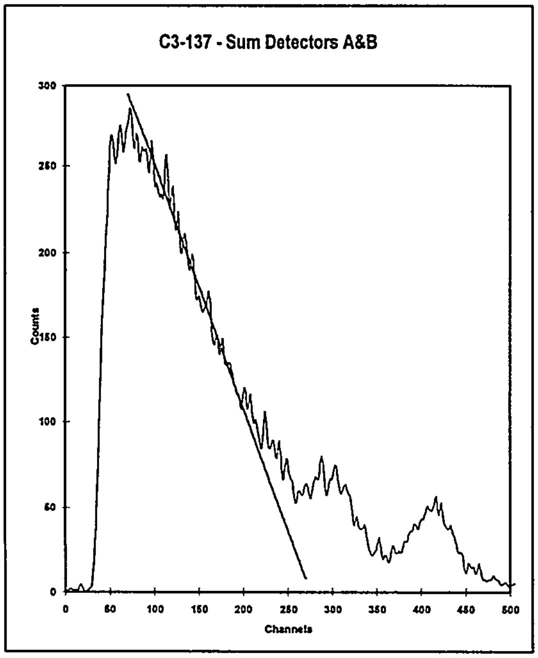

Figure 3. Results from the Cs-137 sample in the CP-5 area.

SECTION 3

PERFORMANCE

Demonstration Plan

The demonstration of the solid scintillation beta-spectrometer (Solid-Scint) technology was conducted per the approved test plan *CP-5 Large-Scale Demonstration Project: Test Plan for Field Transportable Beta Spectrometer.*

The purpose of the demonstration was to test the Solid-Scint in a reactor setting and show its ability to rapidly measure beta-emitting contaminants without requiring a liquid scintillation cocktail. This demonstration was the first time that Solid-Scint was used in an actual work environment as opposed to a laboratory setting. Thus, to some degree, the unit was subjected to varying background radiation and other "field" conditions for the first time. The CP-5 reactor facility is largely devoid of contamination sources outside the reactor core structure. Accessible sources of low-level contamination include the original fuel-storage pool and the lower canal area.

Following the test plan objectives, personnel from ANL (1) and Triangle Research Ltd. (2) set up the solid- scintillation unit (Solid-Scint) next to the CP-5 fuel storage pool. The portable unit was placed on top of a small utility cart found at the location. The instrument was set up and was operating within 30 minutes. An ESH health physics technician was assigned to the exercise and was always present during the demonstration. Continuing with the test plan objectives, background counts were taken. One issue for this first field test was the beta background at the measurement site because the beta counter was operated- without shielding. Calibration counts were made using beta sources (Tc-99, Sr-90, Cs-137, Co-60) adsorbed onto element-selective membrane discs of the type to be used for sample recovery in the field.

Following the test plan, a water sample (1-gallon) from the CP-5 fuel-storage pool was collected and extracted with a selective membrane disc. The extraction disc was then counted on the beta-spectrometer. Another sample, a surface swipe recovered from the lower canal area, was also measured. The time consumed for the various operations was noted in order to provide a basis for assessing the costs and sample turnaround time for a field-implemented technology and make comparisons to baseline technology which separates the sampling, off-site shipment, and fixed laboratory procedures.

Table 1. Technology assessment data

Criteria	Solid Scint Technology	Baseline Technology
Set-up, sample collection and preparation to final results	80 min (aqueous) 65 min (swipe solids)	> 1 day (including off-site shipment)
Amount and type of primary waste	1-4 extracted water effluent 1-2 membrane discs per sample Swipe material	Acids, organic solvents and resins, glass
Type of secondary waste	None	Scintillation cocktails 20-500 ml per sample (mixed)
Radioactivity generated	No rad added	Radiotracers commonly added

Criteria	Solid Scint Technology	Baseline Technology
Sample turnaround time (exclude sample collection)	50 min (aqueous) 30 min (swipes)	1 day –
Personnel required	2	> 2
Ease of use	Minimal training for equipment and procedures	• Extensive lab training in chemical procedures and chain-of-custody protocol
Procedural steps	4	> 6
Limit of detection (dpm)	60 (with shielding) or use 3 x BKGD	~ 60
Labor hours per sample (est.)	0.5	1.0
Automation potential	Excellent	Fair
Equipment cost	< 20 K	25-30 K
Safety issues	• Same as standard counting equipment • No chemicals used • Field- or site-related conditions	• Same as standard counting equipment • Fixed lab setting with corrosives and organic solvents

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Technology Applicability

The transportable beta-counter spectrometer (Solid Scint) can provide excellent support for rapid investigation of beta-emitting contaminants in the DDFA. Solid Scint offers several potential benefits, including faster turn-around time, cost reduction, and reduction in secondary waste.

The portable Solid Scint technology, in combination with the element selective technology, is intended to produce analytical results in the field as a real-time operation. This would be most valuable as a measurement (or screening) tool for beta-emitting contaminants present in groundwater, waste streams, fuel-rod storage pools, and other aqueous systems. The prototype technology has been used to measure fission products such as Tc-99 and Sr-90. This approach, for example, would be especially useful for field measurement of beta-emitting contaminants in wastewater at the DOE diffusion plant sites (e.g., Paducah, Portsmouth) and seepage basin aquifers found at the Savannah River Plant site.

The technology is novel and rapid but there is very limited experience in operations. The counter spectrometer is a working prototype and the associated programmatic control is also a first generation. The CP-5 facility provided a better first-time logistical test than a radiochemical challenge. The former reactor facility presently has very low levels of Cs-137 and Co-60 accessible outside the reactor core structure. More challenging (radioactive) field sites are needed to properly assess the applicability of the technology.

Competing Technologies

The competing technology to this demonstration is off-site laboratory analysis of samples taken. No competing technologies for field capable beta spectroscopy were determined.

Patents/Commercialization/Sponsor

No issue related to patents or commercialization is being pursued at present. Current support (sponsorship) for field applications and further development is derived from a CRADA between Argonne National Laboratory (ER Division) and the 3M Corporation. Additional field demonstrations were scheduled at a gaseous diffusion plant site and a major production facility. Both are U.S. Department of Energy sites.

SECTION 5

COST

Introduction

This cost analysis summarizes and evaluates the innovative technology and estimates the potential for savings relative to a baseline technology. This analysis strives to develop realistic estimates that represent work within the DOE complex. However, this is a limited representation of actual cost, because the analysis uses only data observed during the demonstration. Some of the observed costs are omitted or adjusted to make the estimates more realistic. These adjustments are allowed only when they will not distort the fundamental elements of the observed data (i.e. do not change the productivity rate, quantities, work elements, and so forth,) and eliminates only those activities which are atypical of normal D&D work. Descriptions contained in later portions of this analysis detail the changes to the observed data. The Technical Data Reports for this technology provides additional cost information.

Methodology

This cost analysis compares an innovative field-transportable beta spectrometer (FTBS) technology used for rapid characterization of facility contaminants against a baseline technology of laboratory (lab) analysis. The FTBS technology demonstration took place at the Chicago Pile - 5 Reactor (CP-5) facility at ANL. Under controlled conditions, an ANL chemist operated the FTBS and the activities were observed and results quantified so that the production rates could be determined. For the purposes of comparison, this cost analysis does not show costs for sample collection, as this should be identical for both technologies. Additionally, the technology is viewed as a field screening method and the quality control and analysis report documentation is assumed to be consistent with field screening. For consistency, the laboratory baseline alternative also assumes similar quality control and report documentation. The FTBS technology is currently the property of ANL and should be considered to be in the prototype stage of development.

Data collected during the demonstration included:

- Activity duration.
- Work crew composition.
- Equipment used to perform the activity.
- Supplies used including the parts replacement for the machines and utilities.
- Training courses required.
- Quantification of activities.

There was no concurrent demonstration of the lab technology. Baseline information was developed from information obtained from conversations with ANL lab personnel and the test engineer. Since the baseline costs are not based on observed data, additional efforts are applied in setting up the baseline cost analysis to ensure an unbiased comparison.

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

Engineering, quality assurance, administrative costs and taxes on services and materials are also omitted from this analysis for the same reasons indicated for the overhead rates. The standard labor rates established by ANL for estimating D&D work is used in this analysis for the portions of the work performed by local crafts. Additionally, the analysis uses an eight hour work day with a five day week.

All hourly equipment rates, used in the estimates, include required maintenance costs and allow for depreciation and the facility's capital cost of money (FCCM). These are computed in accordance with the Construction Equipment Ownership Schedule (USACE EP-1110-1-B, 1995).

Summary of Cost Variable Conditions

The DOE complex presents a wide range of D&D work conditions because of the variety of functions and facilities. The working conditions for an individual job directly affect the manner in which D&D work is performed and, as a result, 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 presented in Table 2. This table is intended to help the technology user identify work differences that can result in cost differences.

Table 2. Summary of cost variable conditions

Cost Variable	Field Transportable Beta Spectrometer Technology	Baseline Technology
Scope of Work		
Quantity and Type of Material	Six samples (one solid and five liquid)	Six samples (one solid and five liquid) - equivalent to the innovative technology.
Location	CP-5 Test Reactor pool.	CP-5 Test Reactor pool (estimated, not observed).
Nature of Work	Characterization of samples.	Characterization of samples- analysis methods similar to liquid scintillation (assumed for Technetium 99)
Work Environment		
Worker Protection	Hard hats, safety glasses with side shields, and vinyl gloves. No anti-contamination clothes were necessary.	Standard laboratory personnel protection equipment (not observed).
Level of Contamination	Demonstration area is not a radiation area. No radiotracers are added to the samples.	None. Radiotracers are commonly added to samples.
Work Performance		
Acquisition Means	ANL "Rad II" trained technicians (estimated, not observed).	ANL - on-site lab.
Scale of Production	Sample analysis performed at the work site.	Samples delivered to on-site lab for analysis, rate for small number of samples
Production Rates	One sample per hour (includes sample preparation).	Minimum of one-day turnaround time.
Equipment & Crew	Two "Rad II" trained technicians (estimated, not observed) will operate the FTBS.	On site lab and personnel.
Primary Waste	1-4 liters extracted water effluent, 1-2 membrane discs per sample, and swipe material.	Acids, organic solvents and resins, and glass.
Secondary Waste and Consumables	None	Scintillation cocktails, 20-500 milliliters per sample (mixed).

Table 2. Summary of cost variable conditions (cont'd)

Cost Variable	Field Transportable Beta Spectrometer Technology	Baseline Technology
Work Process Steps	1. Mobilization and set-up at sample site 2. Determine background count 3. Collect samples (not included in analysis) 4. Sample preparation 5. Sample analysis 6. Data Interpretation 7. Shutdown and demobilization	1. Mobilization and set-up 2. Collect samples (not included in analysis) 3. Transport to lab 4. Lab analysis and report generation
End Condition	Field screening level of sample characterization.	Complete sample characterization and analysis.

Potential Savings and Cost Conclusions

For the conditions and assumptions established for cost comparisons, the innovative technology was approximately 433% of the cost of the baseline alternative. The following chart summarizes the cost comparison between the field transportable beta spectrometer technology and the baseline technology consisting of sampling and laboratory analysis.

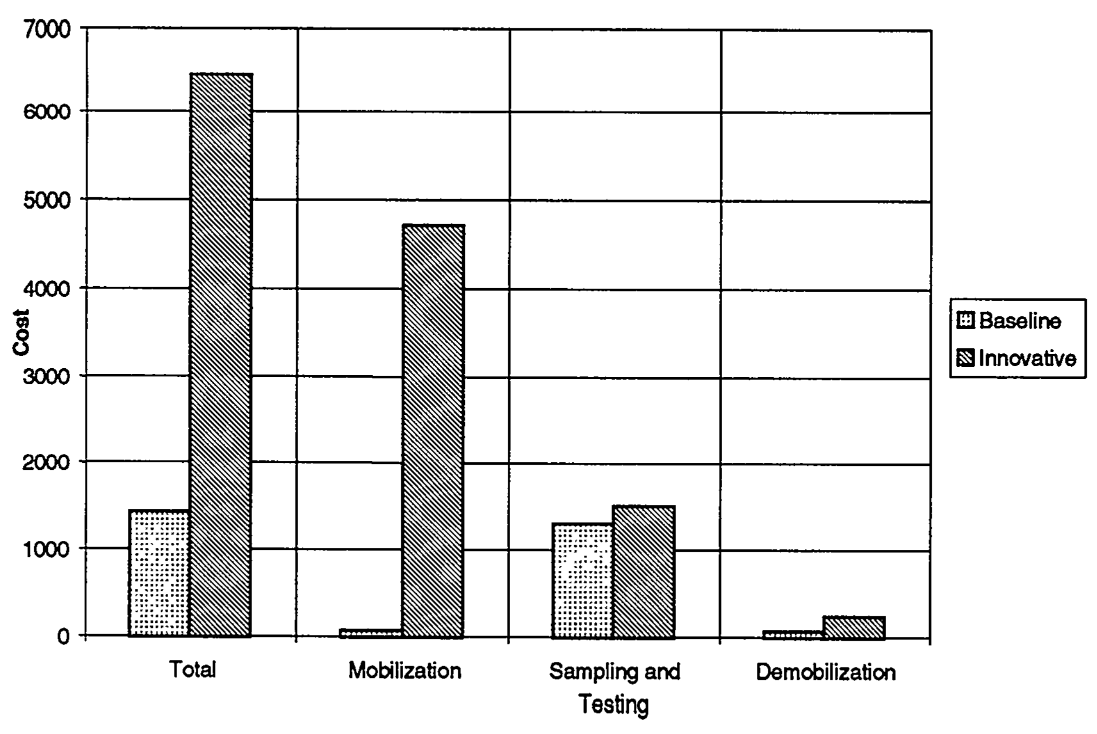

Figure 4. Technology comparison.

The laboratory baseline, for the conditions stated in Table 2, and assumptions established in Appendix C, saves $6,263 over the innovative FTBS technology alternative for this demonstration. A comparison of the costs for mobilization, sampling and testing, demobilization, and waste disposal for both technologies can be seen in Figure 3. As Figure 3 shows, the FTBS has higher costs in mobilization, sampling and testing, and demobilization cost categories. Waste disposal costs were not separately identified for the laboratory analysis technology and are included in the hourly lab rate. Therefore, a waste disposal comparison between the technologies was not possible.

Although the baseline is less expensive than the FTBS for the conditions of the demonstration, it should be noted that the largest cost factor in the cost analysis is the estimated two weeks of on-the-job training required for the equipment operators. This training should be a one-time, non-recurring cost. Perhaps the largest cost factor which is absent from this cost analysis because of its ambiguity is the opportunity cost of the estimated one day turnaround time required for using the on-site laboratory. Because of its mobility, the FTBS can provide quicker sample characterization than the baseline. The possible cost and time advantages of the FTBS may be further enhanced when labs have backlogs resulting in longer turnaround times. This may result in potential efficiency gains in project schedules. Unfortunately, savings as a result of FTBS are difficult to determine. Potential users of the FTBS should examine the time and cost savings for their specific situation.

The FTBS is in the prototype stage of its development and is not a replacement for the services offered from a typical government or commercial laboratory. The FTBS currently offers what can be considered a field screening level of analysis by offering both quantitative and qualitative sample characterization. The FTBS does not currently offer the same level of quality assurance and sampling protocol that may be required by various regulatory agencies. The FTBS is intended to be developed to a point where it is equivalent to the services offered by commercial and government laboratories. In doing this, there will be many protocol, quality control, and increases documentation issues to resolve. These factors will increase costs above those shown in this cost analysis.

Because the FTBS is currently owned and operated by ANL and is in a prototype stage of development, there are many uncertainties as to its future availability, estimated life, training requirements, and what the equipment will cost. The assumptions made within this cost analysis comprise only one of many possible scenarios representing the development and commercial availability of the FTBS. It should be recognized that the selling price of the FTBS might possibly vary by a factor of two or three from the estimated cost used in this cost analysis. Therefore, parties interested in this technology should consider future FTBS developments from the time of this document and how they impact the cost of this technology.

In conclusion, the FTBS is in an early stage of development and currently offers the convenience of mobility over stationary laboratories.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

The regulatory/permitting issues related to the use of the beta-counter spectrometer at the ANL CP-5 Research Reactor are governed by the following DOE Orders and safety and health regulations:

- DOE Orders

—DOE 5400.5	Radiation Protection of the Public and the Environment
—DOE 5480.11	Radiation Protection for Occupational Workers
—DOE 5820.2A	Radioactive Waste Management

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

—1926.300 to 1926.307	Tools - Hand and Power Electrical
—1926.400 to 1926.449	Electrical - Definitions
—1926.28	Personal Protective Equipment
—1926.53	Ionizing Radiation
—1926.55	Gases, Vapors, Fumes, Dusts and Mists
—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 Equip.
—1910.301 to 1910.399	Electrical - Definitions
—1910.132	General Requirements (Personal Protective Equipment)
—1910.133	Eye and Face Protection
—1910.134	Respiratory Protection

Certain training requirements pertaining to the field sites may be encountered. For example, in order to visit certain sites contaminated with radioactive waste, or a variety of wastes combined with radioactive waste, some preliminary training in rad-worker operations or hazardous site operations may be necessary before site entry. The level and type of training will be dictated by some local, state, federal guidance as given above.

The baseline technology would be subject to the waste characterization requirements for low level wastes as specified by disposal facilities used by ANL. These 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

Safety, Risks, Benefits, and Community Reaction

The proposed beta-counter spectrometer technology in combination with the element selective technology is considered safe. The technology does not employ corrosives and the instrumentation is of a passive analytical design. For example: A typical field test would consist of processing ambient groundwater containing low levels of fission product contaminants, such as Technetium-99 and Strontium-90. The primary waste would be the groundwater devoid of the recovered radioactive analyte. There would be no secondary mixed waste produced. A dry membrane disc with a low-level radioactivity would be the only disposable item.

SECTION 7

LESSONS LEARNED

Implementation Considerations

More challenging field sites are necessary to gain logistical and operational experience. Field tests of the demonstration technology have been arranged at relevant U.S. Department of Energy sites and a commercial nuclear facility.

The hardware and processor software which comprise the beta-counter spectrometer provided a working prototype for the first demonstration. Some software and electronic corrections are in order to adjust the anticoincidence function. The power supply used to build the prototype needed repairs immediately after the CP-5 demonstration and may have affected the beta-counting efficiency during the demonstration. The next level of this technology needs more refined electronics and software control in order to reduce the cosmic and other background effects. The technology would benefit from a capacity to do pattern recognition.

A more compact design, including configuration for battery operation, would increase portability.

Technology Limitations and Needs for Future Development

The background radiation reaching or generated within the detectors at any location would dictate the limits of analyte detection at that measurement site. Provisions to reduce the background without lessening the portability of the technology can only improve the use and applications of the technology.

Multiple beta sources applied to detectors would strongly affect the qualitative function of the technology. Heavy reliance has been placed on the element selective technology used with the beta-counter technology. The associated separation technology allows the isolation of a single contaminant for application to the detector. Improvement in resolving multiple source signals can result from incorporation of a "pattern recognition" capability into the technology. Capacity to compare sample spectra to reference standard spectra would also improve the implementation and applicability of the technology.

This technology is intended to fulfill the need for rapid investigations of contaminated facilities and their environs within the Deactivation and Decommissioning Focus Area (DDFA). This is a field-oriented technology that can capture data in real-time and which offers several potential benefits, including faster turn-around time, cost reduction and reduction in secondary waste.

APPENDIX A

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APPENDIX B

ACRONYMS AND ABBREVIATIONS

ACE	Activity Cost Estimate (Sheets)
ALARA	As Low As Reasonably Achievable
DDFA	Deactivation & Decommissioning Focus Area
Decon	Decontamination
Demo	Demonstration
Demob	Demobilization
DOE-CH	DOE- Chicago
Eq	Equal
Equip	Equipment
ER	Environmental Restoration
FCCM	Facilities Capital Cost Of Money
FETC	Federal Energy Technology Center
FTBS	Field Transportable Beta Spectrometer
HEPA	High Efficiency Particulate Air
H&S	Health And Safety
HPT	Health Physics Technician
HR	Hour
HTRW	Hazardous, Toxic, Radioactive Waste
ICT	Integrating Contractors Team
LF	Lineal Feet (Foot)
LLW	Low Level Waste
LS	Lump Sum
mCi	milliCurie
Min	Minute
mm	millimeter
Mob	Mobilization
NESP	National Environmental Studies Project
OT	Overtime
PCs	Protective Clothe(S) (Clothing)
PLF	Productivity Loss Factor
PPE	Personal Protective Equipment
Qty (Qnty)	Quantity
RA	Remedial Action
RCRA	Resource Conservation and Recovery Act
SAFSTOR	Safe Storage
SF	Square Feet (Foot)
UCF	Unit Cost Factor
UOM	Unit Of Measure
USACE	U.S. Army Corps Of Engineers
WBS	Work Breakdown Structure

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 - Field-Transportable Beta Spectrometer

Mobilization (WBS 331.01)

Equipment Operator Training

Definition: Required training to ensure proper use and interpretation of characterization results. This is an estimated activity and was not observed during the demonstration.

Assumptions: Two "Rad II" trained technicians will be trained for two weeks on the proper use of the FTBS.

Transport Personnel and Equipment

Definition: Transport personnel and equipment from a central location, possibly a laboratory, to the field location where sampling is to take place.

Assumptions: Requires 0.5 hours. This is an estimated, not observed time.

Sampling & Testing (WBS 331.02)

Equipment Set-up

Definition: Equipment set-up consisting of setting up a table for the equipment, connecting the cables, and turning-on the FTBS.

Assumption: Requires 0.5 hours, observed from the demonstration.

Move FTBS

Definition: A move of the equipment to an area with a lower background was required.

Assumptions: Requires 0.5 hours, observed from the demonstration.

Background Counts

Definition: Background counts are necessary prior to characterization.

Assumptions: Four background counts were made during the demonstration at 20 minutes each. Counts may not be required this frequently in the future.

Sample Analysis

Definition: This activity includes sample preparation, placement into the counter, and interpretation of the results of the count. Sample preparation varies somewhat depending on whether it is a water or soil sample.

Assumptions: One soil and five water samples were analyzed by the FTBS during the demonstration. Liquid samples require approximately 0.7 hour of preparation and a 1.0 hour count and soil samples require 0.1 hour of preparation and a 1.0 hour count.

HPT Support

Definition: Cost for one HPT during all mobilization activities (Includes both standby and survey time).

Assumptions: HPT is present at all times.

Demobilization (WBS 331.21)

Equipment Shutdown and Dismantling

Definition: Equipment shutdown consisting of turning-off the equipment, disconnecting cables, and dismantling the table.

Assumption: Requires 0.5 hours, observed from the demonstration.

Transport Personnel and Equipment

Definition: Transport personnel and equipment from the field to a central location, possibly a laboratory.

Assumptions: Requires 0.5 hours. This is an estimated, not observed time.

HPT Support

Definition: Cost for one HPT during all mobilization activities (Includes both standby and survey time).

Assumptions: HPT is present at all times.

Cost Analysis

The FTBS is currently owned by ANL. Development of the prototype FTBS is ongoing. Currently, it is ANL's intent to continue developing this technology until it can be transferred to a private company for manufacturing. Because this technology is in such an early stage of development, the following assumptions were made in an attempt to develop a conceptual estimate of the selling price for the equipment in order to develop a cost analysis:

- The manufacturer of this technology will spend $100,000 in preparation for production;
- The life-cycle demand was estimated to be between 50 and 100 FTSB machines. Therefore, the mid-point of 75 was assumed for the development of the equipment price;
- Interest paid by the manufacturer for start-up, initial production equipment, and material is 15% per year;
- The manufacturer's profit margin is 10%;
- The equipment life was estimated to be seven years with a utilization rate of 1,000 hours per year;
- A new laptop computer will be purchased every 2.5 years;
- One new photo-multiplier tube will be purchased every three years;
- Yearly calibration and maintenance is estimated to be $500.

This cost analysis assumes that prospective users (e.g., other DOE sites) of this technology will purchase the FTBS rather than renting it as a service. Therefore, the equipment rate was calculated assuming government ownership.

The typical costs incurred while operating the FTBS consist of the following:

- equipment set-up;
- moving the equipment to an area with a lower background:
- performing background counts;

- analyzing solid and liquid samples with the FTBS;
- shutdown and dismantling of the FTBS;
- waste disposal charges, and;
- full-time health physics technician (HPT) support.

The following assumptions were made regarding the FTBS cost analysis:

- The FTBS is performs field screening sample analysis and does not currently offer all of the services of lab analysis;

- ANL does not intend to recover the estimated $250,000 it will spend on fully developing this technology;

- Acceptable sample analysis is performed at a rate of one sample per hour;

- The crew operating the FTBS consists of two ANL "Rad II" trained technicians. This is an assumption of what the typical commercial practice will be, and is not what was observed in the demonstration;

- An initial, non-recurring two week training period is required to familiarize technicians with the equipment;

- One HPT is present during all demonstration activities;

- Costs for the Triangle Research personnel present during the demonstration are not included as they were present to assist only in the development of the equipment's software and did not assist in the demonstration activities. Therefore, these costs are considered development costs outside the scope of the demonstration;

- The manufacturer will provide a representative for two weeks of on the job training for the FTBS crew. An allowance for the representatives airfare, salary, and per diem has been made;

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.

ANL is actively developing and improving the FTBS technology. The estimated total development cost of $250,000 represents a machine which is anticipated to be capable of both quantitative and qualitative sample characterization of the same caliber as a full laboratory analysis.

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

Table C-1. Cost summary - field transportable beta spectrometer

Work Breakdown Structure (WBS)	Unit Cost (UC)						Total Quantity (TQ)	Unit of Measure	Total Cost (TC)(1)	Comments
	Labor Hours	Labor Rate	Equipment Hours	Equipment Rate	Other Rate	Total UC				
MOBILIZATION (WBS 331.01)								**Subtotal:**	**$ 5,969.9**	
Equipment Operator Training					$5,930	$5,930.0	1.0	Lump Sum (LS)	$ 5,930.0	Provides for a manufacturer representative's salary, per diem, and airfare for two weeks of on-the-job training with the site crew.
Transport Personnel and Equipment	0.5	$67.2	0.5	$12.7		$ 39.9	1.0	Trip	$ 39.9	Assumes 0.5 hour will be required to transport equipment and personnel from a central location to the field.
SAMPLING AND TESTING (WBS 331.02)								**Subtotal:**	**$ 1,506.8**	
Equipment Set-Up	0.7	$67.2	0.7	$12.7		$ 53.2	2.0	Days	$ 106.5	One set-up per day.
Move FTBS	0.5	$67.2	0.5	$12.7		$ 39.9	1.0	Moves	$ 39.9	A short move to a lower background area.
Background Counts	0.3	$67.2	0.3	$12.7		$ 26.6	4.0	Counts	$ 106.5	Crew wait-time during background counts.
CP-5 Surface Swipe	0.1	$67.2	0.1	$12.7	$ 0.5	$ 11.2	1.0	Samples	$ 11.2	One sample with unknown analyses. 0.5 hour count plus 0.1 hour preparation.
CP-5 Pool Sample	1.2	$67.2	1.2	$12.7	$ 6.0	$ 99.2	1.0	Samples	$ 99.2	One sample with unknown analyses. 0.5 hour count plus 0.7 hour preparation. Other = one gallon of water per sample - low level waste (LLW) @ $52.78/cubic foot (CF).
Liquid Sample	1.0	$67.2	1.0	$12.7	$ 6.0	$ 85.9	4.0	Samples	$ 343.5	Known analyses. 0.5 hour count plus 0.5 hour preparation. Other = one gallon of LLW water per sample @ $52.78/CF.
Data Interpretation	0.1	$67.2	0.1	$12.7	$ 6.0	$ 12.7	6.0	Samples	$ 75.9	Data interpretation estimated at five minutes per sample.
Consumables:										
Active Absorbent Discs					$ 50.0	$ 50.0	5.0	Discs	$ 250.0	One disc per liquid sample.
HPT Support	8.5	$56.0				$ 474.1	1.0	LS	$ 474.1	One Health Physics Technician (HPT) present during all sampling activities.
DEMOBILIZATION (WBS 331.21)								**Subtotal:**	**$ 221.1**	
Equipment Shutdown and Dismantling	0.7	$67.2	0.7	$12.7		$ 53.2	2.0	Days	$ 106.5	One shutdown and dismantling per day.
Transport Personnel and Equipment	0.5	$67.2	0.5	$12.7		$ 39.9	1.0	Trip	$ 39.9	Assumes 0.5 hour will be required to transport personnel and equipment from the field to a central location.
HPT Support	1.3	$56.0				$ 74.7	1.0	LS	$ 74.7	One HPT present during all sampling activities.
								Total:	**$ 7,697.9**	

(1) TC = UC * TQ

Baseline Technology - Laboratory Analysis

Mobilization (WBS 331.01)

Sample Collection

Definition: This is the activity covers the physical acquisition of the sample.

Assumption: This activity is assumed to be equivalent to that performed for the innovative, therefore, it has not been included in this cost analysis.

Transport Samples to On-site Laboratory

Definition: Transportation of samples from the field to the laboratory.

Assumptions: Only one technician is needed to transport the samples.

Sampling and Testing (WBS 331.02)

Laboratory Analysis

Definition: On-site analysis of samples using conventional analytical laboratory methods and equipment.

Assumption: Costs provided by ANL (Kent Orlandini) based on past experience with sample analysis costs. Costs for solid and unknown liquid samples were assumed to be $250 and the known liquid samples were assumed to be $200. The analysis methods were assumed to be similar to those used for Technetium 99. (i.e. duration of laboratory effort for analysis is similar to this).

Demobilization (WBS 331.21)

Return Sample Results to the Customer

Definition: Transportation of the characterization results from the laboratory to the customer.

Assumptions: Only one technician is needed to transport the samples.

Cost Analysis

The cost of performing the work consists of the following activities:

- transporting the samples to the on-site lab;
- perform lab analysis of samples, and;
- return sample results to the customer.

The baseline technology was not demonstrated, therefore the following are assumptions for the baseline based on information and conversations with ANL lab personnel:

- The on-site laboratory does not have a backlog of samples;
- Solid samples with unknown analyses cost $250/sample and the quality control and report documentation are consistent with field screening methods;
- Liquid samples with unknown analyses cost $250/sample and the quality control and report documentation are consistent with field screening methods;

- Liquid samples with known analyses cost $200/sample and the quality control and report documentation are consistent with field screening methods;
- Sample/result transport requires one ANL technician for one hour at $33.60/HR;
- Six samples (one solid and five liquid) were analyzed to match the innovative technology demonstration;
- All sampling costs (such as waste disposal, worker protection, etc.) are included in the $110/HR lab rate;
- Sample analysis turn-around time is estimated at one day.

No estimate was made for any crew wait-time or work stoppage resulting from time spent for lab analysis.

The activities, quantities, production rates and costs utilized in the baseline are shown in Table C-2.

Table C-2. Baseline technology cost summary

Work Breakdown Structure (WBS)	Unit Cost (UC)						Total Quantity (TQ)	Unit of Measure	Total Cost (TC)[1]	Comments
	Labor Hours	Labor Rate	Equipment Hours	Equipment Rate	Other	Total Unit Cost				
MOBILIZATION (WBS 331.01)								**Subtotal:**	**$ 67.2**	
Transport Samples to the On-Site Laboratory (Lab)	1.0	$33.6				$ 33.6	2.0	Days	$ 67.2	Done once per day at the completion of sampling activities.
SAMPLING AND TESTING (WBS 331.02)								**Subtotal:**	**$ 1,300.0**	
Laboratory Analysis:										Based on ANL's lab rate for sample analysis. Includes testing, documentation, and waste disposal. The hourly lab rate includes waste disposal costs.
CP-5 Surface Swipe					$250.0	$ 250.0	1.0	Samples	$ 250.0	One sample with unknown analyses. Requires alpha and beta identification. Other = $250/sample.
CP-5 Pool Sample					$250.0	$ 250.0	1.0	Samples	$ 250.0	One sample with unknown analyses. Requires alpha and beta identification. Other = $250/sample.
Liquid Samples					$200.0	$ 200.0	4.0	Samples	$ 800.0	Known analyses. Other = $200/sample.
DEMOBILIZATION (WBS 331.21)							5.0	**Subtotal:**	**$ 67.2**	
Return Sample Results to the Customer	1.0	$33.6				$ 33.6	2.0	Days	$ 67.2	Done once per day at the completion of laboratory analysis activities.
								TOTAL:	**$ 1,434.4**	

(1) TC = UC * TQ

Equipment Rate Computation

Hourly rates for equipment ownership are computed based on life cycle costs for that equipment. The computation of the hourly rate is consistent with the Construction Equipment Ownership and Operating Expense Schedule (USACE EP-1110-1-B, 1995). The EP-1110-1-B is a manual that is used throughout the US Army Corps of Engineers and containing equipment ownership rates for construction equipment. The hourly rates consist of:

- Ownership Costs
- Operating Costs

  ⇒ Fuel, Filters, Oil, Grease and other consumable items
  ⇒ Repairs, maintenance, overhauls and calibrations

The consumables, such as tool bits or hoses, may not appear in this hourly rate if it is an item that can substantially vary in the quantity consumed from situation to situation. Rather, the observed quantity for the consumable is shown as a line item cost element in the analysis summary table so that a potential technology user is alerted to this cost item and can evaluate the appropriate cost for the conditions at his site.

The ownership costs are computed by amortizing the initial purchase price and shipping cost over the service life of the equipment. The facility capital cost of money (FCCM) is determined by the Secretary of the Treasury pursuant to P.L. 92-41, 85 Stat. 97). The service life for a piece of equipment typically is expressed in the number of hours of operation life, such as 10,000 hours. Since the equipment may not be utilized fully throughout the year, the service life must consider the Use Rate (number of productive hours for equipment during the year) when computing the amortized amount. If the equipment is used only a few hours out of each year, then the equipment life will extend to many more years (and result in more years over which to amortize) as compared with equipment that is used all the time. The computation of amortization is shown below:

(Purchase Price + Shipping) * (Annual Cost Factor) / (Hours Per Year) = Hourly Rate for Ownership

- Annual Cost Factor is a function of number of years of service life and the FCCM rate
- Number of years of service life = Operation Life (in hours) / Use Rate (hours per year)

The use rate either is based on historical experience, on an amount of use determined from a survey of rental firms for the specific equipment item, or on engineering judgment. Historically, some of the radiological survey instruments currently used at ANL have been in service for the past 15 years.