INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0390

Gamma-Ray Imaging System

Deactivation and Decommissioning Focus Area

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INNOVATIVE TECHNOLOGY
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Gamma-Ray Imaging System

OST Reference #1793

Deactivation and Decommissioning
Focus Area

Demonstrated at
Hanford Site
Richland, Washington

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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

EXECUTIVE SUMMARY

The RadScan 600 gamma-ray imaging system is designed to survey large surface areas for radiological contamination with accuracy and efficiency. The resulting survey data are clear, concise, and precise in describing how much contamination is present at exact locations. Data can be permanently stored electronically and on video tape, making storage and retrieval economical and efficient. This technology can perform accurate measurements in high radiation contamination areas while minimizing worker exposure. The RadScan 600 system is a safe and effective alternative to hand-held radiation detection devices. Performance data of the demonstrated survey area of the RadScan 600 system versus the baseline, which is the hand-held radiation detection devices (RO-2 & RO-7) for a given survey, production rate is 72% of the baseline. It should be noted that the innovative technology provides 100% coverage at a unit cost of $8.64/m^2$ verses a static measurement of a unit cost of $1.61/m^2$ for the baseline.

Technology Summary

The RadScan 600 gamma-ray imaging system, developed by British Nuclear Fuels Ltd. (BNFL) and Pajarito Scientific Co. (PSC)/BNFL Instruments. The RadScan system characterizes contaminated sites containing high levels of surface radiation (contact dose rate of $5x10^{-5}$Gy/hr (5 mR/hr) at 30 cm (12 in.) distance). This system provides real-time data on the location and concentration levels of gamma radioactive material. Since the inspection head is operated remotely, worker exposure and access constraints typically associated with traditional hand-held survey instrumentation are minimized. The RadScan 600 employs spectroscopy to identify isotopes on any hot spots automatically identified by the system. Computer-based data files and video imaging provide efficient data storage and retrieval features. Surveys of contaminated surfaces and reporting times are improved while the volume and quality of data generated are enhanced.

RadScan 600 inspection head.

Problem Addressed

At the Hanford Site, decontamination and decommissioning (D&D) planning and operational activities require characterization of radiation fields, for both inside and outside of facilities, often in high-exposure areas. Commonly used technology employs hand-held survey instrumentation that is operated in the radiological zone by radiological control technicians (RCTs) wearing anti-contamination coveralls with hoods and, often, respirators. This method is sometimes hampered by worker exposure concerns and limited access to confined areas. The data generated by such surveys are minimal, and the precision and accuracy level are barely adequate. The time required to conduct a survey and to produce a report is lengthy. In summary, measurement difficulties, worker exposure, and physical access constraints have limited the effectiveness of hand-held survey technology. The traditional (baseline) approach requires sample acquisition and analysis to obtain isotopic identification.

There is a need for flexible survey instrumentation that provides real-time data that can be operated remotely, outside of contaminated areas, both to limit worker exposure and to reduce fatigue caused by operation of hand-held instrumentation. The need for precise reporting of survey data including isotopic information also exists. The remotely controlled RadScan 600 gamma-ray imaging system is an attractive alternative to traditional surveying methodologies that satisfies these needs.

Features and Configuration

Major Features:

- Controlled remotely to minimize worker exposure
- Survey data are available immediately
- Data are stored in both electronic and video media
- Electronic data are supplemented by graphics in the form of contour/surface maps
- Spectroscopy is used to obtain isotopic information.

Components:

Inspection Head

- Thallium-doped cesium iodide and silicon photo diode scintillation detector (20-mm by 25-mm)
- Truncated cone shield/collimator combination made of tungsten (with 2, 4, and 9 degree view angles)
- Laser range finder (±15 cm at 1 to 30 m from surfaces)
- High-resolution video camera with a zoom lens and a 500-W floodlight

Remote Workstation

- Personal computer (PC) (controller) with Microsoft Windows™ 3.1-based software for controlling the equipment and collecting data
- PC-based multichannel analyzer card
- Super video graphic architecture (SVGA) display screen.

Potential Markets

Marketplace opportunities for the RadScan 600 are at radiologically contaminated sites containing high surface radiological contamination. The technology can be applied to those sites where characterization, remediation, and D&D activities are planned, such as at U.S. Department of Energy (DOE), U.S. Environmental Protection Agency, and U.S. Nuclear Regulatory Commission sites.

Advantages of the Innovative Technology

The following table summarizes RadScan survey technology and compares the baseline technology areas:

Category	Comments
Cost	Higher than the baseline (unit cost of $8.64/m^2 verses $1.61/m^2 for the baseline), but more continuous data and includes includes isotopic information
Performance	Performs better than the baseline technology for reliability and completeness of data
Implementation	No special site services required for implementation
Secondary waste generation	Does not generate secondary waste
ALARA/Safety	Use of this tool improves ALARA practice and safety compared to baseline
Ease of use	Easy to operate, but much heavier 105 kg (231 lbs) than the baseline instruments

Shortfalls/Operator Concerns

Due to the physical size and geometry of the RadScan technology, there is some difficulty maneuvering the unit in congested areas, and it is also somewhat difficult to obtain near-corner and wall measurements.

™Microsoft Windows 3.1 is a registered product of the Microsoft Corporation, Bellevue, Washington.

Skills/Training

This system does not require a skilled operator, and an RCT familiar with computer operation can learn to operate the system in a very short time (<4 hr).

■ Demonstration Summary

This report covers the March 1997 period when the RadScan 600 gamma-ray imaging system was demonstrated on asphalt-coated concrete floors, walls, columns and curbs surfaces in the southeast corner of the C Reactor Fuel Storage Basin.

Demonstration Site Description

At its former weapons production sites, the DOE is conducting an evaluation of innovative technologies that might prove valuable for facility D&D. As part of the Hanford Site Large-Scale Technology Demonstration (LSTD) at the C Reactor Interim Safe Storage Project, at least 20 technologies will be tested and assessed against baseline technologies currently in use. DOE's Office of Science & Technology/Deactivation and Decommissioning Focus Area, in collaboration with the Environmental Restoration Program, is undertaking a major effort of demonstrating improved and innovative technologies at its sites nationwide. If successfully demonstrated at the Hanford Site, these innovative technologies could be implemented at other DOE sites and similar government or commercial facilities.

Applicability

The DOE's Richland Operations Office (DOE's Hanford Site) has successfully completed a demonstration to verify the capabilities of the RadScan 600 gamma-ray imaging system. This system represents an innovative technology that can be used where there is a need for characterizing contaminated surfaces with high levels of radiation in support of D&D or remedial design projects. The technology is currently commercially available for floors and walls.

Key Demonstration Results

- The RadScan 600 gamma-ray imaging system was capable of accurately correlating radiation levels to specific locations (± 2cm at approximately 2 meters from surfaces). The dynamic range of the detector is approximately from 10 µCi to < 0.2 Ci for Cs-137 in field of view of detector at 1 meter. The detector should be repositioned as needed to view surfaces that are otherwise behind objects.
- The system produced useful radiological data that were conveniently stored in database format and were easily retrievable.
- The data were supplemented by clear, concise graphical representation of survey data in the form of contour/surface maps.
- A video tape documented the location of measurements.
- The system works best in areas with higher radiation contamination levels due to its high minimum detection level.
- The monetary costs of implementing the RadScan 600 gamma-ray imaging system were higher than the baseline (hand-held survey instrumentation, i.e., Eberline RO-2 and RO-7 probes) and it took somewhat longer than the baseline to set up for project application. However, there were benefits that were not available with the baseline technology. For example, with the new technology, worker exposure in radiation areas is reduced, spectroscopy information is available, and precision and comprehensiveness of data is much greater.

- Since the RadScan 600 can do in situ gamma spectroscopy, isotopic analysis can be done with some measurements, thus, eliminating the need for ex situ sample analysis. Core samples to determine depth of contaminant penetration can also be eliminated if at least two gamma analyses are available to perform peak ratio/shield theory analysis. These advantages of the innovative technology reduce characterization cost compared to baseline characterization methods.

Regulator Issues

The RadScan 600 is an investigation tool for characterizing contaminated surfaces. Therefore, there are no special regulatory permits required for the use of this technology. This system is not designed to meet the intent of 10 *Code of Federal Regulations* Parts 20, 835, or Proposed 834.

Technology Availability

This technology is commercially available for gamma surveys of floors and walls. Patents have been granted to BNFL/PSC for this technology.

Technology Limitations/Needs for Future Development

The major concern encountered during the demonstration was maneuvering the unit in congested areas. Also, due to physical size and geometry of the RadScan 600 and measurement location geometry, near-corner and wall measurements could not be easily obtained. The demonstrated innovative system is not suitable for surveying areas with low levels of radiation, such as for release surveys. However, there is currently no need to modify the system demonstrated at the Hanford Site's C Reactor.

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Other
All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM-50 web site, provides information about OST programs, technologies, and problems. The OST reference # for the Gamma Ray Imaging System (PSC/BNFL RADSCAN 600) is 1793.

TECHNOLOGY DESCRIPTION

■ Overall Process/Technology Description

DOE's nuclear facility decommissioning program requires the characterization of radiation fields, inside and outside of facilities, as part of D&D planning and activities, especially in higher exposure areas. Historically, this has been attempted using hand-held survey instrumentation, surveying accessible areas as best achievable. Various measuring difficulties, worker exposure, and physical access constraints have limited the effectiveness of the traditional approach. The RadScan 600 provides a viable alternative to the current survey method. The system description presented here follows PSC documentation (Reference 2 in Appendix A) on this technology.

Inspection Head and Video System

The inspection head (Figure 1) incorporates the following components:

- <u>Gamma detector</u> - The detector is a thallium-doped cesium iodide scintillation crystal with a silicon photo diode. The crystal is 20 mm diameter by 25 mm long. A main amplifier incorporated within the detector allows the output signal to be connected directly to a multichannel analyzer system.

- <u>Collimator</u> - One of three tungsten collimators with angles of 2, 4, and 9 degrees can be fitted to the inspection head.

- <u>Laser-based range finder</u> - The head assembly has motorized pan and tilt capabilities, allowing large angles (340 degrees laterally for panning and 130 degrees vertically for tilting) to be scanned both manually and automatically using the remote workstation. The range finder allows the system to automatically record its distance from the surface. The tolerance is ± 15 cm at 1 to 30 m.

- <u>Video Camera</u> - This is a high-resolution color charge collective device with a zoom lens. The lens for the camera is focused remotely from the workstation keyboard and has a motorized zoom that is also remotely controlled. A 500-W floodlight has been added to the basic system.

- <u>Telemetry Unit</u> - Inspection head movement is controlled by a telemetry unit that communicates with the remote workstation.

Workstation

The remote workstation (Figure 2) houses all the processing electronics and with the standard system cable can be located up to 40 m (~131 ft) from the inspection head, preferably in a clean environment where it will not become contaminated. (Longer cables can be deployed.) Full control of all scanning and data acquisition facilities, including the analysis of results, is provided by the workstation, which contains the following components:

- <u>Computer</u> - The onboard computer is mounted in an industrial chassis.

- <u>SVGA Monitor</u> - The SVGA picture signal is input to a video recorder. The monitor and associated software allow video to be displayed from a composite or S-video source [e.g., camera or video cassette recorder (VCR)]. The video appears in a window on the display screen.

- <u>Software</u> - The video signal is displayed on an SVGA monitor in real-time using the Microsoft Windows™ software environment. The RadScan 600 software provides a video replay facility where all the VCR control push buttons are duplicated on the computer monitor.

- <u>Video Cassette Recorder</u> - Video information is recorded on a high-fidelity VCR controlled by the computer. The operator can select a particular control function (e.g., play, pause, forward) by clicking the appropriate button, allowing inspection data to be easily replayed.

Figure 1. RadScan 600 inspection head.

Figure 2. RadScan 600 workstation.

Software

The RadScan 600 runs Microsoft Windows 3.1™ under the MS-DOS operating system. The user interacts with the system through a number of window displays. The software allows the real-time count rate information to be displayed in one of three ways:

- Count mode - Displays the count rate(s), corrected for dead time, at the detector from objects within the current viewing zone with no correction for distance. The count mode can be set for up to three user-defined regions of interest.

- Range corrected mode - Allows the operator to correct the real-time count rate(s) to the rate(s) that would appear if the object were at a user-specified distance.

- Normalization mode - Allows the operator to correct the real-time count rate(s) to the count rate from a user-specified object and to correct for range. The corrected rate enables the operator to estimate whether a zone contains more or less activity relative to the normalization zone.

Surveys can be performed manually or automatically in any one of the three system output modes described above. When operated manually, the operator controls the movement of the inspection head from the PC keyboard and uses the viewing zone circle that is overlaid on top of the video image to identify the origin of the gamma radiation. Alternatively, scanning can be carried out by manually setting the extreme scan limits initially and allowing the RadScan 600 software to automatically scan the area of interest in a raster pattern, recording all important information at incremental positions.

■ System Operation

The remote workstation houses all of the processing electronics and is mounted on wheels. Ideally, the workstation will be located in a clean environment (as was done for this demonstration) to prevent and control equipment contamination. Full control of all scanning and data acquisition facilities, including the analysis of results, is provided by the computer workstation.

Set Up Procedure

The operator starts the RadScan 600 software and enters the following survey parameters:

- survey name (file name)
- explanation of the survey being performed
- the solid angle of the collimator (collimator selection)
- the inspection head stand height
- the field-of-view overlap confidence level
- the region of interest
- the date, time, and count time at each solid angle.

Surface Scanning

The scanning system is then activated and begins measurements, recording the results at each solid angle for the preset amount of time. The survey continues through a series of solid angles (by automatically changing the pan and tilt angles of the inspection head) until the entire selected area is surveyed. The system automatically records the distance from the surfaces using the onboard laser range finder, along with the radiological information associated with each solid angle. Any time the system identifies a hot spot, a radiometric measurement of the hot spot for a preset amount of time is conducted based on user-defined regions of interest. A spectroscopic analysis is made at the user's option. All data collected are saved to a hard-disk drive. A video of the area under investigation is simultaneously recorded for data and physical location association. All information stored in the system is analyzed by the onboard computer to produce the final results. Final data can be presented in units of counts per second (cps) for specific tilt and pan angles. Also, data can be presented in the form of cps contours for pan and tilt angles.

This system does not require a skilled operator, and an RCT familiar with computer operation can learn to operate the system in a very short time (<4 hr).

PERFORMANCE

Demonstration Plan

The demonstration of the RadScan 600 gamma-ray imaging system was completed at the DOE's Hanford Site C Reactor as an integral part of the Interim Safe Storage Project. Specifically, surveys intended to detect gamma radiological contamination on surfaces, such as walls, ceilings, and floors (interior or exterior), were conducted in the Fuel Storage Basin. The basin no longer contains water and was dry during the demonstration. The purpose of the characterization surveys is to support assessments and decisions regarding decontaminating and decommissioning alternatives.

The surface area surveyed totaled approximately 47 m^2. The surfaces scanned are concrete, covered with asphalt emulsion up to 3 m (10 ft) high. Walls and column surfaces were scanned to a height of 4.5 m (15 ft). The specifications of the surfaces surveyed for the purpose of the demonstration included:

- 41.8 m^2 (450 ft^2) of wall area at a corner of the Fuel Storage Basin, with approximately 4.6 m (15 ft) vertical distance and 6.1 m (20 ft) horizontal distance from the corner of the wall, as well as 3.1 m (10 ft) horizontal distance on the adjacent wall

- Two faces on each of two columns, with a 4.6 m (15 ft) vertical distance

- 2.8 m^2 (30 ft^2) of a divider wall (curb surface).

All surveys were conducted inside of the Fuel Storage Basin below the upper wooden deck. This area was selected because it has more high-radiation surfaces than other reactor areas.

Performance Objectives

The primary objective of this demonstration was to evaluate the capability, and its application at full scale, and to assess its performance and cost versus the baseline, for surveying radiologically contaminated surfaces from a remotely controlled workstation and of differentiating among radionuclides. The purpose of having the workstation located away from the area of contamination is to limit worker exposure and minimize access restriction impacts. The demonstrated technology was to produce both paper-copy and electronic data for analysis. The vendor was tasked to furnish and operate an appropriate gamma radiation-sensing device and transmitting equipment with the following specifications and capabilities:

A. A 9.1-m (30-ft) minimum-length communications system.

B. Gamma-energy levels and locations recorded electronically at the workstation, including displays of data overlaid on a physical image (developed by the system) of the basin wall, columns, and divider wall (curb), preferably using a real-time video camera and remote video monitor.

C. Production of both electronic and hard copy products.

D. Ability to store and display count rates.

E. The composite electronic file must be downloadable to a commercially available PC system. The computer, software, and software license must be supplied with the unit.

F. Capability to operate in a radiologically contaminated zone and ability to perform the demonstration avoiding contamination (e.g., the system could be wrapped in plastic). Capability to differentiate among radionuclides (e.g., Cs-137) and scan a predefined region of interest.

G. Perform in an energy range of 100 keV to 2 MeV. An extended energy range down to 50 keV is desirable.

H. As a minimum, the ability to read/detect a contact dose rate of $5x10^{-5}$Gy/hr (5 mR/hr) at 30 cm (12 in.) distance with an accuracy of plus or minus 25 percent is desired. The instrument should be capable of the desired sensitivity in a background field ranging from $5x10^{-5}$ Sv/hr (5 mrem/hr) to $1x10^{-3}$ Sv/hr (100 mrem/hr).

I. Preselectable/designated scanning patterns from which the operator can choose are preferred. A scanning-mode selection feature is required that has the ability to set up and scan without user input after the scan pattern is selected.

Major Demonstration Elements

In order to meet the demonstration objectives, PSC developed and submitted a procedure for the completion of surveys of the specified C Reactor Fuel Storage Basin surfaces. The procedure consisted of three primary elements:

- A system pretest to ensure functionality and to check calibration
- The series of gamma surveys
- A post-test to verity that the system remained in calibration and functioned properly.

A technician first made a crude sketch of the area and indicated the location of the RadScan 600 and the surface area that the system was planned to survey. The scanning system was then activated and took measurements, recording the results at each solid angle for the preset amount of the time.

The display provided information during the survey process, including the survey name, average surface gamma activity (cps), pan and tilt angle, and range (system distance from surfaces), as well as a video image of the measurement area.

Demonstration Chronology

The chronology for the demonstration's performance is described below:

All operations vital to the correct operation of the RadScan 600 were verified, including calibration of the cesium iodide detector, by using known calibration sources of Cs-137 and Co-60. Both sources were mounted to the front of the 4-degree tungsten collimator, and a spectroscopic analysis was performed on each source. The variation in channel numbers between the original calibration at PSC and the source- check verification at 100-N was within the limit of expected variation of the system (within two channels).

The RadScan 600 was transferred on March 18, 1997, from the 100-N Warehouse to the C Reactor building area. The RadScan 600 was then moved to the south side of the C Reactor complex. The system was again unpacked and assembled. The support stand, pan and tilt motor assembly, and inspection head were wrapped in 6-mil plastic to prevent possible contamination (Figure 3). After the equipment was thoroughly protected, it was transferred to the platform area (Figure 4) within the fuel basin building to prepare for lowering the system into the Fuel Storage Basin. A ¼-ton hoist was suspended from the overhead gantry rail and positioned over the access opening in the platform. The inspection head (105 kg [231 lb] plus the weight of the support stand) was attached to the hoist and manually positioned by moving the hoist and detector assembly along the gantry rail.

Figure 3. Plastic wrapping of RadScan 600.

Figure 4. Platform area.

The unit was lowered further into the Fuel Storage Basin (Figure 5) and oriented after the support stand made contact with the bottom of the basin. The approximate areas that were scanned in the deep basin included (1) a 6-m (20-ft) by 4.5-m (15-ft) high section of the east wall; (2) a 3-m (10-ft) by 4.5-m (15-ft) high section of the south wall, including a gate to a fuel transfer pit; (3) a 3-m (10-ft) by 0.75-m (2.5-ft) section of a 0.75-m (2.5-ft) high divider wall; and (4) two 0.3-m (12-in.) wide column faces, 90 degrees apart, on each of two vertical columns. These surfaces were constructed of concrete that had been coated with asphalt emulsion up to a height of 3 m (10 ft). The unit was positioned in the southeast corner of the Fuel Basin in Row 2, Position 1 (Figure 6). Further scans were performed during March 19-20 at positions 2 through 7.

Figure 5. Fuel Basin floor, divider walls (curbs), and columns.

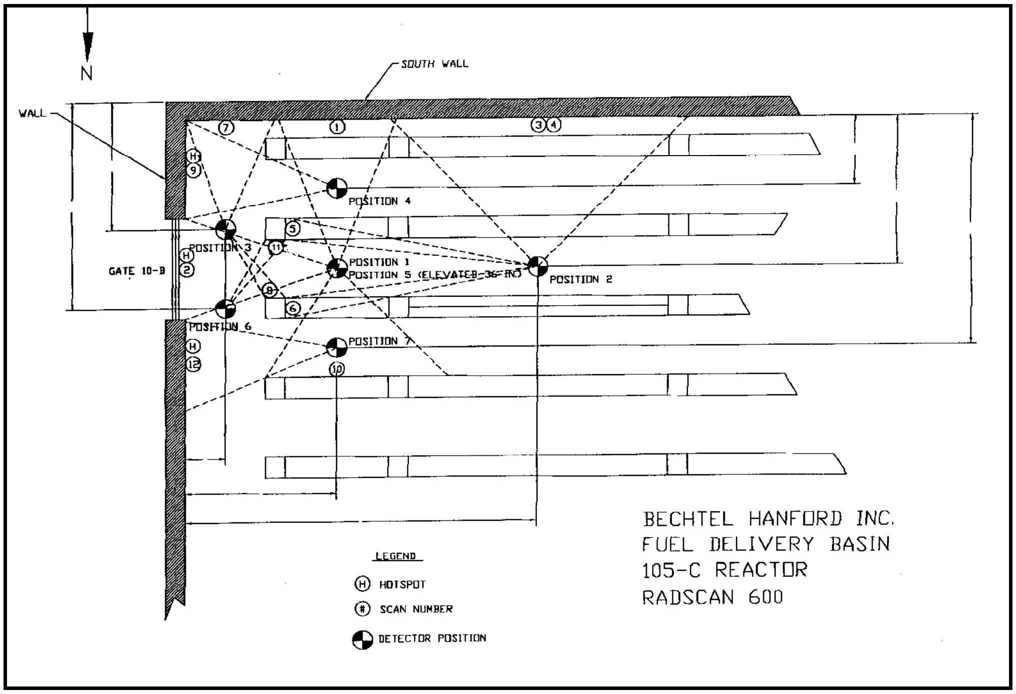

Figure 6. RadScan 600 positions in the Fuel Storage Basin.

When scanning had been completed, the unit was moved back to the access opening in the platform and the unit was lifted out of the fuel basin. The assembly was surveyed by two RCTs and was released to PSC personnel for unwrapping and disassembly. The RadScan 600 was then transferred to the 100-N Warehouse for the post-test source check.

The post-test source check was performed by again verifying the cesium iodide detector's calibration, using known calibration sources of Cs-137 and Co-60. Both sources were mounted to the front of the 4-degree tungsten collimator, and a spectroscopic analysis was performed on each source. The channel numbers at which these energy peaks were recorded were then compared to the calibration performed at PSC/BNFL Instruments in Los Alamos, New Mexico. Source checks indicated that the instruments were functional and were within 10% of the calibration results obtained in the PSC/BNFL Instruments facility.

■ Technology Demonstration Results

To estimate the system response in units of mR/hr, a 7.8-mCi Cs-137 point source was located in front of the inspection head at a distance of 2 m from the detector. The detector response to this source was 580 cps. The radiation field due to this source was measured 0.75 mR/h using a dose rate-probe. These measurements were performed by BNFL at its facility.

The RadScan 600 configuration that was used for this demonstration is as follows:

1. Collimator: 4 degrees
2. Stand height: 0.9 m (35.25 in.)
3. 500-W halogen lamp attached to inspection head
4. 36.4 m (120 ft) umbilical cord
5. System weight = 125 kg (275 lbs), including 105 kg (231 lbs) for the inspection head
6. Operators console outside the radiation buffer area.

A summary of the results from two of the scans where hot spots were noted is outlined as follows:

Scan Number 2 (east wall - Gate 10-B scan to floor)
- Distance from detector to wall = 2.68 m (8.85 ft)
- Total area scanned = 5.73 m^2 (62.45 ft^2)
- Vertical distance = 5.25 m (17.34 ft)
- Horizontal distance = 1.09 m (3.60 ft)
- Field of view overlap confidence level = 50%
- Scan duration = 14.4 minutes
- Scan time per point = 8 seconds
- Highest data point = 964 cps.

Conclusions: Hot spots exist at the bottom of the gate and at the top of the transfer pit gate. Spectroscopy revealed the presence of Cs-137 and Co-60 isotopes (Figure 7, scan 2).

Scan Number 9 (east wall - south corner to floor)
- Distance from detector to wall = 1.89 m (6.23 ft)
- Total area scanned = 6.64 m^2 (72.32 ft^2)
- Vertical distance = 3.11 m (10.25 ft)
- Horizontal distance = 1.60 m (5.29 ft)
- Field of view overlap confidence level = 50%
- Scan duration = 36.6 minutes
- Scan time per point = 10 seconds
- Highest data point = 277 cps.

Conclusions: A hot spot was found on the lower portion of the wall near the floor. Spectroscopy revealed the presence of Cs-137 and Co-60 isotopes (Figure 8, scan 9).

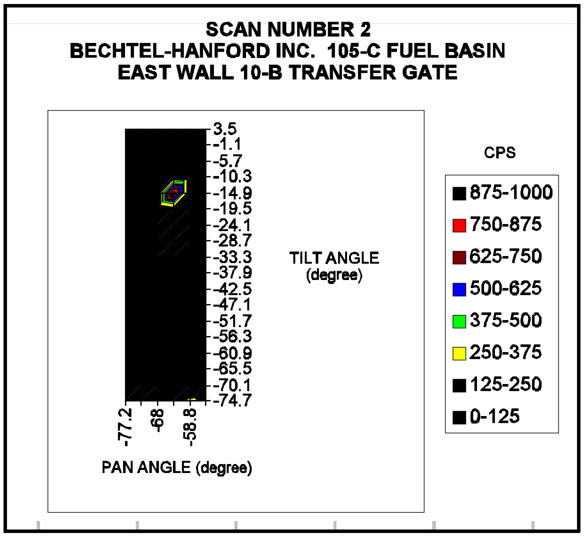

Figure 7. Results of scan number 2.

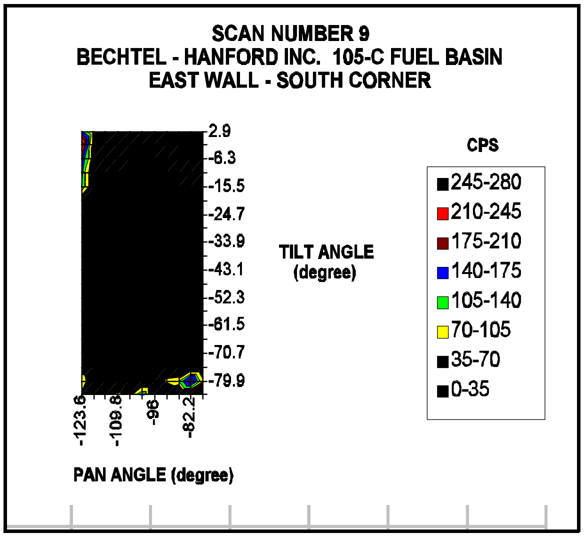

Figure 8. Results of scan number 9.

Monitoring Performance

System Pre/Post-Demonstration Source Check Functionality

The system was source-checked before and after the demonstration. The system was also checked for mechanical functionality before and after the technology demonstration.

Meeting Demonstration Objectives

The demonstration objectives listed in the Demonstration Plan section were met, except for item G. Item G (energy range) could be met as required, but the lower energy range desired, down to 50 keV, could not be met with the model demonstrated. The lower energy range for the system used at the 105-C Reactor was set at 100 keV, well below the gamma energies of the two radionuclides of interest, Cs-137 (662 keV) and Co-60 (1173 and 1333 keV). The system can meet the requirement of 2 MeV for the highest energy level, but was preset by BNFL Instruments at 1.5 MeV in order to maximize crystal sensitivity and collimator effectiveness. The gain of the system can be factory set to measure 2 MeV or higher

Baseline Survey

The standard methodology for determining the extent of contact and general area radiation fields consists of an RCT manually passing a gamma-sensitive detector (typically a RO-2 or RO-7 probe) near the surfaces [contact, approximately 1 cm (0.4 in.) from surfaces] or a set distance [approximately 30 or 100 cm (12 or 39 in.)] away from the surface of the area being surveyed.

Two RCTs performed a pre-job survey of a portion of the interior of the basin, including 5.5 m^2 (60 ft^2) of the south wall (at the east end of the wall) using the traditional instrumentation. Readings were collected with an RO-7 probe positioned approximately 50 cm (20 in.) from the wall. A plastic-wrapped flashlight was taped to the probe, which was suspended from an L-shaped holder approximately 4 m (13.2 ft.) total length to reach near the south wall. The probe with the flashlight was lowered into the basin, with the RCTs stationed above the basin on the wooden decking. The probe was connected to an above-deck portable indicator via an unwrapped cable 15 m (49.5 ft) long. One RCT maintained control of the instrument probe placement at all times, while the other observed the detection instrument response and documented all gamma radiation fields that were observed. Measurements were static-type measurements.

A typical radiological survey report (Figure 9) was prepared that contained relevant information regarding the conduct of the survey (e.g., date, time, instruments used, location) and the survey results. This report included a hand-drawn sketch of the surveyed areas with associated radiation levels. Measurement locations indicated on the survey map were approximate and were not drawn to scale.

Comparison Of Innovative Technology to Baseline

The performance and operation of the innovative technology system compared to baseline technology are tabulated below:

Activity	Innovative Technology	Baseline
Source and system check	1 hour[a]	3 minutes
Survey speed	6-10 seconds @ each angle	Static 4 to 5 seconds at 0.6 to 0.9 m (2 to 3 ft)
Survey time	Approx. 4 hours	3 hours
Survey area	Approx. 182 m^2 (600 ft^2)	18.2 m^2 (60 ft^2)[b]
Survey area coverage	Approx. 100%	Note c
Survey Report	3 minutes	30 minutes
Sensitivity	Poor for release level; good for higher radiation areas	Note c
Flexibility	Low for sensitivity, but flexible for degrees of collimation, speed of data acquisition and size of automatic scans	Low
Precision, accuracy, representativeness and completeness	Better than baseline	Minimally acceptable
Safety	Good, but heavy weight and higher voltage	Good
Durability	Complex system to maintain	Good
Data interpretation	More and better data generated	Minimal data generated
Ease of operation	Note d	Note d
Waste generation	Minimal, but more plastic wrap	Minimal
Utility requirements	115 VAC	Battery

[a] Special pretest and post-test source checks were performed as part of the demonstration to check for gamma-detection system drift and to confirm calibration. Normal use of the system does not require a source check, and a system check can be done in approximately 5 minutes. Also, the survey speed can often be done at 5 seconds at each angle.

[b] More areas in the Fuel Storage Basin were surveyed using the baseline method; these areas were floor, curb walls, and some columns.

[c] The baseline probe has no collimator and is an omnidirectional detector.

[d] The innovative technology requires more training because it uses a computerized system.

VAC = volts alternating current

ERC Radiological Survey Record
- DOSE RATE -

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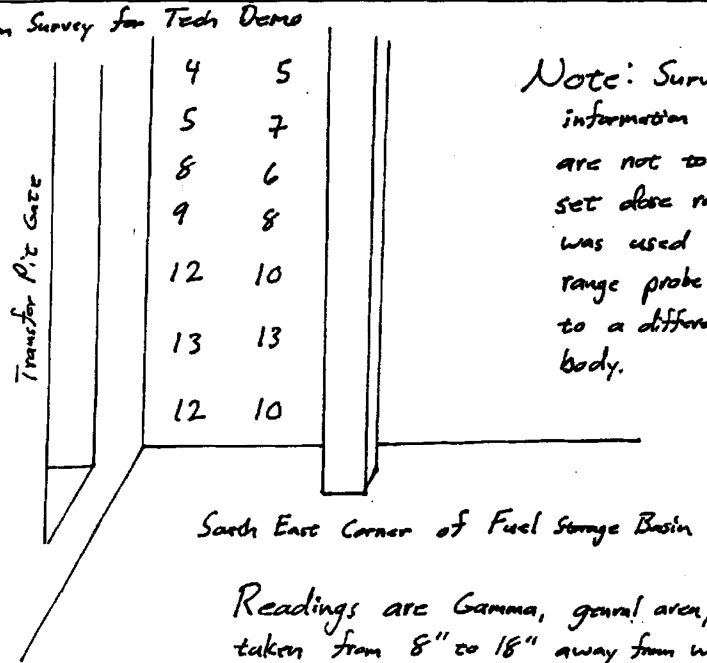
Type of Survey (check one only)			Survey #
☐ Release ☐ Routine ☒ Work Progress ☐ Shipment			RSR - 105C-97-246
RWP # / Rev. # PS-105C-34/0	Date 5-20-97	Time 0900	Location FSB

Comparison Survey for Tech Demo



Note: Survey is for information only. Readings are not to be used to set dose rates. RO-7 was used with low-range probe calibrated to a different RO-7 body.

Readings are Gamma, general area, taken from 8" to 18" away from wall.

-C- Contamination Area	-H- High Contamination Area	-B- Radiological Buffer Area	-AR- Airborne Radioactivity Area	-RM- Radioactive Materials Area	-R- Radiation Area	-HR- High Radiation Area

Δ Micro Rem (μR/hr)	N Neutrons (mRem/hr)	Contact/30 cm γ Contact/30 cm β	General Area Dose Rate = Uncorrected Meter Reading (mr/hr)	-SCA- Soil Contamination Area	-VHR- Very High Radiation Area

Instruments

Model	Serial #	Source ✔ (Initial)	Cal Due Date	Model	Serial #	Source ✔ (Initial)	Cal Due Date
RO-7	0026	NA	3/3/98	NA	NA	NA	NA
DTEBL	0038	NA	12/17/97	NA	NA	NA	NA

COPY

RCT Name/Signature/Date:	RCT Supervisor Name/Signature/Date:
Doug Taylor / [signature] / 5-20-97	S.R. REED [signature] 05/20/97

BHI-TM-R006g (3/97) RSR completed in accordance with BHI-SH-04, Procedure 3.1. Front

Figure 9. Environmental Restoration Contractor Radiological Survey Record.

Expected Performance Under 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. As a result, each individual job is unique. The innovative and baseline technology comparison presented in this analysis is based upon the specific set of conditions or work practices at RL. These conditions are presented in Table 3-1, which is intended to help the technology user identify unique work conditions that could result in cost differences.

Table 1. Summary of variable conditions

Variable	RadScan 600 Gamma-Ray Imaging	Baseline Survey
Scope of Work		
Quantity and Type	128 preliminary scans with 25% overlap* confidence level to cover 3,357 m^2 (36,100 ft^2) and 7 detailed scans to delineate hot spots, with 75% overlap* confidence level to cover 1.21 m^2 (13 ft^2)	Extrapolated to 3,357 m^2 (36,100 ft^2) based on typical production rates observed in the demonstration.
Location	Fuel Storage Basin (no water in basin).	Fuel Storage Basin (no water in basin).
Nature of Work	Columns are present that can obscure areas from being scanned (more setups required); a hoist required to move from one position to the next. The surveying was performed along a grid pattern that follows the spaces between boards in the decking that covers the basin, and duration of individual scan increment is 8 seconds.	Surveying along a grid pattern that follows the spaces between boards in the decking covering the basin.
Work Environment		
Worker Protection	Anti-contamination coveralls with hood, but no respirator.	Anti-contamination coveralls with hood, and respirator.
Level of Contamination	Classified as a contaminated area above the wood decking; at portions of the basin, it is a radiation area.	Classified as a radiation area (and temporarily as an asbestos area, which results in requirement for respirator at times).
Work Performance		
Acquisition Means	For the demonstration, equipment leased (30-day lease) and operation performed by vendor but estimated in this analysis as performed by site personnel with initial instruction in operation provided by vendor.	Site personnel with site-owned equipment.
Production Rates	Preliminary survey using 25% overlap confidence level has an assumed production rate of 0.4 m^2 (4.45 ft^2) per minute [for a distance from the objective of 2.7 m (8.85 ft) the detailed survey rates varied from (0.62 to 2.4 ft^2) per minute to 0.06 to 0.22 m^2].	Baseline production rate is ~0.5 m^2 (5.5 ft^2) per minute based on the average production observed [11 minutes to perform 5.5 m^2 (60 ft^2) of surveys].
Equipment & Crew	One RCT and one D&D worker for the setup portion of the work, and two RCTs for halftime, and one D&D worker halftime for the scanning portion.	Two RCTs using one RO-7 probe.
Work Process Steps	1. Ship equipment to site 2. Transport from receiving area to work location 3. Provide instruction for operators (one time) 4. Set up equipment and wrap with plastic 5. Perform preliminary survey 6. Perform detailed surveys 7. Evaluate 8. Decontaminate and release 9. Transport to shipping area 10. Ship to Los Alamos	1. Prepare survey plans 2. Transport to work area 3. Set up 4. Conduct survey 5. Evaluate data and prepare reports 6. Decontaminate 7. Return transport
End Product	Characterization for planning work	Characterization for planning work

* This is based on the assumption that all of the Fuel Storage Basin surfaces have been scanned (preliminary type) with the innovative technology, plus seven detailed scans of hot spots. The number of hot spots is based on the historic findings of baseline surveys.

** This estimate is based on the demonstration performed and was pro-rated for the total area of the Fuel Storage Basin.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

■ Technology Applicability

- The RadScan 600 technology has the ability to survey large surface areas for gamma radiation with accuracy and a high degree of reproducibility.
- Compared to the baseline, RadScan 600 generates a more concise and understandable representation of the exact location and extent of contamination (radiation) present in an area (see Figures 7 and 8 for the innovative technology and Figure 9 for the baseline).
- Physical locations of readings are accurate to within 15 cm (6 in.) as measured by the range finder; the baseline technique is much less accurate.
- The readings and associated locations are recorded automatically in a computer file; baseline technology readings must be observed and recorded manually.
- The ability of the RadScan 600 to be operated remotely enables the measurement crew to stay in a very low exposure area and perform highly accurate measurements in higher contamination (radiation) areas, keeping exposure as low as reasonable achievable (ALARA).
- This technology can be used to provide well-documented surface radiation exposure and characterization surveys of contaminated or potentially contaminated floors, buildings, and structures prior to and during decommissioning and demolition.
- The RadScan 600 may be used on both interior and exterior surfaces.
- The survey documents provide easier review of characterization results than the survey report produced with the baseline technology, and with better precision and quality.
- The system can be configured with large detectors on mobile platforms, which allows large surface areas such as floors, ceilings, and walls to be surveyed.
- The system can provide relative isotopic information on surface contamination in the survey area, which is not available with the baseline technology.
- The system is applicable to high radiation areas and is useful for pre-job surveys. The RadScan 600 has the ability to map hot spot in high background or multiple hot spots areas. Using the omnidirectional baseline probe is much more subjective when characterizing an area (e.g., room, cubicle, hot cell).

■ Competing Technologies

- The RadScan 600 technology is more costly, but better in terms of worker exposure ALARA practice when compared with hand-held detectors used to characterize a high radiation area.
- An alternative to the RadScan 600 technology is the *Gamma Cam™ system (used at CP5 Technology Demonstration). However, the demonstrated system (RadScan) can automatically pan and tilt to cover wide areas and can perform spectral analysis, for aid in identifying isotopes, which the Gamma Cam system cannot.

*Gamma Cam is a registered trademark of AIL Systems (Deer Park, NY), a subsidiary of Eaton Corporation

Patents/Commercialization/Sponsors

- This technology is commercially available for gamma surveys of floors and walls.
- Patents have been granted to BNFL Instruments for this technology.
- Marketplace opportunities for the RadScan 600 are at radiologically contaminated sites containing high surface radiological contamination. The technology can be applied to those sites where characterization, remediation, and D&D activities are planned (e.g., DOE, U.S. Environmental Protection Agency, and U.S. Nuclear Regulatory Commission sites).

COST

Methodology

Introduction

This cost analysis compares the RadScan 600 gamma-ray imaging innovative technology to the baseline technology of conventional radiological surveying using hand-held instruments. The innovative technology was demonstrated using the vendor's personnel and equipment, and the baseline technology was performed using site labor and equipment. The production rates and durations from the demonstration were used to estimate the cost of characterizing all the surfaces of the Fuel Storage Basin. The estimated cost for characterization by conventional radiological survey methods is approximately 20% of the cost of performing characterization using RadScan 600 gamma-ray imaging technology. However, this cost study does not account for savings from improved ALARA practice that would be realized by using the innovative technology. Details of the cost comparison are covered in Appendix C of this report and summarized in Figure 10.

Cost Analysis

Costs for demonstration of the RadScan 600 technology are based on performing a preliminary survey of an area in the Fuel Storage Basin followed by more detailed surveys of hot spots identified by the preliminary survey. This scenario is intended to represent the cost for normal D&D work using the RadScan 600 gamma-ray imaging system (normal being defined by the vendor experience and judgment of the test engineer) and uses production rate data derived from the demonstration for estimating the cost of surveying the entire basin. One of the several scans performed at a significant distance from the objective was selected to represent the preliminary survey, and several of the close scans were used to represent detailed scans. Other adjustments of the observed data from the demonstration are as follows:

- It is assumed that the equipment is leased and operated by site workers (rather than purchased and operated by the vendor). This assumption was made because of the relatively large capital expense, the limited number of opportunities to use the equipment, costs for mobilizing vendor personnel, and the relative ease of learning to operate the equipment.

- RadScan 600 gamma-ray imaging equipment hourly rates were based on vendor quotes for a 30-day lease.

- 75% overlap confidence level of the scan increments is assumed typical of detailed scans, and 25% overlap confidence level is assumed typical of preliminary scans.

- The onsite calibration that was performed is for demonstration purposes only and would not be part of normal practice (the calibration performed by the vendor at the vendor's facility will be sufficient).

- During the demonstration, the vendor personnel as well as the RCT and D&D personnel were present throughout the demonstration; it is assumed this would not represent normal work (assume two RCTs one-half of the time and one D&D worker one-half of the time).

The activities, production rates, and unit costs observed during the demonstration are shown in Appendix C. The data contained in the innovative technology cost summary, Table C-1, can be used in developing a site-specific cost estimate.

RadScan Cost Data Compared with Baseline

The innovative technology is available from the vendor in the forms and at the rates indicated in Table 2:

Table 2. Innovative technology acquisition costs

Acquisition Option	Item	Cost
Equipment Purchase	Equipment & Software	\$180,000 - \$200,000
Rental or Lease	30 days 60 days 90 days	\$36,000 - \$40,000 \$54,000 - \$60,000 \$64,800 - \$72,000
Vendor-Provided Service	Crew & Equipment Daily Rate	\$1,200/day including subsistence

The rates and prices shown do not include shipping or mobilization costs. The prices will vary from those shown because of fluctuation in the exchange rate, shipping/mobilization distance, and circumstances of the individual job (such as period of work). The vendor will provide current prices upon request.

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

INNOVATIVE TECHNOLOGY RadScan 600 Gamma-Ray Imaging		BASELINE TECHNOLOGY Conventional Radiological Surveys	
Unit Cost	**Production Rate**	**Unit Cost**	**Production Rate**
\$8.64/m^2 (\$2.58/ft^2)	51.8 m^2/hr (170 ft^2/hr)	\$1.61/m^2 (\$0.49/ft^2)	71.6 m^2/hr (235 ft^2/hr)

Note: The unit costs and production rates do not include training, mobilization, and demobilization costs.

The demonstration occurred under specific conditions that directly control cost. The most significant conditions affecting costs for this demonstration are:

- Number of obstructions (number of setups required) (for characterization of all basin surfaces, between 130 and 140 setups would be required)
- Radiologic conditions (classified as a contaminated area above the wood decking and as a radiation area at portions of the basin)
- Number of "hot spots" [detailed surveys required for seven areas for a total of 1.2 m^2 (13 ft^2) of the basin surface]
- Period of lease (the rate used in this analysis was for 30 days).

For additional discussion of cost variable conditions that may occur when using the innovative technology and the potential effect these conditions may have on unit costs and production rates, refer to Section 3 of this report.

Cost Conclusions

The durations and production rates observed from the demonstration were used along with the surface area quantity for the Fuel Storage Basin to estimate the cost of scanning the entire surface of the Fuel Storage Basin. Some of the activities that are included in the cost estimate were not demonstrated (such as training for site operators and preliminary surveys to locate the "hot spots"). The durations and production rates for these two activities were developed from the vendor's experience and from the judgement of the test engineer based on observations made during the demonstration. The costs for the innovative technology and the three baseline technologies are shown in Figure 10. The costs are based on the following work activities:

- Ship equipment to site
- Transport from receiving to work area (C Reactor)
- Training for operators (one-time cost)
- Set up equipment and wrap with plastic
- Preliminary survey
- Detailed survey
- Data evaluation
- Decontaminate and release
- Transport to shipping
- Shipping to Los Alamos.

The costs shown in Figure 10 do not include overhead or general and administrative markup costs.

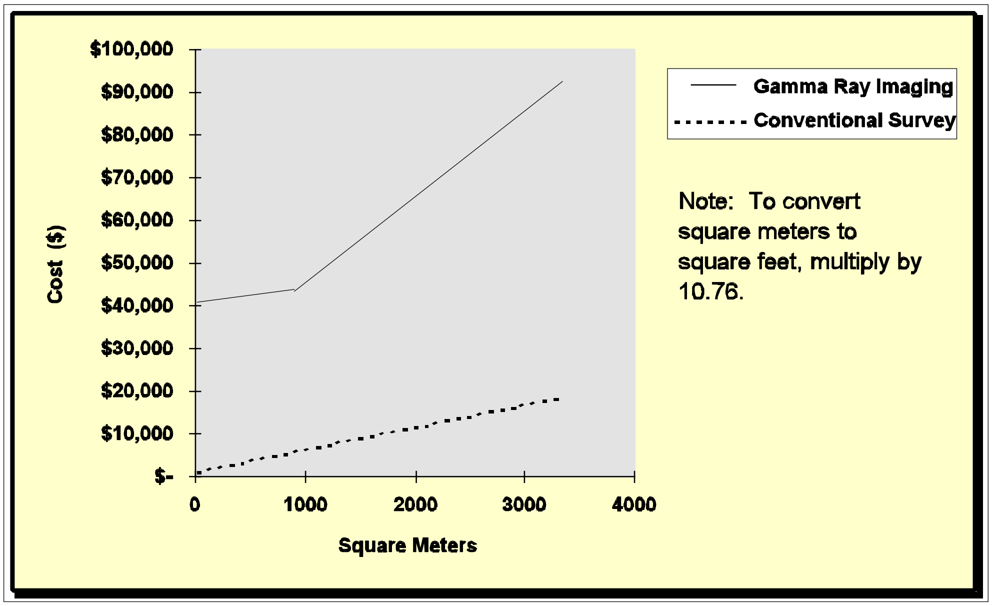


Figure 10. Estimated costs for innovative and baseline technologies for Fuel Storage Basin.

The estimate for characterizing the entire Fuel Storage Basin was based on 135 setups. The many columns and obstructions present in the Fuel Storage Basin require many setups and prevent efficient scanning of large areas. Other D&D sites may not be as severely obstructed as the C Reactor fuel storage basin, and the costs for gamma-ray imaging at other sites may be lower depending on the number of setups required. Productivity rates for scans at a distance of 1.7 m (5.58 ft) were 0.061 m^2/min (0.66 ft^2/min), while scans at distances of 4.2 m (13.78 ft) had productivity rates of 0.223 m^2/min (2.4 ft^2/min). Additionally, the production rates may vary for other situations due to the strength of the source and the resolution required (affects amount of required overlap for the individual scans and duration of each scan).

Since the RadScan 600 can do in situ gamma spectroscopy, isotopic analysis can be done with some measurements, thus, eliminating the need for ex situ sample analysis. Core samples to determine depth of contaminant penetration can also be eliminated if at least two gamma analyses are available to perform peak ratio/shield theory analysis. These advantages of the innovative technology reduce characterization cost compared to baseline characterization methods.

SECTION 6

REGULATORY AND POLICY ISSUES

■ Regulatory Considerations

- The RadScan 600 is an investigation tool for characterizing contaminated surfaces. Therefore, there are no special regulatory permits required for the use of this technology.

- This system is not designed to meet the intent of 10 *Code of Federal Regulations* Parts 20, 835, or Proposed 834.

- Although the demonstration took place at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, no CERCLA requirements apply to the surveys conducted.

■ Safety, Risk, Benefits, and Community Reaction

Worker Safety

- Normal radiation protection worker safety procedures used at the facility would apply.
- Normal lifting and rigging precautions would apply.
- Technology users should implement contamination control practices.
- In high-radiation areas, this system provides ALARA exposures.

Community Safety

- The primary purpose of the RadScan 600 technology is to aid the decision process for cleanup, D&D characterization, radiation source term determination, and planning, as well as decontamination prioritization (especially in high radiation areas). Implementation of this technology would have no adverse impacts on community safety.

■ Environmental Impact

- Implementation of this technology would have no adverse impacts on the environment.

■ Socioeconomic Impact and Community Perception

- No socioeconomic impacts would be anticipated.

SECTION 7

LESSONS LEARNED

■ Implementation Considerations

- To perform a survey effectively, obstructions (e.g., column, thick objects, walls) should not be present in the detector solid-angle view. The detector should be repositioned as needed to view surfaces that are otherwise behind objects.
- Planning for hoists or other rigging to maneuver the inspection head assembly should be considered due to the weight of the unit, which is 105 kg (231 lb) for the inspection head. The weight including the support stand is approximately 125 kg (275 lb).
- The RadScan 600 system demonstrated at the C Reactor is well suited for large open areas.
- The system is suitable for higher radiation areas, and discriminates well between the front and other directions (the detection system is directional). This results in the ability to locate hot spots more accurately than the baseline.
- The system can discriminate hot spot locations in areas with multiple hot spots.

■ Technology Limitations/Needs for Future Development

- The major concern encountered during the demonstration was maneuvering the unit in congested areas.
- Due to physical size and geometry of the RadScan 600 and measurement location geometry, near-corner and wall measurements could not be easily obtained.
- The demonstrated innovative system is not suitable for surveying areas with low levels of radiation, such as for release surveys.
- There is currently no need to modify the system demonstrated at the Hanford Site's C Reactor.
- A similar Gamma Ray Imaging System (Gamma Cam) has been purchased and is scheduled for deployment at Hanford's B Plant.

■ Technology Selection Consideration

- The technology is useful for site characterization in support of D&D engineering design and planning, particularly on floor and wall surfaces.
- This technology has the ability to capture both contamination and exposure level information, along with isotopic information for all surfaces surveyed, with a single detector.
- Reports can be generated automatically that provide a clear, concise, and understandable representation of the exact location and extent of contamination. The data can be used for job planning and decontamination activities, and for loading into dose assessment software packages with more accuracy, completeness, speed, and reproducibility than with the baseline technology.
- All information acquired with the system is scientifically derived and is not subject to subjective observations. The data are electronically logged and are not recorded manually, which enhances comprehensiveness and precision over the baseline technology.

APPENDIX A

REFERENCES

10 CFR Part 835, *U.S. Code of Federal Regulations,* "Occupational Radiation Protection," *Code of Federal Regulations*, as amended..

Proposed 10 CFR Part 834, *U.S. Code of Federal Regulations,* "Environmental Radiation Protection," *Code of Federal Regulations*, as amended.

10 CFR Part 20, *U.S. Code of Federal Regulations,* "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

Ref. 1 *RadScan 600 Operator's Manual*, BNFL Instruments, Ltd., April 1996.

Ref. 2 *Gamma-Ray Demonstration Evaluation Report*, PSC, Los Alamos, NM, May 1997.

Ref. 3 PSC Survey Protocols and Procedures, PSC, Los Alamos, NM, May 1997.

Ref. 4 *Gamma-Ray Imaging Fact Sheet*, Hanford, WA, March 1997.

Ref. 5 AIF, 1986, *Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates,* May 1986, National Environmental Studies Project of the Atomic Industrial Forum, Inc., Bethesda, Maryland.

Ref. 6. USACE, 1996, *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, U.S. Army Corps of Engineers Headquarters, Washington, D.C.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
ALARA	as low as reasonably achievable
BHI	Bechtel Hanford, Inc.
BNFL	British Nuclear Fuels Ltd.
cps	counts per second
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
FETC	Federal Energy Technology Center
LSTD	Large-Scale Technology Demonstration (project)
PC	personal computer
PSC	Pajarito Scientific Co.
RCT	radiological control technician
RL	U.S. Department of Energy, Richland Operations Office
SVGA	super video graphic architecture
USACE	U.S. Army Corps of Engineers
VCR	video cassette recorder
WBS	work breakdown structure

APPENDIX C

TECHNOLOGY COST COMPARISON

The demonstration was conducted at the Hanford Site C Reactor under controlled conditions with onsite personnel operating the equipment for which timed, measured, and quantified activities were recorded.

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

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for an individual site. The overhead and general and administrative (G&A) markup costs for the site contractor managing the demonstration are omitted from this analysis. Overhead and G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis with out having to first back out the rates used at the Hanford Site. This omission does not sacrifice the cost savings accuracy, because 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 indicated for the overhead rates.

This appendix contains cost data for the innovative technology and the baseline. These data are presented in a work breakdown structure for mobilization, characterization, and demobilization. The activities, production rates, and unit costs observed during the demonstration are shown in Table C-1, and can be used to develop site-specific cost estimates given the unique conditions present at the site. The subsequent table, Table C-2, shows cost data for the baseline technology and provides a basis for comparison with the innovative technology.

Table C-1. Cost summary - RadScan 600 gamma-ray imaging system

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor HRS	Labor Rate	Equipment HRS	Equipment Rate	Other	Total UC	Unit of Measure	Innovative Technology - Small Area Comments
Mobilization (WBS 331.01)							**Subtotal**	
Ship Equipment	0.00	$ -	32.00	$250.00	$500	$8,500.00	Each	Shipping from Los Alamos, New Mexico to Central Warehouse (equipment lease period extended by shipping time of 4 days) lease rate in $250/hour
Unload & Transport	2.00	$36.35	2.00	$259.52		$591.74	Each	Teamster and truck to transport equipment from Central Warehouse to C Reactor and includes standby for RadScan 600 equipment
Unpack, Survey & Prepare	4.00	$81.42	4.00	$250.00		$1,325.68	Each	One Radiological Control Technician (RCT) @ $49.45/hr and one D&D worker at $31.97/hr (includes wrapping instrument with plastic sheeting, instrument check out and initialization)
Instructions for Site Crew								One time cost for vendor to travel to RL to provide instruction on use of the equipment
Vendor to Site	8.00	$57.13			$693	$1,149.54	Each	Includes vendor labor during flight from Los Alamos to Pasco (RL), per diem, and air fare
Site Training	8.00	$57.13			$74	$531.04	Each	Site required training for entry to work area includes labor and per diem for one day
Conduct Instruction	8.00	$57.13			$74	$531.04	Days	Training of the site workers for two days as the work proceeds (includes labor and per diem for vendor)
Vendor Return Home	8.00	$57.13			$618.5	$1,075.54	Each	Includes vendor labor during return flight
Characterization (WBS 331.17)							**Subtotal**	
Set-Up & Move for Next Scan	0.17	$81.42	0.17	$250.00		$55.06	Locations	Move equipment from preliminary scan location to the next detailed scan location (3 detailed scan locations) using a hoist, and prepare for next scan, crew is 1 RCT and 1 D&D worker
Preliminary Scan	0.004	$65.44	0.004	$250.00		$1.17	Square Feet	Scan to identify location of hot spots using 25% overlap confidence level and minimum scan duration, crew includes 2 RCTs for ½ time and 1 D&D worker for ½ time
Detailed Scan	0.011	$65.44	0.011	$250.00		$3.56	Square Feet	Detailed scan of identified hot spots, crew includes 2 RCTs for ½ time and 1 D&D worker for ½ time. Unit duration is an average based on total area for 5 surveys divided by total duration for 5 surveys
Evaluate Data & Final Report	1.00	$98.90				$98.90	Each	One RCT and the RCT supervisor
					$22		Man Day	$22/day per person for personal protective equipment (assumes 2 pair used per person per day)
Daily Meeting	0.50	$81.42	0.50	$250.00		$165.71	Each	One safety meeting each morning prior to beginning work
Productivity Loss Factor	0.00	$81.42	0.00	$250.00		$ -	Each	Productivity Loss Factor of 1.27 (adjusts for breaks and personal protective equipment changes by extending the work duration by 27%)
Demobilization (WBS 331.21)							**Subtotal**	
Decon and Survey Out	4.00	$81.42	4.00	$250.00	$0.08	$1,325.76	Each	Survey equipment for free release and remove protective plastic wrap, other costs include waste disposal of 5 lbs of low-level waste at $60/ton
Load & Transport Equipment	2.00	$36.35	2.00	$259.52		$591.74	Each	Transport to Central Warehouse for shipping
Shipping	0.00	$ -	32.00	$250.00	$500	$8,500.00	Each	Return shipping to Los Alamos, New Mexico from Central Warehouse (equipment rental period extended by shipping time of 4 days)
NOTE: TC = UC * TQ							**TOTAL:**	

Baseline Technology - Manual Survey

The cost of performing the work consists of conducting a manual survey of the Fuel Storage Basin surfaces and producing a survey report. The activities, production rates and unit costs utilized in the baseline are shown in Table C-2.

Table C-2. Baseline technology - manual survey

Work Breakdown Structure (WBS)	Unit Cost (UC)						Unit of Measure	Innovative Technology Small Area
	Labor		Equipment		Other	Total UC		Comments
	HRS	Rate	HRS	Rate				
Mobilization (WBS 331.01)							**Subtotal**	
Prepare Survey Plans	2	$98.90	0	$ -	$ -	$198	Each	Labor for two RCTs @ $49.45/hr standard rate for BHI, RL
Transport Personnel & Equipment	1	$98.90	1	$1.25		$100	Each	Includes $0.50 for Eberline RO-7
Source Check Instrument	0.1666	$49.45	0.1666	$1.25		$8	Each	One RCT with an Eberline RO-7
Characterization (WBS 331.17)							**Subtotal**	
Setup	1	$98.90	1	$1.25		$100	Each	Crew of two RCTs and an Eberline RO-7 prepare for survey
Survey	0.00303	$98.90	0.00303	$1.25		$0.30	Square Foot	Production rate of 5.5 ft²
Daily Meeting	0.5	$98.90	0.5	$1.25	0	$50	Each	Daily meetings of ½ hour (typical of Hanford D&D work)
Personal Protection Equipment	0	$ -	0	$ -	$22	$22	Man Day	$22/day per person for personal protective equipment (assumes 2 pair used per person per day)
Productivity Loss Factor	0	$98.90	0	$1.25		$ -	Each	Productivity Loss Factor of 1.27 (adjusts for breaks and personal protective equipment changes by extending the work duration by 27%)
Data Evaluation and Report	10	$49.45				$495	Each	Includes preparation and review by RCT supervisor
Demobilization (WBS 331.21)							**Subtotal**	
Decon and Survey Out	0.1666	$98.90	0.1666	$1.25	$0.03	$17	Each	Labor plus equipment standby and 2 lbs of solid low-level waste generated
Transport for Return	1	$98.90	1	$1.25	$ -	$100	Each	Same as Mobilization cost element
							TOTAL:	

NOTE: TC = UC * TQ