Oak Ridge D&D Plan 3515 Project – Technology Review (2007) and GammaCam™ Technology Demonstration for Characterizing Building 3515 at Oak Ridge (2007)

Darcy Byrne-Kelly, Andrea Hart, Charlie Brown, Diane Jordan
MSE Technology Applications, Inc.
P.O. Box 4078, Butte, Montana 59702

Elizabeth Phillips
U.S. Department of Energy, Oak Ridge Operations Office
200 Administration Road, Oak Ridge, Tennessee 37831

ABSTRACT

This paper presents the results from the Characterization, Decontamination and Decommissioning (CD&D) Study performed by MSE Technology Application, Inc. (MSE) to assist the U.S. Department of Energy (DOE) and Oak Ridge National Laboratory (ORNL) in the preparation of a Project Execution Plan and Remediation Plan for Building 3515 at ORNL. Primary objectives of this study were to identify innovative CD&D technologies and methodologies and recommend alternatives applicable to the CD&D of Building 3515. Building 3515 is a small heavily shielded concrete and cement block structure centrally located in the Bethel Valley portion of the ORNL. The building's interior is extensively contaminated with Cesium 137 (Cs-137), the primary contaminant of concern. A previous attempt to characterize the building was limited to general interior area radiation exposure level measurements and a few surface smears gathered by inserting monitoring equipment into the building on long poles. Consequently, the spatial distribution of the gamma radiation source inside the building was not determined. A subsequent plan for D&D of the building presented a high risk of worker radiation dose in excess of as low as reasonably achievable (ALARA) because the source of the interior gamma radiation field is not completely understood and conventional practices required workers to be in close proximity of the building.

As part of an initial literature search, MSE reviewed new generation gamma source characterization technologies and identified the GammaCam™ portable gamma ray imaging system as an innovative technology applicable to locating the dominant gamma ray sources within the building. The GammaCam™ gamma-ray imaging system is a commercially available technology marketed by the EDO Corporation. This system consists of a sensor head with a co-aligned camera and a portable computer. The system is designed to provide two-dimensional spatial mappings of gamma ray emitting nuclides in real time. The gamma radiation sensor and camera can be set up within or outside of the radiation field while the system operator and PC can be located 30 to 60 m (100 to 200 ft) from the sensor head. The system has been used successfully at numerous DOE and commercial nuclear facilities to precisely locate gamma radiation sources. However, literature attesting to the ability of this technology to detect radiation sources within heavily shielded structures was not available. Consequently, MSE was not certain if this technology would be capable of locating gamma ray sources within the heavily shielded Building 3515. To overcome this uncertainty, MSE sent two individuals to the EDO Corporation for training. At completion of the training, MSE leased the GammaCam™ portable system and brought it to ORNL to evaluate the capability of the system. An overview from this evaluation is summarized in this paper.

INTRODUCTION

Building 3515 is a small building located in the Bethel Valley portion of the ORNL. The building structure shields two hot cells used during the late 1940s and 1950s to develop and demonstrate processes for recovering fission products from liquid radioactive wastes. Eventually, the building interior became contaminated and high gamma radiation fields prevented human entry. Consequently, the building and process equipment were abandoned and entombed by an external layer of concrete and cement blocks. The outer shell of the building measures approximately 4.5 meters (m) or 15 feet (ft) by 8.5 m (28 ft) by 3.6 m (12 ft). The building is currently listed for D&D as part of the ORNL revitalization plan.

A radiological survey of the building interior was conducted in the spring of 1994, but high gamma radiation fields, in excess of 20 Rad per hour (R/hr) inside the building, prevented human entry and limited the survey to general area dose measurements, floor swipes, and adjacent soil samples. The survey indicated the interior floor and adjacent soils are highly contaminated and the major radiation source is believed to remain inside the process equipment. Cs-137 is the primary contaminant of concern, but the actual location(s) of the dominant Cs-137 source has not been determined. In addition, the presence of lead shielding inside the building and buried in adjacent soils indicates the probable presence of higher radiation fields. A D&D plan for removing the building from the site was prepared immediately following the radiological survey but the plan presents an unquantifiable risk of worker radiation exposure because the precise location(s) of the dominant radiation source within the building has not been determined.

MSE assisted DOE and ORNL in preparing a Project Execution Plan and Remediation Plan for Building 3515. The purpose of this study was to identify innovative technologies and recommend alternative methodologies for safely decontaminating and decommissioning the building.

MSE has completed the following tasks:

- researching the building history;
- reviewing the baseline data;
- analyzing potential hazards;
- evaluating the approach for baseline D&D;
- researching characterization/monitoring technologies;
- researching D&D technologies;
- developing alternative approaches;
- preparing a cost estimate to compare the baseline approach with recommended alternative approaches; and
- evaluating the GammaCam™ imaging system as a characterization tool.

Based on the preliminary results of these activities, MSE has determined that the key to developing a viable D&D Plan for Building 3515 is to first determine the precise location of the dominant gamma radiation sources.

Working with ORNL, MSE conducted a series of tests designed to acquire hands-on experience using the GammaCam™ to image radioactive sources with a known activity in the ORNL Radiation Calibration Laboratory. The results of these experiments indicated the GammaCam™ technology has promise for this type of application. The GammaCam™ was able to measure the different source activity levels, and most importantly, it was able to identify source locations from outside the calibration laboratory through a concrete wall approximately 60 m (2 ft) in thickness. When the GammaCam™ was positioned 6.4 m (21 ft) from Building 3515; it was able to locate sources within the building. Based on the results of this initial investigation. MSE is currently preparing a planning document for characterizing the building interior and recommending alternative D&D approaches, technologies, and methodologies based on hypothetical contamination distribution scenarios. The preferred methodology for CD&D of Building 3515 will be determined based upon the results of additional site characterization, decision-making, and technology selection processes.

BACKGROUND

Building 3515 was originally referred to as the Fission Product Pilot Plant (FPPP) because it contained an operationally flexible pilot plant system that developed fission product recovery methods. Plant operations focused on practical means for extracting curie quantities of radioisotopes of ruthenium, strontium, cesium, cerium, and other elements from liquid wastes generated by ORNL and from cleanup of the Chalk River (Canada) operations.

During the earlier years, the FPPP was referred to as the ^{106}Ru tank arrangement. At that time, the facility consisted of a concrete pad with tanks surrounded by stacks of concrete blocks three rows deep. The process equipment was covered by a canvas tent.

Facility modifications in the early 1950s included replacement of the block shield wall with a two-room hot cell having 45-centimeter (cm) [18 inch (in)] thick masonry walls and a 60 cm (2 ft) thick concrete roof. Eventually, the interior of the building became highly contaminated and process testing was halted. The FPPP was taken out of service in 1958. Available records indicate that the last interior arrangement supported a process designed to recover and concentrate Cs-137, referred to as the Caesar Process.

Process vessels and piping, as well as interior surfaces, were not cleaned of chemical or radiological contamination at the time of closure. To reduce potential exposure hazards to on-site workers, the building's west-side access doors were sealed with concrete block and mortar in 1960. Over the next few years, a concrete block wall was constructed around, and away from the original building, and the gap was filled with concrete. An additional 10 to 15 cm (4 to 6 in) of concrete was added to the roof. Concrete slabs and lead and steel sheeting were extended to the south and east of the existing building. By 1964, the resulting shell thickness ranged from 45 to 106 cm (1.5 to 3.5 ft) (including the roof); all penetrations into the original building had been cut off, capped, or sealed by the concrete shell. Figure 1 is a photograph taken from the northwest corner of the building, showing the sealed entrance on the west side of the building.

The FPPP was transferred into DOE's Surplus Facility Management Program in 1976 for eventual D&D. Since then, routine surveillance and maintenance was performed, and extensive roof repairs, including installation of stainless steel sheeting, occurred in 1988.

Building 3515 Interior

As shown in Fig. 2, the interior of the building consists of two cells accessed by entryways approximately 75 cm (30 in) wide and 90 cm (3 ft) long. The cell entrance floors are reportedly covered with lead sheeting. The interior dimensions of the north and south cells are approximately 3 by 3.5 m (10 by 11 ft) and 1.4 by 1.8 m (4.5 by 6 ft), respectively; ceiling heights in the north and south cells are about 3 m (10 ft) and 2.5 m (8 ft), respectively. The interior wall separating the two cells is constructed from stacked masonry blocks, some of which were emplaced without mortar.

The entry of the north cell is blocked by a large steel vessel referred to as S-5. The east portion of the cell contains numerous glass and stainless steel process vessels, 0.5 to 20 liter (L) [0.13 - 5.3 gallon (gal)] capacity, attached to a stainless steel, floor-to-ceiling equipment rack. The northwest portion of the cell does not appear to be occupied with the exception of some small glass bottles on the floor. The vessels attached to the equipment rack are inter-connected and connected to the S-5 vessel via a complex array of small diameter stainless steel piping. Process piping includes connections between vessels in the north cell, connections between vessels in the south cell, lines that previously penetrated the walls and roof for solution or solids additions, product discharge lines, and drainage lines. A hot drain header is located at the bottom of the equipment rack. Flows were controlled remotely via the use of solenoid, needle, check, plug, and gate valves. Liquid transfers used gravity flow or eductors, rather than mechanical pumps.

Fig. 1. North and west side of Building 3515.

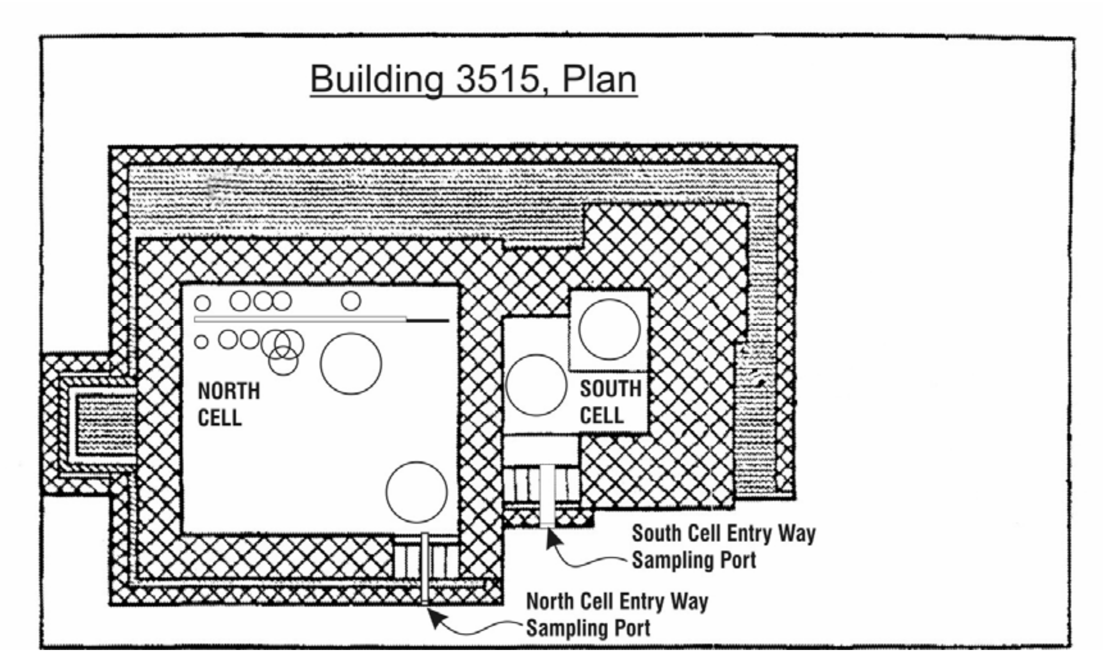

Fig. 2. Floor plan of Building 3515.

The major components in the south cell are the Cesium Transfer Tank, Hot Off-Gas Scrubber, and Crystallizer No.1. The 61 cm (24 in) diameter, 76 cm (30 in) high Cesium Transfer Tank sets on the floor of the cell against the north wall and extends partially into the cell entryway. The 61 cm (24 in) tall by 20 cm (8 in) diameter scrubber vessel sets approximately 1.8 m (6 ft) off the floor in the northeast corner of the cell. The alcove in the rear of the south cell contains a vessel designated as Crystallizer No.1. This vessel sets on top of a 90 cm (3 ft) diameter pedestal approximately 76 cm (2.5 ft) high. The crystallizer vessel is approximately 100 cm (40 in) high and 55 cm (22 in) diameter. Nearly three-fourths of this vessel is shielded with stacked lead bricks. An agitator is situated over the top of the crystallizer, as is the hot off-gas vent line. The vent line is connected to a downstream scrubber and heat exchanger.

Process piping is similar in dimensions and type to that found in the north cell. Some piping passes through the north wall at two locations above the cesium transfer tank and connects the crystallizer and transfer tank (in the north cell) with the filtrate vessel and Precipitator No. 1 in the north cell. Other "north cell" piping exits the south cell through the floor and then under the east wall. A 5 cm (2 in) hot off-gas line penetrates the north wall at about 1.8 m (6 ft) off the floor. A 15 cm (6 in) wide by 15 cm (6 in) deep concrete channel or culvert penetrating the original east wall of the south cell and sloping to a drain has reportedly been sealed with concrete and lead.

Previous Assessments

An *Alternatives Evaluation (A&E) Report* was prepared by Ebasco Services Inc, and issued in January of 1994 [1]. This report evaluated five alternatives considered consistent with the goals of the ORNL D&D program for the D&D of Building 3515.

The goals of the ORNL D&D program are to: 1) achieve final disposition of the facility; 2) maintain compatibility with the Environmental Restoration (ER) Program and ER activities for Waste Area Grouping (WAG) 1 and the Gunnite and Associated Tanks Operable Unit (GAAT OU); and 3) protect human health and the environment.

The five alternatives evaluated in the A&E were:

1) no action or continued Surveillance and Monitoring (S&M);
2) decontaminate and leave in place;
3) entombment in place;
4) dismantle above grade structure and leave the partially decontaminated concrete floor in place; and/or
5) complete dismantlement which includes removal of the below grade structure.

Alternatives 4 and 5 were considered consistent with the goals of the ORNL D&D program, and the recommended alternative was complete dismantlement including removal of the concrete floor.
A *Site Characterization Report* (SCR) for Building 3515 was prepared by Bechtel National Inc, and issued during August of 1994 [2]. The SCR provides evidence of high gamma radiation levels upwards of 20 R/h in the north cell and moderate gamma radiation levels exceeding 450 mR/h in the south cell. Although these measurements were taken over 12 years ago, they can still be considered somewhat representative for estimating the present building contamination characteristics. However, it should be realized that this characterization of the building interior was limited to general area measurements and gross smears, and further characterization is considered essential to acquire information required for developing a viable D&D plan.

The Executive Summary of the SCR noted the following:

- "Directional measurements in the north cell show that the exposure rates due to the floor are higher than those due to walls, this is also the case in the south cell except at a distance of 1.5 to 2 m (5 to 7 ft) from the penetration, where the south wall produces higher exposure rates, perhaps caused by some of the piping in that direction."
- "Comparison of direct measurement and gross smears indicates that most of the contamination is fixed or inside the process equipment. Contamination of process piping and equipment was not investigated."

Section 5.0 of the SCR presents the analytical results of concrete and soil samples taken from core holes through the slab on the south side of Building 3515. The results of the cement and soil sampling activities are summarized in Section 5.5 of the SCR. Soil sample no. 03932 exhibited a Cs-137 concentration of 1,300,000 Pico Curies per gram (pCi/g) (SCR, pg 5-6); total lead and mercury concentrations of 213 milligrams per kilograms (mg/kg) and 12.4 mg/kg respectively. This sample penetration was terminated at 1.4 m (4.5 ft) due to high radiation levels.

Section 8.4 of the SCR concluded:

- "Due to the limited remote characterization performed for the building interior, planning for D&D implementation may require that additional characterization information be obtained, either prior to implementation or during phased implementation. Additional characterization to address data needs could include core sampling from the cell walls and floors, smears from the core locations, detritus samples from the floor, and directional surveys of the equipment and specific floor areas to better define the source term."

The following approach for complete dismantlement of Building 3515 entitled *Decontamination and Decommissioning of the Fission Product Pilot Plant* was presented by G. J. Mandry and W. H. Snedaker at the International Conference on Nuclear Energy, Kyoto, Japan April 23-27, 1994 [3]. This complete dismantlement approach was also described in Section 2.2 of the *D&D Alternatives Risk Assessment* [4].

Baseline D&D Approach

The Baseline D&D approach, as described in Section 2.2 of the D&D Alternatives Risk Assessment (DARA), is consistent with the recommended alternative and provides a methodology for the complete removal of all equipment and demolition of the above and below grade structures including the external concrete pad. Contaminated equipment and materials would be placed in disposal boxes and removed from the building into an adjacent shielded tunnel on a rail system. The disposal boxes would be placed into shielded shipping containers while inside the shielded tunnel. The shielded containers would be removed from the shielded tunnel and disposed at a licensed radioactive waste disposal facility. Following equipment removal, the original interior walls would be removed, followed by the roof and then the exterior walls. The floor, external concrete pad and disturbed soils would be removed last, and the remaining contaminated soil would be capped.

Dismantlement of the building would begin by installing a High Energy Particulate Air (HEPA) filtered and continuously monitored ventilation system to maintain constant interior negative pressure and ensure air borne contaminants are captured and not released to the environment.

The second step in the baseline approach involves drilling access ports through the roof of the building over each cell and constructing a shielded tunnel adjacent to the existing cell entrances in the west wall.

The roof ports would provide cell access for roof mounted remote control robotic arms. The shielded tunnel would provide the means for inserting disposal boxes into the cells, removing the disposal boxes and placing the disposal boxes into shielded shipping containers. Each robotic arm assembly would consist of three arms. One arm would hold video cameras and lights while the other two arms would disassemble and place interior equipment into disposal boxes.

Upon completion of the equipment removal phase, the interior concrete walls would be segmented and removed through the shielded chamber in shielded shipping containers. After removing the interior walls, the shielded tunnel and robotic arms would be removed to allow demolition of the roof and exterior walls.

After removing the roof and exterior walls, the existing floor and concrete pad would be segmented using remote controlled floor saws, and the pieces would be placed in shipping boxes. The subfloor soil would be left in place and capped with an impermeable high-density polyethylene layer, 30 cm (12 in) of clean soil and a concrete pad if additional soils shielding is required.

A *Baseline Risk Assessment* (BRA) [5] and *D&D Alternatives Risk Assessment* (DARA) [4] for Building 3515 were prepared in 1995. These documents explored and summarized the hazards associated with the No Action and Complete Dismantlement alternatives, respectively. The BRA summarized the Incremental Lifetime Cancer Risk (ILCR) for a maintenance worker, working in close proximity to the building exterior 2 hours per month for 25 years, would exceed the U.S. Environmental Protection Agency's (EPA) range of acceptable risk but would be within the1.5 rem per year worker exposure limit used by ORNL. The DARA summarized the ILCR for a worker involved in creating interior access holes in the building walls and roof, as proposed in the Complete Dismantlement Approach, would be exposed to radiation from inside the building in excess of the CERCLA acceptable risk range and worker protection standards. This finding has seemingly stalled further action.

Alternative Approaches

The Alternative approaches suggested by MSE follow the process described in the *Multi-Agency Radiation Survey and Site Investigation Manual* [6]. This process prescribes identifying data gaps, or unavailable information, as the first step in generating the information required to develop a valid D&D plan. Once identified, filling these data gaps becomes the purpose and objectives of additional characterization. Sampling and characterization methodologies and technologies will be selected and employed based on their ability to provide the additional information required.

After reviewing the SCR, MSE has identified the following data gaps:

- exposure levels in the north and west portions of the north cell are not well defined;
- exposure levels in the south cell could be downwardly biased by lead shielding;
- radioactive source distribution and concentrations in the north and south cells are unknown;
- the quantity and size of radioactively contaminated vessels is unknown;
- contaminant concentration and depth of penetration in the north and south cell walls and floors is unknown;
- contamination levels in the soil underlying the building floor are unknown; and
- contamination levels in proximity soils are unknown.

Additional Characterization

Specific objectives of the additional characterization activities would be to fill in the previously listed primary data gaps and identify secondary data gaps. MSE suggests employing a phased characterization strategy as an integral element of developing the D&D plan. This strategy allows planners to make decisions and develop realistic approaches based on reliable data.

As tasked by DOE, MSE has researched new and innovative technologies designed to assist the characterization of radioactively contaminated facilities. Available literature and professional sources indicate the GammaCam™ imaging technology has become widely recognized and used as an effective tool for precisely locating gamma-emitting sources. However, it has not been used detecting radiation sources within heavily shielded structures. The gamma imaging technology was originally developed as a Technology Reinvestment Project funded by the Advanced Research Projects Agency and managed by DOE. The technology has been successfully deployed at numerous DOE and commercial nuclear facilities, and a few reports, including Innovative Technology Summary Reports, have documented the results of these deployments.

Based on this information, and the commercial availability of the gamma ray imaging system, MSE determined this innovative technology could be a valuable tool for performing a relatively rapid, safe, and inexpensive initial survey of Building 3515, especially when compared to conventional manual methods. However, available literature did not indicate any attempts to quantify the relationship between shielding effectiveness and the ability to locate shielded sources when shielding exceeded half-value layers and approached or exceeded tenth-value layers. With the thought that the additional shielding added to Building 3515 may have effectively attenuated gamma radiation emanating from the building interior, MSE conceded it may not be possible to detect interior gamma sources with a gamma imaging system. Therefore, MSE decided the only way to determine whether the gamma imaging system could be used as an effective tool for identifying the dominant sources within Building 3515 was to take the system to the ORNL and evaluate its effectiveness in the field.

MSE leased the gamma imaging system marketed by the EDO Corporation under the trade name GammaCam™. This system consists of a portable sensor head that contains co-aligned gamma ray and visual imaging systems and a portable control computer. The computer can be located from a few to several hundred feet from the sensor head, ensuring the system operator is safely positioned outside the radiation field. When exposed to gamma radiation, a coded aperture within the sensor head distributes the radiation over the surface of the detector and uses a mathematical transformation to obtain the spatial distribution of the source. The radiation field image is displayed in color and superimposed over the black and white video image on the screen of the computer. The radiation field image is color coded with red corresponding to the highest radiation level and blue with the lowest.

Unlike manual method radiological surveys, which had already been performed at Building 3515, the gamma imaging system provides a two-dimensional visual image of the actual position and relative strength of the dominant radiation sources within a shielded structure.

The project objectives were to test and evaluate the system using high activity Cs-137 sources under controlled conditions and then obtain images of Building 3515 under field conditions. Tests conducted at the ORNL were designed to:

- familiarize MSE personnel with the gamma ray imaging system;
- assess the ability of the system to locate gamma-emitting sources within shielding structures; and
- determine the system’s applicability as a nonintrusive tool for identifying the location of the major gamma sources within Building 3515.

The gamma ray imaging system testing at ORNL was limited to 2 days in which a series of five tests were performed. Four tests were performed the first day of testing at the ORNL Radiation Calibration

Laboratory. The first three tests involved positioning the systems sensor head, a stainless steel pipe, and a masonry block within the shielded laboratory test chamber, and exposing Cs-137 sources with known activity levels, while MSE personnel (with the support of ORNL personnel) acquired images of the sources with the system computer located outside the test chamber. Sources were placed within the stainless steel pipe and masonry block to replicate the shielding characteristics of Building 3515 materials.

The fourth test involved positioning the sensor head outside the laboratory and acquiring an image of the radiation from the Cs-137 source exposed within the test chamber as it penetrated through the wall of the building.

The fifth test, performed on the second day, involved moving the gamma ray imaging system to the pavement on the west side of Building 3515. Images of the west side showing the north end and south end cell entrances were acquired.

Testing at the ORNL Radiation Calibration Laboratory

The sensor head was set on a movable table inside Room 202 of the ORNL Radiation Calibration Laboratory for the first two tests. The system operator and computer were located at a desk in Room 200. This arrangement provided the ability to locate the sensor head in a radiation field while the system operator was protected from radiation exposure. The gamma ray sources within Room 202 were normally shielded, and the exposure level could be increased or decreased by remotely removing or adding shielding. The purpose of this test was: 1) to gain familiarity with the system while exposing the sensor head to increasing levels of activity and dose; and 2) to understand operational characteristics of the system while attempting to image discrete sources inside a general area radiation field. The first part of the test involved exposing the sensor head to a gamma ray producing source while taking images of the source as the exposure level was increased and decreased. The second part of the test involved exposing the sensor head to a constant gamma source of known activity and taking images of the source while the background activity was increased and decreased using a gamma-emitting source of higher activity located outside the sensor heads field of view.

The first test was lengthy because many images were acquired under varying conditions to familiarize MSE personnel with the capabilities of the gamma imaging system. The test objective was for training and not source definition and evaluation.

The second test involved placing a 5-millicurie (mCi) Cs-137 source inside a stainless steel pipe with a wall thickness of 0.28 cm (0.110 in) and attaching the pipe to a wooden block placed 350 cm (11.5 ft) from the sensor head. The purpose of this test was to evaluate the response of the system when a gamma ray producing source of known activity is shielded from the sensor head as an image is acquired.

The third test involved placing a 5 mCi Cs-137 source into a standard masonry block with a wall thickness of 3.2 cm (1.25 in) and placing the masonry block 249 cm (98 in) from the sensor head. A smaller Cs-137 source of 7 micro Curies (μCi) was placed in the masonry block, and no image was acquired with either a narrow or a wide field of view, even at a distance of 1 m (3.28 ft). Test four involved moving the sensor head to the roof outside Room 202 of the ORNL Radiation Calibration Laboratory and taking images of the exterior wall of the room while a 600-curie (Ci) Cs-137 source (located 10.5 m (34.5 ft) from the exterior wall) was exposed inside the room. The sensor head was set up 292 cm (114 in) from the outside concrete wall, which was 45 to 60 cm (1-1/2 to 2 ft) thick. Using a narrow field of view and exposure time of 5 minutes, no image was acquired. The exposure time was increased to 10 minutes, and the image shown in Fig. 3 was acquired.

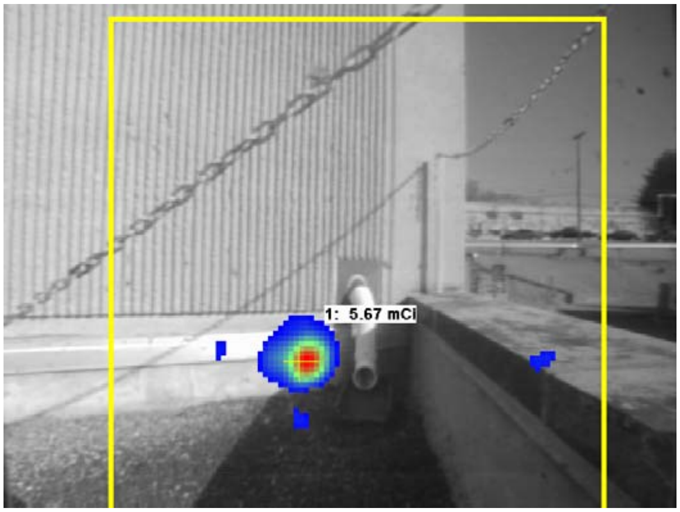

Fig. 3. Image obtained outside the ORNL Radiation Calibration Laboratory.

The final test at the ORNL involved moving the Gamma Imaging System to the west paved area outside Building 3515. The GammaCam™ was placed approximately 6 m (20 ft) from the west wall of Building 3515 and focused on the entryways of the north and south end cells as shown in Fig. 4a.

All images were acquired outside Building 3515 from the paved area and the results are summarized below:

- The gamma imaging system was set for an exposure time of 30 minutes with a wide field of view. An image was acquired; however, the image did not show any gamma activity.
- The gamma imaging system isotope setting was decreased to three, and the field of view was changed to narrow. The camera was set for 30 minutes, and an image acquired also did not show any gamma activity.
- The isotope setting was decreased to two, and the field of view was changed to wide. The system was set to image for 60 minutes at a distance of 6.53 m (21 ft). An image was successfully acquired showing gamma activity within the building through the south cell entryway sampling port and through the wall of the north cell as shown in Fig. 4b.

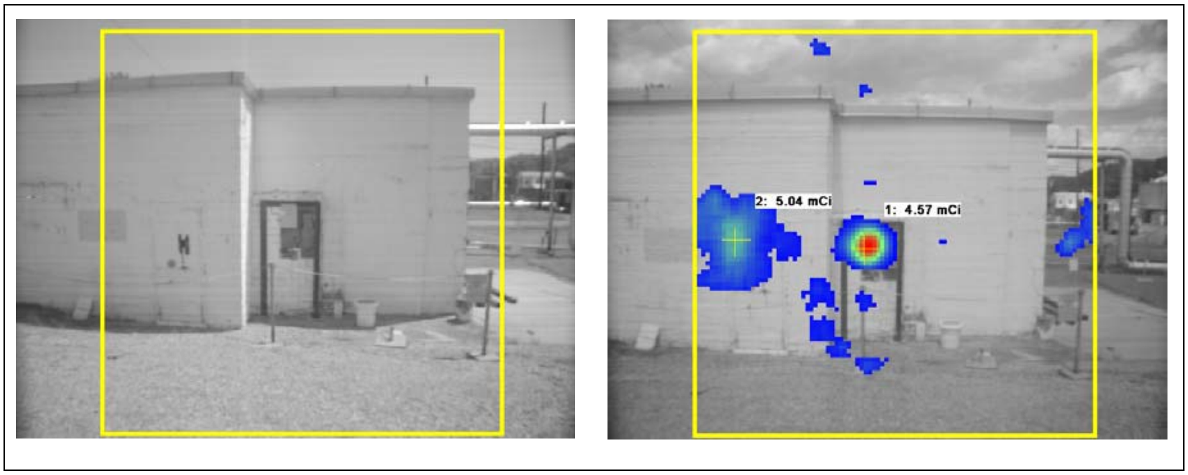

Fig. 4a. West side of Building 3515 showing the north and south cell.
Fig. 4b. West side of Building 3515 showing gamma activity within the building.

Testing conducted at the ORNL demonstrated the GammaCam™ gamma imaging systems ability to safely and efficiently perform a nonintrusive characterization of the dominant gamma producing sources within Building 3515.

Based on the result of this field trial of the gamma imaging system, MSE suggests utilizing this technology to perform the initial characterization of Building 3515. This characterization process would involve utilizing a gamma imaging system set up at different positions around the building perimeter to generate images of the dominant gamma producing sources within the building. Triangulation of these new images, and comparison with existing process arrangement drawings should identify the location of the dominant radiation sources. The gamma imaging system positioning should include elevating the sensor head to gather images of the building roof and proximity grounds. The system operator would operate the system from a ground-based position located outside the radiation field. The gamma imaging system should not be expected to accurately quantify the activity level of a specific source within the building. It would be used as a screening level tool to identify areas of the building exhibiting higher gamma activity. This information should prove to be valuable when planning Phase 2 characterization activities.

The second characterization phase should be designed to repeat the characterization performed in 1994 and documented in the SCR, including additional wall penetrations in the north wall of the north cell and possibly an additional penetration somewhere near the midpoint of the west wall of the north cell. Locations for additional penetrations would be determined based on Phase 1 characterization results. The second phase characterization could utilize sampling methods used in 1994 supplemented with gamma ray images.

The objectives of the second phase of the characterization are:

- validate the results and/or determine changes since completing the 1994 SCR;
- provide a more accurate representation of the exposure levels in the north and west portions of the north cell;
- determine the effect of the lead shielding to overall exposure levels in the south cell;
- aid the access/egress positions determination;
- define shielding requirements for the access/egress points; and
- alleviate some of the risk involved with implementing the Phase 3 characterization.

The third phase characterization would involve using an intrusive gamma ray imaging system to survey the interior surfaces, piping, and vessels in the north and south cells of the building. This phase may be completed after removing the dominant gamma sources from the building.

The fourth characterization phase would involve entering the cells with remote operated equipment outfitted with a coring device to allow characterization of walls, floors, and subsurface soils. This phase could be completed prior to, or after, the process equipment removal phase of the project. This decision would most likely be dependent upon the results of the Phase 3 characterization.

Decontamination and Decommissioning

As tasked by DOE, MSE has been researching new and innovative technologies applicable to D&D Building 3515. A literature review, past experience, discussions with others in the D&D arena, and applicability to Building 3515 focused MSE on remotely operated D&D system and bulk vitrification.

Remotely operated D&D systems have recently become widely accepted and used for D&D of radioactively contaminated facilities. Numerous remotely operated systems designed specifically for entering high radiation fields and performing characterization, decontamination, and demolition tasks are commercially available. These new systems are remarkably small and robust, and relatively cost comparable to their predecessors commonly referred to as stationary manipulators. These systems are not considered one-size fits all applications. A system would be built specifically to fit and function in a particular environment and perform certain tasks. System components would most likely include a mobile platform, manipulator arm, tooling (commonly referred to as end effectors), and control electronics. Ancillary attachments would typically include video cameras, lighting, and radiation monitoring. The systems are commonly electro-hydraulic or battery operated. System components would be selected and assembled in accordance with the size and weight handling requirements of the project. End effectors can be selected in accordance with the type of work that needs to be performed. The industry has made tremendous advancements in the last 10 years while remaining relatively cost effective with aging similar technology. Remotely operated D&D systems for Building 3515 would be specified and built in accordance with the requirements developed after conducting at least the first two characterization phases and determining the location of the dominant radiation sources, the remotely operated D&D systems would be sized to handle the largest of the radioactively contaminated vessels.

Bulk vitrification is a process that uses electrical energy to reduce (melt) an existing structure and underlying soils to a high-density crystalline monolith. This technology is applicable to Building 3515 and can be selected as an alternative approach without conducting additional characterization activities. The GeoMelt Subsurface-Planar Vitrification (SPV)™ method is the state-of-the-art process for implementing vitrification. This process uses two melts initially developed in vertical planes. As electrical power is applied, the melts converge by growing in volume downward and sideways. Material above the melt subsides and becomes incorporated into the melt. This configuration maintains a permeable pathway in the region between the melts allowing vapor and gases to escape before the two melts merge.

Subsurface-Planar Vitrification is an advanced and safer technique than earlier bulk vitrification processes because vapor and gas cannot be trapped in the melt. SPV has been commercially proven at large scale in both government and private sectors, including a well-documented and controlled demonstration at the Los Alamos National Laboratory in 2000. [7]. This project showed that SPV could produce a waste form that can be contact handled and pass land disposal requirements.

SUMMARY

MSE has identified two promising alternatives for achieving DOE's goal of complete dismantlement of Building 3515. The first alternative involves additional characterization utilizing the gamma imaging system, and performing D&D activities with remotely operated D&D systems working within a temporary building encasing the existing Building 3515. The second alternative is vitrification utilizing the Geomelt SPV™ process.

A conceptual approach to implementing the first alternative involves erecting a temporary structure to encase the existing Building 3515 and use remotely operated systems to replace humans at the building interface level. This concept virtually eliminates the risk of worker radiation exposure. A conceptual approach would include fabricating a steel working platform over the existing Building 3515 and using this platform to support the remotely operated systems. A remotely operated stationary system would be mounted to the platform and used to breach the roof structure and hoist materials into and out of the building. Remotely operated systems would be lowered into the building and used to perform equipment removal and other decontamination tasks.

Gamma Imaging would continue from the building exterior and eventually from the interior as dominant sources are removed. Decontamination of the building, including the floor, would continue until previously approved decontamination levels are achieved. A new concrete slab could be poured within the existing structure if contaminated soils are encountered when removing the existing slab. The existing building 3515 would be segmented and removed after decontamination efforts are completed.

An application of the GeoMelt process at building 3515 would involve using the SPV method. A four-sided perimeter wall, made of refractory panels, surrounding the building would serve to insulate and contain the melt, and also support an off gas collection hood. The off-gas collection hood would cover the entire treatment area and ensure all gases developed during the melting process would be drawn into the off-gas treatment system (OGTS). The OGTS would be designed to ensure all gases and particulates are properly treated prior to atmospheric venting. Holes would be drilled through the roof of the building to allow venting of major process vessels and venting of the interior during the melt process. Glass-forming and conductive material (primarily soil) would also be added to the building interior to supply glass-formers to enhance melting and contaminant entrainment characteristics. Details of these building access activities would be finalized in post-conceptual design phases. Electrodes emplacement would be determined based on the volume of material to be vitrified (i.e., just the building, the building and the slab, the building slab without the building, the building, slab, and underlying soils, or just simply the underlying soils).

After emplacement of the electrodes, the vitrification process would commence. The melt planes would grow from exterior of the building inward, to merge together into one final monolith. A two-step process or a total of two melts would most likely be required to entirely vitrify the building. The off-gas hood and containment walls would be removed to allow cooling of the monolith. The cooled monolith would be segmented and detached from the surface at a predetermined depth using conventional segmenting processes such diamond chain sawing. The resulting segments would be suitable for disposal as contact handled low-level waste. The final site condition would achieve the goals of the ORNL D&D program.

RECOMMENDATIONS

MSE recommends implementing the Modified Baseline Approach including an overarching temporary containment building with a gamma imaging and remotely operated system as the most conservative and cost effective approach for the complete dismantlement of Building 3515. This approach would be implemented in phases in accordance with the MARSSIM process. The results of additional characterization activities would be used to determine and plan the next phase characterization and decontamination objectives. Decontamination activities would follow a systematic approach from first containment and usage of remotely operated systems. This methodology would ensure compliance with ALARA principles.

MSE also recommends performing a mock-up demonstration to ensure the remotely operated systems selected for the D&D of the building are properly sized and equipped to perform their intended purposes. The mock-up would involve construction of a building identical to Building 3515 including fabrication and assembly of the external roof access superstructure. The roof and walls of the mock-up building would be constructed of concrete, cement blocks, and a steel roof of the same thickness and construction as that of Building 3515. The interior of the building would be equipped with process systems similar to those in the existing Building 3515. The remotely operated systems specified for Building 3515 D&D would be purchased and used to demonstrate the ability to effectively remove the process system components through the roof of the mock-up structure. After successfully completing the mock-up demonstration, the external roof access superstructure and remotely operated systems would be removed from the mock-up location, reassembled at Building 3515, and used to perform the actual D&D of

Building 3515. Performing the mock-up demonstration would provide the experience required to ensure the actual D&D of building 3515 would proceed as planned.

ACKNOWLEDGEMENT

Work was conducted for the DOE Environmental Management Consolidated Business Center through the Western Environmental Technology Office under DOE Contract Number DE-AC09-EW96EW405.

MSE would like to thank Ms. Elizabeth Phillips (DOE-OR), Ms. Paula Kirk (ORNL), and Mr. David Vesco (NuVision) for their support.

REFERENCES

1. Oak Ridge National Laboratory (ORNL). *Alternatives Evaluation for the Decontamination and Decommissioning of Buildings 3506 and 3515 at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. Prepared by Ebasco Services, Inc. (Oak Ridge, TN) for the U.S. DOE/ERWM Document No. ORNL/ER-216 (1994).

2. ORNL. *Site Characterization Report for Building 3515 at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. Prepared by Bechtel National, Inc. (Oak Ridge, TN) for the U.S. DOE/EM. Document No. ORNL/ER/Sub/87-99053/73 (1994).

3. Mandry, G. J., and W. Snedaker. *Decontamination and Decommissioning of the Fission Product Pilot Plant at the Oak Ridge National Laboratory*. Presented at the International Conference on Nuclear Energy, Kyoto, Japan (April 1994).

4. ORNL. *D&D Alternatives Risk Assessment for Building 3515 at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. Prepared by DASKR, Ltd. and the University of Tennessee, Knoxville, for the U.S. DOE, Office of Environmental Management. Document No. ORNL/ER-334 (1995).

5. ORNL. *Level 3 Baseline Risk Assessment for Building 3515 at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. Prepared by University of Tennessee (Knoxville) and DASKR, Ltd. (WVA) for the U.S. DOE, Office of Environmental Management. Document No. ORNL/ER-311 (1995).

6. U.S. Environmental Protection Agency, U.S. Departments of Defense and Energy, plus Nuclear Regulatory Commission. *Multi-Agency Radiation Survey and Site Investigation Manual, Revision 1*. Document No. EPA 402-R-97-016, Rev. 1 (2000).

7 MSE. *Nontraditional In Situ Vitrification at the Los Alamos National Laboratory, Hot Demonstration Final Report.* Prepared by MSE Technology Applications Inc. for the USDOE Savannah River Office. ECCP (2004).