

## **Transuranic (TRU) Waste Repackaging at the Nevada Test Site - 9287**

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### **ABSTRACT**

This paper describes the activities required to modify a facility and the process of characterizing, repackaging, and preparing for shipment the Nevada Test Site's (NTS) legacy transuranic (TRU) waste in 58 oversize boxes (OSB). The waste, generated at other U.S. Department of Energy (DOE) sites and shipped to the NTS between 1974 and 1990, requires size-reduction for off-site shipment and disposal. The waste processing approach was tailored to reduce the volume of TRU waste by employing decontamination and non-destructive assay. As a result, the low-level waste (LLW) generated by this process was packaged, with minimal size reduction, in large sea-land containers for disposal at the NTS Area 5 Radioactive Waste Management Complex (RWMC). The remaining TRU waste was repackaged and sent to the Idaho National Laboratory Consolidation Site for additional characterization in preparation for disposal at the Waste Isolation Pilot Plant (WIPP), near Carlsbad, New Mexico.

The DOE National Nuclear Security Administration Nevada Site Office and the NTS Management and Operating (M&O) contractor, NSTec, successfully partnered to modify and upgrade an existing facility, the Visual Examination and Repackaging Building (VERB). The VERB modifications, including a new ventilation system and modified containment structure, required an approved Preliminary Documented Safety Analysis prior to project procurement and construction. Upgrade of the VERB from a radiological facility to a Hazard Category 3 Nuclear Facility required new rigor in the design and construction areas and was executed on an aggressive schedule.

The facility Documented Safety Analysis required that OSBs be vented prior to introduction into the VERB. Box venting was safely completed after developing and implementing two types of custom venting systems for the heavy gauge box construction. A remotely operated punching process was used on boxes with wall thickness of up to 3.05 mm (0.120 in) to insert aluminum bronze filters and sample ports to prevent sparking during penetration. A remotely operated cold-drilling process with self-drilling, self-tapping titanium coated spark-resistant filters was used for boxes with wall thickness of up to 6.35 mm (0.25 in). The box headspace was sampled for the presence of flammable gases.

To further accelerate the project schedule, an innovative treatment process was used. Several of the OSBs were re-assayed and determined to be mixed low-level waste (MLLW) which allowed treatment, followed by disposal in the Mixed Waste Disposal Unit at the NTS Area 5 Radioactive Waste Management Complex (RWMC). The MLLW boxes were certified using real-time radiography and overpacked into custom-built polyethylene-lined macroencapsulation containers. The polyethylene-lined lid was welded to the poly-lined box using automatically controlled resistance heating through embedded wiring in the lid. The work was performed under the existing Documented Safety Analysis since plastic welding is

accomplished at low temperature and does not introduce the risks of other macroencapsulation processes, such as welding stainless steel containers. The macroencapsulation process for MLLW not only accelerated the schedule by reducing the number of boxes requiring size reduction, but it also resulted in significantly improved safety with as low as reasonable achievable levels of exposure to workers plus reduced cost by eliminating the need to perform repackaging in the VERB.

## **INTRODUCTION**

The NTS, located in southern Nevada approximately 105 km (65 mi) northwest of Las Vegas, served as the nation's primary site for the development and safe testing of nuclear weapons and experiments from 1951 to 1992. Existing site facilities and infrastructures enable the execution of operations and experiments in support of the nation's Stockpile Stewardship Program. There is also an ongoing Environmental Management mission at the NTS which includes the Area 5 RWMC, a radioactive waste management facility where TRU waste storage, characterization, and shipment preparation activities are conducted and LLW and MLLW is safely and permanently disposed. TRU waste characterization is conducted inside the VERB at the Area 5 RWMC, located in the northern part of Frenchman Flat in the southeastern part of the NTS.

Historically, the VERB was a Hazard Category 3 (HC-3) Nuclear Facility with a mission to provide for the examination, segregation, characterization, and repackaging of radioactive waste stored in waste drums, along with the certification of the resulting TRU waste packages for disposal at WIPP; activities which began in 1997. Following the completion of 48 shipments of TRU waste (1,680 drums) to WIPP, NTS TRU operations were reduced. The allowable material-at-risk (MAR) inventory at the VERB facility was reduced to less than HC-3 quantities, the area was decontaminated, and the facility was downgraded to a radiological facility.

The current mission of the VERB is to provide for the examination, segregation, characterization, size reduction, and repackaging of radioactive waste in greater than HC-3 threshold quantities. The remaining radioactive waste to be processed was stored in 58 OSBs and 136 drums. In addition, empty parent waste containers required size-reduction and repackaging as necessary and TRU payload waste packages, which contain the processed TRU waste from the parent containers, underwent a pre-certification process before shipment to the regional facility for final certification followed by shipment to WIPP for disposal. LLW and MLLW packaged during VERB activities were disposed on site in the appropriate Area 5 disposal cell.

## **WASTE DESCRIPTION**

### **Upsize Boxes**

TRU waste shipped to the NTS in 58 OSBs from the Lawrence Livermore National Laboratory (LLNL) was generated between 1975 and 1985. The OSBs were all of metal construction and considered "strong-tight" containers (not U.S. Department of Transportation rated) and could not be shipped off site under current shipping regulations. The contents of the OSBs are primarily stainless steel gloveboxes and associated articles removed from LLNL decontamination and decommissioning efforts.

As some of the OSBs had been sealed (eighteen were closed with bolted lids and the remaining 40 boxes were all welded construction) for more than 30 years, the installation of filtered vents was required to obtain headspace gas samples. Most of the headspace sample results indicated little or no flammable gas or other contaminants of concern. The single exception was an OSB with nearly 13 percent hydrogen that was allowed to aspirate and was purged prior to processing through the VERB.

Non-destructive assay was performed and acceptable knowledge (AK) exists on all the OSBs; real-time radiography (RTR) was performed on all but two of the OSBs, which provided excellent information to initiate processing through the VERB. At least 28 of the OSBs failed RTR for prohibited items (liquids, aerosol cans, greater than 4 liter unvented containers, improper bag closure, etc.).

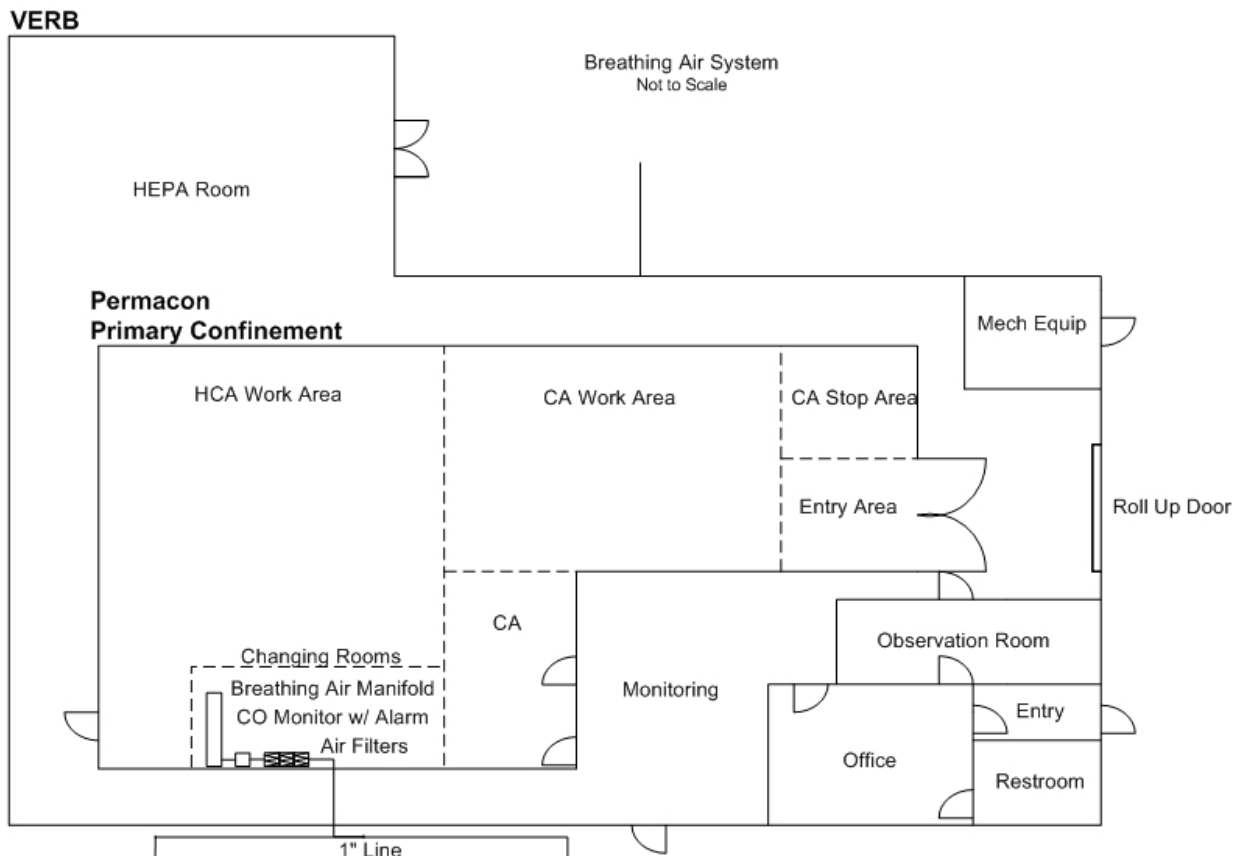
The processing approach required that as much metal waste as practical be segregated and/or decontaminated to allow for disposal at the Area 5 RWMC as LLW. Additionally, a Resource Conservation and Recovery Act (RCRA) compliance analysis was incorporated into a waste profile that was developed and reviewed with the State of Nevada Division of Environmental Protection. This allowed for the proper characterization of metal waste upon visual inspection by removing conservatively applied RCRA waste codes resulting in disposal as straight LLW, as opposed to MLLW.

Based on In Situ Object Counting System (ISOCS<sup>®</sup>) data, the boxes had average plutonium equivalent gram (PE-g) loading of 24.9 grams. The highest-activity box was 349 grams. The maximum TRU alpha activity concentration was  $4.95 \times 10^5$  becquerel per gram (Bq/g) (13,400 nanocurie per gram (nCi/g)). ISOCS<sup>®</sup> results identified nine boxes as LLW, 23 boxes were greater than 3700 Bq/g (100 nCi/g) but less than 14,800 Bq/g (400 nCi/g), and 26 boxes were greater than 14,800 Bq/g (400 nCi/g) up to  $4.95 \times 10^5$  Bq/g (13,400 nCi/g).

## **FACILITY DESCRIPTION**

The primary VERB facility modifications implemented to accommodate processing of the OSBs were: 1) widening of the air-lock doors to 2.4 m (8 ft); 2) installation of three new  $0.944 \text{ m}^3/\text{s}$  (2000 cfm) active ventilation units for radiological control purposes; 3) installation of nine inlet high-efficiency particulate air (HEPA) filters to accommodate the higher ventilation system flow rate, and; 4) installation of a larger backup diesel generator. The as-built configuration of the VERB is shown in Figure 1. Dedicated step-off locations and personnel access/doffing areas were set up to allow personnel to don/doff respiratory protection and anti-contamination (anti-C) clothing.

### **Figure 1. VERB Floor Plan**



The widest OSB was 1.9 m (6.3 ft), which was too wide for the previous Permacon<sup>®</sup> doors. Consequently to accommodate the OSB, the outer air-lock doors were replaced with 2.4 m (8 ft) wide doors of materials and functioning identical to the previous doors. The area of the removed air-lock was designated as a Radioactive Material Area (RMA). Fire retardant plastic sheeting was used to provide transition from the RMA to the Contaminated Area (CA) and from the CA to the High Contamination Area (HCA).

For radiation control purposes, the previous approximate 0.944 m<sup>3</sup>/s (2000 cfm) Permacon<sup>®</sup> ventilation system was replaced by three new 0.944 m<sup>3</sup>/s (2000 cfm) active ventilation units. For adequate radiological contamination control and to provide adequate face velocity at the work zones and through the door opening, a minimum of 12 air changes an hour were required for both the HCA and the CA. The face velocity provided an average of greater than 0.407 m/s (80 ft/min) across the open equipment doors. The differential pressure between the Permacon<sup>®</sup> and the VERB was required to be more than 7.62 mm (0.3 in) water column. Since the VERB relied on the single containment level of the Permacon<sup>®</sup>, these ventilation parameters were key items in the design, development and approval of the required Preliminary Documented Safety Analysis. The minimum differential pressure was not maintained when the doors are open for box transfers; however, the face velocity across the open doors has proven to provide sufficient contamination control.

The primary exhaust from the Permacon<sup>®</sup> was designed to ventilate from the floor level rather than the ceiling as previously configured. Down-draft or side-draft is necessary for acceptable contamination control and is located away from the HCA entry point. In addition to the room exhaust, two point source exhaust ducts were installed. These are wall-mounted moveable flexible ducting systems (PlymoVent<sup>®</sup>) that exhaust 0.475 m<sup>3</sup>/s (1000 cfm) and were highly effective in at-the-source contamination control.

The Permacon<sup>®</sup> was adequate to prevent migration of contamination to other areas of the VERB; however, an additional layer of control was installed on the Permacon<sup>®</sup> floor to reduce contamination spread and speed decontamination efforts. Fire blankets were also used to protect the plastic sheeting from damage during cutting operations.

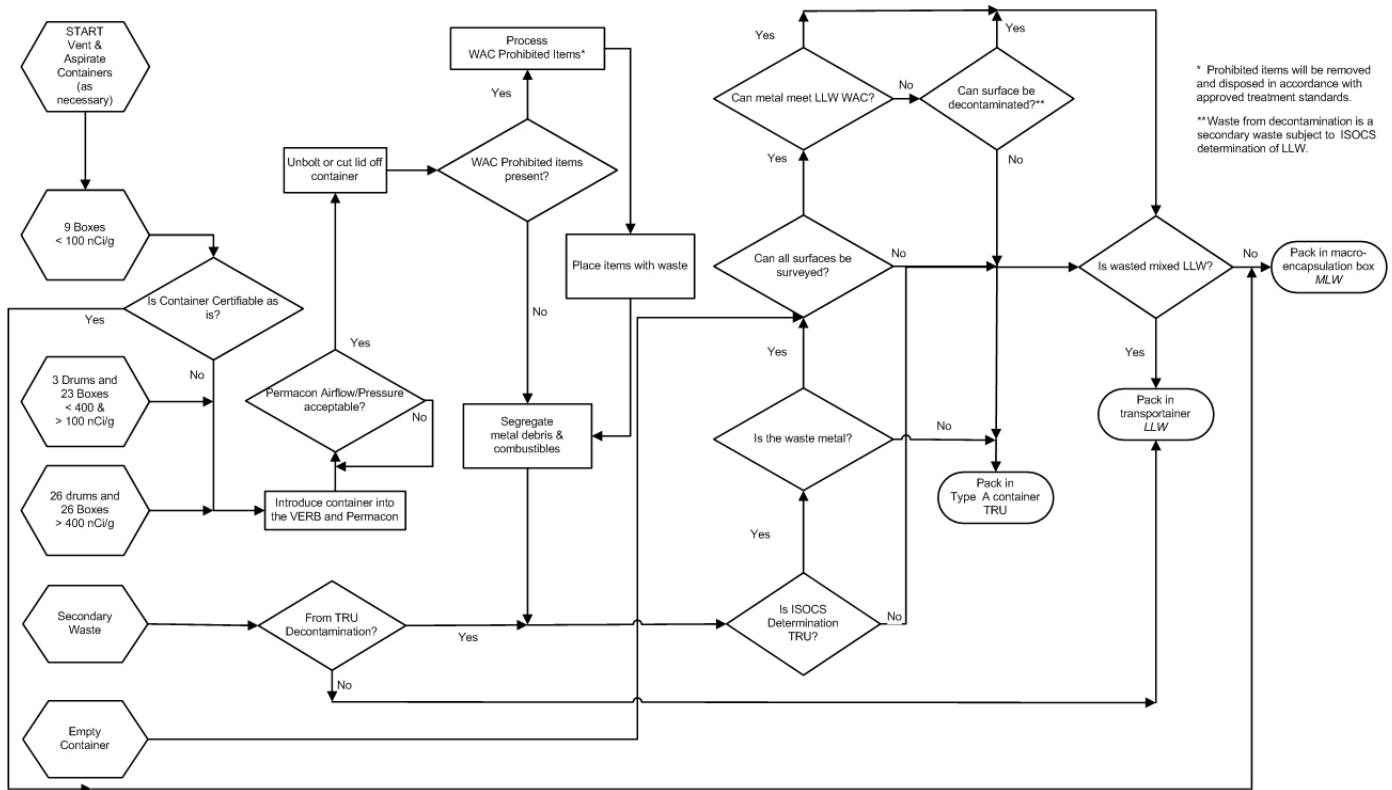
Nine inlet HEPA filters were installed in the Permacon<sup>®</sup> to maintain equilibrium with the increase in system exhaust capacity from the previous flow of approximately 0.944 m<sup>3</sup>/s (2000 cfm) to the new flow of greater than 2.83 m<sup>3</sup>/s (6000 cfm). Air entering the facility is filtered to remove particulates which protects the exhaust HEPAs and provides a filtered pathway in the event the Permacon<sup>®</sup> became positively pressurized. The design of the ventilation system ensured that the flow of air was always from the area of least contamination to the area of highest contamination.

A new backup diesel generator and automatic transfer switch was installed to provide reliable power to the VERB and assure continued operation of the ventilation system. In the event of a loss of normal power, the diesel generator and associated distribution equipment provides power to the VERB exhaust fans and other connected loads. The diesel generator was capable of providing up to 80 kilowatts of power for a minimum of 24 hours without refueling. The automatic transfer switch controls the startup of the backup generator and transfers power to the appropriate panels. Once normal power is restored, the switch automatically transfers loads back to the normal power source.

## OPERATIONS

Figure 2 is a high-level process flowchart indicating the path to disposal for the 58 OSBs. All boxes were vented prior to introduction into the VERB, and then opened for waste examination, characterization and removal/remediation of prohibited items. The waste was segregated into three primary waste streams: 1) LLW, such as nonporous metal that was assayed and decontaminated as necessary for disposal; 2) MLLW, such as combustibles, sludge, and other waste that assayed less than 3700 Bq/g (100 nCi/g) by non-destructive assay, or; 3) mixed TRU waste debris or other waste that assayed at greater than 3700 Bq/g (100 nCi/g). LLW was primarily packaged into cargo containers for disposal on site at the Area 5 RWMC. The MLLW was packaged and treated using a macroencapsulation process for on-site disposal in the Mixed Waste Disposal Unit at the Area 5 RWMC. Mixed TRU waste was size-reduced for packaging in standard waste boxes (SWBs) for disposal. TRU/mixed TRU waste was generated in accordance with DOE Order 435.1, *Radioactive Waste Management* (Reference 1) and the associated *Contact-Handled Transuranic Waste Packaging Instruction* (Reference 2) that was issued mid-way through the repackaging effort.

**Figure 2. Oversize Box Process Flow**



### VERB Waste Operations

Processing OSBs was accomplished by a trained crew of approximately 20 personnel including ironworkers, laborers, radiation control technicians and waste handlers. The hands-on work was conducted in the HCA of the VERB by a six-person crew wearing supplied-air breathing protection. The remainder of the crew provided outside support and rotated into the HCA on later entries.

The workers were the crucial element in safe and efficient waste segregation, size-reduction of large items, waste characterization and packaging, and contamination control. Excellent contamination control of the high-activity waste was essential in order to meet the scheduled completion of packaging activities to support waste shipping on WIPP’s available timetable. Radiation monitoring was accomplished using work process surveys, high-volume air samplers in the HCA, and continuous air monitors in the CA. Radiation control technicians were located in both the HCA and CA at all times during intrusive waste process activities.

The waste containers were opened by unbolting or cutting using a mechanical nibbler, carbide metal circular saw or reciprocating saw. The same cutting techniques were used for large items requiring size-reduction to be packaged into the much smaller TRU SWBs. The processing approach required that as much waste as practical be segregated and/or decontaminated to allow disposal on site at the Area 5 RWMC, which minimized the need for cutting and resulted in an approximately 67 percent reduction of the expected TRU waste generation.

The waste was processed in accordance with DOE-HQ issued *Contact-Handled Transuranic Waste Packaging Instruction* which was issued while boxes were being processed. The draft document was used as the basis for site-specific procedures. Under the instruction, TRU waste generation and packaging activities are required to be video recorded with audio narration to provide indisputable evidence of the packaging configuration, all waste contents, and absence of prohibited items. In addition, box contents were examined to assure absence of prohibited items. Prohibited items discovered and remediated included minor free liquids, potential polychlorinated biphenyl containing fluorescent light ballasts, and greater than 4 liter sealed containers. Radioactive sources also require specific approval prior to final packaging. This process proved effective in compliant packaging and waste certification by off-site Central Characterization Project personnel.

## **Venting**

The Area 5 RWMC Documented Safety Analysis required that the OSBs be vented prior to introduction into the VERB. Box venting was safely completed after developing and implementing two types of custom venting systems for the heavy-gauge box construction. A remotely operated punching process, NucFil<sup>®</sup> RapidPort<sup>®</sup>, was used on boxes with wall thickness of up to 3.05 mm (0.120 in) to penetrate the boxes with aluminum bronze filters and sample ports to prevent sparking during penetration. A remotely operated cold-drilling process, NucFil<sup>®</sup> RapidPort-D<sup>®</sup>, with self-drilling, self-tapping titanium coated spark-resistant filters was used for boxes with wall thickness of up to 3.05 mm (0.120 in). Insertion of the ports allowed for the sampling of box headspace to detect the presence of flammable gases.

The normal RapidPort<sup>®</sup> process used for drum penetration was modified for the OSBs of less than 3.05 mm (0.120 in) thickness. The boxes were indented with a machined dimpling tool to prepare the metal surface for installation of newly developed high-strength Dart filters or sample ports. These filters penetrated the box with a pointed aluminum bronze housing to prevent sparking during insertion. The sharp point fell into the container upon entry allowing a filtered opening for safely venting gases. The process was adapted for remote operation using forklift mounting to position the RapidPort<sup>®</sup> at the box. The headspace gas sampled and analyzed for the 46 boxes vented with Dart filters showed no elevated results.

Twelve OSBs were thicker than 3.05 mm (0.120 in) and were not suitable for installation of the high-strength Dart filter, so the RapidPort-D<sup>®</sup> was developed for containers with thicknesses between 2.29 mm and 6.99 mm (0.090 in and 0.275 in). This system was based on a commercially available magnetic drill adapted for remote operation. The RapidPort-D<sup>®</sup> used a qualified and tested "Cold Drilling" technique for flammability prevention to maintain the drill temperature less than 80 °C (176 °F) or 16.2 percent of the ignition temperature of hydrogen. Also, the drill tips were titanium coated as an additional spark-reducing measure. These boxes were also sampled for hydrogen and other compounds with one box containing almost 13 percent hydrogen.

## **Macroencapsulation**

Several of the OSBs were re-assayed and determined to be MLLW which allowed treatment and eventual disposal on site in the Area 5 Mixed Waste Disposal Unit. OSBs that contained debris and assayed as MLLW were treated by NSTec using high-density/linear low-density polyethylene macro-liners supplied by EnergX for UltraTech. The polyethylene liners were installed in metal boxes that met the NTS Waste Acceptance Criteria (Reference 3). The treatment process is an accepted alternative treatment standard for hazardous debris by the U.S. Environmental Protection Agency and was also approved by the State of Nevada Division of Environmental Protection as an acceptable alternative treatment standard for radioactive lead solids. The process was performed on the Area 5 TRU waste storage pad and in the TRU

Pad Cover Building to prepare acceptable containers of MLLW debris for disposal in the Area 5 Mixed Waste Disposal Unit.

The MLLW was characterized and certified using non-destructive assay, RTR and acceptable knowledge. Each waste stream required a pre-treatment notification and waste profile to be submitted and approved in accordance with the NTS Waste Acceptance Criteria. In cases when the MLLW OSB could not be directly certified due to the potential presence of prohibited items using RTR, the prohibited items were removed in the VERB leaving the remediated parent box suitable for macroencapsulation.

The waste examination and repackaging process also relied on near real-time, non-destructive assay to sort and segregate TRU waste and LLW. Therefore, the boxes that assayed as a whole as TRU waste often could be reduced to MLLW by removal of high-activity items. Following segregation, the debris characterized as MLLW was also treated by macro-encapsulation and processed for disposal at the NTS.

The macroencapsulation process typically consists of the following steps: the waste (either directly loaded or containerized in a drum or box) is placed into the polyethylene macro-liner and an inert filler material (e.g., vermiculite) is placed in the liner to eliminate all void space within the macro liner. Once filled, the polyethylene macro lid is put in place and bonded to the polyethylene liner body using a patented bonding process using controlled resistance heating embedded in the liner. The process is designed to eliminate variables. The time, current, resistance, wire spacing, and compression weight are all fixed to assure repeatability and successful sealing. This yields a nominal 12.7 mm (0.5 in) thick, highly durable, completely sealed polyethylene liner. At this point, the waste is totally isolated and protected from the environment and any potential leaching media by the 12.7 mm thick, chemically inert, polyethylene jacket.

The work was performed under the existing Documented Safety Analysis since bonding of the polyethylene is accomplished at low temperature and does not introduce the risks of other macroencapsulation processes, such as welding stainless steel containers. The macroencapsulation process for MLLW not only accelerated the schedule by reducing the number of boxes requiring size reduction, but it also resulted in significantly improved safety with as low as reasonably achievable levels of exposure to workers plus reduced cost by eliminating the need to perform repackaging in the VERB.

### **Non-Destructive Assay**

NSTec subcontracted non-destructive assay services to Cabrera Services. Cabrera was able to provide near real-time assay of waste items within the VERB HCA during processing to allow segregation of mixed TRU/TRU waste from MLLW/LLW. Also, a multi-node counting and analysis technique was implemented that was designed to fully characterize either the inbound or final waste containers. These techniques supported precision location and removal of TRU items within the OSB to minimize processing time and required size-reduction which also protects the workers and keeps doses as low as reasonably achievable.

Non-destructive assay via *in situ* gamma spectroscopy typically includes high-purity germanium (HPGe) detectors characterized to perform mathematical geometry calibrations. A commercially available package for this purpose is Canberra Industries In Situ Object Counting System (ISOCS<sup>®</sup>). ISOCS<sup>®</sup> uses mathematical models to simulate radioactive sources in various geometries created from standard geometric templates such as boxes, cylinders, and pipes. These templates are then customized with specific information (dimensions, weight, and density) so that the modeled configuration matches the actual object as closely as possible. Cabrera's expertise in geometry modeling and results analysis provided cost-effective and value-added benefits to traditional survey methods.

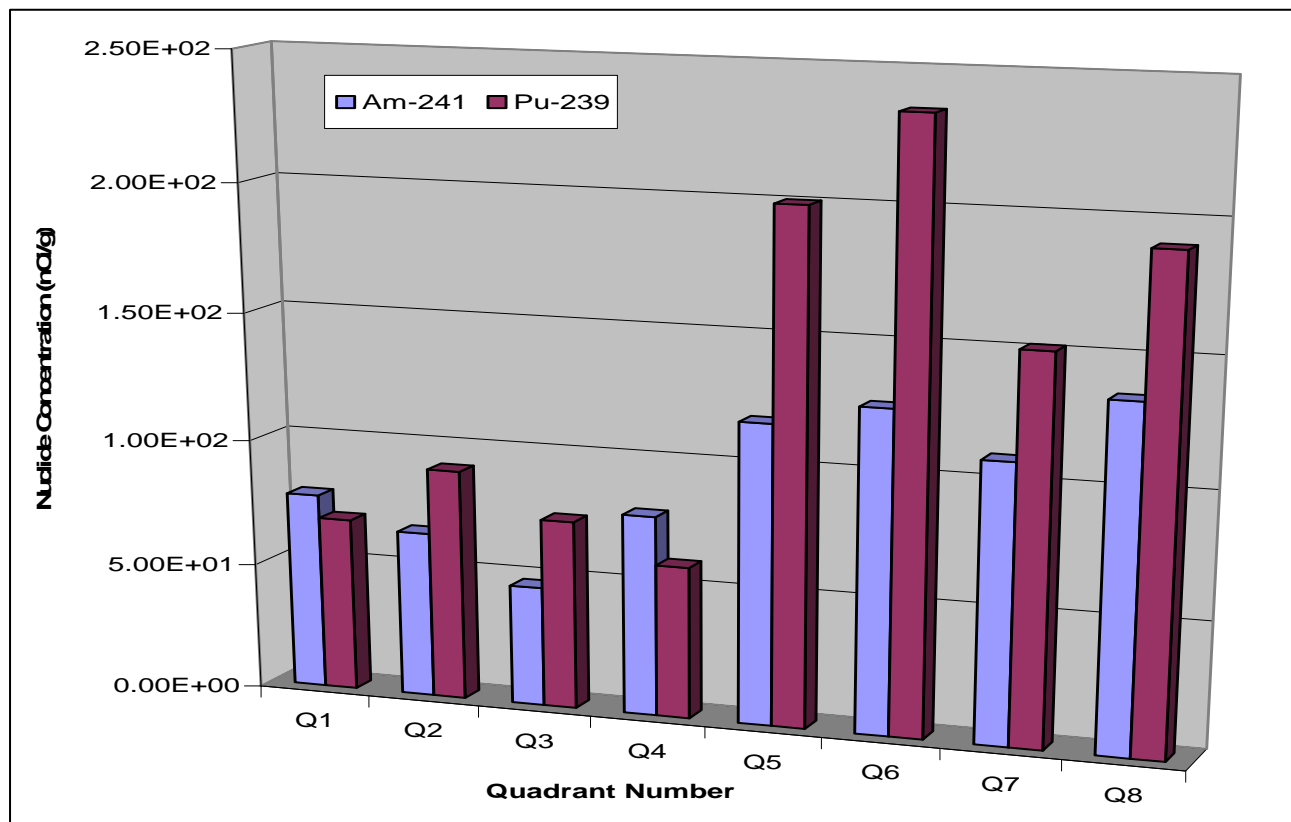


The previous non-destructive assay efforts used a standard *in situ* approach on the OSBs, which utilized a single-point counting geometry to assay the mean TRU concentration in nCi/g. This mean concentration was determined by collecting gamma spectra with an HPGe positioned at the centerline of each long-side of a rectangular box at a distance 0.61 meter (2 ft). A completed box count was the composite average of two side counts. This approach can be a valid non-destructive assay technique for assessing mean concentrations; however, the inherent weaknesses in the model have to be recognized. Principally, a single-point approach relies on one of the following fundamental assumptions being true: 1) center portion of the box (i.e., the portion of the contents within direct-view of the detector) is representative of the entire box (most accurate); or 2) the center portion of the box contains the highest relative activity (most conservative). If neither of these assumptions is true, then the results of the non-destructive assay are not appropriate for assigning a TRU concentration.

Cabrera used advanced non-destructive assay techniques on a sample of these previously assayed OSBs in order to more accurately characterize the waste. Instead of the single-point approach, assay was performed using a multi-node counting and analysis technique designed to fully characterize an OSB. Using this technique, an OSB was split into eight equally-sized quadrants which are counted individually (four quadrants per side). These quadrants were then summed for a composite average or analyzed individually for discretized radionuclide activity information. This approach provides the following benefits:

- Obtains much more information in the same amount of counting time;
- Reports a more-accurate composite average since it does not assume activity homogeneity within the entire container;
- Reduces overall uncertainty associated with the reported mean TRU;
- Provides location-specific activity fractions that can be used to focus intrusive waste recovery during repackaging (See Figure 3.)

**Figure 3. Results of Individual Quadrant Counts for One NTS OSB**



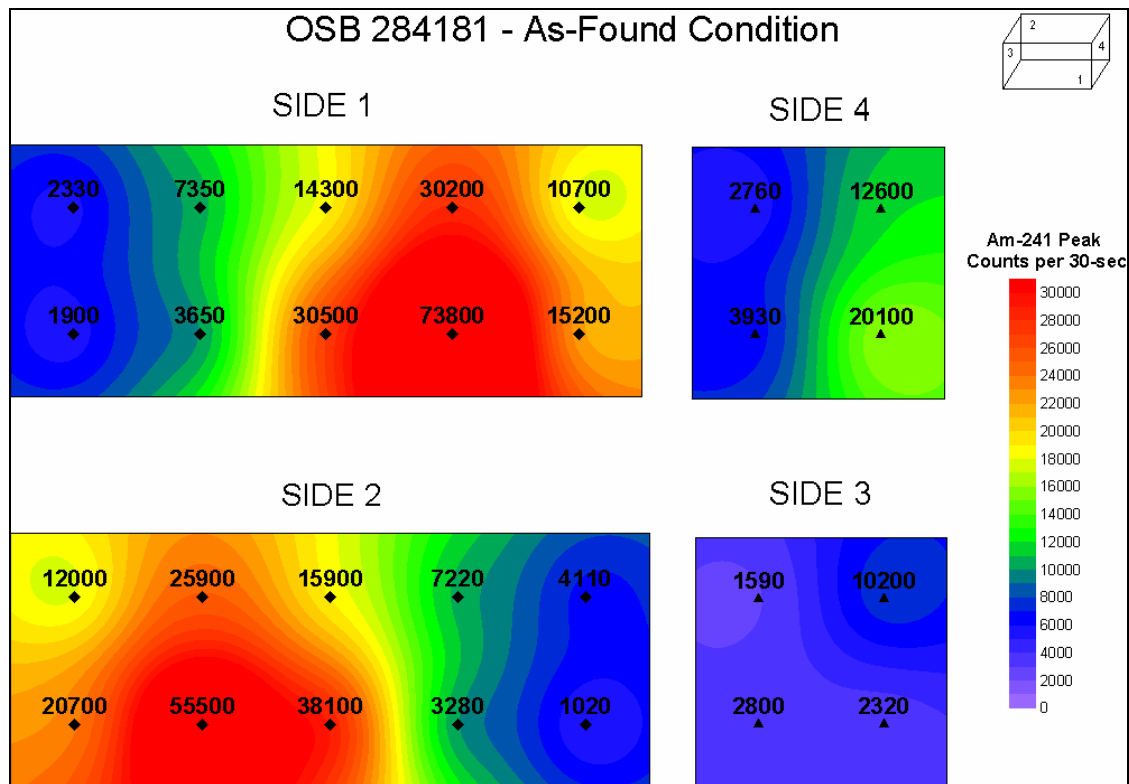
*This plot demonstrates the improved accuracy of the multi-node approach.*

The approach was extended to fully support the TRU repackaging and analysis project for all 56 OSBs in current inventory. The advanced ISOCS<sup>®</sup> modeling and analysis was applied to every phase of the TRU repackaging effort, including:

- Characterization of each OSB prior to being opened;
- Providing near real-time analysis of removed components for TRU/LLW evaluation, and;
- Performance of confirmation counts of all LLW and TRU packages. The results of which were used for final waste characterization and for material-at-risk accountability tracking.

The 'multi-node' approach described previously was adapted to produce graphical images of the radioactive contents within each box. Peak counts from either americium-241 (<sup>241</sup>Am) or plutonium-239 (<sup>239</sup>Pu) are logged from multiple nodes on each side of the box and then contoured in a geospatial mapping program. The result was a color contour map of the gamma fluence with respect to position that can be used to guide repackaging efforts. An example of one of these maps is shown in Figure 4.

**Figure 4. Color Contour Map of the As-Found condition of a Repackaged OSB at the NTS**



*The 'hot' areas shown on Sides 1 and 2 represent a contaminated lathe mounted within a glovebox.*

Since one of the primary objectives of the TRU repackaging effort was to convert the OSB from TRU to LLW as efficiently as possible, these maps were shown to be effective at focusing intrusive component

mining efforts on the most-highly contaminated areas of the box. These plots were proven to be very useful by the repackaging crew in locating and segregating the high-activity items.

Select pieces of suspect TRU waste were assayed as they were removed from an OSB to provide TRU/LLW determination results within minutes during waste segregation and size-reduction activities. This allowed waste determinations to be accomplished 'on-the-fly' so that the total quantities of TRU waste generated were minimized. Having this ability in the field provided the opportunity to realize tremendous TRU waste volume reduction of approximately 67 percent by maximizing the quantities of MLLW/LLW that could be disposed on site at the Area 5 RWMC.

## CONCLUSION

The TRU waste project at the NTS was successfully completed through the partnering of the Nevada Site Office, NSTec, DOE/Carlsbad Field Office and the associated subcontractors. A remarkable effort was required to design and modify a nuclear facility fit for purpose to repack this difficult waste stream. Following a successful operational readiness review, the complex waste repackaging operation was safely completed without any significant contamination events. Through waste assay, segregation and size-reduction efforts, TRU waste generation was reduced by 67 percent. Novel container venting and waste treatment technologies were used which greatly improved worker safety and allowed the project schedule to be accelerated.

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