A Journey From Sandia To Los Alamos - 12465

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ABSTRACT

The U.S. Department of Energy (DOE) relies on laboratory experiments and computer-based models to verify the reliability of the nation's nuclear stockpile. Sandia National Laboratories/New Mexico (SNL/NM) tests various materials in extreme environments designed to mimic those of nuclear explosions using the Z machine. The Z machine is a key tool in the National Nuclear Security Administration's (NNSA) stockpile stewardship mission and is used to study the dynamic properties of nuclear weapon materials (1, 2).

In 2006, SNL/NM and Los Alamos National Laboratory (LANL) signed a Memorandum of Understanding (MOU) defining experiments to be conducted in the Z machine involving plutonium (Pu) provided by LANL (3). Five Pu experiments have been completed with as many as 20 more planned through 2016 (4). The experimental containment vessel used for the experiment and containing the Pu residues, becomes transuranic (TRU) waste after the experiment and termination of safeguards and is considered a LANL waste stream. Each containment vessel is placed in a 55-gallon Type A drum or standard waste box (SWB) for shipment back to LANL for final certification and eventual disposal at the Waste Isolation Pilot Plant (WIPP). The experimental containment vessels are greater than 99% metallic materials (ferrous and non-ferrous metals). In addition to the Pu targets, detonators with high explosives (HE) are used in the experiments to isolate the containment vessel from the Z machine as energy is delivered to the Pu samples (5).

The characterization requirements, transportation issues, required documentation, and the approvals needed before shipments were challenging and required close coordination between SNL/NM, Sandia Site Office, LANL, Los Alamos Site Office, Washington TRU Solutions, Inc., the Central Characterization Project, and the Carlsbad Field Office. Between 2006 and 2010, representatives from SNL/NM and LANL worked to develop an approved path forward to meet the requirements of all stakeholders.

INTRODUCTION

Legislation passed by the Congress in 1992 prohibits above- and below-ground testing of nuclear weapons. Since that time, the U.S. Department of Energy (DOE) has used computer-based calculations and laboratory experiments to verify the reliability of the nation's nuclear stockpile (1, 2). The Z machine at Sandia National Laboratories/New Mexico (SNL/NM) is

capable of performing 200 experiments a year on a variety of materials using electrical currents of approximately 26 million amps reaching peak X-ray emissions of 350 terawatts, with an output of 2.7 megajoules. It allows scientists to study materials under conditions similar to those produced by the detonation of a nuclear weapon and provide data to validate models of vulnerability to radiation, predict problems as the stockpile ages, and develop ways to improve future systems (6).

Los Alamos National Laboratory (LANL) and SNL/NM have historically supported defense missions including stockpile stewardship and collaborate on this project to validate computational models of nuclear weapons performance using the SNL/NM's Z-machine. Figure 1 illustrates a "shot" at the Z machine (7).

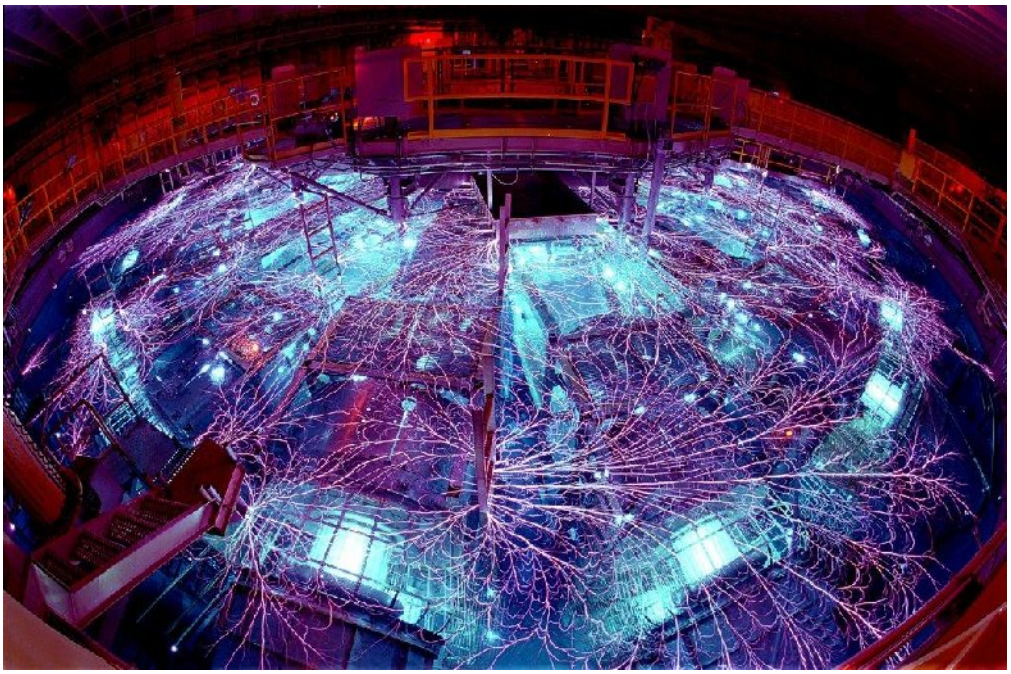

Fig. 1. Firing of the Z Machine

BACKGROUND

In early 2006, SNL/NM (Sandia Corporation) and LANL (The Regents of the University of California) entered into a Memorandum of Understanding (MOU) defining the roles and responsibilities for this project. The MOU stated that LANL would provide plutonium targets and SNL/NM would conduct the Z machine experiments. LANL would own the data and SNL/NM would provide the documentation describing the target and containment hardware. These experiments are known as the Plutonium Isentropic Compression Experiments (Pu-ICE) (3). Once the experiment is complete and the safeguards are terminated, the Pu-ICE containment vessel becomes transuranic (TRU) waste. Figure 2 is a cutaway view of the containment vessel and identifies specific parts of the vessel (8).

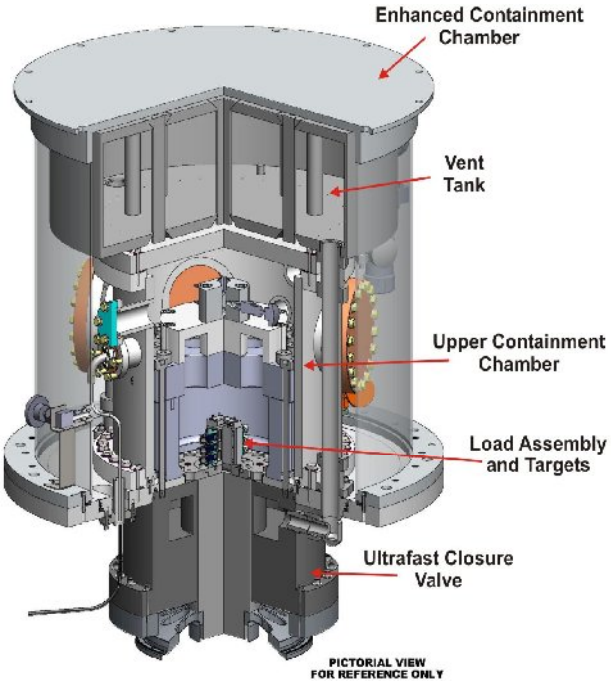

Fig. 2. Cutaway of a Pu-ICE Containment Vessel

The targets are placed in the load assembly and the vessel assembled and placed in the Z machine. Detonators with high explosives (HE) are used to close the Ultrafast Closure Valve (UCV) with small amounts of hydrogen, carbon, nitrogen, and nitrogen oxides (NOx) generated and vented to the vent tank. The experimental radioactive residues (Pu targets) remain in the upper containment chamber (UCC). The containment vessel is manufactured of machined components made up primarily of ferrous metals with minor amounts of non-ferrous metals and inorganic material (9).

In 2005, SNL/NM and LANL began discussions regarding the waste management aspects of the joint experiments. The Radioactive Waste Nuclear Material Disposition Department (RWNMDD) at SNL/NM had responsibilities as calculations indicated the containment vessel would be TRU waste after the experiment was concluded. The project is funded under the DOE Budget and Request Code DP1202010, therefore the waste qualifies as eligible for disposal at the Waste Isolation Pilot Plant (WIPP). RWNMDD personnel met with WIPP and Central Characterization Project (CCP) personnel to discuss what characterization activities needed to be conducted and documented as the waste stream would be considered a newly-generated waste stream. At that time, it was agreed that it was a good candidate for Acceptable Knowledge (AK) Sufficiency because of the level of documentation and quality control associated with the manufacturing of the vessel and the targets. Waste management personnel began assembling information and data required for AK and began developing a Pre-AK Report (10).

In May 2006, Patty Wagner, Manager, Sandia Site Office (SSO) National Nuclear Security Administration, in a letter to Joan Woodard, Executive Vice President, Sandia National Laboratories, deemed the Z machine Pu-ICE experiments satisfactory and authorized the experiments could commence (11). Three experiments were conducted in 2006, and then in

2006, the Z machine was shut down for refurbishment to allow researchers to expose samples to greater pressures than the old machine configuration allowed. Plutonium experiments resumed in 2010 (9).

PHYSICAL, RADIOLOGICAL, AND CHEMICAL PROPERTIES

Prior to the first experiments, discussions were held with the researchers to obtain the necessary specification and material inputs for the containment vessel; the radiological assay processes for the target preparation; and the quality assurance/quality control (QA/QC) plans and procedures. The following subsections discuss the results for characterization.

Physical Properties

The waste stream is composed of post-experiment containment vessels which are manufactured under documented specifications from supplies qualified under SNL/NM's quality assurance program. Currently each vessel weighs in excess of 386 kilograms (kgs), and is composed of approximately 97% iron-based metals/alloys, 2.4% other metals, the remaining being rubber, plastics, and other organic/inorganic materials. Accurate material inputs are documented due to the detailed specifications available and the quality control required by SNL/NM. Table I is an example of the waste material parameters, weights, and weight percent (9).

Table I Waste Material Parameters

Waste Material Parameter	Weight (kgs)	Percent of total weight
Iron-based metals/alloys	379.8	97.2%
Aluminum-based metals/alloys	0.0	0.0%
Other metals	9.4	2.4%
Other inorganic materials	0.0027	0.00%
Cellulosics	0.0	0.0%
Rubber	0.43	0.10%
Plastics (waste materials)	0.33	0.08%
Organic matrix	0.53	0.14%
Inorganic matrix	0.09	0.02%
Soils/Gravels	0.0	0.0%
Steel (packaging materials)	28.1	NA
Plastics (packaging materials)	0.0	NA

Radiological Properties

Four Pu targets are fabricated by LANL for each experiment, loaded into the load assembly, and shipped to SNL/NM. Documentation for each experiment includes certified isotopic information. To date, the gram quantities have varied from 1.3 grams up to 6 grams. The isotopic distribution varies slightly between experiments, but generally the targets are > 93% Pu-239, 5.8% Pu-240, the remainder being Pu-238, Pu-241, Pu-242, and Am-241(9).

At the present time, the Z machine is located in a radiological facility and cannot perform any experiments with Pu greater than 8 grams. In order to document that the containment vessels are and will remain TRU, minimum and maximum calculations were performed using a minimum of 1 gram of Pu and a maximum of 8 grams of Pu, and a minimum weight of 366 kilogram (kg) per vessel resulting in a minimum of 163 nanoCuries/gram (nC/g) and a maximum of 1354 nCi/g. Table II is a typical isotopic distribution (9).

Table II. Typical Isotopic Distribution

Isotope	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241
Weight %	0.035	94	5.8	0.12	0.03	0.003

Chemical Properties

The containment vessels are manufactured to documented and approved specifications, therefore the materials used in the processes are well known and based on calculations, the waste stream is not mixed. The following chemicals are identified as Resource Conservation and Recovery Act (RCRA) regulated hazardous constituents, but process knowledge and calculations demonstrate they do not meet the RCRA requirements. Each experiment is evaluated separately with updated data from the containment vessels, targets, and processes and documented (9).

- Listed Codes: Alcohols are used to clean metal surfaces prior to assembly of the containment vessels, but these compounds are not absorbed and any absorbent material used with the solvents is not included in this waste stream. Furthermore, no K-, U-, or P-listed chemicals are in this waste stream. Therefore, listed codes are not applicable (9).

- Toxicity Codes: Based on procedures, material feeds, and interviews with subject matter experts (SME), two possible toxicity constituents are identified, epoxy and lead (9).

    - LANL uses two epoxies when mounting the targets in the load assembly. Material Safety Data Sheets (MSDS) were obtained for both products and one of the epoxies contained benzene, but at a concentration below the RCRA regulatory limit. The benzene would not be present in the cured epoxy due to its volatility, but also all organics are destroyed during the experiments due to the high heat and pressure.

    - SNL/NM uses two epoxies in the containment vessel, but MSDSs did not list any RCRA constituents.

- Small amounts of lead are listed on the material inputs for the containment vessel in the brass, piezoelectric actuators (PZT), and solder. A spreadsheet was prepared listing the measured mass plus the upper level of uncertainty of the lead in the components and a conservative calculation of the parts per million (ppm) levels was determined. Using the maximum amount of lead divided by the minimum containment vessel mass, the result indicated a maximum of 47 ppm, which is well below the RCRA regulatory limit of 100 ppm for a totals evaluation.

PACKAGING

Currently, the containment vessels are packaged in 55-gallon, Type A drums provided by LANL and equipped with WIPP approved filters. The containment vessels for future experiments are scheduled to be heavier and exceed the weight limit for 55-gallon, Type A drums, so they will be packaged in SWBs. The containment vessels are directly loaded into a drum with no liner or plastic packaging (9). Figure 3 is the containment vessel being loaded into a 55-gallon drum.

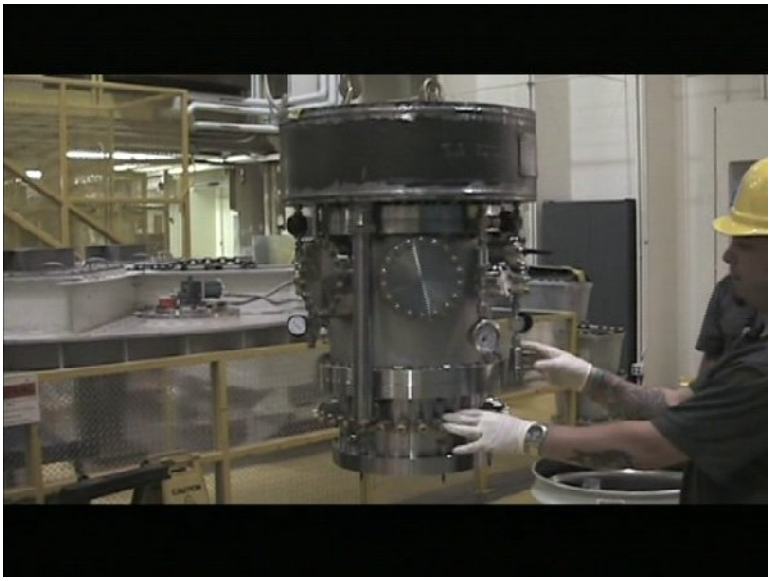

Fig. 3. Containment Vessel Being Loaded into 55-Gallon Drum

The absence of prohibited items is determined by review of manufacturing documentation, waste generating process documentation, procedures, and videotape documentation (9).

- Compressed Gases: At the conclusion of each experiment, the vent tank and UCC are opened to the atmosphere through High Efficiency Particulate Air (HEPA) filters using a valve with a pressure gauge on the vent tank and a valve with a vacuum/pressure gauge on the UCC. This process is verified and videotaped by inspecting the gauges to read “0” while closing and opening the valves.

- Free Liquids: There are no free liquids in this waste stream

- Nonradioactive Pyrophorics: There are no nonradioactive pyrophorics in this waste stream

- Sealed Containers Greater than Four Liters: The UCC and vent tank are greater than 4-liters in volume. Gases are captured in the vent tank during the experiment, but the UCC and vent tank are opened to the atmosphere after removal from the Z machine and before placing the containment vessel in a waste container..

- Explosives: The containment vessels contain detonators and HE, but the HE is verified to be expended based on post-test signals conducted on previous non-TRU experiments where it was demonstrated that if at least one of the detonator initiates, the other detonators fire and the HE is consumed.

- > 1% Radionuclide Pyrophorics: It has been demonstrated that during the experiment, the Pu targets are vaporized and alloyed to the metal matrix of the containment vessel, therefore, it is no longer pure metal.

- Polychlorinated Biphenyls (PCBs): There are no PCBs in this waste stream.

SHIPPING

Between 2006 and early 2010, representatives from SNL/NM and LANL entered into discussions to determine the management (material versus waste) and shipment options. If the containment vessels were considered material, there were challenges with finding a Type B container for shipping back to LANL. Managing the drums as waste allowed shipment in large Type B containers. After many discussions and investigations, LANL, SNL/NM, the Los Alamos Site Office, and the Sandia Site Office determined that the alloyed Pu in the metal matrix was no longer needed for any programmatic purpose and therefore the material could be considered waste after termination of safeguards. With the cooperation of the Carlsbad Field Office, Washington TRU Solutions, and the Central Characterization Project, a path forward was determined. After termination of safeguards, the drums are placed in standard waste boxes due to their weight, and are shipped in a TRUPACT-II to LANL (10).

In order to ship in a TRUPACT-II and meet Department of Transportation (DOT) requirements, data documenting the physical, radiological, and chemical characteristics are required. LANL and SNL/NM prepared a Generator Knowledge (GK) Report which included the necessary information for not only for transportation, but to be used as a source document for preparing the AK Summary Report required for final disposal at WIPP. The GK Report is updated after each additional experiment. LANL has submitted the GK Report to CBFO for review (9). Figure 4 illustrates the loading of the first shipment of Pu-ICE to LANL in December 2010.

Fig. 4. Loading Pu-ICE SWBs into TRUPACT-II

CONCLUSIONS

This project clearly demonstrates successful cooperation between LANL and SNL/NM, and support from the LASO, SSO, CBFO, WTS, and CCP. Key elements were communication and documented plans with responsible parties and due dates. Now that the first successful shipment has been accomplished, it is believed that future shipments will become a more routine activity.

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