ATTACHMENT 4

Plutonium Sealed Source Project (51034) Manufacturing and Quality Plan

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Title: Manufacturing and Quality Plan for the Plutonium Sealed Source and Blank Sealed Source

Work Location: Building 325, RPL

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- ✓ Author
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- ✓ Quality Engineer
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1.0 PURPOSE

The Pacific Northwest National Laboratory (PNNL) is contracted to the Department of Homeland Security – Domestic Nuclear Detection Office (DHS-DNDO) to fabricate a weapons grade plutonium metal sealed source. The Plutonium Sealed Source (PSS) project quality assurance (QA) requirements call for a manufacturing and quality plan (MAQP) to be developed to ensure that all aspects of the process have been fully considered (i.e., design specifications, tolerances, inspection criteria, proper sequencing of process steps, equipment needs, calibration, process parameters, quality control (QC) activities, final inspection and testing, procedure needs, safety, radiological safety, safeguards).

This MAQP describes the fabrication of the plutonium sealed source (PSS) and the accompanying blank sealed source (BSS). The elements of the fabrication process described are:

- Processing steps involved in taking the as-received plutonium metal, casting it into the desired shape and closure of inner and outer housings including inspection, test and QC measurements.
- Description of the new procedures required to complete the fabrication.
- Requirements for qualification of special processes (e.g. welding the inner and outer housings).
- Equipment modifications and purchases.
- Identification and calibration for measurement and test equipment (M&TE).

2.0 TECHNICAL REQUIREMENTS

The technical requirements for assembly of the PSS and BSS are defined in the latest revisions of the design drawing H-3-310767 and the following specifications:

- PSS-SPEC-005, *Welding Specification for Stainless Steel Capsule Closure Welds*
- PSS-SPEC-006, *Welding Specification for Tantalum Closure Welds*
- PSS-SPEC-007, *Final Assembly Specification*

3.0 DEFINITIONS/ACRONYMS

Autogenous – Welding processes where no filler metal is added to the weld area. Components are typically designed with additional material in weld areas so that no filler metal is needed to complete the weld.

GTAW -- Gas-Tungsten-Arc-Welding often referred to as TIG (Tungsten-Inert-Gas) welding. A manual or automated welding process where an arc is developed between the tungsten electrode and the surface of the item being welded. The weld area is protected by an inert gas plasma that flows through the GTAW "torch" that holds the tungsten electrode.

Spot weld – (Resistance) Spot Welding is the joining of overlapping pieces of metal by applying pressure and electrical current. These joints created by resistance spot welding form a "button" or "fused nugget" at the pressure point where the pieces of sheet metal are pressed together by the welding electrodes. Resistance spot welds are found typically on flanges, staggered in a single row of consecutive welds. Spot welding produces virtually no sparks or splatter.

4.0 PROCESS DESCRIPTION

4.1 PSS Design

This section describes the PSS design to aid the reader in understanding the fabrication process. The PSS is illustrated in Figure 4-1. The plutonium metal is in the shape of a 3-inch (76.2-mm) diameter disk approximately 2.2 mm deep. It is encapsulated in a tantalum liner that provides an inert barrier between the plutonium and stainless steel inner housing. The barrier is required to prevent the possible formation

of a eutectic during high temperature accident conditions. The tantalum liner is spot-welded closed and then placed inside the inner stainless steel housing, which is seal-welded closed. The inner housing is then placed inside the outer housing, also of stainless steel, which is seal-welded closed. The inner housing is initially screw-closed to align it for the subsequent seal-weld.

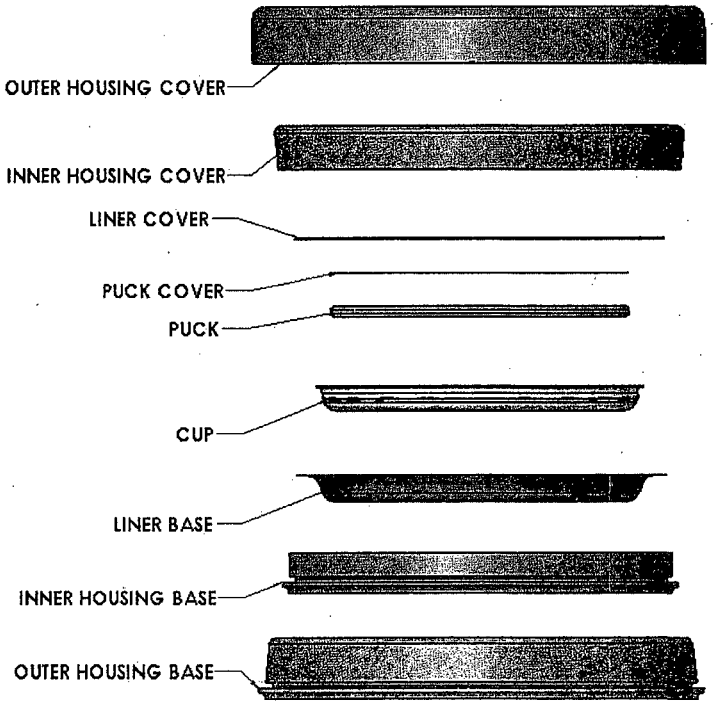

Figure 4-1. PSS Design Schematic

4.2 Collection and Preparation of Parts

Parts for the PSS are fabricated according to PSS-MAQP-006, *Manufacturing and Quality Plan for the Plutonium Sealed Source Parts*. Only inspected and accepted parts may be used for fabrication. The following parts are required to assemble the BSS:

- Tantalum cup.
- Tantalum liner base.
- Tantalum liner lid.
- Tantalum puck cover prototype
- Stainless steel inner housing base.
- Stainless steel inner housing top.
- Stainless steel outer housing base.
- Stainless steel outer housing top.

The following parts are required to assemble the PSS:

- Tantalum cups.
- Tantalum liner bases.
- Tantalum liner lids.

- Puck covers.
- Stainless steel inner housing bases.
- Stainless steel inner housing tops.
- Stainless steel outer housing bases.
- Stainless steel outer housing tops.
- Tantalum plutonium surrogates, fabricated in accordance with PSS-SPEC-009, *Process Specification for Making Plutonium Surrogates for Prototype Tests.*
- Welded liners with tantalum plutonium surrogates (e.g. from the vibration tests or fabricated new according to PSS-PLAN-MAQP-007, *Manufacturing and Quality Plan for the Plutonium Sealed Source Prototypes*, section 4.3.2).

All parts will be cleaned with acetone, de-ionized water and then de-natured ethyl alcohol. One of the PSS inner housing tops will be labeled with a Sharpie pen as 'pre' and another 'post'. The two welded liners with tantalum Pu surrogates will be labeled with a Sharpie pen as 'non-radioactive liner with surrogate'. One tantalum cup and puck cover will be oxidized in a furnace at 500°C for 8 hours. The cup and puck cover will be weighed. Also, one of the PSS outer housing tops will be labeled with a Sharpie pen as 'pre', another 'post' and another marked in accordance with PSS-SPEC-007, *Final Assembly Specification.* The assay (total number of curies) will be determined from the isotopic analysis, the specific activity of each isotope and the weight of metal loaded into the cup.

4.3 BSS Fabrication

An empty tantalum cup with prototype puck cover will be placed into a liner base and the cover welded according to *Weld Procedure RW-PSS-100.* The liner assembly will be placed into an inner housing base, the cover completely screwed shut and then welded according to *GTA-PSS-201, Weld Procedure.* The inner housing assembly will then be placed inside a outer housing base, completely covered with the outer housing cover, which is welded according to *GTA-PSS-201, Weld Procedure.*

All surfaces shall appear metal clean and free of organic films and contaminants throughout the assembly process. The top surface of the outer housing cover will be permanently marked (chemical etch) with the label described in PSS-SPEC-007, *Final Assembly Specification.*

4.4 PSS Fabrication

Assembly of the PSS will be completed in five primary steps as follows:

1. Preparations including oxidizing the Tantalum cup and puck cover to minimize the potential interaction between the molten Plutonium metal and cup;
2. Removal of oxide from the Plutonium metal by polishing and loading the Plutonium into a sample cage and furnace;
3. Melting and cooling the Plutonium in a Tantalum cup under a controlled vacuum;
4. Unloading the sample cage/furnace, insertion of the Plutonium puck into the Tantalum liner, and spot welding the Tantalum liner,
5. Welding both the inner and house stainless steel housings.

Figure 4.2 and Figure 4-3 provides an overview of the assembly process for the PSS.

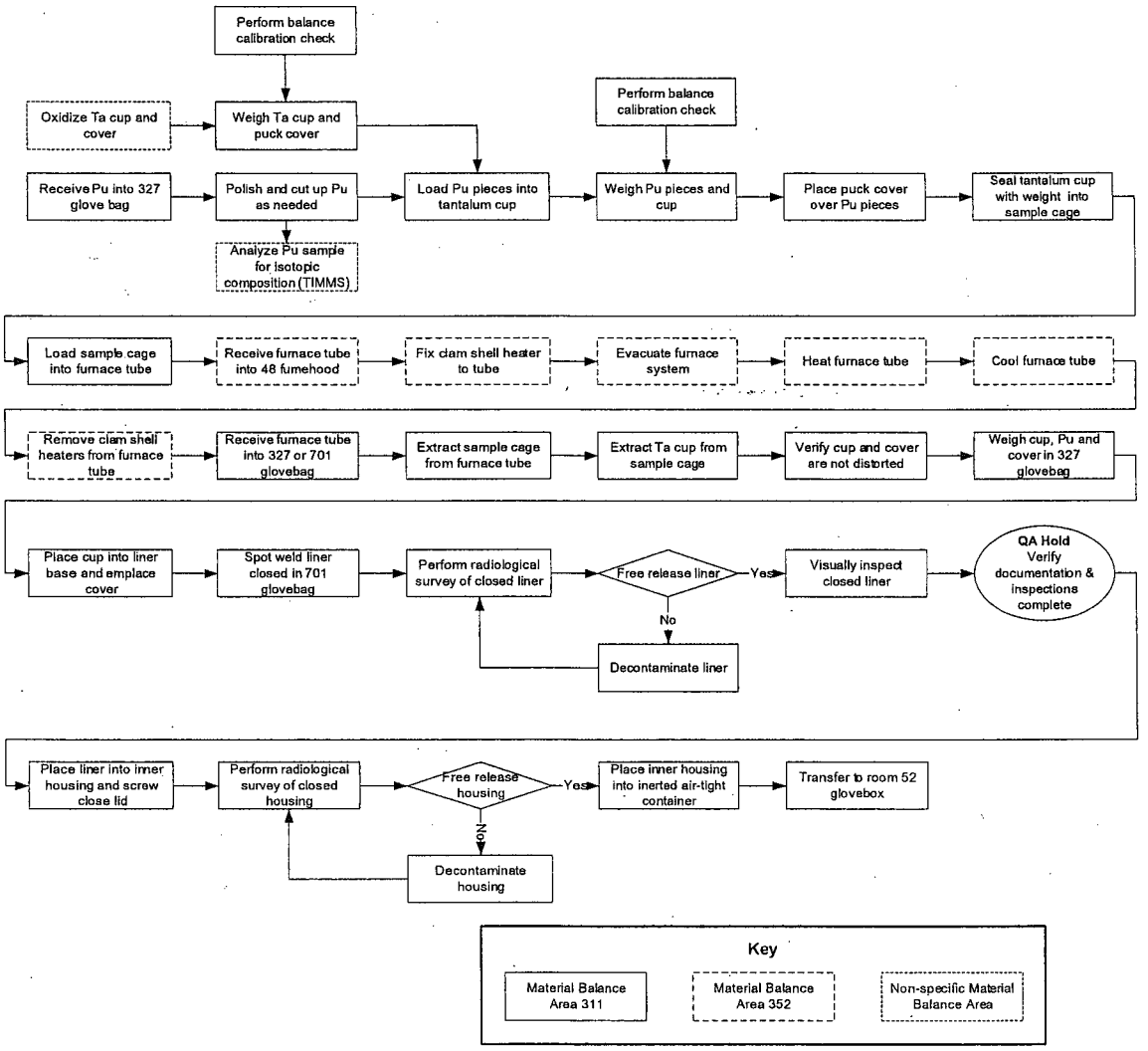

Figure 4-2. Overview of the PSS Plutonium Melting and Liner Closure Process

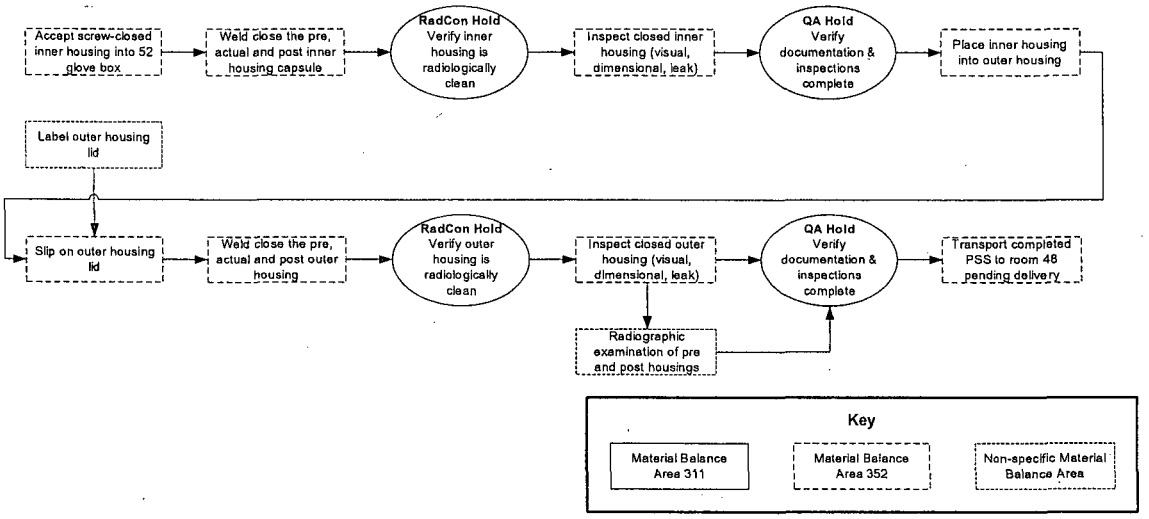

Figure 4-3. Overview of the PSS Final Closure Process

4.4.1 Administrative Preparations

Preparations to be completed prior to beginning work include subject matter expert, Internal Review Committee (IRC) and As-Low-As-Reasonably-Achievable (ALARA) committee reviews of new Radiochemical Processing Laboratory (RPL), building 325 procedures and a dry run demonstration. A Radiological Work Permit (RWP) will be prepared to cover the work described by any new procedures. Staff will be trained to any new procedures.

Due to the complex nature of the work, a Readiness Assessment Review (RAR) will be required. The review team's comments will require written resolution and documentation for authorization from the RPL Manager to proceed with assembly of the PSS. The RAR team will observe the dry run as part of the review.

Plutonium is classified as nuclear material and as such must be controlled and accounted for in accordance with SBMS the subject area, *Nuclear Materials Control and Accountability*. Control and accountability is already facilitated by instituting Material Balance Areas (MBAs) to control and account for nuclear material in a number of rooms within a facility. PSS fabrication will require operations in rooms in two MBAs within RPL. MBA 311 in RPL includes room 327 and room 701 needs to be added to it. MBA 352 includes rooms 48 and 52. Room 48 is also a Limited Area (LA), meaning it can contain greater than 199 g of plutonium metal given the appropriate safeguards categorization. All plutonium metal must be removed from MBA 311to avoid violating its limits as a category IV MBA. This metal will be moved to room 48 and MBA 352 upgraded to category III. The plutonium metal will be transferred between rooms and MBAs in accordance with PNNL administrative procedure RPL-ADMIN-002, *Radioactive Material Tracking*.

4.4.2 Plutonium Metal Preparation and Sample Cage/Furnace Loading

Plutonium metal will be received from Lawrence Livermore National Laboratory (LLNL) and is expected to be of irregular shape and in several pieces. The metal will be unpackaged under pressure with an inert gas such as helium (He) in the first compartment of a 2-compartment glove-bag located in room 327 of RPL.

The plutonium pieces will be wiped with a cotton cloth to remove no more than a few micrograms of plutonium for chemical analysis to determine the isotopic composition. The plutonium will be dissolved off the cotton in nitric acid, dried by evaporation and then submitted via the service center for Thermal Ionization Mass Spectrometry (TIMS) analysis in the Radiochemical Processing Laboratory (RPL) using procedure, PNNL-98523-264 *Mass Spectrometer Isotopic Analysis*.

The metal pieces may be further cut up or polished to remove any surface plutonium oxide. The metal pieces will be transferred to the glove bag's second compartment and evenly distributed in the pre-weighed oxidized tantalum cup. The loaded tantalum cup will be weighed to determine the mass of plutonium. The puck cover will then be placed over the plutonium pieces. The tantalum cup will be fixed inside the stainless steel sample cage, which will be closed by screwing on the lid. The sample cage is equipped with sintered metal filters on the base and lid, as illustrated in Figure 4-4. It is also equipped with an oxidized tantalum weight to ensure the molten plutonium will flow across the area of the cup.

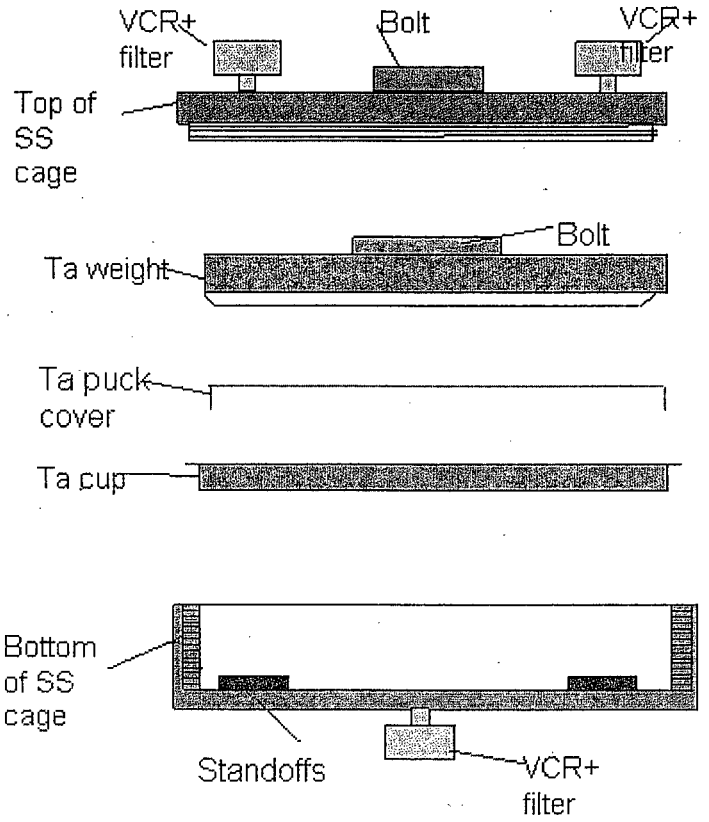

Figure 4-4. Plutonium Sample Cage with Sintered Metal Filters

The sample cage is then loaded into the stainless steel furnace tube. A schematic of the furnace apparatus is illustrated in Figure 4-5.

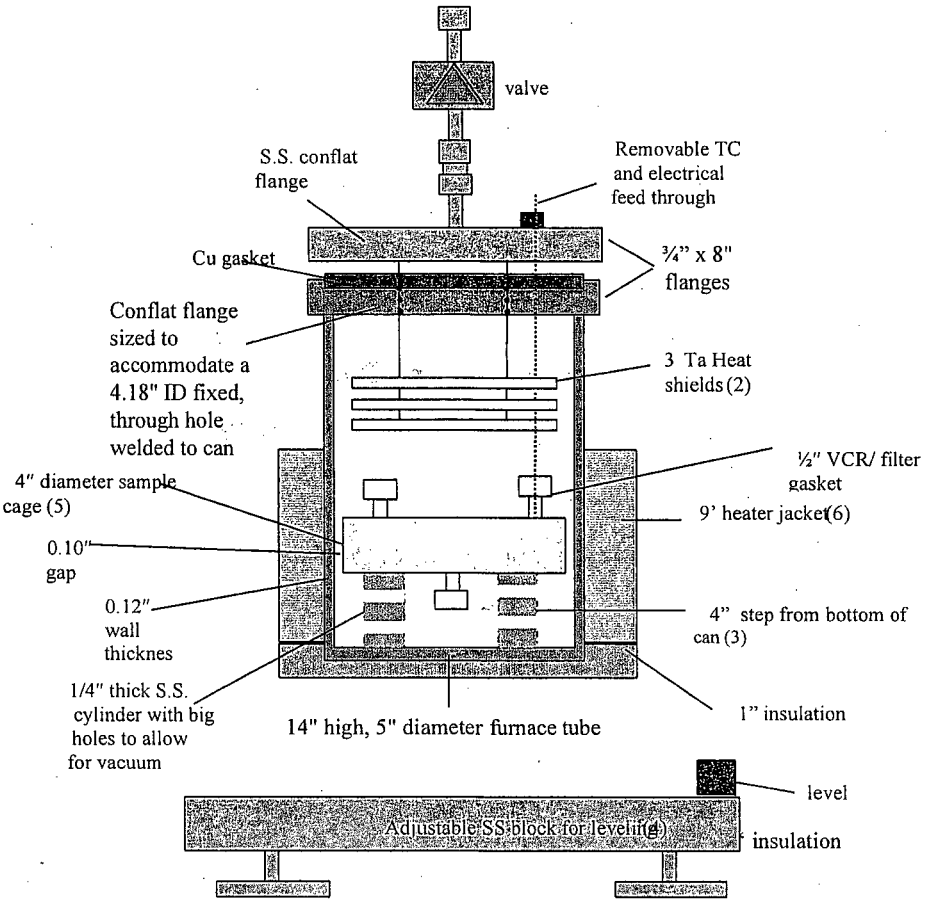

Figure 4-5. Schematic of furnace apparatus

4.4.3 Casting of the Plutonium Metal

The sample cage and furnace combination are next extracted from the inerted glove-bag in RPL 327 or RPL 701 and immediately delivered to room 48, where the heater is located in a fume hood. A vacuum is drawn on the furnace chamber while the heater heats the furnace assembly to the temperature and duration specified in a test instruction in accordance with the new melt procedure described in section 5.0. Upon completing the heating period, the heater is de-energized and the assembly allowed to cool. Once cool, the heaters are removed and the furnace tube extracted.

4.4.4 Unloading of Pu and Insertion into Tantalum Liners

Upon completing the plutonium melt, the furnace tube is transferred to an inerted glove bag located in RPL 327 or RPL 701. In the glove bag, the furnace tube and sample cage are unpackaged to remove the tantalum cup. The tantalum cup is visually inspected to confirm the cup and cover are not distorted and that there no signs that would indicate that the plutonium did not flow across the entire cross-section. The cup/cover/puck combination is again weighed to obtain an as built Pu weight. The tantalum cup and cover are then placed inside a tantalum liner base to ensure a proper fit. Next, the cup/cover/puck are

loaded into a clean tantalum base and closed by affixing the unmarked lid with a series of overlapping spot welds according to PSS-SPEC-006, *Welding Specification for Tantalum Closure Welds*. The closed tantalum liner is surveyed to determine the presence of any radiological contamination. Decontamination of the tantalum container will be performed to remove contamination. The weld on the tantalum liner is visually inspected according to PSS-SPEC-006, *Welding Specification for Tantalum Closure Welds*.

The tantalum liner is then placed inside the stainless steel inner housing base. The inner housing is screw-closed and surveyed to verify that it is radiologically clean. Any contamination of the inner housing needs to be removed. If the housing cannot be decontaminated, then the tantalum container should be placed into a spare inner housing and the process repeated. Once the inner housing is declared radiologically clean then it is extracted and transferred to the inert atmosphere weld glove box in room 52 of RPL. Transport of the inner housing will occur under an inert atmosphere.

4.4.5 Welding of Inner and Outer Housings

The following activities will be completed in the same shift. Each inspection is followed by a **QA hold-point** to verify inspection documentation and travelers are complete. The QE will initial each document and record the date and time.

A welded liner marked 'Non-radioactive liner with surrogate' will be placed inside an inner housing base and the cover marked 'pre' screw closed. This assembly is welded and inspected according to PSS-SPEC-005 *Welding Specification for Stainless Steel Capsule Closure Welds* and *Weld Procedure* GTA-PSS-001.

The unmarked inner housing containing the plutonium will then be welded and inspected (except for the destructive examination).

The remaining welded liner marked 'Non-radioactive liner with surrogate' will be placed inside an inner housing base and the cover marked 'post' screw closed. This assembly is welded and inspected.

The inner housing marked 'pre' will be placed inside an outer housing and covered with the outer housing cover marked 'pre'. This assembly is welded and inspected.

The unmarked inner housing is then placed inside an outer housing base and covered with the pre-marked outer housing cover. This assembly is welded and inspected.

The inner housing marked 'post' will be placed inside an outer housing and covered with the outer housing cover marked 'post'. This assembly is welded and inspected.

4.4.6 Final Survey and Labeling

The completed PSS will be surveyed to confirm it can be free-released. A radiation survey will determine the contact and 30-cm dose rates. Upon completion of all inspections associated with the pre- and post-assemblies and PSS, the latter will be classified as a sealed source.

5.0 NEW PROCEDURES

Assembly of the PSS will require one new procedure for the work to be performed in the RPL. Procedure PIP-PDCF-TP-003, Rev. 2, *Tritium Decontamination of Plutonium* is the basis of the new procedure to cover the preparation, melting and casting of the plutonium metal. The main difference between the new and existing procedures will be the weight of metal, increasing from a current limit of 20 g to 199 g for this work. The new procedure will also include spot-welding tantalum liners and their examination in a radiological environment.

Non-radiological spot and gas-tungsten-arc welding activities in the RPL are covered by RPL procedure, RSG-WELD-010 *RSG Weld Development, Qualification, and Test Procedure*. The RPL procedure PNNL-98523-264 *Mass Spectrometer Isotopic Analysis* governing preparation and TIMS analysis of the plutonium sample requires re-approval.

Variances to Pacific Northwest National Laboratory's Standards Based Management System (SBMS) requirements for criticality control and radioactive material limits in fumehoods are required to allow work with the [redacted] of plutonium. The procedures for obtaining these variances are described in the SBMS subject area *Variances to Subject Areas*. Approved variance request forms are included in the project files. All variances must be approved prior to the Readiness Assessment.

6.0 SPECIAL PROCESS QUALIFICATIONS

The three welds needed to complete the PSS and BSS will be developed and qualified according to the requirements specified in PSS-SPEC-006, *Welding Specification for Spot Welding Tantalum Liner* and PSS-SPEC-005, *Welding Specification for Stainless Steel Capsule Closure Welds*. Qualification of staff performing welding activities is addressed in PSS-QA-901 *Control of Processes*. Welder qualification is documented in notes to the project file: *Summary of Weld Qualification* dated June 13, 2007 and *Summary of Weld Qualification for Tantalum Resistance Weld* dated June 13, 2007.

In general the qualification activity will be an organized method for establishing appropriate welding parameters and techniques to produce acceptable welds. The results of the weld qualification effort will be two weld procedures (one for each of type of weld to be performed) and documentation that specified staff members are qualified to perform these welds as required to complete the assembly.

7.0 EQUIPMENT MODIFICATIONS AND PURCHASES

7.1 Plutonium Preparation and Casting

Two new 2-compartment glove bags are anticipated. Glove bags are used routinely in the RPL to provide additional radiological containment over that provided by a fumehood but when the hazards associated with the task do not warrant using a glove box. Glove bags will be procured from Lancs Industries, Kirkland, Washington. The two compartments will be inter-connected by zippered flaps and each fitted with glove sleeves. The glove bag for room 327 will have an air-lock compartment on one end. The room 701 glove bag will have air-lock compartments on either end. Service sleeves will allow electrical cords to penetrate the glove bag while maintaining containment. A steel or aluminum frame will provide structural integrity to the bag. Dimensions for the glove bag will be determined by those of the fumehood selected for the task.

The second compartment of the 327 glove bag will require a calibrated balance to weigh the plutonium pieces into the tantalum cup. A balance capable of weighing to an accuracy of 0.01 g is required. The Certificate of Calibration and Test Record will be included in the project file. Also required for the second compartment of the 701 glove bag is a spot welder. The welder's power supply can be located outside of the fumehood and one is available in PNNL. The purchased electrodes will necessarily be located in the glove bag and remain there for contamination control. Electrical cords for the weld electrodes and balance will be run through to the glove bag interior using standard service sleeves.

7.2 Welding Equipment

The same equipment used for welding the prototypes (described in PSS-PLAN-MAQP-007 *Manufacturing and Quality Plan for the Plutonium Sealed Source Prototypes*) will be used to fabricate the PSS and BSS.

8.0 MEASUREMENT AND TEST EQUIPMENT

8.1 Balances

A new balance will be purchased to weigh the empty pre-oxidized tantalum cup and the latter cup loaded with plutonium prior to melting it. A request to calibrate the balance before initial use will be made to the PNNL vendor, Quality Control Services, Inc. (QCS) Portland, Oregon. After initial calibration to place the balance into service, balances are re-calibrated annually.. A calibration sticker and a Certificate of Calibration and Test Record is received from QCS, reviewed by the project QE, and will be part of project records. A calibration performance check will be performed by the user with at least a 100-g weight. The acceptance criterion is $\pm 1\%$ of the check weight value.

8.2 Furnace Equipment

The furnace apparatus contains thermocouples and pressure transducers and associated controllers and data acquisition system. All of the equipment will be calibrated by PNNL. Calibration stickers and reports will be requested, reviewed by the project QE, and will be part of project records.

8.3 Weld Inspection Equipment

AREVA and Fluor Hanford staff performing subcontracted inspection activities shall use appropriate helium leak standards for weld inspections. The PNNL Quality Engineer (QE) shall verify the helium leak standard is within its current calibration interval and obtain documentation of the pedigree of the standard for project records.

9.0 REFERENCES

PIP-PDCF-TP-003, Rev. 2, *Tritium Decontamination of Plutonium*

PSS-MAQP-006, *Manufacturing and Quality Plan for the Plutonium Sealed Source Parts*

PSS-PLAN-MAQP-007 *Manufacturing and Quality Plan for the Plutonium Sealed Source Prototypes*

PSS-SPEC-005, *Welding Specification for Stainless Steel Capsule Closure Welds*

PSS-SPEC-006, *Welding Specification for Tantalum Closure Welds*

PSS-SPEC-007, *Final Assembly Specification*

PSS-SPEC-009, *Process Specification for Making Plutonium Surrogates for Prototype Tests.*

RSG-WELD-010, *RSG Weld Development, Qualification, and Test Procedure*

Weld Procedure, RW-PSS-100

Weld Procedure, GTA-PSS-201