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ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 666982

Proj. ECN

1. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental ☐	:ari, PFP Analytical Laboratory, 372-3090	☐ Yes ☒ No	6/05/01
Direct Revision ☐			
Change ECN ☐			
Temporary ☐			
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Supersedure ☐			
Cancel/Void ☐			

6. Project Title/No./Work Order No.	7. Bldg./Sys./Fac. No.	8. Approval Designator

9. Document Numbers Changed by this ECN (includes sheet no. and rev.)	10. Related ECN No(s).	11. Related PO No.

12a. Modification Work	12b. Work Package No.	12c. Modification Work Completed	12d. Restored to Original Condition (Temp. or Standby ECNs only)
☐ Yes (fill out Elk. 12b)	N/A	N/A	N/A
☒ No (NA Blks. 12b, 12c, 12d)		Design Authority/Co Engineer Signature & Bite	Design Authority/Co Engineer Signature & Bate

13a. Description of Change

This **document is being revised to incorporate information to accomodate the use of Pewter can containers due to feed shift to PU-Alloy.**

14a. Justification (mark one)	
Criteria Change	☐
Design Improvement	☐
Environmental	☐
Facility Deactivation	☐
As-Found	[X]
Facilitate Const.	☐
Const. Error/Omission	☐
Design Error/Omission	☐

14b. Justification Details

Design verification not required.

This document is being revised in it's entirety.

15. Distribution (include name, MSIN, and no of copies)

See Attached Distribution Sheet

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16. Design Verification Required
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☒ No

17. Cost Impact

	ENGINEERING	CONSTRUCTION
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18. Schedule Impact (days)
Improvement ☐ N/A
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ill be affected by

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☐
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☐	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☐	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐	None	☒
Environmental Permit	☐	Inventory Adjustment Request	☐		☐

10. Other Affected Documents:, (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

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Design		
Environ.		
Other		

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Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

DISTRIBUTION SHEET

To	From	Page 01 of 01
Distribution	PFP ~~Analytical Laboratory~~	Date 6/05/01
Project Title/Work Order		EDT No. N/A
HNF-6944, Rev.2, Total Measurement Uncertainty for the Plutonium		

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HNF-6944
Revision 2

Total Measurement Uncertainty for the Plutonium Finishing Plant Segmented Gamma Scan Assay System

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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Total Measurement Uncertainty for the Plutonium Finishing Plant Segmented Gamma Scan Assay System

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Total Measurement Uncertainty For the Plutonium Finishing Plant Segmented Gamma Scan Assay System

Table of Contents

1 Introduction

This report presents the results of an evaluation of the Total Measurement Uncertainty (TMU) for the Canberra manufactured Segmented Gamma Scanner Assay System (SGSAS) as employed at the Hanford Plutonium Finishing Plant (PFP). In this document, TMU embodies the combined uncertainties due to all of the individual random and systematic sources of measurement uncertainty. It includes uncertainties arising from corrections and factors applied to the analysis of transuranic waste to compensate for inhomogeneities and interferences from the waste matrix and radioactive components. These include uncertainty components for any assumptions contained in the calibration of the system or computation of the data. Uncertainties are propagated at 1 sigma. The final total measurement uncertainty value is reported at the 95% confidence level.

The SGSAS is a gamma assay system that is used to assay plutonium and uranium waste. The SGSAS system can be used in a stand-alone mode to perform the NDA characterization of a container, particularly for low to medium density (0 - *2.5* g/cc) container matrices. The SGSAS system provides a full gamma characterization of the container content.

This document is **an** edited version of the Rocky Flats TMU Report for the Can Scan Segment Gamma Scanners, which are in use for the plutonium residues projects at the Rocky Flats plant'. The can scan segmented gamma scanners at Rocky Flats are the same design as the PFP SGSAS system and use the same software (with the exception of the plutonium isotopics software). Therefore, all performance characteristics are expected to be similar. Modifications in this document reflect minor differences in the system configuration, container packaging, calibration technique, etc. These results are supported by the Quality Assurance Objective (QAO) counts', safeguards test data, calibration data, etc. for the PFP SGSAS system. Other parts of the TMU analysis utilize various modeling techniques such as Monte Carlo N-Particle (MCNP) and In Situ Object Counting Software (ISOCS).

2 System Operation

The SGSAS system is capable of assaying the gamma content of a variety of sizes of cans ranging in diameter up to 12 inches. At the PFP facility calibrations have been created for two different containers for plutonium-bearing materials. A billet can has been and is employed for the ash stabilization campaigns. The billet can has a maximum diameter ***of*** 5.5 inches and a height of 7.0 inches. The second calibration configuration is for the pewter can, which is used for some high radiological dose rate items. The pewter can has similar dimensions but has a higher attenuation rate particularly for the lower energy gamma rays. The SGSAS performs the measurement in a number of 0.5-inch vertical segments. The number of segments for both the billet can and pewter can is 15. The germanium detector utilizes a lead shield and collimator to limit the field of view of the high purity germanium detector and define the vertical segments. The collimator dimensions used for the Canberra SGSAS systems are 0.5-inch vertical opening x 6 inch depth. The width of the collimator is wide enough that the detector has an unattenuated view of the container radially. During the assay, the container is rotated on a turntable to minimize the potential source nonuniformity in the measurement.

A shielded transmission source is located directly opposite the container from the detector/collimator package and is synchronized vertically with the detector/collimator package. The transmission source is used to measure the absorption of the gamma radiation in the sample matrix. By assaying the container in small vertical segments, the SGSAS system can correct for matrix variations in the container. The assay systems use a Se-75 source that provides transmission lines of 136, 265, and *400* keV, where the 400 keV line is the key transmission line for the 414 keV plutonium line and the 265 keV line is used for the 129keV plutonium line. The 136keV line is currently not being used since it is fully attenuated by absorbers on the transmission source.

The assay system has an efficiency calibration, which covers the energy range from 50 keV to 1000keV and directly measures several gamma-emitting nuclides including Pu-239 and Am-241. The system will also quantify U-233, U-235, Np-237 and U-238. Additional nuclides can be added to the library if they are found in the residues, although it is not expected that there will be other nuclides in the residues waste stream

The system will also perform a plutonium isotopics measurement using the Multi Group Analysis [3] (MGA) isotopics software. The MGA software will provide the weight percents relative to Pu for the Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Np-237, and U-235 isotopes. Under normal operation the measured Pu-239 assay value will be combined with the relative weight percents to calculate the plutonium mass for each of the plutonium isotopes. **A** separate high resolution, low energy, germanium detector is setup and optimized for the isotopics measurements.

The SGSAS system is calibrated using a number of Eu-152 and Am-241 point sources, distributed in the billet can geometry. The calibration was performed using the standard Canberra Gamma Waste Assay Software[4] (GWAS) efficiency calibration technique. This provides an efficiency calibration, which covers the full energy range from 50 keV – 1000 keV. Additional detail on the **SGSAS** calibration can be found in the calibration document [5].

3 Total Measurement Uncertainty For the SGSAS Systems

3.1 Primary Sources of Uncertainty

The primary components of the total measurement uncertainty in the **SGSAS** gamma-ray assay include the following sources:

Calibration source uncertainties
Counting statistics
Matrix absorption
Source self-absorption uncertainties (lumps)
Source nonuniformity
End Effects

Although there are other potential sources of measurement uncertainty, they are typically quite small in comparison to the ones listed above.

The results from the validation testing of the **SGSAS** system for assays over a range from 9 to 203 grams Pu-239 shows that the typical overall uncertainty associated with counting statistics and calibration regression uncertainties is typically less than 5%. This is due primarily to the uncertainty associated with the fabrication of the calibration sources, which typically have a maximum calibration uncertainty of 3%. A smaller portion of the uncertainty is associated with the calibration counting statistics and the fit of the calibration data to the calibration curve. (This uncertainty applies to the linear regression of the gamma ray energy versus detection efficiency for that energy.) This uncertainty is automatically calculated and propagated in the GWAS software so that measurement uncertainties will reflect the calibration uncertainty. Algorithms for propagation of the calibration source uncertainties are contained in the Model S431 Genie-PC Gamma Waste Assay Software Technical Reference Manual [6] Section 6.4. The calibration uncertainty does not take into account any uncertainties or biases that may be caused by differences in the calibration configuration and the actual sample measurement configurations. Subsequent measurement of the calibration standards indicated approximately 6% - 9% positive bias in the calibrations. The effect of this bias is discussed in Section 4.

3.2 Counting Statistics Uncertainties

Counting statistics uncertainties are very small when significant quantities of material are measured but become significant as the radioactive source strength decreases. Since the system is only being qualified for the 2 highest QAO ranges at the present time, the statistical uncertainty is not expected to be a major source of uncertainty (typically in the range of **3%** or less based on the precision results from the QAOs). Because this uncertainty term is propagated in the GWAS software, the TMU analysis will pick up the measured counting statistics uncertainty values so that this term is valid for any measurement range. Data taken during the initial measurement configuration with standards shows a relatively constant standard deviation of about 3% which tracks with the counting statistics uncertainty for the lowest gram levels.

The counting statistics tend to be the primary effect in the precision of the measurements. QAO counts taken with the SGSAS demonstrate a precision of approximately 3% for a 9 gram standard of weapons grade Pu, using a standard 50 sec/segment assay time. The precision is primarily related to counting statistics uncertainties.

Algorithms for propagation of the counting statistics uncertainties are contained in the Genie-PC algorithms manual section B.4.2. (Also see section B.9.1), and the Model S431C Genie-PC Gamma Waste Assay System Technical Reference Manual Section 6.

3.3 Self Absorption Uncertainties

Self absorption uncertainties depend on the quantity of plutonium in a "lump", lump density, and the waste material type. Certain waste streams such as residues may be likely to produce lumps of plutonium where significant self absorption can occur. Using equations from page **163** of Passive Non Destructive Assay of Nuclear Materials". the self absorption reduces the gamma ray flux by up to 50% for a 1 gram spherical lump of pure plutonium metal using the Pu-239 gamma-ray peak at 414 keV. This assumes no additional corrections are applied. For PuO_2 the underestimate drops to about 25%. If a flatter shape is assumed as might be expected and the material was plated onto a crucible or other matrix form, it can be calculated that changing the geometry to a less spherical shape would reduce the self absorption underestimation to approximately 5% to 10%. Going through the same exercise for a larger single 10 gram spherical lump, the underestimation would be approximately 75%, again assuming no differential peak correction. Reconsidering this as a PuO_2 rather than a metal changes this to a 50% underestimation and considering the material in a more plated form would change the underestimation to about 10% - 25%. Furthermore, the probability of a single 10 gram lump is much less probable than a number of smaller lumps summing to 10 g. Finally for containers with high gram loadings (over 100 g) there is a probability of many lumps of plutonium with varying sizes. Since the data review procedure looks for localized concentrations of activity the maximum total gram value for any single position must he considered to be significantly smaller than the total gram value. In summary, there is a wide range of potential uncertainties due to the presence of lumps of plutonium in the container, which increases as the total quantity of the plutonium increases in the container.

Although the effect of lumps or self absorption is always a negative bias, the SGSAS system utilizes a differential peak correction in the calculation of the results for the Radioassay Data Sheet. Differential peak correction is described in the software requirement specification for the TMU software[5]. This applies a correction for the Pu result based on the increased absorption of the 129 keV line over the 414 keV line. The differential peak correction will tend to minimize the effects caused by self absorption and in some cases may actually overestimate the result. Therefore, for the purposes of the TMU uncertainty, the self absorption effect will be considered a random uncertainty rather than a bias.

Since it is not possible to directly quantify the extent of any self absorption in the cans being assayed, the following are assumptions that will be used to determine the self absorption effect in the TMU analysis. The assumptions below were calculated based on information contained in Reference 10. Results shown below are reported as percentages at a 1-sigma uncertainty for the assay value.

- For Pu assays < 1 gram: 0
- For gram loadings between 1g < Pu < 10g: 2.5%
- For gram loadings between 10g< Pu < 100g: 5%
- For gram loadings greater than 100g: 7.5%

For the ash and the Pu alloys matrices the differential peak correction is not used due to the density of the matrix. the ash material is crushed and screened, and therefore not expected to have significant lumps ofplutonium. The Pu alloys, by their fabrication, are distributed materials and are also not expected to have significant lumps.

3.4 Matrix Uncertainties

Uncertainties due to matrix absorption are small for uniform matrices and source distributions. The assay system corrects for this absorption by calculating the matrix density using the transmission correction technique. This technique measures the absorption of the gamma radiation for the matrix by beaming an external source through the container with a gamma energy close to the energy of the primary assay peak. This directly accounts for both the density and the Z effects of the matrix. Therefore, the effects of the elemental composition of the matrix are directly accounted for in the correction technique. Based on the segregation of materials by material type, it is not likely that there will be significant variations in the overall density or Z of the materials in a single can. The most likely matrix effect will be the presence of voids in the material. The Pu alloys may have significant matrix nonuniformities. These are discussed in Section 4.2.

To evaluate the measurement uncertainty associated with a heterogeneous matrix distribution Canberra has modeled the response of a measurement segment. Several test cases are described below:

For the following group of tests the matrix was uniform except for a 10 cc sphere (diameter of approximately 1 inch). This size was chosen, because it represents about the largest size non-uniformity, which could be present without significantly modifying the transmission measurement. Therefore, it should represent the worst case uncertainty. The nonuniformity was positioned off axis so that it would not be in the transmission beam during the full sample rotation. Once the nonuniformity is large enough the transmission correction will adequately handle the average matrix effect and the overall uncertainty will actually be smaller.

The source distribution was considered to be uniform to keep source distribution uncertainties separated from matrix distribution uncertainties. The following are results for the various test cases run where the results shown are the ratio of measured result to the correct result, and the sphere is either placed at the center of the container or at the outside edge:

	Center	Outside edge
I) Container was primarily cellulose at 0.5 g/cm3.		
1) Inhomogeneity was a void sphere:	0.98	1.00
II) Container was primarily ash at 1.0 g/cm3.		
1) Inhomogeneity was a void sphere:	0.96	1.01

Since the **SGSAS** assays the can in small vertical segments, each of which receives a transmission correction, the vertical effects of waste matrix inhomogeneity are insignificant. This minimizes the potential uncertainty associated with stratified matrices of differing densities.

The only significant matrix inhomogeneity effect seems to be a matrix material which is significantly different in density from the average matrix and which is centered radially in the container to the extent that the transmission source is always being effected by the inhomogeneity.

Since each segment receives a separate transmission correction measurement, these examples are considered to be relatively extreme instances and that matrix heterogeneity uncertainty is reduced when averaged over the typical 15 segments. Therefore, from the above test cases, it will be assumed that +/- 4% represents a 2 sigma uncertainty. For the purposes of the TMU calculation, all uncertainties are initially combined using the 1 sigma value or in this case a matrix correction uncertainty of 2 %.

3.5 Nonuniform Source Distribution Uncertainties

The "Billet" and pewter cans used for the residues at PFP are approximately ***5.5*** inch in diameter. This is smaller than the 7 inch diameter of the 8808 container used for the TMU analysis at Rocky Flats. The source nonuniformity is dependent on the container diameter. Since the containers are similar in size the source nonuniformity for the PFP can will be very similar to the source non-uniformity for the 8808 container. Because the PFPcans diameters are slightly smaller than the 8808 can the nonuniformity equation can be considered somewhat conservative when using the analysis from the Rocky Flats TMU.

In order to establish an estimate of the uncertainty for the source nonuniformity uncertainty a series of measurements were modeled using Canberra's ISOCS software. The assumption in the modeling is that a source in the center of the can represents the worst-case underestimate measurement and a source at the outside of container represents a worst case overestimate measurement. Based on a probable distribution of sources in a container, these two measurements represent a 3-sigma limit for the source nonuniformity. Since the calibration is based on a uniform distribution of activity throughout the container, the worst-case underestimate and overestimates are taken as a ratio to the uniform distribution of activity. This was calculated for densities ranging from 0.2 g/cc to 2.5 g/cc. From these measurements, the range of variation in the signal was plotted as a function of matrix density. In addition, the corresponding maximum and minimum signals were determined as a function of density for a gamma energy of 400 keV. In equation form, these maximum and minimum values are given below and are used as a basis for the uncertainty source nonuniformity.

$$ERR_{Max} = (0.035*AverageDens^2) + 0.18*AverageDens + 1.01$$
$$ERR_{Min} = (-0.03*AverageDens^2) - 0.16*AverageDens + 0.99$$

The estimated uncertainty (1σ) due to nonuniform source distribution is then determined as

$$ERR = (ERR_{Max} - ERR_{Min})/6$$

Although not run for the SGSAS geometry, Canberra has run large numbers of simulations[7,8] for random source distributions that support the assumptions above.

3.6 End Effects

A special case of the source nonuniformity uncertainty is known as end effects. It will he considered a separate uncertainty term as discussed below.

Although the collimator used on the SGSAS system minimizes the volume of the container that is measured in each segment, there is some overlap between segments. In general a point source of material can actually be somewhat detected over approximately 3 adjacent vertical segments. Since the assay systems are not set up to assay below the bottom of the outer container, there is an additional uncertainty that may become significant when most of the activity is located at the bottom of the container. In this case, the material is only measured in 1 or 2 segments whereas when the material is located at a higher position in the container it is measured in 3 segments. For containers where the plutonium is reasonably distributed throughout the container this uncertainty is quite small. However, if all of the plutonium is located at the bottom of the container, this uncertainty can be as large as 20 – 35%[9]. In order to minimize this effect on the system, a 0.75 inch high spacer has been placed on the system so that there is an under scan of the container. In addition, procedures"" define a minimum vertical distribution for the material in the containers. Therefore end effects will not be a measurable effect on this system.

End effects at the top of the container are not considered a credible effect since the container is not usually filled completely to the top and the possibility that most of the activity would be at the top of the matrix is very small.

3.7 Summary of Uncertainty Estimates for the SGSAS System

Table 1 is shown below as an example of how the TMU would be expected to vary as a function of three different container densities. All of the uncertainties can be summed in quadrature to calculate the final TMU uncertainty value. The uncertainties are based on values calculated using the above analysis for a waste container containing 5 **gram** of plutonium. The uncertainties are propagated as the square root of the sum of the squares. Uncertainties associated with source non-uniformity dominate the measurement uncertainty. All of the individual uncertainties are shown as 1 sigma limits. The TMU in the bottom row of the table is corrected to **1.96** sigma limits. Results are reported as percentages of the assay value. The 5 gram value was chosen to demonstrate the contribution of a self absorption correction uncertainty while still being small enough to demonstrate counting statistics uncertainties. The different matrices were chosen to actually represent different typical container densities. The densities represent the range that is considered acceptable for use with an SGSAS system. The range of matrix densities shown below is between 0.5 and I.5 g/cc. However based on a review of a number of assay reports the typical ash densities tend to run between 1.3– 1.5 gicc. Therefore the 1.5 gicc value will tend to represent the expected uncertainties for the ash matrix.

The focus of Table 1 is to show that the primary uncertainty term under most conditions is the source positioning uncertainty term. Table 2 demonstrates that at high gram loadings the self absorption uncertainty also becomes a significant term.

Table **1.** SGSAS Uncertainties for approximately 5g Pu loading @ lsigma

(Matrix Density	(1.5 g/cc)	(1.0 g/cc)	(0.5g/cc)
Counting Statistics (Cstat)	3%	3%	3%
Self Absorption Uncertainties (Lerr)	2.5%	2.5%	2.5%
Matrix uncertainties (Merr)	2%	2%	2%
Source nonuniformity uncertainties (Serr)	11.3%	7%	3.4%
Calibration Uncertainty (CALerr)	3%	3%	3%
Total RMS Uncertainty @ 1 sigma	12.5%	8.8%	6.3%
Total Measurement Uncertainty @ 95% Confidence	24.5%	17.2%	12.4%

Table 2. SGSAS Uncertainties for approximately 150g Pu loading @ 1sigma

[Matrix Density	(1.5 g/cc)	(1.0 g/cc)	(0.5g/cc)
Counting Statistics (Cstat)	2%	2%	2%
Self Absorption Uncertainties (Lerr)	7.5%	7.5%	7.5%
Matrix uncertainties (Merr)	2%	2%	2%
Source nonuniformity uncertainties (Serr)	11.3%	7%	3.4%
Calibration Uncertainty (CALerr)	3%	3%	3%
Total RMS Uncertainty @ 1 sigma	14.1%	11.1%	9.2%
Total Measurement Uncertainty @ 95% confidence	27.6%	21.7%	18%

The algorithm used to calculate TMU was:

$$TMU = 1.96 * \text{Sqrt}((Merr)' + (Comb)' + (Serr)' + (Lerr)^2)$$

Where:

Sqrt represents the square root function.

Merr is the uncertainty due to matrix absorption.

Comb is the combination of the propagated counting and calibration statistics from the assay software. $= \text{Sqrt}(Cstat^2 + CALerr^2)$

Lerr is the uncertainty due to source self absorption effects and is calculated as:
Less than 1 g: 0
1.0< g < 10: 2.5%
10< g < 100: 5%
100< g: 7.5%

Serr is the uncertainty due to nonuniform source distributions. It is calculated according to the discussion in Section 3.5.

For the ash matrix, standards measurements were performed at PFP utilizing containers of actual ash material that had been assayed in a calorimeter to compare with the assay results from the SGSAS system. A review of this data in section 3.9 demonstrates that the TMU results shown above are considered to be conservative for the ash matrix. There are no such standards for Pu alloys, so no evaluation can be made prior to processing the material. However, several of the Pu alloys items have been assayed previously by calorimetry, so evaluations during processing will he performed.

3.8 Isotopic Uncertainties

The only uncertainties that are not included in the above TMU calculations are the potential uncertainties associated with the plutonium isotopic ratios. The PFPTMU software requires the use of either measured or declared Plutonium isotopics for the total calculation of values that must be reported to WIPP.

For the SGSAS systems, the software MGA will be used to directly measure the plutonium isotopics. This software calculates the weight percents relative to Pu for each of the plutonium isotopes as well as Am-241 and U-235 and Np-237 if detected. The uncertainty that is calculated for the isotopics encompasses all of the uncertainties associated with the measurement and therefore is a total measurement uncertainty. For normal assays, the plutonium isotopics from the MGA result is evaluated to determine its acceptability. The isotopics are then combined with the Pu-239 assay result to supply the assay values for all of the plutonium isotopes as well as U-235 and Np-237. If differential peak correction is used, the self absorption corrected Pu-239 assay result is used. Under most conditions the measured Am-241, result from the SGSAS assay will be used over the MGA calculated Am-241 result.

If the MGA software cannot perform a good measurement, as defined in ZA-400-302 [13] then a set of declared isotopics are used. This is determined based on the uncertainty for the Pu-238 and Pu-240 results. The maximum acceptable uncertainties for these isotopes are:

Isotope	**1 sigma Uncertainty**
Pu-238	200%
Pu-240	40%

If either uncertainty is above these values, then a set of default isotopics will be used for calculating the isotopics. The default isotopics are listed in the data analysis procedure.

The americium result is based on the calculated result from the SGSAS assay. This uses the 662 keV line to calculate the result. If Np-237 or U-235 is measured by MGA, these ratios will be using the isotopic uncertainties even if the default isotopics are used. The batch data report will indicate whether measured or default isotopics were used.

The isotopics uncertainties are summed in quadrature with the TMU uncertainty to produce the final TMU result for each of the plutonium isotopes.

4 Evaluation of the TMU for Specific Matrices

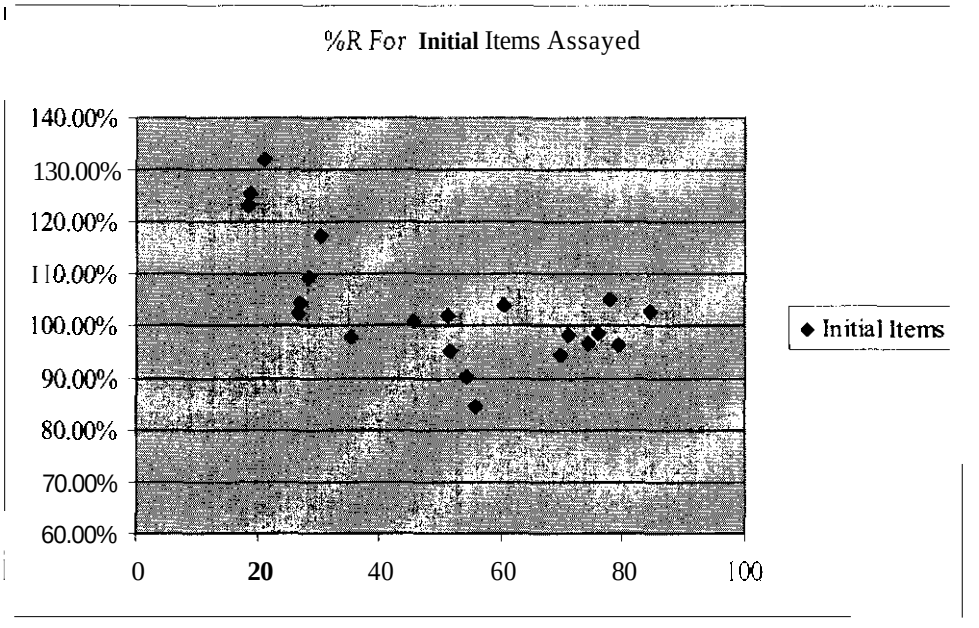
4.1 Rocky Flats and Hanford Ash

The above TMU analysis is designed to cover a variety of potential waste matrices. Characteristics of the ash matrix tend to minimize some of the TMU uncertainties described above so that the actual TMU should be somewhat less than the physics based analysis would predict. Some of these characteristics include:

- The ash is sieved to eliminate any significant lumps of material. This will minimize the self absorption uncertainty.
- Material is mixed with a surrogate prior to filling the billet cans. This tends to ensure that an already relatively uniform source and matrix distribution will be uniform.

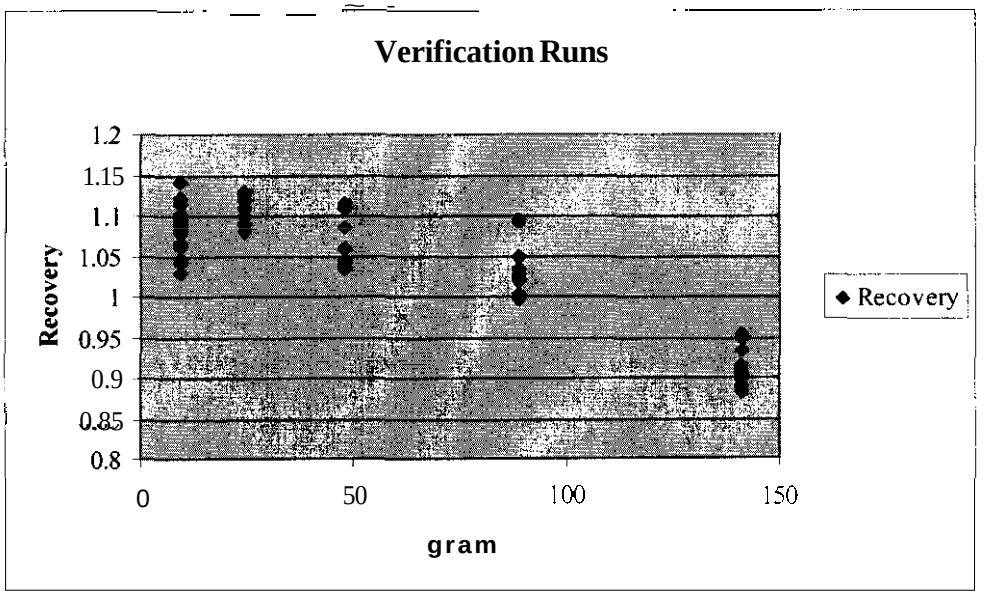
Calorimetry results for a number of the cans, which were initially assayed, have been compared to the assay result. **A** plot of the % recovery for this data (based on the assumption that the calorimetry data has a small uncertainty) is shown in figure 1 below.

Figure 1: Recoveries (vs Calorimetry) for Initial Assay Items



A few assays below 10 grams were eliminated from this data since the uncertainty based on the calorimetry in this gram range is typically as large or larger than the gamma assay data. This data shows that the %R based on this data goes from 80% to **130%.** There appears to be a bias at the lower gram ranges. The ***6%*** bias from the calibration standards measurements appears to be somewhat offset by a dead time issue which is a negative bias, particularly at higher gram levels. This is also supported by data from testing with standards characterized for safeguards purposes which showed a positive bias in the lower gram ranges. **A** graph of this data is show below. In Figure 1 the lowest values exceed the calculated TMU of approximately 27%, however if the measurement uncertainty of the calorimeters was factored into the equation, all values would be within the overall calculated uncertainty. Further work is being performed to reduce the measurement biases. If the measurement bias is removed then the overall TMU based on the above calculations should be able to be considered conservative.

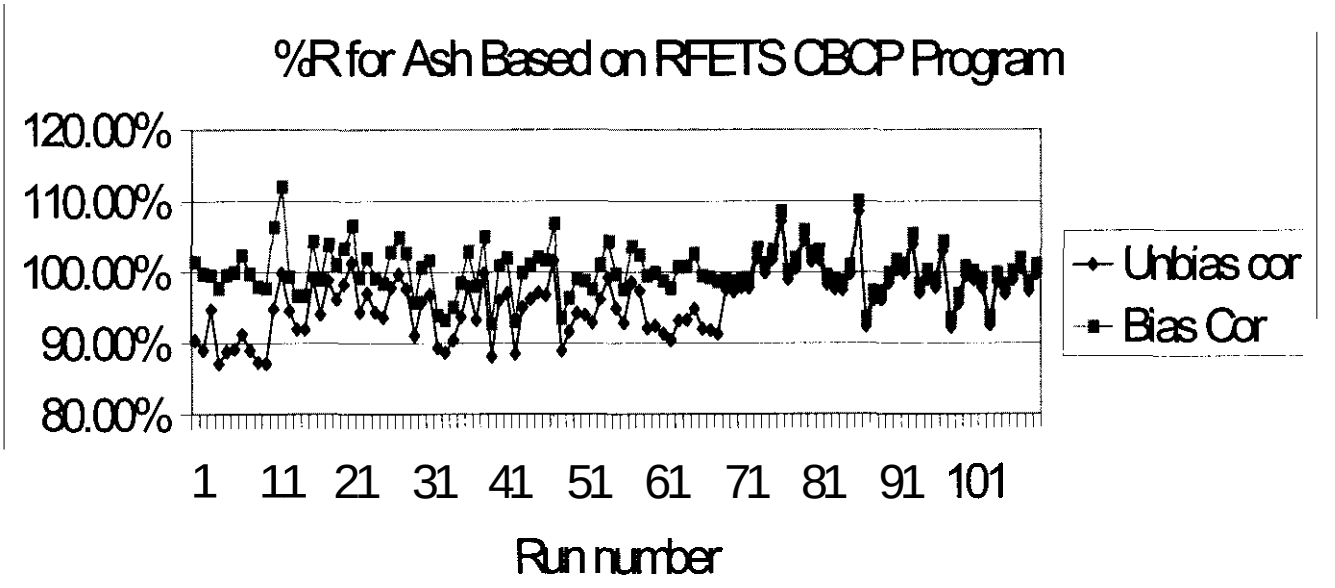
Figure 2: Initial Runs with Safeguards Standard



This is further confirmed by data from the Rocky Flats Continuous Bias Correction Program (CBCP). The CBCP data was provided to Canberra by email as a part of the TMU evaluation at Rocky Flats. This data shows the comparison between Rocky Flats calorimetry and the Rocky Flats SGS systems for a series of randomly selected ash containers that were routinely checked to monitor the Rocky Flats bias correction program.

The Rocky Flats data is from a very similar process, and utilized very similar instrumentation (Canberra can scan systems running the GWAS software) for the gamma assay. Air bath calorimeters were used at Rocky Flats as opposed to water bath calorimeters at PFP. Although not **an** exhaustive comparison, the Rocky Flats data shows a similar range of recoveries to the PFP data and therefore would tend to support the assumption that the TMU value is conservative. Results from this data shown in figure **3** below:

Figure **3:** Comparison Between Rocky Flats Calorimetry and SGS System Data



Since some of the ash assayed at PFP was the Rocky Flats ash **(IDC**420P) this data should also reflect the expected TMU for the PFP **SGSAS** system. The spread of the RFETS data is approximately +/- 10%. This TMU analysis is also expected to apply to Hanford Ash.

4.2 Plutonium/Aluminum Alloys Matrix

The plutonium/aluminum (Pu/Al) alloys matrix has very significant differences from the ash matrices described earlier. In addition it is not easy to create reasonable surrogates for this matrix to test the TMU assumptions. Therefore, in lieu of the ability to demonstrate TMU effects, conservative assumptions will be applied.

Counting statistics will not significantly vary from the ash matrix since the overall container densities are expected to be similar. In addition, since the counting statistics are directly propagated, the actual counting statistics will be used in the actual TMU calculation.

Source non-uniformity in the matrix will be similar to the ash matrix since the plutonium in the Pu/Al alloy is expected to be uniformly distributed. Non-uniformities between the alloy and void spaces are covered under the matrix non-uniformities.

For the Pu alloys this affect may be more significant. The alloys vary in physical composition from chips to structures such as rods, and tubes. Therefore significant portions of the container may be empty, while other portions will have the Pu alloy present. Assuming a worst case scenario for this, would be represented by approximately half of the material on one side of the can. In this scenario the transmission attenuation would be approximately 0.4 vs an actual transmission when passing through the material which should be approximately 0.2 (based on calculations of attenuation through Al in this configuration). The effect on the correction at this energy for the 414 keV peak would be approximately 20% low. This would be the extreme case and is not probable. Therefore it could be considered to be at least a 3 sigma uncertainty. For conservatism a 1-sigma uncertainty for the Pu/aluminum alloys of *6.5%* will be applied.

There is a potential for all of the material to be located in the bottom of the billet can with this matrix. If the situation does occur, the assay will require expert review due to minimum transmission values in those segments. If **an** end affect problem is detected (50% or more of the activity in the bottom 2 segments) then an end effect uncertainty will be applied in the expert review process.

All other uncertainties are expected to be similar to the analysis in the body of the document. Below is the table for the Pu alloys corresponding to that of ash residues.

Table 3. SGSAS Uncertainties for approximately 150g Pu loading @ lsigma

[Matrix Density	(1.5 g/cc)	(1.0 g/cc)	(0.5g/cc)
Counting Statistics (Cstat)	2%	2%	2%
Self Absorption Uncertainties (Lerr)	7.5%	*1.5%*	7.5%
Matrix uncertainties (Merr)	*6.5%*	6.5%	6.5%
Source nonuniformity uncertainties (Serr)	11.3%	7%	3.4%
Calibration Uncertainty (CALerr)	3%	3%	3%
Total RMS Uncertainty @ 1 sigma	**15.5%**	**12.7%**	**11.1%**
Total Measurement Uncertainty @ 95% confidence	**30.3%**	**24.8%**	**21.7%**

The algorithm used to calculate TMU was:

$$TMU = 1.96 * \mathrm{Sqrt}((Merr)' + (Comb)^2 + (Serr)^2 + (Lerr)^2)$$

5 References

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[2] HNF-6945 "Quality Assurance Objectives for Non Destructive Assay with the Segmented Gamma Scan Assay System at the Plutonium Finishing Plant", March, 2001.

[3] Multi Group Analysis Software V9.5A, Canberra Model #: S408.

[4] Gamma Waste Assay Software V2.3A, Canberra Model #: S480.

[5] "Software Requirement Specification for PFPTMU Software", J. Seamans, October, 2000.

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[7] "Q2 - A Very Low Level Quantitative And Qualitative Waste Assay And Release Certification", Proceedings of Waste Management '90 , Tucson, Arizona, February 25-28, 1995.

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[10] Passive Nondestructive Assay of Nuclear Materials, Edited by Doug Reilly, Norbert Ensslin and Hastings Smith, **Jr.,** Report NUREG/CR-5550, March 1991.

[11] 20-160-080, Pipe N Go Operations

[12] ZO-160-081, Pu/Al Alloys Operations

[13] ZA-400-302, Calculation of Assay Results