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Measurement Plan for Uncertainty Contributions to ^{252}Cf Waste Measurements

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National Isotope Development Center

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1. INTRODUCTION

1.1 PURPOSE

This measurement plan establishes the methodology for performing and analyzing mock-up measurements of Building 7930 Cell G Cf waste generated from ^{252}Cf product preparation to better determine the measurement uncertainty contributors. Understanding the uncertainty contributors will establish the total measurement uncertainty. This is critical because it will impact the administrative threshold at which personnel can discriminate between low-level waste (LLW) and transuranic (TRU) waste.

1.2 CONTEXT

TRU waste is significantly more expensive to dispose of compared to LLW. The determination of whether the waste is TRU depends on the activity concentration of radioisotopes that emit alpha particles, have a half-life longer than 20 y, an atomic number >92, and a concentration >100 nCi/g. The LLW activity concentration must be <100 nCi/g, which is calculated by measuring the activity of the entire container and dividing it by the weight of the waste material inside the container [1].

Among the waste in Cell G, ^{248}Cm, ^{249}Cf, and ^{251}Cf are the primary TRU radioisotopes of concern. These isotopes decay by emitting an alpha particle, as well as associated beta particles and gamma rays, and have a half-life of 348,000 y, 351 y [2], and 898 y [3], respectively. The emitted gamma rays will be measured using a non-destructive assay (NDA) technique called gamma spectroscopy to quantify how much ^{248}Cm, ^{249}Cf, and ^{251}Cf are present in the waste when the gamma rays are visible in the measurement. The amount of ^{252}Cf will also need to be determined for shipping manifests.

Gamma spectroscopy was chosen as the measurement methodology because gamma rays are emitted at energies specific to the radioisotope emitting them and can be used to directly identify the radioisotopes present. The counts in a gamma-ray peak are proportional to the amount of that radioisotope present in the item or matrix being measured. To quantify the amount of material present, an efficiency calibration must be applied.

The In-Situ Object Counting System (ISOCS) software, which models the measurement geometry and calculates an efficiency calibration, will be used in the gamma spectroscopy analysis. The ISOCS methodology is an approved characterization technique for determining the TRU waste and LLW concentrations in radioactive waste disposition at the Waste Isolation Pilot Plant (WIPP) in New Mexico and the Nevada National Security Site (NNSS) in Nevada. The advantage of ISOCS is that calibration standards do not need to be prepared for every possible waste container. The disadvantage is that ISOCS is limited in its geometry definitions (i.e., templates), wherein a complex waste container would require simplification of some of its features.

For gamma spectroscopy in general, regardless of the method for determining efficiency, the contents of the container must be considered uniform in material and radioactivity concentration. If hotspots (i.e., localizations of different materials or radioactivity) are known, then an appropriate ISOCS template can be used. However, information regarding the materials, radioactivity concentration, and location must be known or estimated before it can be included in the ISOCS model.

All measurements have an associated uncertainty. In NDA, this is termed total measurement uncertainty, or TMU. The TMU is determined by evaluations of the variable measurement parameters (i.e., ones in which the true value is unknown) either by simulation or direct measurement. This measurement plan lays out the experimental measurement of the uncertainty contributors to the TMU. The TMU will be used by

Oak Ridge National Laboratory (ORNL) to determine the confidence with which the waste can be segregated and dispositioned as LLW vs. TRU. Per Revision 10 of the Waste Isolation Pilot Plant Waste Acceptance Criteria (WIPP WAC), the TMU for alpha activity concentration is not reported [1].

Additional quantities must be calculated called the Lower Limit of Detection (LLD) and Minimum Detectable Activity (MDA). These values quantify the smallest detectable activity that can be measured using the measurement methodology with the current background radiation detectable in the detector. These values are used when a measurement appears to find nothing, but the characteristics of the waste stream indicate the radioisotope should be present. The MDA is reported as the container's activity. This measurement plan will calculate the LLD and MDA for all applicable radioisotopes based on the background measurements performed above Cell G.

1.3 EXPECTED BENEFITS SUMMARY

The analysis methodology used for determining the concentration of ^{249}Cf and ^{251}Cf requires knowledge of the material composition and density of all materials, including the waste, the container, and any other materials between the radioisotope and the detector. Because this information is not available for all materials of the Cell G waste streams, direct measurement is the best way to obtain information regarding the difference between the assumed values and the true values. The difference can be corrected in many cases and thus the accuracy of the measurement is increased. The measurements need be performed only once for each waste stream and understanding all the uncertainty components will simplify expert review.

By understanding the uncertainty components of the measurements, mitigation activities can reduce one or more contributors to reduce the overall uncertainty. Additionally, defensible thresholds can be established for the segregation and quantification of the Cell G waste stream as LLW or TRU waste.

1.4 INFORMATION NEED(S) SUMMARY

To perform representative measurements of the anticipated waste stream, the packaging of the waste cans should be known. The analysis methodology requires as much detailed knowledge of the waste containers as possible to reduce measurement error. If the waste can packaging has more variations, then the more deviation from the analysis model and the greater the uncertainty.

The following information is needed with as much detail as possible:

- Waste material in the container including chemical composition and density;
- Any knowledge of the radionuclide mixture;
- Immediate waste container information including chemical composition and density;
- Packaging configuration including all dimensions, material chemical compositions and densities;
- Transfer pipe material information including chemical composition and density;
- Shielding material information including chemical composition and density; and
- Anticipated detector positioning in relation to shielding and waste container.

The list of radionuclides for quantification is also necessary to ensure the measurement report captures all the radionuclides required for reporting.

Lastly, any training requirements or work performance requirements must be determined before working in Building 7930.

1.4.1 Identified Waste Configurations

As of February 27, 2022, four waste configurations have been identified, which will be referred to in this document as (1) manipulator boot & ring, (2) mixed debris, (3) mop heads, and (4) 1 gal melted poly can.

The manipulator boot configuration consists of a custom plastic manipulator boot topped with a manipulator ring, which is used to secure the boot to the top of the cell. The ring is a large torus of aluminum and rubber. It is anticipated that the center of the ring will be backfilled with the manipulator boot. The boot and ring are expected to be lightly contaminated and uniform in radioactivity distribution.

The mixed debris configuration is when the 3 gal can is filled with random contaminated items. This can be anything from valves, cabling, glass bottles and vials, light fixtures, manipulator fingers, and so on. This configuration will have a wide variety of material types, heterogeneous material distribution, and heterogeneous radioactivity distribution. Thus, many assumptions will be required during the modeling.

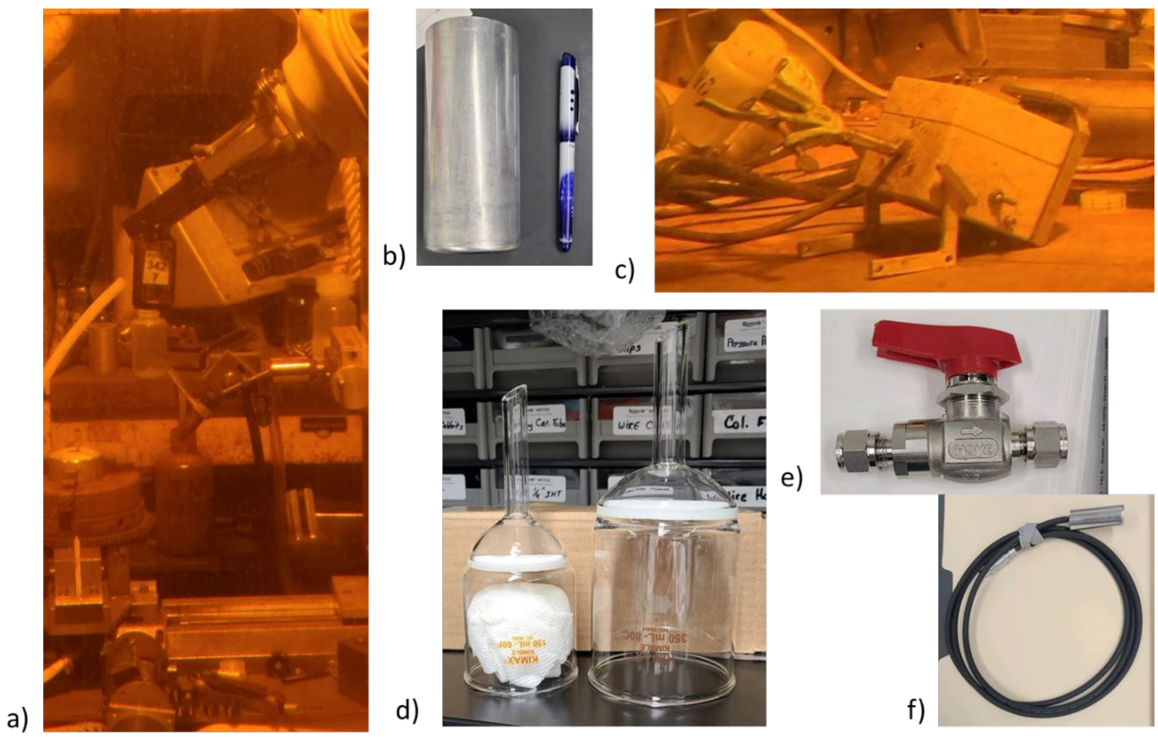

Figure 1. Examples of items that may constitute mixed debris. a) Looking into Cell G. Any item visible could be disposed of in the mixed debris configuration. b) Neutron detector preamplifier. c) Electronic tumbler and poly solution bottle. d) Glass vials and funnels. e) Valve. f) Neutron detector and cable. Photographs courtesy of Don Coffey, January 27, 2022.

The mop heads are another common item that will be included in the mixed debris configuration. The mop head is a microfiber finger duster that has been modified to include a thin metal plate with a grip fixture for the manipulator fingers. The mop heads are anticipated to be uniformly distributed with radioactivity and the material should be approximately uniform despite the metal attachments.

The 1 gal melted poly can configuration includes a 1 gal paint can, filled to approximately 80% capacity with melted poly bottles, centered in the 3 gal can. Mixed debris will be placed on top of the melted poly inside the 1 gal paint can and in the annulus between the paint can and the 3 gal can. It is anticipated the mixed debris items will be heterogeneous in material and radioactivity distribution. In some existing melted polyethylene cans there are spent Cf sources, highly contaminated glass vials, or valves which were added to the polyethylene because polyethylene is an effective neutron shielding material. The placement of these highly contaminated items inside the cans is unknown.

1.5 SCOPE / BOUNDARIES

The anticipated waste measurements will be performed with the gamma detector placed about 10 ft. away from the transfer pipe, called a far field measurement. This measurement plan includes only measurements that meet the definition of a far field measurement.

The ^{249}Cf and ^{251}Cf isotopes have been identified as the primary gamma-ray-emitting TRU isotopes of concern. Therefore, the mock-up measurements will be focused on the uncertainty for those associated gamma rays only.

Mock-up measurements will be performed as allowed by personnel availability and resources.

2. MEASUREMENT LOGISTICS

2.1 EQUIPMENT & SOFTWARE

The following is a list of equipment and specialty software for execution of this measurement plan.

- Falcon 5000 and power cords
- Computer for data acquisition
- Shield/collimator for the respective detector system, as needed
- IdentiFINDER or RadEye
- Detector cart/stand
- Mock-up materials listed below in Section 2.3
- Laser assembly for centering detector
- Registered Lab Notebook
- Sources available to Building 7606A
- Spent ^{252}Cf sources available at Building 7930 with traceable quantities of ^{249}Cf and ^{251}Cf
- Genie 2000 Gamma Analysis Software including ISOCS
- GC6523 (high purity germanium) HPGe detector with Cryo-Pulse 5
- DSA-LX multichannel analyzer

2.2 PERSONNEL

The following personnel will be involved in the execution of this measurement plan:

- Gomez Wright
- Jake Daughhetee
- Greg Nutter
- Susan Smith
- Dan Archer

Brandon Longmire will prepare the test setup and tend to engineering needs.

2.3 PREPARATORY ACTIONS

Before mock-up measurements in the laboratory setting, the following must be completed:

- Fabrication of a tungsten carbide shield for the Falcon 5000
- Fabrication of a tungsten carbide shield for the GR6523 detector
- Identification of appropriate sources to best represent the measurement situation
- Transfer of the following from Building 7930 to Building 7606A
  - Transfer tube mock-up
  - Tube shielding
  - Carrier
  - Three gallon (3 gal) cans
  - One gallon paint can(s)
  - Melted poly insert
  - Manipulator boot rings
  - Manipulator boot
  - Items representative of debris from the cell (values, glass funnels and vials, and so on)
  - Mop heads
  - Falcon 5000 with computer
- Installation of ISOCS characterization for the Falcon 5000 on analysis computer
- Delivery of functional GR6523 detector

Before measurements in Building 7930, the following must be completed: 7930 Work Package and measurement personnel obtain necessary training and access to hot cell area.

It is requested that the temporary construction area above the adjacent hot cell in Building 7930 undergo decontamination and dismantling to represent the anticipated conditions of the waste measurement. Contamination in the temporary construction area will lead to an elevated background, which will increase the measurement error. Because of supply chain issues, the team is aware that this will not be possible before execution of this measurement plan over Cell G. In addition, any equipment that can be removed from the area will help to reduce background. Figure 2 shows the area above Cell G as of February 2022.

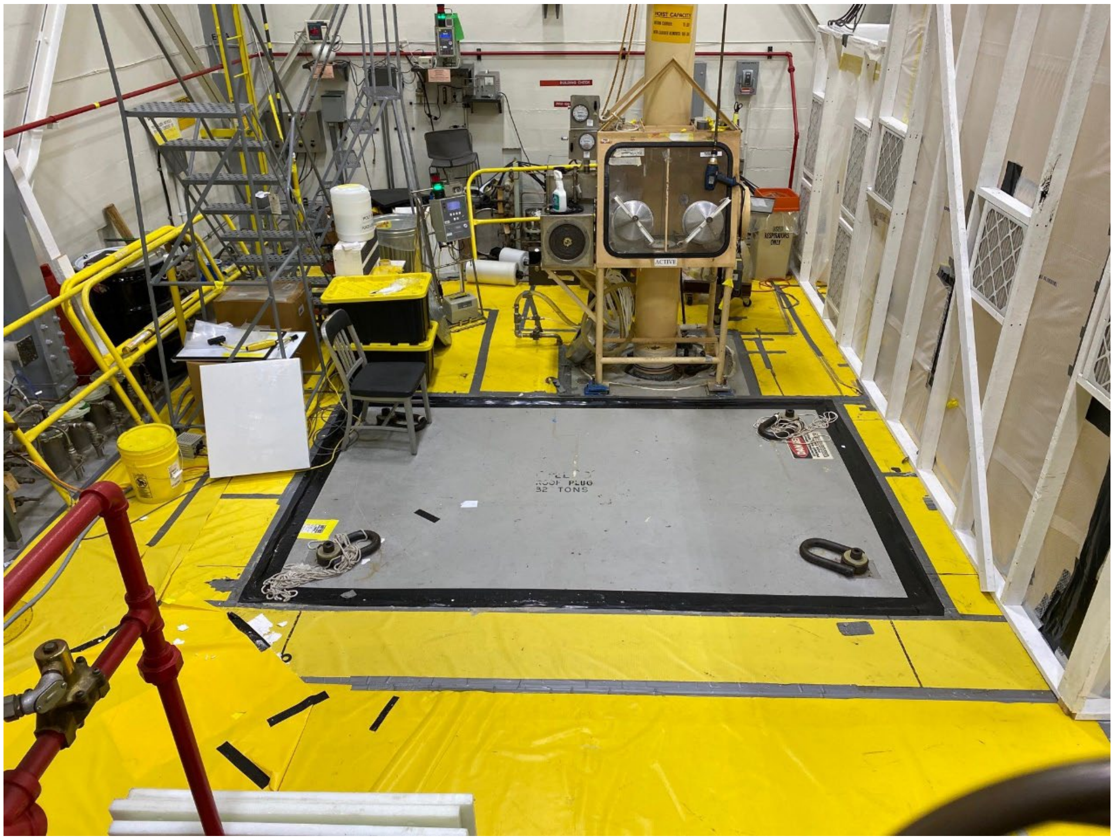

Figure 2. The area above Building 7930 Cell G as of February 2022.

The detector is anticipated to be placed between 10 and 12 ft. away from the transfer tube and glove box. The detector will be placed on a custom table with laser pointers to align the detector at the anticipated location of the carrier and 3 gal Can.

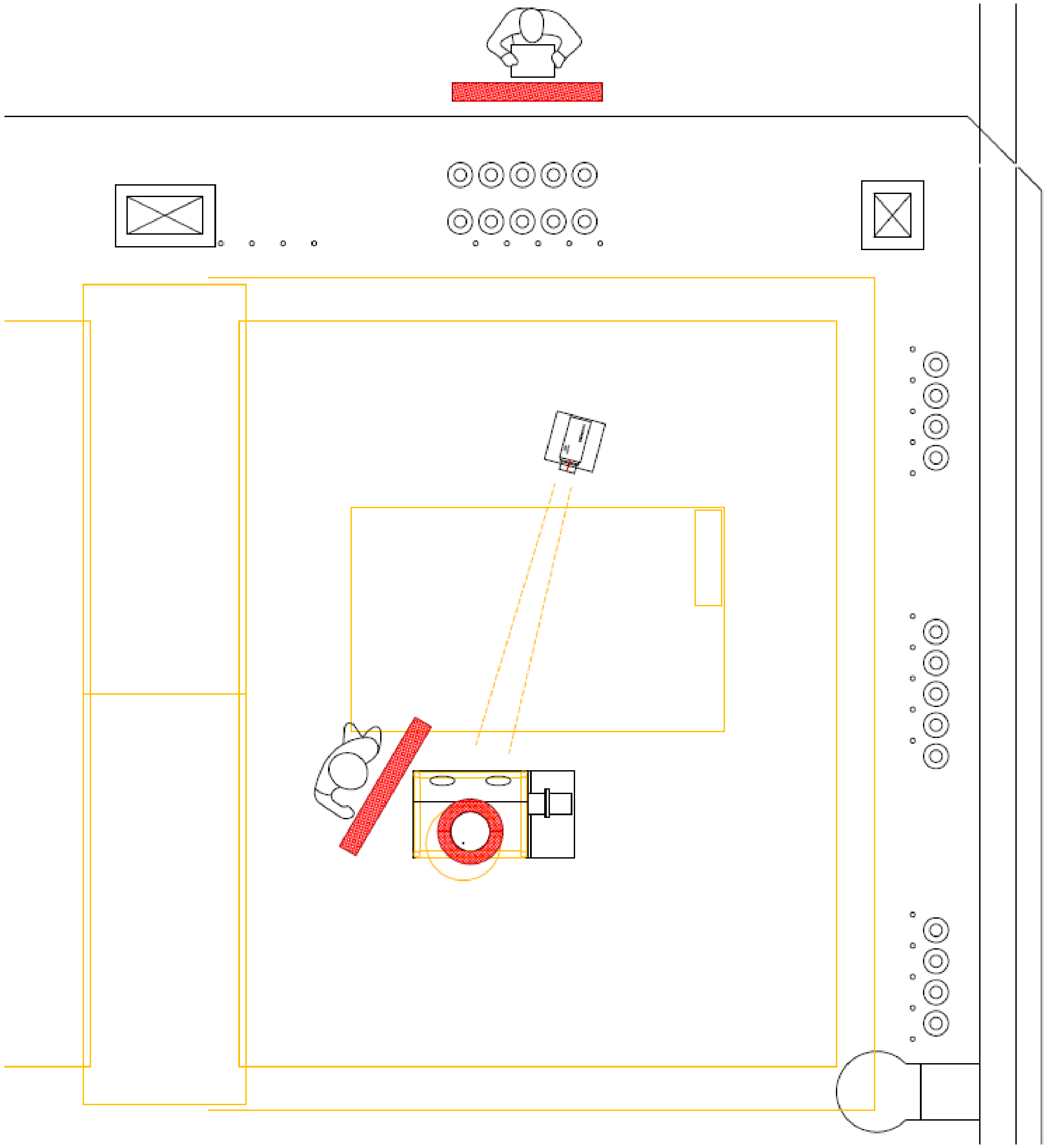

Figure 3. Sketch demonstrating detector position in relation to the glove box and transfer tube.

2.4 DATA COLLECTION AND STORAGE

All measurement data are stored on the measurement computer and transferred weekly to the 7930 cell G waste removal Teams site for long-term storage. All associated analysis files are stored on the internal SharePoint site.

A registered notebook will be used to record the measurements outlined in this measurement plan.

2.5 ANALYSIS PROCEDURE

The ISOCS analysis will be performed using NND-SOP-ISOCS-001. The analysis expert, Ms. Susan Smith, may deviate from the prescribed steps as necessary for the measurement scenario. A redlined copy will be maintained to record analysis changes common to all gamma spectra. This procedure will also be used as the basis for the final measurement and analysis procedure.

3. MEASUREMENTS AND ANALYSIS

Below is a description of the measurements to be performed as part of this measurement plan. The measurements are intended to be performed in order.

3.1 BACKGROUND SURVEY

After removing all nonessential equipment from the area above Cell G, a directional background survey must be performed above Cell G and in the proposed mock-up test area. The purpose of the background survey is to determine the need for a shield on the gamma detector to reduce background contribution.

Large background (i.e., signal from objects other than the contents inside the transfer tube) causes reduced sensitivity and increased measurement uncertainty. The latter may cause the misidentification of an LLW can as TRU.

The following equipment will be used during the background survey:

- Gamma Detector (Falcon 5000 or equivalent)
- Computer
- Thick shielding collar for the gamma detector to block higher energy gamma rays
- IdentiFINDER/RadEye

The procedure for the background survey is listed as follows:

1. Scan the area above the cell with an identiFINDER/RadEye to identify concentrations of radioactivity (i.e., hot spots).

2. Place the gamma detector in the proposed location for the mock-up or waste measurements on a low-mass box (e.e., foam, plastic, and so on).

3. Collect uncollimated/unshielded gamma background measurements, including the empty carrier in the transfer tube, before waste measurements.

4. Collect collimated/shielded background measurements in ~45° angular increments.

5. Collect collimated/shielded background with detector pointed downward towards the cell

Gamma detector measurements are performed for a minimum of 10 min in each position.

The output of the background survey will be maps of the measurement area indicating background levels measured with the identiFINDER/RadEye and the HPGe. The HPGe maps will be created as a function of the angle between the detector axis and the transfer tube.

In addition, the gamma detector spectra will be analyzed to identify the radionuclides present in the background. This step helps determine if there will be interferences with the identified gamma ray peaks of interest, which would result in less accurate measurements.

Based on these results, the following questions will be answered:

- Will shielding and/or collimator reduce background and increase confidence in measurements?
- Is the predetermined location for the HPGe appropriate?
- Is additional shielding of equipment or contamination areas required to improve measurement quality?
- What methodology should be employed in the measurement analysis to compensate for background?

The answers to these questions will influence the mock-up measurements and ultimate strategy for the waste measurements.

3.2 MEASUREMENT CONTROL

Per the WIPP WAC, background and instrument performance measurement control assays should be performed and tracked [1]. The results of all measurement control measurements will be recorded and tracked using control charts to ensure the system is within statistical control. An initial set of 30 replicate measurements will be performed in each location to establish the mean and standard deviation of each parameter.

Background measurements will be performed at the beginning of each day and again at midday. The background measurements will be measured for the same time as the measurements of the filled containers. The role of background measurements is to monitor the presence of radionuclides in the area.

Instrument performance measurements will be performed at the beginning of each day for 5 minutes with the detector-associated ISOCs Source. These measurements will evaluate the energy calibration, gamma ray peak resolution, and detector efficiency.

The results of the measurements will be judged according to the WIPP WAC guidance [1], which is paraphrased in Table 1. The required responses are the actions that will be performed if the system exceeds the warning or alarm limits.

Table 1. Measurement control decision table.

Category	Data range	Required response
Acceptable Range	$\lvert\text{Parameter}\rvert \leq 2\sigma$	No action required.
Warning Range	$2\sigma < \lvert\text{Parameter}\rvert \leq 3\sigma$	The performance check standard shall be rerun no more than two times. If the rerun performance check(s) are within the acceptable range, then work can proceed. If the system continues to fall outside the acceptable range, then the response for the Action Range shall be followed.
Action Range	$\lvert\text{Parameter}\rvert > 3\sigma$ OR Outside Boundary Limits	Work shall stop, the occurrence documented, and an investigation undertaken. The measurement system shall be removed from service pending successful resolution of all necessary actions, and all assays performed since the last acceptable performance check are suspect, pending satisfactory resolution. Recalibration or calibration verification is required prior to returning the system back to service.

3.3 EXPERIMENTAL SETUP

The experimental setup in each location is described here.

3.3.1 Laboratory Setting

Initial mock-up measurements will be performed under laboratory conditions where the measurement geometry and configuration can be well-controlled. The laboratory also provides a low background environment compared to the areas above Cell G in Building 7930. By controlling the measurement conditions, the impacts of departures from the main analysis assumptions can be easily quantified.

A mock-up has been constructed to replicate the transfer tube, poly shielding, and glove box supports. The Building 7930 team will provide materials representative of the measurement conditions and waste streams. All items provided will be cataloged and weighed. All measurements will be recorded in a notebook for later reference. The team is also looking into using a rotator for the mock-up measurements.

Figure 4. Mock-up transfer tube and materials in Building 7606A for laboratory testing. The front row shows the manipulator boot with ring. The second row shows (from left to right) the carrier, mock melted polyethylene paint can on top of a 3 gal can, mock melted polyethylene paint can with manipulator ring around it, wood support stand, and another 3 gal can. The back row shows the mock-up transfer tube including the polyethylene shield and glove box support structure.

At this time, strong sources will be used for the mock measurements that have gamma energies comparable to ^{249}Cf and ^{140}La, wherein the latter can be used to derive the amount of ^{252}Cf. Europium-152 and ^{133}Ba sources have been identified for use. All gamma measurements will be performed for at least 10 min. Table 2 and Table 3 list the measurement scenarios that will be performed to systematically quantify various aspects of the measurement uncertainty when compared to a set of baseline measurements. Apart from the baseline measurements, all measurement scenarios will be repeated three times per iteration.

Table 2. Mock-up measurement descriptions and associated uncertainty component.

Name	Uncertainty component	Planned measurements	No. of measurements
Baseline	Random	The baseline setup includes the 3 gal can placed inside of the carrier, which is then placed inside of the transfer tube with the 4 in. of polyethylene shield present. One or more sources will be placed inside the 3 gal can. The carrier will be positioned so that the open side is facing the detector and placed at a height such that the center of the 3 gal can aligns with the axis of the detector. Thirty replicate measurements will be performed and then analyzed using ISOCS. This series of measurements will serve as the baseline measured value and any deviation from true will be analyzed.	120
Carrier closed	Exclusion of carrier wall in model	Sources in the same position as the baseline measurements. The carrier is incrementally rotated by 45° from 0 (completely open) to 180°(completely closed).	60
Vertical positioning	Vertical positioning does not match model	Sources in the same position as the baseline measurements. The carrier will be positioned such that the top of the 3 gal can aligns with the detector axis. The carrier will then be incrementally raised by 1.5 in. with the last measurement equivalent to the bottom of the carrier aligned with the detector axis.	80
3 gal can Positioning	Horizontal positioning of 3 gal can does not match model	Because of the distance, 1–2 in. horizontal variation will not introduce statistically significant error. This will not be experimentally determined.	None

Table 3. 3 gal can configurations, mock-up measurement descriptions, and associated uncertainty component.

Name	Uncertainty component	Planned measurements	No. of measurements
Manipulator boot and ring	Representation of manipulator boot and ring	The manipulator boot and ring will be added to the 3 gal can. The sources will be repositioned to accommodate the manipulator boot.	12
Debris	Debris in measurement does not match matrix in model	An empty 3 gal can will be loaded with 3–5 different matrices that are representative of the debris in Cell G. Materials used in the matrix will be either provided by Building 7930 staff or approximated using available materials in the lab. Each matrix will be documented, photographed, and weighed. The sources will then be placed in the matrix approximating the baseline configuration as close as possible. Three matrices are planned: a low-density matrix (i.e., glass and polyethylene), high-density matrix (i.e., cables, metal, probes), and mixed debris (i.e., a mixture of items from the other two density matrices). The mopheads were added into the medium-density configuration.	36
1 gal paint can with melted poly	Representation of 1 gal can with melted poly	The addition of the poly can by itself is not credible because the can will always be topped off by other mixed debris. This uncertainty component will be represented by the topped off can representation.	None
1 gal paint can with poly positioning	Horizontal positioning of paint can does not match model	Because of the distance, 1–2 in. horizontal variation will not introduce statistically significant error. This will not be experimentally determined.	None
Hotspots in 1 gal paint can with poly	Divergence from uniform radioactivity inside poly paint can	Two or more sources will be grouped together to portray one or more hotspots inside the melted poly paint can. The source arrangement will be photographed and documented. Plan for 5 source configurations measured at 0 and 180° each.	36
Topped off 1 gal paint can with Poly	Mixed debris hotspots inside 1 gal paint can above melted poly	Representative mixed debris items will be added to the top of melted poly paint can. Two or more sources will be grouped together to portray one or more hotspots in the mixed debris on top of the melted poly. The source arrangements will be photographed and documented. Plan for 3 source configurations.	12
Mixed debris around 1 gal paint can with poly	Mixed debris surrounding melted poly paint can	Representative mixed debris items will be added to the 3 gal can surrounding the melted poly paint can. Two or more sources will be grouped together to portray one or more hotspots in the mixed debris. The source arrangement will be photographed and documented. Plan for 3 source configurations.	36

To represent a uniform distribution, which is a base assumption of the analysis software, all the measurements listed in Table 2 and Table 3 are performed four times, whereby the 3 gal can is rotated 90 degrees between measurements. To accomplish this, the sources must be placed at radii of ~6.42 cm and 11.12 cm.

All cases listed in Table 2 and Table 3 are performed with the ^{152}Eu sources. The following subset should be performed with spent ^{252}Cf sources that are available to the project:

1. Baseline
2. Manipulator boot and ring
3. Mixed density debris
4. Mixed debris around 1 gal paint can with poly

3.3.2 Above Cell G in Building 7930

The mock-up and equipment, or equivalent configuration, will be transferred to Building 7930 and stationed above Cell G. The measurement control limits will be validated for the measurement geometry in Building 7930. Three background measurements will also be performed to establish the magnitude of the background and identify any isotopes that may be present.

Measurement personnel and Building 7930 staff will work together to identify items, debris cans, or materials in Cell G that meet the measurement analysis assumptions of uniformity and have a pedigree of acceptable knowledge.

3.3.3 New Detector – GR6523

After receiving the new detector, the subset of measurements will be performed in the laboratory to verify the system's performance and uncertainty contributions are comparable to those estimated with the Falcon.

The following subset should be performed with spent ^{252}Cf sources available to the project:

1. Baseline
2. Manipulator boot and ring
3. Mixed density debris
4. Mixed debris around 1 gal paint can with poly

3.4 ANALYSIS METHODOLOGY

Analysis of all measurements will be performed using the Genie 2000 software and ISOCS. Because the uncertainty determined here is primarily how the ISOCS-based analysis differs from the true source values, the general assumptions of uniform matrix and radioactivity distributions will be maintained because that will be the basis of many of the waste measurements. Table 4 lists the components of the ISOCS models for each of the measurement groups described in Table 2 and Table 3.

Table 4. Mock-up measurement ISOCS models

Name	Geometry components	Name	Geometry components
Baseline	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can	Debris	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can centered • Matrix dependent upon measurement
Carrier closed	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can	Hotspots in poly paint can	• 4 in. poly shield • Transfer Tube • Open Carrier • 3 gal Can centered • Air outside can • 1 gal paint can centered • Melted Poly matrix
Vertical positioning	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can	Topped off poly can	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can centered • 1 gal paint can centered • Melted poly matrix • Debris matrix at top of 1 gal paint can
Manipulator boot & ring	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can centered • Manipulator boot • Manipulator ring	Mixed debris around poly paint can	• 4 in. poly shield • Transfer tube • Open carrier • 3 gal can centered • 1 gal paint can centered • Melted poly matrix • Debris matrix at top of 1 gal paint can

For each measurement, background will be subtracted. To represent the uniform radioactivity distribution, the 4 gamma spectra collected for each replicate will be added together and the total measurement time in the subsequent spectrum will be modified to represent the total measurement time of 40 mins. This summed spectrum will be analyzed via Genie 2000 using ISOCS efficiency calibrations.

After analysis is complete, the results for each measurement group will be compared to identify the uncertainty components after more material is added to the measurement scenario. Statistical methods will be employed to determine the relative measurement uncertainty across all measurements.

According to the WIPP WAC, the relative measurement uncertainties expressed in terms of percent relative standard deviation represent the precision of the measurements while accuracy is framed in terms of percent recovery. These values will also be calculated for each gamma ray peak that will be used for the waste stream measurements [1].

Two other quantities based on the background measurements performed as part of measurement control will be determined. These values are the lower limit of detection and minimum detectable activity (MDA). The LLD and MDA provide a measure toward the sensitivity of the measurements. Although it is not required to be reported for ^{249}Cf and ^{251}Cf, the difference in LLD and MDA between the two measurement locations will provide additional information regarding the influence of background. The Currie method [4], will be used to calculate the LLD and MDA.

4. RESULTS

After the measurement plan is completed, the following steps will be taken:

- complete a map of the background above Cell G,
- identify key contributors to the measurement uncertainty,
- propose recommendations to mitigate uncertainty components,
- complete a procedure for measurement and analysis of cleanout items, and
- document results in a technical manuscript.

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6. GLOSSARY

The following terminology is from the WIPP WAC and the definitions are included here for reference [1].

Activity—A measure of the rate at which a material emits nuclear radiation, usually given in terms of the number of nuclear disintegrations occurring in a given length of time. The common unit of activity is the curie, which amounts to 37 billion (3.7 × 1010) disintegrations per second. The International Standard unit of activity is the becquerel and is equal to one disintegration per second.

Far field measurement—A measurement where the maximum dimensions of both the container and detector are negligible compared with their separation.

Lower limit of detection (LLD)—The level of radioactivity which, if present, will yield a measured value greater than the critical limit with a 95% probability. The critical limit is defined as that value which measurements of the background will exceed with a 5% probability.

Minimum detectable activity (MDA)—The minimum detectable activity is the smallest amount of radioactivity in a sample that can be detected with a 5% probability of erroneously detecting radioactivity, when in fact none was present (Type I error) and also, a 5% probability of not detecting radioactivity, when in fact it is present (Type II error).

Nondestructive assay (NDA)—A general term for several techniques, such as gamma spectroscopy, passive/active neutron measurement, dose-to-curie, and calorimetry. These techniques provide information on the radionuclide content of waste and sometimes on its spatial distribution inside containers

Precision—A measure of mutual agreement among individual measurements of the same property made under prescribed similar conditions, often expressed as a standard deviation or relative percent difference.

Radionuclide—A nuclide that emits radiation by spontaneous transformation.

Transuranic (TRU) waste—Waste containing >100 nCi of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years and atomic numbers greater than 92, except for (1) high-level radioactive waste, (2) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations, or (3) waste that the NRC has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.