ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE (RFETS) DEPLOYMENT OF THE SUPER HIGH EFFICIENCY NEUTRON COINCIDENCE (SUPERHENC) COUNTER, A MOBILE PASSIVE NEUTRON COUNTING SYSTEM FOR STANDARD WASTE BOXES

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ABSTRACT

The 2006 Closure Project Baseline, May 21,1999 (the Closure Plan), commits RFETS Contractors and the Department of Energy (DOE) Field Office to the goal of completing the deactivation and decommissioning (D&D) of all the Rocky Flats plutonium processing and industrial areas by 2006. To meet the goals of the Closure Plan, RFETS plans to use the largest waste containers available. This measure will save time and money that can then be used to accelerate D&D. As a consequence of using larger waste containers, i.e. standard waste boxes (SWBs) for Transuranic (TRU) waste, RFETS requires additional assay systems. These large container assay systems must be certified by the Waste Isolation Pilot Project (WIPP) and RFETS Nuclear Material Safeguards. Failure in this area could move waste assay onto the critical path and potentially delay the closure of the site. RFETS will meet most of this need by deploying the Mobile Standard Waste Box Counter (SuperHENC) system for plutonium assay of SWBs. This mobile system, developed by Los Alamos National Laboratory (LANL), incorporates existing technology, along with state-of-the-art advances in passive neutron coincidence counting.

RFETS developed the specification for a mobile crate/SWB counter based on WIPP's methodology promulgated in the Quality Assurance Program Plan (CAO-94-1010) for drums. The specifications also include the RFETS Nuclear Materials Safeguards (MAN-010-NMS) measurement requirements for precision and accuracy. A mobile design was selected because it offers the greatest flexibility to RFETS as the Site's buildings are decommissioned. The SuperHENC will meet WIPP and RFETS requirements for precision and accuracy for the following waste forms: light metal waste, dry combustibles, and plastic, containing 0.05-320 g

weapons grade plutonium per SWB, at a nominal density ranging from 0.040 g/cc to 1.20 g/cc. LANL expects the SuperHENC to have a lower limit of detection of 35 mg of weapons grade plutonium and an average throughput of one SWB per half-hour.

This project is being funded equally by the Office of Science and Technology (OST, EM-50) Accelerated Site Technology Deployment Program and RFETS. The total costs of design, fabrication, calibration, validation and deployment are expected to be $3.3 million. Fabrication was completed in November 1999 with WIPP QAO Verification at LANL to be completed by the end of February 2000. The LANL Team expects to deliver SuperHENC to RFETS in March 2000. The technology will be transferred to the private sector through non-exclusive licensing agreements.

Many DOE sites are faced with the need to characterize large pieces of plutonium-contaminated equipment, such as glove boxes, that are most conveniently disposed of in larger containers like the SWB. RFETS expects to be the first site to deploy a WIPP-certified mobile SWB counter system. The SuperHENC system is expected to enable RFETS to count and ship a minimum of 800 SWB per year with one shift operation.

BACKGROUND

In the spring of 1997, EM-50 started the Technology Deployment Initiative (TDI) Program, which was later renamed, the Accelerated Site Technology Deployment (ASTD) Program. The ASTD Program was designed to provide funding to DOE Facilities to stimulate the implementation of demonstrated and proven technologies.

The Rocky Flats Site submitted three proposals to EM-50. One of the Site's proposals was selected, "Enhanced In-Situ Decontamination and Size Reduction of Gloveboxes", May 12, 1997. In October 1997, EM-50 requested a Deployment Plan. The Deployment Plan was written and then approved in January 1998.

The Deployment Plan outlined the deployment of technologies within three technology areas, radiological characterization, in-situ decontamination, and size reduction. A majority of the ASTD funding was devoted to radiological characterization of which $1.7 million was allocated for the Mobile Standard Waste Box Counter. RFETS is matching this funding with $1.6 million.

INTRODUCTION

The 2006 Closure Project Baseline, May 1999 (the Closure Plan) commits RFETS Contractors and the Department of Energy (DOE) Field Office to the goal of completing the deactivation and decommissioning (D&D) of all the Rocky Flats plutonium processing and industrial areas by 2006. To help meet these goals, RFETS D&D Projects plan to use the largest waste containers available. They are consequently placing most of the D&D TRU waste into standard waste boxes (SWBs). This action will translate into significant cost savings in the areas of size reduction, labor, and waste certification (approximately 9 standard 55-gallon drums are needed to hold the waste contained in 1 SWB). The money saved can then be used to accelerate D&D.

To illustrate the potential savings, RFETS estimated the Building 779 D&D Program would have had to spent an additional $4M on labor and personnel protective equipment to dispose of all plutonium contaminated gloveboxes and ducts into 55-gallon drums rather than SWBs. Building 779 contained less than 10% of the Site's gloveboxes. In addition, with less processing required to dispose waste in SWBs, personnel radiation doses are likely to be reduced.

Waste projections for the 2006 Closure Plan indicated that the generation rates of TRU waste and LLW would exceed the Site's current non-destructive assay capabilities. RFETS is striving to ensure that it has the NDA capability to keep up with current and future generation rates of these containers, because of the favorable economics resulting from use of the largest waste containers (LLW crate and TRU waste SWB) available. Failure in the assay area could cause large container waste assay to become the critical path task and delay the closure of the Site. The most conservative rates indicate that the Site will need at least two counters (probably three during the peak waste generation years) capable of assaying crates and SWBs. The current counter is certified for both Safeguards and Nevada Test Site (LLW) measurements, however, RFETS NDA personnel do not believe it can meet the more stringent quality, accuracy and precision requirements for WIPP. Because WIPP has not yet developed a Performance Demonstration Program (PDP) for the assay of SWBs, there are no commercial crate/SWB counters available for lease as there are for drums. The Site has placed a high priority on obtaining a SWB counter that is WIPP certifiable.

In the spring of 1998, RFETS NDA personnel developed a specification for a crate/SWB counter ("Specification for a Mobile Standard Waste Box Counter", Revision 0, May 27, 1998). The specification was based on WIPP's quality assurance program requirements for drums, as these were the only requirements available to follow. The specification included the RFETS measurement requirements for precision and accuracy (97-PLAN-MCA-002, "Nuclear Material Control and Accountability Plan"). For weapons grade plutonium quantities greater than 10 grams the Nuclear Materials Safeguards measurement requirements for accuracy are more stringent than the WIPP's Waste Acceptance Criteria (DOE/WIPP-069). Ultimately the precision and accuracy requirements that will be developed for SWBs will not be any more stringent and most likely less stringent than those for drums, given that the SWB volume is nine times larger than the 55-gallon drum. The specification also included a requirement that the counter be mounted in a trailer, because such a system would offer the greatest flexibility to the Site as more and more of the Site's buildings are decommissioned.

RFETS ASTD personnel reviewed the NDA equipment that was available from the commercial sector and the Los Alamos National Laboratory. This review revealed that LANL's NDA personnel had made some significant advances in the area of passive neutron coincidence counting. Los Alamos's new SuperHENC technology appeared to provide a low risk approach to meeting RFETS's performance and schedule requirements for a SWB counter. This conclusion was based on the performance of the existing commercialized High Efficiency Neutron Counter (HENC) drum counter in the Performance Demonstration Program (PDP) and on the published results of matrix correction improvements for the Super-HENC physics package. The present HENC drum system has participated in and passed cycles 2, 3, and 4 of the PDP and was the best instrument (lowest error) in cycles 2 and 3.

In July 1998, K-H under the RFETS ASTD Program issued an Interoffice Work Order (IWO) to LANL to design, fabricated, certify for WIPP, and deploy at RFETS a Mobile SWB Counter. The Counter will be capable of meeting the WIPP and RFETS Nuclear Materials Safeguards accuracy and precision requirements for the following waste forms: light metal waste, combustibles, and plastic, containing 0.05-320 g. weapons grade plutonium. The waste forms are expected to have a nominal density range of 0.040 g/cc to 1.20 g/cc and contain nominally 90% of the listed matrix with 10% impurity. Typically the waste will be heterogeneous with void space and will contain discrete items exceeding the nominal density range. Los Alamos expects the Super-HENC to have a 35 mg. of weapons grade plutonium lower level of detection.

SYSTEM DESCRIPTION

The Mobile Standard Waste Box Counter or SuperHENC is essentially a trailer mounted passive neutron coincidence counter designed to assay SWBs. Because it will be calibrated to WIPP's drum certification standards, it will also be capable of assaying a single drum. The assay technology is an upgrade to the High Efficiency Neutron Counter that is currently being used by Canberra and MCS. The SuperHENC was designed to be self-sufficient and capable of easily being moved from site to site. The only service the trailer needs is power (phone service is optional).

Design Criteria

The following are the main design features specified in the original IWO:

- The trailer shall have room for the counter, control room and any additional equipment that is necessary to operate the counter (i.e. gamma spectroscopy, dock, load cell, etc.)
- The trailer shall comply with industry standard height and width so as to allow transport on improved highways without special permits.
- The trailer shall be constructed of fire retardant materials and equipped with an alarm system triggered by heat and smoke sensors. The fire alarm system shall be equipped with audible and visual alarms.
- The trailer shall have phone and power hook-ups. The power requirements shall not exceed 480 volts, 50 amps. Clean power shall be provided for the computers and instrument loads.
- An uninterruptible source of power shall supply power to the data acquisition system for 10 minutes to allow orderly shutdown in the event of power loss to the trailer.
- The Counter shall be based on LANL's Super High Efficiency Neutron Counter (SuperHENC) technology. The system shall assay waste contained in SWBs, constructed of low carbon hot rolled steel.
- The counter shall be mounted inside a trailer, which shall have a heated and cooled control room to house the counter's electronic control cabinets and computers.
- All assay system functions shall be computer controlled, whereas loading and unloading shall be manually controlled.
- The SWB handling system shall incorporate an automatic mechanism to center SWBs within the assay chamber and move it into and out of the chamber. The system shall also be capable of assaying a standard 55-gallon drum.
- A digital, automatic weighing system shall be incorporated into the loading dock system, and shall be stored inside the trailer during transport. The scale shall have a digital readout with a capacity of up to 5000 pounds (or 2270 kilograms) with an accuracy of $\pm$10 pounds (5 kilograms). The automatic weighing system shall be integral to the system and shall be linked to the software to eliminate manual entry of the gross weight of each SWB.
- Emergency stop devices shall be provided in suitable locations to permit the operation to be halted from any location where the operator might reasonably observe an unsafe operating condition.
- The system shall be a "Turn-Key" System. A "turn-key" system is defined as a fully operable system capable of meeting the performance specifications without Contractor modifications.
- The equipment shall be rated to operate at 6,500 feet elevation.

The SuperHENC system meets all of these requirements (Figure 1). The trailer is a low boy design that measures 48 feet long by 8.5 feet wide and 13.5 feet tall. The ventilation system for the control room uses a heat pump for heating and cooling. Radiant heaters were installed into the cargo and counter areas. These heaters are only necessary for when the areas are occupied. The counter has been designed to operate in temperatures ranging from -20° to 120° F.

The power is routed through two transformers. The first transformer supplies power to the lights and heating and ventilation systems. The second transformer, which has two line conditioners, supplies clean power to the electronic cabinets and several outlets in the control room. The electronic cabinets are mounted on slides to allow easy access for maintenance. During transport, the electronic cabinets are bolted to the wall.

The counter is mounted in the low boy section of the trailer. A draw bridge type mechanism is used to raise and lower the dock. Four load cells are mounted on the dock for accurate weighing of the waste box or drum. The load cell has an accuracy of 10 pounds. The dock is only 37 inches off the ground when it is lowered. The LANL design enables the dock systems to 1) allow for rapid deployment and 2) minimize the dock's overall height off the ground. The trailer is equipped with an air ride suspension to minimize vibration to the counting equipment during transport. The stairs to the control room are mounted on slides in the control room floor and can be easily deployed by one person. The trailer has four tie down straps to secure the system for the high winds occasionally encounter at Rocky Flats.

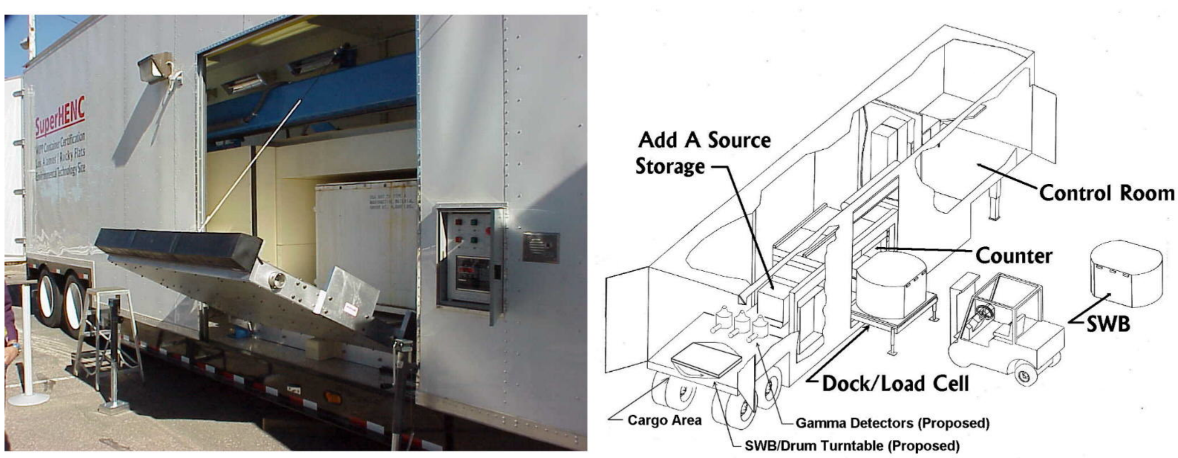

Figure 1, Dock Side and Isometric Views of SuperHENC Trailer

The fire detection system is interlocked with the power distribution system and when the fire detection system is activated, power to the trailer is disconnected. In the initial design meetings the installation of an active fire protection system (a Halon-type system) was discussed. The manufacturer said such a system would not be effective when the dock door was open during routine counting operations, and this concept was dismissed. Therefore the passive system was selected and fire retardant materials were used for the trailer construction.

When the system was first specified, gamma-ray spectroscopic analysis was omitted from the requirements, because site personnel believed that the radionuclides of interest could be identified through acceptable knowledge. The Site has since determined that direct measurement is preferable; therefore a commercial gamma spectroscopy system will be installed into the trailer (cargo area) later in FY2000.

Performance

The SuperHENC will be used to perform two assay functions. One for meeting WIPP criteria and second for meeting Nuclear Materials Safeguards criteria. These criteria are similar in only a few weapons grade plutonium ranges. The differences being Safeguards requires higher accuracy and precision for weapons grade plutonium masses greater than 10 grams. When comparing these values, the more stringent values of the two requirements shall govern. The following are the performance requirements for the SuperHENC:

- The assay system shall be capable of a throughput of no less than 1 SWB per half-hour on the average. (The assay time is from start of assay to finish of assay and does not include loading or unloading operations.)
- The assay system shall comply with all applicable DOE Orders and all other requirements such that it is capable of Waste Isolation Pilot Plant (WIPP) certification.
- The assay system shall meet the requirements stipulated in Section 9 of the Quality Assurance Program Plan, including the following WIPP performance specifications (Table A-1):
- All calculations shall be performed via the methodology stipulated in CA0-94-1010, "Trans-uranic Waste Characterization Quality Assurance Program Plan" and shall meet the requirements presented in Table A-1.

Table A-1

Activity Range in alpha-curies[a]	Precision[b] (% RSD)	Total Bias (%)	Accuracy [Noninterfering Matrix[c]] % R
>0 to 0.02	20	Low: 25 High: 400	Low: 75 High: 125 (± 25%)
>0.02 to 0.2	15	Low: 35 High: 300	Low: 50 High: 150 (± 50%)
>0.2 to 2.0	10	Low: 67 High: 150	Low: 75 High: 125 (± 25%)
>2.0	5	Low: 67 High: 150	Low: 75 High: 125 (± 25%)

a Applicable range of TRU activity to which the QAOs apply, units are Curies of alpha-emitting TRU isotopes with half-lives greater than 20 years

b ± 1 relative standard deviation based on 15 replicate measurements of a non-interfering matrix

c Ratio of measured to known values based on the average of 15 replicate measurements of a non-interfering matrix

- The assay system shall also comply with RFETS Nuclear Materials Safeguards requirements for precision and accuracy (MAN-010-NMS, "Nuclear Material Safeguards Manual") as follows in Table A-2 (Please note: RFETS Nuclear Materials Safeguards modified this table in April 1999. It differs from the one in the original specification in that the number of weapons grade plutonium ranges were compressed from 5 to 3).

Table A-2[a]

RANGE OF Pu (g)	PRECISION (%RSD)	ACCURACY (95% Confidence Interval for mean)
≤1.0	± 50%	± 50%
>1.0 to ≤10.0	± 25%	± 25%
>10.0	± 10%	±15%

[a] Reference: *Nuclear Material Control and Accountability Plan*, 97-PLAN-MCA-002

To meet RFETS performance specification Los Alamos engineered and assembled an integrated system composed of proven crate counter components. The SuperHENC consists of components of the HENC drum counter and other Los Alamos-developed components that are incorporated into existing, Los Alamos-built, instruments. The mechanical and SWB handling assembly were based on the existing Los Alamos Crated Waste Assay Monitor and HENC mechanical structures. These base components were re-engineered and integrated to accommodate:

- The SWB size.
- Lower detection limits in the presence of the high cosmic ray background at high-elevation sites for low-activity waste.
- High precision and accuracy requirements for large volumes (which demand improved capability to correct for matrix, self-shielding and positional effects for high-activity waste)
- A Mobile System.

Los Alamos personnel suggest that the SuperHENC is the most advanced large container, passive neutron coincidence counter currently in existence. The following are the areas where the SuperHENC is an improvement over commercially available systems:

- Higher efficiency detectors and moderator design. Los Alamos has improved both the ^{3}He tubes and the moderator design to give better performance than commercially available physics packages. The counter efficiency has been measured at 40.5%. These improvements permit detection at lower Pu loading for a given count time, and permit improved matrix correction (greater accuracy) for high Pu loading.
- Advanced matrix corrections using the optimum combination of add-a-source, multiplicity analysis, and Monte Carlo Neutron/Photon (MCNP) model simulations. Add-a-source analysis uses a ^{252}Cf source placed at several positions beneath the SWB to define matrix-derived corrections. These improvements are needed to meet the Safeguards accuracy requirements at the high Pu mass loadings in the large SWB. Commercial physics packages either do not have the add-a-source or do not implement it with full effectiveness for the SWB geometry.
- New electronic techniques to make the measured response less sensitive to the position of the Pu in the SWB. This improvement is needed to meet the accuracy requirement at high mass loading.
- Advanced detector material design to reduce the cosmic-ray background source term. This improvement results in a factor of two reduction of the SuperHENC cosmic ray background over the available systems.
- New software analysis to reduce the cosmic-ray neutron background. The "Truncated Multiplicity" (TM) method can eliminate the background events with high multiplicity and the ratio of high/low multiplicity counts is used to correct for spallation neutron background in the iron matrix.

- A new hardware/software method to greatly suppress cosmic ray backgrounds, which is the intellectual property of Los Alamos and has not been transferred to the vendors. This method, together with other techniques described above, is necessary to meet the 35 mg detection limit for weapons grade plutonium at Rocky Flats.
- The fraction of neutrons in the coincidence gate has been increased using new design techniques in the electronics and detectors. This improvement reduces the statistical error at all Pu mass loadings and it makes an advanced multiplicity analysis practical. These improvements are not commercially available.
- LANL has developed an advanced multiplicity analysis that uses new algorithms for making use of the triples rate that reduces the error from the multiplicity analysis. This technology is needed for the high Pu mass loadings where the Pu distribution in the SWB is concentrated in a region that has anomalous neutron shielding properties. This advanced analysis is not available for commercial systems.

CALIBRATION AND VALIDATION: WIPP CERTIFICATION PROCESS

The calibration is comprised of several steps. These elements include 1) constructing a MCNP model for the system, 2) mapping chamber response, 3) obtaining calibration measurements 4) establishing the coincidence calibration curve 5) establishing multiplicity calibration parameters and 6) validation of the calibration on independent plutonium standards. Each of these steps is discussed in more detail below.

MCNP Model

Early in the development process, an MCNP model was developed. This model was used to optimize final design parameters. The model was benchmarked after final fabrication so it provides a quantitative validation of observed response from standards. The model can then be used to investigate system performance for situations that are difficult to achieve in the field. The quantitative response of the model will be used to show that the calibration still meets Safeguards and WIPP precision and accuracy Quality Assurance Objectives (QAOs) at 325 g Pu, as there are insufficient viable standards at a single site to achieve this loading. Because the measured response is linear between the measured (<188 g) and the 325g, the extrapolation using MCNP is valid.

Chamber Response

A known strength ^{252}Cf source was positioned at about 60 different X-Y-Z coordinates within the chamber and the chamber response was recorded. These measurements provide a plot of the chamber efficiency. Figure 2 shows the relative counting efficiency for a vertical cross section of the detector at a height of 50cm above the floor. The efficiency is flat to within 2% over the dimension of the SWB. Ideally, the chamber response would be "flat" – i.e. there would be no variation in chamber response by position. In a typical matrix, there is generally an efficiency change with position. This efficiency will be factored into the Total Measurement Uncertainty.

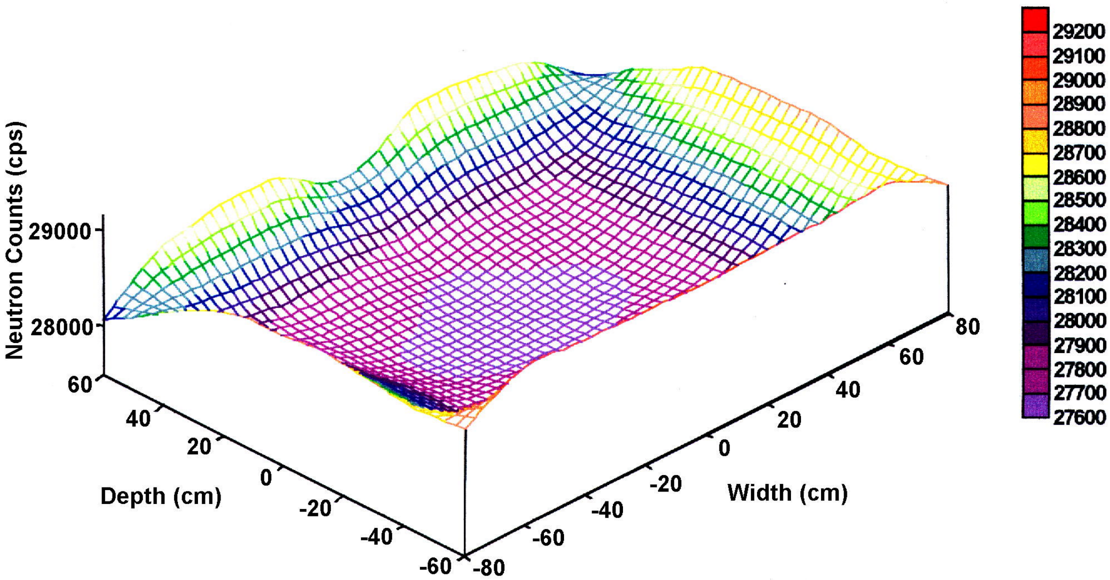

Figure 2, Chamber Response Profile at 40 cm Elevation

Calibration Measurements

Six replicate measurements at five different weapons grade plutonium loadings were taken to establish calibration parameters. The calibration standards consist of weapons grade plutonium oxide in diatomaceous earth and are National Institute of Standard and Technology (NIST) traceable. The standards were loaded in an empty SWB container at the volume average position for all calibration measurements. Measurements were taken for a set time period of 1000 seconds and the results are used for the coincidence calibration. The results will be used for both the coincidence and multiplicity calibrations.

Coincidence Calibration Curve

The calibration standard measurements (corrected for any multiplication in the highest loading) define a straight line through the origin, with counts per second on the y- axis, and $^{240}Pu_{eff}$ mass on the x-axis. There are no matrix corrections applied to the calibration data because the standards are placed in an empty box. This line becomes the calibration curve used in coincidence mode for all matrices and all container types. Matrix specific and container size corrections are handled in the count rate adjustment using the Add-A-Source (AAS). The AAS correction takes the doubles response from the SWB matrix case back to the empty case used for the calibration.

Multiplicity Matrix Corrections

For matrix loadings where the AAS correction factor is large, the multiplicity ratio of triples to doubles counts is used to determine the effective efficiency and the correction factor to correct the doubles rate to the calibration line.

Validation Measurements

After the coincidence calibration is set, the calibration is validated (qualified) by assay of weapons grade plutonium standards that are different from the calibration standards. The suite of National Test Program (NTP) Performance Demonstration Plan (PDP) standards residing at LANL will be used for verification. Fifteen replicates will be taken at four weapons grade plutonium loadings.

The set of sixty measurements will be taken in an IDC 330 (combustibles) SWB standard and then repeated in an IDC 480 (light metals) SWB standard. These samples will be measured to a predetermined precision, as this is the intended mode for waste samples.

The data will be used for two purposes: 1) to qualify the SuperHENC for performing accountability measurement prior to its arrival at RFETS, and 2) to show that it is capable of meeting the WIPP QAOs for 55-gallon drums (DOE/WIPP-069).

Once the system arrives at RFETS, the Site's PDP standards will be used to demonstrate compliance to the WIPP 55-gallon drum QAOs. SWB standards will also be used to test the system performance.

COSTS/SCHEDULE

The development of the SuperHENC system was initially projected to cost ~3.2 million. Modifications made to the design during review raised the total cost approximately $100,000, bringing the expected cost to $3.3 million. As of December 20, 1999, costs from Los Alamos for design, procurement, fabrication and initial stages of calibration at Los Alamos were approximately $2.35 million.

The initial project schedule projected design completion at the end of Calendar Year (CY) 1998, fabrication complete in summer of 1999, delivery at the end of CY 1999, and completion of the project in March of 2000. The schedule slipped during design, but recovered during fabrication, however a funding shortage in the summer of 1999 caused a work stoppage for several months. Current plans call for transporting the completed system to Rocky Flats in early March 2000, and completion of the project in summer 2000.

CONCLUSION

The Mobile Standard Waste Box Counter (SuperHENC) will be a valuable asset to the Rocky Flats Environmental Technology Site (RFETS). It will be part of the technology that will help enable RFETS to meet its closure goals and lower the costs of D&D. RFETS expects to be the first site to deploy a WIPP certified mobile standard waste box counter system. The SuperHENC will incorporate Los Alamos's latest advances in NDA assay technology. It will be both a WIPP and Nuclear Materials Safeguards certified waste assay system. The SuperHENC will be used initially to assay metal, plastics and combustible waste matrixes. Later it will be validated on mixed matrices thus allowing the Site to relax its stringent waste segregation procedures. The SuperHENC will assay up to two Transuranic (TRU) standard waste boxes per hour, which translates to between 1500 to 2000 standard waste boxes per year. For the next year, RFETS expects to generate approximately 800 SWBs. The mobile design offers RFETS the greatest flexibility as the Site deactivates and decommissions both the weapons grade plutonium and industrial area buildings.

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