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Title: Calibration of the Crated Waste Assay Monitor (CWAM) for Deployment at the Y-12 Plant

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Calibration of the Crated Waste Assay Monitor for Deployment at the Y-12 Plant

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ABSTRACT

The Crated Waste Assay Monitor (CWAM) system was designed at Los Alamos National Laboratory to address safeguards and waste measurements issues at the Oak Ridge Y-12 Plant. CWAM utilizes the differential dieaway technique (DDT) to measure ^{235}U-contaminated waste inside B-25 waste crates. The performance objectives for CWAM were twofold: (1) ensure large quantities of material do not leave the Y-12 Plant via waste boxes, and (2) measure fissile contamination at levels as low as the Tennessee landfill limit of 35 pCi/g. This paper begins with a history of the CWAM project describing the motivation for the redesign effort, original goals set for the project, and the design choices made to achieve these goals. The remainder of the paper presents experimental results from a matrix calibration study that included both passive and active assays on three hydrogenous matrices, two B-25 crates and one SWB, and one metallic B-25 crate. The reduction in spatial variation with multiple interrogation positions for each of the surrogate matrices is shown. Sensitivity values for these matrices are also given both in terms of ^{235}U mass (g) and activity concentration (pCi/g).

INTRODUCTION

In March 2000, a new assay system to measure ^{235}U-contaminated waste inside B-25 waste crates was installed at the Y-12 NDA Facility in Oak Ridge Tennessee. The conceptual design basis for the Crated Waste Assay Monitor (CWAM) was a scaled-up version of the Combined Thermal Epithermal Neutron (CTEN) instrument, a Los Alamos National Laboratory assay system for 208-liter drums. Both instruments use the differential dieaway technique (DDT) developed in the late 1970s for the assay of transuranic waste at the < 10 nCi/g level.[1] The high sensitivity to fissile isotopes (^{235}U and ^{239}Pu) and the ability to assay high density matrices such as scrap metal made DDT the best technique to meet Y-12 waste assay requirements.

Although the new assay system is called CWAM, it bears no resemblance to its predecessor, one of the earliest LANL designs that bears the same name. The original CWAM was designed and built by John Caldwell in the mid 1980s for the Oak Ridge Diffusion Plant in support of the Centrifuge Program.[2,3] Its primary purpose was the assay of ^{235}U in failed rotors contained in 4' x 4' x 4' crates using thermal neutron interrogation. In addition to the traditional DDT assay, a secondary function was the assay of ^{238}U in spent alumina contained in 55-gallon drums by fast fission and delayed neutron counting. In both cases, the measured isotope was expected to be at gram (^{235}U) or kilogram (^{238}U) levels.

In 1990, the low-level waste disposal area known as Bear Creek Burial Ground located on the Oak Ridge Reservation was closed by the state of Tennessee. With on-site disposal of low-level waste no longer possible, the need arose for a strong operational NDA program as a means to identify and quantify isotopes for off-site shipments of radioactive waste. For waste containing less than 35 pCi/g of total uranium, on-site sanitary landfill disposal was still an option. For those containers above this fiducial, the amount of ^{235}U had to be quantified to meet DOT regulations and to ensure compliance with waste acceptance criteria at low-level waste disposal facilities. An assessment of the Y-12 waste inventory identified the need for a combination of passive gamma and active neutron assay systems. After the collapse of the Centrifuge Program, CWAM was therefore obtained by the Y-12 Plant, to measure low levels of ^{235}U (sub-gram quantities) in the higher density waste streams contained in B-25 boxes (4' x 4' x 6' containers).

DESIGN

Due to limited operational funds, only slight modifications to the original system were initially approved. However, even with modifications, it became apparent that the system would not be able to measure at the 35 pCi/g level. As the Y-12 site became strained by storage requirements for B-25 boxes, the decision was made to contract LANL to redesign the CWAM system. Design goals were directed at correcting the deficiencies of the original system[a] and can be summarized as follows:

1. Design the moderating cavity and detector configurations using Monte Carlo techniques (MCNP) optimizing thermal interrogation flux profile and fission neutron detection efficiency.

2. Design the mechanical structure and automated crate handing system to accommodate the size and maximum loading of B-25 boxes.

3. Minimize the variation in fissile signal response due to non-uniform neutron interrogation by the use of multiple generators and/or pulsing at different positions along the B-25 box.

4. Update and streamline the detector signal processing electronics and reduce the number of cable runs to the control console.

5. Design data acquisition and analysis software that is well-documented, user-friendly, and easily modified for calibration of new waste streams.

As with all projects of this magnitude, a combination of physics and cost went into the design of the new system. Components that affected neutron population during an assay such as the specifications of the moderating cavity and detectors, were based on Monte

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[a]Deficiency is in reference to the system's ability to measure low-level waste, not to its original design specifications.

Carlo calculations. The figure of merit used in comparing alternative MCNP designs was the product of the thermal flux and detector efficiency. Maximizing the product of these two quantities in theory maximizes sensitivity. To achieve the necessary accuracy, efforts were directed at reducing spatial variation of the fissile signal. This was accomplished by placing the neutron generator on a motorized track thus allowing interrogation from several positions within the assay chamber.

Structural and material handling designs were scaled-up versions of the drum-sized CTEN instrument, which at that time was in the calibration phase at LANL. An electronic module for signal processing, the Preamplifier, Amplifier, Discriminator, ECL Driver Module (PADEM)[4] and a CAMAC-based multiplicity module, Pulse Arrival Time Recording Module (PATRM)[5] that had been developed and funded by the CTEN project were incorporated into the CWAM electronic system. Scaler data acquisition hardware (CAMAC-based) was also patterned on the CTEN design allowing existing software to be adapted with only minor modifications. Although the final CWAM design does not necessarily represent the best engineering solution, all original design goals were met. More importantly unlike the original CWAM, the new instrument is capable of measuring ^{235}U at the 35 pCi/g level thus satisfying Tennessee Sanitary Landfill regulations.

OPTIMIZING NEUTRON GENERATOR POSITION

As a first approximation, the number of induced fissions in a DDT assay is proportional to the interrogating thermal flux and the concentration of ^{235}U in the waste crate. By measuring prompt neutrons from the thermal interrogation region, sensitivities of a few milligrams of fissile mass are attained in a relatively short time. However, the degree of accuracy required to meet performance objectives usually dictates the use of corrections to account for the effects of matrix type and source distribution on the measured response.

The ability to interrogate from more than one position in a DDT assay improves the overall accuracy by providing a more uniform flux profile. In CTEN, the neutron generator is located in the back left corner and the drum makes one revolution during the entire assay. In CWAM, multiple interrogations are performed at predetermined stops along a motorized track located on the back wall of the assay chamber. A complete assay is the sum of the individual interrogations. Figure 1 shows the various neutron generator positions schemes tested during the matrix characterization study. Positions A, B, and C are designated back right, back center, and back left, respectively. Positions D, E, and F result from turning the crate around and interrogating on the other side. The optimal measurement scheme is the one that minimizes the variation of the fissile signal as a function of source position.

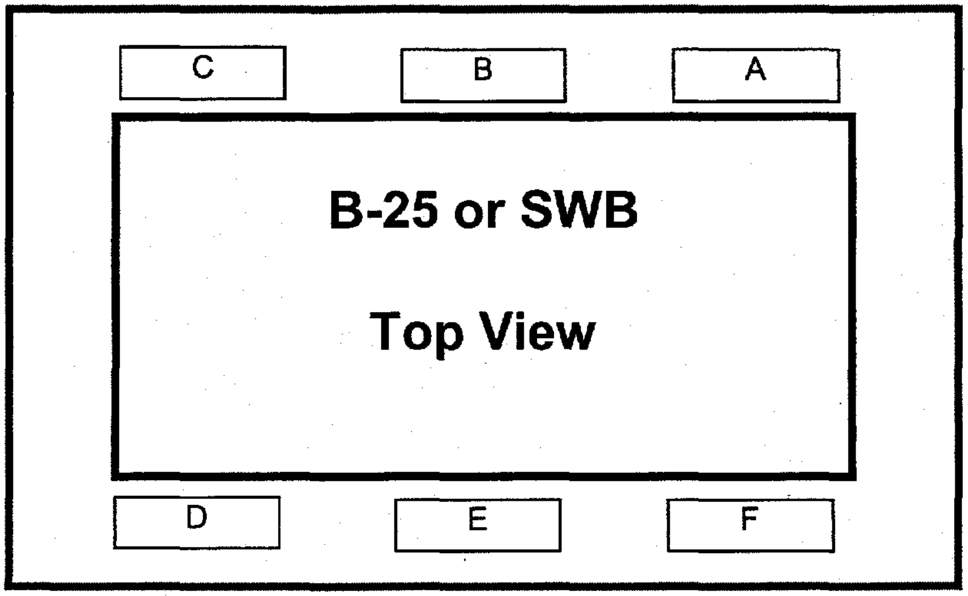

Figure 1. Neutron generator measurement schemes tested during calibration study.

Table 1 shows the spatial variation over 72 positions in each of the surrogate matrices for the five measurement schemes tested. The source used was a depleted uranium metal bar with an apparent ^{235}U mass of 625.6 mg (corrected for self shielding). The generator was pulsed at 50 Hz for 10,000 pulses per position. Although spatial variation is greatest for the hydrogen-containing matrices, the ability to interrogate on both sides of the crate has a significant effect. The optimal configuration was obtained with four positions in which the crate is rotated and interrogated on the back left and right positions. Assay time is 800 seconds with four neutron generator stops at 10,000 pulses per stop. Total measurement time including opening and closing the door, moving the loading platform, and operating the forklift is approximately 50 minutes.

Table 1. Variation of fissile signal over 72 positions for five measurement schemes.

Number of Stops	**Generator Positions**	**Positional Variation (RSD%)**			
		Dry Combustibles	**Wet Combustibles**	**Polyethylene B25**	**Carbon Steel**
1	B	27	37	31	26
2	AC	21	38	29	25
3	ABC	22	35	27	25
4	AC & DF	8	17	11	22
6	(ALL)	12	18	16	22

SENSITIVITY

Although the sensitivity for nondestructive waste assay systems is generally quoted as three sigma over background, the more widely accepted approach is based on Currie's 1968 paper, "Limits for Qualitative Detection and Quantitative Determination."[6] A Martin Marietta Energy Systems position paper published in 1993 was strongly based on the Currie's statistical techniques and therefore was used in calculating landfill limits

Table 2 shows the detection levels for the best, worse, and average positions for each surrogate matrix. A more useful parameter for Tennessee landfill regulations is the detection level in terms of activity concentration of matrix material. Tables 3 and 4 show the detection limits in terms of specific activity for depleted (0.2% ^{235}U) and highly enriched (93.3% ^{235}U) form, respectively. Activity calculations include contributions from ^{234}U, ^{235}U, ^{236}U, and ^{238}U.[7] All of the results quoted in this section are based on the standard 4-position 40,000 pulse active assay.

From the results in Tables 3 and 4, it is clear that CWAM is able to screen both depleted and enriched uranium at the 35 pCi/g level at all positions within all the surrogate matrices.

Table 2. Detection levels in mg ^{235}U for the best worse, and average positions for $\alpha = \beta = 0.05$ (95% confidence level).

Surrogate Matrix	Best Position (mg ^{235}U)	Worse Position (mg ^{235}U)	Crate Average (mg ^{235}U)
Empty B-25	-	-	12.5
Empty SWB	-	-	11.2
Dry Combustibles	12.7	19.9	14.9
Polyethylene	8.8	18.2	10.9
Scrap Metal	26.6	79.7	32.3
Wet Combustibles	19.4	49.4	27.7

Table 3. Detection levels in pCi/g for depleted uranium for the best, worse, and average positions for $\alpha = \beta = 0.05$ (95% confidence level).

Surrogate Matrix	Best Position (pCi/g)	Worse Position (pCi/g)	Crate Average (pCi/g)
Dry Combustibles	8.3	13.0	9.7
Polyethylene	5.4	11.1	6.6
Scrap Metal	5.9	17.6	7.1
Wet Combustibles	6.9	17.7	9.9

Table 4. Detection levels in pCi/g for 93.3% enriched uranium for the best, worse, and average positions for $\alpha = \beta = 0.05$ (95% confidence level).

Surrogate Matrix	Best Position (pCi/g)	Worse Position (pCi/g)	Crate Average (pCi/g)
Dry Combustibles	3.0	4.8	3.6
Polyethylene	1.9	4.1	2.4
Scrap Metal	2.1	6.4	2.6
Wet Combustibles	2.5	6.5	3.6

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