MULTI-PURPOSE CRATE COUNTER FOR THE RFETS

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ABSTRACT

Rocky Flats Environmental Technology Site (Site) is on a very aggressive Decontamination & Decommissioning (D&D) path and is scheduled for closure in 2006. Nondestructive assay (NDA) capabilities at the Site required upgrading and expansion to accommodate this schedule. As part of the crate capability upgrade, BNFL Instruments Inc. was contracted to provide a combined Imaging Passive Active Neutron (IPAN) and Gamma Energy Analysis (GEA) Multi-Purpose Crate Counter (MPCC) for the Site for identifying and analyzing the presence of plutonium, uranium, americium and other elements of interest in varying mass ratio concentrations in low, medium and high density waste matrices contained in wood and metal crates of various sizes. The MPCC is required to comply with both WIPP and Nuclear Material Safeguards (NMS) performance requirements for accuracy and precision for 55-gallon drums. Fifty-five gallon drum criteria were selected as a conservative requirement as crate criteria have not been promulgated to date. The MPCC is also capable of segregating low level waste from transuranic waste at 60 nCi/g levels. To date, the MPCC has been calibrated for two crate sizes (SWB and B-25) and four matrix types (Dry Combustibles, Wet Combustibles, Plastics and Light Metals). The MPCC vastly expands the Site crate capability as it can accommodate waste boxes up to 11,000 pounds and can measure crates of any matrix type that fall within the calibrated range. Factory functionality testing of the MPCC was successfully completed during the first two weeks of October 1999. The MPCC passed all the functionality tests demonstrating initial compliance with both WIPP and NMS requirements. Final algorithm implementation is scheduled upon commissioning of the MPCC at RFETS. A detailed description and report on the performance and status of the system is presented in this paper.

INTRODUCTION

Rocky Flats Environmental Technology Site (Site) is on a very aggressive Decontamination & Decommissioning (D&D) path and is scheduled for closure in 2006. Nondestructive assay (NDA) capabilities at the Site required upgrading and expansion to accommodate this schedule. Current Site crate assay capability consists of a single differential die-away system that was built for the Site in the 1980s by Los Alamos National Laboratory (LANL). The existing system cannot accommodate the weight loadings that Site D&D requires, nor is it suitable for Waste Isolation Pilot Plant (WIPP) certification. As part of the crate capability upgrade, BNFL Instruments Inc. was contracted to provide a combined Imaging Passive Active Neutron (IPAN) and Gamma Energy Analysis (GEA) Multi-Purpose Crate Counter (MPCC) for the Site. The MPCC is a measurement instrument for identifying and analyzing the presence of plutonium, uranium, americium and other elements of interest in varying mass ratio concentrations in low, medium and high density waste matrices contained in wood and metal crates of various sizes. A photo of the MPCC is shown in Figure 1.

Figure 1 Photo of the MPCC at the factory.

SYSTEM DESIGN

System Cavity

The MPCC utilizes a polyethylene shielded assay cavity that is made up of three sections: front, center, and rear. See Figure 2. The front section houses the door assembly and provides polyethylene-shielded space for the crate to be scanned. The middle section houses the neutron detectors and neutron generator. The rear section houses the gamma detectors and also provides polyethylene shielded space for the crate to be scanned. The system is designed to physically accommodate crates up to 59”W x 59”H x 91½”L. A conveyor system runs the length of the cavity allowing a linear scan of a crate.

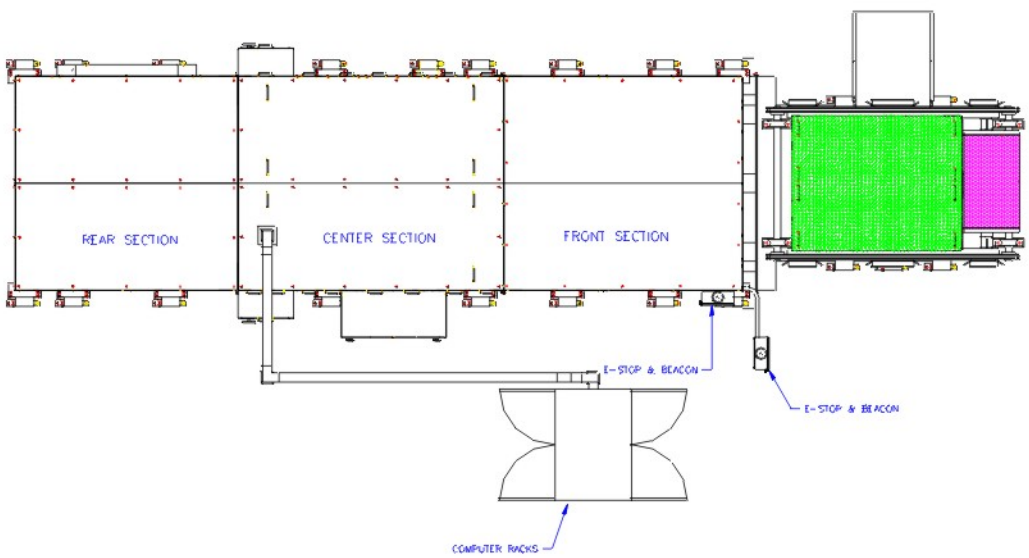

Figure 2 Top view of the MPCC

Neutron Detectors

The top, bottom, neutron generator and level (opposite the neutron generator) sides of the center section of the assay cavity contain cadmium shielded ^{3}He detector packages and polyethylene shielding. See Figure 3. The neutron generator side of the assay cavity contains the Zetatron neutron generator, housed within a moderator assembly (MA) constructed from lead, graphite and polyethylene.

The shielded detector packages comprise an outer low-energy neutron shield of cadmium. Inside the cadmium are ^{3}He neutron detectors arranged in one row and embedded within blocks of polyethylene. These detector packages are therefore sensitive to fast neutrons and insensitive to thermal and low-energy neutrons. The top and bottom of the measurement cavity each contain 20 ^{3}He detectors. The side opposite the neutron generator (level side) contains 22 ^{3}He detectors and the side with the neutron generator contains 16 ^{3}He detectors (MA side). This makes for a total of 78 ^{3}He detectors.

Two types of flux monitor detectors are installed in the MPCC: MA and Cavity flux monitors. The MA flux monitor comprises a bare ^{3}He detector, which is located inside the MA close to the neutron generator. This detector is used to monitor the magnitude of the interrogation flux produced by the neutron generator during the active measurement. Two types of cavity flux monitor detectors are installed inside the assay cavity on the side opposite the neutron generator. These detectors are used to quantify the absorption and moderation properties of the waste material in a crate. The two detector types are bare and shielded cavity flux monitors. A bare cavity flux monitor is a ^{3}He detector that is installed within a cadmium collimator arrangement, which is collimated so that their field of view is limited to neutrons exiting from the waste crate. A shielded cavity flux monitor is a ^{3}He detector that is installed within polyethylene that is completely shielded in cadmium. The two types of cavity flux monitors are configured in bare/shielded pairs at three heights on the side opposite the neutron generator making up three “dual” cavity flux monitors.

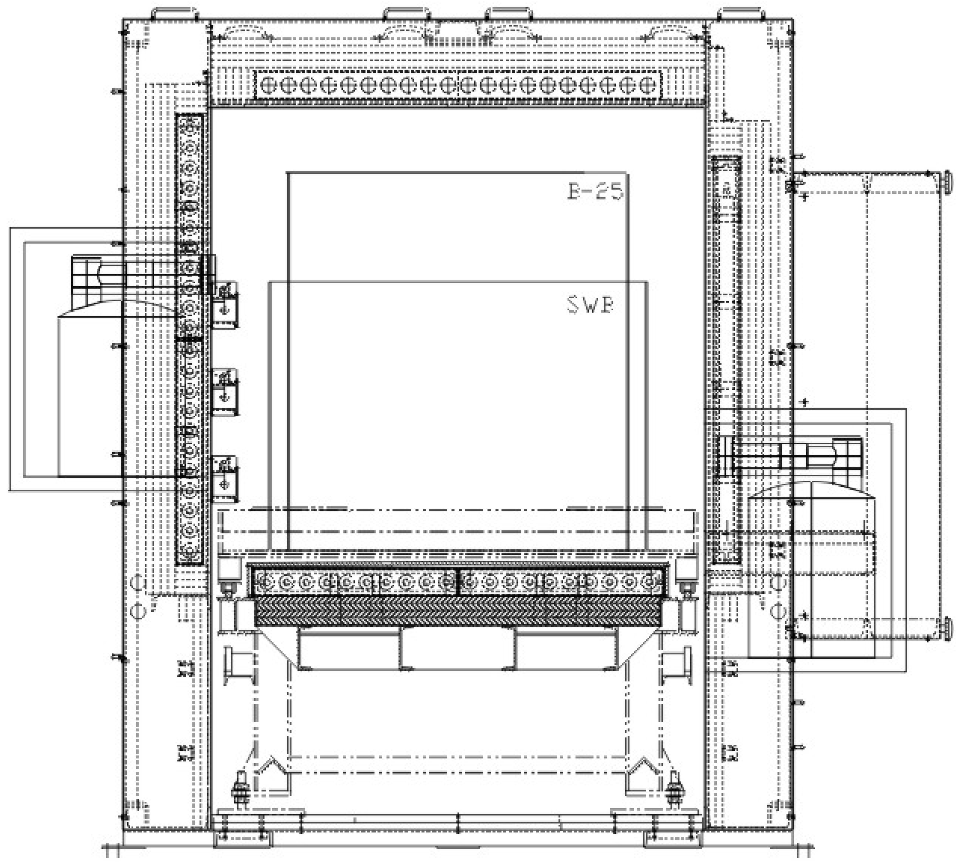

Figure 3 Cross sectional view of the mid-section of the assay cavity showing the neutron detectors, neutron generator and gamma detectors

Gamma Detectors

The back section of the cavity is equipped with two HPGe detectors one on each side of the cavity off set at different heights. See Figure 3. The detectors are offset to accommodate the different sizes of crates that the instrument will assay. The detectors are liquid nitrogen cooled. A filter array is built in to the system using various attenuating materials such as steel and copper to reduce gamma count rates for highly active crates. The operation of the HPGe detectors is fully integrated with the neutron operations of the assay system.

System Turntable

A turntable assembly that receives the crate is located directly outside the door in line with the cavity. The turntable rotates the waste crate 180 degrees so that two configurations of the crate can be assayed providing for a more uniform neutron interrogation of the crate and a symmetric neutron response. See Figure 1.

PERFORMANCE REQUIREMENTS

The MPCC is required to comply with both WIPP and Nuclear Material Safeguards (NMS) performance requirements for accuracy and precision for 55-gallon drums -- fifty-five gallon drum criteria were selected as a conservative requirement as crate criteria have not been promulgated to date -- for a range of matrices including soil, light metal waste, lead waste, dry combustibles, wet combustibles, plastic, and non-borated glass.

WIPP Requirements

The MPCC is required to segregate, at a minimum, low-level waste from transuranic waste at 60 nCi/g level for waste packages of each waste type of a nominal lower net weight of 300 lb.
Accuracy and precision requirements are specified for various activity ranges in Table 1.

Range of Waste Activity in α-Curies	Nominal Compliance Point α-Curies (g WGPu)	Precision (%RSD)	Accuracy (%R)
0 to 0.02	0.008 (0.1)	≤ 20	70-130
>0.02 to 0.2	0.08 (1.0)	≤ 15	70-130
>0.2 to 2.0	0.8 (10)	≤ 10	70-130
>2.0	12.8 (160)	≤ 5	70-130

Table 1 WIPP Quality Assurance Objectives for Radioassay[1] (for 55 gallon drums)

Nuclear Material Safeguards Requirements

The MPCC is also required comply with RFETS Nuclear Material Safeguards requirements for precision and accuracy specified in Table 2.

RANGE OF Pu and U (g)	PRECISION (one relative standard deviation)	ACCURACY (95% confidence interval for mean relative bias)
≤1.0	± 50%	± 50%
>1.0 to ≤10	± 25%	± 25%
>10.0	± 10%	±15

Table 2 NMS Quality Assurance Objectives for Radioassay[2]

FACTORY CALIBRATION

The MPCC underwent initial calibration at the factory from August to October 1999. The system was calibrated using four matrix types based on RFETS waste streams. The calibration matrix types were: Dry Combustibles, Plastics, Wet Combustibles and Light Metals. Also the system was calibrated for two box types SWB and B-25. Each matrix type was represented in each box type resulting in eight calibration points. Two of the matrix crates were provided by the Mixed waste Focus Area (MWFA) and the remainder were constructed by Custom Surrogate Matrices Inc. based on the modular design used by the MWFA for PDP crates. An isometric view of a standard SWB crate design is shown in Figure 4. Surrogate calibration sources were used for the calibration. Depleted Uranium was used for ^{235}U material and as a surrogate for ^{239}Pu. ^{252}Cf was used as a surrogate for ^{240}Pu.

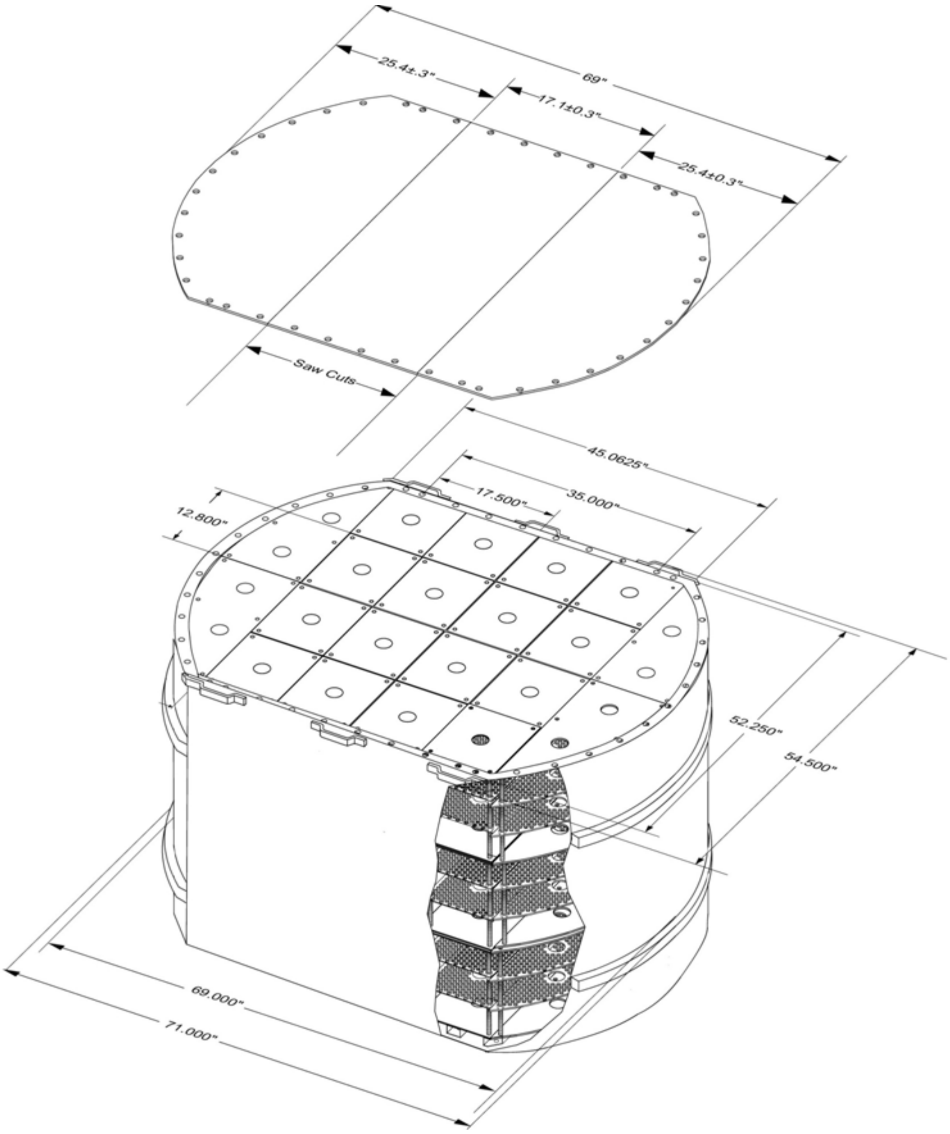

Figure 4 Isometric view of an SWB calibration crate

FACTORY TESTING

The MPCC was tested at the factory for basic system performance evaluation. The focus of the testing was on the neutron mode of the system. The gamma detectors were calibrated and checked for good spectrum quality. The system was evaluated against the accuracy and precision requirements specified in Tables 1 and 2 and the WIPP sensitivity segregation requirement. A representative set of matrix crates from the calibration set was selected for testing over mass ranges that the surrogates represented.

System Performance

The system sensitivity was determined for the dry combustibles matrix (as this represented the nominal case) for a uniform distribution of radioisotopes to be approximately 7 nCi/g. This sensitivity is achieved using the active neutron mode of the system.

Accuracy and precision performance for the neutron mode of the system was determined for sample matrix crates and mass loadings. The results are summarized in Table 3.

Matrix	Pu equivalent Mass (g)	Average Accuracy (% error)	Average WIPP %RSD	Average NMS %RSD
SWB DC	5.1	5.71	NA	NA
B25 WC	0.5	-3.38	1.41	1.40
B25 PL	0.5	-23.26	2.76	1.99
SWB LM	5.1	8.74	1.60	1.68
B25 LM	0.5	-7.17	NA	NA
SWBPL	5.1	6.07	3.16	3.35

Table 3 Neutron mode average accuracy and precision results from factory testing

Two precision values are tabulated as WIPP and NMS use different formulas for calculating percent Relative Standard Deviation (%RSD). For the .5g test source loadings the active mode results were used while for the 5.1 g test source loadings the passive mode results were used. Different test source positions were used among the set of test matrix crates so the results represent both matrix and positional error effects. In all cases the results exceeded the requirements.

ON SITE COMMISSIONING

The MPCC is scheduled for on site commissioning at RFETS from May through December of 2000. The commissioning will include final calibration using actual Pu, U and other representative standards. Final algorithm work will follow calibration. The commissioning will also include acceptance testing that will be used as validation to certify the system for WIPP sentencing of TRU waste. The testing will utilize PDP sources and will include QAO and other WAC qualification measurements.

CONCLUSION

The MPCC will be vital to meeting the aggressive D&D schedule at RFETS. The MPCC vastly expands the Site crate capability as it can accommodate waste boxes up to 11,000 pounds and can measure crates of any matrix type that fall within the calibrated range. The system has demonstrated its ability to perform as required and exceed the performance of previous systems. NMS acceptance and WIPP certification is the final step and ultimate goal for the system and will be achievable after commissioning.

REFERENCES

1."Contact-Handled Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant", DOE/WIPP-069 Rev 7, CAO (November 8, 1999)

2. “Nuclear Material Safeguards Manual” MAN-010-NMS RFETS