Combined Technology Automated Waste Characterization System

J. A. Mason,[a] W. Hage, R. Price, A. C. Tolchard, and A. Towner
ANTECH, A.N.Technology Ltd., Unit 6 Thames Park, Lester Way, Wallingford, Oxfordshire, England OX10 9TA

B. H. Pedersen
Institute of Protection and Security of the Citizen, Joint Research Centre, 21020 Ispra (VA) Italy

R. Estep and S. Melton
Los Alamos National Laboratory, Los Alamos, NM 87545

This paper describes a combined technology automated Waste Characterization System designed the measures fission product and TRU waste arising from nuclear fuel and nuclear materials processing and reactor operations. The system is designed to measure the waste in three drum sizes, including 35-L, 200-L, and 400-L, with a maximum drum weight of 1500 kg. Gamma-ray measurements of radionuclide content are performed by a Tomographic Segmented Gamma-ray Scanner (TSGS), which performs the functions of drum screening, NDE, and where appropriate, drum assay. Coupled to the TSGS is a surface dose-rate measurement station.

Active and passive neutron measurements are performed by an advanced, graphite-lined DDA system, which has three modes of operation. The first two modes are conventional passive neutron coincidence counting and active DDA total neutron counting, based on a range of matrix calibrations. The third mode of operation implements Fission Fission-Neutron Correlation, an absolute technique employing active neutron coincidence counting. Fission Fission-Neutron Correlation (based on extensions to the theory of passive neutron multiplicity counting) virtually eliminates the need for matrix calibration and allows separate uranium and plutonium determination using delayed neutron counting.

Linking the two measurement stations is an automated conveyor with a 20-drum buffer and weight measurement station. Once loaded, the system is designed to perform automatic assay and return drums to the buffer. The first Waste Characterization System of this type will be supplied to JRC Ispra in 2002.

1. INTRODUCTION

This paper describes the characteristics of a Combined Technology Automated Waste Characterization System (CTA-WCS), designed for the measurement of radioactive waste in a variety of container sizes.[1-5] These include 60-L, 200-L, 320-L (85-gal overpack) and 400-L drums, the last with a maximum weight of 1500 kg. The assay technologies include a Tomographic Segmented Gamma-ray Scanner (TSGS) and an active and passive neutron DDA system.

The system is designed to perform radiometric measurements of fission products, activation products, and other radionuclides, as well as determine the quantity of uranium and plutonium in CH waste drums. A variety of waste matrices can be measured, including homogeneous, heterogeneous, hard, soft, and decommissioning waste, and legacy waste from nuclear fuel processing. In addition, the system has NDE capability and can determine both the weight and surface dose of the drums.

The assay stations are linked by a heavy-duty roller conveyor that incorporates a 20-drum buffer store. The conveyor is controlled by a PLC and, in conjunction with the computer-controlled assay stations, allows automatic assay of up to 20 drums. In addition to the assay stations, the system includes a load cell (built into the conveyor), bar code readers, and a dose rate measurement station.

A waste characterization system with characteristics similar to the system described in this paper is being supplied by ANTECH to the Waste Management Unit at the Joint Research Centre, Ispra. JRC Ispra is a laboratory of the European Commission located in northern Italy. Three nuclear reactors have operated on the site, and nuclear fuel processing also has taken place. The system is designed to assay the wide variety of waste types in a range of waste matrices.

[a] Email: mason.john@antech-inc.com

2. TOMOGRAPHIC SEGMENTED GAMMA SCANNER

The CTA-WCS incorporates a TSGS designed to measure drums of up to 400 L, with a maximum weight of 1500 kg (Fig. 1). The TSGS design is based on the ANTECH model 3800-400 but is modified to incorporate a dose-rate station. It employs analysis software developed at LANL. In addition to tomographic measurements, the TSGS is also designed to operate as a simpler Segmented Gamma Scanner (SGS), which is used for measuring homogeneous waste.

The TSGS serves four functions as part of the overall assay system. The first is to screen drums to determine the most appropriate assay technology. The choices available are gamma-ray, passive neutron, or active neutron assay. The second is to perform NDE by providing three-dimensional images of the attenuation coefficient distribution of the matrix and the radioactive source distribution within the matrix. The third function of the TSGS, applicable if plutonium is present, is to determine the plutonium isotopic ratios using the LANL analysis code, PC/FRAM. Finally, the fourth function, depending on the outcome of the screening, is to provide the assay result using the TSGS measurement method. The TSGS extends the range of gamma-ray measurement technology as it is able to correctly determine the radionuclide inventory in heterogeneous matrices.

3. DIFFERENTIAL DIE-AWAY

Active and passive neutron measurements are performed by an advanced, graphite-lined DDA system. The DDA is an active and passive neutron measurement device for determining the fissile content of waste drums. A pulsed neutron generator is employed in active interrogation mode to determine the ^{235}U and ^{239}Pu content of waste drums by induced fission using total neutron counting. With appropriate matrix calibration and flux normalization, it is possible to infer the total fissile mass at low levels contained in the waste drum from the total neutron count rate, as measured in fast neutron detectors.

FIG. 1. The Tomographic Segmented Gamma-ray Scanner (TSGS) is designed to measure drums of up to 400 L with a maximum weight of 1500 kg.

In passive neutron mode, the DDA operates as a conventional passive neutron coincidence counter for measuring plutonium using neutron pairs and neutron total count rates. The sensitivity is more than adequate for measurements of plutonium above the range applicable to active measurements.

A third (active) mode of operation implements Fission Fission-neutron Correlation (FFnC), an absolute technique employing active neutron coincidence counting. FFnC (based on extensions to the theory of passive neutron multiplicity counting) has the potential to eliminate the need for matrix calibration. It permits the direct characterization of the waste by determining both the fissile mass and the detection probability for fast neutrons arising in the matrix being measured. The use of delayed neutron counting allows separate uranium and plutonium mass determination.

The design of the ANTECH model 4100-400 DDT is based on an optimization of the well characterized combined thermal/epithermal neutron (CTEN) DDA design developed at LANL. Monte Carlo neutron modeling (benchmarked to CTEN) is being employed to enhance the design and to extend the thermal neutron die-away time to greater than 550 microseconds, and to increase the fast neutron detection efficiency to greater than 12%. The instrument employs cadmium clad, polyethylene-moderated fast neutron detector modules, as well as drum and moderator flux monitors based on one inch ^{3}He tubes. A D-T neutron generator operated at 100 Hz provides the bursts of 14 MeV neutrons that interrogate the drum.

4. DRUM WEIGHT AND DOSE RATE MEASUREMENT

In addition to the radiometric assay, the CTA-WCS measures other characteristics of the waste drums. Incorporated into the conveyor system is an accurate load cell to determine drum weight. The data from the load cell is recorded as part of the drum data and used as part of the drum matrix assessment.

A drum surface dose-rate measurement station is included in the CTA-WCS. It is incorporated into the TSGS to make effective use of the drum rotation platform. Four Geiger tube detectors measure the surface dose at the drum side: one at 1 m from the drum and one each measuring the surface dose of the upper, middle, and lower sections of the drum. The side surface and 1-m

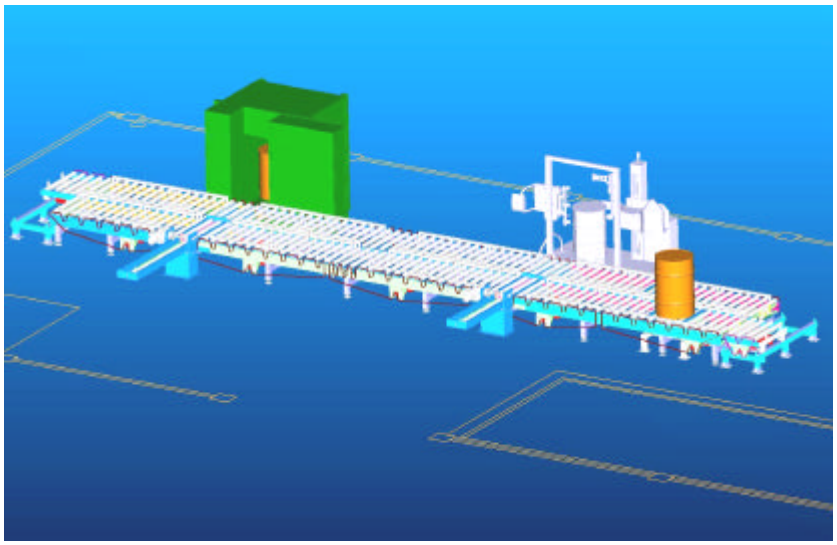

FIG. 2. The Tomographic Segmented Gamma-ray Scanner (TSGS) and DDA assay instruments are coupled to a heavy-duty roller conveyor system, onto which up to 20 waste drums can be loaded.

detectors are mounted on a support frame with adjustable positions to accommodate the different drum sizes. The top detector will be similarly deployed; the bottom detector will be fixed.

5. BUFFER CONVEYOR SYSTEM

The TSGS and DDA assay instruments are coupled to a heavy-duty roller conveyor system, Model 400-1500, onto which up to 20 waste drums can be loaded (Fig. 2). The system will automatically deliver the drums to the various measurement stations, permitting unattended, automated operation of the WCS. Once the drums have been measured, they remain on the conveyer in holding positions waiting to be unloaded. The system is capable of handling and measuring waste drums with a maximum weight of up to 1500 kg.

A program logic controller (PLC) and associated computer form the basis for controlling the automation of the conveyor and the measurement stations of the WCS. A central computer and associated automation software are used to link all of the components of the WCS and control all data acquisition and data management.

6. CONCLUSION

The CTA-WCS is a fully automated state-of-the-art assay system capable of measuring a wide variety of waste types in a range of matrices arising from nuclear fuel and nuclear materials processing, reactor operations, and military wastes.

The TSGS is the most comprehensive gamma-ray measurement solution for the assay of a broad range of waste types, combining conventional high-resolution gamma spectrometry, segmented gamma scanning, and three-dimensional tomographic imaging and NDE capabilities in one complete system.

DDA is the most sensitive assay technique for the measurement of low levels of fissile material in waste and, combined with FFnC, delivers an absolute technique, eliminating the need for matrix calibration, and allowing the separate determination of uranium and plutonium mass.

Linking the two measurement stations is an automated conveyor with a 20-drum buffer, drum weight measurement station, and surface dose measurement station. Once loaded, the system is designed to perform automatic assay and return drums to the buffer.

The Waste Characterization System described in this paper is the most comprehensive waste assay solution for the measurement of CH and RH waste. The system can be readily converted to the measurement of low-level waste by substituting the TSGS model 3800 described above with an ANTECH model 3900 shielded TSGS.

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