This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

INLINE MONITORS FOR MEASURING CS-137 IN THE SRS CAUSTIC SIDE SOLVENT EXTRACTION PROCESS

V.R. Casella, T.N. Riley, F.S. Moore and D.J. Pak
Westinghouse Savannah River National Laboratory
Aiken, SC 29808

The Department of Energy (DOE) selected Caustic-Side Solvent Extraction (CSSX) as the preferred technology for the removal of radioactive cesium from High-Level Waste (HLW) at the Savannah River Site (SRS). Before the full-scale Salt Waste Processing Facility (SWPF) becomes operational, a portion of dissolved saltcake waste will be processed through a Modular CSSX Unit (MCU). The MCU employs the CSSX process, a continuous process that uses a novel solvent to extract cesium from waste and concentrate it in dilute nitric acid. Of primary concern is Cs-137 which makes the solution highly radioactive. Since the MCU does not have the capacity to wait for sample results while continuing to operate, the Waste Acceptance Strategy is to perform inline analyses. Gamma-ray monitors are used to: measure the Cs-137 concentration in the decontaminated salt solution (DSS) before entering the DSS Hold Tank; measure the Cs-137 concentration in the strip effluent (SE) before entering the SE Hold Tank; and verify proper operation of the solvent extraction system by verifying material balance within the process. Since this gamma ray monitoring system application is unique, specially designed shielding was developed and software was written and acceptance tested by Savannah River National Laboratory (SRNL) personnel. The software is a LabView-based application that serves as a unified interface for controlling the monitor hardware and communicating with the host Distributed Control System. This paper presents the design, fabrication and implementation of this monitoring system.

INTRODUCTION

The Department of Energy (DOE) selected Caustic-Side Solvent Extraction (CSSX) as the preferred technology for the removal of radioactive cesium from High-Level Waste (HLW) at the Savannah River Site (SRS). Before the full-scale Salt Waste Processing Facility (SWPF) becomes operational, a portion of dissolved saltcake waste will be processed through a Modular CSSX Unit (MCU) shown in Figure 1.

The MCU employs the CSSX process, a continuous process that uses a novel solvent to extract cesium from waste and concentrate it in dilute nitric acid. The CSSX process, which is the basis for the MCU, removes cesium from alkaline salt solutions. Of primary concern is Cs-137 which makes the solution highly radioactive. Removal of cesium from the alkaline salt solution is accomplished by contacting an immiscible organic solvent with the waste, then separating the phases again using centrifugal contactors. The contactors are arranged in banks of multiple contactors.

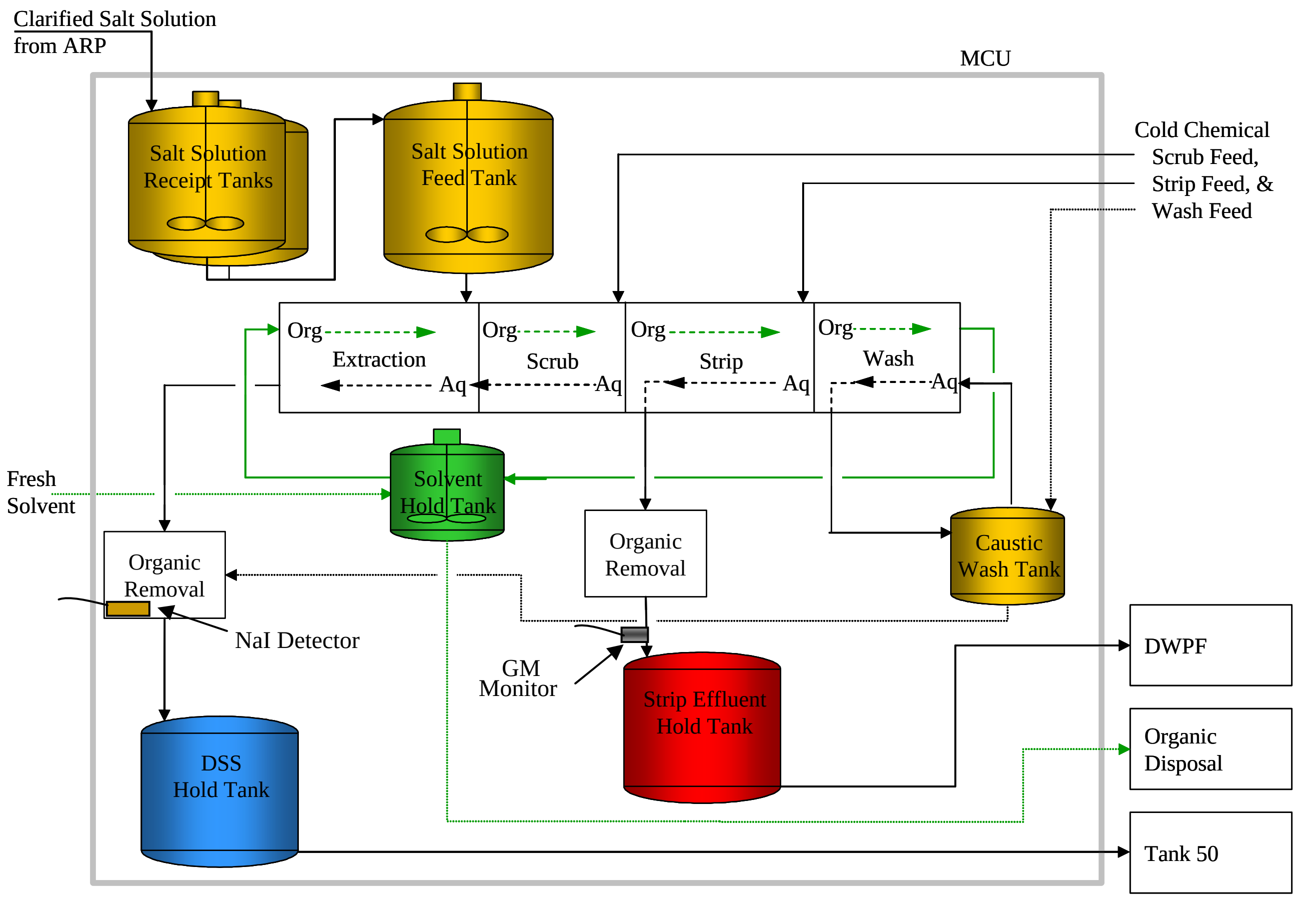

Figure 1. MCU Process flow diagram.

Gamma-ray monitors are required to:

a) Measure the Cs-137 concentration in the decontaminated salt solution (DSS) before entering the DSS Hold Tank,

b) Measure the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank,

c) Verify proper operation of the solvent extraction system by verifying material balance within the process.

SYSTEM DESCRIPTION

General Description

Gamma-ray monitors will be provided at two MCU locations shown in Figure 1 for the purpose of measuring Cs-137 and for monitoring normal transfers of radioactive materials. These include:

- Two sodium iodide (NaI, 1-inch x 1-inch, Am-241 seeded) spectrometers at the DSS monitor; and
- Two Geiger-Mueller (GM) detectors at the strip effluent monitors.

Hardware Description

The MCU-GRM hardware consists of two redundant systems. Each sodium iodide system consists of a detector (NaI) and photomultiplier tube, a spectroscopy amplifier, a high voltage power supply and a MCA card, while each GM system consists of a GM tube, a power supply and pulse conversion module, and a counter/scalar card. These detector systems electronics are mounted in a modular Nuclear Instrumentation Module (NIM) bin and power supply with a computer, keyboard, a Foundation Field Bus card, and the associated connection hardware shown in Figure 2.

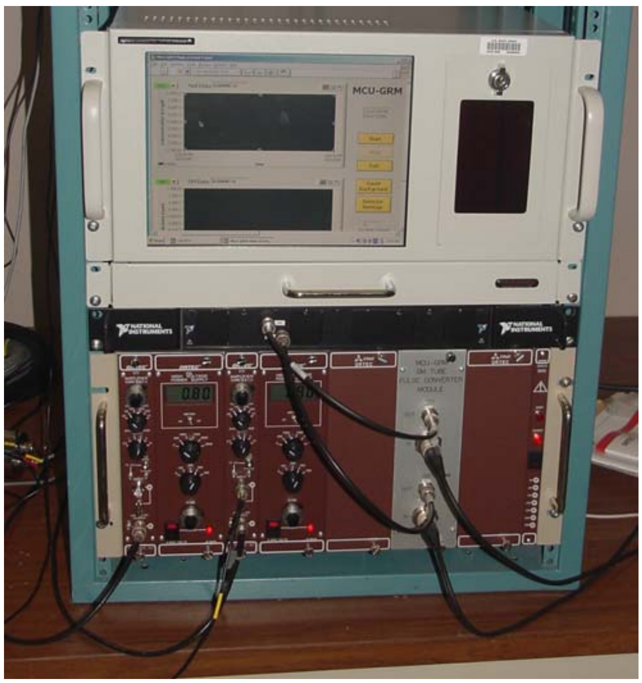

Figure 2 MCU-GRM Electronics Rack

The amplified and scaled output signals from each NaI detector are connected to an ORTEC Trump-PCI card located inside the MCU-GRM computer housing. The Trump-PCI card is a computer controlled Multi-Channel Analyzer (MCA) for nuclear spectroscopy applications.

Two GM detectors are connected by a single coaxial cable to an Aware Electronics PMI30 instrument module. The Aware module is a self contained radiation detection system that provides detector high voltage, as well as pulse scaling and amplification. The Aware modules are mounted inside a blank double width NIM module along with a custom circuit board designed to convert the Aware module pulse output to TTL compatible signal levels. This scaled output signal is applied to a National Instruments 6602 counter/scalar card for gross activity counting.

The two Trump-PCI cards and the NI 6602 counter card are installed in spare PCI slots in the MCU-GRM computer, along with a National Instruments PCI-FBUS/2 Foundation FieldBus card which is required for communication between the MCU-GRM and the Distributed Control System (DCS). A block diagram of the MCU-GRM hardware is shown in Figure 3 below.

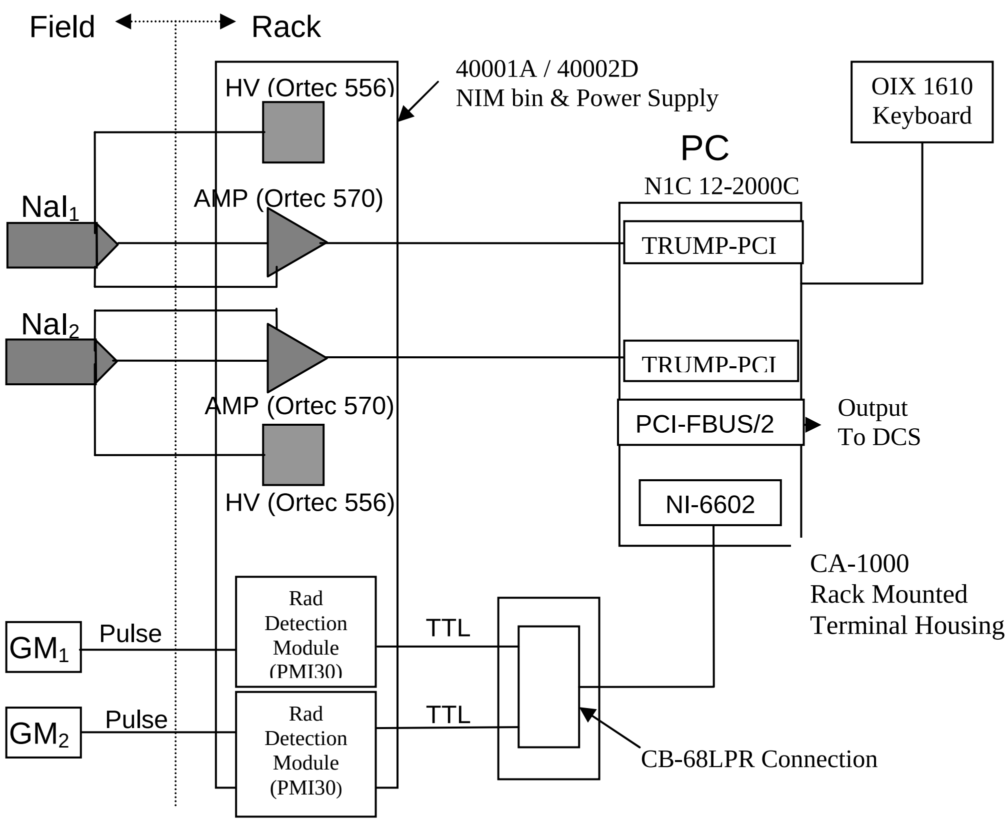

Figure 3. MCU-GRM Hardware Block Diagram

Detector Shields

The NaI shield shown in Figure 4 provides a collimated beam from the piping to impinge on the side of the detector so that the photomultiplier tube is not directly exposed to the beam.

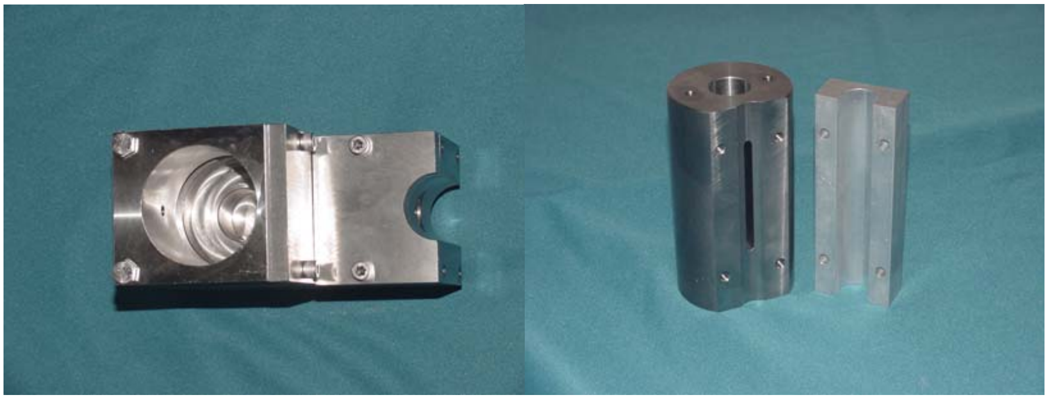

Figure 4. NaI shield design (left) and GM Shield (right).

The shield is made of tungsten and has two apertures of either 0.313-inch or 0.616-inch diameter. A tungsten tube insert provides a means to change the aperture. A clamp, also made of tungsten, is used to hold the shield to the piping. This clamp has a cavity for insertion of a pipe calibration standard if desired.

The GM shield design is also shown in Figure 4. It is nominally one-inch thick tungsten with a 3-inch long collimator. This length of the collimator provides insurance that the detector will be exposed to the Cs-137 gamma rays, regardless of where the actual detector is located within the four-inch casing.

Software Description

The MCU-GRM production software is a LabView based application that serves as a unified interface for controlling the MCU-GRM hardware and communicating with the host Distribution Control System (DCS). These activities are accomplished through five basic software modules. These software modules are the MCU-GRM Application Window, Detector Selection, Detector Configuration Settings, Background Counting, and Routine Data Acquisition.

The major component of the MCU-GRM software is the application window, shown in Figure 5. Besides serving as the primary user interface, this window provides a means for selecting the appropriate NaI or GM detector, performing routine MCU-GRM measurement activities, performing a background measurement, or gaining access to the detector configuration settings screen. All actions associated with the MCU-GRM software originate from this screen. The system time is displayed in the upper right hand corner of the screen and is updated every second to indicate that the system is active.

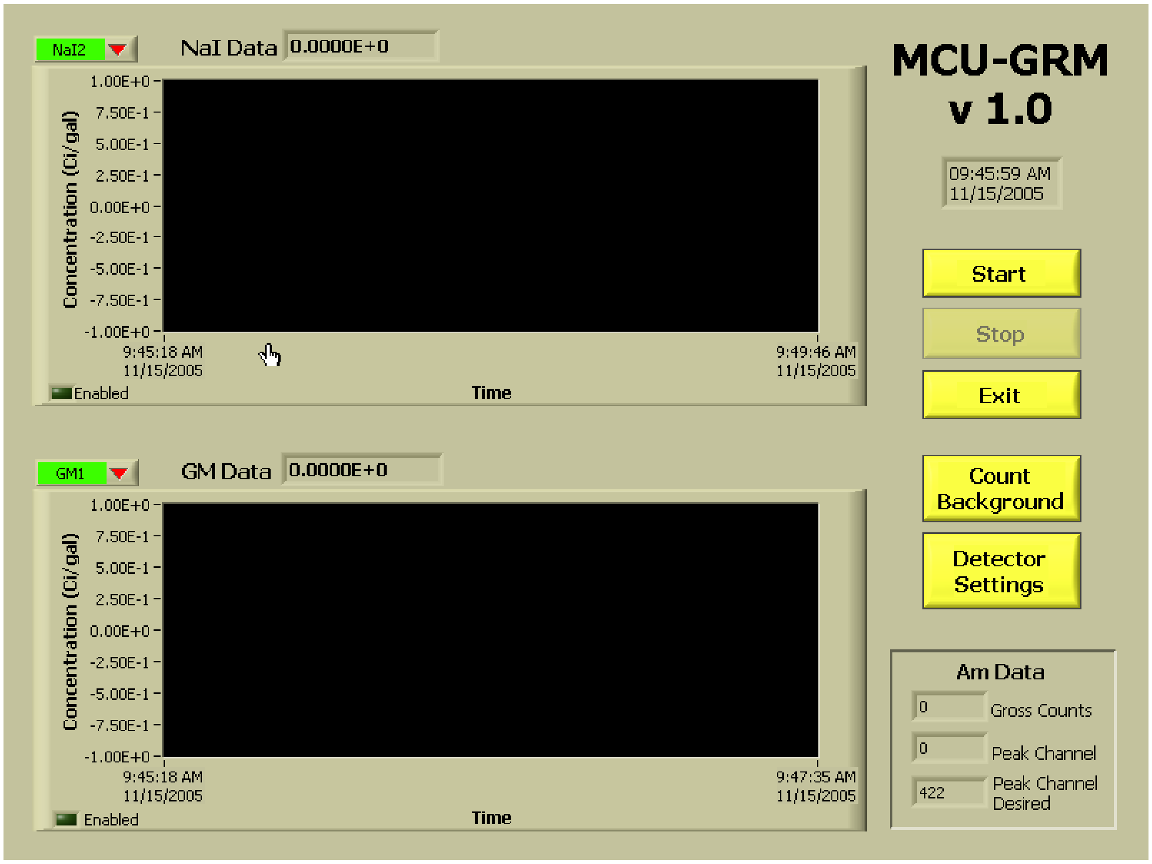

Figure 5. MCU-GRM Application Window

The most prominent features on the application window are the measurement history graphs. Two graphs display the 50 most recent data points collected during routine measurement activities. This serves as a visual reference of the measurement trend over the past 50 cycles. Additionally, the data display at the top center of each graph shows the most recently acquired data point for the selected detector. Selection of the desired NaI or GM detector is performed from the MCU-GRM Main screen by clicking on the red arrow selector located beside both detector selection menus.

The user can set the detector settings screen by clicking on the **Detector Settings** button on the MCU-GRM main screen. A password is required for access to this screen which is shown in Figure 6. Detector operating parameters (efficiencies, backgrounds and cycle times) are set in this way.

The Routine Data Acquisition mode is the primary mode of operation for the MCU-GRM software. In order to start the routine monitoring application, the user should verify that the desired detector pair has been selected (one GM and one NaI detector) and then the **Start** button is clicked on the MCU-GRM application window. Using the data in the configuration screen and the collected data, the program calculates the cesium concentrations (Ci/gal) in the DSS and SE.

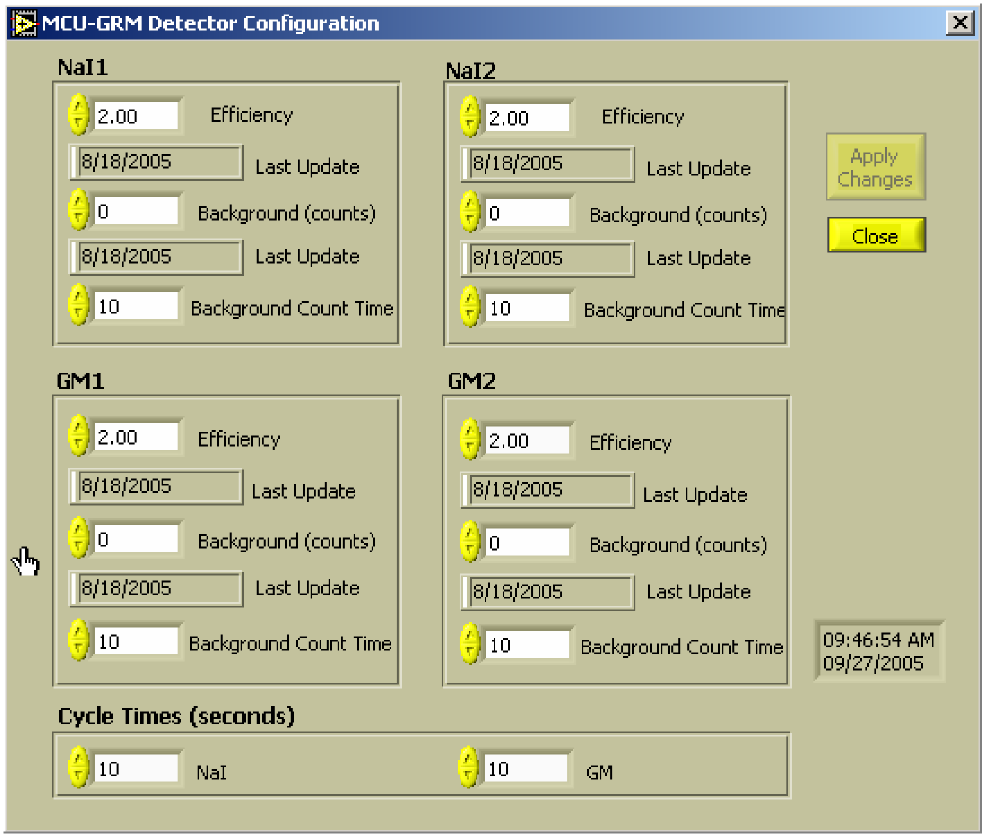

Figure 6. Detector Configuration Screen

For the Am-241 seeded NaI detector, the program calculates the net counts in the Americium peak as well as the location (spectrum channel number) of the Am peak centroid. The actual Am peak centroid channel number is compared against its desired location to determine if adjustments need to be made to the amplifier gain. If the Am peak channel is outside of an acceptable band or an Am-241 peak is not observed, an error message will be displayed and the system will not perform its monitoring function until this condition is corrected. By keeping the Am-241 peak in a specific channel adjusts for any gain shift and ensures that Cs-137 region-of-interest does not change.

At the completion of the acquisition cycle, the two new data points are written to their corresponding graphs and any linked digital displays. Each new data point is also passed along to the DCS through the Foundation FieldBus interface.

In order to perform the background subtraction and report only the activity of the solution moving through the system, periodic background measurements must be performed. Frequency will depend on the measured background variations during processing. This task must necessarily be performed in-situ, as this is the only method for accurate determination of the ambient activity levels. Detector backgrounds are automatically updated by clicking the **Count Background** button on the application window.

A typical spectrum collected using the Ortec Corporation spectral stripping program Maestro is shown in Figure 7. The Cs-137 peak and Am-241 pulser peak are evident.

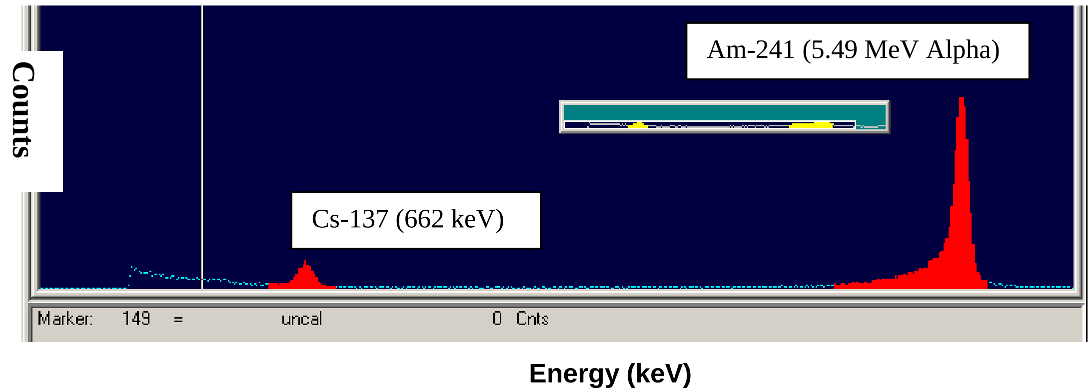

Figure 7. Spectrum from Na(Tl) detector with Am-241 Pulser

Detector Calibrations

In order to calibrate the detectors, NIST traceable standard sources were purchased from Analytics Corporation, Atlanta, GA. The average Cs-137 efficiencies (cps/dps) for the NaI detectors are 4.0E-6 for a 0.313-in collimator aperture and 3.5E-5 for a 0.616-in collimator aperture, while the average efficiency for the GM detectors was approximately 3.0E-6. The GM detectors were shown to be linear for concentrations from 0.1 to 38 Ci/gal, within the expected concentration range. Since the GM detector efficiency varies with rotational positioning within the shielding, it is imperative to ensure that the angular position of the detector is the same during calibration and for the measurements.

RESULTS AND CONCLUSIONS

Inline monitors will be used to measure Cs-137 concentration in the MCU product streams (DSS and strip effluent). Sodium iodide monitors have been developed for use at the piping before the DSS Hold tank, while GM monitors have been developed for Cs-137 measurements before the Strip Effluent Hold Tank. Tungsten shields were designed using Monte Carlo calculations and fabricated to reduce the process background radiation at the detector positions. These monitors were calibrated with NIST traceable standards that were specially made to be the same size as the piping being monitored. Since this gamma ray monitoring system is unique, specially designed software was written and acceptance tested by Savannah River National Laboratory personnel.

REFERENCES

1. U-MT-H-00085, Rev 1, "Cesium Removal Implementation Using Caustic Side Solvent Extraction Technology"

2. G-ESR-H-00072, Rev 1, "Interface Control Document Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU)"