WSRC-RP-2005-01902
Revision #1

MODULAR CAUSTIC SIDE SOLVENT EXTRACTION UNIT (MCU) GAMMA MONITORS SYSTEM FINAL REPORT

Vito R. Casella, Timothy N. Riley, Mark G. Hogue, Javier Reyes-Jimenez, Paul E. Filpus-Luyckx, Frank S. Moore and Donald J. Pak

June 2007

Analytical Development
Savannah River National Laboratory
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under Contract Number DEAC09-96SR18500

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EXECUTIVE SUMMARY

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, the Liquid Waste Organization (LWO) plans to process a portion of dissolved saltcake waste through a Modular CSSX Unit (MCU).

This work was derived from Technical Task Request SP-TTR-2004-00013, "Gamma Monitor for MCU." The deliverables for this task are the hardware and software for the gamma monitors and a report summarizing the testing and acceptance of this equipment for use in the MCU. Revision of this report is a deliverable in Technical Task Report SP-TTR-2006-00010, "NaI Shield Box Testing."

Gamma-ray monitors were developed to:

- Measure the Cs-137 concentration in the decontaminated salt solution before entering the DSS (Decontaminated Salt Solution) Hold Tank,
- Measure the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank,
- Verify proper operation of the solvent extraction system by verifying material balance within the process (The DSS Hold Tank Cs-137 concentration will be very low and the Cs-137 concentration in the Strip Effluent Hold Tank will be approximately fifteen times higher than the Cs-137 concentration in the Feed Tank.)

Cs-137 concentration ranges are: MCU feed $\leq$1.1 Ci/gal; solvent $\leq$ 4.7 Ci/gal; DSS $\leq$ 0.1 Ci/gal; and strip effluent $\leq$ 16.5 Ci/gal. (MCU design will achieve a minimum decontamination factor of 12 with a concentration factor of 15. Therefore, the original feed Cs-137 concentration (1.1 Ci/gal) will be reduced to less than 0.1 Ci/gal.). This work assumes that the process solution concentrations and facility conditions will not be changed from the present configurations that were used as the basis for this report.

Sodium iodide monitors are used to measure the Cs-137 concentration in the piping before the DSS Hold tank, while Geiger-Muller (GM) monitors are used 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 as the piping being monitored. Test results show that sensitivity goals are attained in this challenging high radiation environment.

Details of the design and functionality of the gamma monitors are described in this report and referenced documents. The performance criteria (revised from Revision 0 of this report) for the NaI monitors are an accuracy of $\pm$ 10% and a detection limit of 0.01 Ci/gal, while the required accuracy of the GM monitors is $\pm$ 20% and the detection limit must be less than 10% of the strip effluent concentration. In all cases, these performance criteria were exceeded.

Since this gamma ray monitoring system is unique, specially-designed 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 (DCS). In order to provide user-friendly software for the process personnel, the software was broken down into just a few software modules. These software modules are the Application Window, Detector Selection, Detector Configuration Settings, Background Counting, and Routine Data Acquisition. Instructions for using the software have been included in a user's manual that is appended to this report.

The work presented in this report meets all of the requirements set forth in the project task plan to design and implement gamma ray monitors for the MCU. Additional setup and testing of the system is required when it is implemented in the process. This report has been revised because the shielding for the NaI detectors was redesigned to meet the higher background requirements caused by facility changes after the initial design. High activity lines were implemented near these detectors and originally planned tank shielding was not installed. Also, higher-range GM detectors were installed to increase the detector lifetime.

Additional work on this project includes completion of software implementation, detector field calibrations, implementing procedures for monitor operation and implementing methods for monitor repair. Spare parts must be maintained for system repairs. Background and efficiency checks will be performed on the detectors periodically, as determined by MCU personnel.

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LIST OF ACRONYMS

ARP	Actinide Removal Process
CSSX	Caustic Side Solvent Extraction
DCS	Distributed Control System
DOE	Department of Energy
DSS	Decontaminated Salt Solution
DSSHT	DSS Hold Tank
DWPF	Defense Waste Processing Facility
EPD	Electronic Personal Dosimeter
FFB	Foundation Fieldbus
GM	Geiger-Mueller
LWO	Liquid Waste Organization
MCA	Multi-channel Analyzer
MCNP	Monte Carlo N Particle
MCU-GRM	Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitor
MDA	Minimum Detectable Activity
NaI	Sodium Iodide
NIM	Nuclear Instrumentation Module
NIST	National Institute of Standards Technology
SEHT	Strip Effluent Hold Tank
SRNL	Savannah River National Laboratory
WAC	Waste Acceptance Criteria
WCP	Waste Compliance Plans

1.0 INTRODUCTION AND BACKGROUND

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, the Liquid Waste Organization (LWO) plans to process a portion of dissolved saltcake waste through a Modular CSSX Unit (MCU).

The MCU provides cesium removal for the clarified salt solution after the Actinide Removal Process (ARP). 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 MCU provides this function without impeding ARP operations. Since all Savannah River Site (SRS) inter-area and intra-area transfers are batch transfers, the MCU has product and receipt tanks sufficient to facilitate accepting and transferring solutions.

A larger-scale facility that also utilizes the CSSX process is scheduled to begin operations at a later date. At such time, the MCU will no longer be needed; therefore, the operating window for the MCU is two to three years. The MCU is scheduled to be ready for radiological operations by June 2008. The accelerated development/design schedule, combined with constraints placed on the facility, necessitate that Waste Compliance Plans (WCP) for downstream facilities rely on a combination of targeted sampling, instrumentation, and process knowledge.

Typically, once a facility completes a product batch, a sample is taken and the batch is held while the sample is transported for analysis. Once the sample results confirm the batch is within the Waste Acceptance Criteria (WAC) of the downstream facility, the product is transferred. The MCU does not have the capacity to wait for sample results while continuing to operate. The Waste Acceptance Strategy is to demonstrate compliance to downstream facility WACs prior to final design and development of WCPs.

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. A process flow diagram can be seen in Figure 1-1. 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.

The process is broken down into four sections; extraction, scrub, strip and wash. The extraction section is a bank of seven contactors where the cesium is extracted from the alkaline waste into the solvent. Once the waste exits the extraction bank, it has been decontaminated of cesium. The waste is then considered Decontaminated Salt Solution (DSS).

The solvent flows to the scrub section next. This bank of two contactors neutralizes any alkaline carryover from the extraction section and returns any sodium or potassium to the aqueous waste feed stream. The aqueous phase for the scrub section is dilute nitric acid, which is combined with the waste feed of the extraction section as it exits the scrub section.

The solvent then flows to the strip section, which is another bank of seven contactors. The strip section strips the solvent of the cesium and concentrates it in a very dilute nitric acid stream. The nitric acid stream exiting the strip section contains the cesium and is called strip effluent. Finally, with the cesium removed, the solvent flows to the wash section. The solvent is washed with caustic solution to prevent the buildup of unwanted organics in a bank of two contactors. Once the solvent exits the wash section, it is ready to be reused in the process.

Both the strip effluent and DSS are sent to decanters to remove any solvent carryover before being collected for transfer in the Strip Effluent Hold Tank (SEHT) and the DSS Hold Tank (DSSHT) respectively. The DSS is transferred to Tank 50, which is the feed tank to the Saltstone Production Facility (SPF) for solidification in grout. Streams destined for Tank 50 must meet the SPF WAC. The strip effluent in the SEHT is sent to the Defense Waste Processing Facility (DWPF) for vitrification.

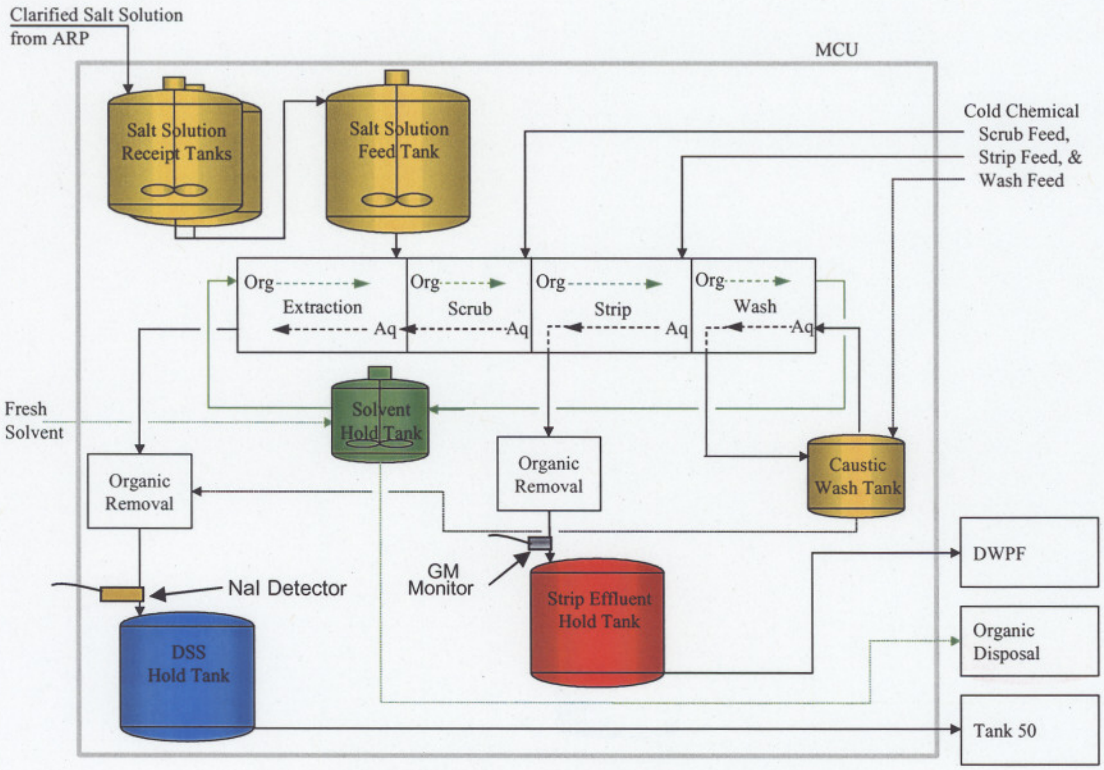

Figure 1-1: MCU Process flow diagram.

This work was derived from Technical Task Request SP-TTR-2004-00013, "Gamma Monitor for MCU." The deliverables for this task will be the hardware and software for the gamma monitors and a report summarizing the testing and acceptance of this equipment for use in the MCU. Revision of this report is a deliverable in Technical Task Request SP-TTR-2006-00010, "NaI Shield Box Testing."

Gamma-ray monitors are required to:

- Measure the Cs-137 concentration in the decontaminated salt solution before entering the DSS Hold Tank,
- Measure the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank,

- Verify proper operation of the solvent extraction system by verifying material balance within the process (The DSS Hold Tank Cs-137 concentration will be very low and the Cs-137 concentration in the Strip Effluent Hold Tank will be fifteen times higher than the Cs-137 concentration in the Feed Tank.)

The only observable gamma-ray for Cs-137 decay is from its short-lived Ba-137m daughter. Chemical processes, such as the CSSX, will disrupt the secular equilibrium between this parent-daughter pair since Ba-137m is not extracted by the solvent; meaning that, measurement of Ba-137m will not necessarily yield information about Cs-137 content. While this is a complicating factor that can not be ignored, it is also controllable by either: 1) allowing sufficient time for equilibrium to be reestablished (about 25 minutes), or 2) by making multiple measurements with sufficient statistical precision to determine the extent of disequilibrium. For the CSSX process, there will be sufficient time after extraction and before Cs-137 measurements (>25 minutes) such that Cs-137 / Ba-137m equilibrium will be reestablished.

The following monitor criteria are required:

- Accuracy of the NaI monitor will be ±10% or better,
- Accuracy of the GM monitor will be ±20% or better,
- Output signals from the monitors will be provided to the Distributed Control System,
- NaI monitor output will be used to control a diversion valve to divert flow for recycling in the event of a high reading (diversion valve and programming for diversion valve will not be provided by SRNL),
- Monitor shielding sufficient to reduce radiation backgrounds to the levels needed to meet measurement requirements,
- Monitor collimators having fields of view both to yield adequate gamma-ray flux at the detector and to control the signal rate to acceptable dead-time levels.
- Monitors must be able to measure cesium activities for the concentrations ranges given below.

Expected (best estimates) environmental conditions, concentration ranges and flow rates at the monitor locations are:

- Atmospheric pressure,
- Total integrated exposure of 1.5E08 Rad over 5 years for the process, but this is not the background level and this exposure may not apply to the monitors. The monitors must be in a relatively low radiation background area or proper shielding must be employed to ensure that the detectors can provide accurate measurements. The Cs-137 background level should be at least a factor of ten below the lowest Cs-137 concentration detected.
- Temperature range of 21 to 104 degrees Fahrenheit. (At temperatures below 45 degrees Fahrenheit, the electronics may not provide reliable results, and above 85 degrees Fahrenheit the useful life of the electronics is greatly shortened. Therefore, the preferred temperature range is 45 to 85 degrees Fahrenheit.)
- Relative humidity range of 5 to 100%. (Electronic equipment is very sensitive to environmental conditions with high humidity, and this will adversely affect measurement capabilities. In general, if the non-condensing humidity gets above 80%, there is an adverse effect on the electronics per the manufacturer's manual.)
- Cs-137 concentration ranges are: MCU feed ≤1.1 Ci/gal; solvent ≤ 4.7 Ci/gal; DSS ≤ 0.1 Ci/gal; and strip effluent ≤ 16.5 Ci/gal. (MCU design will achieve a minimum decontamination factor of 12 with a concentration factor of 15. Therefore, the original feed Cs-137 concentration (1.1 Ci/gal) will be reduced to less than 0.1 Ci/gal.)

- DSS waste stream flow rate between DSS decanter and DSS hold tank is estimated to be 10 gpm.
- Strip effluent to Strip Effluent Hold Tank is estimated to be 0.5 gpm.

2.0 APPROACH

Gamma-ray monitors were provided at two MCU locations for the purpose of measuring Cs-137 and for monitoring normal transfers of radioactive materials. These include:

- Two sodium iodide spectrometers as the DSS monitor.
- Two Geiger-Mueller strip effluent monitors.

2.1 Sodium Iodide Monitors

2.1.1 Detector Description

A thallium-doped sodium iodide, NaI(Tl), gamma-ray spectrometer provides quantitative Cs-137 concentration data. In the event that the system fails, the project will provide spare parts, including detectors and associated electronics. A redundant detector will be able to provide equivalent data. In this case, when one of the two detectors is operational, the other will operate in a flow-through mode. Results from either detector can be obtained by designating through software (Section 3.5.2) which detector is being used. The two NaI systems are automated to switch data-acquisition modes (isolated or flow-through) in order to detect changes in monitor performance by comparing results from both detectors.

Tests (Section 3.2.2.2) at Savannah River National Laboratory (SRNL) showed that short-duration counts (30-minute) provide the anticipated required detection limits using a 1 inch by 1 inch NaI (Tl) detector viewing a few milliliters of effluent. The detector and its preamplifier are contained in a hermetically sealed chamber. The detector housing is a 1.2-inch diameter by 1-inch long steel pipe, containing the detector, which is connected to a 2.3 inch diameter by 10 inch long steel pipe containing the photomultiplier tube (PMT) /preamplifier assembly.

The shield (Section 3.2.2) 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. To assure that the detector signal is representative of the sample rather than other MCU components, the detector and PMT are shielded to reduce the background from materials other than sample to less than 0.5 mrem/hour. This background requirement applies during normal operations.

The detector assembly is removable from the process system in order to permit maintenance or replacement, if necessary. The shield assembly allows precise repositioning of the detector relative to the collimator and the piping in order to maintain calibration. The detector views a vertical section of the piping and the region of pipe being assayed must always be filled (no void volume). The process solution (0.001 M nitric acid) in the flush lines contains no radioactivity so that background measurements can be performed.

2.1.2 Data Acquisition Electronics

Personal-computer-based data-acquisition electronics are located nearby (within ~150 feet to the detectors) for proper operation. NaI(Tl) detector electronics include high voltage bias supplies, amplifiers and multichannel analyzers. Photopeak areas and continuum backgrounds are analyzed using the PC. The analyses apply calibration data that are determined using traceable standards. Photopeak areas are also corrected for photopeak background data that are acquired.

Note that preamplifier power, high voltage bias and analog signal cables are run from the detector positions to the data-acquisition electronics.

2.1.3 Performance Checks

Backgrounds and low-level check source measurements can be obtained by isolating the piping at the monitors and flushing with nonradioactive process solution.

Therefore, the piping containing the detector includes a capability for occasional flushing (every few weeks when the process is not operating) with a nonradioactive solution. After flushing, the nonradioactive solution must be held statically in the loop while detector background data are acquired. This test is needed to measure and compensate for any changes in full-energy peak backgrounds that may result, for example, from accumulation of cesium on piping. Solid deposits of radionuclides that have plated on the pipe walls may not be removed by this occasional flushing operation. Although the increase in background from these solid deposits is expected to be low, it must be monitored and included in the method uncertainties.

2.2 Geiger-Mueller Monitors

2.2.1 Detector Description

The Geiger-Mueller (GM) monitor measures the gross count rate per the radiation field. This count rate can then be converted to Cs-137 activity in curies per gallon. Shielding is also necessary because of its proximity to radiation sources other than the piping being measured. It is calibrated and tested with a standard pipe source (Section 3.6). An accuracy of $\pm$20% is required for the GM monitors and a detection limit must be less than 10% of the solution being measured.

Before the Strip Effluent Hold Tank, a high range (25 mR/hr – 30 R/hr) Geiger-Mueller (GM) tube is used to measure the Ba-137m (in equilibrium with Cs-137) in the piping.

2.2.2 Data Acquisition Electronics

GM tube signals are used to generate Transistor-Transistor-Logic (TTL) pulses that are summed in PC-based counter-scalers. Each of the GM tubes is 1 inch diameter by 3.5 inch long with a 0.65 inch overall length electrical connector on it.

2.2.3 Performance Checks

GM tubes are adequate at each of these strip effluent monitoring points. The GM tubes must be 1) installed such that exposure from other process components is less than 10% of the count rate of the process solution in the pipe being measured, 2) removable to allow maintenance if needed, 3) view a vertical or horizontal section of full pipe, and 4) provide the ability to flush the line to re-evaluate pipe background levels. The tube viewing the strip effluent line must be mounted to allow precise repositioning of the sensor, or the detector must be re-calibrated if it is moved or replaced. The detector shields have a cavity area for insertion of a check source.

2.3 System Software

Software, meeting WSRC E7 Manual requirements, has been written to process the instrument output and obtain the Cs-137 concentrations. Background radiation must be subtracted from the results, and calibration data are used to derive the reported Cs-137 concentrations.

Software has been developed to provide real-time concurrent data from multiple gamma-ray spectrometers and from multiple gross gamma counters. The software must:

- Account for the specific models of multichannel analyzers,

- Provide calibration capabilities,
- Provide background measurement and subtraction,
- Provide graphical (strip-chart) representation of data with time.

3.0 RESULTS

3.1 GM Shield Design

A GM detector gives a pulse for each gamma photon interacting within the sensitive volume of the detector. There is no energy information in the output of the detector and therefore the calibration is simply the total count rate as a function of the gamma field seen by the detector.

The gamma field seen by the GM detector is composed of two parts, the general background in the area in which the detector is located, and the field from the pipe which it is intended to measure. Shielding must be supplied to ensure that the detector sees the gamma rays coming from the pipe, and not those from the area background.

Analyses of the dose rate from the pipe were performed. Assuming the pipe to be 1-inch schedule 40 pipe at a maximum 16.5 Ci/gallon concentration, the dose rate at the detector was calculated to be less than 6 R/hr. The contribution from the pipe would be completely masked by the much larger dose rate from the tanks. Hence shielding must be supplied to reduce the contribution from the tanks.

Tungsten was selected for the monitors' shields, though both lead and tungsten were studied. Lead is less expensive to purchase than tungsten; however, it is a hazardous material while tungsten is not hazardous. When purchased in the machinable (alloy) form, tungsten machines essentially like stainless steel (but takes longer to machine), thus simplifying fabrication. Therefore, even though it is more expensive to purchase, the total cost of using tungsten over the life of the project is similar or lower than using lead.

Ludlum model 133-7 GM detectors were chosen for this application. This detector has a linear range of from 25 mR/hr to 30 R/hr with no deadtime correction. The maximum dose rate at 16.5 Ci/gallon is much less than 30 R/hr, so there is sufficient overrange (above 6 R/hr) to allow for the higher concentration. The nominal detector size is 1" in diameter by 4" long. Originally, model 133-6 detectors were planned for this project but the lower count rate of the 133-7 by about a factor of five versus the 133-6 means that the expected usage lifetime is about five times longer than the 133-6. Per vendor input (Randy Stevens, Design Engineer, Ludlum Measurement, Inc.), an estimate of the expected total counts per tube lifetime is 1.0E+10 counts. Since the approximate count rate for a 10 Ci/gal solution is about 100 cps, the 133-7 detectors average expected lifetime is about 3.3 years, while the average expected lifetime under the same conditions for the 133-6 is only about 8 months. This lifetime only refers to the condition where the high voltage is applied to the tube. When a detector is not in use, the high voltage is not applied and there is no effect on the tube lifetime.

The shield is a 3-inch diameter by 6.25-inch long cylinder. The final GM shield design is shown in Figure 3-1. It is nominally one-inch thick tungsten with a 3-inch long collimator along the length of the shield. 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. One inch of tungsten surrounds the GM tube on all sides to allow maximum flexibility in locating the detector. One side is flattened to permit attaching the pipe clamp to hold it in place.

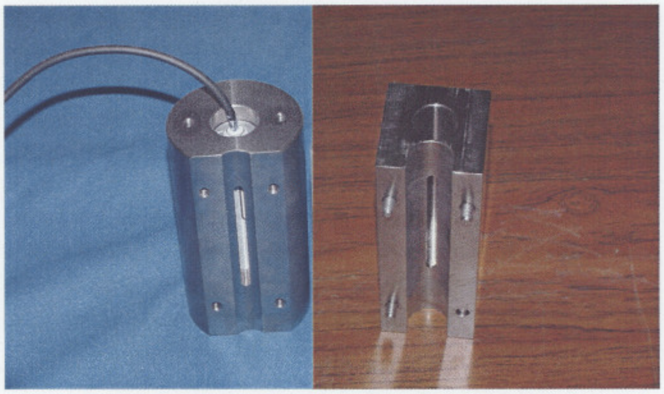
Figure 3-1. Final GM shield design.

There is also one inch of tungsten shielding on the top of the detector with a cable strain relief clamp attached that holds the electrical feed on the bottom of the detector in place. The top of the shield assembly with the electrical feed is positioned away from the most intense radiation source. Figure 3-2 (drawing R-RI-H-00339) shows the tungsten plate and cable strain relief clamp implemented on the top of the GM shield to preclude any gamma streaming from the cable penetration.

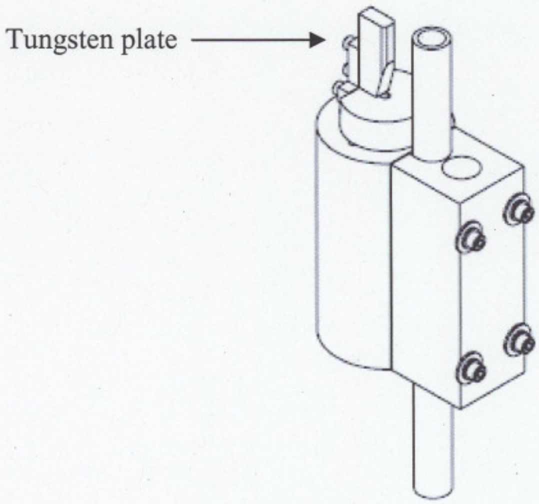

Figure 3-2 Tungsten plate above cable hole to prevent gamma streaming.

The pipe clamp/source-holder, shown in Figure 3-1, has a slit exactly the same as the shield slit, and was designed such that a standard pipe source can be placed in the clamp assembly to re-calibrate or verify that the detector efficiency has not changed. The count rate of the pipe source is correlated to the previously measured efficiency for future efficiency measurements. This source can be counted after purging the lines with 0.001 M nitric acid. Any increase in count rate will be due to contamination deposited on the area of the pipe being counted. Since there are two monitors measuring the same solution, both monitors will give the same result within the experimental uncertainty. This provides another verification that the monitors are operating properly. The calibration of the GM monitors must be done in the field to ensure that the calibrations are done for the exact detector positions.

A GM monitor inside the 1" thick tungsten enclosure is located inside the Strip Effluent Decanter (SED) cell to monitor the concentrated salt solution line from the contactor to the tank. The GM monitor is used to determine the Curie content of the concentrated salt strip effluent stream from the contactors. The curie concentration will be used to determine operational efficiency during the MCU extraction. Regulatory and Radiation Technology determined the gamma flux inside the shielding enclosure from background sources and the gamma flux from the line being monitored. Two cases were analyzed, 1) The gamma flux from the SED tank, coalescer, new accumulator and associated pumps (noise or background) and 2) Gamma flux from the 16.5 Ci/gal line or signal without the background from the SED cell.

Dose rates were calculated using the computer code MCNP, "Monte Carlo N-Particle Transport Code System", CCC-700. The input file was executed using MCNP. The following code executables were used:

1. MCNP version 5.14 for dose rates.
2. MCNP Visual Editor, Revised version MCNP5-Nov-2005-19L for visual examination of the geometric model.

MCNP has been tested and verified, as documented in N-TR-B-00002, "Software Validation and Verification Report for MCNP5 and MCNP4C2"; MCNP is controlled in accordance with the RTG Software Quality Assurance Plan (S-SQP-G-00001, Rev 0, 12/20/2001) and Software Validation and Verification Plan, report N-TR-B-00001, Revision 0, 6/26/2006.

The following Assumptions / Input Data were used.
1. The Strip Effluent Decanter (SED), coalescer, accumulator, and adjacent pumps are full with 16.5 Ci/gal of Cs-137.
2. Design basis source terms, SED tank volume, and model dimensions are obtained from N-CLC-H-00663. The gamma sources include secondary gammas or bremstrahlung generated in the source solution.
3. Four ½" OD diameter lines segments, of about 10" long, were modeled to determine the signal inside the shielding tungsten enclosure where the GM tube will be located.
4. The GM tube shielded enclosure is located in the north-east corner of the SED cell, 13' 2" from the floor, and 2 feet from the west wall.
5. To determine the gamma flux inside the shielded enclosure from the SED, the shielded enclosure is modeled as a tungsten cylindrical body 1" thick. This model provides slightly conservative dose rates since one portion of the enclosure is not modeled.
6. The GM monitors location and dimensions, model description, and source terms for both the sample line and the SED are given in N-CLC-H-00085.

MCNP calculations determined the gamma flux inside the tungsten shielding enclosure (background) and from the sources in the SED cell and from the 16.5 Ci/gal lines. Figure 3-3 shows the gamma flux vs. energy for sources in the SED cell and the sample lines. The dose rate inside the shielded enclosure from the sources in the SED cell is 96 mrem/hr, and the dose rates in the same location from the sample lines, not including the source in the room is 8.54 Rem/hr. The gamma flux from the components in the SED cell is much lower that the gamma flux from the 16.5 Ci/gal lines, which is being sampled. **The dose rate from background is about 1.1 %**

of the total dose rate of 9.5 Rem/hr (signal plus background). This result exceeds the design requirement that the background dose be less than 10% of the signal plus background dose rate. The 10% requirement is to account for the fact the background changes with process conditions, and this requirement allows for an accurate way of subtracting the measured background. For additional discussion refer to report N-CLC-H-00669. The calculated gamma fluxes include gammas with energies higher than the 0.662 MeV; these gammas come from the bremsstrahlung created in the source from beta decay of Cs-137.

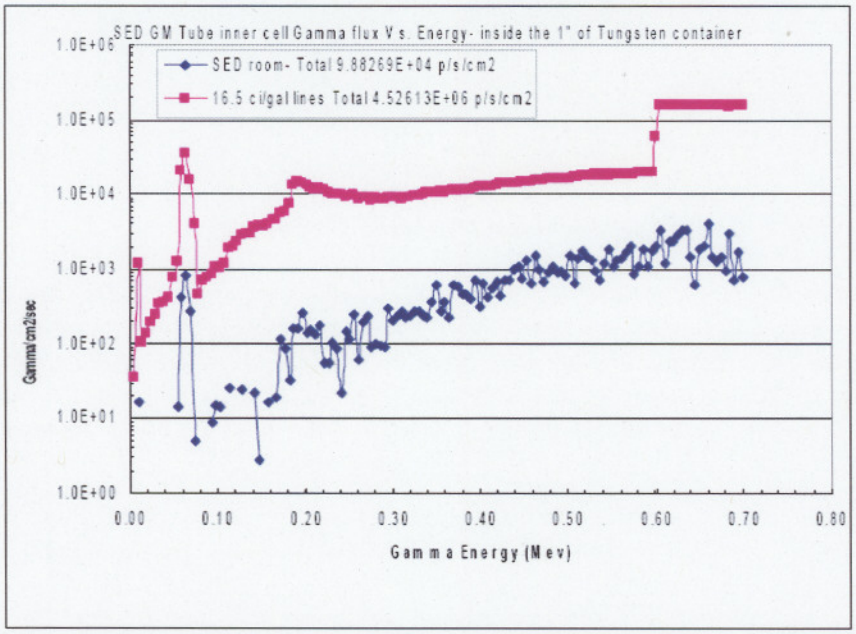

Figure 3-3 Comparison of background and signal gamma flux for GM shield.

Since the cable hole was ignored for the calculation in this study, a tungsten plate (Figure 3-2) was added to the top of the shielding enclosure to prevent gamma streaming through the hole where the electrical cables are routed through the shield.

3.2 NaI Shield Design

As previously discussed, two redundant NaI gamma-ray monitors are used as DSS monitors in the MCU process. Tungsten shields were designed and described in the first revision of this report. However, process conditions changed resulting in a much higher background level in the area where the NaI detectors are located and the detection limit requirement was reduced from 0.1 Ci/gal to 0.01 Ci/gal. Background conditions had changed from the original design because high activity pipes were put in close proximity to the monitors, and the original design had concrete walls around the process tanks but these walls were not implemented. MCNP calculations showed that the original tungsten shields were not adequate for the new background conditions. The original Task Technical and QA Plan (WSRC-RP-2004-00875) for this work states "SRNL will review and approve, as necessary, design documents that impact implementation of the monitors. Of particular interest are impacts on the radiation background levels at the monitor locations."

A lead box was designed to provide additional shielding for the NaI detectors/tungsten shields arrangement that was originally to be implemented in the MCU and is discussed below.

3.2.1 NaI Shield Design - Lead Box/Tungsten Shield Assembly

3.2.1.1 Lead Box/Tungsten Shield Assembly Design

The original NaI shield design is shown in Figure 3-4. The shield is made of tungsten and has a clamp, also made of tungsten, to hold the shield to the piping. The detector is surrounded by

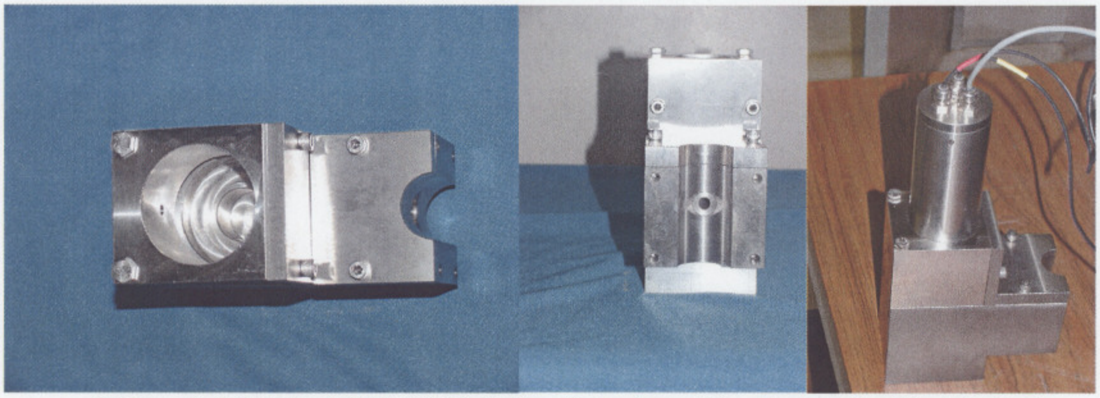

Figure 3-4 Original NaI shield design (top view, side view, and with detector).

at least one inch of machinable tungsten, and there are two inches of machinable tungsten on the bottom of the shield to provide more shielding based on the original requirements for the projected radiation field. (Drawing P-PM-H-0825)

Additional machinable tungsten plate material (3/8" to 1") was added around the detector PM tubes (sticking out of the shield in Figure 3-4) to provide shielding for the detector in the base of the shield. Also these tungsten shields were enclosed in a two-inch lead box (Drawing P-PM-H-08285) in order to reduce the gamma radiation background. The Lead box/NaI detectors/tungsten shields arrangement is shown in Figure 3-5.

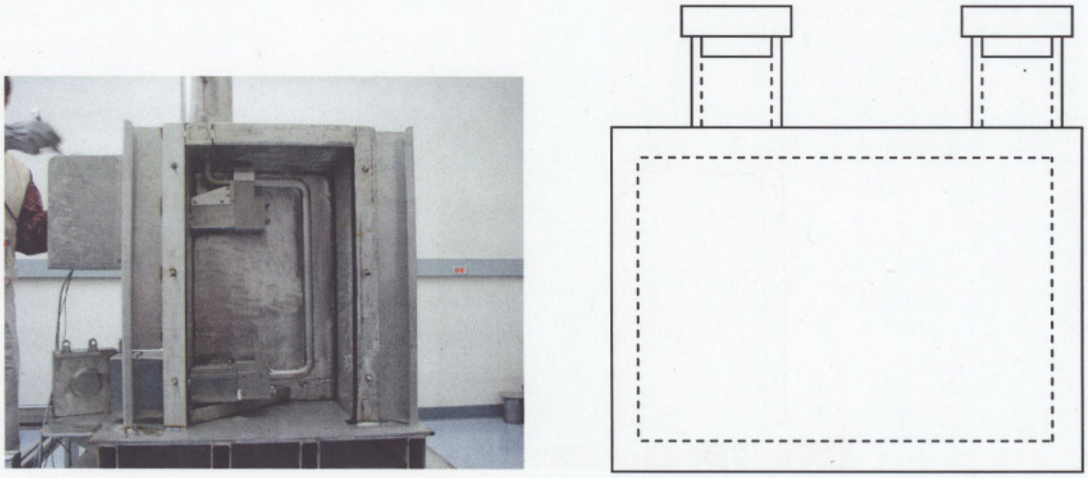

Figure 3-5 Lead box/NaI detectors/tungsten shields arrangement (left – front view rotated 90 degrees; right – diagram of two-inch lead box with one-inch thick detector tophats).

3.2.1.2 Lead Box/Tungsten Shield Assembly Testing

SRNL performed experimental testing of the lead box/NaI detectors/tungsten shields arrangement to determine the performance of the NaI Gamma Monitor System within this shield box configuration in a high gamma radiation field at the 735-2B calibration facility. MCNP calculations were used to relate the results from these irradiations to facility conditions. The experimental results were used to determine the capability of the NaI Gamma Monitor System to measure a 0.1 Ci/gal or 0.01 Ci/gal stream, if possible, at facility conditions. The test also verified experimentally if there were impactive un-modeled leak paths in the shield box. If any un-modeled leak paths were found, SRNL was to determine a mitigation/fix for the leak path.

3.2.1.3 Lead Box/Tungsten Shield Measurement Process

Irradiations were done at the 735-2B Calibration Facility using a high-activity Cs-137 source that provided a beam strength of 3.8 to 3.9 rem per hour. Thallium-doped sodium iodide, NaI (Tl), gamma-ray spectrometers with personal-computer-based data-acquisition electronics and spectral stripping software provided a measured count rate in the region-of-interest. Electronic personal dosimeters (EPD) were used to evaluate any leak paths within the shielding.

The test configurations are given in Procedure SP-17-009, "MCU Gamma Shield Performance Test." The planned irradiation positions of the shield were:

- Shield bottom (without and with lead on the corner seams)
- Shield front (without and with lead on the corner seams)
- Shield top (without and with lead on the corner seams)
- Shield top (with lead on the seams and also on the shield top hats that contain the detector photomultiplier tubes)

Figure 3-6 shows the preparation of the shield for irradiations, while an example of the NaI spectrum is shown in Figure 3-7.

Figure 3-6. Shield preparation for lead box irradiations.

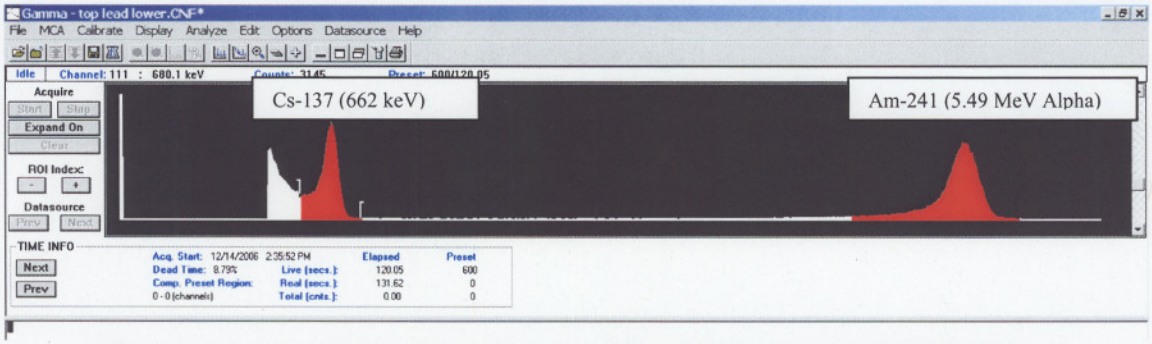

Figure 3-7. Cs-137 spectrum from Na(Tl) detector with Am-241 pulser.

3.2.1.4 Lead Box/Tungsten Shield Measurement – NaI Results

The NaI counting results for the irradiations are presented in Table 3-1.

Table 3-1. NaI Results for the Test Irradiations of the Lead Box/Tungsten Shield

West Detector

Configuration	Count Time (s)	Cs-137 Peak Counts	Cs-137 Peak cps	Cs-137 Integral Counts	Cs-137 Integral cps	Am-241 Counts	Am-241 cps
Background	600	0	0	0	**0**	292809	**488**
Bottom no lead	600	0	0	3494	**6**	292462	**487**
Front no lead	233	34420	148	98829	**424**	114402	**491**
Top no lead	124	23211	187	40534	**327**	61157	**493**
Front w/lead (seams)	123	11163	91	46267	**376**	60494	**492**
Top w/lead (seams)	129	24977	194	45569	**353**	62611	**485**
Tophat with lead	162	2752	17.0	4267	**26**	78660	**486**

East Detector

Configuration	Cs-137 Time (s)	Cs-137 Peak Counts	Cs-137 Peak cps	Cs-137 Integral Counts	Cs-137 Integral cps	Am-241 Counts	Am-241 cps
Background	600	12	0.02	1362	**2**	264061	**440**
Bottom no lead	600	0	0	3618	**6**	266652	**444**
Front no lead	48.2	0	0	737	**15**	21232	**440**
Top no lead	120	25061	209	36330	**303**	53121	**443**
Front w/lead (seams)	127	0	0	2034	**16**	56431	**445**
Top w/lead (seams)	120	22479	187	34818	**290**	54065	**451**
Top hat with lead	147	212	1.4	1117	**8**	65472	**445**

The following conclusions can be derived from the data given in Table 3-1. The last column (Am-241, cps) shows extremely consistent results for the Am-241 peak for each measurement.

This peak is due to the Am-241 "seed" on the detector itself and will give essentially the same results if the detector is working properly. Therefore, this validates that the detectors and associated electronics were operating properly throughout the test. The reason that both detectors do not give the same Am-241 value is because the amount of Am-241 "seed" used varies somewhat for each detector. Also, the detection limit, based on the count rates listed in Table 3-1, is lower for the East detector than the West detector, and this confirms the decision to model only the West detector as being a conservative approach to the MCNP calculations.

It is obvious from the data in Table 3-1 that adding lead shielding on the top hats provides the biggest reduction in Cs-137 count rate. This is because there is no tungsten shielding above the detectors at the top hat (photomultiplier tube) region. The count rates for the West and East detectors are reduced by factors of 14 and 36, respectively. Adding lead to the seams produces about a 10 to 15% reduction in observed Cs-137 counts.

The Cs-137 Integral, cps column is particularly noteworthy because it gives the count rate for gamma rays in the Cs-137 region-of-interest. Therefore, it is used for calculation of the detection limit. The Cs-137 integral count rate for a 0.01 Ci/gal solution in the process piping has been measured using standards to be 18 cps (Revision 0 of this report) for the 0.31-inch diameter collimator arrangement; however, the background requirement is 10% of this value.

Table 3-2. Comparison of MCNP to Measured Results[1] for Lead Box/Tungsten Shield.

Box Side	Cs-137 (cps)	Beam CF Test/MCU (580–700 keV)	MCU Det Limit for 0.01 Ci/gal (cps)	MCU Detection Limit (Ci/gal)
Front	424	2.43	1.8	0.97
Top	327	8.22	1.8	0.22
			Measured Detection Limit	**1.19**
Front	376	2.43	1.8	0.86
Top	353	8.22	1.8	0.24
			Measured Detection Limit (shielded seems)	**1.10**
Front	376	2.43	1.8	0.86
Top	26	8.22	1.8	0.02
			Measured Detection Limit (shielded seems and tophats)	**0.88**
			Calc. (MCNP) Detection Limit	**1.33**

[1] Per N-CLC-H-00671, page 11, the values above have been corrected by a value of 5.33 due to a correction in the detector volume.

Table 3-2 lists the detection limit (Ci/gal) for the lead box/tungsten shield configuration in the MCU calculated from the MCNP calculations to be 1.33 Ci/gal and compares this calculated value to the experimental results. The integral counts-per-second (cps) were obtained from the top and front counts-per-second values given in Table 3-1, while the bottom did not make a significant contribution. In order to make the conversion, the 662 keV Cs-137 beam intensity at the calibration facility must be correlated to the beam intensity and gamma rays hitting the detector in the region-of-interest (~580 keV to 700 keV) from the facility flux.

The beam conversion factors (CF) given in Table 3-2 were obtained from the beam fluxes hitting the detector and, in the case of the top, a correction was made for the detector attenuation of the beam. In general, the MCU beam fluxes for each side of the box were approximately the same as the test facility (within 25% of each other), except for the top of the box. The test facility beam at the top of the box was a factor of 3.6 times the flux at the MCU. The detector attenuation correction was made for the top of the box because it affected the experimental results and was not included in the MCNP model.

It is obvious from the data that there is excellent agreement of the measured results and calculated results, and MCNP calculations give a very good value for the actual detection limit.

It is also obvious from the data in Table 3-2 that the present shield configuration is not adequate to meet the NaI measurement requirements in the MCU. A reduction in background radiation in the energy region-of interest is required for the measurements. Both the calculated and measured results show that additional shielding is required for the front, top and seams.

3.2.1.5 Lead Box/Tungsten Shield Measurement - Electronic Personal Dosimeter (EPD) Results

Electronic personal dosimeters (EPDs) were placed at the lead box seams and at strategic positions within the box to detect increased levels of radiation within the box. EPDs were also placed in the tophats and on the inside tungsten shields at each detector and at the outside of the East (lower) detector pipe clamp.

The box was irradiated in the top, front and bottom positions and the EPDs were removed and the dose data were downloaded and reset to zero dose. Subsequently, the EPDs were replaced in essentially the same positions and irradiations were performed with lead on the front seams, lead on the top seams, and lead on both the top seams and the tophats.

The EPD results in mrem/hr are given in Table 3-3. The following conclusions can be derived from these data. For the front and top seam, there was a large decrease in dose when lead was placed on this seam. This was to be expected because there is an obvious gap at this seam. For the front and bottom seam, there was no change in exposure when lead was added to the seams because this seam is essentially closed. The top and steel plate seam showed a large decrease in dose when lead was placed on this seam as expected. Not much information could be gleaned from the bottom and steel plate seam because lead was not placed on this seam.

The dose rates for the EPDs in the tophats during the front irradiations were very high. This was to be expected because they were extending out into the beam and were only shielded by the tophat lead walls. A decrease in dose to zero was observed when lead was put on the top seams and, of course, was the same when lead was added to the tophats. Very little difference in dose was observed at the detectors (outside tungsten shield) and at the East detector clamp, except for a small detector dose increase for the bottom irradiation.

Table 3-3. EPD Results in mrem/hr for Lead Box seams.

EPD Number	Bottom No Lead mrem/hr	Front No Lead mrem/hr	Front Seams w/ Lead mrem/hr	Top No Lead mrem/hr	Top Seams w/ Lead mrem/hr	Top Hat w/ Lead mrem/hr
Front and Top Seam (EPDs on front)						
33761	6	24	10	6	6	2
103043	12	28	10	6	6	2
31849	14	70	45	10	11	9
33558	14	24	12	10	11	4
Average	**12**	**36**	**19**	**8**	**8**	**4**
Front and Bottom Seam (EPDs on front)						
9551	10	10	5	5	4	2
16080	10	10	5	8	8	4
33906	12	12	7	12	13	9
10018	16	15	25	17	21	22
Average	**12**	**12**	**11**	**10**	**12**	**9**
Top and Steel Plate Seam (EPDS on top)						
10080	39	10	12	29	4	4
33669	23	13	15	53	4	4
10079	27	18	17	33	4	4
34610	27	12	15	47	8	7
Average	**29**	**13**	**15**	**41**	**5**	**5**
Top and Steel Plate Seam (EPDs on steel plate)						
103061	14	14	15	81	6	7
34608	16	15	20	47	11	7
10098	20	16	20	39	6	7
9970	31	16	22	49	15	18
Average	**20**	**15**	**19**	**54**	**10**	**9**
Bottom and Steel Plate Seam (EPDs on bottom)						
33602	33	9	12	13	6	7
33631	90	10	12	15	8	7
33663	82	12	15	17	11	11
34641	55	15	20	20	17	18
Average	**65**	**12**	**15**	**16**	**11**	**10**

Table 3-3. (continued) EPD Results in mrem/hr for Lead Box seams.

Bottom and Steel Plate Seam (EPDs on steel plate)						
34613	92	10	12	9	6	7
15605	98	13	17	13	8	9
34793	72	17	20	17	13	13
33543	86	28	30	26	21	20
Average	**87**	**17**	**20**	**16**	**12**	**12**
TopHat W						
34701	**0**	**35**	**79**	**6**	**6**	**0**
TopHat E						
33551	**2**	**31**	**45**	**5**	**6**	**0**
W Detector						
34362	**16**	**7**	**7**	**7**	**6**	**2**
E Detector						
66342	**20**	**9**	**12**	**10**	**8**	**7**
E Det Clamp						
33661	**10**	**8**	**10**	**15**	**15**	**11**

3.2.1.6 Lead Box/Tungsten Shield – Conclusions/Recommendations

SRNL performed experimental testing of the lead box/NaI detectors/tungsten shields arrangement to determine the performance of the NaI Gamma Monitor System within this shield box configuration in a high gamma radiation field at the 735-2B calibration facility. MCNP calculations were used to relate the results from these irradiations to facility conditions. The experimental results were used to determine the capability of the NaI Gamma Monitor System to measure a 0.01 Ci/gal stream at facility conditions. The test also determined experimentally if there were leak paths in the shield box and provided a mitigation/fix for the leak path. Based on this experiment, the as-built shield is predicted to be able to detect the MCU DSS stream at concentrations above 1.2 Ci/gal and this compares favorably to the MCNP prediction of 1.3 Ci/gal. Additional shielding is required, particularly to the box front and tophats, to reduce the detection limit to the desired level. Tungsten shielding should also be considered.

- This experiment showed excellent agreement between the experimental results and the MCNP calculations.

- Additional shielding is required for the NaI monitors to meet the detection limit of 0.01 to 0.1 Ci/gal in the MCU facility or the monitors should be moved to a lower background area. MCNP calculations and experimental verification should be done for any new shield arrangement.

- Moving the NaI monitors to a much lower background area would be the most desirable way to provide dependable results and less shielding is required compared to the present position in the MCU.

- A smaller and more efficient tungsten shield that would be less cumbersome and easier to machine can be designed to reach the desired detection level.

- The EPD results confirm that the shielding of the tophats is not adequate and that there is leakage at the front/top seam that must be shielded.

3.2.2 NaI Shield Design - Tungsten Alloy Shield Assembly

Since the previously discussed Lead Box/Tungsten Shield arrangement did not provide adequate shielding for the MCU background radiation based on the new facility modifications, a tungsten shield was designed. SRNL performed experimental testing of a tungsten shield /NaI detector arrangement to determine the performance of the NaI Gamma Monitor System within this configuration in a high gamma radiation field at the 735-2B calibration facility. MCNP calculations were used to relate the results from these irradiations to facility conditions. The experimental results were used to determine the capability of the NaI Gamma Monitor System to measure a 0.01 Ci/gal stream for “worst case” facility conditions.

Figure 3-8 shows the tungsten alloy NaI shields and clamps. The dimensions of these shields are documented in drawings R-R4-H-000517 and R-R1-H-00335. Ultrasonic testing was done on the shields to determine if there were any voids. There was one void detected for the West detector and it is discussed below. No other voids were detected in the East or West shields.

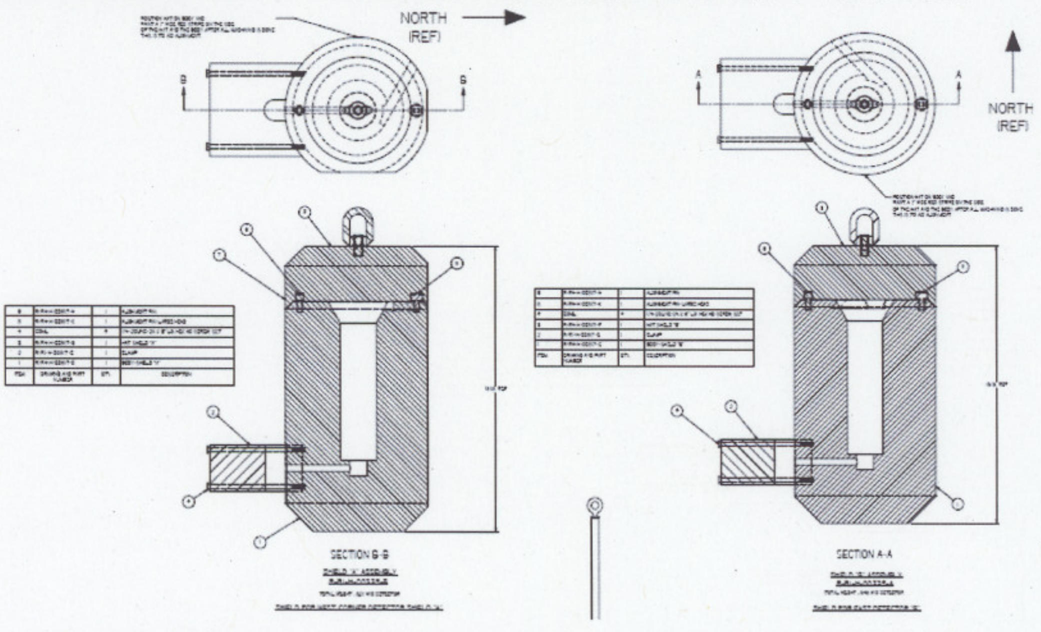

Figure 3-8. West (right) and East (left) tungsten alloy NaI shields and clamps.

Figure 3-9 shows pictures of the West shield and clamp. For the West detector, a void was discovered during the machining of the shield. The shield was fabricated so that this void was positioned in the rear (lowest dose area) of the shield. This void is shown in the Figure 3-9 and the position of the void (in the back of the shield) is verified because it is just to the back of the cable penetration. During the testing of this shield, it was necessary to verify whether or not MCU background radiation would penetrate this void and increase the detector background. Ultrasonic testing did not detect any other voids in the tungsten shields.

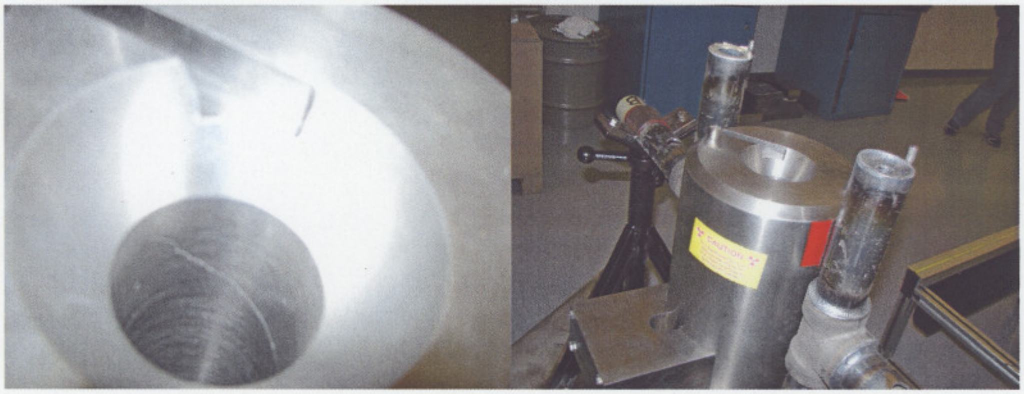

Figure 3-9. Void in back (North) position of West shield.

3.2.2.1 Tungsten Alloy Shield Assembly - Measurement Process

Irradiations were done at the 735-2B Calibration Facility using a high-activity Cs-137 source that provided beam strengths of 3.27 to 3.48 rem per hour. A thallium-doped sodium iodide, NaI (Tl), gamma-ray detector with personal-computer-based data-acquisition electronics and spectral stripping software measured count rates in the region-of-interest.

The West tungsten shield was tested at the 735-2B calibration facility. These results were converted to those that would be expected at the MCU facility. At the MCU facility, repetitive 30-minute count (cycle) times are presently planned and 30-minute counts times were also used at the test facility. The detector-shield configuration was calibrated with specially ordered NIST-traceable pipe standards that consist of MCU piping and Cs-137 contained in an epoxy material with a density closely matched to the process solution (Section 3.6). The dose rates used at the calibration facility are comparable to the MCU dose rates (3.66 to 3.99 rem per hour) for the bottom, South and West shield directions. The MCU dose rate for the top of the shield is lower (1.35 rem per hour) and for the East and North shield directions the MCU dose rates are negligible. The testing takes into account these dose rate differences.

The 662-keV beam flux at the test facility is much more penetrating than the MCU beam flux that has a range of gamma energies (0 to 662 keV) due to Compton scattering. A correction of the data for this difference in flux energies is also made based on MCNP calculations. Figure 3-10 shows the preparation of the shield for irradiations and Figure 3-11 shows an example of a NaI spectrum while Figures 3-12 and 3-13 show the vertical and horizontal irradiation positions.

The test configurations are given in Procedure SP-17-010 Rev.1, "MCU Tungsten Gamma Shield Performance Test." The irradiation positions of the shield were:

- Shield vertical (rotate every 30 degrees for 12 irradiations)
- Shield top and bottom (irradiate top and bottom and rotate 30 degrees in each direction for 6 irradiations)

Figure 3-10. Shield preparation for irradiations.

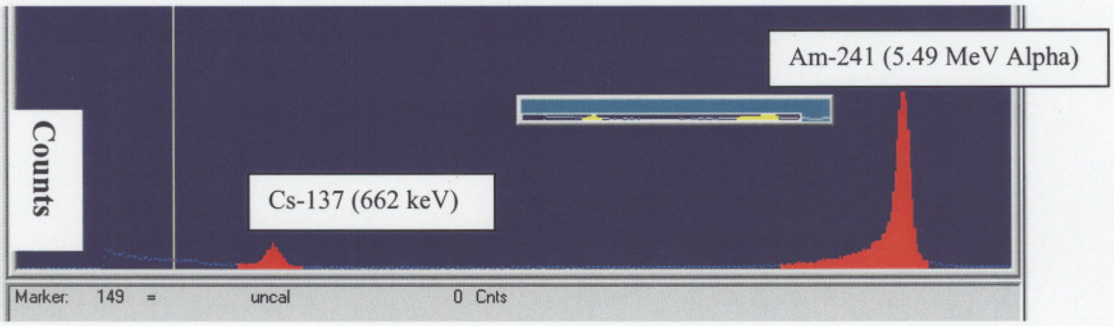

Figure 3-11. Cs-137 Spectrum from NaI (Tl) detector with Am-241 Pulser

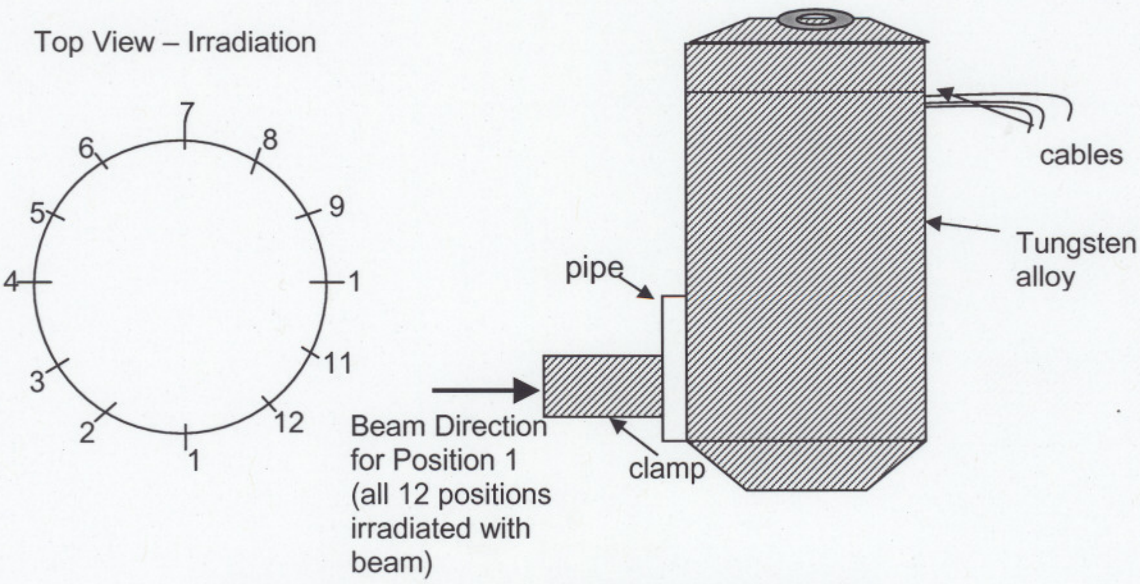

Figure 3-12. Tungsten shield in vertical position.

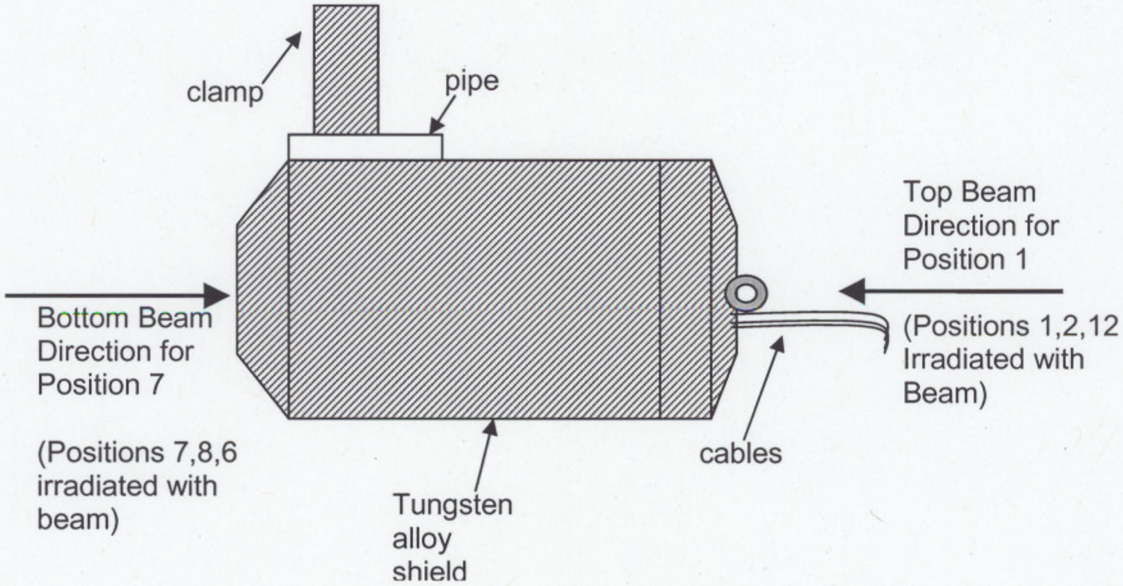

Figure 3-13. Tungsten shield in horizontal position.

The results for the test irradiations are presented in Table 3-4.

Table 3-4. Results for 30-minute Irradiations of West Detector/Tungsten Shield.

Position	Beam Rem/Hr	Cs-137 Peak (c)	Cs-137 Uncert. (c)	Cs-137 Integral (c)	Cs-137 MDA (c)	Cs-137 MDA or Peak (cps)	Am-241 Integral (c)
Vertical							
1 (West)	3.40	280	107	4828	323	0.179	840742
2	3.40	0	0	4641	317	0.176	839706
3	3.40	0	0	4947	327	0.182	839755
4 (North)	3.40	115	109	4974	328	0.182	841185
5	3.40	197	110	5027	330	0.183	843089
6	3.40	229	110	5076	331	0.184	843337
7 (East)	3.40	0	0	4846	324	0.180	844252
8	3.40	32	110	4948	327	0.182	846138
9	3.40	0	0	5066	331	0.184	845704
10 (South)	3.40	349	109	5070	331	0.194	845652
11	3.40	121	110	5049	330	0.184	842101
12	3.40	277	102	4457	310	0.172	842404

Table 3-4(continued). Results for 30-minute Irradiations of West Detector/Tungsten Shield.

Position	Beam Rem/Hr	Cs-137 Peak (c)	Cs-137 Uncert. (c)	Cs-137 Integral (c)	Cs-137 MDA (c)	Cs-137 MDA or Peak (cps)	Am-241 Integral (c)
Horizontal							
7 (Bottom)	3.27	2100	133	8477	428	1.167	843955
8	3.31	0	0	4925	326	0.181	841554
6	3.31	0	0	4637	317	0.176	844021
1 (Top)	3.48	693	109	5276	338	0.385	846963
2	3.44	0	0	4318	306	0.170	846390
12	3.44	0	0	4410	309	0.172	844581

The following conclusions can be derived from the data given in Table 3-4. The last column (Am-241, counts) shows extremely consistent results for the Am-241 peak for each measurement. This peak is due to the Am-241 "seed" on the detector itself and will give essentially the same results if the detector is working properly. Therefore, this validates that the detectors and associated electronics were operating properly throughout the test.

The first column gives the irradiation positions previously discussed; the second column gives test beam intensity in rem per hour; the third and fourth columns give the measured Cs-137 peak and uncertainty counts; the fifth column is the integral counts in the Cs-137 spectral region-of-interest; the sixth column is the minimum detectable activity in counts calculated from the integral counts; the seventh column is the larger of the measured peak area or MDA for each position divided by the count time of 1800 seconds. The Cs-137 peak refers to the stripped result (background under peak subtracted), while the Cs-137 integral contains all counts in the region-of-interest (including the region under the peak).

In most of the listed positions, except positions 10 (South), 7 (Bottom) and 1 (Top), the measured peak area is less than the minimum detectable activity (MDA). Therefore, there are no discernable Cs-137 gamma rays that penetrate the shield for these positions. Position 10 (South) is barely above the MDA, while the only statistically significant Cs-137 peaks observed were for positions 7 (Bottom) and 1 (Top). This might be expected for the top because the eye hook removes some of the tungsten shielding directly above the detector and replaces it with steel. The top chamfer and cable groove would not provide a reduction in tungsten thickness for the top irradiation because they are not in line with the direction of the test beam. The irradiations at $\pm 30^0$ from the top (positions 2 and 12) were also not affected by this chamfer and groove as shown by the experimental results.

However, it is not apparent why there is a small amount of Cs-137 gamma rays detected when the beam irradiation is directly on the bottom of the shield. It would appear that there is slightly less shielding on the bottom of the shield. Ultrasonic testing did not detect a void in the tungsten at the bottom of the shield.

In the MCU configuration, there is also an I-beam beneath the shield that provides approximately one inch of steel as additional shielding and would reduce this contribution by at least a factor of three. Also, there would not be this high of dose rate from a shine directly below the shield. As shown by subsequent discussion, these small observed Cs-137 peaks from the test beam have only a very small contribution to the shield MDA.

3.2.2.2 Tungsten Alloy Shield Assembly - Data Evaluation

Several experimental parameters were considered in calculating the shield detection limit. Some of these parameters are given in Table 3-5 for the four shield positions that contribute to the detection limit. In order to equate the test beam to the MCU radiation field, the beam dose rate (Rem/hr) must be known for each facility, and a factor must be used to account for the difference in gamma ray energies for the two beams. These parameters are given also in Table 3-5. The beam energy factor of 3.09, obtained from MCNP calculations, means that the test facility 662 keV beam is 3.09 times more likely to penetrate the shield than the MCU radiation field in the detected range of 580 to 700 keV. (Report N-CLC-H-00672 gives a factor of 3.64 for gamma rays detected for a 4 Rem/hr test beam and this value was reduced to 3.09 because the average test beam dose rate was approximately 3.4 Rem/hr.)

The Cs-137 Integral (21.6 $\pm$0.2 cps) is the counts per second for a measured 0.01 Ci/gal solution as determined by a pipe standard measurement in the exact MCU shield configuration. This agrees to within the counting uncertainty of the value of 21.8 cps predicted by the MCNP calculations (N-CLC-H-00672) based on previous standard measurements. This column is particularly noteworthy because it gives the count rate for gamma rays in the Cs-137 region-of-interest and tailing from the Am-241 peak. Therefore, it is used for calculation of the detection limit. As stated, the Cs-137 integral count rate for a 0.01 Ci/gal solution in the process piping is 21.6 cps (Section 3-6); however, the background requirement is 10% of this value. Since the MCU background radiation changes as the process changes (feed solution concentration, amount of solutions in the tanks, etc.), this 10% requirement allows for a reasonably accurate subtraction of background radiation that penetrates the shield. This is a small correction that is done in the software that would still be well within the overall measurement uncertainty of 10%.

Table 3-5. Data for Tungsten Shield Detection Limit Calculation.

Position	Test Beam Rem/hr	MCU Beam[1] Rem/hr	Beam Energy Factor (Test/MCU)	Cs-137 Integral cps/0.01 Ci/gal	DL Required = 0.1 x 21.6 cps/0.01 Ci/gal
Top	3.27	1.35	3.09	21.6	2.16
Bottom	3.48	3.66	3.09	21.6	2.16
South	3.40	3.80	3.09	21.6	2.16
West	3.40	3.90	3.09	21.6	2.16

[1]The dose rates (Rem/hr) of the East and North sides of the tungsten shield are considered negligible.

Table 3-6 lists the beam corrected count rates and detection limits (Ci/gal) calculated for the top, bottom, South and West directions of the tungsten shield configuration in the MCU. The calculation formulae used for this calculation are given in the table footnote.

Table 3-6. West Detector Detection Limit for a 30-min Count for 1.1 Ci/Gal Feed Solution and Process Tanks Full of Solution.

	Cs-137 MDA or Peak cps	MCU Shield cps	Detection[1] Limit (Ci/gal)
Top	0.385	0.051	0.00024
Bottom	1.167	0.397	0.00184
South	0.194	0.070	0.00032
West	0.179	0.066	0.00031
	Total =	0.59	0.0027

[1] MCU Shield (cps) = (cps Cs-137)(MCU Beam (Rem/hr) / Test Beam (Rem/hr))(1/3.09)
[2]DL (Ci/gal) = MCU (cps) x (0.01 Ci/gal / 2.16 cps)

As shown in Table 3-6, the tungsten shield MDA for a 30-min count time and the "worst case" facility conditions of having 1.1 Ci/gal feed solution and having all of the process tanks full is determined to be $\leq$0.003 Ci/gal. The primary factors contributing to the detection limit are a very small amount of Cs-137 activity detected through the shield bottom and the background observed in the Cs-137 region-of-interest due to tailing from the Am-241 pulser peak.

Since the steel I-beam below the shield will provide attenuation of at least a factor of three, the "worst case" shield MDA will actually be <0.002 Ci/gal because the MDA of the bottom would be reduced by 0.0012 Ci/gal. If only the tailing from the Am-241 peak is considered for the present NaI detectors that contain 27 nCi of Am-241, then the lowest MDA that can be achieved, based on the sum of the lowest possible MDAs (0.00011; 0.00028; 0.00032, and 0.00031 Ci/gal for the Top, Bottom, South and West, respectively), is 0.001 Ci/gal for a 30-min count time. About 27 nCi of Am-241 was used for the detector pulser, while 10% of this amount is adequate to obtain excellent counting statistics for the pulser peak. When additional detectors are ordered, the Am-241 seed should be in the range of 2 to 5 nCi. This improvement will lower the shield detection limit even more.

Based on this experiment, the as-built shield is predicted to be able to detect the MCU DSS stream at concentrations above 0.003 Ci/gal under the "worst case" field conditions. If the feed solution radioactivity concentration decreases, a corresponding decrease will be observed for this detection limit (to a lower limit of 0.001 Ci/gal for the 27 nCi Am-241 seeded detectors presently used.). This experiment showed that the facility radiation not attenuated by the tungsten shield would represent less than a 3% increase of the measured background radiation. Since this would result in a very slight conservative bias in the measurement and since the required measurement accuracy is $\pm$10%, the slight increase in background due to the radiation penetrating the shield can be ignored or a very small correction can be used.

3.2.2.3 Tungsten Alloy Shield Assembly - Conclusions/Recommendations

- **Based on this experiment, the as-built shield is predicted to be able to detect the MCU DSS stream at concentrations above 0.003 Ci/gal under the "worst case" field conditions with a MCU feed solution of 1.1 Ci/gal and all of the process tanks completely full.**

- The tungsten shield was irradiated in 12 vertical (every 30 degrees) and 6 horizontal positions (top and bottom) and there was no Cs-137 peak observed above the MDA for 16 of these positions. Very small Cs-137 peaks were observed when the beam was directly on the top and bottom of the shield, but no peaks were observed at angles of $\pm$30 degrees of the top and bottom.

- This experiment showed that there is excellent agreement between the experimental results and the MCNP calculations based on previous standard measurements. The MCNP calculations predicted that, based on the collimator diameter and length, the Cs-137 integral counts would be 21.8 cps and the measured value was 21.6 $\pm$ 0.2 cps.

- The slight increase in background due to the radiation penetrating the shield can be ignored or a very small correction can be used. Since it is unlikely that the actual "worse case" conditions will be approached, it is not likely that a background correction will be necessary. (If a background correction were needed, a prudent background correction can be made based on the present work.)

- When additional detectors are ordered, the Am-241 seed should be in the range of 2 to 5 nCi to lower the Am-241 tailing in the Cs-137 region-of-interest so that the detection limit can be lowered.

- If only the tailing from the Am-241 peak is considered for the present NaI detectors that contain a 27 nCi of Am-241, then the lowest MDA that can be achieved is 0.001 Ci/gal for a 30-min count time. A lower detection limit can be achieved by increasing the count time or using detectors with less Am-241 seed. A two-hour count time will reduce the detection limit by a factor of two as compared to the 30-minute counts.

3.3 Detector Installation

Figure 3-14 shows the detector arrangement within the process. The detectors will be positioned onto a trap of the process piping such that the pipe is full of liquid. Redundant detectors ensure that the measurement can be performed even if one of the detectors is not operational.

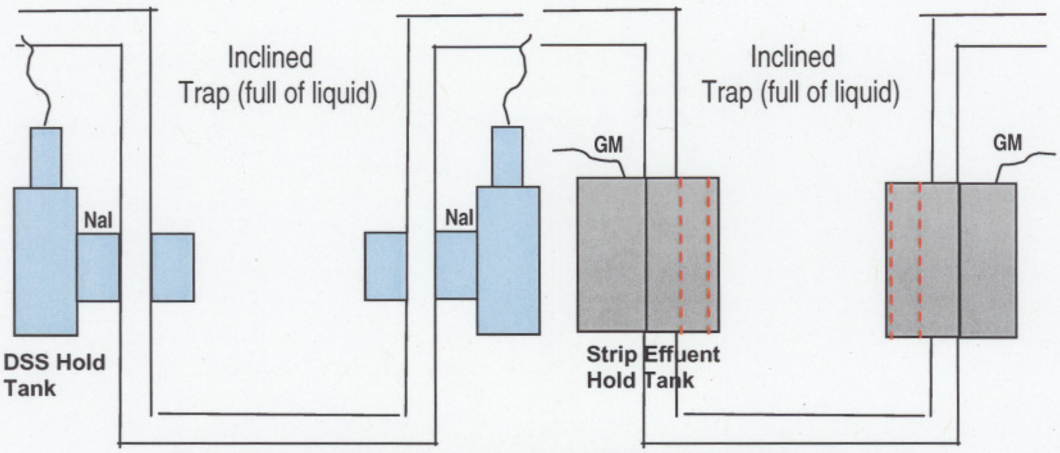

Figure 3-14 Redundant detector arrangement within the process.

3.4 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. A materials and equipment listing for the MCU-GRM hardware is included in Appendix D – Software User's Manual for the MCU-GRM and the electronics rack is shown in Figure 3-15.

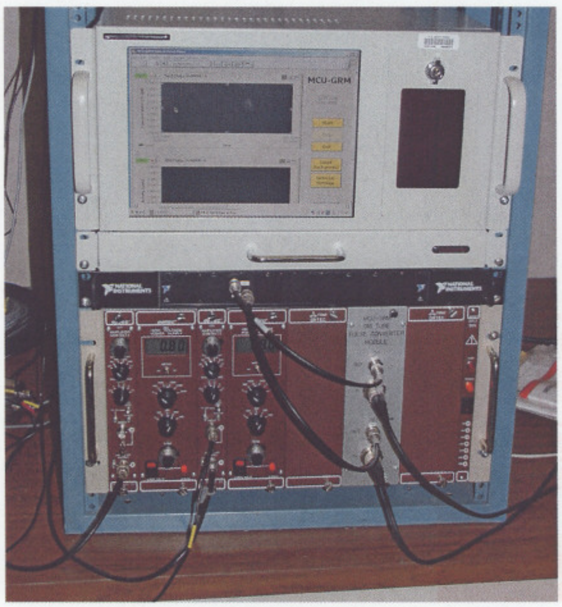

Figure 3-15 MCU-GRM Electronics Rack

Two NaI spectrometers (one online and one backup) are used for measuring the Cs-137 concentration in the decontaminated salt solution entering the DSS Hold Tank. High voltage and preamp power are provided to the detectors through Nuclear Instrumentation Module (NIM) based modular electronics. The amplified and scaled output signals from each 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) geared specifically towards nuclear spectroscopy applications.

Two GM tubes (one online and one backup) are used for measuring the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank. These 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 3-16 below.

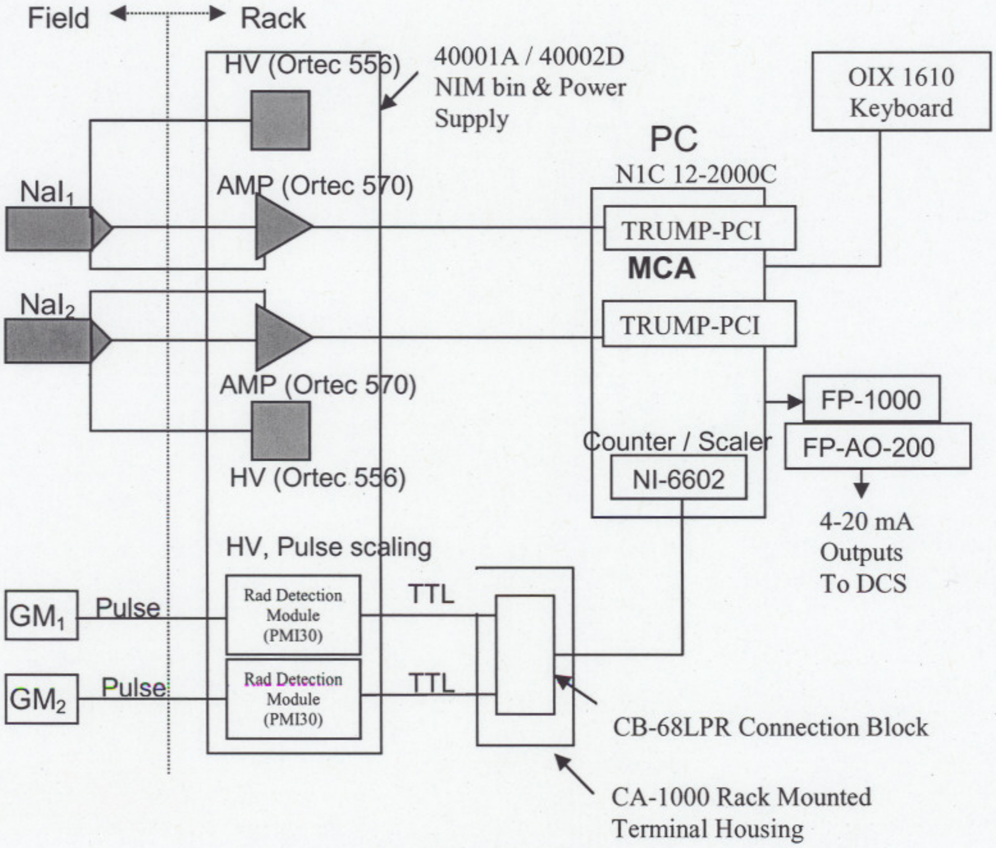

Figure 3-16 MCU-GRM Electronics Block Diagram

3.5 MCU-GRM 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 that are described in detail in J-DD-H-00001 "MCU-GRM Design Document for Software". The MCU-GRM software source code number is L814-J-002v Version 1.0.

From the User's point of view, the MCU-GRM software can be broken down into just a few software modules that will be described in this section. These software modules are the MCU-GRM Application Window, Detector Selection, Detector Configuration Settings, Background Counting, and Routine Data Acquisition.

3.5.1 Application Window

The major component of the MCU-GRM software is the application window, shown in Figure 3-17. 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.

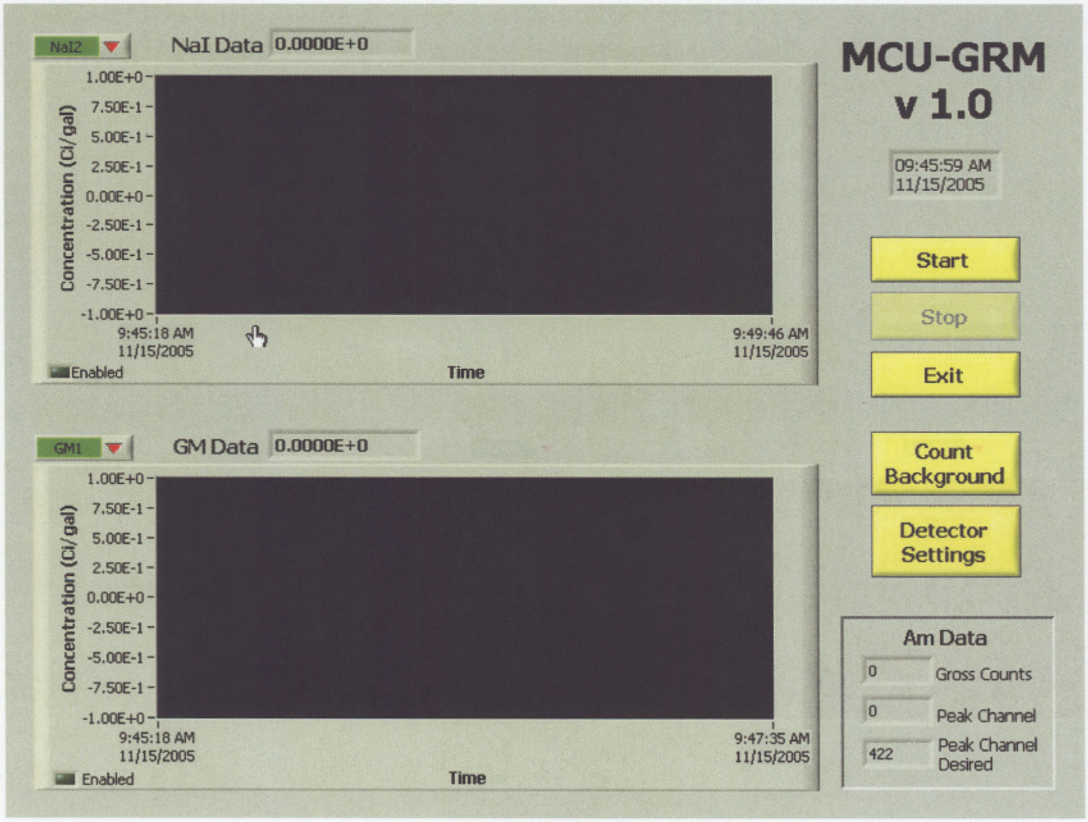

Figure 3-17 MCU-GRM Application Window

The most prominent features on the application window are the measurement history graphs. The 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.

3.5.2 Detector Selection

Selection of the desired NaI or GM detector is performed from the MCU-GRM Main screen, as shown in Figure 3-17, by clicking on the red arrow selector located beside both detector selection menus. This action brings up a pull-down menu from which the user can select the desired detector. Only one detector of each type may be selected at any given time. When NaI1 is on, NaI2 is off and vice versa. The same rules apply to the GM detectors. The detector selection function is disabled if either the MCU-GRM routine data collection or background counting options have been started.

3.5.3 Detector Configuration Settings

As is the case with any gamma monitoring system, the user must know certain detector operating parameters such as the detector efficiency and measured background count in order to make compensations to the measured activity for variations in the detector internals and for the amount of activity entrained within the system. Without these values, accurate determination of the solution activity is impossible. The MCU-GRM stores these values in a configuration file (MCU_GRM_CONFIG.ini). The format of this file is shown in Appendix D – Software User's Manual for MCU-GRM.

The user is granted access to these parameters only through the detector configuration utility. The user can access this utility, by clicking the **Detector Settings** button on the MCU-GRM main screen (Figure 3-17). Because these values are crucial to the operation of the system and its ability to produce reliable output data, a password is required for access. The Password Utility Screen is shown in Figure 3-18.

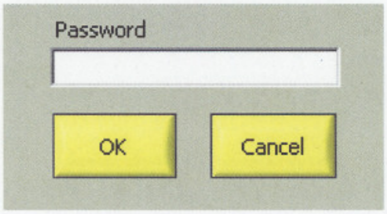

Figure 3-18 Detector Configuration Settings Password Screen

The password utility is case sensitive. Upon entering the correct password, the user will be able to access data on the Detector Configuration screen as illustrated in Figure 3-19. The user can change the password by changing the password character string in the password file. The filename is not included in this document. *NOTE: The password will be changed by the User after the project turnover.*

The Detector Configuration Screen is divided into 5 sections. Four identical sections, two for the NaI detectors and two for the GM detectors, are used for setting the detector operating parameters. This allows for independent parameter settings that are specific to each detector in the system. The single section at the bottom of the screen is used for setting the cycle times for routine data collection.

Within each of the detector sections, the user can set values for the detector Efficiency, measured Background, and Background Count Time. Changes can be made by either clicking the yellow up or down arrows next to each of the fields, or by typing a value directly into the text box. Each field performs automatic range checking on the entered data to allow only numerical entries within a predetermined range of values. The final range will be determined empirically when the system functional testing is performed.

If changes are made to either the detector Efficiency or measured Background settings, the associated Last Update fields are automatically imprinted with the current date. This is to help keep track of the last entries made for the critical detector operating parameters. Changes to the Last Update fields are done programmatically and are not accessible to the user. The user can select the Background Count Time for each detector. Optimal values will be determined empirically during system functional testing. Once changed, the new values are stored in the configuration file (MCU_GRM_CONFIG.ini) and are used for all future computations.

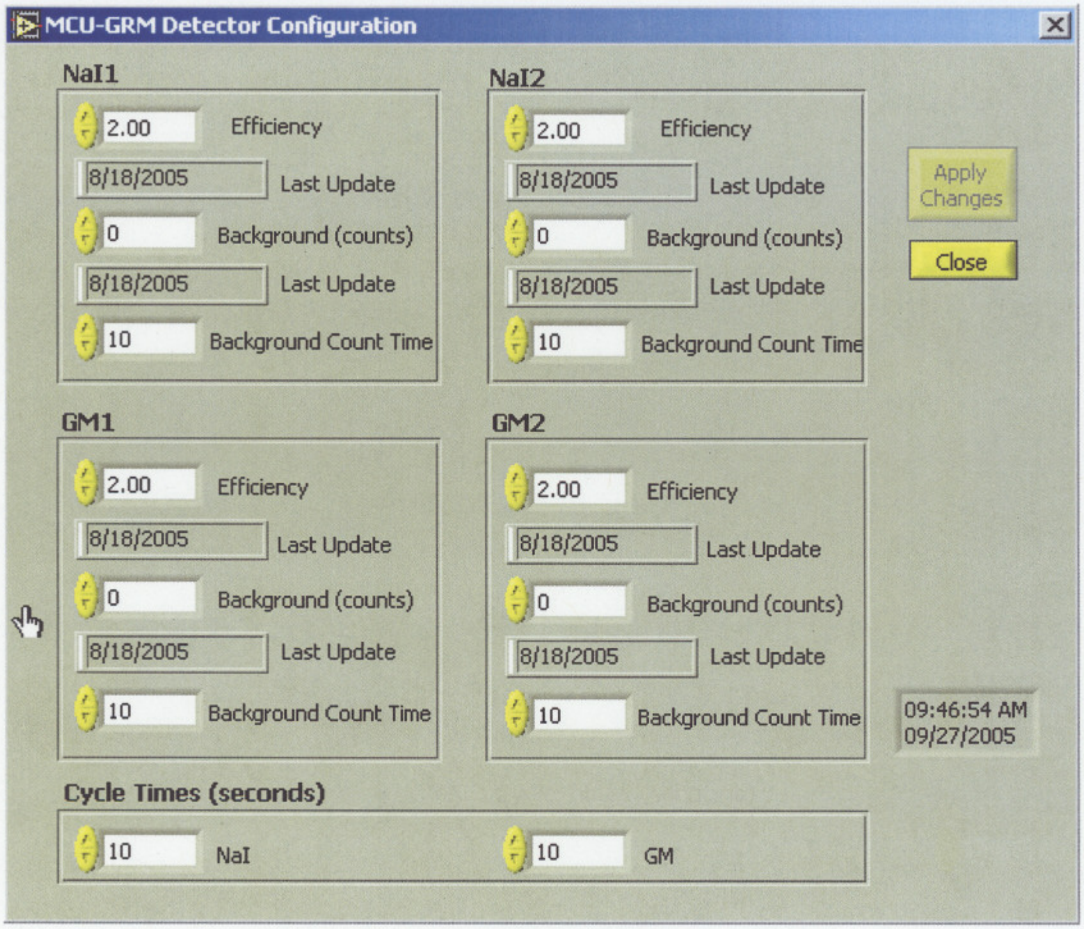

Figure 3-19 Detector Configuration Screen

3.5.4 Routine Data Acquisition

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 click the **Start** button on the MCU-GRM application window (Figure 3-17).

At this point, the application changes to the running state as indicated on the screen. In the running mode, the time remaining for each detector's acquisition cycle is displayed in the corresponding Next Update counter along the top of each graph. The Next Update counter is updated once a second to show the time remaining until the end of the current acquisition cycle. By default, the data acquisition cycle for both detectors is set for 60 seconds.

At the start of Run cycle, the program reads the GM and NaI detector configuration data as set previously using the Detector Configuration Utility. The system starts the first count by writing the live time preset to the Trump Card to start the spectrum collection. The Trump card performs all the required spectrum collection functions as instructed without further interaction from the MCU-GRM software. The system also initializes and starts the NI-6602 counter to monitor the pulse output of the GM signal train.

After the NaI time interval has elapsed, the program polls the Trump card to determine if the required live time spectrum collection has completed. If the live time interval has not completed the program waits for its completion. (NOTE: These two times should be about equal, unless a significant amount of dead time is encountered.) At completion of the counting cycle, the program queries the Trump card to get the raw counts in the Cesium photo-peak, along with other Cesium Region-of-Interest (ROI) statistical information. The program also reads the raw counts from the Americium photo-peak as well as the Am peak centroid channel number within the Am peak ROI. The ROIs in question are those established by the user (SRNL) during the initial system setup and calibration and should be the one containing the Cs and Am photo-peaks respectively. The program then issues commands to the Trump card to clear the current spectrum and restart the NaI data acquisition cycle. After the Trump card is restarted, the MCU-GRM software calculates the net counts in the Cesium photo-peak. At this point, the program has enough information to calculate the Cesium Concentration (Ci/gal) in the decontaminated salt solution. This is done by subtracting the measured background value from the net counts and dividing the result by the detector efficiency.

To wrap up the processing of the NaI data, 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 in the detector HV supply or the amplifier gain. If the Am peak channel is outside of an acceptable band, the system will flag the user with an error message similar to that shown in Figure 3-20. The NaI detector system will not perform its monitoring function until this condition is corrected. If the system electronics fail and do not provide an Am peak, this error message will also appear and will be an indication of a system hardware problem. These adjustments are covered in Appendix D, Software User's Manual for the MCU-GRM.

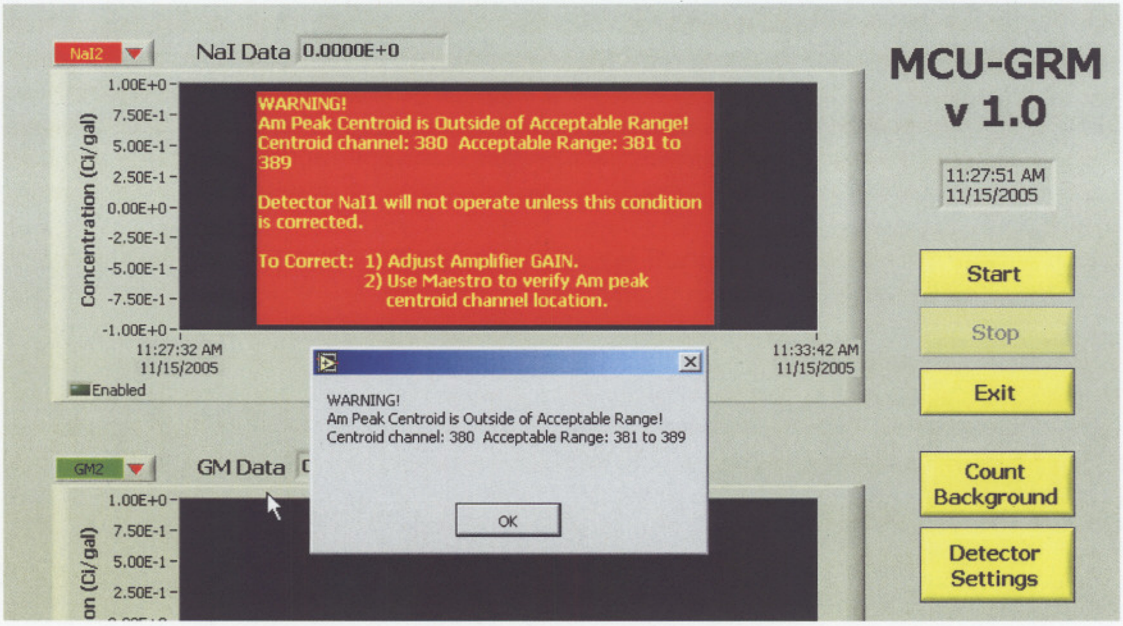

Figure 3-20. Am Peak Channel Error State

Like the NaI detector cycle, the MCU-GRM software issues commands to stop the NI-6602 counter and to read the total count collected during the GM data acquisition cycle. When this is completed, the program issues commands to clear and restart the count for the next cycle. Similar to the NaI data, the GM net counts are calculated using the GM detector measured background and the detector efficiency.

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. The new data and a selected subset of system and detector parameters are written to a log file (See Appendix D – NaI and GM DataLog file Format). Both acquisition cycles continue until the user clicks the **Stop** button on the application window.

3.5.5 Background Counting

In order to gain an accurate picture of the activity of the solution moving through the system the system must be able to separate out that portion of the measured activity that is contributed by the salt solution from the portion that is due to the entrained particles within the system and its surroundings. In order to do this, the software must be able to null out the contribution of the system components to the overall measured activity. The MCU-GRM software accomplishes this through background subtraction. 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.

The performance of this measurement requires coordination between the MCU-GRM and the DCS because a thorough flushing is required for all components within the detectors field of view. Since the detector is shielded, the field of view only consists of the piping section where the detectors are located. The system setup for this operation will be procedurally controlled within the facility and is outside the scope of this document. What is covered here is the performance of a background measurement as related to the MCU-GRM.

From the MCU-GRM point of view, the user will initiate a background count by first selecting the desired detector pair (one GM and one NaI detector) and then clicking the **Count Background** button on the MCU-GRM application window (Figure 3-17). The Start Background dialog box will be displayed as shown in Figure 3-21.

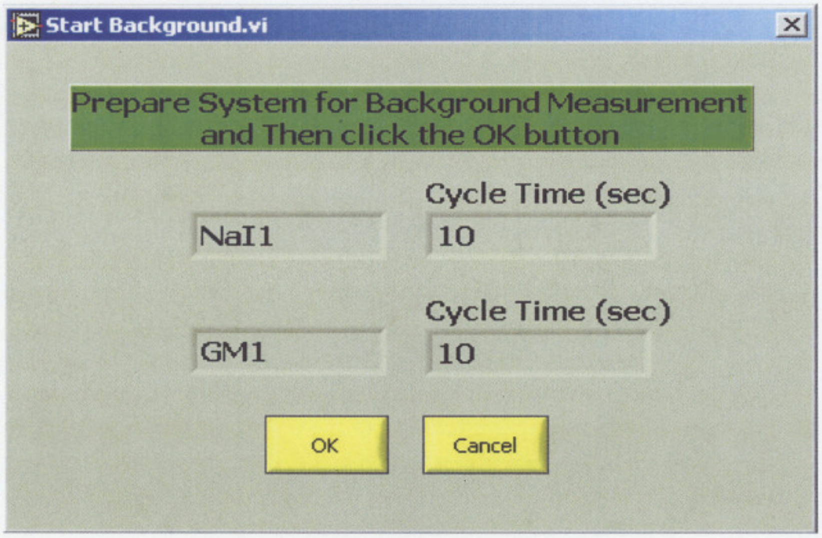

Figure 3-21 Start Background Count Screen

The Start Background screen shows the detectors currently selected for the background counting operation, as well as the background count time for each detector. The screen also contains a message to remind the user the system preparation should be completed prior to performing the background measurement. The MCU-GRM software only reminds the user that these activities should be performed, but has no method to enforce the requirement. Inadequate system preparation may result in inaccurate readings for the measured background values.

To proceed beyond the initial screen, the user must either accept or cancel the activity. If cancelled, the Start Background screen will disappear and the MCU-GRM application window will be displayed. If accepted, the Background count will commence. The count will be performed for the length of time specified in the window for each detector. During the count, the Next Update field on the MCU-GRM main screen (Figure 3-17) will count down to indicate the time remaining in the current counting cycle. At the completion of the background counting cycle for each detector a Background Count Complete dialog box will appear. This screen is shown in Figure 3-22.

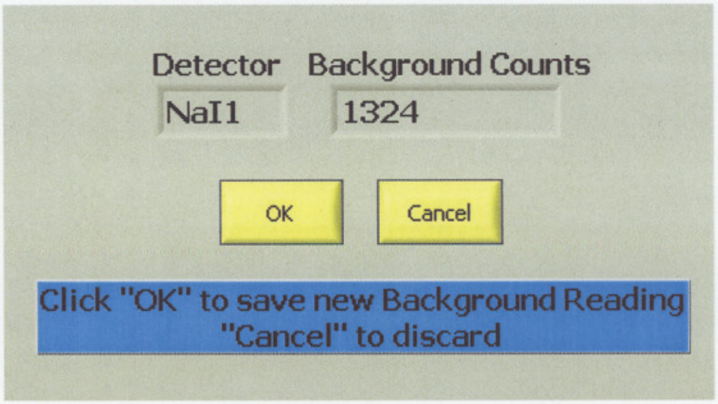

Figure 3-22 Background Count Complete Screen

The Background Complete screen displays the newly acquired background data point for the indicated detector and prompts the user to decide whether to keep or discard the new data. If the user decides to keep the new data point, the data are written to the detector configuration file (MCU_GRM_CONFIG.ini) and used for all subsequent calculations requiring background correction. This would also cause the Last Update field to be changed to reflect the new data point change. (Refer to Figure 3-19.) Otherwise the data are discarded and the current settings retained. When the background counts for both detectors have completed, the system returns to the standby mode awaiting further instructions from the user.

To summarize, the Background Counting mode performs a count for the two detectors that are currently selected, one GM and one NaI detector. Each count is performed for a preset period of time as determined by the setting in the Detector Configuration Window for the specified detector. At the completion of the count the new measured background data point may either be discarded, or written to the detector configuration settings file to be used on all subsequent calculations. Neither of the data points is written to the graph or to the digital display on the MCU-GRM application window. The procedure for routine startup and operation of the MCU-GRM software is given in Appendix D.

A typical spectrum collected using the Ortec Corporation spectral stripping program Maestro is shown in Figure 3-23. The Cs-137 peak and Am-241 pulser peak are evident.

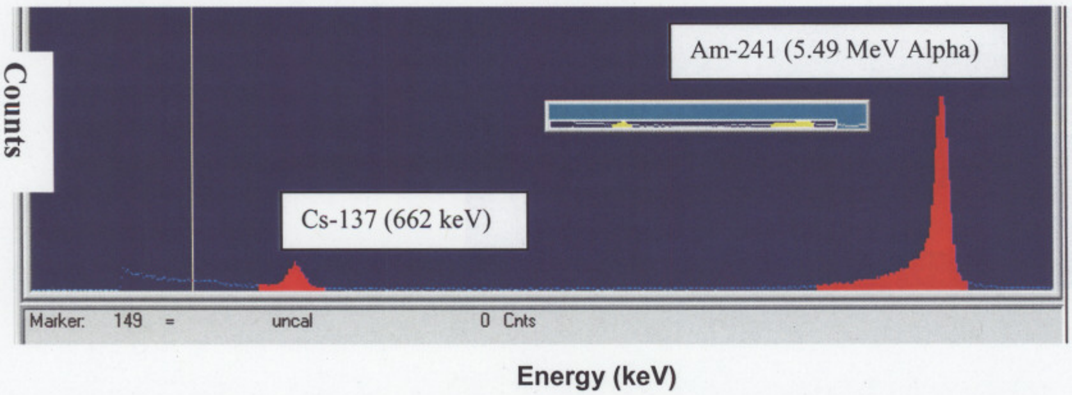

Figure 3-23 Cs-137 Spectrum from Na(Tl) detector with Am-241 Pulser

3.6 Detector Efficiencies and Operations

3.6.1 NaI Detector Efficiencies

In order to calibrate the detectors, NIST-traceable standard sources were purchased from Analytics Corporation, Atlanta, GA. These consisted of Cs-137 activity in a polymeric matrix that were contained in one-inch schedule 40 pipe for NaI monitor calibrations and half-inch schedule 40 pipe for GM calibrations. These standards are shown in Figure 3-24, and the NaI calibration results are shown in Table 3-7. The source certificates of calibration are given in Appendix F. When these efficiency calibrations were done, the Cs-137 activities of the standards were 217 and 479 microcuries each in a two-inch long, one-inch diameter schedule 40 pipe. The calculated Cs-137 concentrations were 0.0290 and 0.0641 Ci/gal for the two standards. As listed in Table 3-7, these efficiencies are for the 0.406-inch diameter collimator of the tungsten alloy shields and a detector bias of 520 volts.

Since these calibrations were not done with the MCU system, actual deadtimes are not listed. Based on the data from Revision 0 of this report, the count rate will increase by 50% for the new shield collimator resulting in a small increase in deadtime (since the Am-241 is a major source of deadtime). If the DSS stream concentration is above 0.2 Ci/gal, an evaluation of the spectra must ensure that peak area calculations are accurate. If the DSS concentrations are considerably above 0.2 Ci/gal, faster electronics may have to be implemented.

As shown in Table 3-7, the NaI efficiencies calculated for both shields (Figure 3-8) were essentially the same, agreeing within the counting statistics uncertainties of the measurements. The overall efficiencies were determined to be 6.21E-06 ± 6.3 E-08 cps/dps and 1718 ± 17 cps/(Ci/gal).

Table 3-7 Calibration results for the NaI Detectors (SAM 333 and SAM334).

NaI Efficiency Determinations (900 second counts) Tungsten Shield (West -- cylinder)
(Volts= 520; Collimator = 0.406 in)

Detector	Cs-137 Counts	Integral	Am-241 Counts	Integral	cps	Cs-137dps	EFF	cps/(Ci/gal)
SAM 333	9	2613	416885	438041	0.01	0		
SAM 333	-35	2634	419170	438413	-0.04	0		
SAM 333	44486	56825	415153	438714	49.43	8.03E+06	6.16E-06	1705
SAM 333	44423	56444	413605	437057	49.36	8.03E+06	6.15E-06	1702
SAM 333	99629	123933	415717	439880	110.7	1.77E+07	6.24E-06	1726
SAM 333	99697	123618	414867	439412	110.8	1.77E+07	6.25E-06	1727
SAM 334	110	2549	397127	419952	0.12	0		
SAM 334	-53	2530	395990	419261	-0.06	0		
SAM 334	44274	55675	399184	421294	49.19	8.03E+06	6.13E-06	1696
SAM 334	43799	56818	395211	419599	48.67	8.03E+06	6.06E-06	1678
SAM 334	99794	123207	397863	420818	110.9	1.77E+07	6.25E-06	1729
SAM 334	99203	123253	397949	422024	110.2	1.77E+07	6.21E-06	1718
						Ave Eff =	6.17E-06	1706
						STDEV=	7.12E-08	19

Table 3-7 (continued) Calibration results for the NaI Detectors (SAM 333 and SAM334).

NaI Efficiency Determinations (900 second counts) Tungsten Shield (East -- chopped cylinder)
(Volts= 520; Collimator = 0.406 in)

Detector	Counts	Integral	Am-241 Counts	Integral	cps	Cs-137dps	EFF	cps/(Ci/gal)
SAM 333	-177	2520	412732	438589	-0.20	0		
SAM 333	-325	2512	417135	439658	-0.36	0		
SAM 333	44663	56880	414514	440590	49.63	8.03E+06	6.18E-06	1711
SAM 333	44738	56955	416096	438947	49.71	8.03E+06	6.19E-06	1714
SAM 333	100031	125306	415218	439982	111.1	1.77E+07	6.27E-06	1733
SAM 333	100497	125464	413100	439231	111.7	1.77E+07	6.30E-06	1741
SAM 334	50	2589	404108	423521	0.06	0		
SAM 334	226	2536	401275	422705	0.25	0		
SAM 334	45066	56909	399510	424348	50.07	8.03E+06	6.24E-06	1727
SAM 334	45064	56944	400187	423097	50.07	8.03E+06	6.24E-06	1727
SAM 334	98879	121842	398615	424170	109.9	1.77E+07	6.19E-06	1713
SAM 334	100577	123155	396073	422570	111.8	1.77E+07	6.30E-06	1742
						Ave Eff =	6.24E-06	1721
						STDEV=	4.64E-08	9
						Tot Eff =	6.21E-06	1718
						STDEV =	6.3E-08	17

Figure 3.24 Detector calibration standards.

3.6.2 NaI Cable Length

Since the detector came with 100 feet of cable and since the process required the use of 150 feet of cable, a study was done to ensure that the NaI system would function properly with the longer cables. A 226 μCi standard was counted in a fixed geometry with 100-foot cables, and then a 50-foot extension was added to the end of the cables and the standard was counted again. The 100-foot cable results were 9737 ± 170 counts (detector SAM333) and 9947 ± 224 (detector SAM 334), while the 150-foot cable result was 9858 ± 164 (detector SAM333) and 9982 ± 223 (detector SAM 334). Obviously, the additional cable length had no effect on the results.

3.6.3 GM Detector Efficiencies

The Cs-137 measurement efficiencies for Ludlum 133-6 GM detectors were determined and this data are presented in Table 3-8. However, as previously discussed, since the Ludlum 133-7 detectors have a longer expected lifetime of about three years versus eight months for the Ludlum 133-6, these detectors are preferred. The efficiencies for the 133-7 detectors are approximately five times lower than those listed for the 133-6 detectors. Since the efficiencies depend on the exact positioning of the detectors, these efficiencies must be determined in the facility after it is certain that they will not be moved or tampered with. NIST-traceable pipe sources are positioned in the shield pipe clamp, so that the efficiency can be determined when needed.

Table 3-8 Determination of Cs-137 Efficiencies for the 133-6 GM Detectors.

Detector	Volts	Count Time (s)	Source	Counts	cps CS-137	dps Cs-137	EFF (cps/dps)
GM1	550	600	none	1			
GM1	550	6000	118 μCi	5847	0.975	4366000	2.23E-07
GM1	550	6000	237 μCi	11560	1.927	8769000	2.20E-07
GM2	550	600	none	0			
GM2	550	6000	118 μCi	7938	1.323	4366000	3.03E-07
GM2	550	6000	237 μCi	16353	2.726	8769000	3.11E-07

The measured efficiencies for two standards were in excellent agreement; however, there was a large variation in the efficiencies of GM1 versus GM2. Therefore, the efficiencies must be determined for each detector and either standard can be used.

3.6.4 GM Linear Detection Range

Since the standards used to determine the efficiencies are much lower than the activities that will be measured in the process, it was necessary to determine how the response of the GM detectors varies with increased activity. In order to accomplish this task, the GM detectors were exposed to high levels of radiation at the SRS health physics instrument calibration facility (Figure 3-25). The GM count rates were measured for Cs-137 exposures from 0.01 to 7 R/hr and this data are presented in Table 3-9.

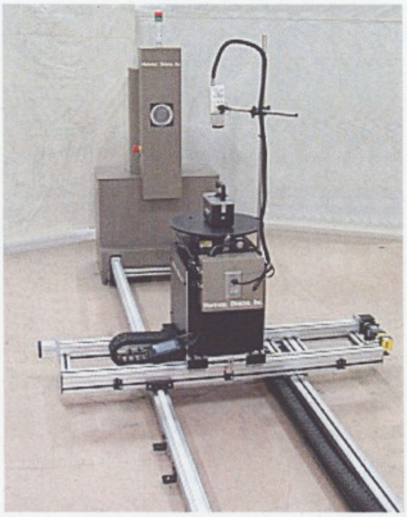

Figure 3-25 SRS Cs-137 gamma source and positioning system.

This graph clearly shows that the detector response varies linearly as the Cs-137 dose increases over the CSSX measurement range (0.1 to 16.5 Ci/gal). Therefore, calibrating the GM detectors with low-level standards and knowing that the detector response is linear in this range provides the basis for detector calibration.

3.6.5 GM Detection versus angular position

Another important consideration when using GM detectors is how the measurement varies if the detector is rotated within the shield. Figure 3-27 shows the GM tube that is covered with a foam material and positioned in the housing. If the tube is centered within the detector housing, there would be no variation in detector positioning in the shield. However, the vendor makes little effort to ensure that the tube is centered in the chamber housing.

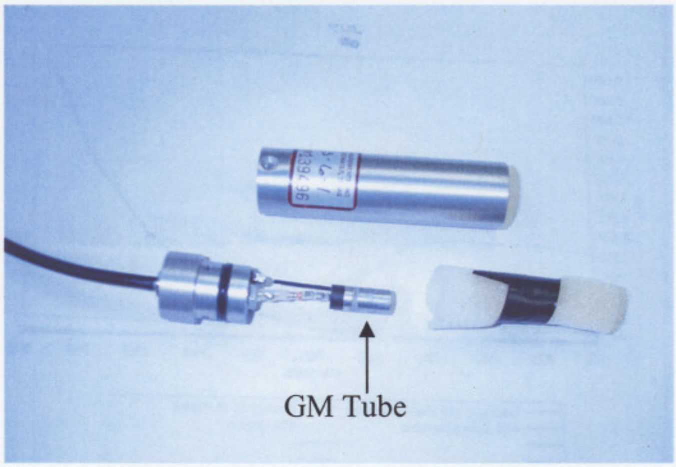

Figure 3-27 GM tube is covered with a foam material and put in housing.

Table 3-10 shows how rotational positioning of the 133-6 detector affects the detector response.

Table 3-10 Angular Position versus Detector Reponse.

Detector	Voltage	Count Time (s)	Source	Angle (degrees)	Counts
GM1	550	600	237 μCi	0	1118
GM1	550	600	237 μCi	45	1144
GM1	550	600	237 μCi	90	1169
GM1	550	600	237 μCi	135	1296
GM1	550	600	237 μCi	180	1421
Average					1230
STDEV					127
GM2	550	600	237 μCi	0	1607
GM2	550	600	237 μCi	45	1622
GM2	550	600	237 μCi	90	1485
GM2	550	600	237 μCi	135	1448
GM2	550	600	237 μCi	180	1486
Average					1530
STDEV					79

The data in Table 3-10 show that the angular positioning of the detector has an appreciable effect on the detector response. For GM1 the counts from the same calibration source varied from 1421 to 1118, about 25% variation compared to the average value, and GM2 counts varied from 1622 to 1448, about an 11% variation compared to the average value. Results would be similar for the 133-7 detectors, used in the MCU. **Therefore, it is imperative to ensure that the angular position of the GM detector is the same during calibration and for the measurements.**

3.6.6 GM Shielding Effect

Another interesting aspect of the GM detector arrangement is how much the collimated shield reduces the radiation seen by the detector. In order to determine this shielding effect, a pipe standard was positioned as a process pipe would be positioned and a count was performed, then the same standard was counted touching the detector with no shielding. Table 3-11 shows the results for the shielding effect. These results are for 133-6 detectors and similar results would be expected for 133-7 detectors.

Table 3-11 Evaluation of GM Shielding versus Count Rate.

Detector	Dose (R/hr)	counts (shield)	counts (no shield)	shield/no shield
GM1	118 μCi	5847	16830	0.35
GM2	118 μCi	7938	21232	0.37

Based on the data given in Table 3-11, the shield reduced the detector exposure by about 64% when compared to using an unshielded detector.

4.0 CONCLUSIONS

Gamma monitors are used to measure Cs-137 concentration in the MCU product streams (DSS and strip effluent). Sodium iodide (NaI) 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.

The original design for the NaI detector shields described in the first version of this report was inadequate due to MCU facility changes that drastically increased the background radiation where these detectors were located. Also, the desired detection limit for Cs-137 was lowered from 0.08 Ci/gal to 0.01 Ci/gal. Also, another complicating factor in these measurements is the fact that the background radiation is not only very high, but the radiation environment is variable because it depends on the feed concentration and tank solution volumes which are variable during operations. After an attempt to solve this issue using additional lead and tungsten shielding was unsuccessful, completely new NaI tungsten-alloy shields were designed, fabricated and tested. The detection limit for the NaI detectors in the new shields was lowered to 0.003 Ci/gal, exceeding facility requirements. If the new NaI shields were not implemented, the detectors would have been rendered useless and inline monitoring could not have been done.

Details of the gamma monitors design and functionality are described in this report and referenced documents. The performance criteria for the NaI monitors are an accuracy of $\pm$ 10% and a detection limit of 0.01 Ci/gal, while the required accuracy of the GM monitors is $\pm$ 20% and the detection limit must be less than 10% of the strip effluent concentration. In all cases, these performance criteria were exceeded.

Since this gamma ray monitoring system is unique, specially-designed software was written and acceptance tested by Savannah River National Laboratory 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 (DCS). In order to provide relatively simple software for the process personnel, the software can be broken down into just a few software modules. These software modules are the Application Window, Detector Selection, Detector Configuration Settings, Background Counting, and Routine Data Acquisition. Instructions for using the software have been included in a user's manual that is appended to this report.

The work presented in this report meets all of the requirements set forth in the project task plan to design and implement gamma ray monitors for the MCU. Additional setup and testing of the system is required when it is implemented in the process. This report has been revised because the shielding for the NaI detectors was redesigned to meet the higher background requirements caused by facility changes after the initial design. High activity lines were implemented near these detectors and originally planned tank shielding was not installed. Also, higher-range GM detectors were installed to increase the detector lifetime.

Additional work on this project includes completion of software implementation, detector (GM) field calibrations, implementing procedures for monitor operation and implementing methods for monitor repair. Spare parts must be maintained for system repairs. Background and efficiency checks will be performed on the detectors periodically, as determined by MCU personnel.

5.0 REFERENCES

1. J-SQP-H-00013, Rev. 0, "Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors Software Quality Assurance Plan"

2. L814-J-002v Version 1.0, "Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors Software User's Manual, Rev. 0"

3. U-FCD-H-00008, Rev. 0, "Modular CSSX Unit (MCU) Software Classification - a portion of the DISTRIBUTED CONTROL SYSTEM (DCS) network"

4. WSRC-RP-2004-00875, Rev 0, "Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction Gamma-Ray Monitors"

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

6. G-TC-H-00041, Rev 5, "Task Requirements and Criteria – Modular Caustic Side Solvent Extraction Unit (MCU)"

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

8. Technical Task Request, SP-TTR-2004-00013, Rev 1

9. WSRC 1Q Manual QAP 20-1, "Software Quality Assurance"

10. WSRC E7 Manual Procedure 5.20 "Software Design and Implementation"

11. IEEE Standard 1016-1998, "IEEE Recommended Practice for Software Design Descriptions"

12. N-CLC-H-00663 Rev 0, "Dose Evaluation from the New Hydraulic Accumulator in the SED and MCU Main Process Cell"

13. M-M6-H-92424, "Modular Caustic Side Solvent Extraction (CSSX) Unit Waste Treatment System Strip Effluent Decanter P&ID.

14. N-CLC-H-00669 Rev 0, "Modular Caustic Side Solvent Extraction Unit (MCU) SED Cell GM Monitor Shielding Evaluation"

15. R-RI-H-00339, "MCU Detector Tungsten Shield Assembly"

16. SRNL-ADD-2006-00086, Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM) Na I Shielding Test , December 2006

17. WSRC-RP-2006-01170, Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction NaI Monitor Shielding Test, December 2006.

18. Procedure SP-17-009, MCU Gamma Shield Performance Test, December 2006

19. N-CLC-H-00671, Rev.1, Evaluation of MCU NaI Detector Configurations, March 2007.

20. N-CLC-H-00672, Rev.1, MCU DSS Detector Test Modeling, March 2007.

21. SRNL-ADD-2006-00086, Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM) Na I Shielding Test , December 2006

22. WSRC-RP-2006-01170, Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction NaI Monitor Shielding Test, December 2006.

23. Procedure SP-17-010, MCU Tungsten Gamma Shield Performance Test, April, 2007.

24. SRNL-ADD-2006-00149, Shield Test Results for MCU NaI Detectors, January 2007.

25. Technical Task Request, SP-TTR-2006, 00010, Rev. 0.

6.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge Fred Ogden of the SRS Health Physics Instrument Calibration Facility and Raymond Dewberry for their assistance in the shield testing experiments. Raymond Sigg has been an invaluable resource throughout this project and his technical reviews are greatly appreciated. We would also like to thank CSSX project personnel for their assistance throughout this project.

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APPENDIX A. DESIGN DOCUMENT FOR MCU-GRM

Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM)

L814-J-002v Version 2.1.

Design Document for Software (U)

Document Number: J-DD-H-00001 Rev 2

Prepared by: ______________________
Tim N Riley
Engineered Equipment & Systems
Savannah River National Laboratory

Date: May 29, 2007

Approvals:

T. N. Riley Design Agency	Date
V. R. Casella IR-1 Independent Reviewer	Date
C.I. Aponte Design Authority	Date
K.P. Burrows MCU Design Authority Manager	Date

SUMMARY OF CHANGES

Revision:	Date:	Description:
A	8/5/05	Initial routing for review and comments
0	10/3/05	Approval
1	6/26/06	Removed FFB hardware description, Added 4-20ma module descriptions
2	5/29/07	Changed MCU-GRM to DCS communication signal descriptions

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TABLE OF FIGURES

1. INTRODUCTION

1.1. Purpose

This document describes the software developed for operation of the Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitor (MCU-GRM). A brief description of the system hardware is included as necessary for clarification of its interaction with the MCU-GRM software.

1.2. Scope

Provisions of this document apply to software developed by SRNL for the Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM). The MCU-GRM software source code number is L814-J-002v Version 2.1. This document does not cover the design or development of the supervisory distributed control system (DCS).

1.3. Definitions and Acronyms

MCU-GRM	Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitor
SRNL	Savannah River National Laboratory
DCS	Distributed Control System
NIM	Nuclear Instrumentation Module
MCA	Multi-channel Analyzer
GM	Geiger-Mueller
NaI	Sodium Iodide
FP	FieldPoint

2. REFERENCES

- J-SQP-H-00013, Rev. 0, "Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors Software Quality Assurance Plan"
- L814-J-002v Version 1.0, "Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors Software User's Manual, Rev. 0"
- U-FCD-H-00008, Rev. 0, "Modular CSSX Unit (MCU) Software Classification - a portion of the DISTRIBUTED CONTROL SYSTEM (DCS) network"
- WSRC-RP-2004-00875, Rev 0, "Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction Gamma-Ray Monitors"
- U-MT-H-00085, Rev 1, "Cesium Removal Implementation Using Caustic Side Solvent Extraction Technology"
- G-TC-H-00041, Rev 4, "Task Requirements and Criteria – Modular Caustic Side Solvent Extraction Unit (MCU)"
- G-ESR-H-00072, Rev 0, "Interface Control Document Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU)"
- Technical Task Request, SP-TTR-2004-00013
- WSRC 1Q Manual QAP 20-1, "Software Quality Assurance"
- WSRC E7 Manual Procedure 5.20 "Software Design and Implementation"
- IEEE Standard 1016-1998, "IEEE Recommended Practice for Software Design Descriptions".

3. GENERAL SYSTEM DESCRIPTION

The Modular Caustic-Side Solvent Extraction Unit – Gamma Ray Monitor (MCU-GRM) provides monitoring of the cesium removal process from the clarified salt solution after the Actinide Removal Process. 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 MCU-GRM hardware is comprised of the following items.

Two NaI spectrometers (one online and one backup) are used for measuring the Cs-137 concentration in the decontaminated salt solution entering the DSS Hold Tank. High voltage and preamp power are provided to the detectors through NIM based modules. The amplified and scaled output signal from each detector is connected to an ORTEC Trump-PCI MCA card.

Two GM tubes (one online and one backup) are used for measuring the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank. High voltage is supplied to these detectors through an Aware Electronics instrument module. The Aware module also provides pulse scaling and amplification. The scaled 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 on the MCU-GRM computer.

Communication between the MCU-GRM and the DCS is handled by five separate 4-20 mA signals. The signals originate within the MCU-GRM software, where they are passed to a National Instruments FP-1000 Network Interface module. The network interface module disperses the individual signals to the appropriate channel of the National Instruments Analog Output module, which in-turn generates the discrete currents proportional to the scaled range of each value.

The MCU-GRM production software serves as a platform for the integration of these devices into a unified interface. From this interface, the user can view the most current data points, change the detector selection for both the GM and NaI detectors, change any of the detector configuration settings, perform a detector background measurement, control the operation of the measurement cycle, and view a historical trend of the measured values.

3.1. MCU-GRM Software Module Descriptions

3.1.1. MCU-GRM Main.vi

The MCU-GRM Main.vi is the primary module for controlling the activities and events in the MCU-GRM production software environment. This module contains the primary user interface from which the user can initiate all the functions needed to perform all normal measurement activities, perform a detector background measurement, or gain access to the detector configuration settings screen.

3.1.2. MCU-GRM Config.vi

The MCU-GRM Config.vi allows the user to change or review the configuration settings, the measurement cycle times, and background counting times for each of the four detectors connected to the MCU-GRM.

3.1.3. Login.vi

The Login.vi controls access to the MCU-GRM Config.vi settings screen through password verification. This is to limit unwarranted access to the detector configuration file.

3.1.4. Start Background.vi

The Start Background module is a dialog box that is displayed at the beginning of the background counting cycle. This module shows the detectors currently selected for the background counting operation, as well as the background count time for each detector. The screen also contains a message to remind the user to prepare the system for background measurement. System preparation may involve flushing the piping and components and other activities that are procedurally controlled by the facility and are outside the scope of the MCU-GRM software. The software only reminds the user that these activities should be performed, but has no method to enforce the requirement. Inadequate system preparation may result in inaccurate readings for the measured background values.

3.1.5. Background Complete.vi

The Background Complete module is a dialog box that is displayed at the end of the background counting cycle. The module displays the newly acquired background data point and prompts the user to decide whether to keep or discard the new data. If the user decides to keep the new data point, the data is written to the detector configuration file and used for all subsequent calculations requiring background correction. Otherwise the data is discarded and the current settings retained.

3.2. Data Description

During the normal operation mode, the most recent data point collected for each of the selected detectors is displayed on the MCU-GRM user interface. The 50 most recent points are graphically displayed in a strip chart format on the MCU-GRM Main.vi main screen to provide a visual historical trend of the data. Each new data point is also passed to the DCS through the National Instruments FieldPoint Interface.

3.3. MCU_GRM to DCS Communication Signals

The MCU-GRM software employs five separate 4-20 mA output signals to communicate key operational parameters to the DCS. The system uses three of the signals for the NaI spectrometers and two for the GM tubes.

The NaI signals are broken down into one for the measured process value (RT3024V), one for the Am peak alignment alarm (RT3024A), and one for the system health signal (RT3024H). The measured value signal is a 4-20 mA output that is linearly scaled to the measured range of 0-1 Ci/gal. The signal is updated at the end of each measurement cycle, nominally 10 minutes. The Am peak alignment signal serves as an indication of a shift in the spectral channel location of the Am pulsar peak. The signal is normally set at the 19 mA level and changes to 5 mA upon detection of the Am peak shift outside of the acceptable band. This signal is also updated at the end of each measurement cycle. The NaI health signal toggles continuously between the 5 and 19 mA levels and serves as an indication that the computer system, NaI MCA hardware, and the MCU-GRM software are operational. This signal is updated on a periodic basis that will be determined during system testing in order to provide timely notification of system failures.

The GM signals are broken down into one for the measured process value (RT3044V), and one for the system health signal (RT3044H). The measured value signal is a 4-20 mA output that is linearly scaled to the measured range of 0-20 Ci/gal. The signal is updated at the end of each measurement cycle, nominally 10 minutes. The GM health signal toggles continuously between the 5 and 19 mA levels and serves as an indication that the computer system, GM pulse counting hardware, and the MCU-GRM software are operational. This signal is updated on a periodic basis that will be determined during system testing in order to provide timely notification of system failures.

3.4. File Creation

Three files are created as a result of the MCU-GRM application software. They are MCU-GRM-CONFIG.ini, MCU_GRM NaI Data_mmyyyy.txt, and MCU_GRM GM Data_mmyyyy.txt. The format of these files is listed in the MCU-GRM Software Users Manual.

MCU-GRM-CONFIG.ini

At startup, the MCU-GRM software reads the detector configuration values from the configuration file **(MCU_GRM_CONFIG.INI). DATA IN THIS FILE CAN ONLY BE CHANGED FROM THE DETECTOR CONFIGURATION WINDOW OR AFTER COMPLETION OF A BACKGROUND MEASUREMENT.**

MCU_GRM NaI Data_mmyyyy.txt & MCU_GRM GM Data_mmyyyy.txt

The MCU-GRM creates two DataLog files, one for NaI data and the other for GM data. At the end of each measurement cycle, the new data points and selected detector and system parameters are appended to the end of the appropriate file for each detector. A new file is created at the beginning of each month to keep the log file to a manageable size. The old log files are stored on the MCU-GRM computer hard drive for future access if needed. The month and year are embedded within each file name as follows: (mm is the 2 digit month and yyyy is the 4 digit year for the month in which the file was first created.)

3.5. Configuration Programs

There are four configuration programs that must be run to set up the MCU-GRM hardware before starting the MCU-GRM application software for the first time. This operation is only required to be performed prior to the initial startup.

The first operation is to run the ORTEC "MCB Config" program to setup the communication channels with MCA1 and MCA2. At the completion of this step, the user must run the ORTEC "Maestro" program to properly establish the two regions of interest (ROIs) needed for the data collection process. Similarly, the user must run the Measurement and Automation Explorer to set up the NI-6602 Counter/Timer card and the FieldPoint module. Instructions for each of these configuration programs are provided by the manufacturer

The MCU-GRM initialization sequence verifies that these operations have been completed. The MCU-GRM application program will be unable to initialize or communicate with the hardware devices and will generate an appropriate error should any of these steps fail to be performed. The procedures for performing all the above actions are listed in the appropriate manufacturer's literature for each device and will not be included in the MCU-GRM documentation.

4. DETAILED DESIGN

The MCU-GRM software can be broken down into four basic sequences: Initialization, Detector Configuration, Run Mode, and Background Counting Mode. Each of these sequences is described in detail below.

4.1. Initialization

The initialization sequence is illustrated in the Initialization State Diagram shown in Figure 1. The process begins at program startup by reading the detector configuration settings file (MCU_GRM_CONFIG.ini) to obtain the latest values. After this is completed, the two multi-channel analyzers, MCA1 and MCA2, are initialized. This is a multi-step process in which the MCA hardware, configuration, and communications are tested to verify the correct hardware is installed, functional, and the proper MCA setup has been performed. Similar initialization protocols are followed for the National Instruments FieldPoint module and the NI-6602 counter/scalar card. The initialization sequence is completed by establishing some programmatic control elements and setting up the user interface.

Failure of any of the initialization steps puts the program in an ERROR state. Since the elements of the initialization process are critical to the operation of the MCU-GRM, the event causing the ERROR state must be corrected before the program can be made operational. If no errors are encountered, the system enters the IDLE state awaiting commands from the user.

There are some preliminary setup operations that must be performed prior to starting the MCU-GRM application for the first time. These operations are only required to be performed prior to the initial startup. The first operation is to run the ORTEC "MCB Config" program to setup the communication channels with MCA1 and MCA2. At the completion of this step, the user must run the ORTEC "Maestro" program to properly establish the two regions of interest (ROIs) needed for the data collection process. Similarly, the user must run the Measurement and Automation Explorer to set up the NI-6602 Counter/Timer card and the FieldPoint Module. The MCU-GRM initialization sequence verifies that these operations have been completed. However, failure to perform any of these steps will result in an error condition as previously stated.

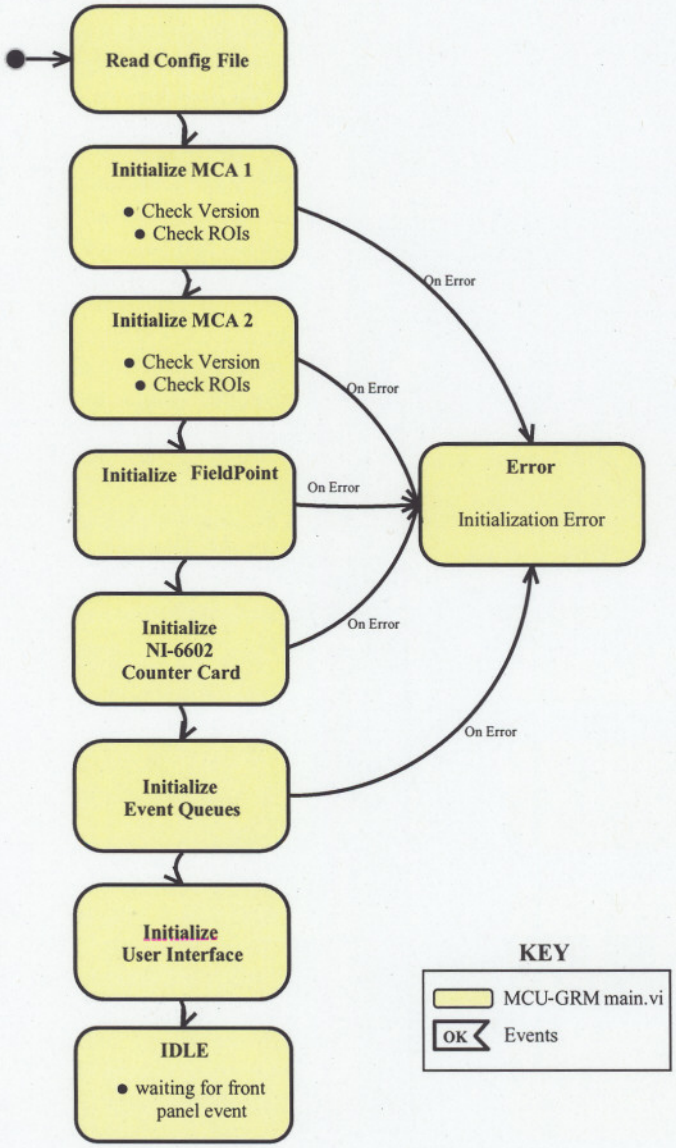

Figure 1: Initialization State Diagram

4.2. Detector Configuration Mode

One of the user actions that can be initiated from the IDLE state is the Detector Configuration Mode. The basic steps in this sequence are illustrated in the Detector Configuration State Diagram shown in Figure 2.

The process begins when the user initiates the CONFIGURE DETECTORS event from the user interface screen. When this event is received, the program displays a Login dialog box prompting the user for a password. If the password is correctly entered the user is granted access to the Detector Configuration screen. From this screen, the user can change any of a number of parameters associated with the four detectors. If accepted, changes are written to the detector configuration settings file (MCU_GRM_CONFIG.ini) where they replace the current values for the corresponding parameter. At the completion of this process, the system then returns to the IDLE state awaiting further user commands.

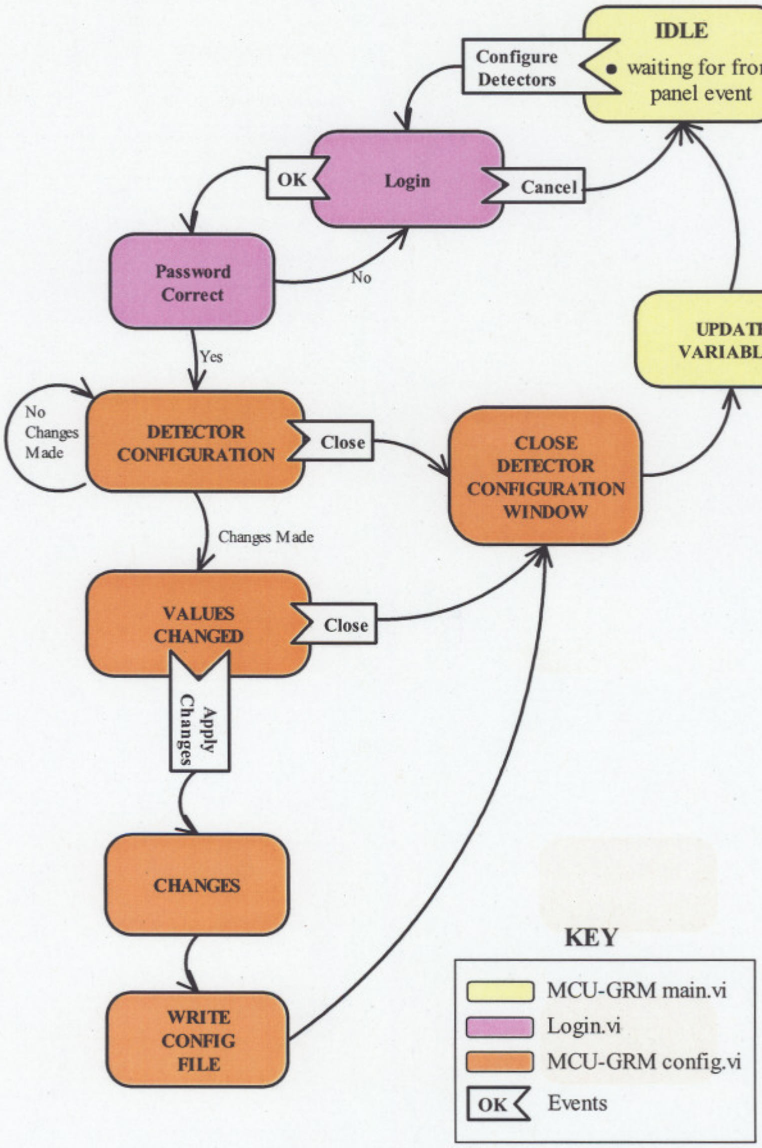

Figure 2: Detector Configuration State Diagram

4.3. Run Mode

Another user action that can be initiated from the IDLE state is the Run Mode. The basic steps in this sequence are illustrated in the Run Mode State Diagram shown in Figure 3. The process begins when the user initiates the START event from the user interface screen.

When the START event is received, the program initiates a data acquisition cycle from the selected MCA and counter channel. The program then enters the RUNNING state, awaiting either a TIMEOUT event or a STOP command from the user. If a STOP command is issued, all data acquisition activities are halted and the program returns to the IDLE state awaiting further user interaction.

TIMEOUT events are generated at periodic intervals (1/second) for the purpose of updating the on-screen clock and cycle timers and for polling the MCA and Counter acquisition timers for completion. When an MCA acquisition has completed, the event handler reads the MCA data, restarts the MCA
acquisition cycle, performs background and efficiency correction of the new data point, evaluates the Am peak centroid channel location, and writes the new data point to the screen and to the data log file. The data point is also passed to the DCS through the FP interface. A similar sequence of events is performed for the Counter cycle. ERROR events are generated when communication cannot be established between either the MCA or Counter. The ERROR event states are not shown in the diagram for clarity. The system will remain in the RUNNING state until the user initiates a STOP event as described earlier.

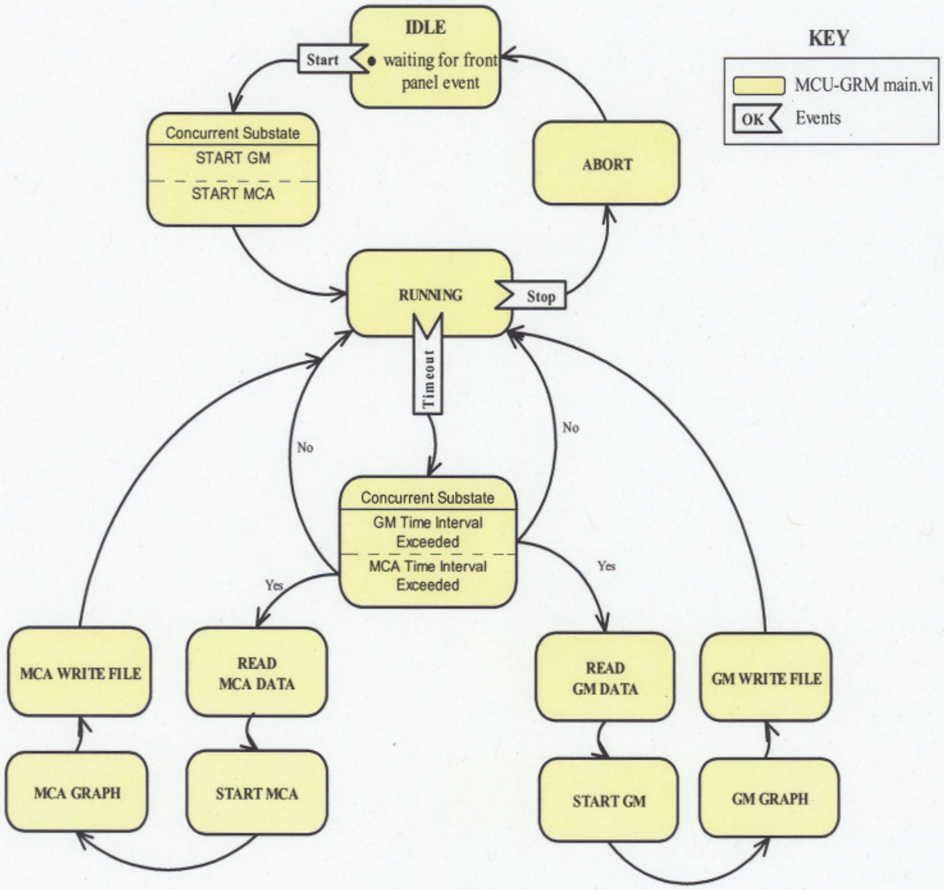

Figure 3: Run Mode State Diagram

4.4. Background Counting Mode

The basic sequence for the Background Counting Mode is illustrated in Figure 4. The process begins when the user initiates the COUNT BACKGROUND event from the user interface screen. This causes the Start Background.vi module to be displayed. From this screen, the user can verify the selected detectors and background count times. The screen also contains a message to remind the user to prepare the system for background measurement. If the user selects CANCEL from this screen, the program returns to the IDLE state awaiting further user interaction. If the operation is accepted, the program initiates a data acquisition cycle from the selected MCA and counter channel. The program then enters the COUNTING BACKGROUND state, awaiting either a timeout event or a STOP command from the user. If a STOP command is issued, all data acquisition activities are halted and the program returns to the IDLE state awaiting further user interaction.

Similar to the Run Mode, TIMEOUT events are generated at periodic intervals (1/second) for the purpose of updating the on-screen clock and cycle timers and for polling the MCA and Counter acquisition timers for completion. When an MCA acquisition has completed, the event handler reads the MCA data, and passes the data point on the Background Complete.vi. The Background Complete module displays the newly acquired background data point and prompts the user to decide whether to keep or discard the new data. If the user decides to keep the new data point, the data is written to the detector configuration file and used for all subsequent calculations requiring background correction. Otherwise the data is discarded and the current settings retained. A similar sequence of events is performed for the Counter cycle. When both counting cycles have completed, program control is returned to the IDLE state.

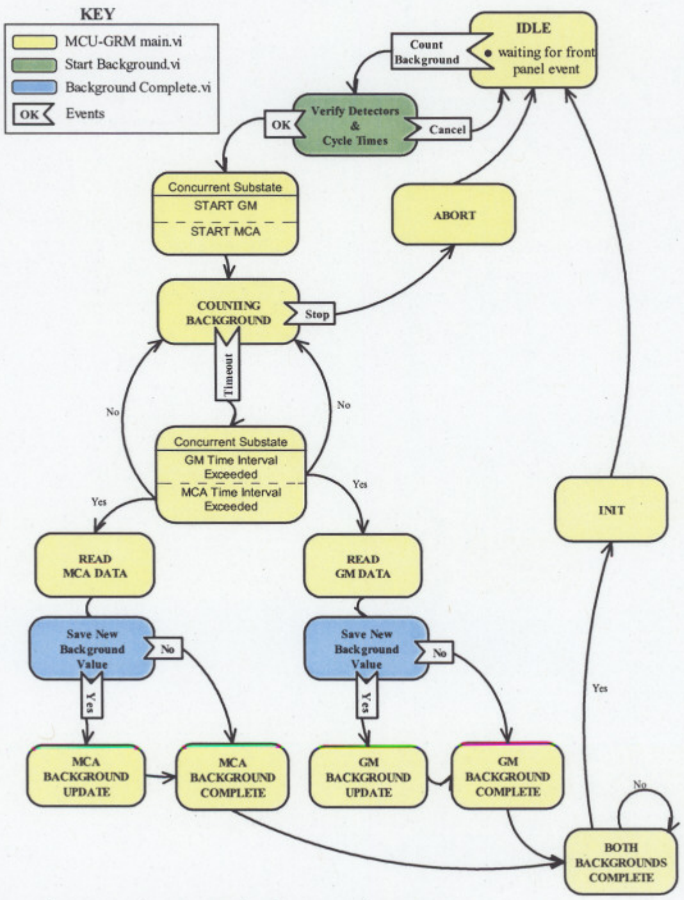

Figure 4: Background Counting Mode State Diagram

APPENDIX B. SOFTWARE QUALITY ASSURANCE PLAN FOR MCU-GRM

Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM)

Software Quality Assurance Plan (U)

Document Number: J-SQP-H-00013 Rev 0

Prepared by: ____________________
Tim N Riley
Engineered Equipment & Systems
Savannah River National Laboratory

Date: May 24, 2005

Approvals:

T.N. Riley Design Agency	Date
V.R. Casella IR-1 Independent Reviewer	Date
S. R. Salaymeh Manager, Sensor and Analyzer Technology	Date
J.P. Gray CQF	Date
G. A. Hill Software Owner	Date
J. C. Wittkop Design Authority	Date
E. A. Brass MCU Design Authority Manager	Date

SUMMARY OF CHANGES

Revision:	Date:	Description:
A	4/14/05	Initial routing for review and comments
0	5/24/05	Approval

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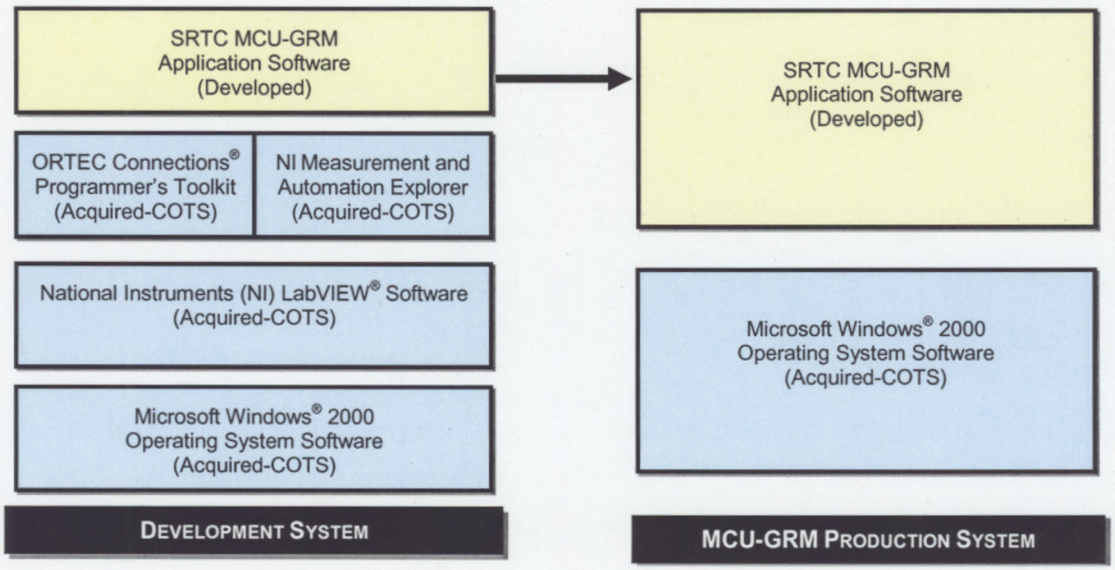
2. SCOPE

This Software Quality Assurance Plan (SQAP) applies to the development of software for the Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM). This SQAP follows guidelines set forth in Manual E7 procedure 5.03 "Software Quality Assurance Plan", WSRC Manual 1Q QAP 20-1 "Software Quality Assurance" and IEEE Standard 730 "Software Quality Assurance Plans". The software engineering approach used to produce this software is a combination of the acquisition of Commercial, Off-The-Shelf (COTS) software elements and the development of MCU-GRM process specific application software elements. The MCU-GRM software has been classified as Production Support (PS) per U-FCD-H-00008. These elements are separated into two distinct software units, development and production. The makeup of each system as related to COTS and developed software applications is depicted below:



Use of the Development System software will be limited to the development and maintenance of the MCU-GRM production software. The MCU-GRM production software is an integration of both developed and acquired elements. The intended use of the MCU-GRM production software is for monitoring and control of the MCU-GRM hardware.

3. ACQUIRED SOFTWARE

The MCU-GRM production software will be developed using the following products: Microsoft Windows 2000 Operating System, National Instruments LabVIEW software, National Instruments Measurement & Automation Explorer software, and the ORTEC Connections Programmer's Toolkit. All software products for this task shall be purchased in accordance with requirements for PS or Level C components. Evaluation/ dedication of acquired software will be in accordance with the requirements of Manual E-7, Procedure 5.07.

4. EXISTING SOFTWARE

All new software will be acquired or developed per Sections 2 and 4 of this SQAP. Software products previously purchased and intended for use with this task shall be evaluated to determine adequacy for their intended purpose through the completion of a Software Evaluation Package (SEP) per Manual E7 Procedure 5.07.

5. DEVELOPED SOFTWARE

All software developed or modified as part of this project shall comply with the task requirements for the following lifecycle activities:

- Requirements
- Design
- Implementation
- Test, Installation & Acceptance

6. SOFTWARE LIFECYCLE

The following documentation will be developed / used per this SQAP. These documents shall be maintained and updated as necessary throughout the software life cycle. Technical baseline documents will be managed per the E7 manual.

Requirements

REQUIREMENTS FOR THE MCU-GRM SOFTWARE ARE LISTED IN ATTACHMENT 1. THESE REQUIREMENTS SHALL BE USED TO FORM THE BASIS FOR SOFTWARE DESIGN, TESTING AND VALIDATION. NEITHER A SEPARATE REQUIREMENTS SPECIFICATION FOR SOFTWARE (RSS) NOR A REQUIREMENTS TRACEABILITY MATRIX (RTM) WILL BE REQUIRED FOR THE MCU-GRM SYSTEM.

Design

The Design Agency shall develop a Design Description for Software (DDS) for the MCU-GRM based on the requirements defined in Attachment 1. The DDS shall follow the format in the Manual E7 Procedure 5.20, where possible. Design Descriptions of other formats may be used as necessary to convey the correct information. If any of these documents should become classified as part of the facility technical baseline, then they shall become documents of record, otherwise, departmental storage with the design agency shall be adequate.

Implementation

THE DESIGN AGENCY SHALL PRODUCE SOURCE CODE AND A SOFTWARE TEST PLAN (STP) WITH TEST CASES TRACEABLE TO THE REQUIRED ELEMENTS SPECIFIED IN ATTACHMENT 1. MCU-GRM SOFTWARE SHALL BE DEVELOPED AND IMPLEMENTED PER THE APPROVED DESIGN DOCUMENTATION AS DESCRIBED IN SECTIONS 5.1 AND 5.2 OF THIS DOCUMENT IN ACCORDANCE WITH MANUAL E7 PROCEDURE 5.20. THE EXTENT OF TESTING AND VERIFICATION WILL BE DETAILED IN THE SOFTWARE TEST PLAN PER MANUAL E7 PROCEDURE 5.40. RESOLUTION OF PROBLEMS AND DEFICIENCIES NOTED DURING TESTING SHALL BE ADDRESSED IN THE SOFTWARE TEST PLAN.

Software Testing

THE DESIGN AGENCY SHALL PERFORM OFF-LINE TESTING OF THE MCU-GRM PRODUCTION SOFTWARE PER THE STP. THE TESTING IS TO BE CONDUCTED ON AN OFFLINE SYSTEM WITH A SUCCESSFUL DEMONSTRATION OF SOFTWARE FUNCTIONALITY TO BE DEMONSTRATED TO THE DESIGN AUTHORITY AND SOFTWARE OWNER PRIOR TO DEPLOYMENT TO THE FIELD.

Software Installation and Acceptance Testing

The following will be required prior to placing the MCU-GRM production software in service:

- Completion of all software design and implementation activities.
- Successful completion of all offline testing and acceptance by the Design Authority.
- Successful completion of the Software Acceptance Test
- Software owner approval.

NOTE: The Test Lead Engineer shall develop a Software Acceptance Test Plan for the MCU-GRM software for testing the system after installation in the facility.

Operation & Maintenance

The MCU-GRM software will be operated using approved operational procedures. Changes to the software configuration are covered in section 7 of this procedure.

Software Retirement

The Design Authority and the Software Owner will determine when the software is to be retired. Removal of the MCU-GRM software from service shall be documented on a CMT per Manual E7 procedure 5.62.

Other Documentation

Documents that relate to the lifecycle of this software include:

1.1.1. Job Folder (EES Job Folder #23075)

A job folder has been established in the 730-A Document Control Facility for collecting all MCU-GRM related documentation. The job folder shall contain a software index, the SQAP, DDS, and STP, etc., as well as any other user documentation developed as part of this project.

1.1.2. User Documentation

SRNL will keep vendor manuals as appropriate for use as reference during the software lifecycle. A User Manual will be developed by SRNL for use by the customer.

7. REVIEWS

In order to ensure the technical adequacy and acceptance of the software and its conformance to system requirements, reviews shall be required for the MCU-GRM production software as specified in this section. Type 1 or Type 2 Independent Reviews of some elements of the MCU-GRM software shall be performed as required by Manual E7 Procedure 5.03. A Type 1 Independent Review (IR-1) is the review of a document performed by an individual knowledgeable in the area of review to ensure that the assumptions, methodology and resulting product reflect sound engineering judgment. An individual other than the individual that did the work being reviewed conducts the IR-1 Review. A Type 2 Independent Review (IR-2) is similar to an IR-1 with the added requirement that it be conducted by an individual subject to a different technical direction (i.e., not assigned to the same project or task).

Software Requirements Review

The software requirements are included as part of this document and will be reviewed during the normal review and approval cycle. This review shall also include a Type 1 (IR-1) review. A separate Requirements Specification for Software (RSS) is not required for this project.

Requirements Traceability Matrix

Not required for this project.

Design Description for Software (DDS)

The Design Description for Software (DDS) and other software design documents may be reviewed and if necessary revised as required during the development phase of the project. A Type 1 (IR-1) review of the DDS will be performed internally by SRNL. The Design Authority will approve the final software design.

Computer Programs

A Type 1 Independent Review (IR-1) shall be performed on all Acquired Software to ensure that the programs meet the design constraints of the MCU-GRM production software.

Software Test Cases

Test cases selected for software testing must be subjected to a Type 1 Independent Review, with the results documented, including identification of the reviewer. The test cases shall be reviewed against the design criteria as specified in Attachment 1 to ensure all design requirements are being tested. The Design Authority will approve the final Software Test Plan (STP).

Software Test Results

All test results must be followed by a Type 1 Independent Review to ensure the test requirements as specified in Section 6.5 have been satisfied. IR-1 results must be documented, including identification of the reviewer. This review must be completed prior to use of the software.

User Manual

The MCU-GRM Software User's Manual shall be subjected to a Type 1 Independent Review, with the results documented, including identification of the reviewer. The Design Authority and Software Owner will approve the final manual.

Installation and Acceptance Test Results

A Type 2 Independent Review shall be performed on all Installation and Acceptance Test Results prior to placing the MCU-GRM system in service. This review shall include verification of the deliverables for each lifecycle phase. It will also determine the acceptability of the detailed software design as depicted in the software design description in satisfying the requirements of the software requirement specifications. The Design Authority and Software Owner shall approve the Installation and Acceptance Test Results.

8. CONFIGURATION MANAGEMENT / BASELINE CONTROL

Software for the MCU-GRM shall be placed under Configuration Management (CM). All Configuration Items (CIs) shall become part of the software baseline and placed in the Configuration Management System (CMS). All items in the CMS shall be uniquely identified, indexed, and tracked by generation / revision throughout the software lifecycle. Configuration change control shall be governed through the CMT process outlined in Manual E7 Procedure 5.62, and tested / accepted by an approved STP per Manual E7 Procedure 5.40.

After the Test and Installation phase and prior to the Operation and Maintenance phase of the lifecycle, the software shall be re-baselined as necessary. At this time a unique identifier, with version number, will be placed on the software main screen. Additionally, the LabVIEW version and serial number will be recorded.

Changes to the configuration shall occur only through approval of the Design Authority and the Software Owner. Changes shall be documented, tested and the software revision number sequentially increased. LabVIEW updates, service packs, etc. shall be reviewed by the Software Owner and Design Authority before incorporation. If incorporated, the software shall be re-baselined and regression testing completed as necessary.

An electronic baseline of the software source code, and all revisions of the source code, shall be placed in an approved Document Control Facility.

Configuration Identification

7.1.1. Identifying Configuration Items

The configuration index provides a comprehensive list of all software configuration items (SCIs). The configuration index is maintained as a plain text electronic file within the Configuration Management System (CMS). The configuration index will support the identification of the current baseline. Configuration items controlled within CMS will be assigned unique generation / revision numbers used for baseline identification.

The MCU-GRM configuration items are the LabVIEW (.vi) files, developed by SRNL. These are the files that comprise of the User Interface, data acquisition and manipulation algorithms, configuration files, and any other user file that is required for proper MCU-GRM software functionality that can be maintained in the CMS.

COTS software supplied by the vendor on a media such as CD-ROM required for a system build / recovery will be tracked on the configuration index.

7.1.2. Naming Configuration Items

All SCIs shall be named within the constraints of the operating system. Duplicate names shall not be allowed and the design agency is responsible for ensuring uniqueness.

7.1.3. Removable Media Requirements

All SCIs controlled in the media library must be labeled in a consistent format to identify the product and generation / revision. COTS products supplied on vendor media should be labeled with the product name / title, copyright notice, and version. Custom products stored on media from either vendor, or developed by SRNL that are not uniquely labeled will be assigned a unique number from the media library log and labeled accordingly. If software on media is subject to modification by SRNL two copies of each generation / revision of the media shall be maintained, one as "Baseline" and one as "Working Copy". All software maintained in media control shall be tracked through the master configuration index stored electronically in the CMS system.

Configuration Control

The MCU-GRM Production software source code is not a part of the facility technical baseline. However, the software requirements used to produce the software and certain key software design documents are part of the facility technical baseline. There are two methods for changes to be made to baseline software:

7.1.4. Non-Technical Modifications

Non-Technical Modifications are modifications to the baseline software that are not driven by a technical baseline document (e.g. graphic changes). Non-Technical Modifications may be performed using a Computer Modification Tracker (CMT).

7.1.5. Technical Modifications

Technical modifications are modifications to baseline software that are driven by changes to one of the software technical baseline documents (SQAP, STP, etc). These changes require a DCP / DCF in addition to a CMT.

9. PROBLEM REPORTING AND CORRECTIVE ACTION

THE SOFTWARE OWNER IS RESPONSIBLE FOR NOTIFYING THE DESIGN AUTHORITY OF PROBLEMS, DESIGN ENHANCEMENTS, AND REPORTING INSTANCES OF OPERATIONAL NONCONFORMANCE DURING THE OPERATION OF THE MCU-GRM SOFTWARE. THE DESIGN AUTHORITY SHALL DETERMINE THE APPROPRIATE LEVEL OF DOCUMENTATION NECESSARY FOR THIS PROCESS. CORRECTIVE ACTIONS SHALL BE CONTROLLED AS SPECIFIED IN SECTION 7.2 OF THIS PROCEDURE. ADDITIONALLY, OPERATIONAL SOFTWARE PROBLEMS AND PROGRAMMATIC DEFICIENCIES SHALL BE REPORTED AS SPECIFIED IN QAP 15-1, "CONTROL OF NONCONFORMING ITEMS", AND MRP 4.23, "SITE TRACKING ANALYSIS AND REPORT (STAR) SYSTEM" AS REQUIRED.

10.ROLES AND RESPONSIBILITIES

Customer and Software Owner: HTF Operations

The Software Owner has the following responsibilities:

- Initiates request for software support.
- Communicates requirements and constraints to organization developing, designing, maintaining or acquiring the software.
- May initiate change requests to modify the baseline software.
- Approves change requests (CMTs) for the proposed modifications to software products.
- Review and approve changes to the software.
- Confirms testing is performed on the software.
- Final authority for installation and removal of software.
- Accept the tested software.
- Ensure that software configuration control is maintained.
- Review and approve software quality documentation as indicated in the task matrix.

Design Authority: MCU & HTF Engineering

The Design Authority has the following responsibilities:

- Perform functional classification for the software in accordance with the E7 manual procedures 5.05 and 2.25.
- Produce the Requirements Specification for Software (RSS) for the system. The software requirements shall be included as part of the SQAP, (See Attachment 1).
- May initiate change requests to modify the baseline software.
- Review change requests for possible impact on the facility technical baseline.
- Approves change requests to modify the baseline software.
- Review and approve the software design and software design changes for items in the technical baseline.
- Develops the Software Acceptance Test plan for the production system.
- Perform Software Acceptance Testing for the production system.
- Provides independent verification of modifications to the software.

Design Agency: SRNL-Engineered Equipment & Systems (EES)

The Design Agency has the following responsibilities:

- Review the technical software requirements for the system.

- Develop the Software Quality Assurance Plan (SQAP).
- Complies with the software requirements of the E7 Manual and site standards.
- Ensures that software products are in compliance with site standards.
- May initiate change requests to modify baseline software.
- Develop Design Document for Software (DDS).
- Develop Software Test Plan (STP) for offline software testing.
- Verifies changes to software.
- Develops user documents and technical documents.
- Loads the software to the target system.
- Participates in Software Acceptance Testing as required.
- Manages the configuration control process for the software products.
- Maintains the software design documentation during the product life cycle.

The role of Design Agency, relative to software, is guided by the E7 Manual Section 5 "Software Engineering & Control" and does not involve development or modifications to the facility technical baseline.

Software Cognizant Quality Function: SRNL-Quality Engineering

The Cognizant Quality Function has the following responsibilities:

- Review and approve the software quality documentation per task matrix.

Tasks

The following table presents the organizational roles for software quality assurance tasks pertaining to MCU-GRM software development.

Task	Design Authority	Design Agency	Quality Assurance	Software Owner
Functional Classification Document	W,A			
Software Requirements Document. Included in SQAP.	W,R,A	R,A		R,A
SQAP (Software QA Plan)	R,A	W,R,A	R,A	R,A
DDS (Design Description for Software)	R,A	W,R,A		
STP (Software Test Plans)	R,A	W,R,A		R,A
Test Cases	R,A	W,R,A		
Test Results	R,A	W,R,A		R,A
User Manual	R,A	W,R,A		R,A
Job Folder (EES #23075)		W		

Software Acceptance Test	W,R,A,P	R,A		R,A
Software Modifications	W,R,A	R,A,P		W,R,A

Legend: P = Perform, R = Review, A = Approve, W = Write

11.TOOLS, TECHNIQUES, METHODS, STANDARDS, PRACTICES, AND CONVENTIONS

Tools for troubleshooting, modifying, and maintaining software products for the MCU-GRM will be those provided by or approved for use by the vendor of the COTS software. If it is deemed that any of these tools are inadequate or additional tools are required such as those for process simulation, modeling, advanced control algorithms, system backup / recovery or products necessary to maintain configuration control "Third Party" applications may be used after sufficient product testing and concurrence from all effected agencies.

12.QUALITY ASSURANCE RECORDS / DOCUMENTATION

All record documentation for software given a controlled number shall be managed in accordance with Manual E7 Procedure 1.20, 1Q QAP 17-1, and the Retention Schedule Matrix. All other software documentation shall be filed in Job Folder #23075 in the 730-A Document Control facility.

THIS DOCUMENT SHALL BE MAINTAINED AS A QA RECORD UNTIL THE SYSTEMS ARE RETIRED OR THE FACILITY IS REMOVED FROM SERVICE.

13.TRAINING

THE SOFTWARE OWNER SHALL DETERMINE THE LEVEL OF TRAINING REQUIRED FOR OPERATION OF THE MCU-GRM SOFTWARE. OPERATOR TRAINING, IF REQUIRED, IS OUTSIDE THE SCOPE OF THIS DOCUMENT.

14.REFERENCE DOCUMENTS

- U-FCD-H-00008, Rev. 0, "Modular CSSX Unit (MCU) Software Classification - a portion of the DISTRIBUTED CONTROL SYSTEM (DCS) network"
- WSRC-RP-2004-00875, Rev 0, "Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction Gamma-Ray Monitors"
- U-MT-H-00085, Rev 0, "Cesium Removal Implementation Using Caustic Side Solvent Extraction Technology"

- G-TC-H-00041, Rev 3, "Task Requirements and Criteria – Modular Caustic Side Solvent Extraction Unit (MCU)"
- Technical Task Request, SP-TTR-2004-00013
- WSRC 1Q Manual QAP 20-1, "Software Quality Assurance"
- WSRC 1Q Manual QAP 17-1, "Quality Assurance Records Management"
- WSRC E7 Manual Procedure 1.20, "Engineering Document Numbering System"
- WSRC E7 Manual Procedure 2.25, "Functional Classifications"
- WSRC E7 Manual Procedure 5.01 "Software Engineering & Control"
- WSRC E7 Manual Procedure 5.03 "Software Quality Assurance Plan"
- WSRC E7 Manual Procedure 5.05 "Software Classification"
- WSRC E7 Manual Procedure 5.07 "Evaluation of Existing and Acquired Software"
- WSRC E7 Manual Procedure 5.10 "Software Requirements"
- WSRC E7 Manual Procedure 5.20 "Software Design and Implementation"
- WSRC E7 Manual Procedure 5.40 "Software Testing, Acceptance, and Turnover"
- WSRC E7 Manual Procedure 5.62 "Computer Program Modification Tracker"
- IEEE Standard 730-1998, "Software Quality Assurance Plans"

ATTACHMENT 1: MCU-GRM SOFTWARE REQUIREMENTS

Requirement # ______1______ Priority: High

Function: The MCU-GRM software shall provide the user with the ability to select between either of the two Sodium Iodide detectors, NaI1 or NaI2. Only 1 detector will be functional at any given time. Selection between the two detectors will be accomplished via user selectable switches on the MCU-GRM User Interface.

Performance: None.

User Interface: Detector selection shall be through a means clearly identified on the User Interface.

Acceptance Criteria: The software will successfully switch between the outputs of both NaI detectors.

Requirement # ______2_______ Priority: High

Function: The MCU-GRM software shall contain a graphical data display of the measured parameters vs time for both Geiger-Mueller (GM1 & GM2) detectors as well as for the selected Sodium Iodide detector (NaI1 or NaI2).

Performance: A graphical display on the MCU-GRM User Interface shall be used to perform the graphical data representation for both systems. As a minimum, each display shall present the 50 most recent data points for each of the monitored detectors. Data points shall be updated whenever new values are acquired.

User Interface: The user interface shall contain an appropriate number of graphical data windows to display the data points versus time for both GM1 and GM2, and for either NaI1 or NaI2.

Acceptance Criteria: The MCU-GRM software graphical displays will faithfully display the most recent data points and maintain the 50 most recent points in the individual plots.

Requirement # _______3______ Priority: High

Function: The MCU-GRM software shall allow the user to perform background measurement and subtraction for the two Sodium Iodide detectors, NaI1 and NaI2, independently of the other. Proper valve alignment and flushing and filling the system piping will be procedurally controlled by the facility and are outside the scope of the MCU-GRM software.

Performance: The MCU-GRM software shall allow the user to periodically perform a background measurement with either detector, NaI1 or NaI2. The MCU-GRM software will automatically update the background readings for the selected detector and record the date when the reading was performed. The MCU-GRM software will use only the new background reading to perform a background subtraction during the normal measurement cycle.

External Interface: Preparation of the system piping for the background measurement is outside the scope of the MCU-GRM software and will not be performed as part of this requirement. It is the responsibility of the user of the software to properly prepare the system for background measurement.

User Interface: The user interface shall provide a mechanism for performing a background measurement using either NaI1 or NaI2. The user interface shall also include a means for manually entering or reviewing the background values for the NaI1 and NaI2 detectors independent of the other setting.

Acceptance Criteria: When in background counting mode, the background count shall be successfully performed and the new background value and date recorded to reflect the latest measured data. In measurement mode, the new values shall be used to compensate for the most recent measured background levels.

Requirement # _______4______ Priority: High

Function: The MCU-GRM software shall provide a means for calibration of all four detectors GM1, GM2, NaI1, and NaI2 through the manual entry of a detector efficiency factor. The efficiency setting of each detector shall be independent of the other detectors.

Performance: Initial calibration of each detector shall be performed during off-line testing of the MCU-GRM software. The calibration will produce an efficiency factor for each of the four detectors. These values shall be manually recorded in the MCU-GRM software along with the date when the reading was performed. The MCU-GRM software will use only the latest efficiency values during the normal measurement cycle.

External Interface: After the system is installed calibration shall be controlled by the facility. It is the responsibility of the Facility to obtain the proper calibration standards and to properly prepare the system for calibration. Proper valve alignment and flushing and filling the system piping will be procedurally controlled by the facility and is outside the scope of the MCU-GRM software.

User Interface: The user interface shall provide a mechanism for manually entering or reviewing the detector efficiency values for detectors GM1, GM2, NaI1, and NaI2.

Acceptance Criteria: In measurement mode, the MCU-GRM software shall provide correction of the raw output of each detector for its own measured efficiency.

Requirement # ______5______ Priority: High

Function: The MCU-GRM software shall contain provisions for communicating the most recently acquired activity levels obtained from GM1 and GM2, as well as the concentration data from either NaI1 or NaI2 to the MCU Distributed Control (DCS) System. There are no DCS controllable features in the MCU-GRM software.

Performance: The MCU-GRM software will take the most recent data points from the GM1 and GM2 detectors and from either NaI1 or NaI2, perform the necessary conversions, and report this data to the MCU-DCS through the interface hardware.

User Interface: The user interface will display the last data points sent to the MCU-DCS system.

External Interface: A Foundation Field Bus Card shall be provided in the MCU-GRM computer for connection to the MCU-DCS. The external interface shall be coordinated between the Design Agency and Design Engineering in accordance with J-J8-H-07866, M-M6-H-02422, M-M6-H-02424.

Acceptance Criteria: The MCU-GRM software will send the most recent data points through the Foundation Field Bus Module.

APPENDIX C. SOFTWARE TEST PLAN FOR MCU-GRM

Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM)

Software Test Plan (U)

Document Number: J-STP-H-00236 Rev. 0

Prepared by: ______________________
Tim N Riley
Engineered Equipment & Systems
Savannah River National Laboratory

Date: August 11, 2005

Approvals:

________________________________ ____________
T. N. Riley Date
Design Agency

________________________________ ____________
V. R. Casella Date
IR-1 Independent Reviewer

________________________________ ____________
G. A. Hill Date
Software Owner

________________________________ ____________
J. C. Wittkop Date
Design Authority

________________________________ ____________
E. A. Brass Date
MCU Design Authority Manager

Summary of Changes

Revision:	Date:	Description:
A	7/22/05	Initial routing for review and comments
0	8/11/05	Approval

TABLE OF CONTENTS

1. SCOPE

This Software Test Plan (STP) is intended to cover the initial offline testing for the Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM) software. Integrated testing of this software with the Modular Caustic Side Solvent Extraction Unit (MCU) DCS system is not covered in this document.

NOTE: The Test Lead Engineer as identified in J-SQP-H-00013 shall develop a Software Acceptance Test Plan for integrated testing of MCU-GRM and MCU-DCS software.

2. SOFTWARE PRODUCT IDENTIFICATION

PROJECT NAME: **MODULAR CAUSTIC SIDE SOLVENT EXTRACTION UNIT (MCU)**
SOFTWARE PRODUCT NAME: **MODULAR CAUSTIC SIDE SOLVENT EXTRACTION UNIT GAMMA RAY MONITORS (MCU-GRM)**
OPERATING DIVISION: **HTF OPERATIONS**
FACILITY: **MODULAR CAUSTIC SIDE SOLVENT EXTRACTION UNIT (MCU)**
LOCATION OF TARGET SYSTEM: **H-AREA (241-278H)**
SOFTWARE LEAD ENGINEER: **TIM N. RILEY**
BUILDING 730-A
725-4801, B17314

3. REFERENCE DOCUMENTS

- J-SQP-H-00013, Rev 0, "Modular Caustic Side Solvent Extraction Unit Gamma-Ray Monitors Software Quality Assurance Plan"
- Attachment 1, "MCU-GRM Software Offline Test Cases"

4. TESTING ACTIVITIES

Software Operating Environment

THE SOFTWARE WAS DEVELOPED USING NATIONAL INSTRUMENTS LABVIEW™ 7.1 AND IS OPERATED UNDER THE MICROSOFT WINDOWS XP™ OPERATING SYSTEM. FOR THE PURPOSES OF THIS TEST, THE MCU-GRM SOFTWARE SHALL BE INSTALLED AND OPERATED ON THE ACTUAL MCU-GRM HARDWARE TO BE INSTALLED IN THE FACILITY.

Operations Support

No operations support is required during the performance of activities addressed under this test plan.

System Configuration

OFFLINE TESTING OF THE MCU-GRM PRODUCTION SOFTWARE SHALL BE PERFORMED IN BUILDING 773-A LABORATORY B154. TESTING SHALL BE PERFORMED AFTER FABRICATION OF THE SYSTEM IS COMPLETE, BUT PRIOR TO INSTALLATION OF THE EQUIPMENT IN THE FIELD. DETECTORS SHALL BE INSTALLED IN THEIR SHIELDS FOR THE PERFORMANCE OF THE TESTING ACTIVITIES.

Testing Sequence

THE SOFTWARE LEAD ENGINEER SHALL PERFORM OFF-LINE TESTING OF THE MCU-GRM PRODUCTION SOFTWARE PER THIS TEST PLAN. THE TESTING IS TO BE CONDUCTED ON AN OFFLINE SYSTEM WITH A SUCCESSFUL DEMONSTRATION OF SOFTWARE FUNCTIONALITY TO BE DEMONSTRATED TO THE DESIGN AUTHORITY AND SOFTWARE OWNER PRIOR TO DEPLOYMENT TO THE FIELD.

Acceptance Criteria

Acceptance criteria for each activity are listed within each test case under the Expected Result column.

Deficiencies

Deficiencies encountered during testing shall be recorded using the Computer Modification Tracking process outlined in Manual E7 Procedure 5.62, and tested / accepted by an approved STP per Manual E7 Procedure 5.40.

Regression Testing

THE DESIGN AUTHORITY SHALL DETERMINE THE EXTENT REGRESSION TESTING OF THE SOFTWARE REQUIRED FOR ANY OF THE FOLLOWING CASES: DEFICIENCIES FOUND; SOFTWARE PATCH OR EQUIVALENT IS INSTALLED; OPERATING SYSTEM IS UPGRADED OR MODIFIED; COMPUTER PROBLEMS EXPERIENCED. REGRESSION TESTING SHALL BE DOCUMENTED THROUGH THE USE OF A TEST LOG.

Recovery Plan

At the completion of testing, the Software Test Engineer will ensure that all components are returned to a safe configuration.

5. TEST RESULTS REVIEW AND APPROVAL

PRINT **SIGNATURE** **DATE**
SOFTWARE TEST ENGINEER

PRINT **SIGNATURE** **DATE**
DESIGN AUTHORITY

PRINT **SIGNATURE** **DATE**
IR-1

PRINT **SIGNATURE** **DATE**
SOFTWARE OWNER

6. BASELINE ESTABLISHED

PRINT **SIGNATURE** **DATE**
SOFTWARE TEST ENGINEER

PRINT **SIGNATURE** **DATE**
DESIGN AUTHORITY

PRINT **SIGNATURE** **DATE**
IR-1

PRINT **SIGNATURE** **DATE**
SOFTWARE OWNER

ATTACHMENT 1: MCU-GRM TEST CASES

Date Executed: ______________
Tester (Print Name): ______________
Tester (initials): ______________

STP # J-STP-H-00236 Rev 0
Test Case: 1
Page 1 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 1

Step	Tester Action	Expected Result	Comments	Initial
	Purpose	The purpose of this test is to ensure that the user is able to switch detectors from the user interface.		
	Methodology	Bring system to a steady-state test condition.		
	Hardware/ Tools	NA		
	Personnel	NA		
	Setup	The MCU-GRM software should be operational.		
1.1	Start the MCU-GRM program	The Main screen for the program should appear.		
1.2	Verify that the system is operational by observing the clock in the upper corner of the user interface.	The time will be incrementing.		

Date Executed: ______________
Tester (Print Name): ______________
Tester (initials): ______________

STP # J-STP-H-00236 Rev 0
Test Case: 1
Page 2 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 1

Step	Tester Action	Expected Result	Comments	Initial
1.3	Observe the NaI Tube selection from the screen. Write appropriate detector in comments column	Either NaI1 or NaI2		
1.4	Observe the GM Tube selection from the screen. Write appropriate detector in comments column	Either GM1 or GM2		
1.5	Select the "Count Background" option from the Main screen and observe the detectors listed in the "Start Background" popup window. Record in comments.	Either NaI1 or NaI2 and Either GM1 or GM2		
1.6	Click the cancel button on the Start Background popup window	The Main screen should be displayed		
1.7	Change tube selections for the NaI and GM detectors by selecting the other remaining detector from each detector selection menu.			
1.8	Observe the NaI Tube selection from the screen. Write appropriate detector in comments column. This should NOT be the same selected in step 1.3	Either NaI1 or NaI2		

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP # J-STP-H-00236 Rev 0
Test Case: 1
Page 3 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 1

Step	Tester Action	Expected Result	Comments	Initial
1.9	Observe the GM Tube selection from the screen. Write appropriate detector in comments column. This should NOT be the same selected in step 1.4	Either GM1 or GM2		
1.10	Select the "Count Background" option from the screen and observe the detectors listed in the "Start Background" popup window. Record in comments.	Either NaI1 or NaI2 and Either GM1 or GM2		
1.11	Click the cancel button on the Start Background popup window	The Main screen will be displayed.		
	END OF TEST			

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP # J-STP-H-00236 Rev 0
Test Case: 2
Page 1 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 2

Step	Tester Action	Expected Result	Comments	Initial
	Purpose Methodology Hardware/ Tools Setup	The purpose of this test is to ensure that the software will faithfully display the most recent data point for the selected detector. Bring system to a steady-state test condition. Radioactive Source The MCU-GRM software should be operational. Maestro should be operational.		
2.1	Start the MCU-GRM program.	The Main screen for the program should appear.		
2.2	Start the Maestro program.	The Maestro screen will appear.		
2.3	Select the "Detector Settings" option from the Main screen.	The "Detector Configuration" screen will be displayed.		
2.4	Change the NaI & GM cycle times to 10 seconds and change change all Efficiency values to 1 and all Background values to 0. Click "Apply Changes" on the configuration screen.	The "Detector Configuration" screen will close and the Main screen will appear.		

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP# J-STP-H-00236 Rev 0
Test Case: 2
Page 2 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 2 ______

Step	Tester Action	Expected Result	Comments	Initial
2.5	Place the source in front of the collimator window on the shield.			
2.6	Record the detector selections in the Comments column.	Either NaI1 or NaI2 and Either GM1 or GM2		
2.7	Select the "Start" option from the Main screen and allow the system to run through several cycles.	The system should start running and acquiring data.		
	FOR EACH CYCLE VERIFY THE FOLLOWING			
2.8	Switch between Maestro and the MCU-GRM software to verify that each new NaI data point is being faithfully represented.	The most recent data point should appear on the digital display after each cycle. This data should also be added to the strip chart display.		
2.9	Check that the GM data is being updated and the data is consistent with the source activity.	The most recent data point should appear on the digital display after each cycle. This data should also be added to the strip chart display.		
2.10	Select the "Stop" option from the Main screen.	Data acquisition should stop.		

Date Executed: ________________
Tester (Print Name): ________________
Tester (initials): ________________

STP # J-STP-H-00236 Rev 0
Test Case: 2
Page 3 of 3

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 2 ______

Step	Tester Action	Expected Result	Comments	Initial
2.11	Change tube selections for the NaI and GM detectors by selection the other remaining detector from each detector selection menu. Record in Comments.	Either NaI1 or NaI2 and Either GM1 or GM2		
2.12	Repeat steps 2.7 - 2.10 for the new detectors.			
	END OF TEST			

Date Executed: ________________
Tester (Print Name): ________________
Tester (initials): ________________

STP # J-STPH00236Rev0
Test Case: 3
Page 1 of 4

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 3

Step	Tester Action	Expected Result	Comments	Initial
	Purpose Methodology Hardware/ Tools Setup	The purpose of this test is to verify that the software will perform a background count and save the new background value and date. Verify that background subtraction is properly performed. Bring system to a steady-state test condition. Radioactive Source Insert Radioactive source in front of collimator window on the shield. The MCU-GRM software should be operational. Maestro should be operational.		
3.1	Start the MCU-GRM program	The Main screen for the program should appear.		
3.2	Select the "Detector Settings" option from the Main screen.	The "Detector Configuration" screen will be displayed.		
3.3	Record the Background value and Last Update value for each detector in the comments section. Click Cancel to close.		NaI1 background: NaI1 Last Update: NaI2 Background: NaI2 Last Update	

Date Executed: ______________
Tester (Print Name): ______________
Tester (initials): ______________

STP# JSTPH00236Rev0
Test Case: 3
Page 2 of 4

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 3

Step	Tester Action	Expected Result	Comments	Initial
3.3 cont			GM1 Background: GM1 Last Update: GM2 Background: GM2 Last Update:	
3.4	Observe the NaI Tube selection from the screen. Write appropriate detector in comments column.	Either NaI1 or NaI2		
3.5	Observe the GM Tube selection from the screen. Write appropriate detector in comments column.	Either GM1 or GM2		
3.6	Select the "Count Background" option from the Main screen and then click "OK" in the "Start Background" popup to initiate the background count.	The Background count will start.		
3.7	When the count has completed record the background counts value for each detector and click OK to close each "Background Complete" window and log the new values.	The Main screen will be displayed.	NaI counts: GM counts:	
3.8	Change tube selections for the NaI and GM detectors by selection the other remaining detector from each detector selection menu. Record new selections in comments.	Either NaI1 or NaI2 AND Either GM1 or GM2		

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP # JSTPH00236Rev0
Test Case: 3
Page 3 of 4

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 3

Step	Tester Action	Expected Result	Comments	Initial
3.9	Repeat steps 3.6-3.7 for the new detectors	same as 3.6 and 3.7	NaI counts: GM counts:	
3.10	Select the "Detector Settings" option from the Main screen.	The "Detector Configuration" screen will be displayed.		
3.11	Verify that the values and dates recorded in steps 3.7 & 3.9 are displayed in the appropriate fields. Click cancel to close.	The Main screen will be displayed.		
3.12	Select the "Start" option from the Main screen and allow the system to run through one cycle.	The system should start running and acquiring data.		
3.13	Switch between Maestro and the MCU-GRM software to verify that background subtraction is done for the new NaI data point.	The data point should be equal to the net counts from Maestro minus the background value for the selected detector.		
3.14	Check that GM data is being corrected accordingly.			
3.15	Change tube selections for the NaI and GM detectors by selecting the other remaining detector from each detector selection menu.	Either NaI1 or NaI2 AND Either GM1 or GM2		

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP#JSTPH00236Rev0
Test Case: 3
Page 4 of 4

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 3

Step	Tester Action	Expected Result	Comments	Initial
3.16	Repeat steps 3.12 - 3.14 for the new detectors.	same as 3.12, 3.13, and 3.14		
	END OF TEST			

Date Executed: ____________
Tester (Print Name): ________
Tester (initials): ____________

STP#JSTPH00236Rev0
Test Case: 4
Page 1 of 2

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 4

Step	Tester Action	Expected Result	Comments	Initial
	Purpose	The purpose of this test is to ensure that the software will perform a detector efficiency correction for each detector.		
	Methodology	Bring system to a steady-state test condition.		
	Hardware/ Tools	Radioactive Source		
	Setup	Insert Radioactive source in front of collimator window on the shield. The MCU-GRM software should be operational. Maestro should be operational.		
4.1	Start the Base Injection Main.	The Main program screen should appear.		
4.2	Select the "Detector Settings" option from the Main screen.	The "Detector Configuration" screen will be displayed.		
4.3	Enter a value of 2 for all detector efficiency settings. Click "Apply Changes" to save the new values.			

Date Executed: ____________________
Tester (Print Name): ____________________
Tester (initials): ____________________

STP # JSTPH00236Rev0
Test Case: 4
Page 2 of 4

Requirements Tested Per Software Test Documentation: Document J-SQP-H-00013 Requirement 4

Step	Tester Action	Expected Result	Comments	Initial
4.4	Record the tube selections from the main screen.	Either NaI1 or NaI2 AND Either GM1 or GM2		
4.5	Select the "Start" option from the Main screen and allow the system to run through one cycle.	The system should start running and acquiring data.		
4.6	Switch between Maestro and the MCU-GRM software to verify that background subtraction is done for the new NaI data point.	The data point should be equal to the half net counts from Maestro.		
4.7	Check that GM data is being corrected accordingly.			
4.8	Change tube selections for the NaI and GM detectors by selection the other remaining detector from each detector selection menu.	Either NaI1 or NaI2 AND Either GM1 or GM2		
4.9	Repeat steps 4.5 - 4.7 for the new detectors.			
	END OF TEST			

APPENDIX D. SOFTWARE USER'S MANUAL FOR MCU-GRM

Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitors

MCU-GRM

L814-J-002v Version 2.0.

Software User's Manual, Rev 1

Prepared by: ______________________

Tim N Riley
Engineered Equipment & Systems
Savannah River National Laboratory

Date: June 26, 2006

Approvals:

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MCU Design Authority Manager
Date

SUMMARY OF CHANGES

Revision:	Date:	Description:
A	9/2/05	Initial routing for review and comments
0	10/3/05	Approval
1	6/26/06	Removed FFB hardware description, Added 4-20mA module descriptions

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TABLE OF FIGURES

1.0 INTRODUCTION

1.1. Purpose

This document describes the software developed for operation of the Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitors (MCU-GRM). A brief description of the system hardware is included as necessary for clarification of its interaction with the MCU-GRM software.

1.2. Scope

Provisions of this document apply to software developed by SRNL for the Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM). This document does not cover the design or development of the supervisory distributed control system (DCS).

1.3. Definitions and Acronyms

MCU-GRM	Modular Caustic Side Solvent Extraction Unit – Gamma Ray Monitor
SRNL	Savannah River National Laboratory
DCS	Distributed Control System
NIM	Nuclear Instrumentation Module
MCA	Multi-Channel Analyzer
GM	Geiger-Mueller
NaI	Sodium Iodide
FP	FieldPoint

2. REFERENCES

- J-SQP-H-00013, Rev. 0, "Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors Software Quality Assurance Plan"
- U-FCD-H-00008, Rev. 0, "Modular CSSX Unit (MCU) Software Classification - a portion of the DISTRIBUTED CONTROL SYSTEM (DCS) network"
- WSRC-RP-2004-00875, Rev 0, "Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction Gamma-Ray Monitors"
- U-MT-H-00085, Rev 1, "Cesium Removal Implementation Using Caustic Side Solvent Extraction Technology"
- G-TC-H-00041, Rev 4, "Task Requirements and Criteria – Modular Caustic Side Solvent Extraction Unit (MCU)"
- G-ESR-H-00072, Rev 0, "Interface Control Document Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU)"
- Technical Task Request, Rev.1, Gamma Monitor for MCU
- WSRC 1Q Manual QAP 20-1, "Software Quality Assurance"
- WSRC E7 Manual Procedure 5.20 "Software Design and Implementation"
- IEEE Standard 1016-1998, "IEEE Recommended Practice for Software Design Descriptions".
- J-DD-H-00001, Rev.0, Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitors (MCU-GRM), Design Document for Software

3. MCU-GRM SYSTEM DESCRIPTION

The Modular Caustic Side Solvent Extraction Unit Gamma Ray Monitor (MCU-GRM) is an integrated hardware/software platform designed specifically for continuous monitoring of the Cesium removal process of the Modular Caustic Side Solvent Extraction Unit (MCU). A simplified MCU process flow diagram is 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. For a more detailed discussion of the CSSX process see WSRC-RP-2004-00875 "Task Technical and Quality Assurance Plan for Caustic Side Solvent Extraction Gamma-Ray Monitors".

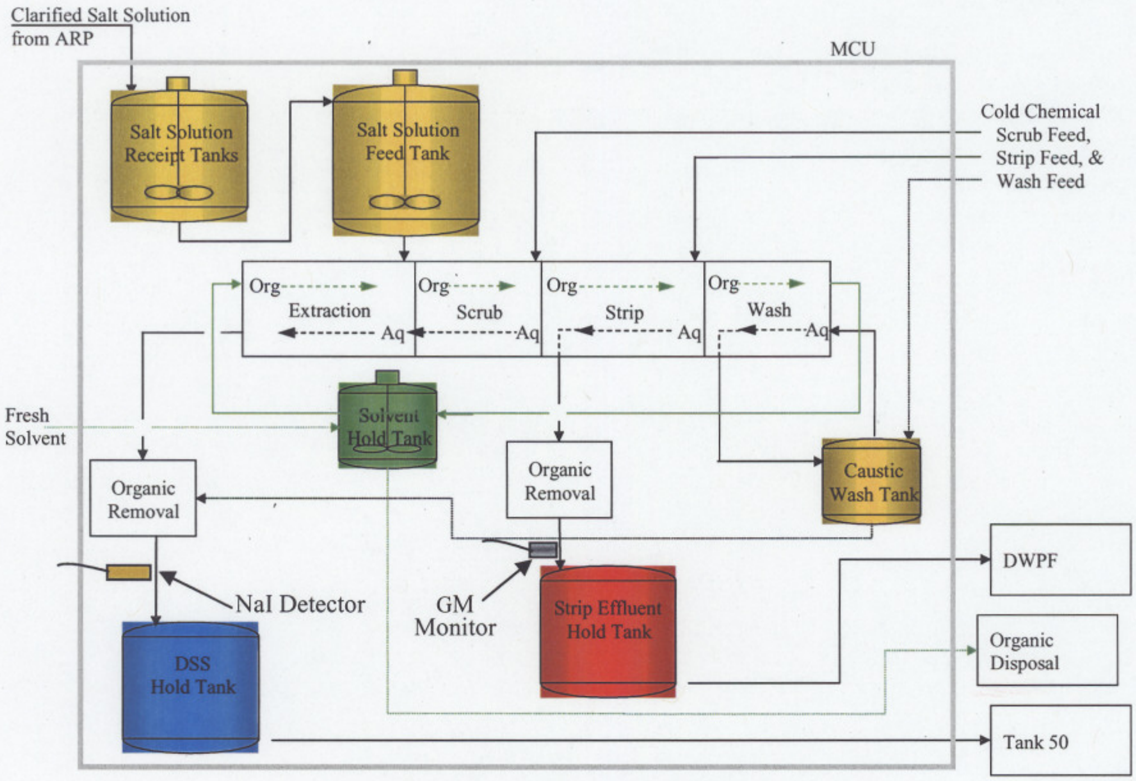

Figure 1: MCU Process Flow Diagram

4. MCU-GRM HARDWARE DESCRIPTION

The MCU-GRM hardware consists of two - Sodium Iodide (NaI) photomultiplier tubes, two - Geiger Mueller tubes, two - spectroscopy amplifiers, two - high voltage power supplies, two radiation detection modules, one - modular Nuclear Instrumentation Module (NIM) bin and power supply, one – computer, one – keyboard, one – pulse counter card and associated connection hardware, two – multi-channel analyzer cards, and one – FieldPoint 4-20 mA Analog Output Module. A materials and equipment listing for the MCU-GRM hardware is included in Appendix A.

Two NaI spectrometers (one online and one backup) are used for measuring the Cs-137 concentration in the decontaminated salt solution entering the DSS Hold Tank. High voltage and preamp power are provided to the detectors through Nuclear Instrumentation Module (NIM) based modular electronics. The amplified and scaled output signals from each 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) geared specifically towards nuclear spectroscopy applications.

Two GM tubes (one online and one backup) are used for measuring the Cs-137 concentration in the strip effluent before entering the Strip Effluent Hold Tank. These detectors are connected by a single coax 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. Communication between the MCU-GRM and the DCS is handled by five separate 4-20 mA signals. The signals originate within the MCU-GRM software, where they are passed to a National Instruments FP-1000 Network Interface module. The network interface module disperses the individual signals to the appropriate channel of the National Instruments FP-AO-200 Analog Output module, which in-turn generates the discrete currents proportional to the scaled range of each value A block diagram of the MCU-GRM hardware is shown in Figure 3-1 below.

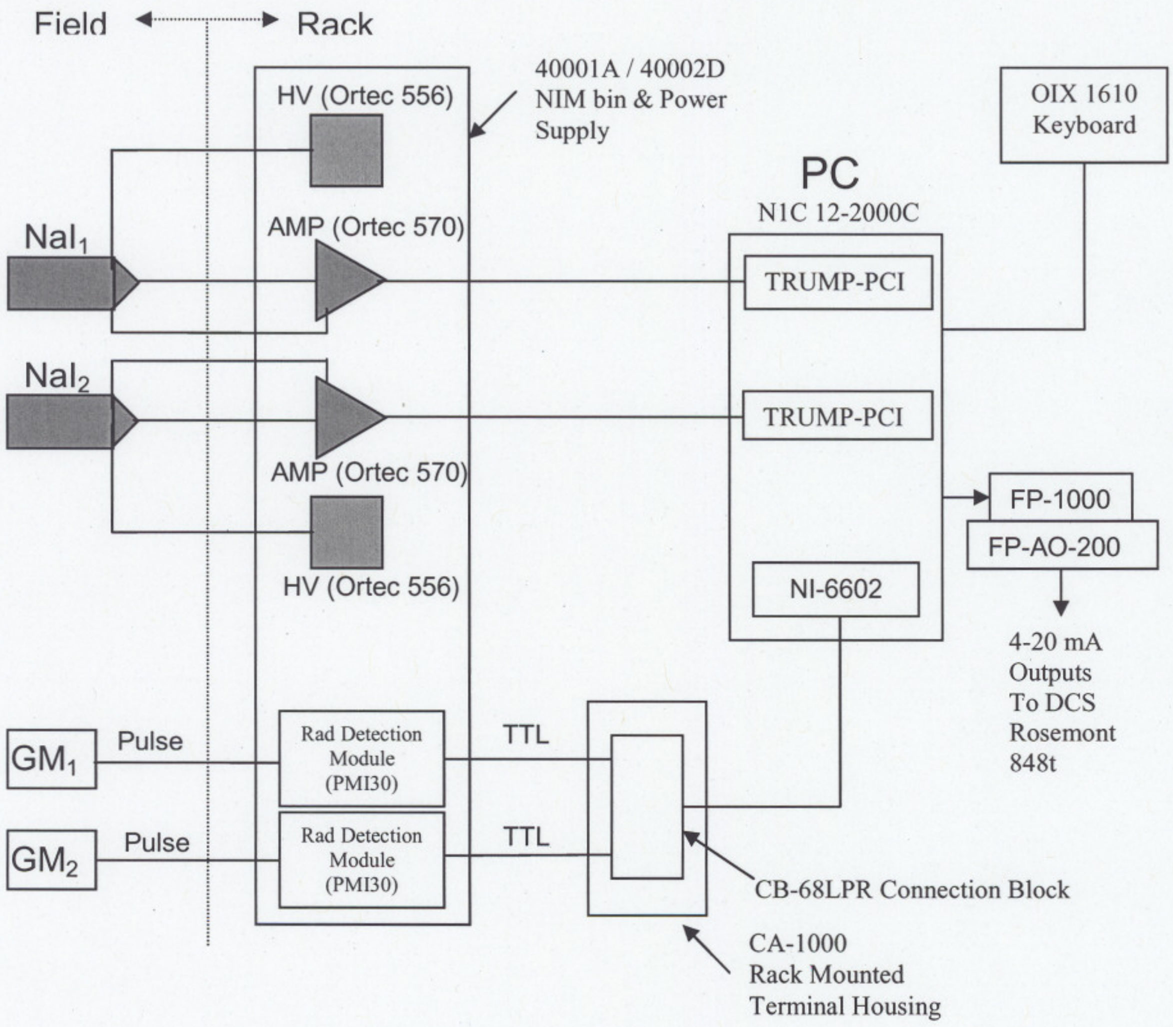

Figure 2: MCU-GRM Hardware Block Diagram

4.1. MCU-GRM to DCS Communications

The MCU-GRM software employs five separate 4-20 mA output signals to communicate key operational parameters to the DCS. The system uses three of the signals for the NaI spectrometers and two for the GM tubes.

The NaI signals are broken down into one for the measured process value (RT3024V), one for the Am peak alignment alarm (RT3024A), and one for the system health signal (RT3024H). The measured value signal is a 4-20 mA output that is linearly scaled to the measured range of 0-1 Ci/gal. The signal is updated at the end of each measurement cycle, nominally 10 minutes. The Am peak alignment signal serves as an indication of a shift in the spectral channel location of the Am pulsar peak. The signal is normally set at the 20 mA level and changes to 4 mA upon detection of the Am peak shift. This signal is also updated at the end of each measurement cycle. The NaI health signal toggles continuously between the 4 and 20 mA levels and serves as an indication that the computer system, NaI MCA hardware, and the MCU-GRM software are operational. This signal is updated on a periodic basis that will be determined during system testing in order to provide timely notification of system failures.

The GM signals are broken down into one for the measured process value (RT3044V), and one for the system health signal (RT3044H). The measured value signal is a 4-20 mA output that is linearly scaled to the measured range of 0-20 Ci/gal. The signal is updated at the end of each measurement cycle, nominally 10 minutes. The GM health signal toggles continuously between the 4 and 20 mA levels and serves as an indication that the computer system, GM pulse counting hardware, and the MCU-GRM software are operational. This signal is updated on a periodic basis that will be determined during system testing in order to provide timely notification of system failures.

5. MCU-GRM 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 DCS. These activities are accomplished through five basic software modules that are described in detail in J-DD-H-00001 "MCU-GRM Design Document for Software". The MCU-GRM software source code number is L814-J-002v Version 2.0.

From the User's point of view, the MCU-GRM software can be broken down into just a few software modules that will be described in this section. These software modules are the MCU-GRM Application Window, Detector Selection, Detector Configuration Settings, Background Counting, and Routine Data Acquisition.

5.1. MCU-GRM Application Window

The major component of the MCU-GRM software is the application window, shown in Figure 3. 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.

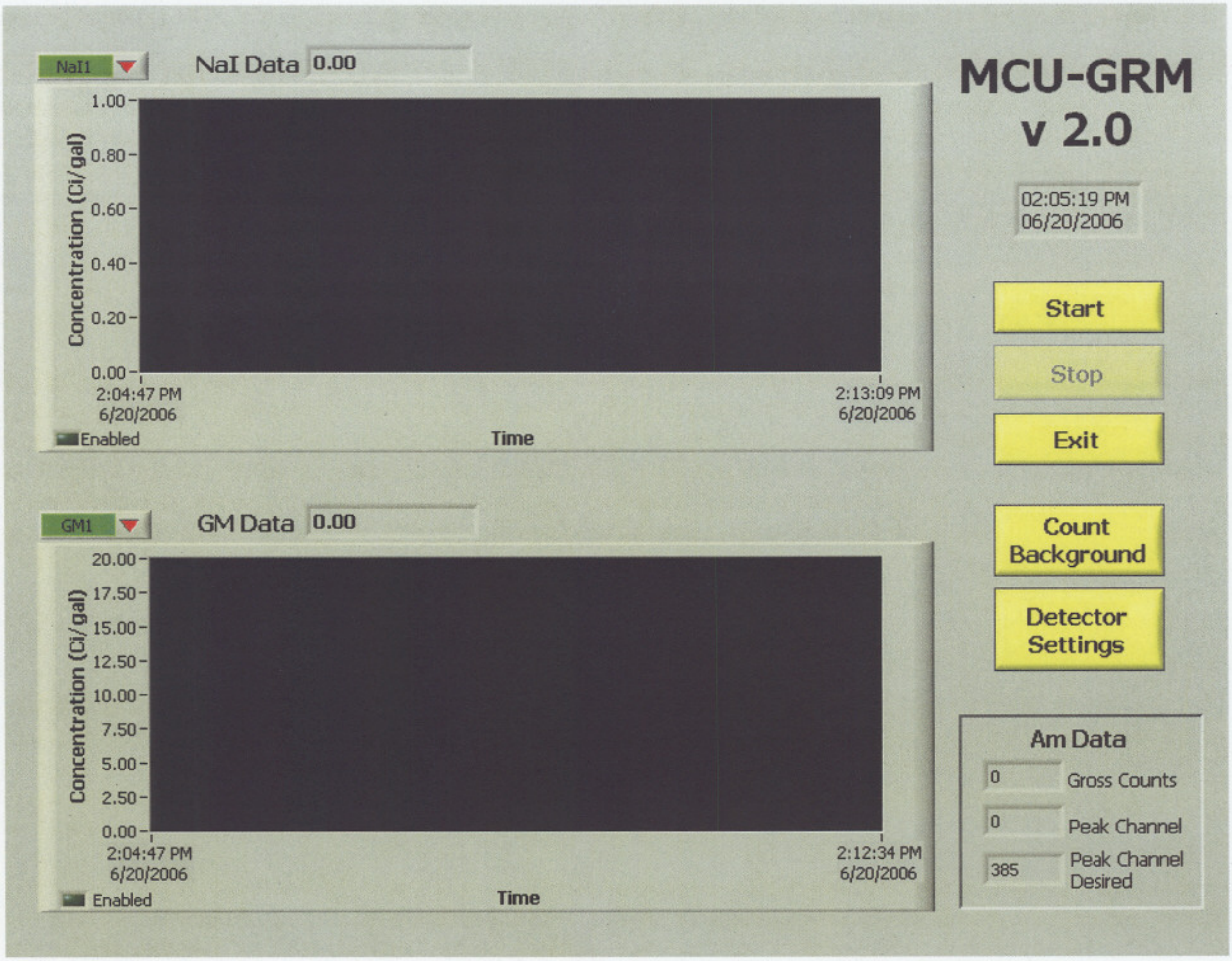

Figure 3: MCU-GRM Application Window

The most prominent features on the application window are the measurement history graphs. The 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.

5.2. Detector Selection

Selection of the desired NaI or GM detector is performed from the MCU-GRM Main screen, as shown in Figure , by clicking on the red arrow selector located beside both detector selection menus. This action brings up a pull-down menu from which the user can select the desired detector. Only one detector of each type may be selected at any given time. When NaI1 is on, NaI2 is off and vice versa. The same rules apply to the GM detectors. The detector selection function is disabled if either the MCU-GRM routine data collection or background counting options have been started.

5.3. Detector Configuration Settings

As is the case with any gamma monitoring system, the user must know certain detector operating parameters such as the detector efficiency and measured background count in order to make compensations to the measured activity for variations in the detector internals and for the amount of activity entrained within the system. Without these values, accurate determination of the solution activity is impossible. The MCU-GRM stores these values in a configuration file (MCU_GRM_CONFIG.ini). The format of this file is shown in Appendix B.

The user is granted access to these parameters only through the detector configuration utility. The user can access this utility, by clicking the **Detector Settings** button on the MCU-GRM main screen (Figure 3). Because these values are crucial to the operation of the system and its ability to produce reliable output data, a password is required for access. The Password Utility Screen is shown in Figure 4.

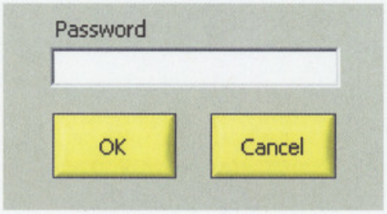

Figure 4: Detector Configuration Settings Password Screen

The password utility is case sensitive. Upon entering the correct password, the user will be able to access data on the Detector Configuration screen as illustrated in Figure 5. The user can change the password by changing the password character string in the password file. The filename is not included in this document. *NOTE: The password will be changed by the User after the project turnover.*

The Detector Configuration Screen is divided into 5 sections. Four identical sections, two for the NaI detectors and two for the GM detectors, are used for setting the detector operating parameters. This allows for independent parameter settings that are specific to each detector in the system. The single section at the bottom of the screen is used for setting the cycle times for routine data collection.

Within each of the detector sections, the user can set values for the detector Efficiency, measured Background, and Background Count Time. Changes can be made by either clicking the yellow up or down arrows next to each of the fields, or by typing a value directly into the text box. Each field performs automatic range checking on the entered data to allow only numerical entries within a predetermined range of values. The final range will be determined empirically when the system functional testing is performed.

If changes are made to either the detector Efficiency or measured Background settings, the associated Last Update fields are automatically imprinted with the current date. This is to help keep track of the last entries made for the critical detector operating parameters. Changes to the Last Update fields are done programmatically and are not accessible to the user. The user can select the Background Count Time for each detector. Optimal values will be determined empirically during system functional testing. Once changed, the new values are stored in the configuration file (MCU_GRM_CONFIG.ini) and are used for all future computations.

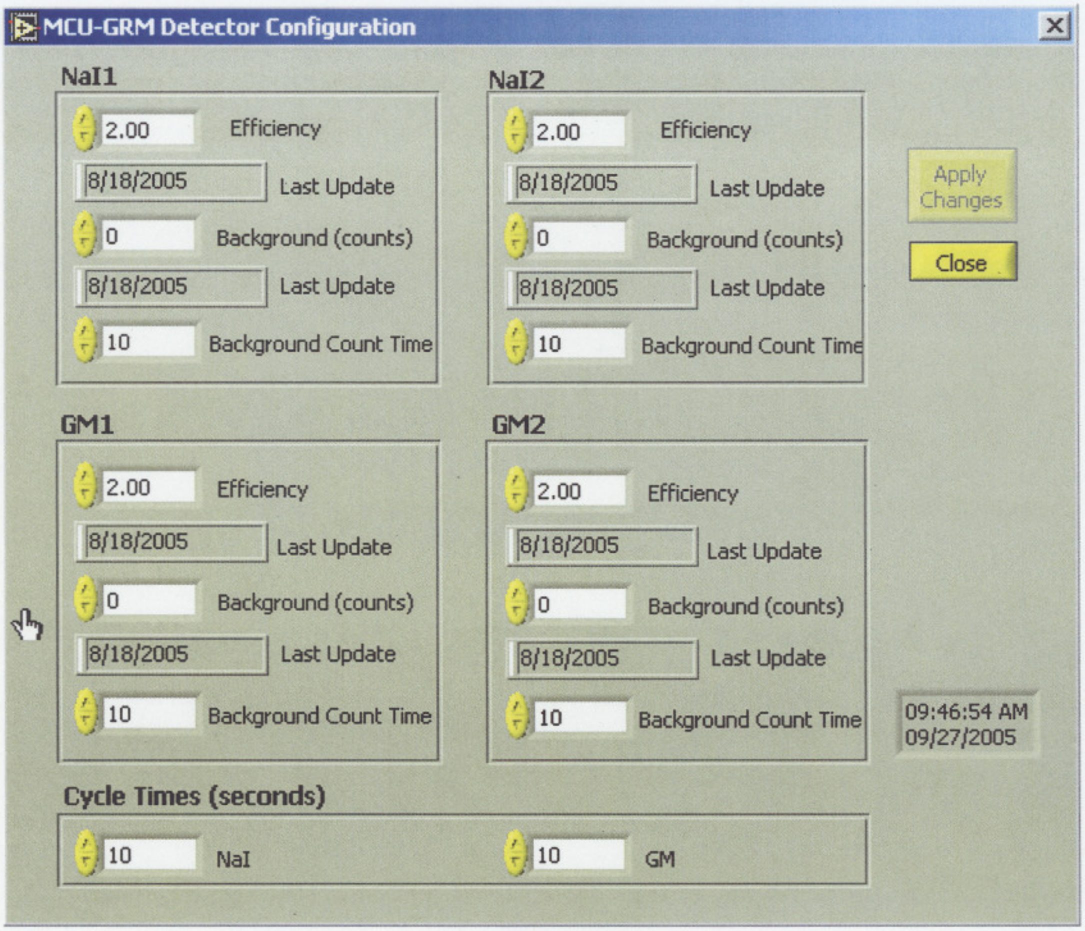

Figure 5: Detector Configuration Screen

5.4. Routine Data Acquisition

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 click the **Start** button on the MCU-GRM application window (Figure).

At this point, the application changes to the running state as indicated on the screen. In the running mode, the time remaining for each detector's acquisition cycle is displayed in the corresponding Next Update counter along the top of each graph. The Next Update counter is updated once a second to show the time remaining until the end of the current acquisition cycle. By default, the data acquisition cycle for both detectors is set for 600 seconds. The health signals (RT3024H & RT3044H) are also updated at this point.

At the start of Run cycle, the program reads the GM and NaI detector configuration data as set previously using the Detector Configuration Utility. The system starts the first count by writing the live time preset to the Trump Card to start the spectrum collection. The Trump card performs all the required spectrum collection functions as instructed without further interaction from the MCU-GRM software. The system also initializes and starts the NI-6602 counter to monitor the pulse output of the GM signal train.

After the NaI time interval has elapsed, the program polls the Trump card to determine if the required live time spectrum collection has completed. If the live time interval has not completed the program waits for its completion. (NOTE: These two times should be about equal, unless a significant amount of dead time is encountered.) At completion of the counting cycle, the program queries the Trump card to get the raw counts in the Cesium photo-peak, along with other Cesium Region-of-Interest (ROI) statistical information. The program also reads the raw counts from the Americium photo-peak as well as the Am peak centroid channel number within the Am peak ROI. The ROIs in question are those established by the user during the initial system setup and calibration and should be the one containing the Cs and Am photo-peaks respectively. The program then issues commands to the Trump card to clear the current spectrum and restart the NaI data acquisition cycle. After the Trump card is restarted, the MCU-GRM software calculates the net counts in the Cesium photo-peak. At this point, the program has enough information to calculate the Cesium Concentration (Ci/gal) in the clarified salt solution. This is done by subtracting the measured background value from the net counts and dividing the result by the detector efficiency.

To wrap up the processing of the NaI data, 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 in the detector HV supply or the amplifier gain. If the Am peak channel is outside of an acceptable band, the system will flag the user with an error message similar to that shown in Figure 6. The software will also signal the Field Point module to set the Am peak alignment signal (RT3024A) to the alarm state. The NaI detector system will not perform its monitoring function until this condition is corrected. These adjustments are covered in Appendix C.

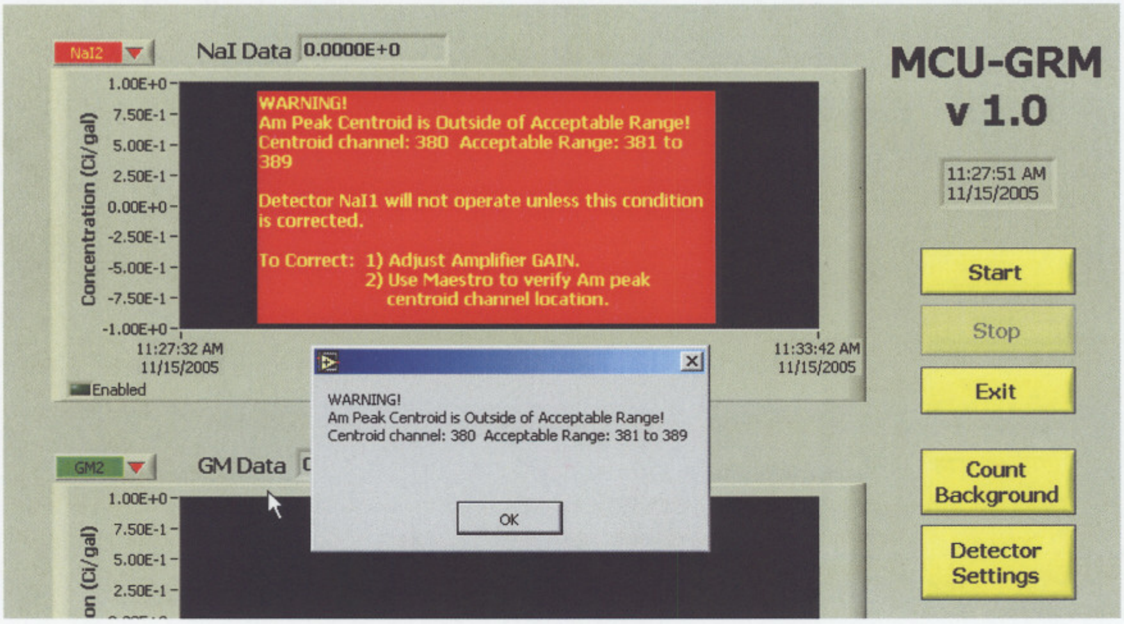

Figure 6: Am Peak Channel Error State

Like the NaI detector cycle, the MCU-GRM software issues commands to stop the NI-6602 counter and to read the total count collected during the GM data acquisition cycle. When this is completed, the program issues commands to clear and restart the count for the next cycle. Similar to the NaI data, the GM net counts are calculated using the GM detector measured background and the detector efficiency.

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 points (RT3024V & RT3044V) are also passed along to the DCS through the FieldPoint interface. The new data and a selected subset of system and detector parameters are written to a log file (See Appendix D). Both acquisition cycles continue until the user clicks the **Stop** button on the application window.

5.5. Background Counting

In order to gain an accurate picture of the activity of the solution moving through the system the system must be able to separate out that portion of the measured activity that is contributed by the salt solution from the portion that is due to the entrained particles within the system and its surroundings. In order to do this, the software must be able to null out the contribution of the system components to the overall measured activity. The MCU-GRM software accomplishes this through background subtraction. 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. This task must necessarily be performed in-situ, as this is the only method for accurate determination of the ambient activity levels.

The performance of this measurement requires coordination between the MCU-GRM and the DCS because a thorough flushing is required for all components within the detectors field of view. The system setup for this operation will be procedurally controlled within the facility and is outside the scope of this document. What is covered here is the performance of a background measurement as related to the MCU-GRM.

From the MCU-GRM point of view, the user will initiate a background count by first selecting the desired detector pair (one GM and one NaI detector) and then clicking the **Count Background** button on the MCU-GRM application window (Figure 3). The Start Background dialog box will be displayed as shown in Figure 7.

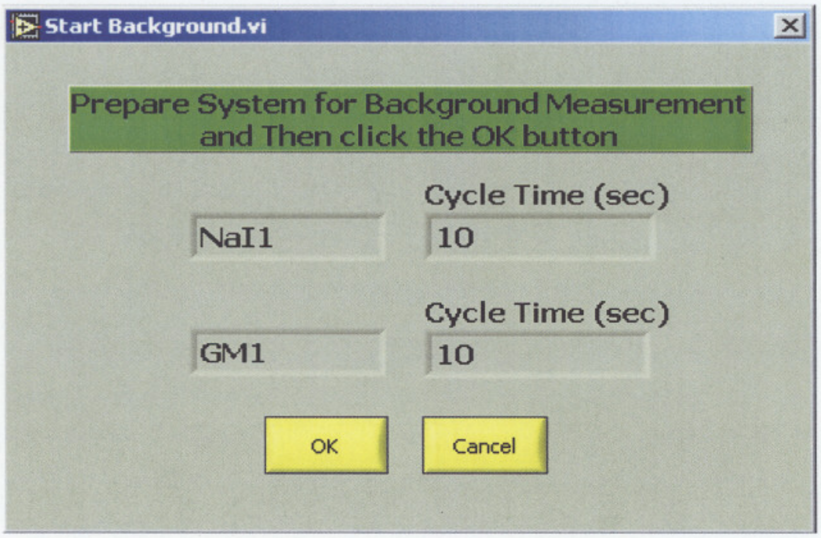

Figure 7: Start Background Count Screen

The Start Background screen shows the detectors currently selected for the background counting operation, as well as the background count time for each detector. The screen also contains a message to remind the user the system preparation should be completed prior to performing the background measurement. The MCU-GRM software only reminds the user that these activities should be performed, but has no method to enforce the requirement. Inadequate system preparation may result in inaccurate readings for the measured background values.

To proceed beyond the initial screen, the user must either accept or cancel the activity. If cancelled, the Start Background screen will disappear and the MCU-GRM application window will be displayed. If accepted, the Background count will commence. The count will be performed for the length of time specified in the window for each detector. During the count, the Next Update field on the MCU-GRM main screen (Figure 3) will count down to indicate the time remaining in the current counting cycle. At the completion of the background counting cycle for each detector a Background Count Complete dialog box will appear. This screen is shown in Figure .

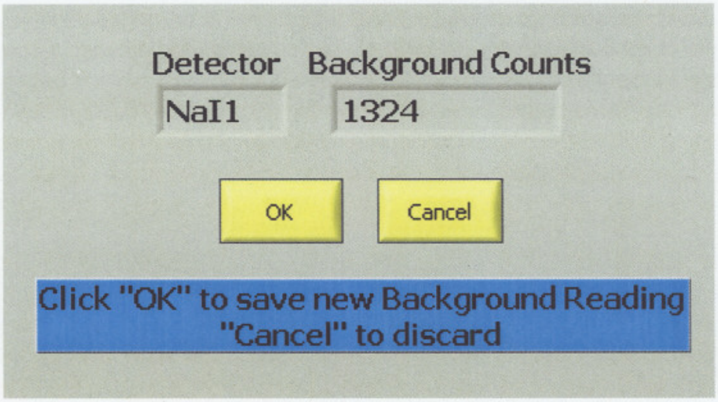

Figure 8: Background Count Complete Screen

The Background Complete screen displays the newly acquired background data point for the indicated detector and prompts the user to decide whether to keep or discard the new data. If the user decides to keep the new data point, the data is written to the detector configuration file (MCU_GRM_CONFIG.ini) and used for all subsequent calculations requiring background correction. This would also cause the Last Update field to be changed to reflect the new data point change. (Refer to Figure 5) Otherwise the data is discarded and the current settings retained. When the background counts for both detectors have completed, the system returns to the standby mode awaiting further instructions from the user.

To summarize, the Background Counting mode performs a count for the two detectors that are currently selected, one GM and one NaI detector. Each count is performed for a preset period of time as determined by the setting in the Detector Configuration Window for the specified detector. At the completion of the count the new measured background data point may either be discarded, or written to the detector configuration settings file to be used on all subsequent calculations. Neither of the data points are written to the graph or to the digital display on the MCU-GRM application window.

6. STARTUP AND OPERATION OF THE MCU-GRM SYSTEM

6.1. MCU-GRM Hardware Configuration

There are four configuration programs that must be run to set up the MCU-GRM hardware before starting the MCU-GRM application software for the first time. This operation is only required to be performed prior to the initial startup.

1. Run the ORTEC "MCB Config" program to setup the communication channels with MCA1 and MCA2.
2. Run the ORTEC "Maestro" program to properly establish the two regions of interest (ROIs) needed for the data collection process.
3. Run the NI Measurement and Automation Explorer to set up the NI-6602 Counter/Timer card and the FieldPoint module.

The MCU-GRM initialization sequence verifies that these operations have been completed. The MCU-GRM application program will be unable to initialize or communicate with the hardware devices and will generate an appropriate error should any of these steps fail to be performed. The procedures for performing all the above actions are listed in the appropriate manufacturer's literature for each device and will not be included in the MCU-GRM documentation. A complete listing of the manufacturer's literature is included in Appendix E. A copy of each document will also be placed in the EES Job Folder #23075 for the project.

6.2. MCU-GRM Application Startup and Initialization

1. The MCU-GRM software is started by **[double-clicking]** the MCU-GRM icon from the Windows desktop.

   At startup, the software performs the following checks: it verifies that the NI-6602 card is installed and functional; it verifies that both Trump-PCI cards are installed and functional and that two ROIs have been established for each device; and it verifies that the FieldPoint Module is installed and functional. The program then runs an initialization loop to setup the MCU-GRM user interface for operation. After these checks have completed, the MCU-GRM main screen is displayed as illustrated in Figure 3. The program remains in an IDLE state until one of the program actions is requested by the user.

6.3. Detector Selection

1. To switch between detectors NaI1 and NaI2, **[CLICK]** on the red arrow button located beside the detector selection pull-down menu on the MCU-GRM application window.

   The Detector Selection option is only active when the MCU-GRM application is in the IDLE mode.

2. When the menu pops up, **[CLICK]** on the desired detector.

3. GM tube selection may be performed in the same manner as described above.

6.4. Detector Configuration Settings

1. To gain access to the Detector Configuration Utility, **[CLICK]** on the yellow **DETECTOR SETTINGS** button on the MCU-GRM application window.

   The Password Screen will appear. The Detector Configuration Settings option is only active when the MCU-GRM application is in the IDLE mode.

2. On the Password Screen, **Type 'CSSX'** and **[CLICK]** the **OK** button. The password is case sensitive.

   *The Detector Configuration Screen will appear. If the user [CLICKS] the **CANCEL** button from the Password Screen, the application will divert execution back the MCU-GRM application window.*

3. Once the Detector Configuration Screen is up, the user may change any of the parameters by **[CLICK]ing** the yellow **ARROW BUTTONS** beside any of the parameter fields, or by **Typing** the **desired value** directly into the text box.

   *Fields that have been changed are indicated by a flashing marker to remind the user to save changes if desired. If changes have been made the **APPLY CHANGES** button becomes active to allow the user to save the changes.*

4. In order to save the changes to the configuration file, the user must **[CLICK]** the **APPLY CHANGES** button on the Detector Configuration Window.

   *This will cause the new values to be written to the detector configuration file for use on all subsequent calculations. Similarly, **[CLICK]ing** the **CLOSE** button will cause any changes to be discarded. In either case, the Detector Configuration Screen will close and control will divert back to the MCU-GRM application window.*

6.5. Start Routine Data Acquisition

1. To start the MCU-GRM routine monitoring application, **[CLICK]** on the yellow **START** button on the MCU-GRM application window.

   *The program will switch to RUNNING mode, as evident from the change in state of the **START** button. In RUNNING mode, the program will continue to cycle through a continuous series of GM and NaI monitoring cycles. At the completion of each cycle, the new data point will be written to the graph and its associated digital display. Each new data point is also passed to the DCS. The program remains in the RUNNING state until the STOP action is requested by the user.*

2. To stop the MCU-GRM routine monitoring application, **[CLICK]** on the yellow **STOP** button.

   Control will divert back to the MCU-GRM application window.

6.6. Start Background Count

1. To start a background count, **[CLICK]** on the yellow **COUNT BACKGROUND** button on the MCU-GRM application window.

   The Start Background Count Screen will appear. The Count Background option is only active when the MCU-GRM application is in the IDLE mode.

2. On the Start Background Count Screen, **[CLICK]** the **OK** button to start the background count.

   *The MCU-GRM application window will appear. The Next-Update field at the top of each graph will count down the time remaining for each detectors counting cycle. The background counting function can be interrupted if the user **[CLICKS]** the **STOP** button from the MCU-GRM application window. As the background* *counting cycle is completed for each detector, the Background Complete screen will appear with the selected detector identifier and the physical count for the background counting cycle.*

3. The user can accept the new background activity values by **[CLICK]ing** the **OK** button on the Background Complete Window.

   *The Background setting in the configuration file will be overwritten with the new data. The Background Complete Screen will close and control will divert back to the MCU-GRM application window. The new values are discarded if the user **[CLICKS]** the **CANCEL** button from the Background Complete screen.*

APPENDIX A – MCU-GRM MATERIAL & EQUIPMENT LISTING

Qty	Manufacturer Part #	Description
2	Scionix 25BS25/2-E2-Am-X	Americium seeded NaI(TI) detector assembly
2	Ludlum 133-6-1	Geiger Mueller tubes
2	Ortec 570	Spectroscopy amplifiers
2	Ortec 556	High voltage power supplies
2	Aware PMI30	Radiation detection modules
1	Ortec 4001A/4002D	Modular NIM bin and power supply
1	CyberResearch N1C 12-2000C	Rack mounted computer
1	CyberResearch OIX 1610	Rack mounted keyboard
1	National Inst NI-PCI-6602	Pulse counter card, NI# 777531-01
2	Ortec Trump-PCI-2K	Multi-Channel analyzer cards
1	National Inst CA-1000	Configurable Connector Assembly Enclosure, NI# 777664-01
1	National Inst CB-68LPR	Connection Block, NI# 777145-02
1	National Inst SH68-68-D1	Shielded 68 pin cable assembly, 1 meter long, NI# 183432-01
8	National Inst Blank Panelette	Blank Panelette for CA-1000 NI# 184483-01
1	National Inst BNC Panelette	BNC Panelette for CA-1000 NI# 184737-01
1	National Inst CA-1000 hardware	CA-1000 Rack Mount Kit (1U), NI# 777665-01
1	National Inst NI FP-1000	Network Interface Module, NI# 777517-00
1	National Inst NI FP-AO-200	Analog Output Module, NI# 777518-200
1	National Inst NI FP-TB-1	Screw Terminal Block, NI# 777519-01
1	Phoenix Contact	24v Power Supply, #mini-ps-120-230AC/24DC/0.65

APPENDIX B – CONFIGURATION FILE FORMAT

The format for the Configuration File is shown below. At startup, the MCU-GRM software reads the detector configuration values from the configuration file (MCU_GRM_CONFIG.INI). DATA IN THIS FILE CAN ONLY BE CHANGED FROM THE DETECTOR CONFIGURATION WINDOW OR AFTER COMPLETION OF A BACKGROUND MEASUREMENT.

[NaI1]	Section Header
Eff:	NaI1 Detector Efficiency.
Eff Date:	Date that the NaI1 detector efficiency setting was last changed.
Bckgnd:	Measured Background value for detector NaI1.
Bckgnd Date:	Date that the NaI1 measured background setting was last changed.
Bckgnd Count Time:	Duration of time (seconds) for NaI1 background counting.
[NaI2]	Section Header
Eff:	NaI2 Detector Efficiency.
Eff Date:	Date that the NaI2 detector efficiency setting was last changed.
Bckgnd:	Measured Background value for detector NaI2.
Bckgnd Date:	Date that the NaI2 measured background setting was last changed.
Bckgnd Count Time:	Duration of time (seconds) for NaI2 background counting.
[GM1]	Section Header
Eff:	GM1 Detector Efficiency.
Eff Date:	Date that the GM1 detector efficiency setting was last changed.
Bckgnd:	Measured Background value for detector GM1.
Bckgnd Date:	Date that the GM1 measured background setting was last changed.
Bckgnd Count Time:	Duration of time (seconds) for GM1 background counting.
[GM2]	Section Header
Eff:	GM2 Detector Efficiency.
Eff Date:	Date that the GM2 detector efficiency setting was last changed.
Bckgnd:	Measured Background value for detector GM2.
Bckgnd Date:	Date that the GM2 measured background setting was last changed.
Bckgnd Count Time:	Duration of time (seconds) for GM2 background counting.
[Cycle Times]	Section Header
NaI Cycle Time:	Duration of time (seconds) for NaI normal measurement cycle.
GM Cycle Time:	Duration of time (seconds) for GM normal measurement cycle.

APPENDIX C – ERROR RECOVERY PROCEDURES

Am Peak Channel Adjustment

1. Note the NaI detector to be calibrated from the MCU-GRM application window.
2. Start the Maestro program and collect a spectrum. Collection time should be long enough to determine where the Cs and Am peaks are located. (To start the Maestro program **Double-Click** the Maestro Icon on the desktop or go to C:\Program Files\Maestro\Mca32.exe).
3. Right click on the Am peak and select "Peak Info" from the pop up menu.
4. Note the channel number of the Am peak centroid.
5. Adjust the detector HV supply or the Amplifier gain to bring the Am peak centroid back to the approximate center of the Am peak ROI.
6. Close Maestro.
7. Select the appropriate NaI detector from the MCU-GRM software main screen.
8. Click the START button and let the program go through one acquisition cycle. Verify that the error has cleared.

APPENDIX D – NAI AND GM DATALOG FILE FORMAT

The format for the DataLog files for both the NaI and GM detectors is shown in Tables D-1 and D-2 below. At the end of each analysis cycle, the new data stream is appended to the end of the appropriate file for each detector. A new file is created at the beginning of each month to keep the log file to a manageable size. The month and year are embedded within each file name as shown in each table below. (mm is the 2 digit month and yyyy is the 4 digit year for the month in which the file was first created.)

Table D-1 –DataLog File Format (C:\MCU_GRM NaI Data_mmyyyy.txt)

[Date/Time]	Section Header
Date/Time String	Date and time that analysis was completed
[Live Time]	Section Header
Live Time:	The live time setting for each iteration. (The number of 20 msec intervals)
[True Time]	Section Header
True Time:	The true time elapsed for the iteration, as read from the Trump Card. (The number of 20 msec intervals)
[Cs Data]	Section Header
Cs Peak Channel:	The channel number of the Cs photo-peak centroid.
Cs Net Counts:	The net Counts in the Cesium photopeak.
[Am Data]	Section Header
Am Peak Channel:	The channel number of the Am photo-peak centroid.
Am Net Counts:	The net Counts in the Americium photopeak.
[Concentration (Ci/gal)]	Section Header
Concentration:	The Cs-137 concentration calculated using the measured background and detector efficiency settings.
[NaI Detector]	Section Header
Detector Selected:	The detector used in the analysis #1-NaI1, #2-NaI2
[Background]	Section Header
Measured Background:	Measured background data as set in the Configuration Utility.
[Efficiency]	Section Header
Detector Efficiency:	Efficiency data as set in the Configuration Utility.
End of Data Marker:	(******************) A flag to signal the end of data for the current analysis.

(Repeat Data for each loop)

Table D-2 –DataLog File Format (C:\MCU_GRM GM Data_mmyyyy.txt)

[Date/Time]	Section Header
Date/Time String	Date and time that analysis was completed
[Cycle Time]	Section Header
Cycle Time:	The acquisition time setting for each iteration.
[Activity (Ci/gal)]	Section Header
Activity:	The calculated activity using the measured background and detector efficiency settings.
[GM Detector]	Section Header
Detector Selected:	The detector used in the analysis #1-GM1, #2-GM2
[Background]	Section Header
Measured Background:	Measured background data as set in the Configuration Utility.
[Efficiency]	Section Header
Detector Efficiency:	Efficiency data as set in the Configuration Utility.
End of Data Marker:	(******************) A flag to signal the end of data for the current analysis.

(Repeat Data for each loop)

APPENDIX E – MANUFACTURER'S LITERATURE

Manufacturer Part #	Description	Revision
Scionix 25BS25/2-E2-Am-X	Specifications and Technical Data Sheets	1/4/2005
Ludlum 133-8-1	Instruction Manual	9/30/2003
Ortec 570	Spectroscopy Amplifier Operating and Service Manual	Rev E,
Ortec 556	Model 556 High Voltage Power Supply Operating and Service Manual	Rev H
Aware PMI30	PMI-30 Pre-Amp – Amp High Voltage Computer Interface User Manual	N/A
Ortec 4001A/4002D	1. Model 4001A Modular System Bin Operating and Service Manual 2. Model 4002D NIM Bin Power Supply Operating and Service Manual	Rev D Rev J
CyberResearch N1C 12-2000C	1. SUPER P4SPA+ SUPER P4SPE User's Manual 2. CyberResearch N1C-12-200C Detailed Specification 3. MXSK CEL-2000 Motherboard Detailed Specification	Rev 1.1a N/A N/A
CyberResearch OIX 1610	CyberResearch OIX 1610 Rack-Mount Keyboard Detailed Specification	N/A
National Inst. NI-PCI-6602	6601 / 6602 User Manual	1/99
Ortec Trump-PCI-2K	TRUMP-PCI-8K TRUMP PCI-2K Multichannel Buffer Card Hardware Manual	Rev E
National Inst. NI FP-1000	1. FP-1000 Programmer Reference Manual 2. FP-1000 Quick Start Guide 3. FP-1000 User Manual	3/1999 4/2003 4/2003
National Inst. NI FP-AO-200	1. FP-AO-200 Manual	10/2002
National Inst. NI FP-TB-1	1. FP-TB-1 Operating Instructions	5/2002
National Inst. CA-1000	CA-1000 Configurable Connector Accessory Enclosure	12/2000
National Inst. CB-68LPR	SCB-68 68 Pin Connector Block User Manual	12/2002

APPENDIX E. CALIBRATION CERTIFICATES FOR CS-137 STANDARDS

ANALYTICS

WSRC-RP-2005-01902
Revision #1

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318 · U.S.A.

Phone (404) 352-8677
Fax (404) 352-2837

CERTIFICATE OF CALIBRATION
Standard Radionuclide Source

70805-147

Cs-137 Solid in 4 Inch Long x 0.5 Inch Diameter Schedule 40 Pipe

This standard radionuclide source was prepared gravimetrically from a calibrated master solution. The master solution was calibrated with an ionization chamber that was calibrated by the National Physical Laboratory, Teddington, U.K., and is directly traceable to national standards.

Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and assay date for this source are given below.

ANALYTICS maintains traceability to the National Institute of Standards and Technology through Measurements Assurance Programs as described in USNRC Reg. Guide 4.15, Revision 1.

U.S. Patent 4,430,258; U.K. Patent GB2,149,194B; CA. Patent 1,196,776. Density of solid matrix 1.15 g/cc.

ISOTOPE:	Cs-137
ACTIVITY (dps):	4.375 E6
HALF-LIFE:	3.007 E1 years
CALIBRATION DATE:	June 24, 2005 12:00 EST
RELATIVE EXPANDED UNCERTAINTY (k=2):	3.3%

Impurities: γ-impurities <0.1%

20 mL solid in customer supplied pipe.

P O NUMBER AC43806G, Item 3

SOURCE PREPARED BY: M. Taskaeva
M. Taskaeva, Radiochemist

Q A APPROVED: 06-24-2005

ANALYTICS

1380 Seaboard Industria
Atlanta, Georgia 30318 ·

Phone (404) 352
Fax (404) 352

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

68709-147

Cs-137 Solid in 2 Inch Schedule 40 Pipe

This standard radionuclide source was prepared gravimetrically from a calibrated master solution. The master solution was calibrated in an ionization chamber that was calibrated by the National Physical Laboratory, Teddington, U.K., and is directly traceable to national standards.

Radionuclide purity and calibration were checked using a germanium gamma spectrometer system. The nuclear decay rate and assay date for this source are given below.

ANALYTICS maintains traceability to the National Institute of Standards and Technology through Measurements Assurance Programs as described in USNRC Reg. Guide 4.15, Revision 1.

U.S. Patent 4,430,258; U.K. Patent GB2,149,194B; CA. Patent 1,196,776. Density of solid matrix 1.15 g/cc.

ISOTOPE:	Cs-137
ACTIVITY (dps):	1.889 E7
HALF-LIFE:	3.007 E1 years
CALIBRATION DATE:	July 14, 2004 12:00 EST
RELATIVE EXPANDED UNCERTAINTY (k=2):	3.3%

Impurities: γ-impurities <0.1%

P O NUMBER AC37844G, Item 1

SOURCE PREPARED BY: [signature], for
M. Taskaeva, Radiochemist

Q A APPROVED: [signature] 7/14/04

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