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AUTHOR(S): S -T. Hsue and M. P. Baker

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Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

NONDESTRUCTIVE ASSAY SYSTEM DEVELOPMENT FOR A PLUTONIUM SCRAP RECOVERY FACILITY

S. -T. Hsue and M. P. Baker
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

A plutonium scrap recovery facility is being constructed at the Savannah River Plant (SRP). The safeguards groups of the Los Alamos National Laboratory have been working since the early design stage of the facility with SRP and other national laboratories to develop a state-of-the-art assay system for this new facility. Not only will the most current assay techniques be incorporated into the system, but also the various nondestructive assay (NDA) instruments are to be integrated with an Instrument Control Computer (ICC). This undertaking is both challenging and ambitious; an entire assay system of this type has never been done before in a working facility. This paper will describe, in particular, the effort of the Los Alamos Safeguards Assay Group in this endeavor. Our effort in this project can be roughly divided into three phases: NDA development, system integration, and integral testing.

NDA Development

In the NDA development category, four instruments are being designed and fabricated for this facility:

(1) Feed Coincidence Counter (FCC)
(2) Low Solution Assay Instrument (LOSAI)
(3) NaI Monitors (NaI)
(4) Waste Coincidence Counter (WCC)

The FCC is designed to assay the feed plutonium before it enters the process. Although the FCC is not as accurate as a calorimeter, each assay requires only 1000 s. The combination of the FCC and the calorimeters provides several possible measurement strategies enabling the operator to optimize either the accuracy or the measurement throughput, or both. Several improvements will be incorporated into the FCC in contrast to the traditional neutron coincidence counter. First of all, Amptek fast electronics will be used to reduce the coincidence deadtime by a factor of roughly 4. [1] This will enable the FCC to assay samples with much higher counting rates (for example, high americium samples). Sample self-multiplication correction will be incorporated into the software. Diagnostic checks [2] will also be performed in the FCC. The checks will include the total-to-accidentals test, the totals test, and the coincidence test. Similar checks like these have been in use at the International Atomic Energy Agency for some time as a part of the measurement control procedure. [2]

After the dissolution, a portion of the material is passed through anion exchange columns to separate the plutonium from the other impurities, mainly americium and ^{237}U. The effluents from these columns normally contain the majority of the impurities, and some low residual levels of plutonium. There are two possibilities of assaying the low plutonium concentrations in these solutions: monitoring the passive L x rays, or monitoring the 414-keV ^{239}Pu gamma rays. The passive L-x-ray technique [3] would require a chemical separation when the americium/plutonium weight ratio exceeds 0.3, which is often the case with these solutions. Although the plutonium has higher intensity gamma rays at lower energies, the presence of large quantities of ^{237}U, which emits an intense 208-keV gamma ray, precludes the usefulness of these gamma rays for assay purposes. We selected the 414-keV gamma ray as the assay peak. Although the branching intensity of 414-keV gamma rays is relatively low ($3.4 \times 10^{+4}$ photons/s/g), this can be compensated to some extent by using a higher efficiency detector (25% efficiency), by reducing the relative distance between the sample and the detector, and by increasing the solution volume to be viewed by the detector. This method is more accurate than the L-x-ray method, because the higher energy photons are not affected as much by attenuation in variable solution matrix. We plan to correct for pulse pileups that result from the summing of the 208-keV gamma rays. The design basis of the LOSAI is ± 25% relative standard deviation (for a 2000 s assay) of a 20-mg Pu/L sample.

In the process area, two types of NDA instruments are being fabricated. The wastes generated in the process are to be measured with the WCC to be installed in the solid waste handling cabinet. This instrument is designed to determine whether the waste can be disposed or whether it should be recovered, depending on the assayed value. The recycle level is set at 1 g of plutonium. The WCC is very much like the FCC, although some of the diagnostic checks will not be performed because of the go/no-go nature of this instrument.

The second instrument in the process area consists of thirteen NaI detectors. These detectors will be installed to view the dissolver tanks, the chemical treatment tanks, the anion exchange columns, and other miscellaneous tanks and pipes. These detectors are designed to perform several functions. When the separation process is in progress, the NaI detectors can provide process information on what nuclear species are being separated when the tanks are being filled or the columns are being loaded. This information has the potential of improving the separation process. At the end of a batch when the various tanks and columns have been emptied, the data from the NaI detectors can be used to estimate the plutonium holdup in the various process vessels. In addition, the NaI detectors will also perform criticality alarm functions, in that, when preset alarm levels are exceeded, the facility process control system will be informed immediately. These software alarms will be complemented with single channel analyzers and alarm rate meters so that the criticality alarms will be functional even when the computer and/or the multichannel analyzer are not operational.

System Integration

For the various NDA instruments to work cohesively as an integrated system and not solely as stand-alone instruments, it is important that several items be standardized:

(1) Communication protocol between NDA instruments and ICC,

(2) Measurement control (MC), and

(3) Operator-instrument interaction.

Most of these are based on what we have previously developed or simple extrapolations thereof.

The communication protocol between the various NDA instruments and the ICC is based on the FAST neutron interrogator that we have installed at the Idaho Chemical Processing Plant (ICPP) complex at Idaho Falls. [4] All communications are to be initiated by the NDA instruments. Except when acknowledging receipt of information or sending requested information, the central computer is ready to receive messages. Several features are incorporated into the protocol for checking the correctness of messages. Each message contains a byte count (to check the message length) and a checksum (to check the longitudinal sum of the message characters) so that the integrity of the communication message can be verified. All information is transferred in ASCII characters so that a nonintelligent terminal can be used for debugging.

To assure the validity of the NDA assay results, it is crucial to have a well-designed MC program. The MC for the various instruments is based on what has been developed for the Los Alamos Plutonium Facility. [5] This MC program has been in operation at Los Alamos for the last five years and substantial operational experience has been accumulated. The measurement controls can be divided into two levels. Level 1 MC is performed at the individual NDA instruments where a few simple statistical checks are performed. These checks include bias check, precision check, and backgrounds check performed at regular intervals. In addition to the statistical checks, diagnostic checks [6] will also be incorporated. For gamma-ray systems, the diagnostic checks consist of detector resolution check and zero and gain stabilizer checks. For neutron coincidence systems, the diagnostic checks would include totals-to-accidentals test, totals test, and coincidence test. The diagnostics checks will be performed for every assay. Level 2 MC is performed at the ICC level. At this level, control charts will be maintained for all the NDA systems to monitor the trends of the bias check and precision check data. Besides performing more extensive statistical checks, all the MC data will be archived at the ICC and can be retrieved to study individual instrument performance.

Because the various NDA instruments are to be provided by several national laboratories, it is important to standardize the operator-instrument interactions. The standardization not only will reduce operator training, but also will reduce potential confusion since the same operator may be assigned to run several instruments. The operator-instrument interaction is based on our experience in installing instruments at the Los Alamos Plutonium Facility for the past five years. During this period, the operator-instrument interaction has been constantly improved for each new instrument installed in the facility so that the instrument is more user friendly.

Integral Testing

The final phase of the project is the integral testing. For this test, all the NDA instruments will be shipped to Los Alamos where all systems will be operated and exercised together with their communications to the ICC. It is anticipated that "bugs" will be discovered during this testing period and the operation streamlined so that the system delivered to CRP will perform reliably.

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