DP-MS-77-111

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CONTROL SOFTWARE FOR A HIGH-THROUGHPUT NEUTRON ACTIVATION ANALYSIS SYSTEM

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A paper accepted for presentation at the
American Nuclear Society Topical Conference in
Mayaguez, Puerto Rico
April 30-May 3, 1978 and for publication in the proceedings

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

DISCLAIMER

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ABSTRACT

To provide uranium, thorium, and associated elemental analyses of about 300,000 samples collected for the National Uranium Resource Evaluation program, Savannah River Laboratory has installed a high-throughput neutron activation analysis facility. The facility is totally automated and is controlled by a minicomputer, with respect to sample handling, data acquisition, and data reduction. The software package described in this paper resulted from an extensive software design phase which was undertaken to incorporate systematically as much analytical flexibility as possible into a minimum amount of coding. The control portion of the software consists of 32 separate modules containing about 150 subroutines.

* The information contained in this article was developed during the course of work under Contract No. AT(07-2)-1 with the U. S. Department of Energy.

INTRODUCTION

Savannah River Laboratory (SRL) has the responsibility for a geochemical reconnaissance of 2.2 million km^2 in 30 eastern states as part of the National Uranium Resource Evaluation (NURE) program conducted by the Grand Junction Office of the U.S. Department of Energy. By April 1983, approximately 300,000 samples of stream sediment and ground and surface water are to be collected and analyzed for uranium, thorium, and associated elements. Neutron activation analysis was chosen as the prime analysis technique because of its sensitivity and specificity for uranium using delayed-neutron counting and recycle activation regimes.

A pilot-scale neutron activation facility was designed and installed in a Savannah River Plant production reactor in 1975. That facility processed about 20,000 samples for orientation and early reconnaissance phases of the NURE program. Design and operating criteria developed from the pilot facility have been applied to a recently installed production-scale facility. This paper describes the expanded facility in terms of pneumatic transport configuration and the hardware and software developed for the control and data acquisition/reduction computer.

MATERIALS AND METHOD

Hardware

The pneumatic transport system is shown schematically in Figure 1. Major components include:

- 6 activation stations at the reactor
- 2 combination delayed neutron/gamma-ray detector stations
- 8 gamma ray counter stations (4 with fixed geometry and 4 with computer-selectable counting geometries)
- 2 retrievable sample storage units
- system loader and unloader for automatically introducing samples into the sample storage units.

Transport paths are through polyethylene tubing interconnected via four-way selector units controlled by the computer. Photo-detectors located near the ends of the transport paths signal capsule passage to the computer.

The control computer is a Systems Engineering Laboratory (SEL) 32-55 Central Processor Unit (CPU) with 288 kbytes of memory. Peripherals consist of card reader, line printer, video terminal, control console, magnetic tape, 80-Mbyte disk, direct-memory access module, and an analog/digital input/output (ADIO) unit. The ADIO unit provides the interfacing between the CPU and 85 solenoid-operated valves, 72 limit switches, and 31 photo-detectors which operate the transport system. The ADIO unit also provides communication to 10 scalers and controls 12 pulse height analyzers (PHA). Data from each PHA are transferred to memory by the direct-memory access module.

The PHA units were built at SRL with the following characteristics: successive approximation analog-to-digital converter (12-bit, 17 μsec constant conversion time), 4096 channel (20-bit) solid-state memory, automatic hard-wired dead-time correction (<5% error at 60 k pulses per second), a high-count rate capability (resolution <2.0 keV at 60 k pulses per second at 662 keV), built in leading- and trailing-edge pileup rejection, and $5000 cost per PHA unit.

Control Software

From our operating experience with the pilot facility, the following features were established as major design goals for the control software:

- Unattended operation - To reduce cost per analysis, the facility should operate continuously with operator interaction required only during normal day shift.
- Maximum throughput - Each activation and counting station should be processing a sample at all times.
- Minimum coding changes - The software and data storage areas should be structured to allow changes and expansions of system hardware with minimal coding modifications.
- System maintenance - Diagnostic aids should be provided to assist maintenance operations on both hardware and software.
- Aborts - The software should sense and log all malfunctions of the transport system and take corrective action (if possible) using the redundancy designed into the hardware configuration.

- Data reduction - Appropriate communication linkages should be provided to enable online reduction of acquired data.
- Analytical flexibility - Without coding modifications, the software should support the widest possible variety of analysis regimes composed of the types of analysis steps listed in Table I.

The Real-Time Monitor operating system supplied with the SEL 32-55 CPU provides the following features which were extensively used in implementing the design goals:

- Timer Scheduler - Permits one software module to initiate another immediately, after a delay or on a periodic basis under a multilevel priority structure with resident or roll in/out capability.
- Fortran IV - Extended and optimized, supporting byte and bit manipulations as well as half-, single-, and double-word operations.
- Random access I/O - Fully supported by a simple but powerful data manager from Fortran IV.
- Intertask communications - Read/write via GLOBAL and write-protected DATAPOOL common areas.
- Interfacing - Fortran IV callable system routines for complete communication with ADIO unit.

To implement the goals listed above, a control software package was developed utilizing the supplied operating system as much as possible. The software package has the following characteristics:

- Resource driven - Whenever a resource (activation or detector station) becomes available, the storage devices are searched for the highest priority sample which can use that type of resource.
- Table operation - The details of system component operation (which valves and limit switches are connected to which device) and transport path configuration (valve and switch settings) are stored in tables in memory and/or disk files.
- Analysis steps - Parameters describing the various analysis steps are stored in a "self-threading" table such that one step points to the next. An entire analysis regime may be assigned to a sample by listing only the number of the first step.
- Modular design - The software is broken into small modules, each of which performs a single function. Module boundaries correspond to "wait" functions (eg., a pause awaiting hardware response to software commands, capsule transport times, etc.) so that a module can service several capsules. Even though a wait function is provided by the operating system, none is coded in any module. Waits are accomplished by one module timer-scheduling another before terminating itself.
- Fortran IV - All coding is FORTRAN IV except for small assembly routines which link some tables to system handlers.

- No internal constants - All numerical values are supplied via input tables except for array sizes in dimension statements. No coding changes are required for system expansion if the expansion does not exceed array specification and if no new device types are added.

As the design of the software developed, opportunities to extend analytical flexibility beyond original goals became apparent. Examples include:

- Some of the detectors are fixed in counting geometry. The go/no-go decision mechanism developed for use of these detectors was expanded to permit controlled selection of detector geometry for four detectors. Analysis steps which may contain samples with high activities are routed to these detectors with the computer selecting the geometry yielding the least statistical error without risking detector overload.
- The test-type analysis step requires regime branching based on a pass/fail test with respect to specified limits. This concept was expanded such that all analysis steps have tabulated limits and step numbers corresponding to a normal (passed) and an alternate (failed) next step. The analysis regime can thus be automatically tailored to the sample based on data acquired early in the analysis regime.

RESULTS

The control software package consists of 32 separate modules containing about 150 subroutines. Additional modules which support control operation include:

- Ten modules to read from cards, scrubb for errors, and translate descriptive input data to build the control system data tables.
- Two modules, RAGS and RICHES, reduce the acquired data to elemental concentration.
- Two modules store reduced data for completed samples on magnetic tape and delete these data (after successful archiving) from the disk data base of the control computer.

System capacity is ∿100,000 samples per year allowing for 50% overall system and reactor operation. This capacity is sufficient to meet the SRL reporting schedule for the NURE program.

TABLE 1

Types of Analysis Steps Supported by Control Software

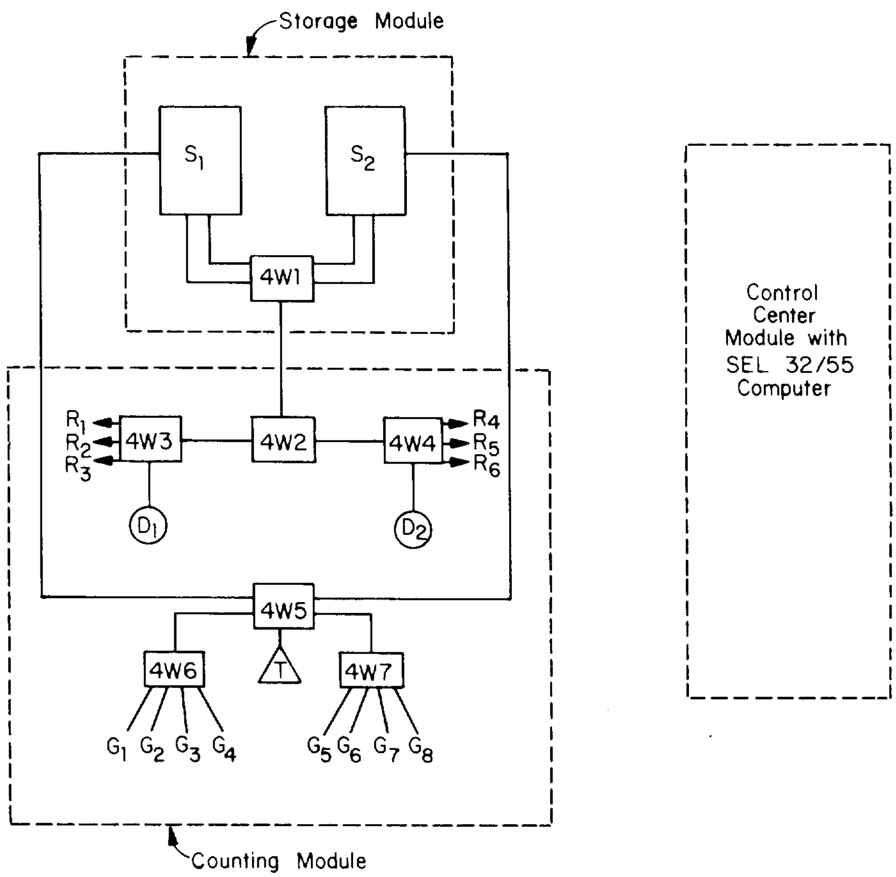
Test - Brief activation followed by go/no-go decision based on neutron and gamma rates.

Recycle - Up to 40 activation/counting cycles for short-lived gamma and neutron-active products.

Long Activation - Up to 30 min activation to induce long-lived activities.

Delayed Count - Up to 30 min gamma counting period following specified decay intervals.

A typical analysis regime may include a test, a recycle, and a long activation step followed by 3 delayed counts.



S Storage Stack
4W Four-way Diverter
R To Reactor Irradiation Position
— Pneumatic System

D Delayed-Neutron Ge(Li) Detector
G Ge(Li) Detectors(1-4 Movable)
T Turnaround Station
--- Module Walls

Fig. 1. Hardware configuration for full-scale NAA facility