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DP-MS-79-35
CONF-791049--1

A HIGH-CAPACITY NEUTRON ACTIVATION ANALYSIS FACILITY

by

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A paper prepared for presentation at the 23rd Conference on Analytical Chemistry in Energy Technology at Gatlinburg, Tennessee, on October 9-11, 1979.

DISCLAIMER

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ABSTRACT

A high-capacity neutron activation analysis facility, the Reactor Activation Facility, was designed and built and has been in operation for about a year at one of the Savannah River Plant's production reactors. The facility determines uranium and about 19 other trace elements in hydrogeochemical samples collected in the National Uranium Resource Evaluation program, which is sponsored and funded by the United States Department of Energy, Grand Junction Office. The facility has a demonstrated average analysis rate of over 10,000 samples per month, and a peak rate of over 16,000 samples per month.

Uranium is determined by cyclic activation and delayed neutron counting of the U-235 fission products; other elements are determined from gamma-ray spectra recorded in subsequent irradiation, decay, and counting steps. The method relies on the absolute activation technique and is highly automated for round-the-clock unattended operation.

INTRODUCTION

The Reactor Activation Facility (RAF) is a highly automated neutron activation analysis (NAA) system. The facility is installed at the Savannah River Plant's C-Area production reactor and has been in operation since September 1978. The

*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.

RAF was built to provide NAA for the large number of hydrogeochemical samples collected in the National Uranium Resource Evaluation (NURE) program, which is sponsored and funded by the United States Department of Energy, Grand Junction Office. The Savannah River Laboratory (SRL) is one of three laboratories participating in the hydrogeochemical and stream sediment reconnaissance portion of the NURE program, and is responsible for sampling, analyzing, and reporting on an area of about 1,500,000 square miles in 30 eastern and 7 western states.

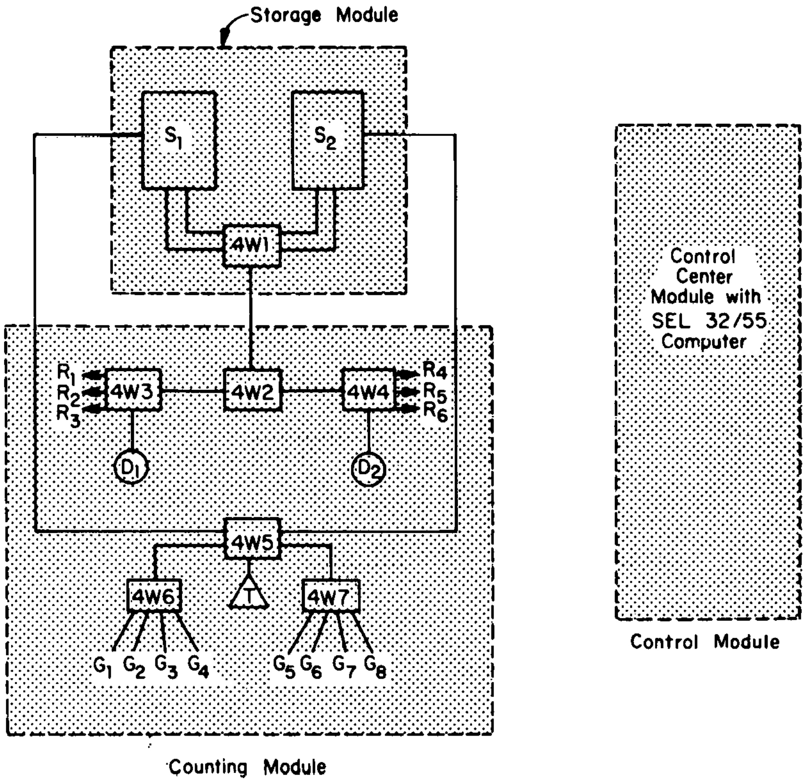
The RAF is intended to provide analyses for an estimated 400,000 samples to be collected in SRL's portion of the NURE program, and replaces a smaller pilot scale facility which was operated from September 1975 to November 1977. The facility has a demonstrated average analysis rate of over 10,000 samples per month, and a peak rate of over 16,000 samples per month. Uranium and up to 19 other elements are determined in sediment samples, and in ground and stream water samples after concentration on ion-exchange resin. Sediment and resin samples are prepackaged into special polyethylene irradiation capsules. Up to 2400 capsules can be loaded into the system for 72 hours of round-the-clock unattended operation.

Uranium is determined by cyclic activation and delayed neutron counting of the U-235 fission products, other elements are determined from gamma-ray spectra recorded in subsequent irradiation, decay, and counting steps. The method relies on the absolute activation technique. Details of the absolute activation technique are given by MacMurdo and Bowman,[1] and additional information about installation, checkout, and calibration of both the pilot facility and the RAF are documented in SRL-NURE quarterly and semi-annual reports.[2]

RAF LAYOUT AND PNEUMATIC TRANSPORT SYSTEM

A schematic of the RAF is shown in Figure 1. The three modules shown in the schematic are located about 20 feet above and 60 feet laterally from an irradiation assembly which butts up to the reactor containment wall. A very well moderated flux of about 5×10^{12} n/cm -sec is available.

The Control Module contains a computer and assorted process control and data acquisition instrument components. As its name implies, it is the control center of the entire facility. Similarly, the Counting Module contains the various neutron and gamma detectors required for sample analyses. The Counting Module also contains the bulk of



S Storage Stack
4W Four-way Diverter
R To Reactor Irradiation Position
— Pneumatic System
D Delayed-Neutron Detector
G Ge Detectors(1-4 Movable)
T Turnaround Station
--- Trailer Walls

FIGURE 1. Hardware Configuration for Operating System (Stack Loading/Unloading System not shown)

the RAF's pneumatic transport system including connections to the six identical irradiation positions within the irradiation assembly. The Storage Module contains two identical sample storage devices called stacks. The stacks provide computerized control of all sample loading and unloading, and storage of irradiated samples for intermediate decay.

The pneumatic transport system is a network of one-inch I.D. polyethylene transport tubing and four-way (4W) diverter units. Each terminus point of the transport system is connected by pneumatic valves to a propulsion air manifold and an exhaust air manifold. Transport of a sample capsule is a simple matter of opening a propulsion valve at the sending end, and an exhaust valve at the receiving end. Capsules are tracked for position and time by photodetectors located at all terminus points.

Two ports on each of the two stacks (S1 and S2) are connected through Diverter 4W1 to Diverter 4W2. Diverter 4W2 is used to select either gamma-neutron Detector Station D1 or D2. Diverters 4W3 and 4W4 connect D1 and D2 to Irradiation Positions R1-R3 and R4-R6, respectively. One port on each stack is connected to a turnaround station (T) by Diverter 4W5. Once a capsule is at the turnaround, any of the Gamma Counting Stations G1-G4 or G5-G8 can be accessed through Diverters 4W6 and 4W7, respectively.

Control Module

Hardware of the Control Module is shown schematically in Figure 2. The heart of the RAF is the Systems Engineering Laboratories (SEL) 32/55 computer. It is a full 32-bit machine with 128K words of memory. Besides the usual I/O devices, are two 80-megabyte moving-head disks. The disks are used to store programs and data, and increase effective system memory considerably.

The computer performs all process control and data reduction tasks.[3] The real-time peripheral unit provides bidirectional interfacing between the computer and all of the pneumatic components of the Counting and Storage Modules. Action commands by the computer are answered by responses such as tripped photodetectors or set limit switches. Twelve scales and ten pulse-height analyzers (all of SRL design) support the various neutron and gamma detectors.

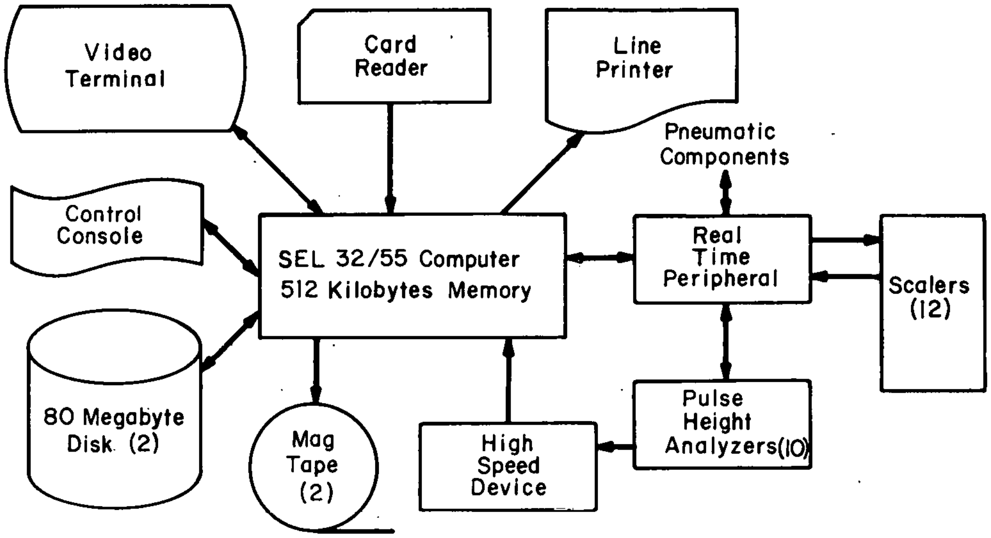


FIGURE 2. Configuration for SEL 32/55 Computer

Counting Module

The Counting Module (Figure 1) contains the neutron and gamma detectors which provide for the analysis of uranium and other elements, respectively.

Positions D1 and D2 are identical combined neutron and gamma counting stations. The neutron detectors each consist of an annulus of 10 stainless steel tubes containing boron trifluoride. The gamma detectors are intrinsic or high-purity germanium devices each of about 10% efficiency and 2.0 keV resolution. A sample at detector station D1 or D2 is counted simultaneously for delayed neutrons (uranium) and gamma-rays (short-lived activation products).

The gamma detectors at Gamma Counting Stations G1-G8 are also intrinsic devices all of about 8% efficiency and 1.8 keV resolution. Stations G1-G4 are variable-geometry counting stations. Atop the detectors are vertical drop tubes. Each drop tube can provide up to five different counting geometries by extending or retracting stops in the tube which vary the sample-to-detector distance. Stations G1-G4 are used primarily for measuring intermediate-lived activities present in samples 10 minutes after irradiation.

Stations G5-G8 each have a single counting geometry which is identical to those of Stations G1-G4 with all their stops retracted (i.e., closest counting geometry). Stations G5-G8 are used primarily for measuring long-lived activities present in samples seven days after irradiation.

Storage Module

Each of the two stacks in the storage module can hold about 6000 samples; both are mechanically and operationally identical. A stack is a 16 x 16 array of vertical storage tubes held on 1½-inch centers by a precision lattice plate. Each tube can hold 25 samples. In the bottom of each tube is a grabber, a circular device of finger-like springs. Spreading the fingers allows a sample to fall from the bottom of the tube. Conversely, a sample can be pushed up into the tube (by a piston) to a position where it is held by the fingers.

A store/retrieve or Z-motion device under the lattice plate can either store or retrieve the bottom sample in any of the stack's 256 tubes. Once a sample is in the Z-motion, it can be moved to any tube, or pneumatically fired from any of the stack's three exit/entry port tubes to the

Counting Module. The Z-motion rides on the ways of a Y-axis track, which in turn rides the ways of an X-axis track. Motion along the X- and Y-axes is controlled by four binary-incremented air cylinders with strokes of 1½, 3, 6, and 12 inches. By extending or retracting the appropriate air cylinders, the computer can position the Z-motion under any tube. Feedback from the air pressure that operates the cylinders signals their states to the computer through pressure switches. A photodetector senses the presence or absence of a sample in the Z-motion device.

REFERENCES

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3. W. W. Bowman, "Rapid Analysis of Germanium Spectra," Nucl. Instr. Meth. 96, 135 (1971).