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ENRICHED URANIUM ACTIVE ASSAY PROGRAM

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Approved:

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ABSTRACT

Under the AEC Plant Instrumentation Program, United Nuclear Corporation has undertaken to install and operate at its Wood River Junction, Rhode Island, Scrap Recovery Plant, a nondestructive assay system for uranium. This system utilizes a pulsed D-T generator to induce fissions in the uranium, and a high-efficiency neutron counter to detect delayed neutrons resulting from those fissions. This report, covering the first three months of effort in the program, contains descriptions of the system as it is expected to be when in operation, the manner in which it will be calibrated and used, and an indication of the status of the work as of June 30, 1970.

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1. INTRODUCTION

United Nuclear Corporation's Scrap Recovery Plant, Wood River Junction, Rhode Island, processes highly enriched unirradiated uranium on a commercial basis. Control of material inventory to reduce the probability of loss or diversion and to identify a loss rapidly, if it should occur, will be significantly improved if the ability to determine nondestructively the uranium-235 content of shipping and storage containers is obtained.

Under the AEC Plant Instrumentation Program, a system has been specified and is being established to develop this capability. The system consists of:

- A pulsed neutron source
- A monitor of the source yield
- Devices to locate and move samples under investigation
- A high-sensitivity neutron detector and associated electronics to indicate the delayed neutron intensity resulting from fissions in the sample
- Radiation shielding to protect personnel.

The system has been designed to permit examination of all containers normally received or shipped, and containers used for in-plant storage of substantial quantities of uranium.

In defining a nondestructive assay procedure, such as the one in which we are engaged, the approach normally involves a series of compromises between

convenience, speed, accuracy, and cost.

In this effort, we have attempted to develop a system whose operation is simple and reliable at a reasonable cost. There have been some sacrifices in the speed with which an assay can be completed and the system will be less flexible than one intended for research applications.

We have specified a sealed tube generator to eliminate the need for frequent tritium target changes with their attendant inconvenience and risk. When examining large samples we plan to traverse these samples past the neutron generator so that each portion of the sample is subjected to essentially the same neutron fluence. While such an "effectively infinite" traverse will require additional measurement time and will reduce the signal-to-background ratio in comparison to some other possible modes of operation, the interpretation of the output data will be simple and less subject to judgment error on the part of the operator.

2. DESCRIPTION OF SYSTEM

2.1 NEUTRON GENERATOR

An order has been placed for an Accelerators, Inc., Model ST-1000P generator which produces 14-Mev neutrons by the $\text{H}^3(\text{d},\text{n})\text{He}^4$ reaction. The maximum neutron yield during the approximately one-second pulses will be at least 3×10^{10} neutrons/sec. During the approximately one-second interval between pulses, the high-sensitivity detector output will be gated on.

A major contribution to the background response of the delayed fission neutron detector will be neutrons resulting from the decay of N^{17} , which is created by the $\text{O}^{17}(\text{n},\text{p})\text{N}^{17}$ reaction in the sample and the walls of the irradiation area. The magnitude of this background will be reduced by surrounding the target end of the neutron generator with lead. The background response which is expected with the delayed neutron counter 30 in. from the neutron generator corresponds to the delayed fission neutron response from approximately 20 g of U^{235} . The use of this system to examine small samples, therefore, will require relocation of the detector closer to the neutron generator to increase the signal-to-background ratio.

2.2 MONITOR OF GENERATOR YIELD

A fission counter will be located adjacent to both the sample and the generator to monitor the neutron environment produced by the generator. The count-

ing channel for the monitor consists of a high-voltage supply, preamplifier, linear amplifier, discriminator and scaler. The integrated output of this detector during the sample interrogation period will be used to normalize the delayed neutron detector response.

2.3 DELAYED FISSION NEUTRON COUNTER

This counter consists of a linear array of He^3 proportional counters in a polyethylene matrix. A total of eighteen 1-in. diameter tubes with 20-in. sensitive length has been ordered from Reuter-Stokes. A sketch showing the arrangement of the counter is given in Fig. 1. The polyethylene on the sides and back of the counter serves to attenuate the delayed neutrons from N^{17} incident upon the counter from these directions.

The He^3 tubes will be connected in parallel to a single preamplifier and high-voltage supply. The output of the preamplifier will be fed to a linear amplifier which drives a discriminator and scaler through a delayed gate. The counter will be on during the generator pulse, but its output will not be fed to the scaler until approximately 50 msec after the generator pulse has terminated.

2.4 SAMPLE SCANNERS

Two mechanical devices will be provided to position samples relative to the neutron generator. One, called the barrel scanner, will raise and lower a sample through a distance of up to 7 ft at constant speed and, when required, will rotate the sample at constant speed. The second device is a horizontal belt conveyor which moves a 3-in. $\times$ 8-in. $\times$ 8-ft box at constant speed between the neutron generator and the delayed neutron counter. The conveyor is in two parts. One is permanently located, and the second, which bridges the elevator mechanism, can be moved out of the way when not in use. The conveyor drive and the vertical drive on the barrel scanner will be operated by the same control buttons with a selector switch so that only one of the two sample positioning devices can be used at any time.

Fig. 1 — Horizontal Section through Delayed Fission Neutron Counter

2.5 SHIELD STRUCTURE

Radiation shielding will be provided by concrete and earth as indicated in Fig. 2, which shows a plan view of the shield structure, and Fig. 3 which shows a vertical section through the structure. A contract for shield construction has been awarded to E. M. Gallo Construction, Inc.

Personnel access to the irradiation area is through the labyrinth corridor. All samples, except the 8-ft long boxes, will be brought in and out through the same corridor. The 8-ft long boxes will be introduced and removed through the port in the northwest corner of the shield.

2.6 OPERATIONAL INTERLOCKS

The interlocks are intended to prevent inadvertent operations which could subject personnel to significant exposures. The objective is, therefore, to inhibit operation of the neutron generator except under well-controlled conditions.

Power to the neutron generator is provided through a key-operated switch. Operation is inhibited through an interlock circuit which requires closure of a series of switch contacts. These include the following functional indications:

- Personnel access door to irradiation room closed
- Sample access port plug in place
- Generator cooling water flow greater than present value
- Sample scanner control switch in "Remote" position.

In addition, the operator at the control console normally will have visual access to the irradiation area via a closed circuit TV and audible access via an intercom. Providing power to the neutron generator will activate indicator lights outside the personnel access door and in the irradiation area, and will activate a short-duration audible alarm in the irradiation area.

3. SYSTEM CALIBRATION

The response of this assay system to a given quantity of uranium is a function of many parameters including the spatial distribution of the uranium, the type and amount of other material included in the sample, the type of container in which the sample is placed, and the enrichment of the uranium.

The purpose of the calibration procedures is to evaluate the system response in a series of well-characterized situations which cover the range of parameters to be encountered in measurements of samples whose uranium content is not known.

Two major subdivisions of samples will be encountered. The first category includes samples normally containing relatively small amounts of uranium (<380 g) but a wide variety of additional materials with the possibility of gross inhomogeneity in the uranium distribution. The second category includes samples whose uranium content may be quite large, but which are normally quite homogeneous with well-characterized compositions.

For samples in the first category, the problem of neutron multiplication in the sample is not expected to be serious. The principal effort in the calibration program for these samples, therefore, will be to determine the variation of response with total sample mass, with matrix material type and, to estimate limit of error in this type of measurement, with uranium distribution in the sample.

This calibration program will be carried out with multiple 2-g U^{235} samples which will be distributed through clean matrix materials to simulate both uniform and nonuniform uranium distributions. The individual samples are small enough to make self-shielding of the sample negligible. The output of this series of calibration measurements is expected to be system response per gram of U^{235} as a function of total sample mass for each type of container and category of matrix material.

Samples of the second category will be calibrated in one of two ways. When appropriate, well-characterized uranium oxide product from the recovery operation will be used. The most sensitive parameters are expected to be sample geometry and uranium concentration resulting in a nonlinear response as a function of total uranium content. Where the uranium oxide product may not be a satisfactory calibration material, specific samples of as-received material will be separately reprocessed as far as the dissolution stage to permit quantitative chemical assay.

4. NORMAL OPERATION

For the materials to be examined in this facility, the gross and tare weights, the material and container types, and an expected uranium content will be known. The choice of appropriate calibration data can be made, therefore, prior to the sample examination. If the uranium content derived from the examination is substantially different from the expected value, further investigation of the sample will be required to determine whether inappropriate calibration data were used (i.e., the sample geometry or composition were not as reported), or the uranium content is, in fact, different from the expected value.

Normal operations will involve a number of activities. Satisfactory operation of the system will be checked on a frequent basis by examination of monitor and delayed fission neutron counter outputs with no sample present. On a regular, but less frequent basis, measurements will be made with a standard sample.

A large majority of the measurements to be made will involve samples using the barrel scanner. The sequence of operations which we expect to follow for these measurements is:

1. Bring the sample into the facility and place it on the barrel scanner. With most samples, we expect to place a cadmium shield around the sample to reduce the effects of thermal neutron room return.

2. Position the scanner at the lower limit of the vertical traverse which is required for that sample. This may require repositioning of the adjustable lower limit switch.
3. Leave the irradiation area, transferring control of the scanner to the control console.
4. Insert key and turn on the neutron generator power.
5. Activate sample rotation.
6. Activate neutron generator.
7. Activate automatic traverse which:
 - a. Initiates vertical motion
 - b. Activates data accumulation on monitor and delayed fission neutron counting channels.
 - c. Terminates data accumulation at end of automatic traverse.
8. Turn off neutron generator and remove power key.
9. Record output data.
10. Return scanner to position to remove sample.
11. Remove sample and start over again with the next sample.

The shift from vertical to horizontal traversing mechanisms (or horizontal to vertical), while quite simple, is expected to require enough time to motivate scheduling of measurements on long boxes in groups to minimize the number of shifts from one traversing mechanism to the other. The operating procedure will be essentially the same except that the samples will be introduced through the port in the corner of the irradiation room and the sample will not be rotated.

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