APPLICATION NOTE

Los Alamos National Laboratory

Shipper Receiver Confirmatory System

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Safeguards Assay Group N-1

MS E540

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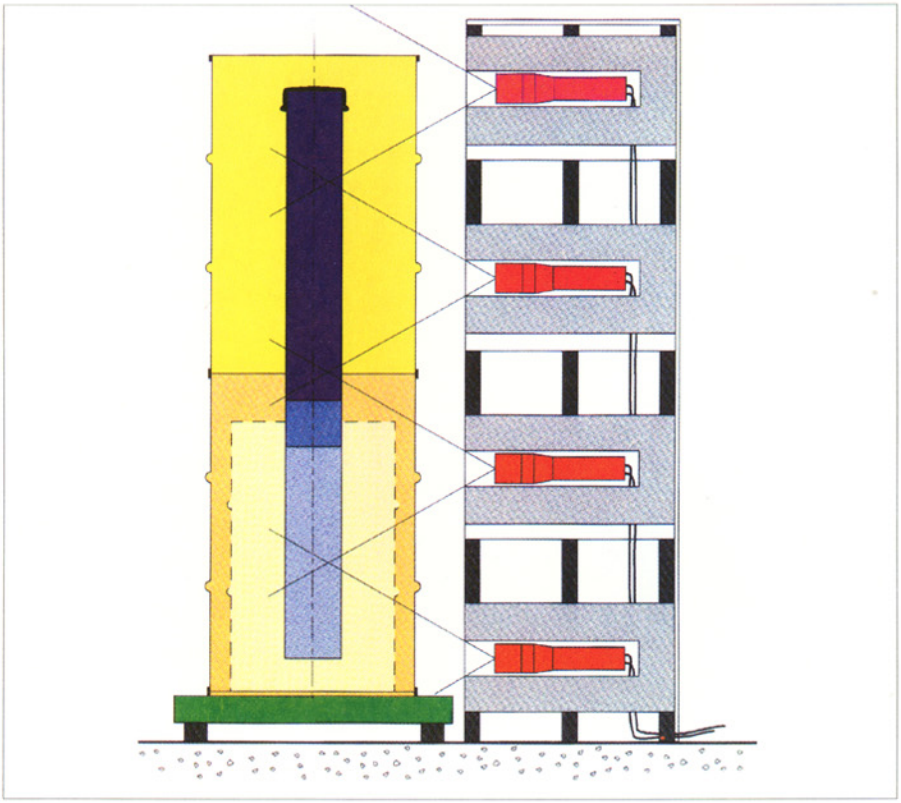

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Figure 1. Cross-sectional view of the SRCS showing the four low-resolution detectors (red) in their lead shields (grey). Three sizes of shipping containers, 30, 55, and 110 gal., are shown in front of the detectors. The smallest container is shown in light yellow with the corresponding volume for special nuclear material shown as light blue. Two larger containers with their respective usable volumes are shown in darker shades of yellow and blue. The green box under the containers represents a rotator and a scale.

The Shipper Receiver Confirmatory System (SRCS) produces a unique fingerprint for a sealed shipping container of uranium by measuring the gross weight of the container and the intensity of gamma rays emitted at 185.7, 1001, and 2614 keV. This fingerprint can confirm that the uranium in the container was not tampered with during shipping between facilities or while in storage at a facility. The measurement does not require calibration and the container does not have to be opened.

SRCS Applications

Operations in the DOE complex involve the transfer of special nuclear materials (SNM) between facilities in a strategically attractive, pure form. These transfers of nuclear material in various chemical forms and standardized shipping containers are physically well safeguarded. However, DOE Orders 5630.2 and 5630.10 require confirmatory measurements of the contents of the container within 10 days if the receiver does not promptly make accountability measurements. Confirmatory measurements complement physical security by ensuring that the contents of the containers were not altered.

To satisfy DOE Orders, it is sufficient to demonstrate qualitatively that all of the material in a container shipped from A was received at B. This can be accomplished by precisely measuring an attribute of the SNM in the container at A and B with identical hardware and does not require determining how much SNM is in the container. Thus the biases between two measurement techniques or results are not an issue and calibration and measurement accuracy are not relevant.

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Figure 2. This figure shows three of the four 1000-lb lead shields positioned in the SRCS measurement head. The low-resolution detector in the lowest shield is out of the shield for illustration. It is a 3-in.-by-3-in. NaI (Tl) detector. Each detector is recessed in the cylindrical shield 3 in. and covered by a 0.070-in.-thick cadmium filter. The rotator for the sample drum is in the foreground.

The SRCS can make these confirmatory measurements for shipments between facilities and is being considered for proposed uranium storage facilities. The SRCS can also perform replicate measurements within a facility to verify the inventory.

Measurement Requirements

To reliably detect tampering or diversion, confirmatory instruments must

- measure items quickly and cheaply,
- discriminate among similar items, and
- discern change in the characteristics of an item.

If confirmatory measurements do not fulfill these criteria, traditional quantitative measurements that yield more information are used. Confirmatory measurements do NOT replace accountability measurements but supplement them. The SRCS satisfies confirmatory measurement requirements specified in DOE Orders 5630.2 and 5630.10 for uranium-bearing items.

Confirmatory Measurement Procedure

The SRCS needs 200 seconds to measure the gamma rays emitted from the item. This is less time than analytical techniques require for a measurement. Much time is saved because the shipping container does not have to be opened; the container and contents are measured as a unit. In addition to reducing the time required to measure an item, the use of SRCS also reduces the potential for contamination and the opportunities for tampering with the contents. The physical protection seals on the shipping container remain intact.

The SRCS is an inexpensive complement to physical security systems such as guards and fences, which protect items but are not able to confirm what is in each item. The SRCS relies on a fingerprint unique to uranium and its enrichment to provide information about the contents of an item.

Discrimination and Precision

The SRCS detects minute differences between highly similar items. What is a problem for quantitative assay is now an advantage; it is difficult to

deduce the uranium mass in an item from passive gamma-ray emissions because the physical nature of the container and its contents decreases the intensity of the gamma ray as it leaves an item. Small differences in geometry or attenuation must be corrected for a mass to be measured accurately. However, these small differences are advantageous for SRCS because they give similar items unique signals.

The SRCS fingerprint can distinguish between items that differ by less than 1% in some particular attribute. Even uranium items of the same enrichment and mass, in identical packaging, can be distinguished from one another by the 2614-keV gamma ray. This gives excellent discrimination between items and against bogus or mislabeled items.

The Fingerprint

The SRCS measures the count rates of several gamma rays. The 185.7-keV gamma ray is from the decay of ^{235}U and the 1001-keV gamma ray is from a daughter of ^{238}U. Consequently, the combined gamma-ray fingerprint correlates with the enrichment of the uranium. The 2614-keV gamma ray is from the thorium decay chain, which originates from reactor fuels returned to the enrichment plant feed. The characteristics of the sample and its history do not allow the 2614-keV count rate to be simply predicted. Consequently the 2614-keV contribution to each sample's signal is unique. The responses of each detector are compared separately between two measurements of one item. Consequently the SRCS is sensitive to height variations between similar samples.

No Calibration Required

No calibration is used to deduce the sample mass from the measured count rates. The SRCS does not have to be calibrated because it compares two measurements of one item using identical hardware instead of comparing a measurement of the item with a measurement of a calibration standard. Adding a calibration would increase the system's measurement uncertainty because calibration errors would be folded in. Rather, the small differences that plague accurate calibration allow us to obtain unique signals from similar items. Because no calibration is needed, the use of the SRCS eliminates the costs of specifying, procuring, and storing calibration materials.

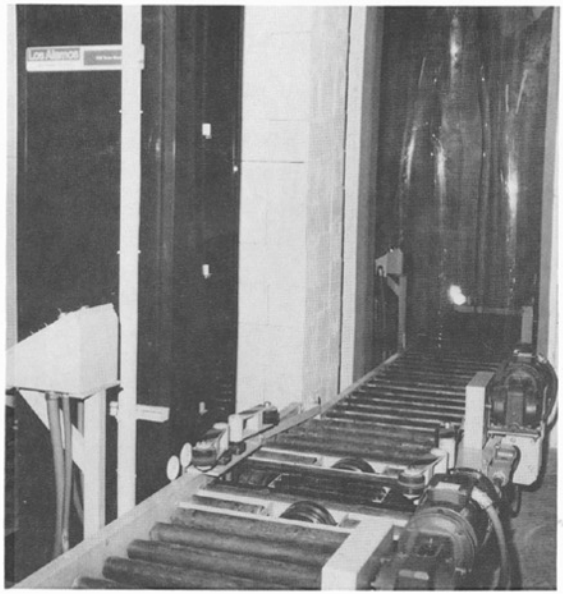

Figure 3. This photograph shows the SRCS measurement head installed at a Department of Energy facility. A conveyor system in front of the measurement head is interfaced to the SRCS. The conveyor has three sample rotation positions that can be used simultaneously. Only one sample measurement position is shown in the photograph. The conveyor has one scale that precedes the three measurement positions.

Advantages of the Fingerprint for Inventory Verification

Facilities are required to verify their SNM inventories periodically. Typically, many items in the inventory have not been used or disturbed during the inventory period. These items can be verified by comparing an accurate quantitative measurement with a previous measurement or by comparing a "fingerprint" of the item with a previous fingerprint. The fingerprint check is simpler and faster, particularly for items that are heterogeneous and difficult to assay for uranium mass.

The SRCS measures the entire contents of the container. The container does not need to be sampled and the sampling errors caused by inhomogeneous items are avoided. The fingerprint measured by the SRCS is a quick and precise way to confirm or verify the uranium contents of shipping containers nondestructively and unobtrusively.

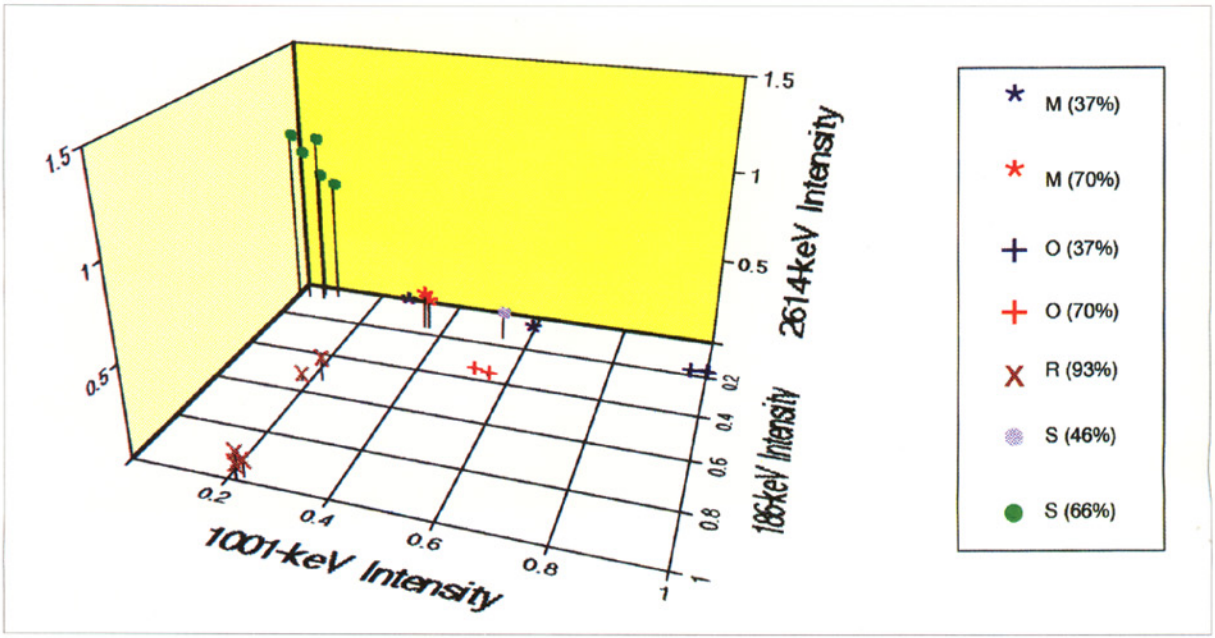

Figure 4. These results, for 20 shipping containers, were obtained from one NaI detector. The three axes correspond to the normalized count rates at 185.7, 1001, and 2614 keV. This subset of an SRCS fingerprint is sufficient to distinguish 19 of the 20 containers (the double point is the far right dark blue plus). The rest of the fingerprint provides additional information sufficient to distinguish all of the containers. This set of data includes uranium of four material types, indicated by the four different shapes, and five enrichments, indicated by the five different colors. The enrichment values are listed in the symbol key as percentages. In the legend, the M stands for metal, the O for oxide, the R for impure metal, and the S for impure oxide. Five pairs of containers in this set contain uranium with "identical" chemical form, enrichment, and mass. These are indicated by the various clusters on the graph. Four of these pairs are distinguished with this part of the SRCS fingerprint. Figure prepared by James K. Sprinkle, Jr., Group N-1.

Additional Sources of Information

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