

Los Alamos
National Laboratory

Segmented Gamma-Ray Scanner

March 1991

Safeguards Assay
Group N-1

Los Alamos National
Laboratory

Los Alamos, NM 87545

N-1 Group Leader
George W. Eccleston
505-667-7110
FTS: 843-7110
FAX: 505-665-4433
FTS FAX: 855-4433

Technical Contact
Thomas E. Sampson
505-667-6968
FTS: 843-6968

LALP-91-011

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California under contract W-7405-ENG-36 for the U.S. Department of Energy.

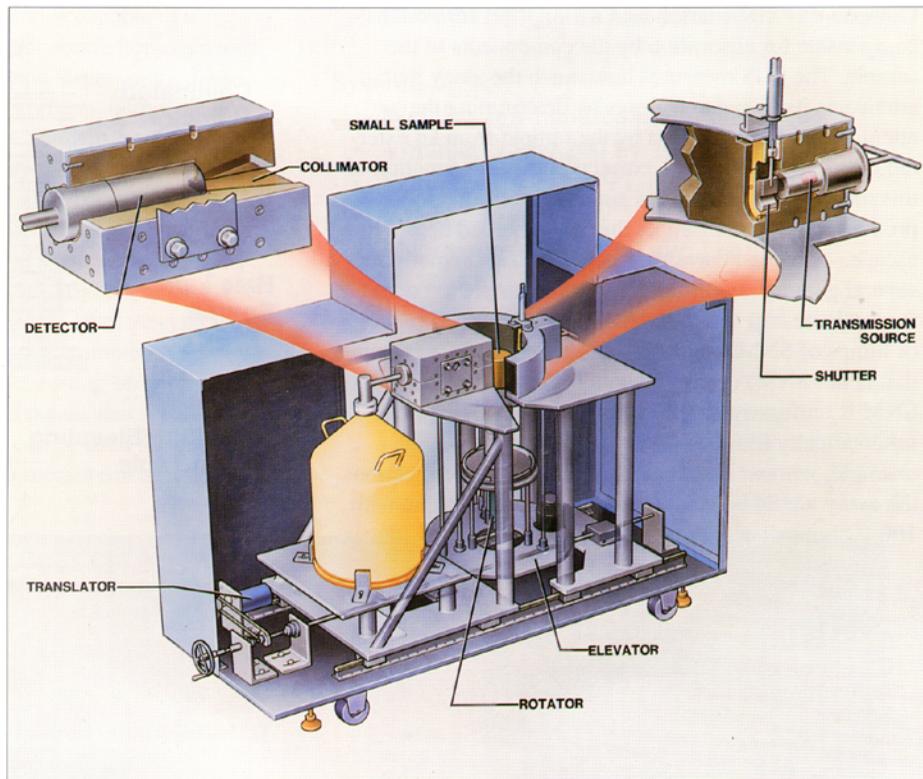


Fig. 1. In the segmented gamma-ray scanner above, segments of the sample (small golden brown waste container) are scanned by the transmission source (red) as the sample is raised by the elevator and turned about a vertical axis by the rotator. Gamma radiation from the sample and the source is detected with a collimated germanium detector (grey) cooled with liquid nitrogen from a cryostat (yellow). Combining the results from each segment yields the assayed isotope mass in the sample.

The segmented gamma-ray scanner (SGS) is a rugged, versatile nondestructive assay instrument used to quantify the radioisotope content of low-density scrap and waste containers. The SGS is most often used to measure waste containers holding the isotopes of uranium and plutonium. The SGS combines physical motion and active radiation detection in the assay. (Figure 1 shows the details.) The SGS has been constructed in various configurations allowing measurements on items ranging from small vials to 200-L drums. This device is well adapted to in-plant operation; its design is rugged, its components are reliable, and it is available from commercial sources. It may be the most widely used gamma-ray-based nondestructive assay instrument.

The SGS measures gamma radiation arising from natural radioactive decay. Correction factors and refinements are then applied to the measurement to improve its accuracy. These enhancements fall into three categories: gamma-ray attenuation and absorption corrections, sample rotation and vertical scanning, and rate-loss corrections.

Gamma-ray attenuation and absorption corrections compensate for absorption by the components of the sample. The SGS measures how much the assay item attenuates its own gamma rays by determining the attenuation of gamma rays by the sample from an external radioactive source. A correction that is a function of this measured attenuation is applied to gamma rays produced within the sample that are absorbed before they escape. A second correction uses the measurement of several gamma rays emitted from the sample to correct for the increased self-absorption by large, dense particles or lumps of SNM in the matrix (everything in the sample that is not SNM) compared with the case in which the SNM is uniformly distributed in the matrix. Figure 2 schematically illustrates these two corrections. For example, without the second portion of these corrections the assay would be low by about 10% for a sample with 100- μ “lumps” of uranium metal in a low-density matrix.

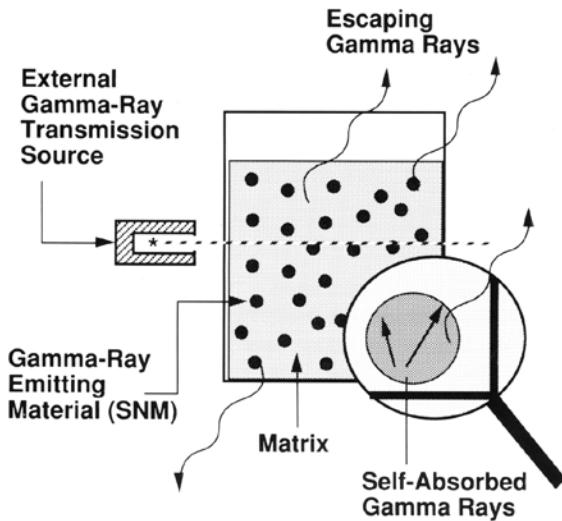


Fig. 2. Illustration of the problem caused by heterogeneity in SNM samples. The transmission measurement reflects the average attenuation by the matrix and the SNM. The large, dense lumps increase the SNM radiation self-absorption.

Sample rotation and vertical scanning allow a more uniform response from radioactive material in the assay item (illustrated in Fig. 3). The SGS rotates the sample during measurement to reduce the bias from radial

heterogeneity. It also incrementally elevates the sample to scan horizontal segments (hence the technique name) to account for segment-to-segment attenuation differences. The total SNM content of the sample is obtained by summing the assay results from the individual segments.

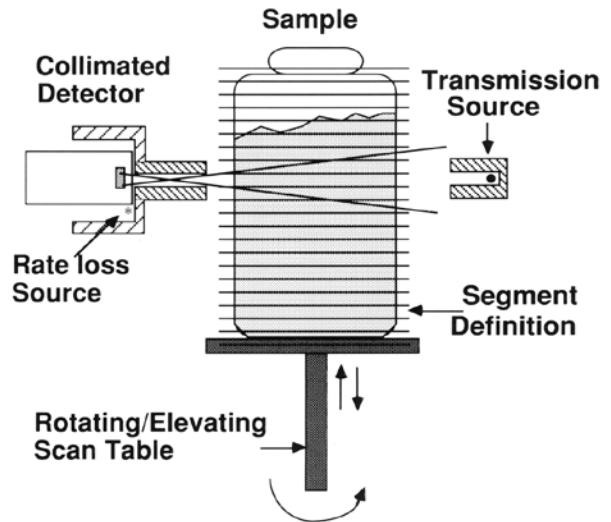


Fig. 3. Instrument components in a segmented gamma-ray scanner assay.

Rate-loss corrections are made for count-rate-related losses in the electronics of the gamma-ray spectroscopy system. The relative rate of a small radioactive source fixed to the detector provides a basis for this correction.

The preceding corrections make the SGS method applicable to a wide range of low-density SNM-bearing materials such as paper, plastics, ash, sand, and liquids. Dispersed higher-mass constituents, such as metals, can also be measured with somewhat lower accuracy, if the containers are not too big. Calibration is usually accomplished with samples consisting of dilute mixtures of SNM in oxide form mixed with sand or graphite. This technique provides the important advantage of *not* requiring the calibration standard to be a chemical, physical, or geometric match with the unknown.

SGS systems are most often found in two sizes: larger systems measure barrels and drums with capacities of 100–200 L (30–55 gal.); smaller “can-sized” systems are used to measure items ranging in size from a few inches in diameter to 5-gal. pails.

The SGS is built to accurately *quantify* the SNM isotope masses in the sample and is capable of a measurement accuracy of 1% for small, homogeneous samples. As the samples become larger, more dense, more heterogeneous, and less uniform, both in the distribution of the SNM and in the density of the matrix, the measurement accuracy may deteriorate to 5%, 10%, or more. Items with approximately 1 g of ^{239}Pu or ^{235}U represent a practical lower limit for reasonable quantification [measurement precision $\sim 10\%$ (1 relative standard deviation)]. While the SGS is not specifically designed for low-level detectability, its lower detection limit can range from about 10 mg to 100 mg of ^{239}Pu or ^{235}U , depending on specific measurement conditions. This means that a barrel SGS, under many conditions, can be used to sort waste at the 100 nCi/g level in measurement times of around 20 min.

Characteristics of a Typical Can SGS

SGS Source, Shielding, and Detector

- Transmission source: 15 mCi ^{75}Se
- Source shielding: 14 kg (tungsten)
- Detector shielding: 68 kg (lead)
- Detector: 25% efficient HPGe (LN₂ cooled)

System

- Weight: few hundred kilograms
- Volume: 75 by 200 by 200 cm
- Sample size: 1 to 19 L (1 qt to 5 gal.)
- Power: 20 A, 110 V
- Measurement time: 20 min./ item

Accuracy for scrap and waste in 2-gal. cans

- up to 10 g 1% to 5%
- 10 to 100 g 5% to 10%
- 100 to 500 g 10% to 25%
- homogeneous items 1%



Fig. 4. The results from an SGS (left) at Savannah River are combined with those from a neutron coincidence counter (NCC) (right). Agreement between the two techniques gives the operator confidence in the assay.

Even with its wide applicability, the SGS may not be the best choice for all measurement situations. Some examples are dense items whose transmission cannot be measured, short items (height less than half the diameter), items for which the matrix or SNM is extremely lumpy or heterogeneous, and large items such as 55-gal. drums containing isotopes emitting low-energy gamma rays (for example, the 185-keV gamma ray from ^{235}U). Some of these items may be better measured with an active or passive neutron assay technique (Fig. 4).

Contacts listed on the front page of this note can assist you with specific measurement problems.

Two divisions of Canberra Industries, Inc., build a variety of SGSs to accommodate samples ranging from 1 to 55 gal. Current users of the equipment include Los Alamos and Oak Ridge national laboratories, the Portsmouth Gaseous Diffusion Plant, and the Rocky Flats Plant.

The divisions of Canberra can be contacted at the following addresses:

Canberra Nuclear
Jomar Systems Div.
110 East Gate Drive
Los Alamos, NM 87544
(505) 662-9811

Canberra Industries, Inc.
Applied Systems Div.
One State Street
Meriden, CT 06450
(203) 238-2351

Examples of Los Alamos Prototype Segmented Gamma-Ray Scanners

Location	Sample Size	SNM	Innovation
Savannah River	0.2–5-gal. cans	^{235}U , ^{239}Pu	Mechanical design, background shields
Savannah River	0.2–5-gal. cans	^{235}U , ^{239}Pu	Lump correction combined with NCC
LANL	1-gal. cans	^{239}Pu	In glove-box line
Savannah River	55-gal. barrels	^{235}U , ^{239}Pu ^{238}Pu	Combined with shuffler for low-level waste

Additional Sources of Information

E. R. Martin, D. F. Jones, and J. L. Parker, "Gamma-Ray Measurements with the Segmented Gamma Scanner," Los Alamos Scientific Laboratory report LA-7059-M (December 1977).

J. L. Parker, "The Use of Calibration Standards and the Correction for Sample Self-Attenuation in Gamma-Ray Nondestructive Assay," Los Alamos Scientific Laboratory report LA-10045-revised (November 1986).

J. K. Sprinkle, Jr., and S. -T. Hsue, "Recent Advances in SGS Analysis," in *Proceedings, Third International Conference on Facility Operations—Safeguards Interface*, (San Diego, California, November 29 to December 4, 1987), p. 188.

C. W. Bjork, "Current SGS Technology," *Proceedings, Third International Conference on Facility Operations—Safeguards Interface*, (San Diego, California, November 29 to December 4, 1987), p. 129.

"Standard Test Method for Nondestructive Assay of Special Nuclear Material in Low-Density Scrap and Waste by Segmented Passive Gamma-Ray Scanning," ASTM C1133-89 (American Society for Testing and Materials, Philadelphia, Pennsylvania, 1989).

J. K. Sprinkle, Jr., G. E. Bosler, S. -T. Hsue, M. P. Kellogg, M. C. Miller, S. M. Simmonds, A. R. Smith, "NDA of Pu-Bearing Scrap and Waste," American Nuclear Society meeting, San Francisco, California, November 1989. Los Alamos National Laboratory document, LA-UR-89-2373.

S. M. Simmonds, J. K. Sprinkle, Jr., S. -T. Hsue, and M. P. Kellogg, "Nondestructive Assay of Pu-Bearing Scrap and Waste with the Advanced Segmented Gamma Scanner," Los Alamos National Laboratory document, LA-UR-90-252. (To be presented at the Institute for Nuclear Materials Management annual conference, July 1990.)

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545