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Standard Guide for In-Plant Performance Evaluation of Automatic Pedestrian SNM Monitors[1]

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1. Scope

1.1 This guide is affiliated with Guide C1112 on applying special nuclear material (SNM) monitors, Guide C1169 on laboratory performance evaluation, Guide C1189 on calibrating pedestrian SNM monitors, and Guides C1236 and C1237 on in-plant evaluation. This guide to in-plant performance evaluation is a comparatively rapid way to verify whether a pedestrian SNM monitor performs as expected for detecting SNM or SNM-like test sources.

1.1.1 In-plant performance evaluation should not be confused with the simple daily functional test recommended in Guide C1112. In-plant performance evaluation takes place less often than daily tests, usually at intervals ranging from weekly to once every three months. In-plant evaluations are also more extensive than daily tests and may examine both a monitor's nuisance alarm record and its detection sensitivity for a particular SNM or alternative test source.

1.1.2 In-plant performance evaluation also should not be confused with laboratory performance evaluation. In-plant evaluation is comparatively rapid, takes place in the monitor's routine operating environment, and its results are limited to verifying that a monitor is operating as expected, or to disclosing that it is not and needs repair or recalibration.

1.2 In-plant evaluation is one part of a program to keep SNM monitors in proper operating condition. Every monitor in a facility is evaluated. There are two applications of the in-plant evaluation: one used during routine operation and another used after calibration.

1.2.1 *Routine Operational Evaluation*—In this form of the evaluation, nuisance alarm records for each monitor are examined, and each monitor's detection sensitivity is estimated during routine operation. The routine operational evaluation is intended to reassure the plant operator, and his regulatory agency, that the monitor is performing as expected during routine operation. This evaluation takes place without pre-testing, recalibration, or other activity that might change the monitor's operation, and the evaluation simulates the normal use of the monitor.

1.2.2 *Post-Calibration Evaluation*—This form of the evaluation is part of a maintenance procedure; it should always follow scheduled monitor recalibration, or recalibration connected with repair or relocation of the monitor, to verify that an expected detection sensitivity is achieved. Nuisance alarm data do not apply in this case because the monitor has just been recalibrated. Also, having just been calibrated, the monitor is likely to be operating at its best, which may be somewhat better than its routine operation.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The guide is based on ASTM standards that describe application and evaluation of SNM monitors, as well as technical publications that describe aspects of SNM monitor design and use.

2.2 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials

C1112 Guide for Application of Radiation Monitors to the Control and Physical Security of Special Nuclear Material

C1169 Guide for Laboratory Evaluation of Automatic Pedestrian SNM Monitor Performance

C1189 Guide to Procedures for Calibrating Automatic Pedestrian SNM Monitors

C1236 Guide for In-Plant Performance Evaluation of Automatic Vehicle SNM Monitors

C1237 Guide to In-Plant Performance Evaluation of Hand-Held SNM Monitors

[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.12 on Safeguard Applications.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3. Terminology

3.1 *Definitions:*

3.1.1 *alternative test source*—although no other radioactive materials individually or collectively duplicate the radioactive emissions of uranium or plutonium, some materials have somewhat similar attributes and are sometimes used as alternative test sources.

3.1.2 *alternative gamma-ray test sources*—examples of alternative gamma-ray sources are HEU or ^{133}Ba used in place of plutonium when a plutonium source is not readily available or is prohibited.

3.1.2.1 *Discussion*—Table 1 tabulates amounts of HEU mass, plutonium mass, and ^{133}Ba source activity that produce equal response in two different types of monitor.

3.1.3 *alternative neutron test source*—a common alternative neutron source used in place of plutonium is ^{252}Cf that emits neutrons from spontaneous fission as does plutonium.

3.1.3.1 *Discussion*—Alternative test sources may have short decay half-lives in comparison to SNM isotopes; for example, the half-life of ^{133}Ba is 10.7 years and ^{252}Cf 2.64 years. Larger source activities than initially needed are often purchased to obtain a longer working lifetime for the source.

3.1.4 *confidence coefficient*—the theoretical proportion of confidence intervals from an infinite number of repetitions of an evaluation that would contain the true result.

3.1.4.1 *Discussion*—In a demonstration, if the true result were known the theoretical confidence coefficient would be the approximate proportion of confidence intervals, from a large number of repetitions of an evaluation, that contain the true result. Typical confidence coefficients are 0.90, 0.95 and 0.99.

3.1.5 *Confidence Interval for a Detection Probability*—An interval, based on an actual evaluation situation, so constructed that it contains the (true) detection probability with a stated confidence.

3.1.5.1 *Discussion*—Confidence is often expressed as 100* the confidence coefficient. Thus, typical confidence levels are 90, 95 and 99 %.

3.1.6 *detection probability*—the proportion of passages for which the monitor is expected to alarm during passages of a particular test source.

3.1.6.1 *Discussion*—Although probabilities are properly expressed as proportions, performance requirements for detection probability in regulatory guidance have sometimes been expressed in percentage. In that case, the detection probability as a proportion can be obtained by dividing the percentage by 100.

3.1.7 *nuisance alarm*—a monitoring alarm not caused by SNM but by other causes, such as statistical variation in the measurement process, a background intensity variation, or an equipment malfunction.

3.1.8 *process-SNM test source*—an SNM test source fabricated by a facility from process material that differs in physical or isotopic form from the material recommended in 3.1.11 for standard test sources.

3.1.8.1 *Discussion*—This type of source is used when it meets plant operator or regulatory agency performance requirements and a suitable standard source is not readily available. Encapsulation and filtering should follow that recommended in 3.1.11.

3.1.9 *SNM*—special nuclear material: plutonium of any isotopic composition, ^{233}U, or enriched uranium as defined in Terminology C859.

3.1.9.1 *Discussion*—This term is used here to describe both SNM and strategic SNM, which includes plutonium, ^{233}U, and uranium enriched to 20 % or more in the ^{235}U isotope.

3.1.10 *SNM monitor*—radiation detection system that measures ambient radiation intensity, determines an alarm threshold from the result, and then, when it monitors, sounds an alarm if its measured radiation intensity exceeds the threshold.

3.1.11 *standard SNM test source*—a metallic sphere or cube of SNM having maximum self attenuation of its emitted radiation and an isotopic composition listed below that minimizes the intensity of its radiation emission. Encapsulation and filtering also affect radiation intensity, and particular details are listed for each source. This type of test source is used in laboratory evaluation but, if suitable and readily available, may be used for in-plant evaluation.

3.1.12 *standard plutonium test source*—a metallic sphere or cube of low-burnup plutonium containing at least 93 % ^{239}Pu, less than 6.5 % ^{240}Pu, and less than 0.5 % impurities.

3.1.12.1 *Discussion*—A cadmium filter can reduce the impact of ^{241}Am, a plutonium decay product that will slowly build up in time and emit increasing amounts of 60-keV radiation. Begin use of a 0.04-cm thick cadmium filter when three or more years have elapsed since separation of plutonium decay products. If ten or more years have elapsed since separation, use a cadmium filter 0.08 cm thick. The protective encapsulation should be in as many layers as local rules require. A nonradioactive encapsulation material, such as, aluminum (≤0.32 cm-thick) or thin (≤0.16 cm-thick) stainless steel or nickel, should be used to reduce unnecessary radiation absorption.

3.1.13 *standard uranium test source*—a metallic sphere or cube of highly enriched uranium (HEU) containing at least 93 % ^{235}U and less than 0.25 % impurities. Protective encapsulation should be thin plastic or thin aluminum (≤0.32 cm thick) to reduce unnecessary radiation absorption in the encapsulation. No additional filter is needed.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *post-calibration evaluation*—verifies performance after repair, relocation, or recalibration. Monitor is prepared for

TABLE 1 Alternative Test Source Equivalent Amounts[A]

Monitor Category	Monitor Description	Plutonium, g	Uranium, g	^{133}Ba (μCi) Required in	
				NaI(T1) Scintillator Monitors	Plastic Scintillator Monitors
I	Standard plutonium	1	64	2.5	3.2
II	Standard uranium	0.29	10	0.9	1.4
III	Improved sensitivity	0.08	3	0.4	0.6
IV	High sensitivity	0.03	1	0.2	0.3

[A] This table combines information from Tables II and V of the report referenced in Footnote 8. Note that the term "category" refers to an SNM monitor performance category used in that report and not to an SNM accountability category. Also note that the ^{133}Ba source strengths depend on individual differences in how the scintillators respond to radiation from the barium isotope and plutonium.

best operation. Monitor is not yet in routine operation. Only sensitivity is evaluated.

3.2.2 *routine-operational evaluation*—verifies performance in routine operation. Simulates normal use of a monitor. Uses no monitor preparation procedures. Both sensitivity and nuisance alarm probability or rate are evaluated.

4. Summary of Guide

4.1 *Preliminary Steps Common to Both Forms of In-Plant Evaluation*:

4.1.1 The monitor being evaluated is an automatic walkthrough-portal or monitoring booth.

4.1.2 The monitor's indicated background measurement value is recorded for possible future use in troubleshooting.

4.1.3 *Nonmandatory Information*—If a gamma-ray survey meter (see 6.1) capable of quickly and precisely measuring environmental gamma-ray intensity is available, its use and recording its measurement value may provide additional beneficial information for future troubleshooting.[3] Independent knowledge of the ambient background intensity also can help to interpret performance differences at different monitor locations or at one location at different times.

4.2 *Steps for Routine Operational Evaluation*:

4.2.1 Determine nuisance alarm probability during the period since the monitor was last maintained, calibrated, or evaluated (see 8.1). Use recorded numbers of alarms and pedestrian passages from records kept during routine monitor use.

4.2.1.1 Handwritten alarm logs or records from the monitor's control unit can provide total alarms (see Section 6) from which alarms from daily or other performance testing and alarms explained by radioactive material presence in follow-up searches must be subtracted.

4.2.1.2 Total pedestrian passages can be estimated from operating logs or recorded information from the monitor's control unit.

4.2.2 Estimate detection probability by transporting a standard SNM, process-SNM, or alternative test source (see Section 7) through the monitor in a specific way adopted for evaluation beforehand (see 8.2).

4.2.2.1 Record the results, detect or miss for each passage.

4.2.2.2 End testing when a total number of passages, selected beforehand, is reached.

4.2.2.3 Analyze the results as a binomial experiment (see 8.2).

4.3 *Steps for Post-Calibration Evaluation*:

4.3.1 Calibrate the monitor according to procedures suggested by the manufacturer, Guide C1189, or local practice.

4.3.2 Estimate detection probability by transporting a standard SNM, process-SNM, or alternative test source (see Section 7) through the monitor in a specific way adopted beforehand (see 8.2).

4.3.2.1 Record the results, detect or miss for each passage.

4.3.2.2 End testing when a total number of passages, selected beforehand, is reached.

4.3.2.3 Analyze the results as a binomial experiment (see 8.2).

5. Significance and Use

5.1 SNM monitors are an effective and unobtrusive means to search pedestrians for concealed SNM. Facility security plans use SNM monitors as one means to prevent theft or unauthorized removal of designated quantities of SNM from access areas. Daily testing of the monitors with radioactive sources guarantees only the continuity of alarm circuits. The in-plant evaluation is a way to estimate whether an acceptable level of performance for detecting chosen quantities of SNM is obtained from a monitor in routine service or after repair or calibration.

5.2 The evaluation verifies acceptable performance or discloses faults in hardware or calibration.

5.3 The evaluation uses test sources shielded only by normal source filters and encapsulation and, perhaps, by intervening portions of the transporting individual's body. The transporting individual also provides another form of shielding when the body intercepts environmental radiation that would otherwise reach the monitor's detectors. Hence, transporting individuals play an important role in the evaluation by reproducing an important condition of routine operation.

5.4 The evaluation, when applied as a routine-operational evaluation, provides evidence for continued compliance with the performance goals of security plans or regulatory guidance. It is the responsibility of the users of this evaluation to coordinate its application with the appropriate regulatory authority so that mutually agreeable evaluation frequency, test sources, way of transporting the test source, number of test-source passages, and nuisance-alarm-rate goals are used. Agreed written procedures should be used to document the coordination.

6. Apparatus

6.1 *Gamma Ray Survey Meter (Nonmandatory Information)*—Historical records of gamma-ray background intensity may provide useful information for troubleshooting future monitoring problems. An evaluation offers a good opportunity to record both the monitor's indicated background count and the gamma-ray background intensity. If desired, gamma-ray intensity can be measured with a survey meter and recorded during the evaluation. The gamma-ray survey meter should have a NaI(T1) or plastic scintillator capable of measuring environmental gamma radiation in the range from 60 keV to 3 MeV at background intensities that normally range between 5 and 25 μR/h (1.3 and 6.5 nC kg/h or 0.36 and 1.8 pA/kg).

6.2 *Recording Devices*—Written operator logs can provide records of alarms and passages needed for determining nuisance alarm rates. In some cases, monitor controllers can automatically accumulate these records and communicate them to operators or maintenance personnel by data terminal, printer, or other means. If so, operator logs are still essential for providing information on alarms that result from testing or detected passage of radioactive material.

[3] Fehlau, P. E., Sampson, T. E., Henry, C. N., Bieri, J. M., and Chambers, W. H., "On-Site Inspection Procedures for SNM Doorway Monitors," U.S. Nuclear Regulatory Commission Contractor Report NUREG/CR-0598 and Los Alamos Scientific Laboratory Report LA-7646, 1979.