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Standard Guide to In-Plant Performance Evaluation of Hand-Held SNM Monitors[1]

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1. Scope

1.1 This guide is one of a series on the application and evaluation of special nuclear material (SNM) monitors. Other guides in the series are listed in Section 2, and the relationship of in-plant performance evaluation to other procedures described in the series is illustrated in Fig. 1. Hand-held SNM monitors are described in of Guide C1112, and performance criteria illustrating their capabilities can be found in Appendix X1.

1.2 The purpose of this guide to in-plant performance evaluation is to provide a comparatively rapid procedure to verify that a hand-held SNM monitor performs as expected for detecting SNM or alternative test sources or to disclose the need for repair. The procedure can be used as a routine operational evaluation or it can be used to verify performance after a monitor is calibrated.

1.3 In-plant performance evaluations are more comprehensive than daily functional tests. They take place less often, at intervals ranging from weekly to once every three months, and derive their result from multiple trials.

1.4 Note that the performance of both the hand-held monitor and its operator are important for effective monitoring. Operator training is discussed in Appendix X2.

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

1.6 *This standard does not purport to address all of 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.*

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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 monitoring.

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
C1189 Guide to Procedures for Calibrating Automatic Pedestrian SNM Monitors

3. Terminology

3.1 *Definitions:*

3.1.1 *alarm*—the audible sound made by a hand-held SNM monitor to indicate that it has detected radiation intensity at or above the alarm threshold.

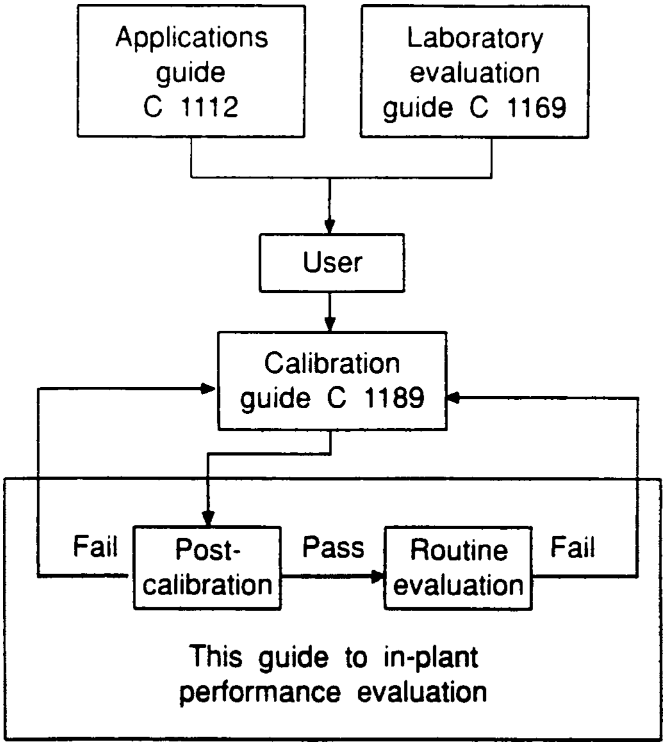
3.1.1.1 *Discussion*—One or more closely spaced alarms may be chosen to signify detection of SNM.

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

3.1.2.1 *alternative gamma-ray test sources*—Examples of alternative gamma-ray sources are highly enriched uranium (HEU) or ^{133}Ba used in place of plutonium when a plutonium source is not readily available or is prohibited.

3.1.2.2 *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.

[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.



NOTE 1—The procedures shown "above" the user provide the user with information before acquiring a monitor, and those "below" assist the user to obtain continuing acceptable performance from the monitor.

FIG. 1 The Relationship of In-plant Evaluation to Other Procedures Described in Guides for SNM Monitors

TABLE 1 Alternative Test Source Equivalent Amounts[A]

Monitor		Plutonium, g	Uranium, g	^{133}Ba (µCi) Required in:	
Category	Description			NaI(Tl) Scintillator Monitors	Plastic Scintillator Monitors
I	Plutonium	1	64	2.5	3.2
II	Uranium	0.29	10	0.9	1.4

[A] This table combines information from Tables II and V of the report referenced in Footnote 5. 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.

3.1.2.3 *alternative neutron test source*—A common alternative neutron source used in place of plutonium is ^{252}Cf, which emits neutrons from spontaneous fission as does plutonium.

3.1.2.4 *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.

3.1.3 *confidence coefficient*—the approximate percentage of confidence intervals from a large number of repetitions of an evaluation that would contain the true result.

3.1.3.1 *Discussion*—For example, a confidence coefficient is being referred to by the words "with 95 % confidence."

3.1.4 *confidence interval*—a range that contains the (true) detection probability for an evaluation situation with a stated confidence.

3.1.5 *detection*—one or more alarm sounds from a hand-held SNM monitor may constitute detection of SNM.

3.1.5.1 *Discussion*—Nuisance alarms are more likely to occur in hand-held monitors than in other types of SNM monitors for several reasons. Repeated alarms are most often used to indicate detection of SNM.

3.1.6 *detection probability—for hand-held monitors*, expressed as the proportion of trials with a particular test source for which the monitor is expected to detect the 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 *hand-held SNM monitor*—a hand-held radiation detection system that measures ambient radiation intensity, determines an alarm threshold from the result, and then when it is used for monitoring, sounds an alarm whenever its measured radiation intensity exceeds the threshold.

3.1.8 *nuisance alarm*—a monitoring alarm not caused by SNM but by other causes, that may be a statistical variation in the measurement process, a background intensity variation, or an equipment malfunction.

3.1.9 *operator*—an individual who uses a hand-held SNM monitor to search pedestrians, packages, or vehicles to detect the presence of SNM.

3.1.10 *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 3.1.12 for standard test sources.

3.1.10.1 *Discussion*—This type of source is used when it meets plant operator or regulatory agency performance requirements and a standard source is not appropriate or readily available. Encapsulation and filtering should follow that recommended in 3.1.12.

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

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

3.1.12 *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, also may be used for in-plant evaluation.

3.1.12.1 *standard uranium SNM test source*—a metallic sphere or cube of 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.

3.1.12.2 *standard plutonium SNM 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.

3.1.12.3 *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 0.08 cm thick cadmium filter. The protective encapsulation should be in as many layers as local rules require. A nonradioactive encapsulating 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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *post-calibration evaluation*—verifies the performance of a hand-held monitor immediately after calibration, recalibration, or repair and calibration. The hand-held monitor is prepared for best performance.

3.2.2 *routine-operational evaluation*—verifies the routine performance of a hand-held monitor. The monitor is being used in routine operation.

3.2.3 *saturation*—an undesirable condition in which a hand-held SNM monitor exposed to intense radiation ceases to function, falls silent, and does not indicate that SNM or intense radiation is present.

4. Summary of Guide

4.1 Each evaluation, routine-operational or post-calibration, is carried out using a predetermined test source, number of trials, and alarm criteria. The evaluation is summarized as follows:

4.1.1 *Steps for Routine-Operational Evaluation:*

4.1.1.1 Put the monitor into operation and check for saturation.

4.1.1.2 Use the evaluation procedure (see Section 8) in a series of trials to check for nuisance alarms. Record the results, alarm or no alarm for each trial.

4.1.1.3 Use the evaluation procedure again in a series of trials, this time to estimate the detection probability of a hand-held monitor in routine operation. Record the results, detect or miss for each trial.

4.1.1.4 End the testing when the preselected total number of trials is reached.

4.1.1.5 Analyze the results (see Section 9) to determine whether the hand-held monitor achieves a minimum requirement.

4.1.1.6 Report the results (see Section 10).

4.1.2 *Steps for Post-Calibration Evaluation:*

4.1.2.1 Calibrate the monitor according to procedures suggested by the manufacturer or other standard practice.

4.1.2.2 Put the monitor into operation and check for saturation.

4.1.2.3 Use the evaluation procedure (see Section 8) in a series of trials to check for nuisance alarms. Record the results, alarm or no alarm for each trial.

4.1.2.4 Use the evaluation procedure again in a series of trials, this time to estimate whether the detection probability of the hand-held monitor meets a minimum requirement. Record the results, detect or miss for each trial.

4.1.2.5 End the testing when the preselected total number of trials is reached.

4.1.2.6 Analyze the results (see Section 9) to determine whether the hand-held monitor achieves a minimum requirement.

4.1.2.7 Report the results (see Section 10).

5. Significance and Use

5.1 Hand-held SNM monitors are an effective and unobtrusive means to search pedestrians or vehicles for concealed SNM when automatic SNM monitors are not available or have sounded an alarm. Facility security plans apply SNM monitors as one means to prevent theft or unauthorized removal of SNM from designated areas. Functional testing of monitors on a daily basis with radioactive sources can assure they are in good working order. The significance of a less frequent, in-plant evaluation of an SNM monitor is to verify that the monitor achieves an expected probability of detection for an SNM or alternative test source.

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 encapsulation. However, shielded SNM test sources could be used as well.

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.

NOTE 1—It is the responsibility of the users of this guide to coordinate its application with the appropriate regulatory authority so that mutually agreeable choices for evaluation frequency, test sources, detection criteria (whether a single or multiple alarms constitute detection), minimum distance for first detection, number of trials, and reporting procedures are used. Regulatory concurrence should be formally documented.

6. Apparatus

6.1 Besides a hand-held monitor to evaluate, the following list of apparatus and supplies are needed.

6.1.1 *Metre Stick, Tape Measure, or Other Means for Measuring Distance.*

6.1.2 *Means of Support,* for the test source and hand-held monitor during the evaluation. For example, the test source could be supported on a table or shelf and the monitor moved towards it by a person holding the monitor and moving slowly towards the source. A better example would be to use a long wooden, or similar, plank (test plank) with a marked test source position and marked minimum distance for first detection. The plank could be supported with sawhorses. The person could then slowly move the monitor along the plank towards the test source in a more reproducible manner.

6.1.3 *Evaluation Report Forms and Some Means to Record Evaluation Results.*

7. Test Materials

7.1 The materials needed for performance evaluation are preselected (and agreed upon, see 5.4.1) test sources that may be standard SNM (see 3.1.12), process SNM (see 3.1.10), or alternative test sources (see 3.1.2). Standard 3-g and 10-g ^{235}U spherical test sources (see 3.1.12.1) are used in laboratory evaluations of automatic pedestrian monitors.[3] Standard low-burnup plutonium test sources, triply encapsulated and filtered with cadmium, are available.

7.2 A monitor's performance for detecting certain types of SNM, listed as follows, can be estimated using alternative test sources.

7.2.1 *Alternatives for ^{233}U and ^{238}Pu*—Performance for detecting standard HEU or low-burnup plutonium test sources demonstrates that a monitor has adequate gamma-ray sensitivity for detecting equal amounts of the more radioactive forms of SNM, ^{233}U, and ^{238}Pu.[4]

7.2.2 *Alternatives for Low-Burnup Plutonium*—Detecting a standard HEU or substitute ^{133}Ba test source demonstrates that a monitor has adequate gamma-ray sensitivity for detecting low-burnup plutonium in the amounts listed in Table 1. The amounts were derived from source measurements in automatic pedestrian SNM monitors. When using ^{133}Ba, which has a 10.7-year half-life, purchasing approximately twice the activity listed in Table 1 will give the test source a useful lifetime of about 10 years. The reasoning is that a source with twice the activity is equivalent to the listed amount of low-burnup plutonium with 3-years accumulation of radioactive daughters. At the end of its 10-year useful lifetime, the source activity is reduced to the listed amount of plutonium freshly separated from its daughters. Hence, the equivalence is maintained over the period that standard plutonium sources may be used without filtering (see 3.1.12.2).

7.2.3 *Alternative Sources for SNM Neutron Emission*—Performance for neutron monitors detecting ^{252}Cf, a spontaneous-fission neutron source, can demonstrate adequate neutron sensitivity for detecting low-burnup plutonium in an amount corresponding to 1 g of ^{240}Pu for each 1000 neutrons/s from ^{252}Cf. For example, a 6000-neutron/s ^{252}Cf test source is equivalent to 6 g of ^{240}Pu. This in turn is equivalent to a 100-g quantity of plutonium containing 6 % ^{240}Pu. Note that if only neutron sensitivity is to be evaluated, the neutron source should be used inside 5-cm thick lead gamma-ray shielding for evaluating a hand-held instrument that senses both gamma rays and neutrons.

7.3 The information on alternative test source size in Table 1 applies to monitoring situations that require detecting the small quantities of SNM that appear in the table. In other monitoring situations, alternative test source amounts should be determined on an individual basis, and the table should not be used.

7.4 The performance of any SNM monitor will depend on its environmental background, hence one test source may not serve to evaluate all monitors in all circumstances. Different locations may require different test sources.

8. Evaluation Procedure

8.1 *Preliminary Considerations*—The evaluation procedure uses the distance between a monitor and a test source at first detection to evaluate the monitor's performance. In a routine operational evaluation, the monitors are in routine service. In a post-calibration evaluation, the monitors have just been calibrated. Before beginning, the following choices must be made and agreed upon. (If they have not already been preselected and agreed upon, see 5.4.1.)

8.1.1 The test source (see Section 7).

8.1.2 The number of trials (see Section 9).

8.1.3 The minimum distance between monitor and source at first detection.

8.1.4 The alarm definition: a single alarm signal or more than one alarm signal if more than one is normally required for detecting SNM.

8.2 Begin the evaluation by turning on a hand-held monitor and allowing it to obtain a background and establish an alarm threshold. Once an indicated background is shown on the monitor's display, record it on an evaluation report form (see the example in Appendix X4).

8.3 Check for saturation. With the monitor in its search mode, place the test source in contact with the monitor at a point nearest its detector and verify that the monitor continuously alarms. If the monitor saturates and the alarm sounds cease, the monitor should be repaired or replaced before restarting the evaluation procedure. Record the result.

8.4 *Nuisance Alarm Check*—Nuisance alarms can influence the outcome of an evaluation. Repeat 8.4.1 through 8.4.3 for the preselected number of trials *without* a test source to check for nuisance alarms. If an alarm occurs, the cause must be found and corrected, and the evaluation must be restarted.

8.4.1 *Monitor Placement*—Support the hand-held monitor (in its operating orientation) at the location that will be later used to begin its approach to the test source. Make sure that any test sources are stored well beyond the detection range.

8.4.2 *Monitor Approach*— Move the monitor slowly (a few inches per second) toward the location where the test source will later be positioned until that location is reached. Record the result, no alarm or alarm. If an alarm occurs, find the cause, correct it, and restart the evaluation.

8.4.3 Pause every few minutes to allow the monitor's background to update.

8.5 *Performance Evaluation*—Place the preselected source on a flat surface near a metre stick or other measuring device. Repeat 8.5.1 through 8.5.3 for the preselected number of trials.

8.5.1 *Monitor Placement*—Support the hand-held monitor (in its operating orientation) at a great enough distance from the source that the monitor does not alarm.

8.5.2 *Monitor Approach*—Move the monitor slowly (a few inches per second) toward the test source and stop when the first detection occurs. Measure the distance between the monitor and the source. If the distance is greater than or equal

[3] Group NIS6 of the Los Alamos National Laboratory can provide these sources to DOE Contractors. The address is MS J562, Los Alamos, NM 87545.

[4] Fehlau, P. E., "An Application Guide to Pedestrian SNM Monitoring," *Los Alamos National Laboratory Report LA-10633-MS*, February 1986, p. 8.