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

This standard is issued under the fixed designation C 1237; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 C 1112, and performance criteria illustrating their capabilities can be found in Appendix X1.

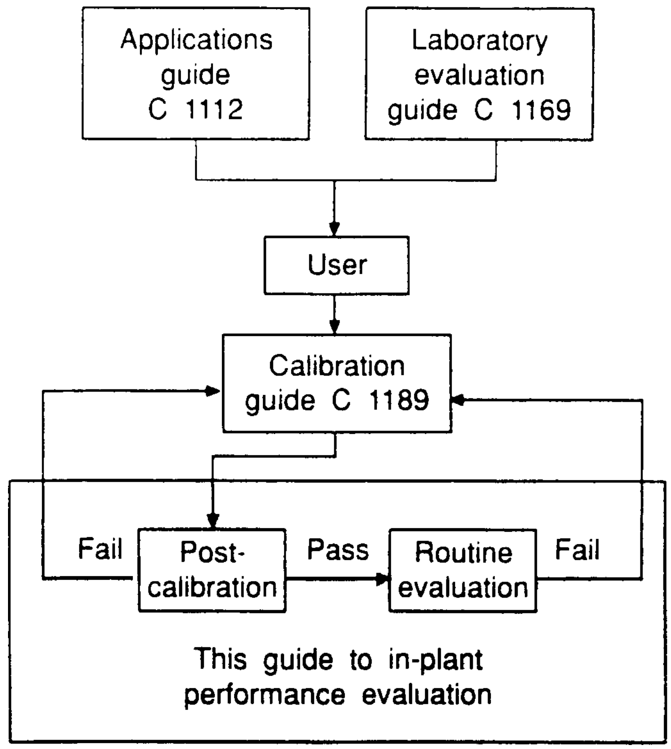
1.2 The purpose of this guide to in-plant performance evaluation is to provide a comparatively rapid procedure to verify that a hand-held SNM monitor performs as expected for detecting SNM or alternative test sources or to disclose the need for repair. The procedure can be used as a routine operational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



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

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:*

C 859 Terminology Relating to Nuclear Materials[2]

C 993 Guide for In-Plant Performance Evaluation of Automatic Pedestrian SNM Monitors[2]

C 1112 Guide for Application of Radiation Monitors to the Control and Physical Security of Special Nuclear Material[2]

C 1169 Guide for Laboratory Evaluation of Automatic Pedestrian SNM Monitor Performance[2]

C 1189 Guide to Procedures for Calibrating Automatic Pedestrian SNM Monitors[2]

C 1236 Guide to In-Plant Performance Evaluation of Automatic Vehicle SNM Monitors[2]

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

[1] This guide is under the jurisdiction of ASTM Committee C-26 on Nuclear Fuel Cycleand is the direct responsibility of Subcommittee C26.12 on Safeguard Applications.

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[2] *Annual Book of ASTM Standards*, Vol 12.01.

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.

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 C 859.

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 *Descriptions of Terms Specific to This Standard:*

3.2.1 *post-calibration evaluation*—verifies the performance

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.

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]

[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.

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 to the chosen minimum distance at first detection, record the trial as a detection. If not, record it as a miss (not detected).

NOTE 2—A test plank (see 6.1.2) could have the threshold distance marked and avoid the need for remeasurement in each trial.

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

8.6 Analyze the results as described in 9.4.

9. Analysis Procedures

9.1 The results of the evaluation are compared to acceptance and rejection criteria listed in Table 2. The criteria are based on

TABLE 2 Number of Detections for Acceptance and Rejection

NOTE 1—The preselected number of trials must have been completed and the criteria for that number of trials must be used to determine acceptance or rejection of the monitor's performance.

Total Number of Trials	Number of Detections for Acceptance	Number of Detections for Rejection
5	5	4 or less
10	9 or more	8 or less
15	12 or more	11 or less
20	15 or more	14 or less
30	20 or more	19 or less

plots published by Dixon and Massey.[5]

9.2 Table 2 offers five choices for the total number of trials. The choice is preselected, but it may have to change if operating conditions vary or if alternative sources decay (any change should be agreed upon beforehand as discussed in 5.4.1). The smallest practical number of trials is often a good choice that allows time to meet the goal of routinely carrying out the evaluation correctly.

9.3 The acceptance criteria in Table 2 provide at least 95 % confidence that the probability of detection for the test source is greater than 0.50 when using the evaluation procedure (8.5). Therefore, if the number of detections is at least the number listed in the acceptance column for the total number of trials (detections plus misses), the hypothesis that the monitor is operating as expected is accepted. Rejection criteria in Table 2 for the preselected total number of trials do not provide 95 % confidence that the detection probability is greater than 0.50, so the hypothesis is rejected. In that case, the monitor can be repaired, recalibrated, and evaluated again. In either case, record the result.

9.4 Besides the criteria in Table 2, other criteria (for more passages, different detection probabilities, or accumulated results) could be used as well. Appendix X3 provides additional criteria for verifying a test source detection probability with 95 % confidence in an evaluation. The criteria also can be used to make a point estimate of detection probability for accumulated results from more than one evaluation.

10. Report

10.1 Written reports should be used to document the evaluation.

10.2 Written reports may include any of the following. The content and form of the written report should be part of the agreement mentioned in 5.4.1.

10.2.1 Identification of the hand-held monitor and test source used.

10.2.2 Monitor's displayed background count rate.

10.2.3 Nuisance alarm check data.

10.2.4 Criteria for a detection.

10.2.5 Performance evaluation data and results.

10.2.6 Signatures.

10.3 See Appendix X4 for an example evaluation report.

11. Error and Bias

11.1 The outcome of an evaluation is a decision that a hand-held monitor performs as expected or not. Wrongful rejection or wrongful acceptance of the expected level of performance will likely be corrected after recalibration and reevaluation or during the next routine operational evaluation.

11.2 Consistently lower than expected performance may result from operating a monitor in an inappropriate environment or calibrating it inappropriately. Besides manufacturer's manuals, other information is available that may help.

11.2.1 *General Information*—Part 1 of the report referenced in Footnote 5 discusses general factors that affect monitor operation, and the Los Alamos hand-held monitor user's guide[6] describes procedures for hand-held monitoring.

11.2.2 *Calibration Information*—Guide C 1189 for calibrating automatic SNM monitors discusses calibration factors that affect monitor performance.

11.3 Biased procedures can influence detection probability results; try to avoid them. For example, an irregularly shaped test source may emit different amounts of radiation in different directions; use a different source orientation for each trial to help avoid a problem. The approach speed of the test source also may alter the amount of radiation detected. To avoid an incorrect conclusion of low-detection probability, move the source as directed in 8.5.2.

11.4 The monitor's environment can bias the evaluation outcome. Evaluation during unusual, short-term environmental circumstances, such as unusually high-background intensity, may change the outcome of an evaluation. Refer to previous evaluation records for comparison, and, wherever possible, use a second hand-held monitor to monitor the background intensity during evaluations.

11.5 Routine operational evaluation results could be biased by any pretesting or adjustment of the monitor that is not part of the normal routine for each working day. If preparatory or remedial adjustments are necessary, designate the evaluation a post-calibration evaluation.

11.6 Inattention to the outlined procedures in Section 8 and the sources of bias and error in this section can influence the evaluation outcome.

12. Keywords

12.1 material control and accountability; nuclear materials management; radiation detectors; radiation monitors; safeguards; security

[5] Dixon, W. J., and Massey, F. J., *Introduction to Statistical Analysis*, McGraw-Hill Book Co., New York, NY, 1969.

[6] Fehlau, P. E., "Hand-Held Search Monitor for Special Nuclear Materials, User's Manual," *Los Alamos National Laboratory Brochure LALP-84-15*, 1984.

APPENDIXES

(Nonmandatory Information)

X1. PERFORMANCE CRITERIA FOR HAND-HELD SNM MONITORS[7]

X1.1 Introduction

X1.1.1 This guide provides guidelines and minimum standards for performance of hand-held SNM detection instruments intended to supplement visual searches at material access and protected areas in license-exempt Energy Research and Development Administration (ERDA) contractor facilities. The performance of specific designs of such instruments submitted for ERDA approval under ERDA Manual 2405, "Physical Protection of Unclassified Special Nuclear Material," must meet or exceed these standards. The evaluation of designs submitted for ERDA approval may include tests not designated herein. In any event, full disclosure of design information and complete access to a working model shall be required for evaluation prior to approval. Considerable latitude is allowed intentionally in features such as type of detector, method of signal processing, search time, data storage, and instrument size in order to accommodate the tradeoffs implicit in the preferences of various instrument makers and the needs of various purchasers. However, since hand-held instruments must be moved rather closely over the subject or object, means shall be provided for alerting the operator without diverting his attention from the subject.

NOTE X1.1—ERDA is the predecessor to DOE.

X1.1.2 The sensitivity requirements are expressed herein in terms of the ability to detect highly enriched uranium or plutonium. If either enriched uranium or plutonium but not both is expected to be present in the protected area, then the monitor need meet only the applicable portion. The sensitivity for highly enriched uranium as detailed in X1.3.1 is also adequate to define instrument performance for other ^{235}U enrichments under the coverage requirements of ERDA Manual 2405 and the appendixes of this guide. Likewise the sensitivity for plutonium in X1.3.3 is satisfactory for all isotopic compositions of plutonium and for ^{233}U.

X1.2 Discussion

X1.2.1 Hand-held SNM detection instruments will be used at both outdoor and indoor locations by personnel with minimal experience in the use of such instruments. Therefore, the instrument should be designed for rugged use: temperature extremes and shock.

X1.2.2 Signal readout should be simple and should not require that the operator, while searching, pay strict attention to readout devices such as count rate meters. Audible monitoring of the count rate is not considered an acceptable method of alarm determination. Since the ear is not very sensitive to small count rate variations, this approach is difficult for an operator to use at low-detection levels. A logic circuit can better detect alarms at levels of a small fraction of the background and can do so uniformly with less interference from a high-noise level or a distracting environment.

X1.2.3 Sensitivity tests are described in X1.3. These tests are not searches but are designed to allow objective evaluation of instrument sensitivity under controlled conditions at scanning speeds approximating those used in actual searches. In order to facilitate a more rapid accumulation of statistically significant test results, a detection probability[8] of more than 0.50 (rather than 0.95) is required. In normal searches the detection probability will be considerably higher because of the generally smaller distance of closest approach (0.15 to 0.2 m) used during searches of personnel.

X1.3 Sensitivity

X1.3.1 The hand-held SNM detection instrument shall be capable of detecting with greater than 0.50 probability a spherical test source of highly enriched uranium metal moved past the instrument. The instrument shall be capable of meeting the sensitivity requirements when operated in a background of natural radiation of at least 20 μR/h. The test source shall be not more than 10 g of ^{235}U in uranium metal of at least 93 % enrichment containing at least 99.75 weight percent uranium.

X1.3.2 The test source will be moved past the face of the detector mechanically in the intended operational orientation at a velocity greater than 0.5 m/s with the distance of closest approach being not less than 0.25 m from detector face to source center. Source speed and distance of closest approach will be held constant during the series of detection trials.

X1.3.3 Plutonium sensitivity shall be determined as in X1.3.2 with a plutonium source. The plutonium source shall consist of 1 g of ^{239}Pu in plutonium metal containing at least 99.50 weight percent plutonium and having a minimum density of 19.44 g/cm^3. The ^{239}Pu content shall be at least 93.5 %, and the ^{240}Pu content shall be less than 6.5 %. Less than three years shall have elapsed since chemical separation of the plutonium. The source shall be encapsulated in at least 0.25 mm of stainless steel or nickel to provide protection from contamination. When double encapsulation is required it should be provided with similar materials.

X1.3.4 The instrument shall provide suitable signals to assist the operator in localizing the position of a hidden source once it has been detected.

X1.4 Background

X1.4.1 An alarm level for the determination of significant count rate excursions must be generated from a radiation

[7] This background information clarifies the performance that has been demanded of hand-held SNM monitors. It was developed for ERDA as a procurement standard entitled "Standards for Hand-Held SNM Detection Instruments for Personnel, Package, and Vehicle Search," and its most recent revision (*Los Alamos Document A-2-74-254*, July 26, 1976) appeared in *Entry-Control Systems Handbook, Sandia National Laboratories Report SAND77-1033,* October 1978, pp. 4.8–4 to 4.8–6.

[8] Probabilities were expressed in percentage in the original document but are converted to a proportion here for consistency.

background measurement by the instrument. The alarm level shall be updated manually on demand, or automatically at least every 100 s, but not more frequently than once every 30 s, to ensure that the required comparison between gross signal and alarm level during personnel or object scan is made with a background appropriate to that time.

X1.4.2 An indication shall be given to the operator in the event of an abnormal background condition that reduces the instrument sensitivity below that specified in X1.3.

X1.4.3 A separate indication shall be given if the radiation background falls to less than 50 % of normal, as this may indicate possible equipment malfunction.

X1.4.4 If the above indications are not provided automatically by the equipment design, some other means, such as a simple sensitivity test procedure with a weak source, must be provided for determining daily whether an abnormal background condition exists.

X1.4.5 It shall be the responsibility of the manufacturer and the purchaser to verify that the monitor meets the appropriate sensitivity requirements at the operating location.

X1.5 Equipment Protection

X1.5.1 The design of the instrument shall provide reasonable protection against unauthorized or accidental changing of control settings or instrument parameters.

X1.6 Environmental Requirements

X1.6.1 Environmental requirements and limitations shall be specified by the manufacturer. The warranty period and conditions under these limitations shall also be specified by the manufacturer.

X1.7 Instructions

X1.7.1 Operation, calibration, test, and maintenance procedures shall be provided by the manufacturer.

X2. OPERATOR EVALUATION

X2.1 Operators being trained to use a hand-held SNM monitor benefit from hands-on experience using a monitor during their training. An instructor also benefits from observing trainees use a monitor for evaluating and improving his teaching effectiveness.

X2.2 Trainees can search for concealed SNM if a pedestrian (or phantom), package, or vehicle that can conceal test sources is available. Test sources can be concealed in some instances but omitted in others to try to develop trainee confidence in having conducted a thorough search.

X2.3 Operators in routine service at a monitoring location also could be evaluated in much the same manner. The results might provide information on whether the training is effective and whether the frequency of operator training is adequate.

X3. ADDITIONAL DETECTION CRITERIA

X3.1 Acceptance criteria for various detection probabilities and numbers of total trials are illustrated in Table X3.1. The total number of trials and number of detections can be the results of one evaluation or they can be results accumulated over a period of time from a number of evaluations, as long as the same test object is used and the monitor has been in continuous operation during the period without recalibration, adjustment, or repair. When using accumulated results, all results obtained during the period must be included. If a monitor has required repair, adjustment, or recalibration, only results accumulated afterward can be used to evaluate the monitor's performance.

X3.2 Example of Using Table X3.1

X3.2.1 Suppose that a facility evaluates a monitor once a week using 10 trials with a particular test object and accumulates results for ten weeks. If the results total 94 detections and 6 misses for 100 trials, the 100 trials row in Table X3.1 gives a point estimate of 0.85 for the detection probability over the 10 week period.

X3.2.2 Fifteen weeks later, assuming the monitor for some reason still has not been recalibrated, if the accumulated results are 235 detections and 15 misses out of 250 total trials, the 250-trial row gives a point estimate of 0.90 for the detection probability over the 15-week period.

X3.2.3 At this point, suppose the monitor is recalibrated, and the initial 10 trials provided 9 detections. Table 2 then shows that the monitor's detection probability is verified to be greater than 0.50 with at least 95 % confidence. At this point,

TABLE X3.1 Detection Criteria for Verifying Detection Probability

Total Number of Trials	Listed Number of Detections or More Required to Verify a Detection Probability[A] of:					
	0.50	0.75	0.80	0.85	0.90	0.95
20	15	19	20	20	...[B]	...
30	20	27	28	29	30	...
50	32	43	45	47	49	...
100	59	83	87	92	96	99
250	139	200	211	223	234	244
1000	527	774	822	869	916	962

[A] For total trials from a single evaluation, the detection probability is estimated to be greater than the column heading value with at least 95 % confidence. For accumulated trials from more than one evaluation, the column heading is a point estimate of the detection probability.

[B] An inadequate total number of trials to estimate the indicated detection probability with at least 95 % confidence in a single evaluation.

no accumulated data from previous evaluation can be included because of the recalibration.

X4. AN EXAMPLE OF A HAND-HELD SNM MONITOR IN-PLANT EVALUATION REPORT FORM

X4.1 Fig. X4.1 illustrates an example of a hand-held SNM monitor in-plant evaluation report form.

HAND-HELD SNM MONITOR IN-PLANT EVALUATION REPORT

Date: ________

Evaluation Type-Routine ________ Post-Calibration ________

Monitor Information

Monitor identification ________
Evaluation location ________
Switch settings, if any ________
Calibration date (or due date) ________

Operational Information

Monitor background display ________
Saturation check result ________ Saturates ________ Does not saturate

Results of No-Source Trials

Trial 1.	Alarm ________	No Alarm ________
Trial 2.	Alarm ________	No Alarm ________
Trial 3.	Alarm ________	No Alarm ________
.	. .	. .
.	. .	. .
Trial 29.	Alarm ________	No Alarm ________
Trial 30.	Alarm ________	No Alarm ________
Result	Fail (alarms) ________	Pass (none) ________

Detection Probability Evaluation Data and Result

Test source identification ________
Starting distance ________
Minimum distance at first detection ________
Number of trials ________
Criterion for Acceptance ≥ ________ detections

Trial 1.	Detect ________	Miss ________
Trial 2.	Detect ________	Miss ________
Trial 3.	Detect ________	Miss ________
.	. .	. .
.	. .	. .
Trial 29.	Detect ________	Miss ________
Trial 30.	Detect ________	Miss ________
TOTALS	________	________

Result

Evaluation Result ________ Accept ________ Reject
Names and signatures of evaluators

________________________ ________________________
________________________ ________________________

FIG. X4.1 An Example of a Hand-Held SNM Monitor In-Plant Evaluation Report Form