U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

March 2014
Division 5

DRAFT REGULATORY GUIDE

Contact: A. Tardiff
301- 415-7015

DRAFT REGULATORY GUIDE DG-5038

(Proposed Revision 1 of Regulatory Guide 5.27, dated June 1974)

SPECIAL NUCLEAR MATERIAL DOORWAY MONITORS

A. INTRODUCTION

Purpose

The U.S. Nuclear Regulatory Commission (NRC) developed this regulatory guide to describe a method that the NRC staff considers acceptable to implement the search requirement for concealed special nuclear material (SNM) applied to personnel exiting a material access area (MAA).

For holders of a reactor license under Title 10 of the Code of Federal Regulations (10 CFR) (Ref.1), Part 50, "Domestic Licensing of Production and Utilization Facilities," a combined license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," or a fuel cycle facility license under 10 CFR Part 76, "Certification of Gaseous Diffusion Plants," having the need to possess or use SNM within their facility, the NRC typically has included in their license a condition granting a general license to use SNM under 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material."

Applicable Rules and Regulations

The requirements for physical protection found within 10 CFR Parts 50, 52, 70, and 76 refer to the physical protection requirements of 10 CFR Part 73, "Physical Protection of Plants and Materials." Part 73 requires, in part, in 10 CFR 73.46(d)(9) and 10 CFR 73.60(b), that each individual exiting an MAA is searched for concealed SNM. Specific testing and maintenance requirements, as stated in 10 CFR 73.20(b)(4), 10 CFR 73.46(g), and 10 CFR 73.60(d)(1) also apply.

Purpose of Regulatory Guides

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

Information Collection Requirements

This regulatory guide contains information collection requirements covered by 10 CFR Part 73, "Physical Protection of Plants and Materials," that the Office of Management and Budget (OMB) approved under OMB control number 3150-0002. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

This regulatory guide is being revised because it was out-of-date with current related guidance and references in the CFR. Related specifications and standards for SNM monitors and metal detectors have been updated or developed since the previous revision was issued in 1974. This revision has been developed to provide detection practices and criteria that licensees may use to augment programmatic information within the general reference, NUREG-1964, "Access Control Systems: Technical Information for NRC Licensees," (Ref. 3) issued in April of 2011 and NRC regulations.

Background

Special nuclear material doorway monitors provide an efficient, sensitive, and reasonably unobtrusive way of searching individuals for concealed SNM upon exit from an MAA. With proper installation and operation, gram quantities or less of SNM can be detected with a high level of reliability while maintaining a low false alarm rate. Portal type walk-through metal detectors are often used in conjunction with radiation detection to assure that personnel entering or leaving MAAs are screened for metallic nuclear shielding materials.

Theory of Operation

The doorway monitor comprises one or more detector unit(s), associated electronics, and alarm logic. The detector units are sensitive to the SNM radiation and responds to the emitted radiation (gamma rays and neutrons) by generating electronic current pulses. These pulses are amplified, filtered, and fed to alarm logic circuits that interpret the number (or rate) of pulses during a sampling. The alarm logic may be either a digital or analog system. In either case, if the rate of pulses exceed a set level, the alarm is triggered. Additional information pertaining to detector theory can be found in reference 4, "Radiation Detection and Measurement."

General Characteristics

Doorway Monitors

Doorway monitors detect gamma-ray radiation using scintillation or semiconductor detectors. To detect neutrons, plastic scintillators or gas-filled proportional counters are used. Geiger-Mueller counters have been used in this application; however, their lower intrinsic efficiency renders them less suitable than scintillation detectors. Scintillation detectors are often used for discriminating pulses based on imparted energy. Plastic scintillation detectors have the advantage of responding well to gamma-ray and energetic neutrons whereas the sodium iodide thallium-activated NaI(Tl) scintillation detectors have good gamma-ray sensitivity but poor neutron response. Helium-3 (He-3) gas is used in tubes as a proportional counter for neutron detection. The trend in industry is to use both scintillation detectors and He-3 detectors for doorway monitor systems.

Detectors are arranged so that a detection area is defined by a plane perpendicular to the line of passage of individuals through the doorway monitor. Various arrangements of the detectors are possible. However, specific placement of detectors should be based on the need to eliminate areas of no detection.

Commercially available doorway monitors are equipped with an automatic radiation background updating system that periodically monitors and averages the background count rate. A doorway monitor

equipped with an automatic radiation background updating system is also provided with a treadle pad or beam-break system to indicate that the zone of detection is occupied. When the zone of detection is occupied, the radiation level detected by the doorway monitor is compared to the mean background. If the level is greater than the mean background by a predetermined trigger level an alarm is actuated. Alarm actuation point is usually determined by a comparison between the radiation level within the zone of detection while occupied to with the mean background while unoccupied, while adding a factor to account for predetermined statistical accuracy.[1]

Thus the condition for an alarm can be written as

$$G>B+n(B)^{1/2}$$

Where B is the mean background, G is the radiation level within the zone of detection while occupied and n is a multiplier, usually between 4 and 10.[2]

Although the automatic background updating system allows unattended use of the doorway monitor, for technical reasons, the system may be less effective in certain situations. Techniques to prevent this are provided in the regulatory position.

Whether or not a doorway monitor is equipped with an automatic background updating system, high background activity will decrease sensitivity. Measuring activity in the zone of detection for longer periods of time will compensate somewhat for a high radiation background. However, longer measurement periods can make the use of the doorway monitor less convenient. Because of the adequate radiation detection sensitivity and high-throughput capability associated with processing many personnel through the detection system on a daily basis, walk-through pedestrian monitors are the primary SNM detection system used in personnel portals at MAAs.

Hand-Held Monitors

Hand-held monitors can use detectors made of NaI(Tl), plastic scintillators, semiconductors, or He-3 gas-filled tubes. Commercially available systems have rechargeable batteries that assist in ensuring continuous availability. Training the operator of a hand-held monitor is essential. The operator must scan an individual in the correct way for a hand-held monitor to be fully effective. In addition, the operator must understand the capabilities of the equipment, when the equipment is working within acceptable parameters and when it is not.

Radioisotope identification systems that detect radiation with high purity germanium (HPGe) detectors can be hand-held. These monitors are commercially available and may have a special cooling device, instead of a cryogenic bath, to cool the semiconductor HPGe crystal. Special cooling devices (e.g., Stirling cooler) allow a light-weight design useful as a hand held detection system.

---

[1] The square root of the mean of a Poisson-distributed quantity is the unbiased estimate of the standard deviation of that quantity.

[2] Note that, in general, for a count rate system, the condition for alarm should be modified to account for the response time of the instrument as follows:

$$G>B+n(B)^{1/2}(1-e^{-t/r})$$

Where t is the counting time and r is the time constant of the instrument. If, as should be the case, t/r>5, the added factor is essentially unity.

Hand-held monitors complement SNM search operations by enabling a more thorough search of an individual to locate the radiation source after a doorway monitor has alarmed, enabling pedestrian searches to continue when a doorway monitor is inoperative and, if technically outfitted to do so, identify specific radionuclide(s) causing a doorway alarm.

Because of the time required to scan an individual with a hand-held monitor, it is used as a secondary SNM detection system at an MAA personnel portal.

Harmonization with International Standards

The International Atomic Energy Agency (IAEA) has established a series of safety guides and standards constituting a high level of safety for protecting people and the environment. IAEA safety guides present international good practices and increasingly reflects best practices to help users striving to achieve high levels of safety. Pertinent to this regulatory guide, "IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities," issued January 2011, (Ref. 5) et. al., addresses considerations necessary for a nuclear material security program. While the NRC has an interest in facilitating the harmonization of standards used domestically and internationally, the NRC does not specifically endorse the IAEA document, and is only acknowledging that it may be useful as a reference for general information.

Documents Discussed in Staff Regulatory Guidance

This regulatory guide endorses the use of one or more codes or standards developed by external organizations, and other third party guidance documents. These codes, standards and third party guidance documents may contain references to other codes, standards or third party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a regulatory guide as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific regulatory guide. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a regulatory guide, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approval as an acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified and consistent with current regulatory practice, consistent with applicable NRC requirements such as 10 CFR 50.59.

C. STAFF REGULATORY GUIDANCE

1. Considerations for SNM Doorway Monitors

a. General

(1) Metal detectors should be used in conjunction with an SNM doorway monitor as an SNM detection system and can be one of the two required separate searches for concealed SNM (10 CFR 73.46(d)(9)). The metal detector unit should be installed in the pedestrian passageway as described in Regulatory Guide 5.7, "Entry/Exit Control of Personnel Access to Protected Areas, Vital Areas, and Material Access Areas" (Ref. 6) with the SNM monitor in such a way that objects cannot be passed over, around, or under the detection area.

(2) Alarm actuation for detectable metal mass should be 100 grams or the amount necessary to shield SNM that would allow a protracted theft of a formula quantity of strategic SNM to occur before the inventory process identifies it as missing, whichever is the lesser mass. The minimum mass of metal to undergo testing should be constructed into the configuration that optimizes SNM shielding capability and minimizes metal detection capability.

(3) The detector elements should be designed and positioned so that detection sensitivity is as uniform as possible over the zone of detection; in no case should any area within the zone of detection not be able to detect SNM.

(4) Power, sensitivity, and other controls of the doorway monitor and metal detector should be tamper-safe when unattended.

(5) Metal and SNM detection equipment should be provided with uninterruptible power sources.

(6) Signal lines connecting alarm relays to the alarm monitors for both metal and SNM detectors should be supervised electronically.

(7) Some doorway monitors may require an individual to occupy the detection area for a specified time (e.g., longer than what a normal walking pace would provide). In this case, the doorway monitor should be provided with a treadle pad and a timer to ensure that the zone of detection is occupied for the requisite time. Audible and visual alarms should actuate if the individual being searched does not occupy the detection area for the entire count period.

(8) The doorway monitor should be equipped with a high-background radiation alarm, which will announce if the measurement of the radiation background exceeds the appropriate maximum permissible background. The doorway monitor should not be used during periods of high background radiation. Calibration and determination of allowable background thresholds should be done in accordance with American Society for Testing and Materials (ASTM) C1189-11, "Standard Guide to Procedures for Calibrating Automatic Pedestrian SNM Monitors," (Ref. 7).

(9) System Specifications for specific radioisotopes are identified below. See ASTM C1112-99(2005), "Standard Guide for Application of Radiation Monitors to the Control and Physical Security of Special Nuclear Material," (Ref. 8) for supporting information.
.

(a) Plutonium-239. A doorway monitor used to detect plutonium (Pu) should be capable of detecting 0.5grams of plutonium with an isotopic content of at least 93 percent Pu-239 and less than 6.5 percent Pu-240. The Pu should contain less than 0.5 percent impurities. The form of the material should be a metallic sphere or cube. The impact of Am-241, a Pu decay product that will build up over time and emit increasing amounts of 60-keV gamma radiation, must be minimized by including a cadmium filter 0.04 cm to 0.08 cm thick as part of the source encapsulation. Protective encapsulation should be in as many layers as local rules require of a material such as aluminum (≤0.32 cm thickness) or thin (≤0.16 cm thickness) stainless steel or nickel that minimize unnecessary radiation absorption. The source should be encased in a minimum of 3 mm brass and detected at a 50 percent probability of detection with a 95 percent confidence limit. The false alarm rate should be less than 0.1 percent.

(b) Uranium-235. A doorway monitor used to detect uranium-235 (U-235) should be capable of detecting highly enriched (i.e., 20 percent or more) uranium containing at least 93 percent U-235 and less than 0.25 percent impurities. The form of the material should be a metallic sphere or cube. Encapsulation should be thin plastic or thin aluminum (≤0.32 cm thickness) to minimize unnecessary radiation absorption in the encapsulation. The source should be encased in a minimum of 3 mm brass and detected at a 50 percent probability of detection with a 95 percent confidence limit. The false alarm rate should be less than 0.1 percent.

(c) Uranium-233. Adequate sensitivity for uranium-233 (U-233) may be demonstrated by meeting the detection requirements for U-235.

2. Operations with Doorway and Hand-Held Monitors

In general, doorway monitors are the primary method used to search for concealed SNM, hand-held monitors are secondary, and a physical search is tertiary. Doorway monitors should be used in locations with minimum background radiation and minimum background radiation fluctuation. If circumstances dictate the use of a doorway monitor in an area of high background radiation, sufficient shielding should be provided to maintain necessary sensitivity.

a. The procedures, or changes to procedures developed to implement requirements of 10 CFR 73.46 should be prepared sufficiently in advance of intended implementation to provide verification of satisfactory performance.

b. The plan for metal detection equipment functionality and performance testing periodicity, procedures, and test sources should be submitted to the NRC for approval within 360 days for licensed operating facilities, 180 days before revising existing licensee SNM search programs, and 180 days before initial start of operations for newly licensed facilities.

c. During use, the doorway monitor system should check the radiation background and reset the alarm threshold of detected radiation at least every 15 minutes.

d. Doorway monitors shall be attended by two armed guards at an MAA (10 CFR 73.46 (d)(9)) within a facility containing a formula quantity of strategic SNM. Doorway monitors should be attended at non-power reactors.

e. Each individual to be checked should, in turn, enter the doorway monitor detection area and be required to remain still long enough for the device to operate properly.

f. With the individual in the doorway monitor detection area, an alarm should audibly and visually announce in the vicinity of the monitor if the activity in the detection area exceeds the set alarm threshold for radiation, possibly indicating the presence of SNM. At a facility containing a formula quantity of strategic SNM, the alarm shall also announce in the primary and secondary alarm stations, and at least one other alarm station (10 CFR 73.46(e)(5)).

g. When a doorway monitor signals an alarm, the individual generating the alarm should pass through the monitor a second time to confirm the signal. If the second pass through the monitor also generates an alarm, the individual should be retained and subjected to a body search, typically with a hand-held monitor, as described in ASTM C1237-99 (2005), "Standard Guide to In-Plant Performance Evaluation of Hand-Held SNM Monitors," (Ref. 9), to locate and identify the source of the signal. If the hand-held monitor does not confirm the alarm signals generated by the doorway monitor, the hand-held monitor should be tested against a known source to confirm it is working properly. If it responds to the source in the anticipated manner, it should be concluded that the doorway monitor should be investigated, repaired if necessary, and recalibrated before reentry into service. The individual generating the alarm should be released after confirmation that no SNM was detected. If detection is suspected to be from SNM contamination, health physics personnel should verify this finding. A monitoring flow diagram is provided in Figure 1.

h. A hand-held SNM monitor should be used when the doorway monitor is not functioning as intended. Search personnel should be trained on the correct use of the hand-held monitoring. A hand-held monitor should have the capability to identify specific radioisotopes.

3. Physical Searches and Training

a. A physical search for concealed SNM should be conducted as necessary.

b. To enhance the probability of detection, random searches for concealed SNM at the protected area boundary may be conducted, including searches of hand-carried items.

c. At facilities with formula quantities of strategic SNM, personnel having search duties and responsibilities must be trained and qualified.(10 CFR 73.45(g)(1)(i)).

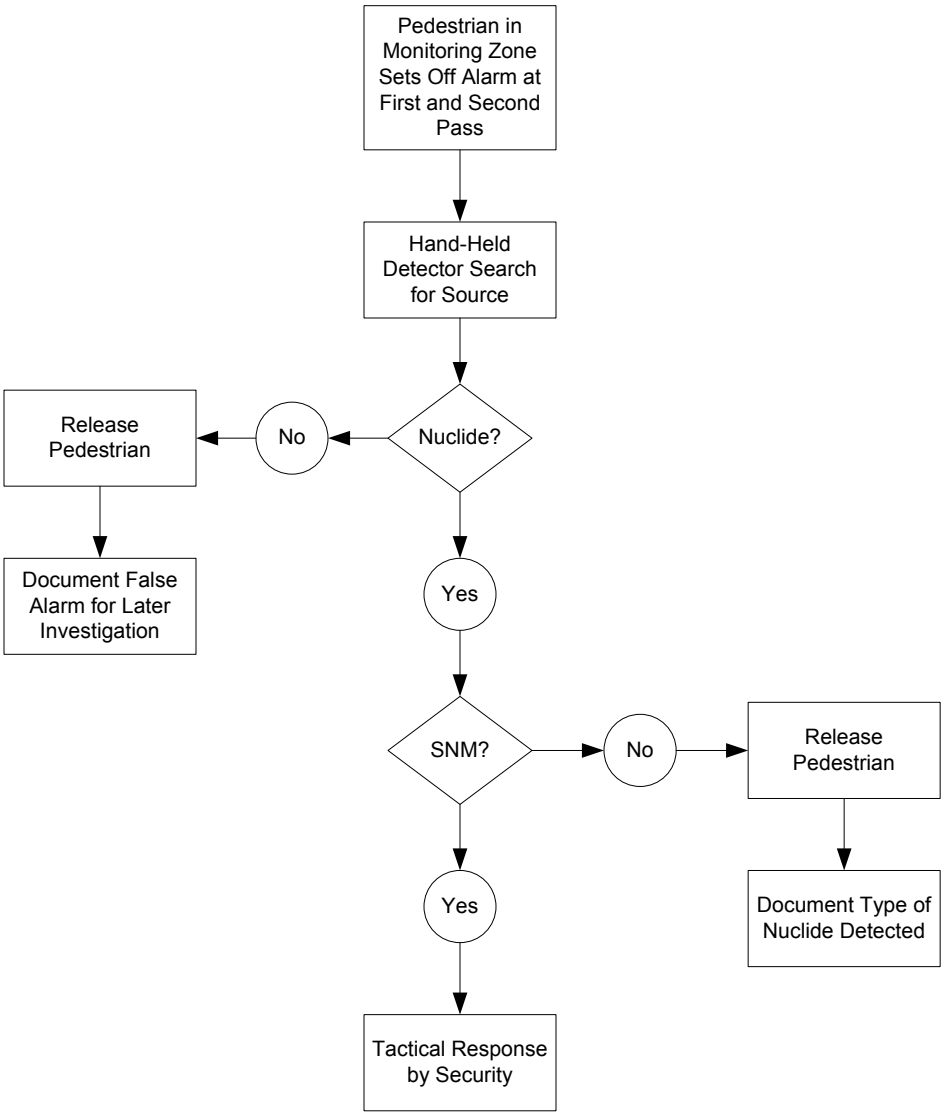

Figure 1 Flow diagram for SNM searches

4. Calibration, Testing, Maintenance, and Operating Instructions

a. Calibration

Doorway and hand-held monitors should be calibrated with a source of the amount, configuration, and variety of SNM to be detected. Doorway and hand-held monitor calibration should be conducted in accordance with Reference 5. Calibration should be conducted before initial use and after monitor repair or maintenance. Calibration should be conducted at least every three months. As a quality assurance measure, consideration should be given to having SNM calibration standards traceable to certified reference standards or materials.

b. Testing

(1) Doorway and Hand-Held SNM Monitors

Methods of performance testing doorway and hand-held monitors are found within ASTM C993-97(2012), "Standard Guide for In-Plant Performance Evaluation of Automatic Pedestrian SNM Monitors," (Ref. 10) and Reference 9. The references may be used to develop instructions for testing SNM monitors to assure system specifications are met. Daily testing is a simple functional test to assure the detector is working. Daily testing should be performed during each shift, or once if there is only one shift per day. Routine operational evaluations (and the similar post calibration evaluations) are more extensive than daily testing as they examine the alarm and sensitivity of the monitoring system. Routine operational evaluations should be conducted at intervals no greater than 3 months, and are often scheduled more frequently depending on the stability of the system. As described in reference 8 and reference 10, testing sources may be different than those used during calibration.

(2) Metal Detectors

Sensitivity mapping and operational sensitivity testing methods are described within ASTM C1270-97 (2012), "Standard Practice for Detection Sensitivity Mapping of In-Plant Walk Through Metal Detectors," (Ref. 11) ASTM C1269-97 (2012), "Standard Practice for Adjusting the Operational Sensitivity Setting of In-Plant Walk-Through Metal Detectors," (Ref. 12) and ASTM C1309-97 (2012), "Standard Practice for Performance Evaluation of In-Plant Walk-Through Metal Detectors," (Ref. 13). The references may be used to develop instructions for testing the metal detection system used to search for concealed, shielded strategic SNM. The metal detection system should be capable of detecting the minimum metal shielding concealed anywhere on an individual three times out of three trials. Daily functional testing should be conducted shiftly or at least daily. Operability sensitivity testing should be conducted at least every 3 months. The testing should consist of passing the minimum metal test source through a honeycomb configuration test apparatus that covers the entire detection area as described in references 11, 12 and 13. The honeycomb channels should be a maximum of 6 inches by 6 inches in dimension. The test source should be passed through the detection area as close as possible to the same rate (speed) as a pedestrian walking through the metal detector unit. Attaching the metal test source to a wooden dowel rod to conduct this test can facilitate the effective rate of passage of the metal source through the honeycomb test apparatus. A detection of the metal test source in each of the honeycomb test channels constitutes an acceptable performance test.

c. Maintenance

Metal detection and SNM monitoring equipment shall be maintained functioning as intended (10 CFR 73.20(4), 10 CFR 73.46(g), and 10 CFR 73.60(d)(1)).

d. Operating Instructions

Operating instructions should be available near the search activity. The procedural elements listed below should be included in the procedures for the search activity. A management system shall provide for the development, revision, implementation, and enforcement of security procedures (10 CFR 73.46 (b)(3)). Written procedures detailing the duties of search personnel for

operation of SNM monitors and metal detection equipment shall be developed (10 CFR 73.46 (b)(3)(i)). Procedures should address the following:

- metal detection threshold criteria,
- test sources and their use,
- monitor background reduction and sensitivity,
- searching pedestrians with doorway and hand-held monitors,
- recording, retention, and analysis of monitor performance data,
- recording and resolution of alarm events,
- quarterly performance testing,
- daily operational testing,
- environmental operating constraints (e.g., temperature and humidity),
- search operations during an emergency or loss of power,
- maintenance of monitors and metal detection equipment,
- security for the system equipment, communications, software, and data,
- training for operating personnel, and
- documentation requirements for authorized removals of SNM.

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[3] may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with the Backfit Rule found in 10 CFR 50.109(a)(1), 10 CFR 70.76(a)(1), 10 CFR 76.76(a)(1) or any applicable finality provisions in 10 CFR Part 52.

Use by Applicants and Licensees

Applicants and licensees may voluntarily[4] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged**.** The acceptable guidance may be a previous version of this regulatory guide.

Licensees may use the information in this regulatory guide for actions which do not require NRC review and approval. However, voluntarily using the subject matter in the guidance may change the facilities security plan such that NRC review may be required under the provisions of 10 CFR Part 50.54, 10 CFR Part 70.32 or 10 CFR Part 76.68, and should be evaluated prior to incorporating the methods into the security plans. Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the regulatory guide, generic communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

During regulatory discussions on plant specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this regulatory guide, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the licensing basis of the facility. However, unless this regulatory guide is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

---

[3] In this section, "licensees" refers to holders of, and the term "applicants" refers to applicants for, the following: (1) special nuclear material licenses under 10 CFR Part 70; (2) licenses for nuclear power plants under 10 CFR Parts 50 and 52; and (3) certificates of compliance or approvals of a compliance plan for gaseous diffusion plants under 10 CFR Part 76.

[4] In this section, "voluntary" and "voluntarily" means that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1), 10 CFR 70.76(a)(1), 10 CFR 76.76(a)(1) or any applicable finality provisions in 10 CFR Part 52.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 14) and the NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref 15).

REFERENCES[5]

1. 10 CFR Part 73, "Physical Protection of Plants and Materials," U.S. Nuclear Regulatory Commission, Washington, DC.

2. 10 CFR Part 76, "Certification of Gaseous Diffusion Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

3. NUREG-1964, "Access Control Systems: Technical Information for NRC Licensees," U.S. Nuclear Regulatory Commission, Washington, DC. (ML1115A078)

4. Knoll, Glenn F., *Radiation Detection and Measurement*, 3rd ed., John Wiley and Sons, 2000.

5. "IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities," January 2011[6]

6. Regulatory Guide 5.7, "Entry/Exit Control of Personnel Access to Protected Areas, Vital Areas, and Material Access Areas," U.S. Nuclear Regulatory Commission, Washington, DC.

7. ASTM C1189-11, "Standard Guide to Procedures for Calibrating Automatic Pedestrian SNM Monitors," American Society for Testing and Materials, West Conshohocken, PA, 2005.

8. ASTM C1112-99(2005), "Standard Guide for Application of Radiation Monitors to the Control and Physical Security of Special Nuclear Material," American Society for Testing and Materials, West Conshohocken, PA, 2005.[7]

9. ASTM C1237-99(2005), "Standard Guide to In-Plant Performance Evaluation of Hand-Held SNM Monitors," American Society for Testing and Materials, West Conshohocken, PA, 2005.

10. ASTM C993-97(2012), "Standard Guide for In-Plant Performance Evaluation of Automatic Pedestrian SNM Monitors," American Society for Testing and Materials, West Conshohocken, PA, 2005.

11. ASTM C1270-97, "Standard Practice for Detection Sensitivity Mapping of In-Plant Walk Through Metal Detectors," American Society for Testing and Materials, West Conshohocken, PA, 2003.

---

[5] Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or 800-397-4209; fax 301-415-3548; and e-mail pdr.resource@nrc.gov.

[6] Copies of this publication are available thru the IAEA website at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1481_web.pdf

[7] Copies of American Society for Testing and Materials (ASTM) standards may be purchased from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959; telephone 610-832-9585. Purchase information is available through the ASTM Web site at http://www.astm.org.

12. ASTM C1269-97, "Standard Practice for Adjusting the Operational Sensitivity Setting of In-Plant Walk-Through Metal Detectors," American Society for Testing and Materials, West Conshohocken, PA, 2003

13. ASTM C1309-97 (2012), "Standard Practice for Performance Evaluation of In-Plant Walk-Through Metal Detectors," American Society for Testing and Materials, West Conshohocken, PA, 2003

14. NUREG-1409, "Backfitting Guidelines," U.S. Nuclear Regulatory Commission, Washington, DC.

15. Management Directive 8.4, "Management of Facility-specific Backfitting and Information Collection," U.S. Nuclear Regulatory Commission, Washington, DC.