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TITLE SPECIAL NUCLEAR MATERIAL RADIATION MONITORS FOR THE 1980's

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SPECIAL NUCLEAR MATERIAL RADIATION MONITORS FOR THE 1980s*

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ABSTRACT

During the two decades that automatic gamma-radiation monitors have been applied to detecting special nuclear material (SNM), little attention has been devoted to how well the monitors perform in plant environments. Visits to 11 DOE facilities revealed poor information flow between developers, manufacturers, and maintainers of SNM radiation monitors. To help users achieve best performance from their monitors or select new ones, Los Alamos National Laboratory developed a hand-held monitor user's guide, calibration manuals for some commercial SNM pedestrian monitors, and an applications guide for SNM pedestrian monitors. In addition, Los Alamos evaluated new commercial SNM monitors, considered whether to apply neutron detection to SNM monitoring, and investigated the problem of operating gamma-ray SNM monitors in variable plutonium gamma-radiation fields. As a result, the performance of existing SNM monitors will improve and alternative monitoring methods will become commercially available during the 1980s.

INTRODUCTION

Automatic gamma-radiation monitors to detect SNM removal from material access areas were first developed in the late 1960s. At that time, a pedestrian doorway monitor[1] designed by EG&G, Inc.** for the Technical Support Organization of Brookhaven National Laboratory inspired a series of similar developments that extends into the 1980s. Pedestrian, package, and vehicle SNM monitors were developed by DOE plants and laboratories and by private businesses. Most of this equipment received little impartial standardized evaluation and scant attention was paid to how well nonscientific personnel operated and maintained it. As a result, selecting and implementing adequate, reliable, and easily maintained monitoring equipment can be a difficult task.

The Advanced Nuclear Technology group at the Los Alamos National Laboratory, which has studied monitoring physics for the last 13 years, develops new monitors of its own as well as evaluates commercially available equipment. During the past two years, we have extended our interest to studying the in-plant problems with SNM monitoring equipment at DOE facilities. Visits to 11 locations uncovered a few faults in particular monitors or in the way they are applied. However, our most important discovery was the lack of information: a gap exists in documentation for calibrating and maintaining commercial SNM monitors and in up-to-date DOE regulatory advice on the availability and expected in-plant performance of monitoring equipment. In an attempt to remedy this lack of information, we have completed or are working on tasks that may make SNM monitors both easier to apply and more effective.

BETTER PERFORMANCE FROM EXISTING MONITORS

Many of the SNM monitors in use today could operate more effectively if sufficient technical information were available on suitable applications and proper maintenance. Unfortunately, SNM monitor manufacturers do not supply that information, and with good reason. These manufacturers are small businesses that do not routinely handle significant quantities of SNM or conduct research related to transient signal detection. They typically manufacture equipment based on technology developed elsewhere--at certain DOE facilities, for example, but seldom are they invited into the facilities to study their equipment in operation. When manufacturers do have their own SNM, they may be unaware of the specific composition of the material; the emitter may produce exceptionally intense radiation that is unsuitable for measuring SNM monitor performance. Hence, manufacturers can seldom develop calibration procedures to obtain the lowest detection thresholds. As a result, users may not obtain effective SNM monitor performance with the inadequate information at hand.

Hand-Held SNM Monitors

Los Alamos has completed three tasks to provide better information for calibrating and using certain SNM monitors (Fig. 1). The first task was to develop and

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**EG&G, Inc., Goleta, California.

Fig. 1.
User's manual and calibration manuals are a help in obtaining the best performance from SNM monitors. Developing such manuals requires considerable experience with the monitor.

publish a user's manual for hand-held SNM monitors.[2] The manual instructs security inspectors how to manually search pedestrians and vehicles for SNM. It serves both as a training aid in a course of instruction and also as a reference when a copy is placed at each guard station. Proper training and supervision are important in hand-held monitoring because monitoring effectiveness depends equally on effective monitoring instruments and an effective monitoring technique. In portal monitors, the analogous means to achieve effective monitoring is proper calibration. The remaining two tasks developed the portal monitor calibration manuals described in the next section.

Portal-Monitor Calibration Manuals

We recently developed calibration manuals for two of the commercial pedestrian SNM monitors that we evaluated in the mid 1970s. These monitors found widespread use at DOE facilities and, although many of them are now 10 years old, they are still highly effective monitoring systems when they are properly maintained. Proper maintenance depends on good documentation both for the reasons stated previously and also because the people who maintain the monitors do so for limited periods of time. Career progression usually results in job turnover--experienced technicians move to new areas after they become proficient with the SNM monitors. After a year or two, new technicians have difficulty finding written documentation to help with on-the-job training. Calibration guides for the National Nuclear Corporation* analog personnel monitor[3] (model DM2) and the TSA Systems, Inc.** personnel monitor[4] (model PM 203) have been supplied to some DOE plant maintenance personnel; they are available, along with the other references, from the author.† Additional calibration assistance with the TSA Systems monitor is now available from the manufacturer†† for those who would like to standardize the PM 203 electronics to match the calibration procedure.

IN-PLANT PERFORMANCE EVALUATION

Since the early 1970s, Los Alamos has evaluated SNM monitoring equipment, primarily as a DOE task to qualify equipment for use at DOE facilities. Lately its evaluations have been conducted under the auspices of DOE-sponsored direct facility support to DOE facilities that have purchased untested monitoring equipment or that would like to purchase equipment that is being offered as "improved," "high sensitivity," or otherwise better than average. Such evaluations are worthwhile as independent, impartial evaluations, but they would be unnecessary if manufacturers and plants were able to conduct the simple tests that could help them develop effective monitors. What has made this impossible is the lack of standard test sources.

Laboratory testing of walkthrough SNM monitors entails a study conducted in a specific radiation environment using both standard evaluation techniques[5] and standard test sources. Facilities and manufacturers often are satisfied to test with standard sources in the environment at hand. Facilities, for example, should conduct tests each quarter or so to verify that their walkthrough monitors effectively detect SNM. However, standard sources are not widely available and the plutonium sources that are available soon age and become unsuitable because of build up of plutonium radioactive decay products that are themselves radioactive. To make testing possible, we have fabricated standard uranium test sources in the form of 10-g ^{235}U metallic spheres that contain a total of 10.7 g of uranium (Fig. 2); we are supplying them to facilities and manufacturers. These sources have about half of their emitted radiation spectrum in a 100-keV x-ray region in common with the freshly separated ^{239}Pu (weapons-grade plutonium) radiation spectrum. A walkthrough monitor that can detect these sources is capable of detecting about a 0.29-g quantity of that type of plutonium.

The Table puts this test into perspective among the walkthrough monitor categories that are available to us today. Most monitors are Category II monitors, that is, standard walkthrough portals. Category III monitors may have an added foot counter. Category IV monitors may

*National Nuclear Corporation, Mountain View, California.

**TSA Systems, Inc., Boulder, Colorado.

†Telephone (505) 667-5372 or FTS 843-5372.

††Telephone (303) 447-3553.

have very narrow portal spacing and possibly both head and foot counters. Most Category I monitors are being retired; a few are special applications of a pedestrian SNM monitor that requires extremely wide portal spacing.

The final columns in the Table estimate the amount of ^{133}Ba that can be used as a substitute test source when a non-SNM source is required. This type of source is most useful for daily testing because its control requirements are less than those for SNM. It is not a universal substitute test source because its spectrum covers the range but not the shape of the plutonium spectrum. Its 10.7-year half-life reduces the source intensity significantly in a few years, but ^{133}Ba sources are easily replaced.

GUIDANCE FOR APPLYING SNM MONITORS

Regulatory guidance for applying SNM radiation monitors at DOE facilities varies. The standards branch of the Atomic Energy Commission (AEC) became part of the Nuclear Regulatory Commission (NRC) when the AEC split into the DOE and NRC. The NRC developed a regulatory guide for SNM monitors that is now out of

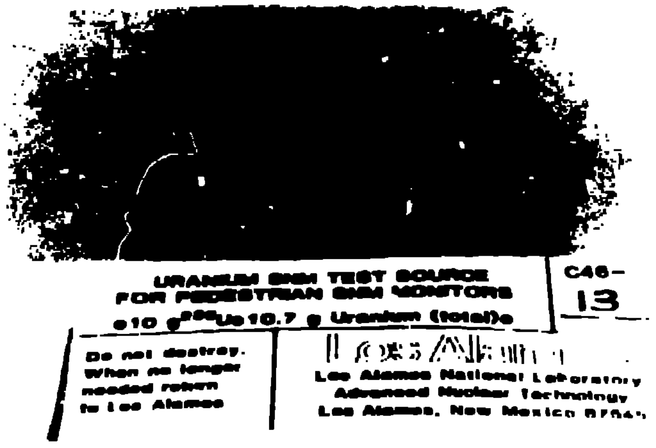

Fig. 2.
The 10-g ^{235}U test source is a metallic highly enriched uranium sphere with about a 3/8-in. diameter. It is minimally encapsulated in a paper envelope and outer plastic envelope. The label requests that the source be returned to Los Alamos when it is no longer needed.

TABLE

QUANTITY DETECTED IN WALKTHROUGH SNM MONITORS[a]

Category	Monitor	Uranium[b] (g)	Plutonium[c] (g)	^{133}Ba[d] in NaI(Tl) (μCi)	^{133}Ba[d] in Plastic (μCi)
I	Standard plutonium	64	1	2.5	3.2
II	Standard uranium	10	0.29	0.9	1.4
III	Improved sensitivity	3	0.08	0.2	0.6
IV	High sensitivity	1	0.03	0.1	0.3

[a]Test conditions: background intensity 25 μR/h; standard metallic source material of specified purity in the form of spheres; source attached to a variety of pedestrians below the ankle on the inside as they walk through the monitor at their own normal speed, adjusting their pace to swing the source through the monitor; test results give 95% confidence that the probability of detection is 50% or greater.

[b]Highly enriched uranium.

[c]Weapons-grade plutonium freshly separated from daughter products.

[d]The response to ^{133}Ba is different in NaI(Tl) and plastic scintillation detectors because the first responds better to the very intense low-energy radiation from the source.

date.* DOE manual chapters impose monitoring requirements but provide no technical guidance. In the past, technical guidance was provided by an informal Los Alamos performance specification and a Sandia National Laboratories handbook, both of which are now hard to find and out of date. At this time, we are drafting an applications guide for pedestrian SNM radiation monitors for the DOE Office of Safeguards and Security. Later, we will provide a similar guide for vehicle SNM monitoring.

The draft applications guide (Fig. 3) provides an overview of SNM pedestrian monitoring, a technical discussion of monitoring physics and SNM monitors, and a catalog of available SNM pedestrian monitors. In addition to explaining the principles of SNM monitor operation and outlining performance objectives for the monitors in both controlled laboratory test environments and plant applications, the guide discusses how to calibrate and maintain walkthrough monitors and suggests ways to obtain higher sensitivity, such as slowing traffic through monitoring stations or adding detectors in low sensitivity portions of walkthrough monitors. At the time of writing, the guide is in rough draft form.**

NEUTRON-DETECTING SNM MONITORS

Seldom has neutron detection been applied to SNM monitors because some forms of SNM emit few neutrons and most others have relatively low-intensity neutron emission. Neutron detection is attractive, however, because it remains effective when gamma-ray shielding is applied to plutonium. But neutron detectors are so expensive that the technique is appropriate only to monitoring systems that must detect large quantities of plutonium. For example, a monitor developed by Los Alamos and Sandia[7] detects some tens of grams of unshielded plutonium; its neutron proportional counters alone cost $28,800. Contrast this expense to a complete gamma-ray walkthrough monitor available at the same price that detects a fraction of a gram of unshielded plutonium as well as detecting other forms of SNM.

Los Alamos is now developing less expensive neutron monitors based on a neutron-chamber principle developed by Caldwell[8] that requires fewer proportional counters (Fig. 4). Monitor controllers are also being developed specifically for the Poisson-distributed counting data from small neutron detection systems. Our task will be to develop a monitoring system for

*Los Alamos published an updated version of the NRC guide in 1979 that also is becomming out of date (see Ref. 6, pp. 3-10).

**Copies are available from the author.

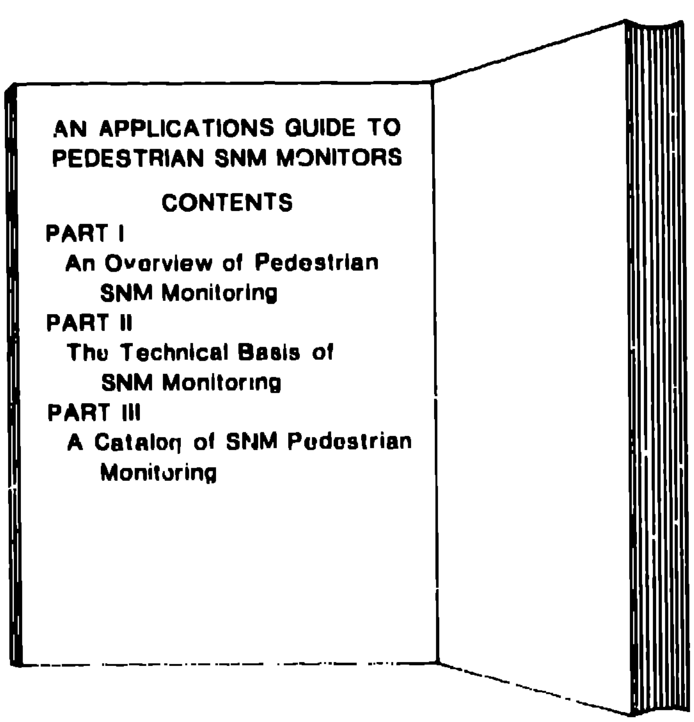

Fig. 3.
The draft applications guide for pedestrian SNM monitors is written for a varied audience. The three-part guide will provide the information required by regulatory personnel, security specialists, and maintenance personnel.

Fig. 4.
When its cover is in place, a neutron monitor moderates neutrons and traps them within the enclosure. As the moderated neutrons bounce around, they are repeatedly exposed to detection in the neutron proportional counters.

motor vehicles as well as to investigate the possibility of applying neutron detection to pedestrian SNM monitoring. The vehicle monitoring system will eventually be commercially available.

RECENTLY DEVELOPED MONITORING EQUIPMENT

New, High-Sensitivity Pedestrian Monitors

Recent development activities at Los Alamos center around vehicle SNM monitors, but we are also developing a pedestrian monitor and evaluating new pedestrian monitors developed by others. All of these monitoring systems are briefly described in a workshop handout.*

In the area of new, commercially available monitors, the high-sensitivity pedestrian monitors that we evaluated (Fig. 5) performed less well than expected. Surprisingly, these monitors were produced by manufacturers whose previous monitors had met DOE performance specifications during the mid 1970s. The most serious problem with these pedestrian monitors was the signal-conditioning electronics; the manufacturers had developed their own rather than purchase high-quality scintillation electronics from other manufacturers. This discovery is a major justification for conducting independent and impartial evaluations to establish how well monitoring equipment performs relative to its potential. The purchaser's susceptibility to a vendor's salesmanship or to the lowest bid often results in inferior monitors that do not perform as well as expected. The legacy from such transactions bequeathes unnecessary nuisance alarms, poor detection sensitivity, and overwhelming service requirements. When the

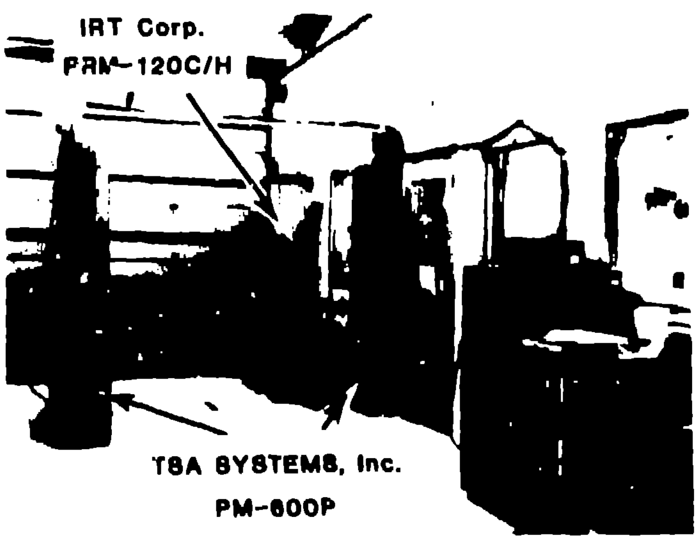

Fig. 5.
During recent evaluations we examined monitors intended for application with wide separation between the detector pillars. The TSA Systems PM-600P suffered from poor electronic design that limited its performance to Category II. The IRT PRM120C/H had similar but more severe electronic shortcomings that placed it in Category I.

purchaser does find a monitor that is effective and reliable, he must keep its exact specifications for future purchases or be subject to inferior substitutions once again.

Detector Collimation and Filtering

SNM monitors operating in material process areas are exposed to a widely varying background that often causes false alarms. To overcome that problem, we developed a narrow-angle collimator (for the DOE Rocky Flats Plant) that limits the field of view of a portal monitoring system and added a low-energy radiation filter behind the collimator to absorb radiation scattered by the filter itself. This collimator/filter arrangement (Fig. 6) considerably reduced the monitor's sensitivity to background plutonium radiation without greatly reducing its sensitivity to plutonium passing through the portal. The collimator/filter is now installed on a monitor at Rocky Flats for further evaluation.

SUMMARY

Recent observations of SNM monitoring in DOE plants heightened our awareness of the particular needs of users who must apply SNM monitors as only one of a host of perimeter security techniques. We have written manuals to make calibration and operation of some monitors easier and more effective. We will soon be

Fig. 6.
The detector collimator/filter excludes much of the radiation from outside the monitor's field of view without greatly reducing its detection sensitivity for SNM passing through the portal.

able to provide guidance to users or manufacturers so that they can evaluate monitoring equipment in a consistent manner and understand whether it attains a reasonable level of performance. We shall continue to compare new monitoring methods to existing proven techniques and endeavor to improve the performance of gamma-radiation monitors.

ACKNOWLEDGMENTS

I appreciate the assistance of many members of the Advanced Nuclear Technology Group who helped install and evaluate the SNM monitors and fabricate the detector collimator/filters. I am also indebted to the group publications staff for producing the user's manual and calibration guides.

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