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TITLE PERIMETER RADIATION MONITORS FOR THE CONTROL AND PHYSICAL SECURITY OF SPECIAL NUCLEAR MATERIALS

AUTHOR(S): Paul E. Fehlau

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Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

PERIMETER RADIATION MONITORS FOR THE CONTROL AND PHYSICAL SECURITY OF SPECIAL NUCLEAR MATERIALS

Paul E. Fehlau
Los Alamos National Laboratory
Los Alamos, NM 87545

ABSTRACT

Perimeter radiation monitors are gamma-ray and neutron measurement systems that can provide timely notice of theft or diversion of special nuclear material (SNM). The monitors may be hand-held instruments operated by security inspectors or automatic pedestrian or vehicle monitors located in exit pathways. A monitor's performance depends on its design, the characteristics of SNM and the operating environment, and proper monitor calibration and maintenance. Goals of ASTM Subcommittee C26.12 are to describe monitoring technology, how to apply it, and how to test its performance.

Key Words:

Radiation Monitor
SNM Monitor
Special Nuclear Material
Perimeter Security
Radiation Detection
Confirmation Measurement
Verification Measurement
Nuclear Safeguards

INTRODUCTION

The ASTM Subcommittee C26.12 on Safeguards Applications is developing performance standards for security devices that are used to prevent theft or diversion of special nuclear material (SNM) at the perimeters of material access areas or protected areas. The subcommittee's goal is to provide guidance for applying the devices, for maintaining them, and for evaluating their performance. At present, the subcommittee has made significant progress in developing standards for SNM monitors, which are radiation detection systems that sense the presence of SNM by detecting its radioactive emissions. This paper briefly describes radiation monitors for SNM monitoring and the subcommittee's progress in writing standards.

SNM MONITORS

SNM monitors offer an unobtrusive means to search for concealed nuclear materials as part of a material control or security plan for the materials. The monitors are intelligent radiation detection systems that measure ambient radiation background intensity and determine an alarm threshold from the result; during monitoring, they compare measured radiation intensities with an alarm threshold and sound an alarm if necessary. The monitors range in size and complexity from hand-held instruments used for manually searching pedestrians or vehicles to large automatic systems for monitoring pedestrians or vehicles as they pass through or wait for exit clearance. Each type of monitor comprises the essential components shown in Fig. 1: one or more radiation detectors; power supplies; signal conditioning electronics; an intelligent control and analysis unit; and devices that sense occupancy (for separating background measurement and monitoring periods) and communicate monitoring information.

Hand-Held SNM Monitors

Hand-held SNM monitors are small, battery-powered detection systems that owe their effectiveness to a conscientious operator. The operator manually triggers a background update, then searches for SNM by scanning the instrument over a pedestrian or throughout the interior of a motor vehicle. For maximum effectiveness, the operator tries to bring the monitor's radiation detector close to every location that may conceal SNM.

Hand-held SNM monitors (Fig. 2) look something like health physics instruments, but differ in using relatively large scintillation detectors for high sensitivity and digital alarm logic for unambiguous source detection. Commercially available hand-held monitors are available with one of two types of scintillation detector: sodium iodide or plastic. Sodium iodide scintillation detectors are used to detect gamma rays from unshielded SNM. Plastic scintillation detectors detect both gamma rays and neutrons, and their neutron sensitivity allows them to detect shielded plutonium in addition to unshielded SNM.

The detection logic in present-day hand-held monitors is microprocessor based and uses moving averages of 50-ms measurements to detect small amounts of SNM. The 0.4-s moving averages are continually compared with an alarm threshold as the operator rapidly (0.5 m/s) scans for concealed SNM by coming within 15 cm of possible locations. The instrument's alarm rate can be used by the operator to locate SNM precisely, which makes hand-held instruments useful for investigating alarms in automatic monitors as well. The instruments[1] are commercially available, lightweight, and rugged, with some able to operate for up to 60 h on rechargeable batteries.

Automatic Pedestrian SNM Monitors

Automatic pedestrian SNM monitors use very large plastic scintillation detectors in cabinets that form a portal (Fig. 3a) or that are positioned to surround a pedestrian being monitored (Fig. 3b). The monitors continuously monitor background radiation intensity. Background is suspended when a pedestrian is sensed by an interrupted light beam and monitoring begins. In a walk-through portal monitor, a pedestrian is continuously monitored as he passes through by comparing a sequence of moving averages of monitoring measurements with an alarm threshold. In a monitoring booth where a pedestrian waits for exit clearance, another form of sequential monitoring analysis can minimize the measurement time needed to achieve desired detection and nuisance-alarm probabilities. In either type of monitor (walk through or booth), an alarm sounds whenever the alarm threshold is exceeded, and each one must be investigated to locate any concealed SNM. To avoid unnecessary alarm investigations, automatic monitors are designed to have low nuisance-alarm rates from statistical variation in measurements or from background variation. Many types of automatic pedestrian monitors are commercially available and are also described in Ref. 1.

Automatic Vehicle SNM Monitors

Several types of vehicle SNM portal monitor and one type of vehicle SNM monitoring station are commercially available. These are described below and more thoroughly in Ref. 2.

Vehicle portal monitors

Commercially available vehicle SNM portal monitors (Fig. 4a) are similar to pedestrian monitors. They too have large plastic scintillators that form a portal and provide measurement data for continually monitoring the occupant, a vehicle in this case, that slowly passes through. However, a major difference in monitoring vehicles is that they are good absorbers of low-energy radiation. As a result, a monitor's background count rate significantly decreases when a vehicle is present, which diminishes the monitor's detection sensitivity. The decrease cannot be compensated because the amount of radiation absorbed differs significantly for varying sizes and types of vehicle. Hence, vehicle SNM portals are used where they need only detect large amounts of SNM.

Vehicle monitoring stations

Vehicle monitoring stations (Fig. 4b) are used where smaller quantities of SNM must be detected. High sensitivity is obtained by surrounding a vehicle with large plastic scintillators positioned as closely as possible and by monitoring a stationary vehicle for an extended period of time. A few detectors are located overhead to view the vehicle interior through the roof, which is usually relatively thin. Most of the detectors are positioned below the vehicle in the roadway. These detectors are divided into three groups that, together with the overhead fourth group, are treated as independent monitors. Sequential monitoring analysis of data from the four monitors minimizes the monitoring time, and if only background radiation is present, a consensus monitoring decision is usually obtained in an average of 20 s.

Neutron-Detection-Based SNM Monitors

SNM monitors that detect only neutrons are now becoming commercially available, and while they are not as sensitive to unshielded plutonium as plastic scintillators, they are more sensitive to gamma-ray shielded plutonium than plastic scintillators. Plastic scintillators sense fast neutrons, but they also sense gamma rays that predominate the natural background radiation. Gamma-ray background limits the detection sensitivity of a plastic scintillator for neutrons. On the other hand, a ^{3}He neutron proportional counter responds only to neutrons in the natural background. As a result, it has an extremely low background count rate and can have good sensitivity for detecting neutrons from gamma-ray shielded plutonium. A novel detector design with large, hollow, polyethylene moderating chambers that enclose a small number of proportional counters has made commercial neutron-detection-based monitors possible. The design has been applied in prototype neutron-detection-based pedestrian and vehicle portals (Fig. 5).

Although neutron shielding is possible, it would probably be used around a gamma-ray shield because a gamma-ray monitor would normally be used alongside a neutron monitor. Hence, a neutron shield would be relatively large. It would also have to be very thick to be effective because neutron-chamber detectors are undermoderated, and their sensitivity initially increases with shielding thickness. Hence, effective combined shielding would be large, heavy, and noticeable. Reference 2 discusses neutron monitoring further.

Other Types of SNM Monitors

Besides monitors for routine pedestrian and vehicle traffic, other types of SNM monitor are in use or being evaluated for other situations. One monitor uses timed coincidences between two plastic scintillators spaced along a sanitary sewer line to detect any plutonium leaving a material access area via that route. Another unusual monitor is a detection system for emergency exits that is intended to limit the amount of SNM that could be diverted during an emergency evacuation. A similar detection system can be mounted on the bumper of a pickup truck and used to scan fence lines for possible diverted material after emergency evacuations. Two types of package monitor are being evaluated: one monitors lunch-box-size packages that fit inside its detector array, and another both weighs and measures radiation intensity from a broad range of package sizes.

Finally, two types of hand-held instrument are now commercially available for verifying the contents of packages or other items that may contain SNM. One is a stabilized, microprocessor-based, gamma-ray scintillation spectrometer that verifies a particular type of SNM by measuring and stripping background from a characteristic peak region. The other microprocessor-based instrument verifies the presence or absence of plutonium using pulse-height analysis to monitor neutron interactions in a ^{6}Li(Eu) scintillator. In addition to being used for safeguards package monitoring and confirmatory measurements, the two instruments are being used for other applications: treaty verification; verifying that military test warheads are non-nuclear before being flight tested; and locating holdup in a uranium enrichment plant. Figure 6 illustrates these verification instruments that are further described in Ref. 3.

ASTM Subcommittee C26.12 Activity

The subcommittee has published one standard (a "Standard Guide for Applying Radiation Monitors to the Control and Physical Security of SNM," ASTM designation C1112-88) that describes radiation monitors, operational considerations for applying them, and general procedures for calibrating and testing them. The subcommittee is well along in developing standards for laboratory and in-plant evaluation of pedestrian monitor performance, and it has begun work on a standard guide for calibrating pedestrian monitors.

Summary

The state of the art of SNM monitoring is well developed, with readily available effective and reliable commercial equipment. The equipment is in widespread use at nuclear facilities both in the United States and abroad. ASTM subcommittee C26.12 is striving to make the equipment more familiar to users, to emphasize the importance of manufacturers providing sensitive equipment with low nuisance-alarm rates, and to encourage users to test and maintain their equipment in a manner that will produce the best performance.

References

1. P. E. Fehlau, "An Applications Guide to Pedestrian SNM Monitoring," Los Alamos National Laboratory report LA-10633-MS (February 1986).

2. P. E. Fehlau, "An Applications Guide to Vehicle SNM Monitors," Los Alamos National Laboratory report LA-10912-MS (March 1987).

3. P. E. Fehlau, "Rugged, Lightweight, and Long-Operating Hand-Held Instruments for Neutron and Gamma-Ray Verification Measurements," Proceedings of the 22nd Midyear Topical Meeting of the Health Physics Society on Instrumentation, San Antonio, Texas, December 4-8, 1988. (Los Alamos National Laboratory document LA-UR-88-2780).

Figure Captions

Fig. 1. SNM monitors comprise scintillation detectors, power supplies, signal conditioning and analysis electronics, microprocessor control and decision logic, and communication devices.

Fig. 2. Lightweight, rugged, and long-operating hand-held search instruments are useful as a primary monitoring system as well as for investigating alarms in automatic monitoring systems.

Fig. 3. Until recently, commercially available automatic pedestrian monitors have been limited to walk-through portal monitors. Now a number of manufacturers offer wait-in portals, and one facility has parallel monitoring booths in operation.

Fig. 4. Automatic vehicle SNM monitors have been commercially available for some time. They take the form of drive-through portal monitors and wait-in vehicle monitoring stations.

Fig. 5. Neutron-detection-based monitors are now becoming commercially available. The monitors are used alongside gamma-ray monitors to detect gamma-ray shielded plutonium carried by pedestrians or vehicles.

Fig. 6. Hand-held verification instruments measure specific SNM attributes that can confirm the presence or absence of nuclear materials.

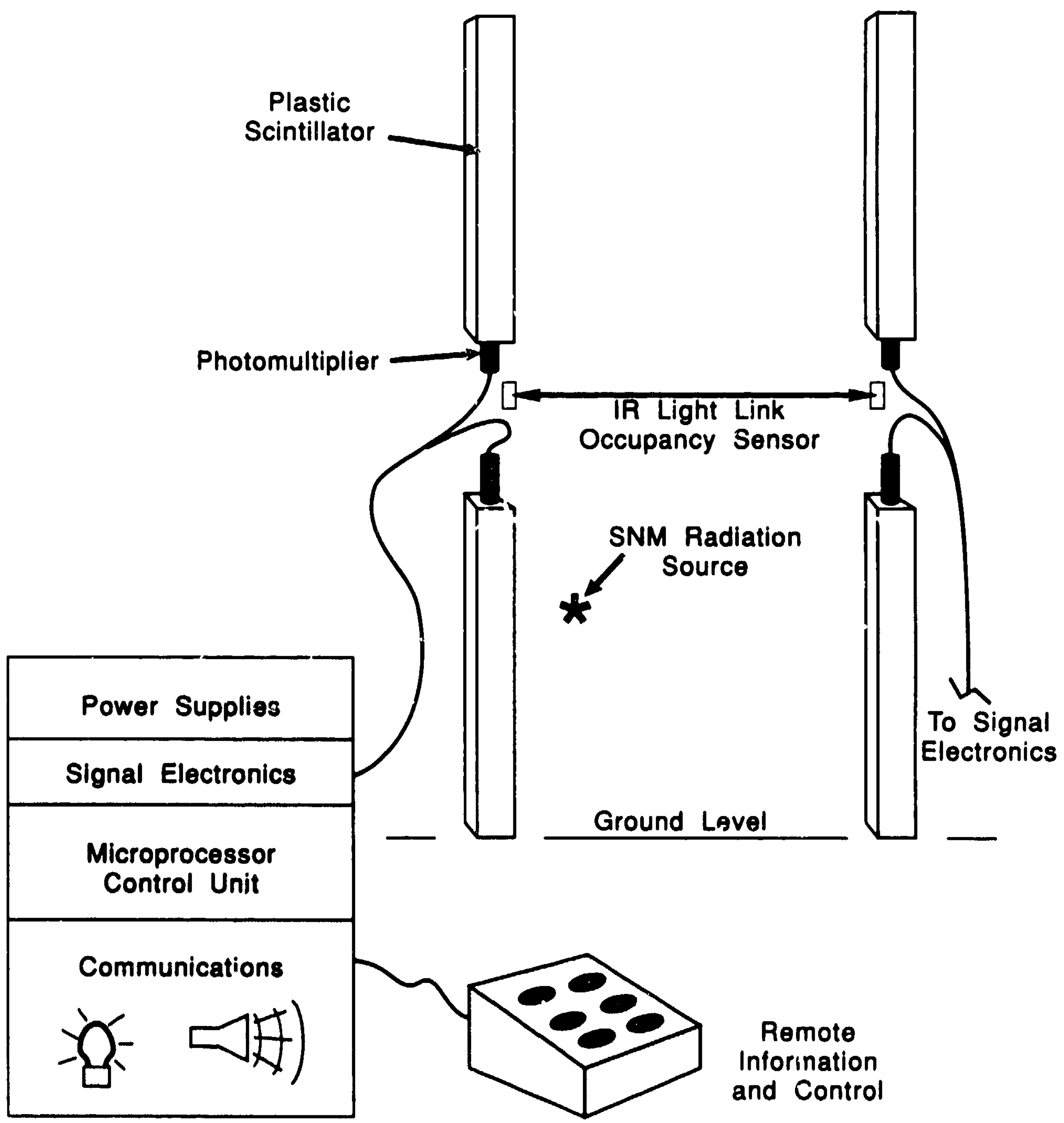
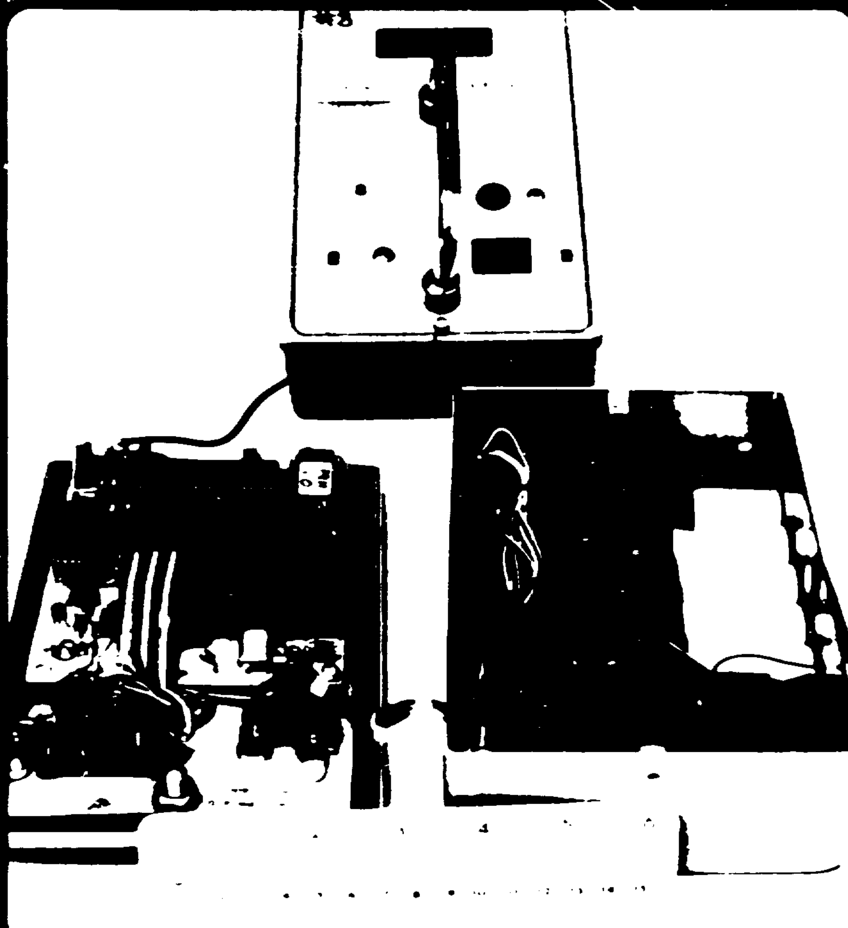

Plastic
Scintillator
Photomultiplier
IR Light Link
Occupancy Sensor
SNM Radiation
Source
To Signal
Electronics
Ground Level
Power Supplies
Signal Electronics
Microprocessor
Control Unit
Communications
Remote
Information
and Control

Fig. 1

Hand-Held SNM Search Instruments



Instruments

Operational Use

Advanced Nuclear Technology

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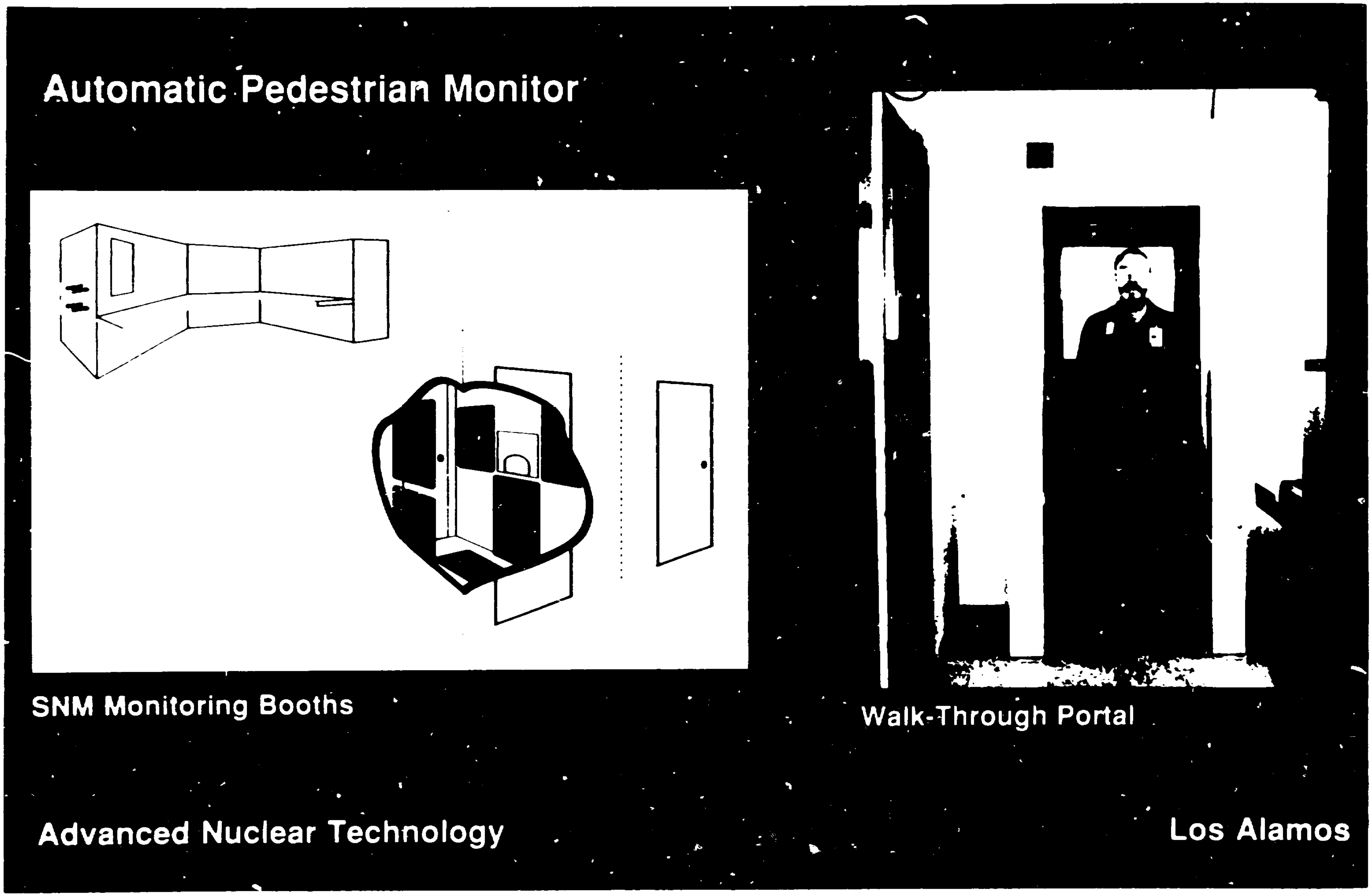
Automatic Pedestrian Monitor
SNM Monitoring Booths
Walk-Through Portal
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Fig. 7

Automatic Vehicle SNM Monitor

Drive-Through Vehicle Portal

Wait-In Vehicle Monitoring Station

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Neutron-Based-Detection Portal Monitor

- High sensitivity
- Low cost
- High credibility

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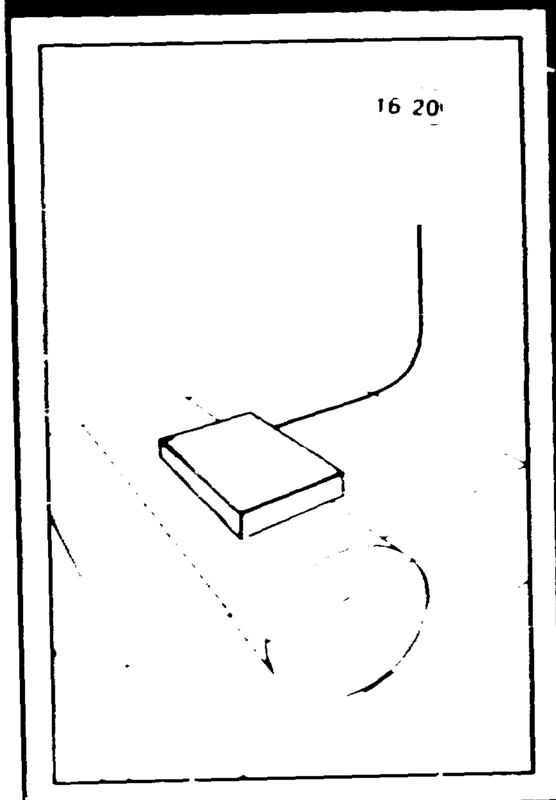
Fig. 5

Other Types of SNM Monitors



Fluid Line SNM Monitor

Non-Nuclear Verification Instruments

SNM Scan Car