LA-UR--83-3384

DE84 003842

CONF-840202--1

TITLE: HEALTH PHYSICS APPLICATIONS OF NUCLEAR SAFEGUARDS RADIATION MONITORS

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SUBMITTED TO: Health Physics Society
17th Midyear Topical Meeting
for presentation in
Pasco, Washington
February 5-9, 1984

HEALTH PHYSICS APPLICATIONS OF
NUCLEAR SAFEGUARDS RADIATION MONITORS

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ABSTRACT

Nuclear safeguards needs fostered the development of radiation monitors whose sensitivity and microprocessor-controlled logic permit detection of small, transient increases in environmental levels of gamma radiation. While this capability was originally developed to detect the diversion of the special nuclear materials ^{235}U and plutonium, adaptation to health physics monitoring is straightforward. Applications of the safeguards instruments range from small, hand-held instruments used to monitor laundry or salvage-bound materials to more complex systems devoted to monitoring moving vehicles at entry/exit points. In addition to these health physics applications, other new applications for safeguards instruments are being considered.

INTRODUCTION

Nuclear safeguards and security procedures require searching personnel, packages, and vehicles to prevent unauthorized removal of the special nuclear materials enriched uranium and plutonium. Searching, which takes place at the perimeter of nuclear material access areas, is the responsibility of the protective force. Because pat down or visual searches are time consuming and may be ineffective for lack of visual clues, specialized instruments were developed at Los Alamos to quickly search departing traffic by detecting the gamma rays or neutrons that are spontaneously emitted by nuclear materials. These specialized safeguards monitors differ from traditional health physics radiation monitors in two ways. First, they detect very small increases in radiation intensity from the transient presence of small quantities of diverted material. Second, they are intelligent instruments that can operate without the need for interpretation by the user. For example, monitors must allow protective force personnel with a minimum amount of specialized training to conduct sensitive searches for nuclear materials.

SAFEGUARDS RADIATION MONITORS

Intelligent safeguards monitors range in size from small, hand-held instruments to very large systems for monitoring motor vehicles. All of the monitors have the same basic elements

(Figure 1). The scintillation detector may be NaI(Tl) or a solid organic, plastic scintillator. In either case, the detector views a monitored region of space and may be shielded against unnecessary background from other directions. Power supplies and signal-conditioning electronics are scintillation-quality circuits. The detection-logic circuits tally detector counts falling in energy regions of interest; they depend on presence sensors to tell whether to accumulate background or carry out monitoring. Decisions during the monitoring periods are based on comparing monitoring measurements to expected values from background results. The particular decision algorithm may be quite simple in a hand-held monitor, a comparison of the measurement to its expected value plus a fraction of the value, but fixed monitors usually apply more complex decision methods. For example, they may use a sliding interval technique (Chambers et al. 1974) that matches a count interval to a particular time profile of a signal or a more recent hypothesis-testing method based on sequential probability ratio calculation (Fehlau et al. 1983). The results of monitoring are announced visually and audibly whenever the monitor detects a radiation source.

Examples of the different types of safeguards monitors range from the hand-held monitor being used to search a passenger car in Figure 2 to the

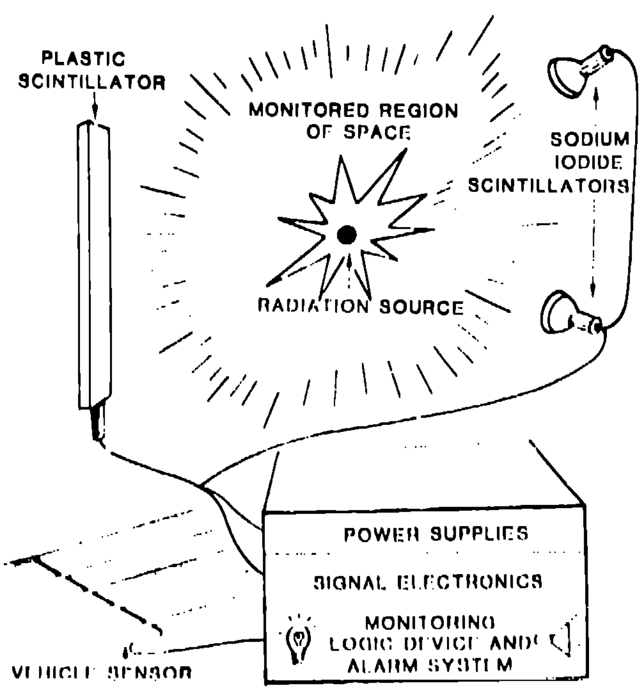

Figure 1. Four basic elements of a safeguards monitor are radiation detectors with power and signal-conditioning electronics, occupancy sensors, microprocessor logic circuits, and communicating devices.

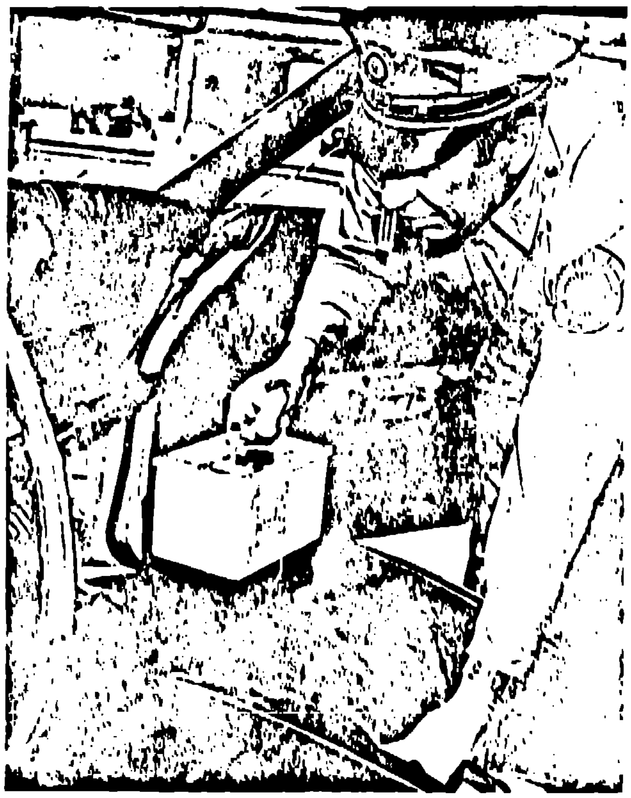

Figure 2. An operator must move a hand-held monitor around a search area; however, the monitor's portability makes it applicable to searching people, parcels, and vehicles.

personnel portal monitor in Figure 3 to the vehicle portal monitor in Figure 4. The hand-held monitor in this case has a 3.8-cm-diameter by 3.8-cm-long NaI(Tl) detector operated by battery-powered electronics. Its self-contained digital logic circuits count background on demand and establish an alarm level at about 1.3 times background intensity. Monitoring is based on 0.3-sec-long counting intervals during which the count is continuously compared to the alarm value. As soon as the counts exceed the alarm value, the audible signal sounds until the next count begins. Hence, the alarm alerts the operator to a nearby source and gives him an estimate of

Figure 3. Personnel portal monitors can monitor people walking at a normal pace. A switchmat or ultrasonic presence detector signals the controller when to start monitoring.

the radiation intensity by the duration of the sound. If the operator cannot locate the object precisely, a manual background update near the radioactive object allows him to pinpoint the object at reduced sensitivity.

Personnel portal monitors (Fehlau et al. 1979), which monitor people as they pass through at normal walking speed, were developed to avoid monitoring delays during shift changes. These monitors have a count period of 0.6 sec that corresponds to the time a person is in the portal. Two detector configurations are possible. One uses 8 to 14 detectors that are 5-cm-diameter by 2.5-cm-long NaI(Tl) scintillators; the other uses four detectors that are 13- to 27-cm-wide and 3.8-cm-thick by 1-m-long plastic scintillators. Power and signal-conditioning electronics are NIM modules as is the monitor's microprocessor control module. Logic comparisons are most often to an alarm level about 4 standard deviations above the expected background. Monitoring comparisons take place when a light link, switchmat, or similar occupancy sensor indicates that a person is present. During unoccupied periods, the monitor continuously measures and tests background. The upper test threshold prevents an operator from using the monitor when high background reduces its sensitivity. The low threshold announces loss of detector efficiency or shielding of the detectors. The detection sensitivity of these portals ranges from 0.8 to 3 μCi of ^{137}Cs passed through the minimum sensitivity region of the monitor at walking speed.

Vehicle portal monitors (Fehlau 1983) are recently developed instruments for monitoring motor vehicle traffic. Estimated passage speed

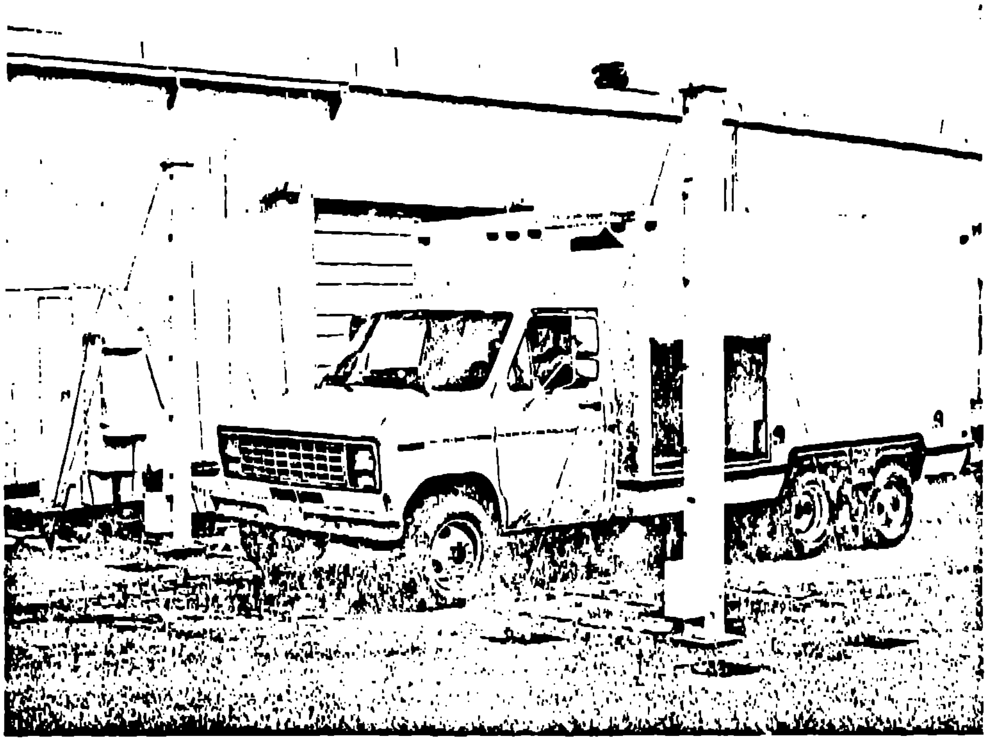

Figure 4. Vehicle portal monitors check moving vehicles as they pass through at about 8 km/hr. The monitor's controller interrogates the traffic sensors to sense and monitor outgoing traffic only.

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through these monitors is about 8 km/hr; to detect occupancy, there are traffic-control current loops in the roadway or switches attached to gates that open to admit vehicles. Radiation detectors similar to those in personnel portals are located near the ends of a 3-m-long vertical axis to provide surveillance of vehicles as tall as 3.4 m. NIM electronics modules are housed in an air conditioned electronics cabinet or other climate-controlled space. Communication with protective force personnel is by a separate control module (Figure 5) that has only the essential controls and indicator lamps. Monitoring decisions are made by a sliding-interval or sequential-logic program executed in a microprocessor. As in other monitors, detection sensitivity varies with ambient background, source geometry and shielding, passage speed, and precise source location in the carrier (Fehlau 1982). An estimated sensitivity for optimum monitor performance in the 22-μR/hr background at Los Alamos is about 8 μCi of ^{137}Cs.

HEALTH PHYSICS APPLICATIONS

Our initial application of safeguards technology to a health physics problem at Los Alamos helped to reduce the likelihood of someone accidentally removing activated target materials from the experimental areas of the Los

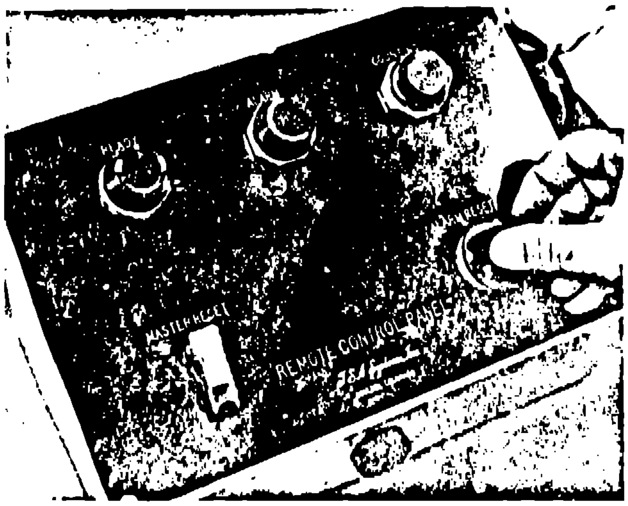

Figure 5. A separate control panel provides information and necessary switch selections to the operator without giving him access to tamper-safe electronics.

Alamos Meson Physics Facility. The method was to station hand-held monitors on tables near the doorways to areas containing irradiated material and near the doorways to areas where radioactive materials are prohibited (Figure 6). Persons transporting radioactive material are audibly alerted to the fact as they approach the doorway. A second check point was established at the vehicle exit to the Meson Physics Facility. This check point (Figure 7) measures radiation intensity as a vehicle, slowed by speed control depressions in the roadway, passes over a NaI(Tl) detector in the roadway. At first, a portal-monitor controller analyzed the detector's counting data, but rapid background variation from the accelerator's radioactive gas plume introduced too many false alarms for that method. A simple analog comparitor now rapidly tracks inputs from both the roadbed detector and a remote reference detector to obtain the accurate background

Figure 6. Hand-held monitors placed on tables near exit points notify individuals of radioactive materials they may have accidently carried out of experimental areas.

information in real time needed for constant detection sensitivity without unnecessary false alarms.

A second application of safeguards instruments to health physics resulted from the ability of the hand-held monitors to detect low-level contamination in routine monitoring procedures for possible contamination of an unknown type. Using the hand-held security monitors, health physics surveyors are occasionally able to identify slightly contaminated items after they finish their normal survey with instruments appropriate for the

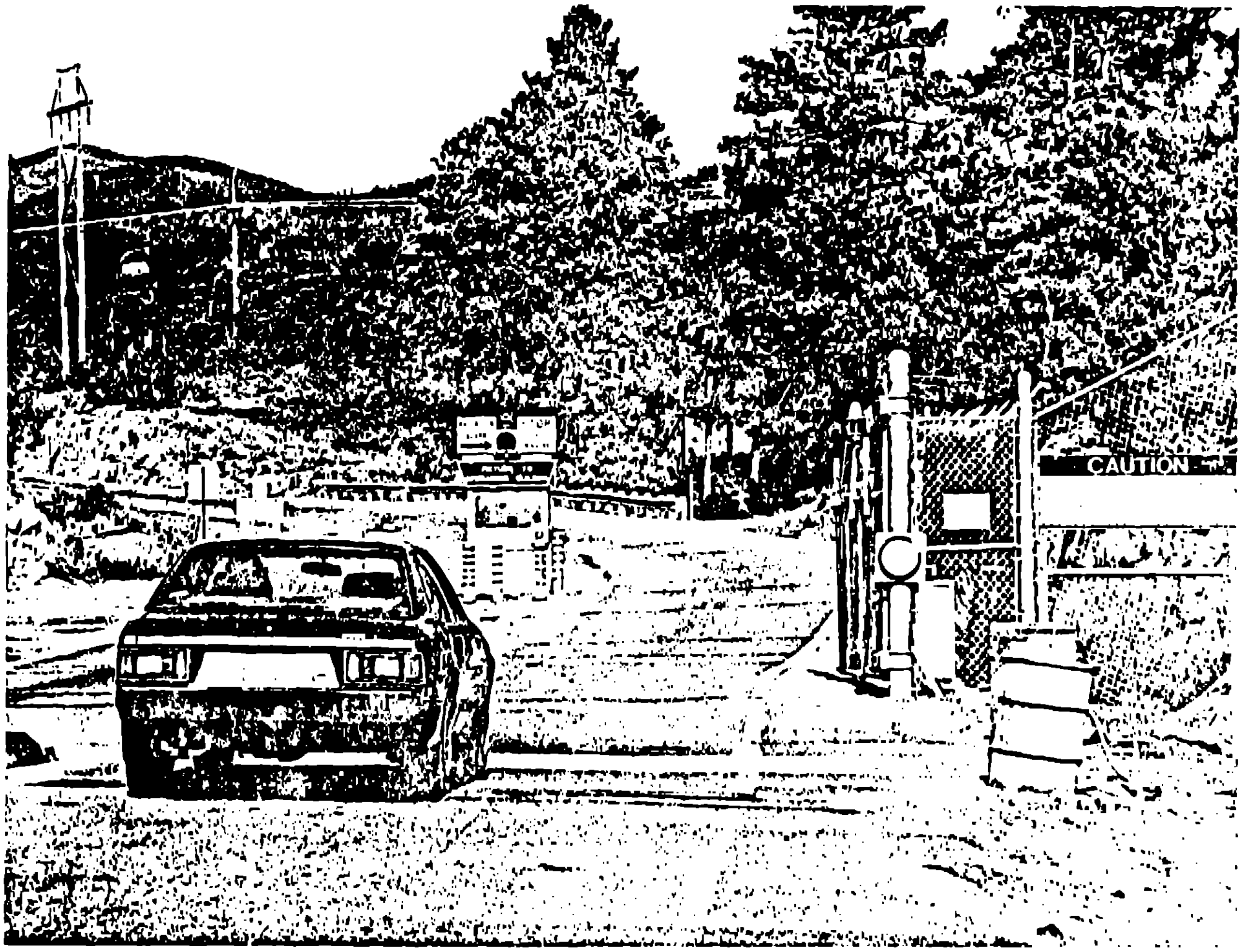

Figure 7. The vehicle check point provides a last look at departing traffic. At that station, vehicles are automatically monitored for radioactive material. If the monitor detects radiation, the vehicle occupants are notified to return to the operations area. A photograph records the encounter in sufficient detail to trace vehicles should they not return.

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expected type of contamination at a particular work site.

A developing application of the safeguards personnel portal monitors with their high sensitivity is monitoring for radioactive surface contamination at nuclear power plants (Littleton 1982). Standard versions of the monitors are being used at reactor sites to obtain a sensitivity of a few hundred nCi of ^{137}Cs on the body surfaces of people who pass through. Although safeguards monitors are not ideal for detecting contamination, a narrow safeguards personnel portal can, in a few seconds monitoring time, detect 200 nCi or better of mixed fission and activation products at the portal's midplane.

A final application of safeguards monitors focuses on vehicle portal monitors. Harshaw Crystal

Electronic Products has developed a monitor for hospitals to prevent radioactive trash from entering normal waste streams (McFarland 1981). The Harshaw system resembles a safeguards portal monitor but instead depends on a fixed ratemeter alarm point. A safeguards controller could both improve sensitivity and reduce false alarms with its background-following alarm level. An entire safeguards vehicle portal could perform the trash-monitoring task at a more central location in the waste stream such as at a landfill entry point.

NEW DEVELOPMENTS

Recently developed hand-held instruments for safeguards (Fehlau 1984) have been made smaller and lighter (Figure 8) by incorporating smaller detectors and power supplies as well as microprocessor logic. These instruments not only reduce operator fatigue but the smaller components also allow more separation between detector and electronics. For instance, one version of the hand-held monitor has a lightweight aluminum pole supporting the detector and high-voltage power supply at 3 m from the electronics package (Fehlau 1984). This pole monitor (Figure 9) is a convenient and relatively untiring way to provide high-sensitivity monitoring at a distance.

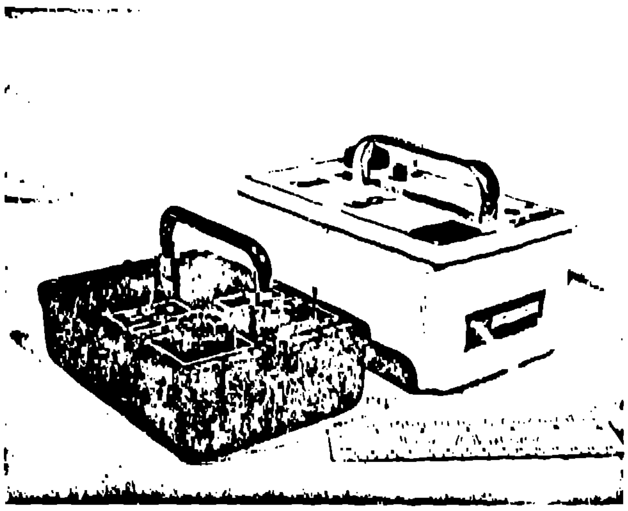

Figure 8. Newly developed monitors are much lighter and smaller than early models. Their light weight reduces operator fatigue and helps to maintain the effectiveness of hand-held monitoring.

MANUFACTURERS

The safeguards monitoring equipment is commercially available from manufacturers a the following locations. Bicron Corporation in Newbury, Ohio; CMS, Inc., in Goleta, California; Harshaw Crystal and Electronic Products in Solon, Ohio; National

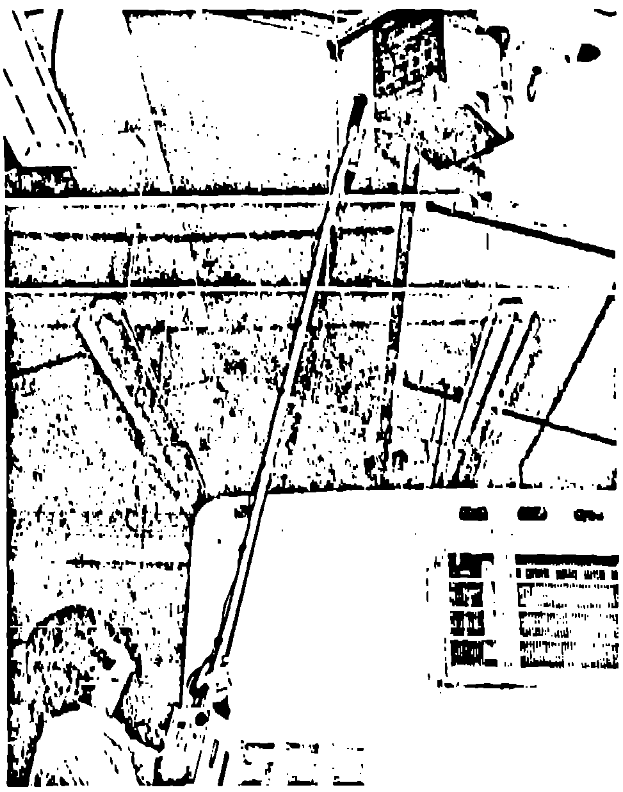

Figure 9. This pole monitor is a lightweight detection system for searching out-of-reach areas.

Nuclear Corp. in Mountain View, California; and TSA Systems, Inc., in Boulder, Colorado.[a]

ACKNOWLEGMENTS

We thank the present and past members of the Advanced Nuclear Technology Group at Los Alamos who have contributed to the development and evaluation of methods and intelligent instruments for safeguards radiation monitoring.

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