LA-UR- 95-1564

Conf-950512--151

Title: **Nonproliferation and Safeguarding via Ionization Detection**

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Submitted to: Symposium on Safeguards and Nuclear Material Management
Aachen, Germany
May 9-11, 1995

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NONPROLIFERATION AND SAFEGUARDING VIA IONIZATION DETECTION

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Abstract

A significant signature of the presence of special nuclear material (SNM) is ionizing radiation. SNM naturally decays with the emission of alpha particles, gamma rays, and neutrons. Detecting and monitoring these emissions is an important capability for international safeguards. A new detection method collects the ions produced by such radiation in ambient air. Alpha particles in particular are specific to heavy nuclei but have very short range. The ions produced by an alpha, however, can be transported tens of meters to an ion detector. These new monitors are rugged, very sensitive, respond in real time, and in most cases are quite portable.

1. Introduction

The assay of special nuclear material (SNM) is a key capability in the safeguarding and management of nuclear material. A common form of nondestructive assay is the detection of nuclear radiation. The radiation originates from decay of the SNM and is composed of alpha and beta particles, gamma rays, and neutrons. Radiation is detected in nuclear material management situations such as the detection of trace amounts of material (as in, for instance, contamination), the detection of diversion of nuclear material, and monitoring at portals and borders for SNM movement. Nondestructive assay can also provide evidence for proliferation activity.

Traditionally, the radiating particles are detected directly. However, it is possible instead to detect the ions these particles produce in ambient air. In the case of alpha radiation in particular there are special advantages offered by detection of ions. Traditional techniques for alpha detection have a number of limitations. Off-site laboratory analysis of field samples of SNM or material with traces of SNM can be fairly sensitive but logistics, cost, and especially response time are disadvantages to the method. Instruments for monitoring alpha radiation in real time are delicate, inflexible in application, and have poor sensitivity. These limitations are alleviated by detecting some of the 140,000 ion pairs produced as the alpha particle loses energy in the ambient air. Moreover, these ions travel much farther than the few centimeter range of the alpha particle - especially in electromagnetic fields or air currents. This long-range alpha detection (LRAD) technique therefore has greater sensitivity, quicker response, and a greater range. Moreover, the detection of ions is relatively simple given the sensitive ammeters developed today. Therefore instruments based on ion collection can be rugged yet fieldable.

Several scenarios will be considered for which the real-time detection of alpha and gamma-ray activity is especially beneficial. These scenarios include trace material detection, detection of material diversion, and portal and border monitoring.

Long-range alpha detection technology

Long-range alpha detection (LRAD) technology consists of detecting the ions produced in air by the ionizing alpha particles instead of detecting the alpha particles directly. The typical alpha particle emitted by SNM has an energy of 4 to 6 MeV. The energy lost by an alpha particle in ionizing an air molecule (generally N_2 or O_2) to produce an ion pair is approximately 35 eV. Therefore each alpha particle produces over 140,000 ion pairs. The ionized electron normally attaches quickly to another air molecule and so an ion pair consists of two large, charged molecules. The ion pairs can be transported to an electrode (Fig. 1).

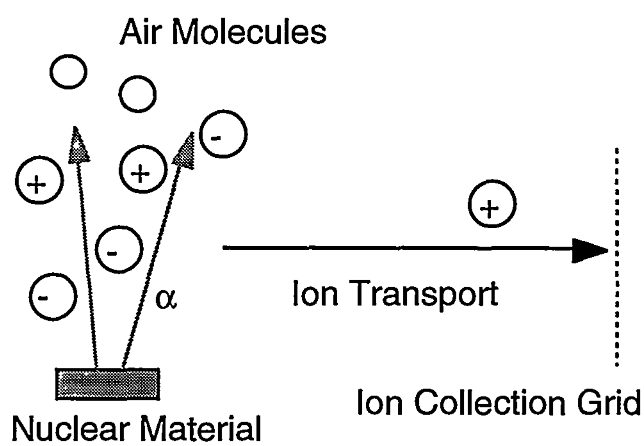

Fig.1. Long-range alpha detection via the ions produced in air.

One limitation of traditional fieldable detectors is range; the LRAD technique is limited by the range over which the ions can be transported (tens of meters) rather than the range of the alpha particles (a few centimeters). Ion range is determined essentially by the probability of recombination of ions with nearby surfaces. Depending upon the geometry of the detection situation, the measured lifetime for ions ranges from 5 seconds up to over 20 seconds /1,2/.

Another limitation of traditional fieldable detectors is sensitivity. With LRAD the charge amplification of 140,000 to 1 generally implies a better signal-to-noise ratio. Moreover while a fraction of an alpha particle cannot be detected, a fraction of the 140,000 ion pairs can be. Such a fraction would represent an alpha particle that has lost some energy (and may be below the threshold of a traditional detector) or would represent detection at a great distance - following recombination of some of the ion pairs.

LRAD technology other advantages over traditional detection. The electrodes comprising the ion detector can be virtually any size and can be sturdy. The signal processing consists of a small electrometer for measuring the DC current produced by the ions. Thus an LRAD itself can be very rugged yet portable.

The statistical nature of detecting 140,000 ion pairs rather than one alpha particle means that the response time of an LRAD-based detector is very quick - in some applications less than a few seconds. Most applications measure only the DC current from the collection electrode produced by the ions - on the order of femtoamperes (fA). Different realizations of LRAD technology, however, are under consideration /3/. In particular, low-noise detectors have been prototyped which count pulses of current due to individual alpha decays /4/.

The characteristics of an LRAD of long range, quick response, ruggedness, and simplified electronics make for an alpha detector that is easier to operate - and less operator dependent - than a traditional field monitor.

The technology of detecting air ions applies to other ionizing particles. Alpha particles are preferentially detected, however, since beta, gamma, and neutron radiation deposit less energy per unit distance in air per unit incident energy. We will also consider in this paper an application for detecting gamma rays.

Ion transport

Two methods have been developed for transporting the ions from the path of the alpha particle to an ion detector. Fig. 2 is a schematic of an electrostatic detector based on LRAD technology. A large potential applied to the signal electrode creates an electrostatic field that permeates the active volume of the detector and acts to separate the ion pairs immediately, reducing the amount of recombination. Ions of the appropriate polarity are collected on the signal electrode (normally a solid plate /5/); both polarities of bias voltage work equally well. This method of ion transport is most appropriate when monitoring flat surfaces such as soils, floors, walls, and liquid surfaces. The signal electrode can be brought close to - and equidistant from - the surface (Fig. 2). Externally-induced air currents are eliminated in order to reduce the 10^7 ions/cm^2 typically carried in ambient air.

Uses of this technology in safeguards and nuclear material management are discussed below, including contamination measurements of surfaces and smears, and monitoring of liquids and for gamma rays.

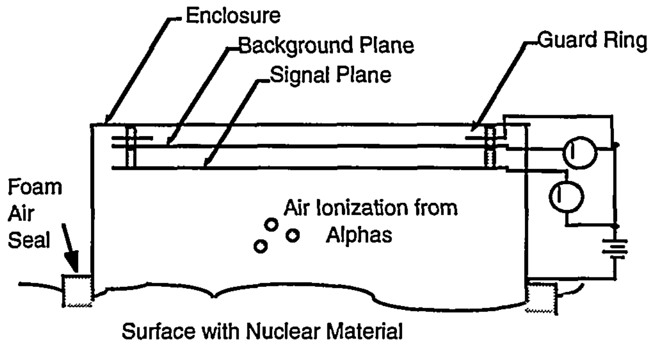

Fig. 2. An electrostatic LRAD as a (soil) surface monitor. No airflow is required in this LRAD. The ions produced by emitted alpha particles are electrostatically attracted to the signal plane. The ion current is read out by the electrometer. The guard plane reduces leakage currents through the electrometer by a factor greater than 10^5.

The alternate method of ion transport involves entrainment on air currents (Fig. 3). The air passes through a particulate filter which removes large particles and decouples air currents inside the LRAD from air currents outside. The air passes through a simple electrostatic filter which removes any ions already present. The filtered air that flows uniformly through the chamber collects any ions generated by sources of alpha particles within the chamber. Because air must flow through the ion detector, the electrodes are in the form of wire mesh or grids. The flow of these ions to the case of the enclosure is measured by a sensitive electrometer. A manifold of fans draws the air through

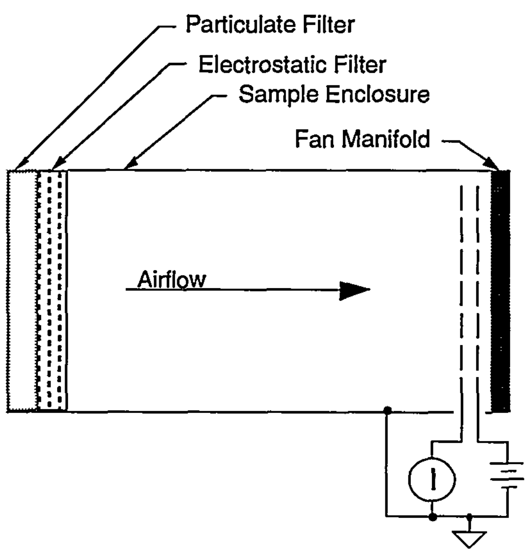

Fig. 3. Schematic of an airflow LRAD in an object monitor configuration. Filtered ambient air is drawn over the object to be monitored (not pictured) by the fans. The ions produced by emitted alpha particles are

collected on the first grid, and the current created by the ions is read out by an electrometer.
the chamber. Certain commercial furnace filters work well for particulate and electrostatic filtering. In connecting a bias voltage, either polarity works equally well. Fig. 3 shows a positive bias that will attract the negative ions and force the positive ions onto the signal grid. The detector illustrated detects only one polarity of ions, although both are present /6/.

The airflow approach works well on objects with complex shapes for which air flowing around or through the object collects ions produced by alpha particles emanating from any surface - including interior surfaces and the inside of cracks. LRAD-based detectors utilizing air flow can also be adapted for applications in which the object under study forms the enclosure; for example, the inner surface of pipes /2/, ducts, and even gloveboxes /7/. Moreover, with suitable appropriate filters these detectors can serve as room ionization detectors, air-borne contamination monitors, or radon detectors.

3. Trace material detection

Surface monitoring

Contamination of surfaces is possible as an adjunct to regular handling of SNM. If the contamination level is high, it can be detected with conventional alpha particle monitors. Detecting lower levels of contamination conventionally is more difficult.

Direct measurements. LRAD technology is uniquely suited to measuring alpha contamination dispersed over surfaces. The electrostatic LRAD monitor (Fig. 2) is used in an open-bottom configuration (in many different sizes) for direct monitoring of the surface. Advantages of an LRAD-based surface monitor for checking walls or floors (or ceilings) is that the alpha-emitting contamination might itself reside in cracks in the material. The alpha particles may not get beyond the surface in such cases, yet the electrostatic field of an LRAD-based monitor can pull the air ions onto the collection plate of the monitor. A coating of paint might cover the contamination - unless the paint is chipped or peeling.

All the surface monitors operate with a 300 V bias. This voltage is chosen to balance the plateauing of the detector response with the need to supply the voltage with small, stable, long-lived batteries. A reading of one femtoampere (10^{-15} A, or 1 fA) corresponds to 6 disintegrations per minute (dpm) of ^{239}Pu, as determined by National Institute of Standards and Technology (NIST)- traceable sources. The response varies as the average energy of the alpha particle. Linearity of the response has been measured from 100 dpm to 300,000 dpm and is excellent. The guard rings (Fig. 2) reduce leakage currents through the electrometer by a factor of at least 10^5 /5/.

Results are normally presented in units of dpm/ 100 cm^2 as per U.S. regulations. For soils or concrete, it is possible to report activity in units such as pCi/g if assumptions are made about alpha particle range in the material and the material density.

Three monitors have been constructed and operated for environmental remediation projects. Two 1-m by 1-m by 20.3-cm soil surface monitors, each weighing about 136 kg, are mounted on the front loaders of separate small farm tractors. These are used almost exclusively for monitoring the surfaces of soils. Currently, each tractor is operated only to move its detector and does not run while measurements are being taken. A smaller 0.5-cm by 0.5-cm by 15.25-cm monitor is mounted on a handtruck. For either size of detector, the data acquisition electronics are left attached and running and so the set-up time consists of positioning the monitor at either a suspect location or at a point on a pre-established survey grid. Data collection times vary from 5 to 15 minutes at each location, depending on the sensitivity desired. A background reading is obtained by taking a measurement with the monitor placed on a thin aluminum plate. This background is due to the normal LRAD backgrounds from cosmic ray penetration of the monitor, leakage currents, and electronic noise. The background reading is subtracted from the direct surface readings. The detectors have an additional plate for the subtraction of background such as radon /8/.

An entire large LRAD surface monitor, including data acquisition and display computer, is powered in the field by its own automotive battery and DC-to-AC converter. Each tractor can be stored and transported in a trailer outfitted with minor modifications to handle this task.

It must be kept in mind that an LRAD surface monitor measures only alpha-emitting contamination in the surface layer of the soil (or other material), because the alpha particles must penetrate any overhead soil and then produce ion pairs in the air. This penetrable depth of soil is approximately 36 µm for typical alpha particles of about 5 MeV, but the depth depends somewhat on the composition and porosity of the soil being monitored.

Reproducibility in repeated readings of an LRAD soil surface monitor at the same location is currently 8% depending largely on ground moisture (such as morning dew). Another cause for variation - which is under operator control - is the degree of sealing between detector and ground.

Existing LRAD soil surface monitors have been operated in the field - within the laboratory site, within New Mexico, and elsewhere in the U.S. An independent comparison of soil monitoring technology is ongoing at the Uranium in Soils Integrated Demonstrations at the Fernald Environmental Management project in Ohio. A private company is now using one of these detectors commercially.

The handtruck-mounted surface monitor has been fielded at a blasting pad at Los Alamos National Laboratory and on calibration pads at Grand Junction and Grants. The calibration pads consist of cement mixed with known amounts of radioisotopes. The blasting pad is an old asphalt pad left from the Manhattan Project. The LRAD data were taken on the staggered grid points shown in Fig. 4. The grid points are at intervals of 3 and 1.5 meters. Interpolation with the graphics software is again used in generating the shaded areas. (The rectangle at the middle of the left side represents a concrete pit.) For comparison, at the hotter spots indicated by the LRAD surface monitor a hand-held Ludlum 139 alpha survey meter was used. In Fig. 4, the Ludlum data are shown at the proper locations in terms of boxed numbers representing counts per minute. Due to its low response rate and small monitoring area (4.4-cm by 17.8-cm) it is difficult to calibrate the Ludlum against the LRAD. However, relative response over the locations measured is similar for the two technologies. Both technologies find two spots on the pad which are above background levels.

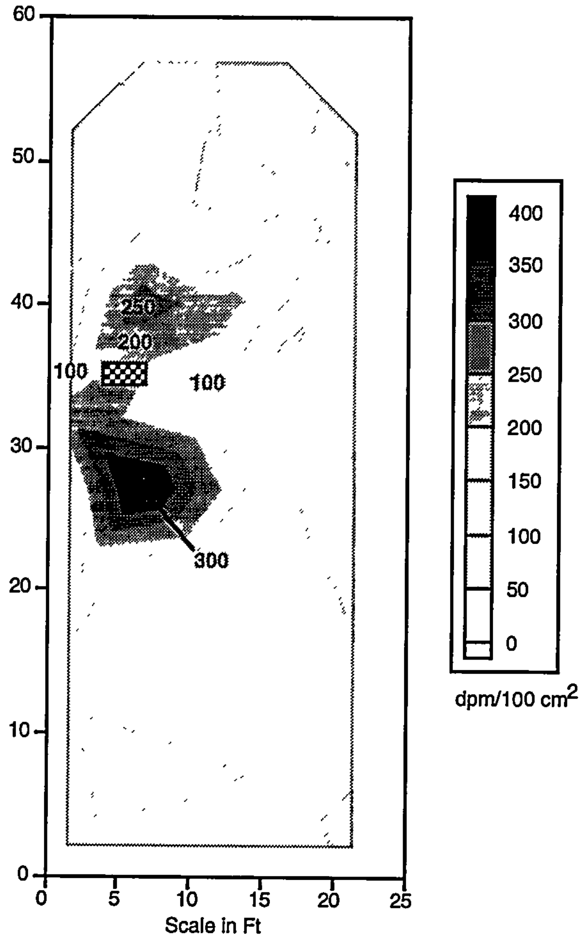

Fig. 4. Comparison of small surface LRAD monitor with spot results from a conventional hand-held survey meter Results obtained on an old blasting pad at Los Alamos National Laboratory.

Smaller surface monitors (Fig. 5) have been prototyped and tested in the field at calibrated pads at Grants, NM, and at a Decommissioning and Decontamination project at Los Alamos National Laboratory /9/. Results of such a detector are graphed in Fig. 6. A smaller, lightweight prototype with a footprint of about 15 cm by 20 cm and a weight of approximately 5 kg is under development for on-site nonproliferation inspections. This will be more than a scaled-down version of the larger monitor - issues include making the monitor lightweight yet sufficiently sturdy to avoid flexion of the chamber during use. Additionally, the air seal and the electrical grounding must be adequate for such a lightweight instrument. If the surface is a poor conductor, the prototype LRAD monitor can be affected by capacitive coupling to the outside of the monitor. It is possible to alleviate this problem. Lastly, the measurement and display of the ion current must be portable and user-friendly.

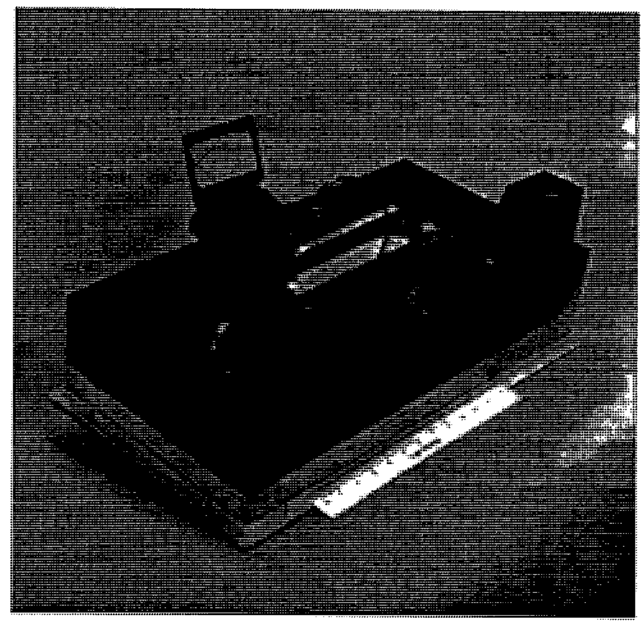

Fig. 5. Small surface monitor used in decontamination and decommissioning projects at Los Alamos.

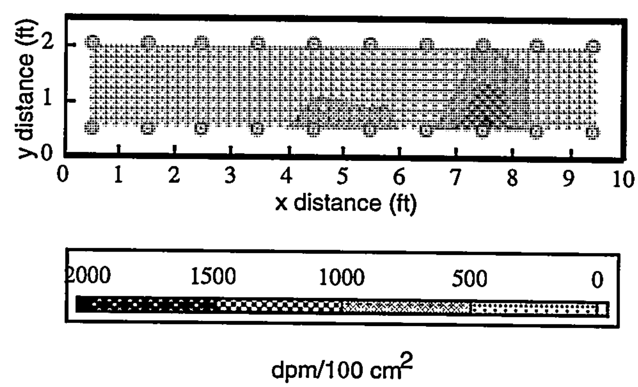

Fig. 6. Contamination levels on a stainless steel countertop at Los Alamos. Comparison data have not yet been taken..

Indirect measurements. We note that it is possible to obtain a sample of a surface (especially for soils) and spread the sample in the bottom of an electrostatic monitor. A detector has been discussed elsewhere /10, 11/.

For more general indirect measurement of surface contamination, the conventional method is to take a "swipe" or "smear" over the surface with a piece of cloth called a swipe. This is necessary in cases for which the surface is convoluted (such as around a gas or liquid valve). This operation can serve to concentrate contamination on the swipe - but will miss contamination fixed to the surface. The conventional monitoring of the swipe itself then involves a large, shielded detector to attain low background and high sensitivity. An LRAD-based electrostatic monitor, however, is portable and simpler to use. The swipe is placed on the bottom of a closed chamber that is otherwise similar to that depicted in Fig. 2. Compared to its larger cousins, such a detector has low background because of a smaller volume and better elimination of outside air.

In testing of a prototype portable swipe monitor, measurement issues relate more to the process of swiping than to the monitoring of the swipe in the LRAD-based detector /12/.

Portable object monitor

Traces of SNM on objects can prove difficult to detect. The surfaces of an object can be sampled via swipes - if the contamination is loose. The traces may, however, be fixed - or left in grooves or cracks and on other interior surfaces even after an attempt has been made to clean the object. Air flowing around the object will collect the ions resulting from alpha particle emission even if the alpha particles never get beyond the exterior surface of the object. An LRAD-based object monitor which uses airflow for ion transport can thereby monitor more of the object surfaces simultaneously.

A portable object monitor has been developed for the U.S. Department of Energy for on-site nonproliferation inspections /13, 11/. The current prototype (Fig. 7) fits into a metal briefcase for transporting by hand or can be worn off the shoulder. In laboratory tests, it can detect total alpha activity of less than 50 dpm on an object. A clear response is obtained after tens of seconds.

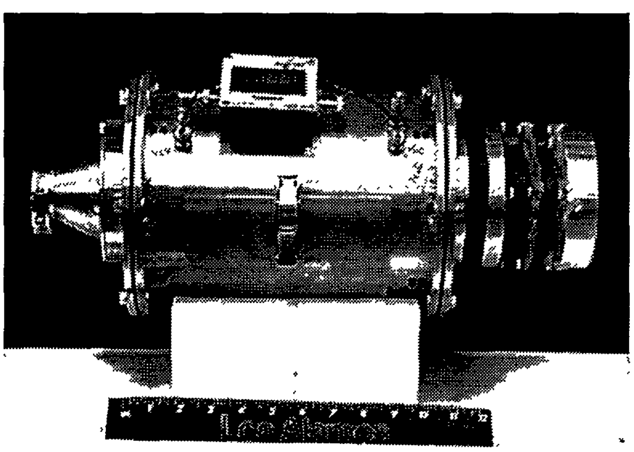

Fig. 7. Portable object monitor. Objects are placed within the detector and air is drawn across the objects. Nuclear material creates ions in the air current via alpha decay.

A large object monitor based on airflow LRAD technology is produced commercially /14/.

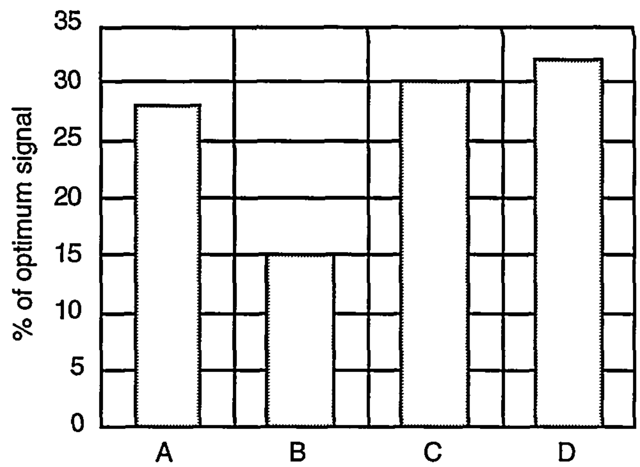

Fig. 8. Response of POM to an 1100 dpm Pu-239 source within different objects, relative to the response to the bare source. The source is placed in a hole inside an aluminum block, without (A) and with (B) a cap over the source. The source is also placed within (C) a square aluminum tube and (D) a mock NIM module.

Barrel monitoring

Barrels at a storage facility will contain nuclear material or might contain process waste. If the barrels are cracked or otherwise damaged, the damaged areas of the barrel are prime locations to check for leaks of SNM. Swipes can be taken, and monitored with an LRAD swipe monitor. A hand-held surface monitor could be placed on the surface of the barrel. The barrel could be placed in a generic LRAD-based object monitor. These LRAD-based monitors have been discussed above. Alternatively, a barrel monitor optimized for such a purpose could be constructed. The monitor would be similar to an object monitor except perhaps without the airflow implementation /15/. A conductive outer container, for example, could form one of the electrodes in an electrostatic design, for increased efficiency over airflow designs.

Personnel monitoring

Trace amounts of SNM contaminating personnel can be difficult to detect. Resultant ions, however, have been detected in some instances. Conceivably, diversion of SNM by personnel carrying material from the facility might be detected as well; however, conventional portable monitors are better suited for the detection of this bulk material via gamma rays or neutrons.

Two prototype LRAD monitors have been constructed for monitoring personnel in plutonium processing facilities. These portable monitors can also be used for monitoring personnel in an inspection. Each LRAD monitor is an airflow design - one just large enough to monitor a hand, the other in the form of a pipe which can monitor an arm. The airflow implementation is ideal for picking up contamination on any surface of a hand or arm. Traditional "frisking" monitors are unlikely to register alphas emanating from contamination under the fingernails or between the fingers, for example (although gamma-ray detectors might work). Such "out of the way" places are likely locations for contamination to collect and not get properly washed away.

It is also possible to monitor a whole person in a very large airflow LRAD monitor /16/. Such an monitor would essentially be a telephone-booth sized object monitor. A fan manifold serving as the top of the chamber would draw air through the chamber, over the individual and the clothes and objects on his person. The ion collection grid would be placed just underneath the fan manifold, to catch the ions drawn from alpha emission from all surfaces in the enclosure. The air intake would be provided by a filter in the floor of the booth.

Considerations in monitoring personnel have been presented in more detail elsewhere /11/.

Air monitoring

Monitoring for air-borne contamination is certainly a personnel safety issue but not much of a consideration for safeguards. The topic has been discussed in applicatoins to nonproliferation /11/ and a prototype is under development. This section will address only capabilities of an LRAD-based detector according to filtration.

An object monitor with an ideal filter on the air intake and no object within is a radon monitor. Radon decaying within the detector chamber will be detected. LRAD-based detectors have been used for such a purpose and developmental work indicates that an optimized radon detector might be the best real-time radon monitor to date /17, 4/.

Airborne contamination by actinides is generally borne on particulates. Such contamination will be detected in an LRAD airflow detector if filtration on the air intake is imperfect yet removes any charged particulates (i.e. ambient air ionization). The actinides which alpha decay within the monitor will be detected. This method is attractive as the monitor is generally able to withstand any corrosive gases (as possibly within an air stack) and may work at high air-flow rates. The signal component due to radon in the air can be determined with a radon monitor collocated in series or parallel.

If there is no filtration on the intake of an LRAD-based air monitor, such a monitor will see any ions reaching the collection grid from the immediate area in addition to radon and actinides decaying within the detector. This ambient ionization may be due to radon or air-borne actinides near the detector, nuclear material on nearby surfaces - or, of course, myriad ion sources unrelated to nuclear material, such as combustion products. Two situations where this measurement may actually be useful are discussed below: vehicle monitoring at checkpoints and intrusion monitoring in vaults.

4. Diversion of nuclear material in waste streams

Solid waste monitoring

Diversion of SNM by "throwing it away" in the trash is a safeguards concern. Bulk material (such as trash) leaving a facility must be monitored by passage through portal monitors. The nuclear material can be expected to be concealed (shielded) within other solid material and so alpha detection will not be useful. Gamma-ray detectors and neutron detectors need be utilized.

Liquid effluent monitoring

Monitoring of liquids for special nuclear material is more important for detecting diversion than for contamination concerns. The chief scenario is that of nuclear material thrown into liquid effluent. A real-time, unattended, alpha detector is needed for this task if its sensitivity is competitive with an appropriate gamma-ray detector.

An electrostatic, LRAD-based liquid monitor detects alpha emitters at or near the surface of the liquid. The ion collection apparatus is situated above the liquid. A prototype (Fig. 9) has been tested at a Los Alamos National Laboratory waste processing facility /18/. The radioactive liquid used in the test had an alpha activity of 280 pCi/liter as determined by independent analysis to a level of ±40 pCi/liter. (This level of contamination represented 1/150 the typical level of activity for liquids at that facility.) The LRAD detector noted a level 3.5 times the background level, with 1% sensitivity. In repeated sampling, the average signal was 4 times the background level, with a deviation of 4%. No activity above background was left on a sample tray after the measurements. Given these results, the sensitivity of an LRAD liquid monitor in that environment could be

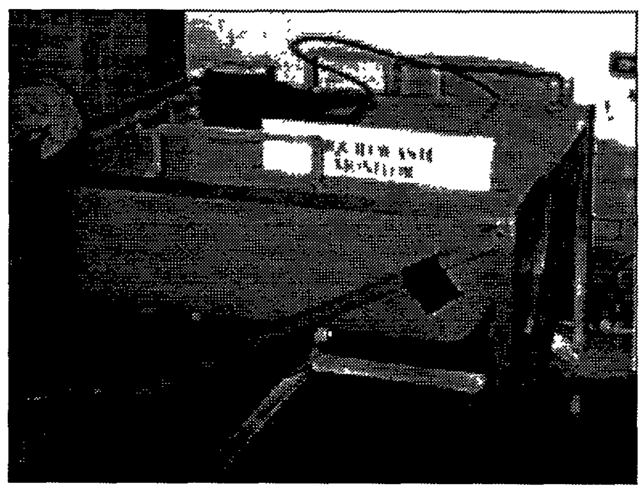

Fig. 9. A prototype liquid monitor for radioactive waste. The monitor can be used to detect the diversion of nuclear material in liquid waste streams.

conjectured to reach 70 pCi/liter for stable monitoring situations. In flowing liquid an brief increase in alpha activity due to nuclear material would be evident as a spike in detector signal.

The continuous flow of liquid raises the issue of splashing as well as condensation, although these issues are tenable. The chemistry of the liquid is unimportant unless there is a large amount of beta emitters in solution or the liquid is highly corrosive. Also, extreme differences in density of the liquid could affect the detector response - increasing density would mean that less depth below the liquid surface would be monitored.

5. Portal and border monitoring

Large gamma-ray activity

In order to note the movement of nuclear material into or out of a facility, a gamma-ray monitor could be placed nearby. Normally, this would be considered portal monitoring, and traditional, efficient scintillating detectors would be used. If cost and reliability are a factor, however, traditional portal monitoring has a high unit cost and must be maintained periodically by personnel. Alternatively, it might be useful to place a detector at a border checkpoint, or at a train station (Fig. 10).

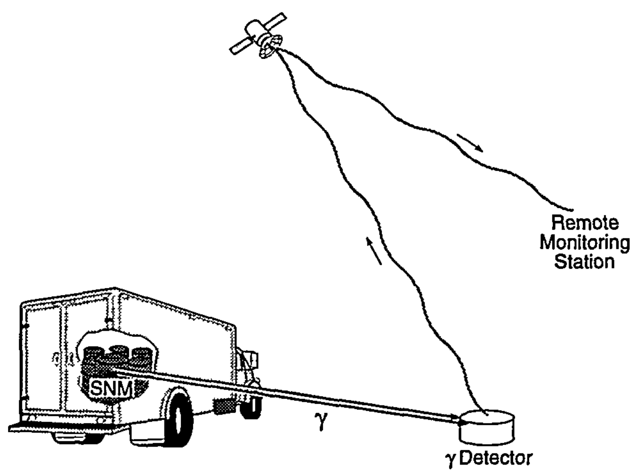

Fig. 10. Conceptual view of gamma ray monitoring at borders or other checkpoints. At the site depicted, the monitor is unattended and so alarms due to nuclear material passing nearby are relayed via satellite to remote stations.

A gamma-ray detector based on LRAD technology could be very useful in long-term, unattended monitoring. Such a detector works by collecting the ions produced in photon interactions in the walls and in the air within the detector. The key advantage of the LRAD-based gamma detector over the conventional gamma-ray detector is ruggedness and durability. Since the LRAD detector is not composed of a photomultiplier tube or a sensitive and expensive crystal, it can be mass produced inexpensively and left in unforgiving terrain. At remote border crossings, the low power demands of the detector are a useful feature. An easily achievable scenario would involve placing (perhaps even concealing) the gamma-ray monitor in an area where there should not be any movement of nuclear material. The monitor would take data continuously and send it to a receiver where the baseline could be monitored. Any large increase in signal would easily be detected and would help to provide proof that nuclear material was being moved.

An LRAD-based gamma detector would be a large cylindrical electrostatic detector with the walls of the cylinder acting as one electrode and a rod along the axis of the cylinder acting as the other electrode. The advantage of this configuration would be to maximize the volume of the detector while minimizing the distance the freed ions would need to drift before they were collected. The thickness of the metal walls would be maximized for a number of reasons. First, the thicker walls would lead to a more durable detector. Secondly, the thickness of the walls would correspond to the maximum range of the electrons generated in the walls. By having the walls thicker but not larger than the maximum range of the electrons, the number of electrons generated and collected in the detector is maximized.

A test was conducted at Los Alamos in 1994 by placing an LRAD large object monitor at known distances ranging from 300 m to 1.6 km, and running a critical assembly to different power levels as a source of gamma rays. Also included in the test was a comparison between the substitute gamma-ray detector (based on LRAD technology) and the established detection capabilities of a sodium iodide (NaI) detector.

It must be noted that the detector used in the gamma tests, is not the most efficient detector that could be designed using LRAD technology. In fact the large object (airflow rather than electrostatic) monitor utilized for the test is usually used to minimize contaminated waste streams /19/.

Locations for the detectors were chosen for their distance from the critical assembly as well as whether there was a direct line of sight from the critical to the detector or whether the line of sight was blocked by earth (rock, trees, etc.) Having the detector at a non-line of sight location meant that the signal was mainly due to skyshine, the redirection of radiation by scattering events in the atmosphere. The data from both the NaI and the LRAD monitor (current in femptoamperes) were normalized to a current (10^{-5} RAP A) in an ionization chamber located next to the critical assembly that is used to measure the criticals power level and thus the total output fluence. The detector response is plotted as a function of distance in Fig. 11.

The characteristics of the curves for both the LRAD and the NaI detectors are similar in nature for the skyshine locations, with only a slight difference at distances less than 500 meters. Insufficient data had been taken for line of sight locations to draw conclusions on relative response vs distance, partly because of a lack of locations at large (>600 m) distances due to the geographical nature of the area.

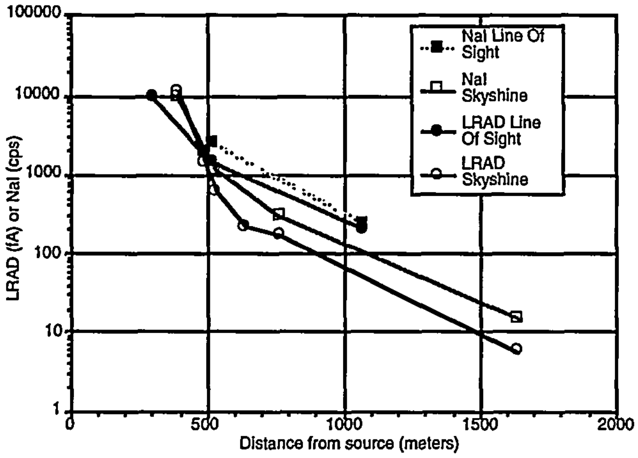

Fig. 11. Response of a mock LRAD gamma-ray monitor and a NaI detector at different distances from a gamma-ray source (a critical assembly).

Transportation vehicle monitor

Trucks or other vehicleswith cargo bays might be inspected at checkpoints for the presence of (or traces of) nuclear material. In addition to the gamma-ray monitor described above, an LRAD-based air monitor might be used to check the gross ionization or any airborne nuclear material in the large cargo volume. The truck may be empty, or full of cargo. Interestingly, the cargo might include produce from fall-out regions.

Options for such measurements include grabbing an air sample, or sealing off or simply shutting a monitor within the volume for a few minutes to draw multiple chamber-fulls of air (as illustrated in Fig. 12). This is one of the more straightforward applications of gross ionization monitoring, once a standard range of ambient ionization within vehicle volumes is known. There would be little additional sources and sinks of ions (such as people or operating electrical equipment).

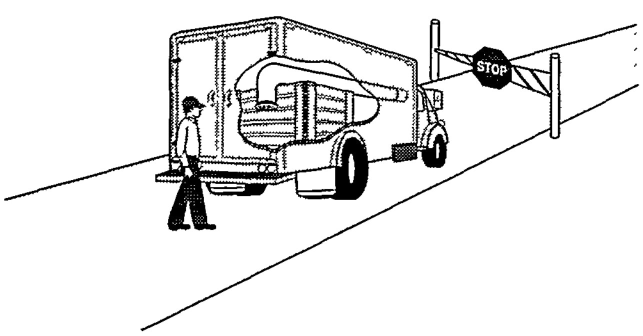

Fig. 12. Conceptual drawing of truck monitoring. The gross ionization detector is placed briefly within the open volume of a cargo space. Air is circulated through the chamber. Ideally, if alpha-emitting nuclear material is located on any surfaces within the volume, the equilibrium ion concentration will be greater than typically found.

A careful benefits analysis relative to other radiation detection measurements is necessary before real development of such a monitor is undertaken.

Storage vaults

A gross ionization monitor within a storage vault would act as an intrusion device. Given that the ion concentration in the air within a sealed vault is fairly stable, an ion monitor will immediately register a breach in the seal because of the 10^5-10^7 ions/cm^3 that would rush in with the outside air. An LRAD air monitor without input filtering is capable of this, as it can easily see a point source of 100 dpm - or 1.4 x 10^6 ions within a volume of 6000 cm^3. The LRAD air monitor would be coupled to a radon monitor, as the major component of a background signal would be the varying level of radon present.

Personnel monitoring

Generally, personnel are often monitored for gamma ray and neutron emitters at a portal monitor upon entering or exiting a facility. Sometimes hand-held probes are used to search for alpha emitter contamination as well. A sensitive alpha particle monitor could be useful in conjunction with gamma-ray portal monitoring. LRAD-based personnel monitors have been discussed above.

6. Conclusions

Several areas in the safeguarding and management of nuclear materials have been suggested for which alpha particle detection can be useful. However, without detectors which were both real-time and sensitive these uses were undeveloped. Indirect detection of alpha particles from nuclear material via the ionization produced by the alphas in ambient air offers a chance to handle assay of material in these scenarios. Such scenarios were addressed in trace material detection and contamination assay, in monitoring for diversion of nuclear material in waste streams, and in border and portal monitoring. Appropriate detectors have already been fielded in some cases for other purposes. Most other detectors proposed in this paper have been demonstrated to work in principle. The chief disadvantage of the real-time assay technology as applied to surface, liquid, gamma-ray, and volume monitoring is the lack of isotopic information. But the advantages lie in sensitivity, ruggedness, unit cost, and low power requirements as well as real-time response.

7. Acknowledgments

The authors gratefully acknowledge the contributions of K. S. Allander, R. D. Bolton, J. A. Bounds, J. D. Johnson, D. W. MacArthur, M. Rawool-Sullivan, and S.G. Walters. We are grateful for discussions with G. Bosler and D. A. Close.

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