CONF-950868--4

LA-UR- 95-2277

Title: ALPHA DETECTION FOR DECONTAMINATION AND DECOMMISSIONING: RESULTS AND POSSIBILITIES

Author(s): D. Mac Arthur

Submitted to: Environmental Remediation, August 17, 1995

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RECEIVED
AUG 29 1995
OSTI

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

Alpha Detection for D&D: Results and Possibilities

ABSTRACT

Alpha detectors based on the long-range alpha detection (LRAD) technology have numerous uses, both potential and demonstrated, in facility D&D. These monitors operate by detecting the ions created by alpha particles interacting with ambient air. Thus, detection is not limited by the short range of the alpha particle and no window is required between the contamination and the detection region. These properties make LRAD-based detectors ideal for operation in field environments where complex objects to be monitored are the norm and reliability is crucial. Three monitors of particular interest in D&D operations are the building surface monitor, the internal volume monitor for use on the inner surfaces of pipes, ducts, and tanks, and the conveyer belt monitor for concrete rubble and structural steel. Surface monitors have been used extensively, both in laboratory and field environments, internal volume monitors have been tested in the laboratory, and the conveyer system is still a conceptual design. These monitors and related applications demonstrate the utility of LRAD-based monitors for D&D operations as well as exploring some of the new ways that fieldable monitoring systems can be used for D&D. Ion collection sensing technology can be used to solve many of the alpha detection problems unique to the D&D field.

INTRODUCTION

Characterization of contaminated sites is often viewed as a single event that occurs prior to the "real" D&D work at the site. Certainly this type of characterization is required to determine the location and extent of contamination, but characterization is also an integral part of decontamination and final closure. No matter what type of decontamination method is chosen, its value lies in its ability to remove contaminated material. Thus, characterization is an essential part of the decontamination process as it can determine the hazards associated with an ongoing operation, the effectiveness of the operation, and the need for possible repetitions of the operation. After any D&D operation is finished, the public and regulatory agencies must be convinced that the site is indeed as clean as claimed. This proof again requires efficient, effective, and understandable site characterization.

Instruments that are sensitive to gamma and beta radiation are currentlyused extensively the site characterization measurements. The relatively long range of these particles makes detection in the field fairly straightforward. In contrast, alpha particles will only penetrate a few cm of air or a very thin window in front of a detector. The easier and more reliable γ and β measurement have been more widely used. However, some contaminants, such as Plutonium and Americium, have strong alpha signatures and weak or nonexistent other signatures. In these cases, effective alpha detection is the best way of locating the contamination. Since the alpha radiation will not penetrate pipes, concrete, or even paper, a useful alpha detector must be able to detect contamination that is not visible from the sensor location. The long-range alpha detection (LRAD)-based monitors described in this paper meet these requirements.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

LRAD DETECTION METHOD

As an ionizing radiation particle passes through a gas, it loses energy by creating ion pairs at a rate of about 35 eV per ion pair (depending on the gas). This ion production occurs in ambient air as well as specialized detector gasses. The long-range alpha detection (LRAD) method[12] for sensing alpha particles (or other ionizing radiation) depends on detecting the ions rather than the alpha particles themselves. As an alpha particle stops in air it leaves a trail of ionization with a total production of about 150,000 ion pairs per 5-MeV alpha particle. Since the range of alpha particles in air is only several cm., all of the ionization from a given particle can be collected in a single volume and transported to an ion collector. Other types of ionizing radiation will also generate air ions but the rate of production is much lower for other particles and the range is generally much longer. Thus, in most cases, it is impossible to capture all of the ionization generated by these other radiations (tritium, Technetium-99 and other low-energy β emitters are an exception). The sort range and dense ionization trail of the alpha particle, combined with the difficulty of detecting small amounts of alpha contamination with traditional detectors, makes sensors based on LRAD technology ideal for measuring alpha particles.

All of the ions generated by a contaminated object or surface are swept into a single ion detector where they generate a small current. This current is proportional to the number of ions generated and hence to the rate of alpha decay on the object or surface. We have used two methods to transport the ions from the contaminated area to the ion detector.[3] In an airflow LRAD sensor (Fig. 1.a), a current of air transports the ions to the ion detector; in an electrostatic monitoring system (Fig. 1.b), the ions are transported by an electric field that is established between the ion collection plate and the surface being monitored. Airflow systems are work well for monitoring complex objects, the insides of enclosed volumes, and the air itself. Electrostatic monitors are better adapted for measuring contamination on relatively flat surfaces such as soil, buildings, or water.

DETECTORS AND RESULTS

A. Surface Monitors[4]

As discussed earlier, electrostatic monitors are ideal for sensing contamination on flat surfaces. Materials used in construction, such as concrete, can often be monitored for surface contamination *in-situ*, prior to removal. An example of this type of monitoring is the building floor illustrated in Fig. 2. One "hotter" spot was located in this scan extending out from under the machinery in the upper center. This result illustrates the sensitivity of LRAD-based concrete monitoring systems. No processing has been applied to this data; fig. 2 represents the same information that would be available to cleanup personnel working on the floor.

Larger surface monitors can also be used to monitor soil surfaces for alpha contamination. Figure 3 is the contamination map collected at a potentially contaminated location at Los Alamos. This figure illustrates the sensitivity of the LRAD-based field instrumentation as well as its ability to scan relatively large areas in a short time (about 20 points in 8 hours). These large surface monitors are completely self-contained, requiring no power or other connections.

B. Volume Monitors[5]

Since all of the ions generated in an enclosed area can be sensed in a single detector, LRAD-based monitors, and airflow monitors in particular, are ideal for monitoring contamination inside of a pipe, glove box, or other enclosed area. An air current flowing through the enclosed volume will sweep all of the ions to a detector mounted outside the volume. These detectors have the advantages of being non-intrusive and not requiring access to the entire pipe or volume. These volume monitors are best used to verify that a pipe is clean following decontamination rather than to measure to level of contamination in a "dirty" pipe. Since the number of ions measured depends somewhat on the distance from the ion detector to the source, these monitors may not be highly accurate. In addition, since alpha particles can only penetrate a few tens of µm of solid material, a 1-cm layer of contamination will generate the same alpha signature as a 30-µm layer.

An example of monitoring results in a 10-cm pipe is shown in Fig. 4. In this case, the pipe is bent to 90 degrees in the middle. If the source is placed after the bend, the signal loss is similar to what would be expected from distance alone, i.e. with no bend present. Thus these detectors can be used to monitor for contamination that is hidden from the detector by bends and other equipment geometry considerations.

Another example of this type of detector is the glove box monitor,[6] results from which are illustrated in Fig. 5. This is a set of data taken by moving an alpha source around inside a glove box mockup. The ions from the entire glove box are sensed in a single ion detector connected over one of the glove ports. Although there is some sensitivity change as the source is repositioned, the signal is never lost in the noise. This type of detector is also best used for verifying the cleanliness of a glove box following decontamination.

C. Conveyer Belt Systems

A row of either electrostatic or airflow detectors mounted over a conveyer belt can be used to detect alpha contamination on soil or debris passing underneath the detectors. An airflow system have the advantage of probing all surfaces of complex objects but requires fans, directed airflow and possibly a perforated conveyer belt. As in smaller detectors, the electrostatic system is ideal for relatively flat surfaces such as soil or fine concrete rubble, but not as good on objects such as pieces of I-beam or large blocks of rubble.

Building the conveyer monitor from several smaller monitor "modules" has several advantages. Troubleshooting and shakedown can occur using a single module and then additional modules can be added to achieve the sensitivity and/or throughput requirements. Multiple module systems can also be instrument adaptively, i.e. if the first module defines the waste material as undoubtedly contaminated or clean, then the monitoring is complete for that sample and another sample is moved into the first module. If, however, the reading from the first module is inconclusive, the sample is moved to the second module and the second result added to the first, thereby reducing the uncertainty in the measurement . This additive process is continued until a definitive measurement is possible. Thus, each sample is monitored for as long or as short a time as is required to make a definitive measurement. With this system, the average measurement time is shorter than the maximum measurement time. If each sample were monitored by a single detector large enough to discriminate every sample, the average time would be as long as the maximum time. Since the throughput is inversely proportional to the average measurement time, the segmented system will be capable of larger throughput than the single, large, monitor.

RELATED MONITORS

A. Logbook Monitors - An electrostatic monitor in a closed box with a door wide enough to admit logbooks can be used to monitor the pages of the logbook for residual alpha contamination. This is especially useful for archived logbooks that were used before the current contamination controls were implemented. The LRAD-based system can monitor an entire page in a single measurement and does not depend on the efficiency of the human operator.

B. Wire and Conduit Monitoring - All ions coming from a length of wire or electrical conduit can be collected in a single measurement. This provides a rapid, sensitive, and repeatable measurement for alpha contamination on the surface of the wire or conduit. A conceptual wire monitor might consist of a long, pipe-shaped, ion collector volume through which the wire is pulled for monitoring.

C. Air Monitors[7] - Radioactive gas atoms (such as radon) produce the same ionized air molecules as surface contamination. Detection of these ions produced in a decay volume can be used to monitor radon levels of < 0.1 pCi/l in real time.

D. NORM[8] - The use of alpha decay to detect contamination is not limited to contaminants from human sources such as plutonium and americium. Most natural substances also have radioactive constituents such as radium, polonium, and thorium. These elements also produce alpha particles in their decays. Thus, many of the same techniques used to monitor for plutonium or uranium in the pipes and surfaces of old processing facilities can also be used to look for naturally occurring radioactive material (NORM) in mine tailings drilling equipment, and petroleum processing equipment.

E. Personnel Protection - Since LRAD-based detectors measure contamination from all surfaces of an object simultaneously, they are ideal for monitoring hands, feet, arms, or entire bodies. Contamination on all surfaces is detected in a single measurement and, unlike traditional alpha probes, the efficiency of the person operating the monitor will not affect the sensitivity of the result.

CONCLUSIONS

The LRAD-based alpha monitors have several advantages over other alpha measuring devices. These include:

a) Response time: they respond in real time and can be used by field personnel to decide on the relative dangers associated with different options.
b) Ruggedness: there are no thin windows, fine wires, or sensitive electronics enabling true *in-situ* operation with good reliability.
c) Support requirements: as required for field operation, these sensors do not need ac power, cooling, or complex electronics and are easily transportable.

D) Sensitivity: LRAD-based sensors have been built with 10-dpm/100 cm2 surface sensitivity, 50-dpm spot sensitivity, and 0.1 pCi/l radon sensitivity.

Thus, LRAD-based systems combine the portability of hand-held instruments and the sensitivity of laboratory instruments with ruggedness offered by neither one.

Real-time measurements of sufficient sensitivity (as in LRAD-based systems) allow for hazard characterization during demolition to cost effectively reduce the exposure of personnel. These monitors are sensitive enough to provide realistic hazard analysis and rugged enough to stand up to use during a D&D operation.

REFERENCES__

---

[1] D. W. MacArthur, K. S. Allander, J. A. Bounds, M. M. Catlett and J. L. McAtee, "Long-Range Alpha Detector for Contamination Monitoring", IEEE Transactions on Nuclear Science, Volume 39, Number 4, Page 952 (1992) .

[2] D. W. MacArthur, K. S. Allander, J. A. Bounds, K. B. Butterfield, and J. L. McAtee, "Long-Range Alpha Detector," Health Physics, Volume 63, Number 3, Page 324 (1992).

[3] D. W. MacArthur, K. S. Allander, J. A. Bounds, M. M. Catlett, R. W. Caress, and D. A. Rutherford, "Alpha Contamination Monitoring of Surfaces, Objects, and Enclosed Areas," IEEE Transactions on Nuclear Science, Volume 40, Number 4, Page 840 (1993) .

[4] D. W. MacArthur, K. S. Allander, J. A. Bounds, M. M. Catlett, R. W. Caress, and D. A. Rutherford, "LRAD Surface Monitors," Los Alamos National Laboratory publication LA-121524-MS, February 1993.

[5] R. W. Caress, K. S. Allander, J. A. Bounds, M. M. Catlett, and D. W. MacArthur, "LRAD-Based Airflow Monitors," Los Alamos National Laboratory publication LA-12742-MS, March 1994.

[6] M. Rawool-Sullivan, R. D. Bolton, R. Marshall, "Defensible Alpha Characterization of Glove Boxes at D&D Sites," Proceedings on WM'95, Tucson AZ, Feb 27 - March 3, 1995.

[7] R. D. Bolton, "Radon Monitoring using Long-Range Alpha Detector-Based Technology," Proceedings of the IEEE Nuclear Science Symposium, Norfolk VA, Oct. 30 - Nov. 4, 1994.

[8] K. S. Allander, J. A. Bounds, and D. W. MacArthur "Applications of Long-Range Alpha Detector (LRAD) to the Detection of Naturally Occurring Radioactive Materials (NORM)," proceedings WM '94, Tucson, AZ, Feb 27 - March 3, 1994.

CO-AUTHORS

K. S. Allander, Ph (505) 665-5492, J. A. Bounds, Ph (505) 665-0446, J. E. Koster, Ph (505) 667-3346, M. Rawool-Sullivan, Ph (505) 667-6628, S. Rojas, Ph (505) 665-9838

All Authors

MS J-561, Los Alamos National Laboratory, Los Alamos, NM 87545, FAX (505) 665-9277

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

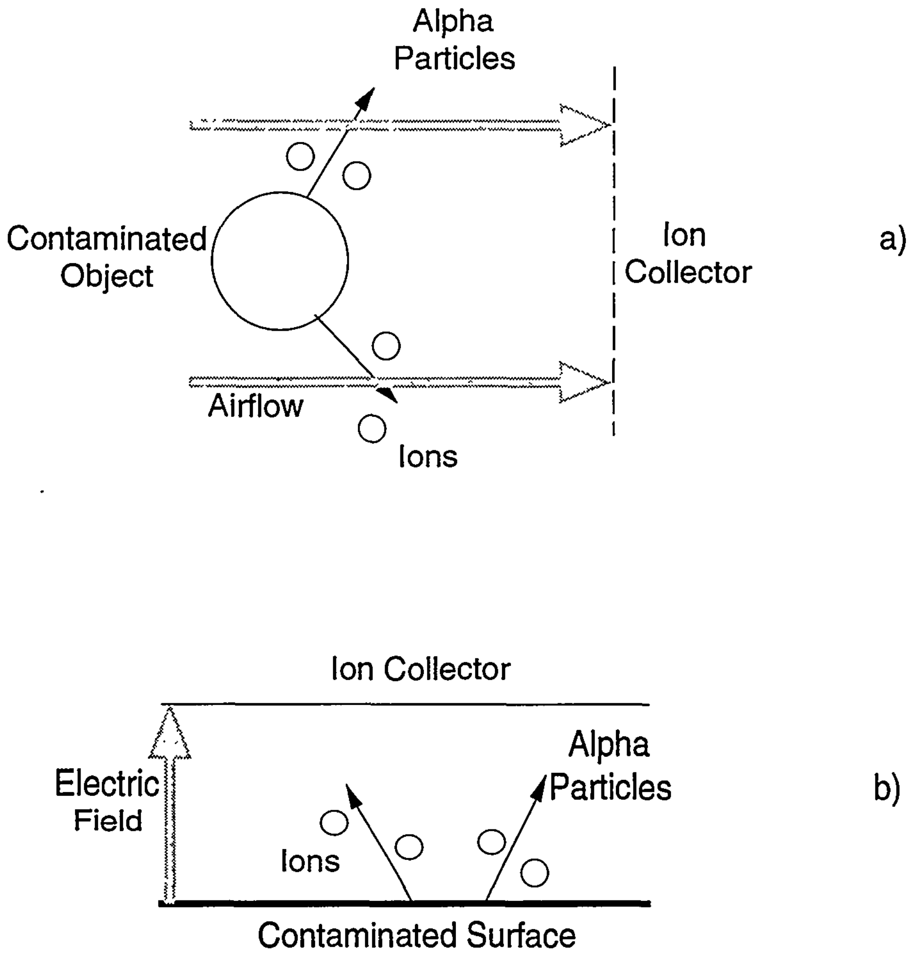

Fig. 1. Two types of LRAD-based alpha particle detection. In both cases, ions generated by alpha decays are transported to an ion collector. In an airflow sensor (a), the ions are transported to the ion collector by an air current. In an electrostatic sensor (b), the ions are transported by an electric field between the ion collector and the surface being monitored.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

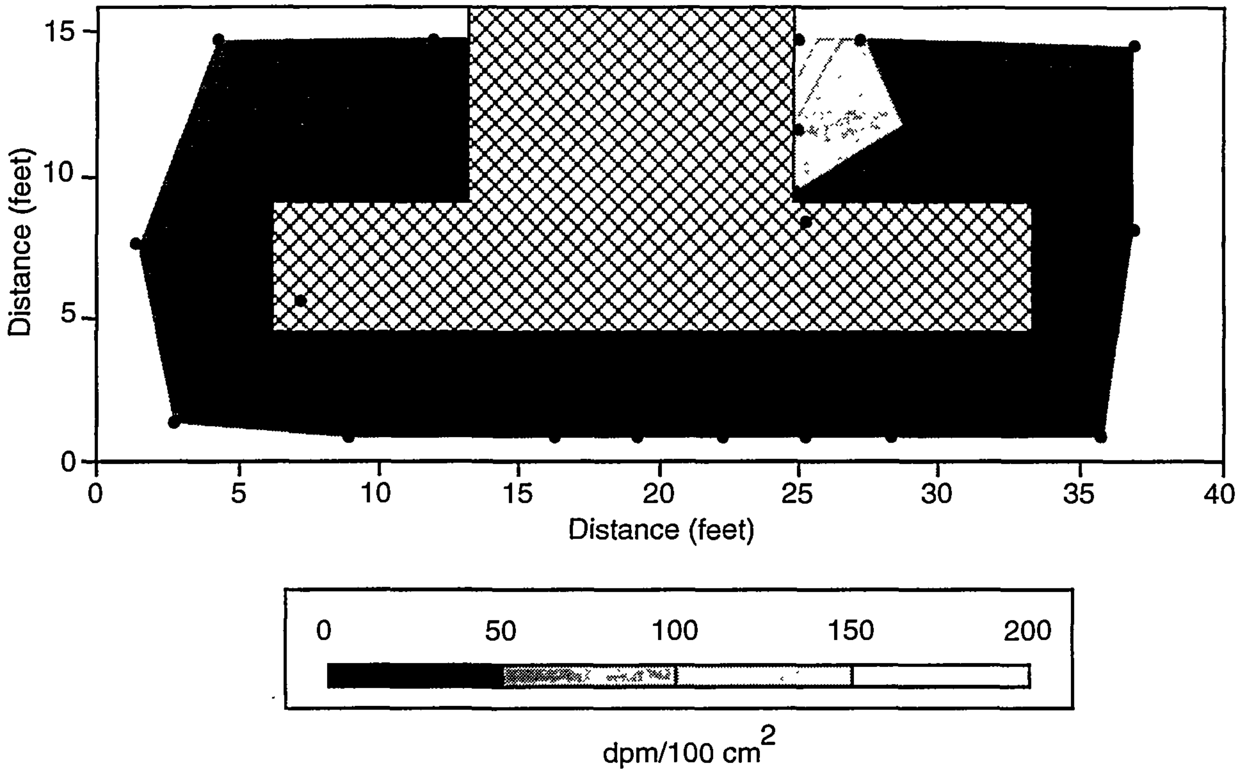

Fig. 2. Contour plot of contamination on the floor of Building 146 at TA-21 in Los Alamos. The cross-hatched area represents machines and storage covering the floor. Measurement were made at the black dots; the shaded contours were interpolated between the measurements.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

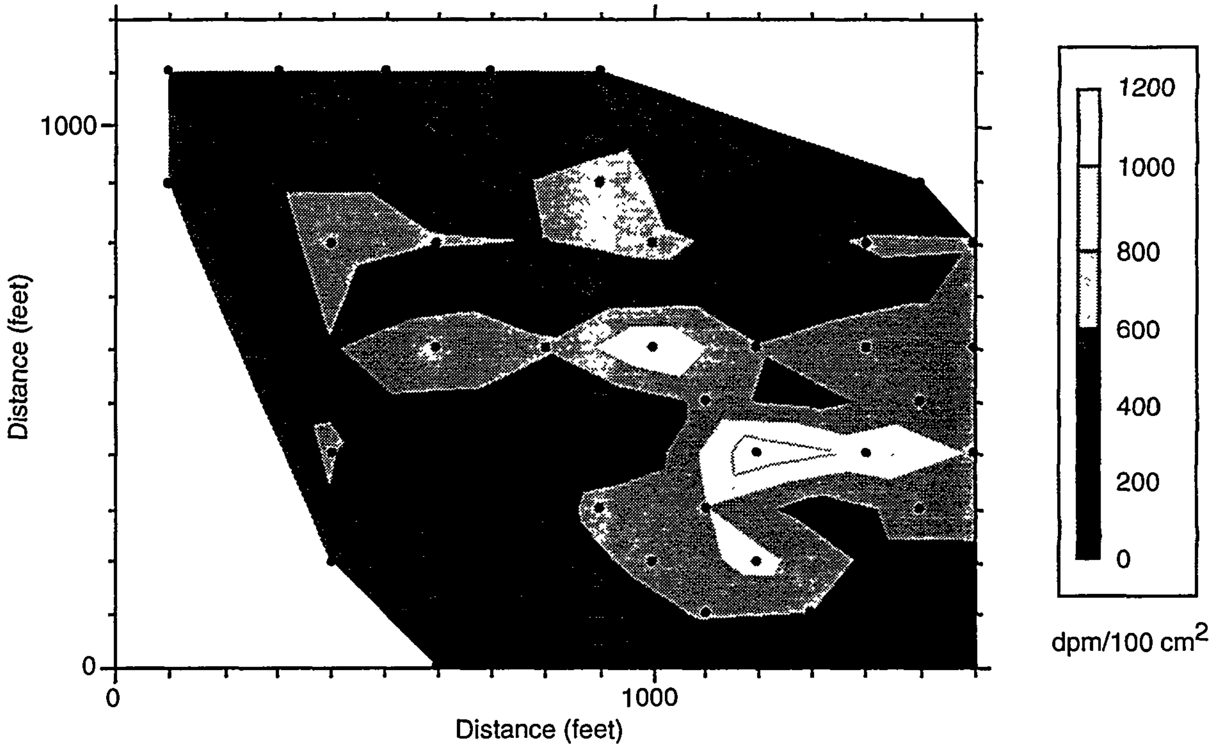

Fig. 3. Soil surface monitoring results for gross alpha contamination at a soil cleanup site. The black dots represent the measurement points. The shaded contours were interpolated between the measurements.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

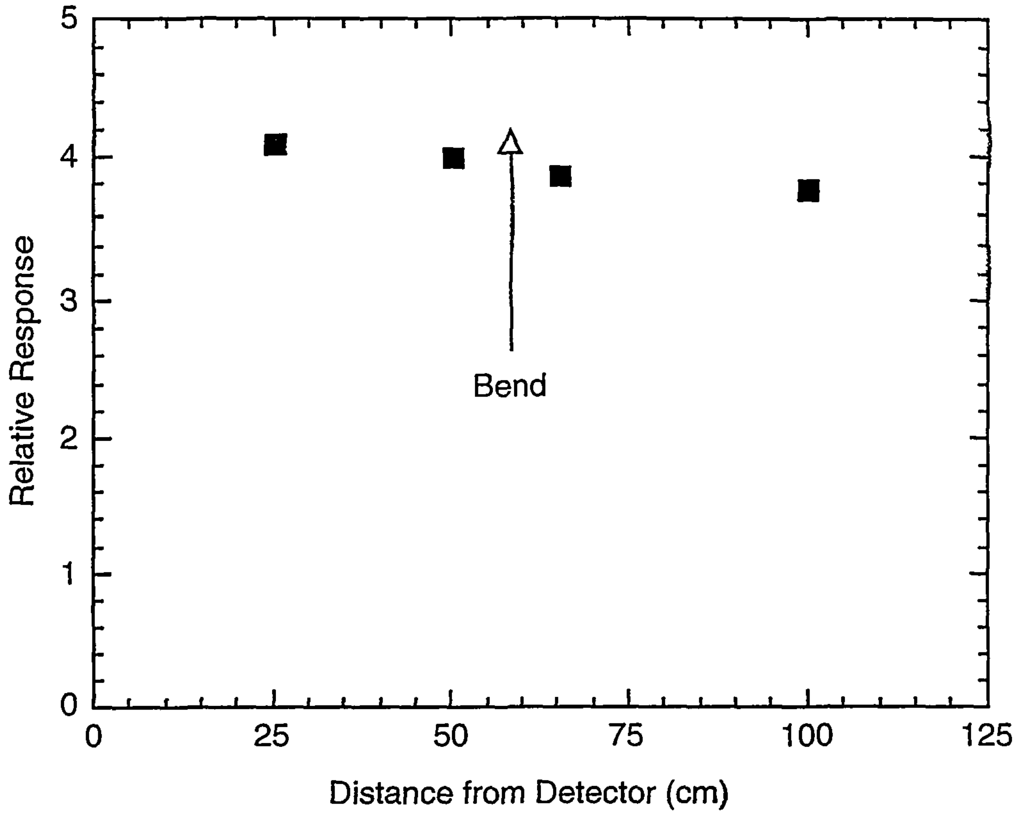

Fig. 4. Response of an alpha source placed at 4 positions in a 10-cm diameter pipe which is 125-cm long. The pipe is bent at a 90-degree angle about 60-cm from the ion detector (indicated by the arrow in the figure). Very few ions are lost in the bend.

1205
Duncan MacArthur
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-8943 (Phone)/(505) 665-9277 (FAX)

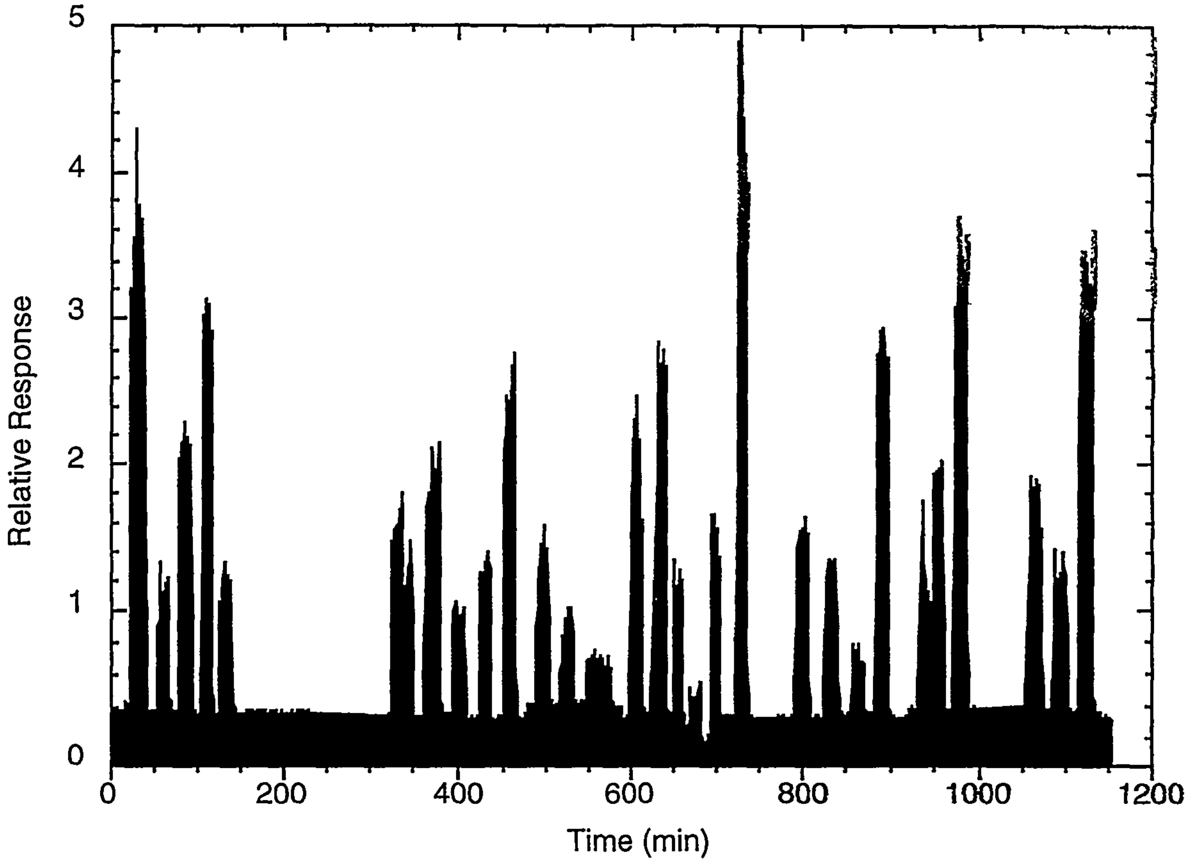

Fig. 5. Response of an airflow LRAD monitor mounted on one port in a glovebox mock-up. A large (~125,000 dpm) alpha source was placed in many different locations in the mock-up. Although the sensitivity varies, the signal is never lost in the noise.