LA-UR-94-3633

Conf-941102--33

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Submitted to: ANS 1994 Winter Meeting
Nov. 13-17, 1994
Washington, DC

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ALPHA DETECTION FOR CHARACTERIZATION OF D&D SITES

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ABSTRACT

Characterization of radioactive contaminants is required during D&D operations at any facility where radioactivity is suspected or known to exist. Alpha radiation is an excellent indicator of the presence of many isotopes (such as Pu-239) which are otherwise difficult to observe. However, traditional fieldable alpha detectors have been hampered by the short range of alpha particles in air and in detector windows. We have developed an alpha detection technology that avoids the problems mentioned above. In a monitor using the long-range alpha detector (LRAD) technology, we detect the ion pairs produced by an alpha particle's interaction with air rather than the particles themselves. In this paper, we discuss several applications to air and soil monitoring as well as potentially contaminated building surfaces and process equipment.

I. INTRODUCTION

The short range of alpha particles in air forces most alpha detectors to be used very close to, or in contact with, the contaminated object. This, together with the small size of traditional monitors, limits their usefulness on large or irregularly shaped objects. To reduce alpha particle attenuation, the front window of the detector is often very thin, making it fragile and easily damaged. The other commonly used characterization method is sampling and remote analysis or counting. These techniques do not provide the timely information that is required during a decontamination and decommissioning (D&D) operation.

In contrast, monitors using the LRAD[1] method measure the number of ions produced by an alpha particle interacting with air rather than the alpha particle itself. Thus, these detectors are not limited by the range of the alpha particle and have no detection gas requiring supply bottles or thin windows. In addition, all LRAD-based monitors provide real-time feedback to the operator rather than requiring laboratory analysis.

II. LONG-RANGE ALPHA DETECTORS

All monitors that use the LRAD detection technique are sensitive to air ions produced by alpha particles rather than the alpha particles themselves. These ions have a measured lifetime of ~ 5 s in a 3.2-cm aluminum pipe,[2] which implies a much greater range (up to tens of meters) than the alpha particle (~ 4 cm). This relatively long lifetime is primarily caused by wall interactions rather than particle collisions, so the lifetime in larger enclosures is longer than 5 s. Since the ions have a long range, a single detector can monitor all contamination present on an object in a single measurement. Ambient air is used as the detection medium, so no window is required between the detector and the contamination. Two types of monitors based on this technology are an airflow system, where an air current (generated by fans) transports the ions to the ion detector, and an electrostatic design, where an electric field attracts the ions to the ion detector.

A. Airflow Detectors

In an airflow monitor, the ions are transported from their source to a detector by an air current. The critical features of an airflow LRAD are illustrated in Fig. 1. Specific design parameters are discussed in other reports[2,3] and the references discussed therein. Ambient air enters an enclosed volume through a filtering system. Typically, this filter removes both ions and particulates from the air stream. The "enclosure" should be closed to keep unfiltered air from entering but is otherwise non-critical and can be part of the equipment to be monitored rather than a separate enclosure.

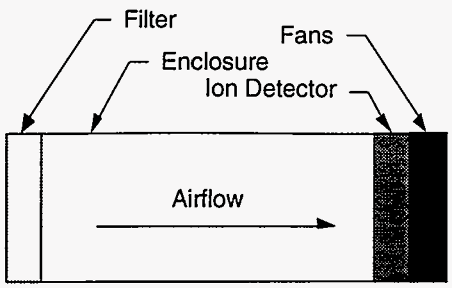

Figure 1. Critical elements of an LRAD-based airflow detector. Small objects can be placed in an enclosure with a door for monitoring, or the enclosure can be a pipe or a piece of process equipment. In the latter case, the internal surface is monitored for alpha contamination.

After passing through the enclosure, the air, with alpha-induces ions, passes into an ion detector where the number of ions (and hence the amount of contamination in the enclosure) is measured. Air must pass into the enclosure through a filter and out through the ion detector. The fans in Fig. 1 are shown pulling air through the chamber. This geometry creates a small negative pressure in the chamber which reduces the potential for contamination spread. The fans can also be placed in front of the filter and push air through the enclosure. This configuration ensures that all air entering the enclosure is filtered but also encourages leaks. Both geometries are equally sensitive, so the ultimate placement of the fans depends on operational constraints.

Airflow detection systems are best used for detection of contamination on complex objects (such as tools or machine parts) or for monitoring the inside of enclosed volumes (such as pipes, ducts, and process equipment). Air itself is an "object" which can be placed in an airflow detector, so air quality monitors are also based on this technique.

B. Electrostatic Detectors

Figure 2 illustrates the operating principle of an electrostatic ion detection system. This conceptual drawing ignores several important features such as mechanical and electrical connections that are detailed elsewhere.[2,4]

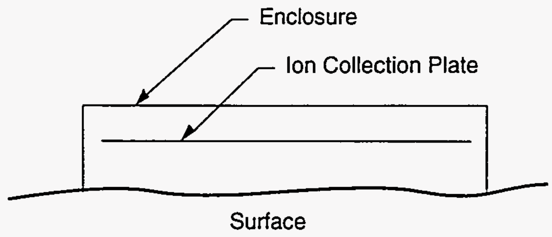

Figure 2. Conceptual drawing of an electrostatic monitoring system. An electric field between the collection plate and the surface (generated by a battery - not shown) attracts ions to the collection plate. The number of ions is measured with an electrometer (also not shown).

In this case, the enclosure is open on one face. The surface to be monitored makes up the final side of the monitoring volume. Thus, any contamination present on the surface is inside the detection volume once the monitor is in place. Alpha particles coming from surface contamination will generate ions in the air between the surface and the ion collection plate. These ions are attracted to the plate by an electric field between the plate and the surface. There are equal numbers of positive and negative ions so either field orientation will produce the same sensitivity.[2]

Monitors using electrostatic LRAD detectors are suited for monitoring on flat surfaces such as soil, concrete, building surfaces, and liquids. Electrostatic monitors do not generate air movement, so the potential for spreading contamination is smaller.

III. DETECTORS FOR D&D

In this paper, we describe four monitoring systems which utilize the advantages of the LRAD design in a D&D setting. All of these monitors are real-time and make measurements *in situ* without disturbing the surroundings or generating secondary waste.

An air quality monitor is an airflow system that can be used to measure both particulate and radioactive content of dust occurring in a D&D operation. Internal volume monitors (IVMs) are another type of airflow monitor that can detect contamination inside closed volumes such as pipes, ducts, and process equipment. The soil monitor can be used on the soil or parking areas surrounding a facility to determine the extent of contamination migration. Smaller versions of this electrostatic monitor can be used to locate contaminated areas on floors, walls, and ceilings of facilities.

A. Air Quality Monitoring

Johnson *et al.* [5] have demonstrated the effectiveness of LRAD-based monitors for detecting airborne contaminants. These monitors are sensitive to 0.1 pCi/L of radon gas and also to alpha contamination attached to airborne particulates. Radon gas, and other alpha emitters, are detected directly via the ions produced by the alpha particle decay products. The detection mechanism for particulate concentration measurements is somewhat different. Radon daughter products in the ambient air become attached to particulate matter due to their chemical activity. Thus, the number of daughters decaying in the sensor is proportional to the number of particles present. This proportionality remains valid as long as the number of radon daughters exceeds the number of particles. A monitor for both radon and particulates is shown schematically in Fig. 3.

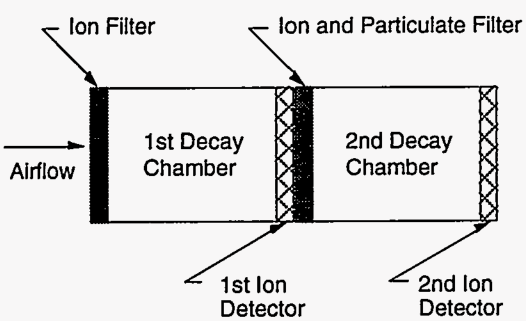

Figure 3. Conceptual drawing of a system that simultaneously monitors a) radioactive gases and daughter products (1st decay chamber and ion detector) and b) only the gaseous component (2nd chamber and ion detector).

Ambient air, containing both gases and metallic daughter products, is drawn into the first decay chamber. The ion filter removes extraneous ions but neither gas nor daughter products. Either the radioactive gas or daughter products (attached to particulates) can decay in this chamber generating an ion signal (in the first ion detector) proportional to both gaseous and daughter decay rates.

The ion and particulate filter removes the daughter products and particulates from the air (as well as any ions that make it past the first ion detector). Thus, only the radioactive gas remains to decay in the second chamber, and the signal from the second ion detector is proportional to the amount of radioactive gas in the air. The difference between the two ion detector signals is proportional to the amount of non-gaseous contamination, i.e., to the daughter products (or other radioactive material) attached to particulates.

B. Internal Volume Monitor (IVM)

A need expressed by many members of the D&D community is that a method is required for performing non-destructive, *in situ*, measurements to detect radioactive contamination inside enclosed volumes. These volumes may include, but are not limited to, pipes, ducts, and process equipment. Currently available contamination monitoring technologies cannot address the problems presented by alpha, and low-energy beta, contamination located in small-diameter pipes, complex process equipment, and inaccessible volumes.

Most DOE facilities, including Savannah River, Lawrence Livermore, Rocky Flats, Los Alamos, Hanford, Oak Ridge, and others, have waste pipe systems and/or equipment that is internally contaminated with various (often undetermined) radionuclides. In addition, three facilities (Oak Ridge, Paducah, and Portsmouth) have gaseous diffusion plants requiring significant internal radiological characterization of process equipment. Current disassembly techniques require personnel and dispersal protection assuming the worst possible combination of contaminants. These requirements are directly caused by the lack of an *in situ* monitoring method which could be used to determine the hazard level prior the dismantlement.

The IVM is based on the airflow LRAD described above. Since the ions in an LRAD monitor can travel distances of many tens of meters in an enclosed volume, the IVM ion detector can be located far from the source of contamination. Although most of the existing work has focused on alpha contamination, low-energy betas can also be detected using this technology.

The success of the IVM in a large volume depends on the lifetime of the ions. We have measured this lifetime; in a 3.2-cm diameter pipe it is 5 ± 1 seconds. This is a lower limit; in larger pipes the lifetime may be longer, but it will not be shorter. Thus, the major factor limiting detection distance in an IVM is the distance that the ions can be transported in 5 s.

We have measured the sensitivity of related ion monitors, and, while the results will not transfer directly to the IVM, these results are indicative of the level of sensitivity expected. For example, large object monitors, similar to the Eberline LRAD-1, are sensitive to point sources of 50 to 200 disintegrations per minute (dpm).

C. Soil Monitors

The soil surface monitor is a tractor-mounted electrostatic monitor with an active area of 1 m by 1 m. This monitor is used to measure the surface contamination of up to 30 points per day. From these nonintrusive surface measurements, contour maps of surface alpha contamination, such as shown in Fig. 4, can be generated in near real time.

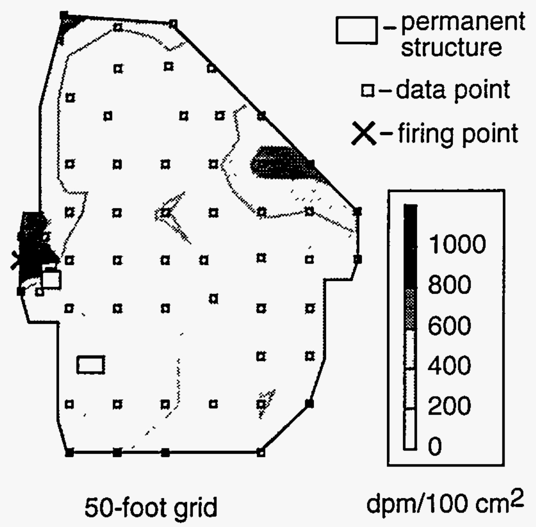

Fig. 4. Surface contamination mapping of a blasting site at Los Alamos National Laboratory. Notice the uncontaminated overfill surrounding the blasting point and the evidence for contamination beyond the overfill area.

Surface contamination data was taken at each point marked in the figure. The contour lines were computer generated to fill the areas between measurements. This technique is best suited to air- or water-spread contaminants that are spread over a large area as opposed to pieces of radioactive material that might be missed by the sampling grid.

The measured sensitivity of a similar soil surface monitor (also an electrostatic LRAD design) was ≤ 10 disintegrations per minute (dpm) per 100 cm^2. This sensitivity was reached in < 5 min on concrete and <15 min on soil.

D. Building Surface Monitors (BSMs)

Currently available fieldable alpha monitoring technologies applicable to building surfaces do not have adequate sensitivity and ruggedness for D&D activities. To achieve acceptable sensitivity, laboratory analysis must be used; this analysis is time consuming, expensive, and generates additional waste.

Concrete and other materials were used extensively in the construction of nearly every large nuclear facility. During operation of these facilities, many of the building surfaces have become contaminated with radioactive materials. As with the IVM, traditional characterization technology is often insufficient to provide real-time hazard identification for construction (destruction) personnel.

The building surface monitor (BSM) is based generally on the electrostatic LRAD technology. More specifically, it is a smaller descendant of the soil surface monitor described above. Since all of the ions from a contaminated area can be collected in a single BSM, not only does the monitor *not* have to be in contact with the source of contamination, but larger areas can be monitored than is possible with traditional sensors.

The success of the BSM in D&D applications depends on the size and maneuverability of the ion detector system. We have operated similar surface monitors ranging from 1 m^2 down to 100 cm^2; the optimum D&D detector size will probably be intermediate. Current soil monitors are mounted on a tractor which allows only 2 degrees of freedom. The BSM would require 3 degrees of freedom which can be obtained using readily available commercial equipment.

The sensitivity of other surface monitors is indicative of the expected sensitivity of a BSM. The detectors most similar to the proposed BSM are the soil surface monitors; these are sensitive to surface contamination levels of 10 dpm/100 cm^2. This corresponds to a volumetric sensitivity of about 2 to 10 pCi/g. (However, alpha particles will not penetrate more than 10 to 50 micrometers in a solid - the BSM will be primarily a surface monitor.)

IV. OTHER RELATED DETECTORS

The LRAD detection system used in these monitors represents a technology, not a single detector. Like other detector technologies, such as plastic scintillators or wire chambers, the LRAD technology can be applied to a number of different problems, resulting in completely different implementations. Several other implementations are briefly described below.

A. D&D

Several more specific applications of LRAD technology to D&D have been described by Rawool-Sullivan.[6] These include monitors for the insides of glove boxes, the insides of pipes, as well as concrete floor and lab bench top monitors.

B. Personnel Safety

Object monitors, such as the Eberline LRAD-1 and related smaller and larger sensors, can be used to monitor tools, equipment, and other items at the exit of a controlled area. An object monitor with a hole in the side can be used as either an arm or hand monitor, depending on the size of the system. Since air is used as the "detection gas" in LRAD-based monitors, a person can enter a very large (telephone booth sized) monitor for scanning; clothing, exposed skin, and hand-carried items could be monitored for alpha contamination in a single measurement.

C. Environmental Restoration

In addition to the soil surface monitor described above, various types of soil sample monitors can be used to screen soil samples in the field. We have demonstrated radon monitors[5] similar to the air quality monitors described above. Large electrostatic monitors can be used for liquid waste and groundwater monitoring.

D. Waste Minimization

Object monitors can be applied to solid waste minimization as well as personnel safety. All potentially contaminated waste is often disposed of as radioactive simply because it is too hard to measure. All surfaces of a waste object can be monitored in a single measurement for increased throughput. Liquid waste is similarly difficult to monitor with traditional sensors. This limitation also results in much clean waste being disposed of as contaminated.

E. NORM

Any material removed from the ground (such as oil, gas, uranium, and potash) will include greater or lesser amounts of naturally occurring radioactive material NORM (mainly uranium, thorium, radium, and polonium). Drilling and pumping equipment, processing facilities, and waste disposal areas all become contaminated with radioactive (alpha-emitting) material. Specific applications to NORM contamination include surface, radon emanation, drill pipe, and process equipment monitors.

V. CONCLUSIONS

The D&D monitors described in this paper (and other related monitors[5]) combine the speed of traditional field alpha monitors and the sensitivity of laboratory systems with field reliability not present in either one. Many of the characteristics of the LRAD systems (such as ruggedness, reliability, sensitivity, and the capability for real-time and *in situ* measurements) make them well suited for D&D applications.

ACKNOWLEDGEMENTS

This work was supported by the US Department of Energy and Los Alamos National Laboratory.

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