APPLICATION OF THE LONG-RANGE ALPHA DETECTOR (LRAD) TO THE DETECTION OF NATURAL-OCCURRING RADIOACTIVE MATERIALS (NORM)

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ABSTRACT

Standard fieldable alpha detectors are severely limited when monitoring alpha contamination on equipment, large surfaces, or the inside surfaces of pipes. New regulations are driving a need for new technologies to address these problem areas. The Long-Range Alpha Detector (LRAD) technology addresses these problems by detecting ion pairs created by an alpha particle in ambient air, rather than the alpha particle directly. These ion pairs, whose lifetime is several seconds, are transported to a collection grid by using either an airflow or an electric field. When collected, these ion pairs create a small electric current (typically 10^{-13} to 10^{-14} A) that is read by an electrometer and displayed on a data acquisition system. This method of detection is also being used to create monitoring systems for health physics, environmental site characterization decontamination characterization, and it is adaptable to cover the new needs of the power industry.

INTRODUCTION

The presence of excessive accumulations of natural-occurring radioactive material (NORM) in the power industries has been known since the early 1900s, but it has only recently become an issue when radiation levels several times higher than those considered to be safe were found as soil contamination in the Gulf States. Since then, studies have verified there are quantities of NORM significant enough to cause health effects. This material is found in various forms, such as ^{210}Pb on gas and oil producing equipment, scale material on the inside of piping, in soils where this scale material was deposited during decontamination procedures, and in the from of radon gas emitted from the accumulations of this material.

Conventional radiation monitors are not always capable of detecting this material efficiently or in a time- and cost-effective manner. Therefore, new technologies must be developed to address these needs. The LRAD detection system has been (and is being) developed to address similar concerns with in the DOE complex. Fully fieldable systems have been and are being developed for the DOE in the form of soil surface contamination monitors, internal pipe monitors, object and tool monitors, and air quality monitors. Similar systems can be developed and adapted to address the needs of the power industry.

We have identified several potential types of LRAD contamination monitors that can be applied to NORM contamination problems:

- Interior surface scrap pipe monitors (nondestructive),
- Real-time in-line pipe monitors,
- Soil Surface monitors, and
- Real-time radon emission monitors.

A related object monitor is currently available commercially through Eberline Equipment Inc., who is our industrial partner.(1)

Traditional Alpha Detector Operation

Because of the short range of alpha particles, and the small fragile probes associated with standard fieldable detectors, traditional alpha detection has been time-consuming, relatively insensitive, and limited in its applications. The traditional fieldable alpha detector usually consists of a hand-held instrument with a small probe (typically 100 cm^2) that is moved slowly over the surface being monitored at a rate of one to two inches per second. The probe must be held close to the surface being monitored (usually at a distance of one-quarter inch or less), thus severely limiting its ability to detect contamination on nonuniform surfaces. The accuracy of these instruments is determined by the user's interpretation of the analog readout; the sensitivity is determined by both the speed at which the probe is moved across a surface and by the distance it is held from the surface being monitored. Because of this, the application to NORM detection for traditional alpha monitors is severely limited.

LRAD Monitor Operation

Although an alpha particle has a short range,(2) it has a significant mass and energy, which is absorbed in ambient air to create a large number of ion pairs. A typical alpha particle with an energy of 5 MeV creates about 150,000 ion pairs in ambient air. These ion pairs have a lifetime on the order of several seconds,(3) and when they are collected they have enough energy to create a small dc current, which is proportional to the number of ions created by the alpha particle and, hence, the amount of activity present. The LRAD system transports these ion pairs to a signal grid, where the dc current is read by an electrometer. This current is then displayed in a graph format on a computerized data acquisition system. For NORM applications, this data acquisition system can be developed as a small electronic readout. Figure 1 shows the detection of ions and a schematic of the basic system.

We have developed two LRAD systems based on this technique: the first system uses an airflow to transport the ion pairs and it can easily detect a 100-disintegration-per-minute (dpm) source; the second system uses an electric field to transport the ion pairs. These detectors (depending on size and surface being monitored) have a sensitivity of ~10 dpm/100 cm^2.

AIRFLOW DETECTOR

In all of the airflow monitors described below, an air current is used to transport the ions from the contaminated area to the detector. For NORM applications, this system will consist of four parts: a filtration stage, an object or volume being monitored, a detector assembly, and a data acquisition device. A small fan or bank of fans (mounted on the outlet side

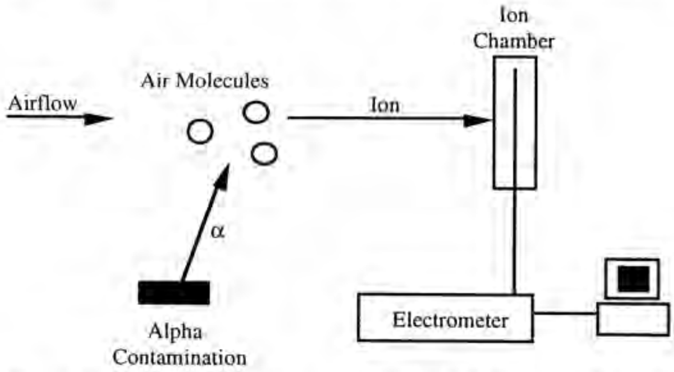


Fig. 1. Detection of air ions produced by alpha particles with the LRAD system.

of the detector) will draw ambient air through the filtration system into or over the surface being monitored, and the into the detector itself. The data acquisition system will then display a dc current that is proportional to the contamination present. This system permits sensitive alpha detection without the mechanical constraints imposed by a traditional alpha detectors.

Filtration Stage

In order to use ambient air to transport the ion pairs created by an alpha particle, a clean flow of air must be maintained. If this airflow is unfiltered, dust particles as well as naturally occurring ion pairs present in ambient air can and will dominate the response of the LRAD system. To prevent this, we use a two-stage filtration system. The first stage consists of a high-efficiency particulate air (HEPA) filter that removes all particulate contaminants and ensures a laminar flow of air through the detector. The second stage consists of an electrostatic precipitator that removes all unwanted ion pairs from the airflow. We are currently developing a single-stage baffled electrostatic filter to replace the existing filtration system.

Detector Assembly

The detector assembly consists of four main parts:

- A perforated metallic plate mounted on guarded standoffs (signal plane),
- A grounding plane mounted on the outlet side of the assembly,
- A fan or bank of fans attached to this ground plane, and
- An electrometer.

The detector assembly works by applying 45 V to a signal plane. This voltage provides enough potential to ensure efficient ion collection. (3) To reduce the effects of any leakage current from this voltage, we mount the signal plane on guarded standoffs and float the electrometer. The ground plane, mounted on the outlet side of our detector, decouples the signal plane from the outside environment, and the fans draw the airflow through the system. The electrometer reads the current that is produced on the signal plane, which is displayed on our data acquisition system (3) (see Fig. 2).

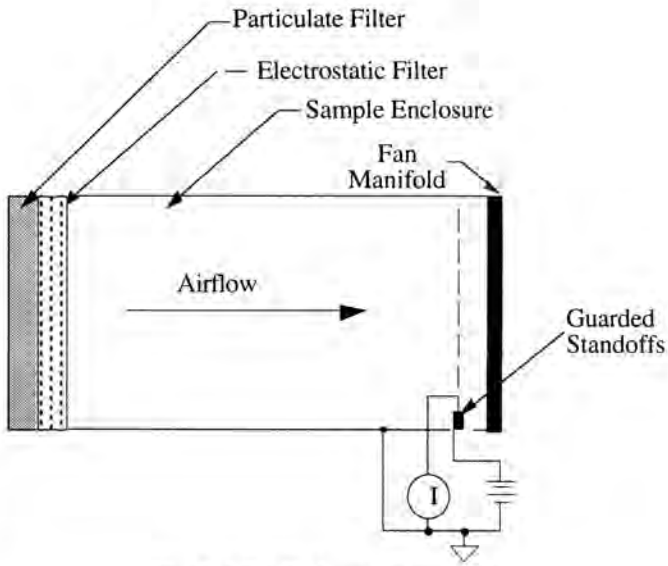


Fig. 2. LRAD detector assembly.

Data Acquisition System

We are currently using a Macintosh-based system that runs the LabVIEW data acquisition program. By using the LabVIEW as the programming language, we are able to easily modify existing programs to meet the changing needs of our detector program.

Airflow Detector Applications

Scrap-Pipe Monitoring: A potential scrap-pipe monitor is illustrated below (Fig. 3). Ambient air would be drawn through the filter assembly and into the pipe section. Alpha-induced ions would then be collected by this airflow from the interior surfaces of the pipe and transported to the LRAD detector.

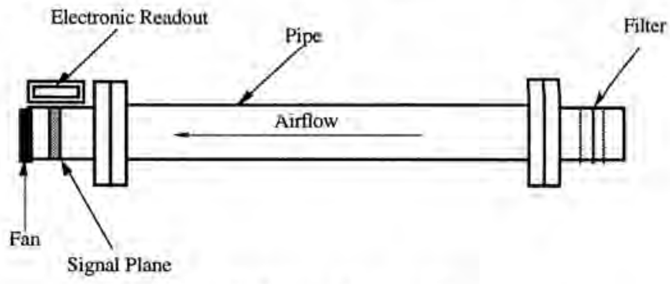


Fig. 3. Scrap-pipe monitor.

Both the filter and detector would be lightweight and fully self-contained. The data acquisition system would be reduced to a small electronic readout device. We envision that one or more filter/detector pairs could be rapidly moved to monitor many loose sections of pipe in a scrap yard. Both modules would be easily carried by a single person so that one or several small teams could monitor pipes in existing piles without requiring movement or restacking. A full survey of the interior surface of a pipe could be accomplished in a few minutes with good sensitivity, reliability, and less human error than associated with traditional alpha monitors.

In-Line Pipe Monitors: In an in-line pipe monitor (Fig. 4), the natural gas itself would be the transport medium for the

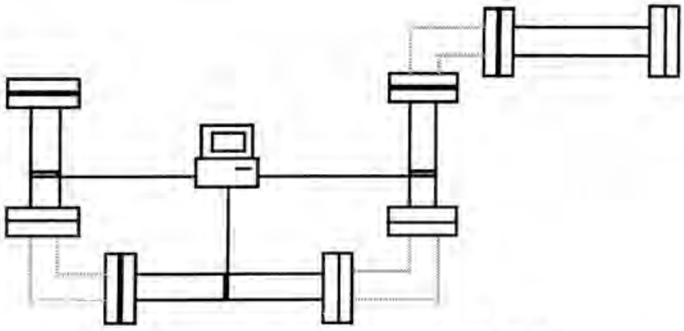


Fig. 4. In-line pipe monitors.

alpha-induced ions; no physical interruption of the gas flow would be required.

For in-line, real-time monitoring of NORM contaminants in pipes, several LRAD monitors would be installed (as illustrated above) in strategic locations throughout an existing pipe matrix. These detectors would give a real-time indication of the NORM buildup in the pipe network by displaying their data on a single data acquisition system. These monitors would be (semi)permanently installed in a gas system to continuously monitor the same sections of pipe.

ELECTROSTATIC DETECTORS

Similar to our airflow detectors, electrostatic detectors also detect the ion pairs created by an alpha particle in ambient air. However, these detectors utilize an electric field to transport the ion pairs to a signal plane. We have developed two detector systems using this technique for the expedient characterization of soil contamination within the DOE complex: the soil surface monitor and the soil sample monitor. (4) These systems are fully fieldable and have been field tested; and they can be used for NORM soil contamination characterization as well.

Electrostatic Monitors and Applications

Soil Surface Monitor: The soil surface monitor (4) consists of four major components:

- A 1-m^2-detector (five-sided aluminum box),
- A signal and guard plane,
- An electrometer , and
- A data acquisition system.

A 1-m^2-detector is constructed by using a five-sided aluminum box. Low density foam is attached to the exterior surface of the detector 0.6 cm (1/4 in.) below its open face. This foam will provide an air seal when the detector is set open-face down during data acquisition. The air seal stops the exterior ions from contributing to our signal. Both a signal and guard plane (large copper or aluminum plates) are mounted to the interior surface of the top plate of the detector. Three hundred volts are applied to the signal and guard plane. This voltage provides enough potential to ensure efficient ion collection. By floating the electrometer at the same 300 V, we are able to read the dc current produced from the alpha contamination, while minimizing the effects of the leakage current (see Fig. 5). The same computer data acquisition system that is used with the airflow detector displays this current in a graph format.

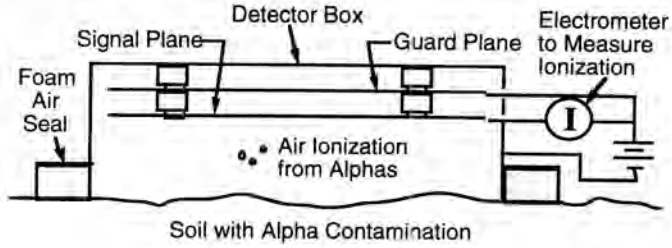


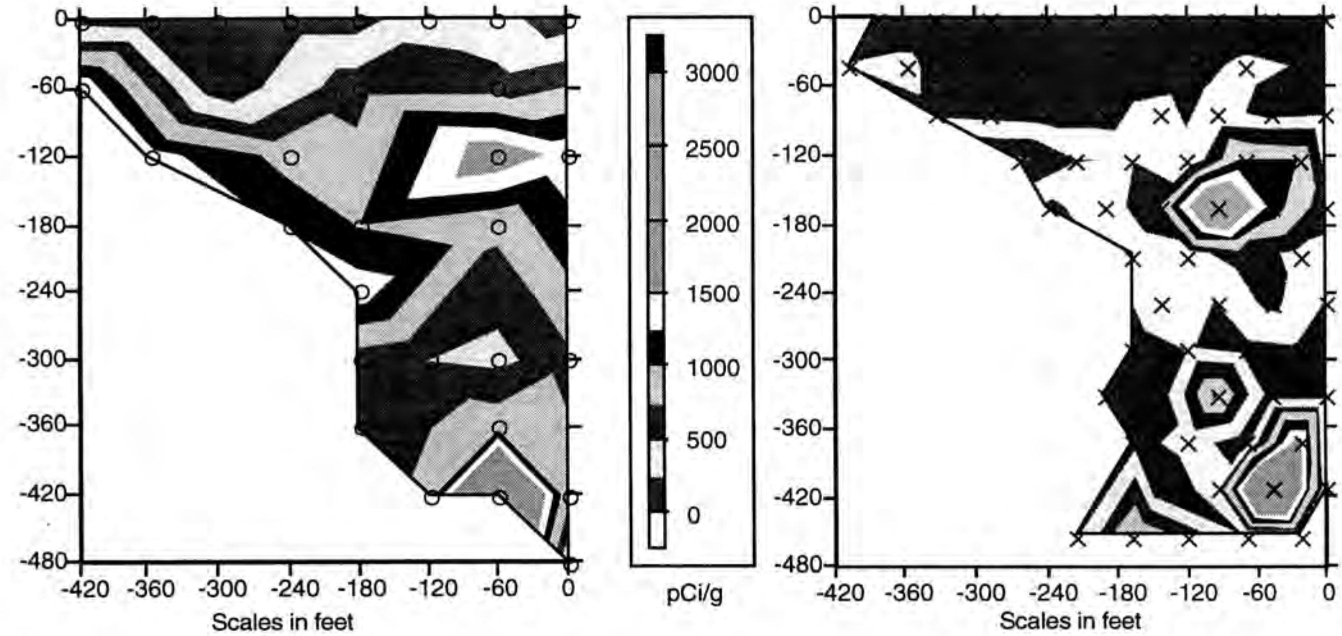
Fig. 5. Soil surface monitor.

Weighing about 300 lb, this 1-m^2 soil surface monitor is the heaviest of our systems. Therefore, we have mounted it on the front of a small tractor. This makes the system portable and easy to use in the field. To use this system, the operator lays out a grid on the plot of land to be characterized. Data are taken on this grid, stored, and then analyzed. A contour map is produced showing the amount of surface contamination present. This map can be updated on a daily basis, giving the end user the information in an expedient manner. (5) Using this system, a two-acre plot of soil can be characterized in as little as two days, compared to three months it takes for the same results using standard sampling and analysis techniques. Figure 6 shows the data comparison of the LRAD system and traditional sampling and analysis technique from the D&D area in Fernald, Ohio. (4,6)

Radon Emission Monitor: Real-time radon emission monitoring can be accomplished by modifying the soil surface monitor. The radon emission monitor is constructed in the same fashion as our soil surface monitor using the foam and five sided aluminum box. The signal and guard planes are now both are used as signal planes. The distance between the top signal plane and the top plate of the aluminum enclosure must be the same as the distance from the bottom plane and the surface being monitored. Three hundred volts is applied to the plates and a small fan is mounted within the sample enclosure to circulate air. The alpha-induced ions are collected by the bottom plane while the radon decay daughters are detected by the top plane. Transportation of the alpha-induced ions is eliminated by both the fan speed and the voltage that is applied two the two plates. A simple subtraction of these two reading gives the surface contamination reading, the radon contribution, and the difference between the two (see Fig. 7).

CONCLUSION

The need for faster and better radiation characterization technologies is prevalent throughout the DOE complex as well as private industry. Systems must be fieldable, reliable, and work under adverse conditions. These systems must be capable of producing real-time results, they must be simple and easy to operate, and they must still be cost effective. Steps must be taken to ensure the usability and the validity of these technologies. We feel the LRAD detector meets these criteria. These systems have been awarded several patents and can be made commercially available upon request. We have participated in integrated demonstrations (5,6) comparing our technology to standard technology and are currently seeking EPA approval for several of our systems. The LRAD systems have been fully field tested in varying environmental conditions and have performed well. With little effort these systems, which have been designed to meet the DOE



LRAD data **Traditional core sampling and analysis**

Fig. 6. Comparison of LRAD data versus traditional sampling and analysis.

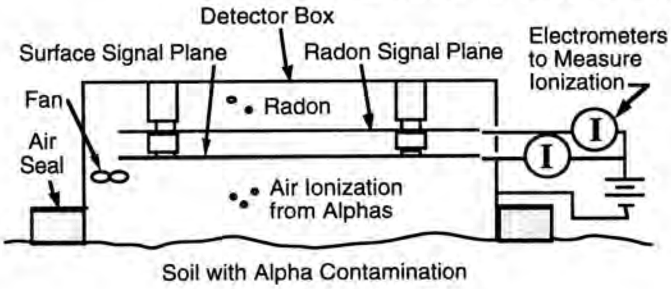


Fig. 7. Radon emission monitor.

characterization needs, can be modified to meet the needs of the power industry.

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