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Activities: Technology Overview*

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*Alpha Contamination Assessment for D&D Activities:
Technology Overview*

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ALPHA CONTAMINATION ASSESSMENT FOR D&D ACTIVITIES: TECHNOLOGY OVERVIEW

by

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ABSTRACT

Instruments based on the principle of Long-Range Alpha Detection (LRAD) detect the ions created in ambient air by ionizing radiation, particularly alpha radiation, interacting with air molecules. Using either an electrostatic field or forced convection, these ions can be transported to a detection grid where the ions produce a small current that is measured with a sensitive electrometer. LRAD-based instruments can give separate, simultaneous measurements of alpha-emitting solids and inert radioactive gases such as radon. LRAD-based instruments assess surface contamination on an entire object or large surface area in a single, rapid measurement, including relatively inaccessible areas such as interior surfaces of pipes and process equipment. The LRAD concept is well proven and has been developed into a range of different radiation detection devices. This paper presents an overview of the technology, while several associated papers explore specific applications in greater detail.

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INTRODUCTION

Long-Range Alpha Detector (LRAD) technology was developed at Los Alamos National Laboratory to provide rugged, sensitive instruments to detect ionizing radiation. Instead of detecting the radiation directly, LRAD-based instruments detect the ions created in ambient air when the radiation interacts with air molecules. Although LRAD-based detectors are sensitive to all forms of ionizing radiation, these sensors are ideally suited for detecting alpha particles, which ionize heavily over a short range. Because of this short range, all of the ionized air can be collected in a relatively small volume. The LRAD concept is well-proven and has been diversified into a range of specialized devices; some of these have been commercialized, some are in the test stage, and some are still conceptual.

Review of Ion-transport Technology

A 5-MeV alpha particle can travel roughly 4 cm through air under normal conditions. As that particle interacts with air, it generates approximately 150,000 ion pairs, losing some 35 eV for every ion pair produced.¹ Either an electrostatic field or forced convection (airflow) can be used to transport these ions, which have a mean lifetime of a few seconds, to a detection grid or plate (Fig. 1). There, the ions produce a small current that is measured with a sensitive electrometer.²⁴ The measured current is proportional to the total alpha particle energy lost in the ionization process if all the ions are collected; in practice, a calibrated LRAD instrument can give reasonably accurate, reproducible measurements of surface alpha contamination even though it is unlikely that all the ions are collected.

While LRAD-based instruments cannot in general identify specific radioactive isotopes, they can give separate, simultaneous measurements of alpha-emitting solids, on the one hand, and inert radioactive gases such as radon on the other. This allows, for instance, a soil surface measurement of particulate contamination to be corrected for natural radon emanation that would otherwise be a source of variable and possibly large error. Similarly, a stack emissions monitor can be configured to give separate measurements of alpha-emitting particulates and radioactive gases.

Ion Transportation Methods

In the airflow collection technique (Fig. 1), the ions are transported to a perforated grid by an air current; the air passes through the grid and the ions are collected. An electrostatic collector (Fig. 2) relies on an electric field between the collection plate and the contaminated surface to collect the ions. Each of these two collection mechanisms has advantages and disadvantages. Airflow ion collection is ideal for collecting ions from the surfaces of complex objects or the insides of pipes or process equipment. However, the air current can transport contaminated materials such as particulates and requires additional power for a fan. Electrostatic collection is ideal for relatively flat surfaces such as floors, soil, concrete, or liquid waste, but the electric field cannot penetrate the cracks and crevices of a complex object.

Fig. 1. In the airflow-type LRAD design, air is drawn by a fan through a filter, across the surface or object being investigated, through the ion collection grid, and out.

Fig. 2. In the electrostatic-type LRAD design, ions of either positive or negative charge (in this illustration positive charge) are moved by an electrostatic field to the collection grid. In the design illustrated here, ions of the opposite charge are moved to the sample chamber wall.

In the ideal case, the collected charge at the electrode is proportional to the number of ions created inside the enclosed volume, which in turn is proportional to the number of alpha particles emitted into the air in the enclosed volume. In practice, some error is introduced because of incomplete collection of ions and the fact that alpha particles from common alpha-emitting contaminants have similar but not identical energies (Table 1). To minimize this error, the system should be individually calibrated for each application both for system geometry and expected alpha emitters.

Table 1. Energies of principal alpha particles emitted by various contaminants.

Nuclide	Energy of principal alpha particle (MeV)
^{232}Th	4.0
^{235}U	4.4
^{238}U	4.2
^{238}Pu	5.5
^{239}Pu	5.2
^{240}Pu	5.2
^{242}Pu	4.9

Advantages of the LRAD approach

Many of the advantages of LRAD technology over conventional alpha monitors result from the fact that LRAD-based instruments assess surface contamination on an entire object or large surface area in a single, rapid measurement, including relatively inaccessible areas such as interior surfaces of pipes and process equipment. Because of the short range of alpha particles in air, conventional sensors must be brought into close proximity to alpha sources to detect their presence. This limitation results in slow scans of large surfaces and may require disassembling or cutting pipes and process equipment. Typically, a 100 cm² sensor must be manually moved across the surface at a rate slower than 5 cm/s. This implies that under the best of conditions, a 1-m² surface can be scanned in 200 s. While this is a tedious process, a more important concern is the difficulty of ensuring complete coverage of the surface using conventional alpha scanning.

An LRAD soil-surface monitor can assess contamination of a 1-m² surface in a single measurement requiring one or two minutes, with complete coverage assured. Similarly, an object such as a rock or hammer can be placed inside an LRAD object monitor, a device that somewhat resembles a microwave oven, and the total surface contamination can be assessed in a minute or two. As a third example, an LRAD flow-through monitor, attached to the end of a potentially contaminated pipe, draws air through the pipe and assesses internal contamination by the ions detected in that air. Because of these characteristics, measurements with LRAD-based instruments are generally faster than conventional alpha scanning, sometimes orders of magnitude faster, and are generally much more complete in their coverage. LRAD can easily handle some jobs that are practically impossible

with conventional alpha meters. Finally, LRAD-based instruments are sensitive even to background levels of contamination and are inherently rugged and stable.

LRAD configurations

The LRAD sensor technology can be adapted to a wide variety of specialized applications in the same way that scintillation detectors have been developed into hundreds of diverse products over the years. Some examples of specific LRAD applications are discussed below. These have been divided into general categories based on the geometry and type of application.

Surface monitors

Surface monitors are instruments that are placed against a surface to assess average contamination over that surface. Various configurations include soil-surface monitors (Fig. 3), concrete monitors (Fig. 4), and other types of specialized surface monitors that use an electrostatic field to collect the ions.⁵⁻⁹ LRAD surface monitors have been built that cover surface areas of up to 1 m², and larger monitors are entirely feasible.

Fig. 3. Soil-surface monitor mounted on tractor.

Fig. 4. Concrete monitor.

Object monitors

An object monitor is a device with an internal sample chamber into which objects are placed to estimate total contamination on the object's exposed surfaces (Fig. 5). These can be of various sizes and specialized for various applications.¹⁰⁻¹¹

Fig. 5. Object monitor.

Batch monitors

A batch monitor is a specialized, large-scale object monitor designed to assess a large quantity of decommissioned building materials, rubble, scrap metal, and so forth in a single measurement. The material can be loaded into bins or pallets and moved into the measurement chamber by conveyor or forklift (Fig. 6).

Fig. 6. Batch monitor and conveyor belt.

Flow-through monitors

In a flow-through monitor, air is drawn from a potentially contaminated volume through a detector grid.¹²⁻¹⁴ Flow-through monitors include pipe, duct, and tank monitors (Fig. 7) and air-quality monitors of various types designed to assess room air, outside air, or vented gasses for contamination.

Fig. 7. Pipe monitor.

Liquid monitors

A liquid monitor has been tested for detecting large changes in alpha activity in a liquid radioactive waste stream.¹⁵ Although alpha particles will only be detected if they leave the liquid and enter ambient air, turbulent flow or stirring can produce a repeatable reading that can be calibrated under well-controlled conditions (Fig. 8).

Fig. 8. Liquid monitor.

Status of LRAD development

Above, we compared LRAD to scintillation technology; scintillator-based instruments are used in a wide variety of applications. Some scintillator-based instruments are highly advanced, sophisticated, and reliable, while others may be newly developed prototypes that must still be tested and calibrated under a variety of operating conditions to ensure reliability. The same is true for LRAD-based instruments. Some of these are well tested and, in one case, commercially available, while others are in the prototype or even conceptual stage.

Summary

LRAD-based instruments detect ions created in ambient air by alpha radiation interacting with air molecules. This approach gives LRAD instruments the advantages of detecting contamination at a distance, many meters in the case of pipe and duct monitors, and performing bulk analyses of large and irregular objects and surfaces. The LRAD concept is well proven and has been diversified into a range of specialized devices, including surface monitors, object monitors, batch monitors, flow-through monitors, and liquid monitors. Some of these have been commercialized, some are in the test stage, and some are conceptual.

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