APPLICATIONS OF THE LONG-RANGE ALPHA DETECTOR FOR SITE-CHARACTERIZATION TECHNOLOGY

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ABSTRACT

Traditional alpha-particle detectors are limited by relatively poor sensitivity, small size, and difficulty of operation. These factors result in laborious effort and imprecise results. In addition, it is difficult for these detectors to monitor the inside of pipes and large areas having nonuniform surfaces. To be effective, traditional monitors require the probe to be held less than 1 cm from the surface while scanning with a slow, steady, and continuous motion. Long-range alpha detector (LRAD) technology overcomes the limitations imposed by the short range of alpha particles and provides a detailed analysis of alpha contamination in a cost-effective manner. Using a combination of LRAD airflow and electrostatic methods, we have developed several monitors for the detection of alpha contamination on hands and arms, in surface soil, and for radon gas.

INTRODUCTION

Detection of alpha contamination has been limited in the past by the short range that alpha particles travel from their source. As a consequence, conventional probes are limited in sensitivity. Figure 1 shows a conventional probe with its limited detector window size and short range of operation. Because of these limitations, conventional probes have often been inadequate for monitoring personnel and many types of terrain. In addition, due to the short range of an alpha particle, conventional alpha monitors cannot

1. monitor complicated surfaces with the sensitivity demanded by DOE and EPA regulations,
2. permit standardized monitoring techniques that could effectively and efficiently be used for a wide range of alpha-contaminated surfaces,
3. survey low-level alpha contamination in real time, and
4. monitor airborne contamination such as radon gas.

LRAD technology, on the other hand, operates by detecting the ion pairs created by an alpha particle interacting with ambient air. An alpha particle with an energy of 35 eV can ionize a single molecule into an ion pair, so a typical 5-MeV alpha particle will produce about 150,000 ion pairs as it loses energy in air (1). Moreover, these ion pairs can be transported over many meters, overcoming the short range of alpha particle. A sensitive electrometer in the LRAD measures the ions produced by alpha contamination. By using air as the detector gas, LRADs can detect contamination on any surface that air can penetrate. Therefore, unlike the conventional alpha monitor, an LRAD can

1. monitor complicated surfaces with the sensitivity demanded by DOE and EPA regulations,
2. be automated to minimize operator error,
3. monitor alpha contamination in real time, and
4. monitor radon with minimal response time.

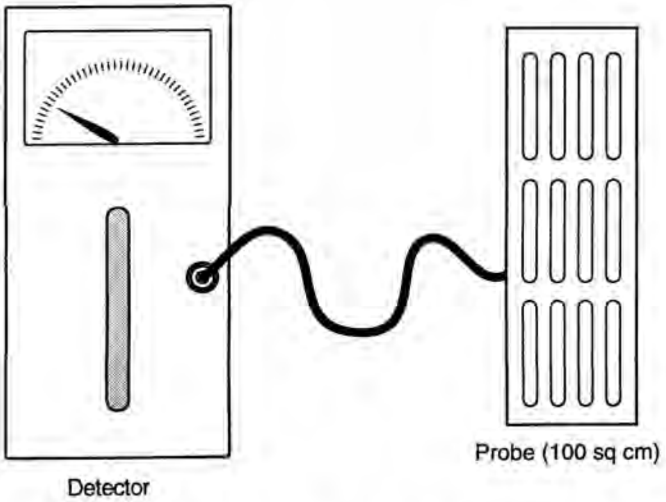

Fig. 1. A typical alpha probe. Note the limited area of detection.

Figure 2 shows the LRAD concept of detecting alpha contamination.

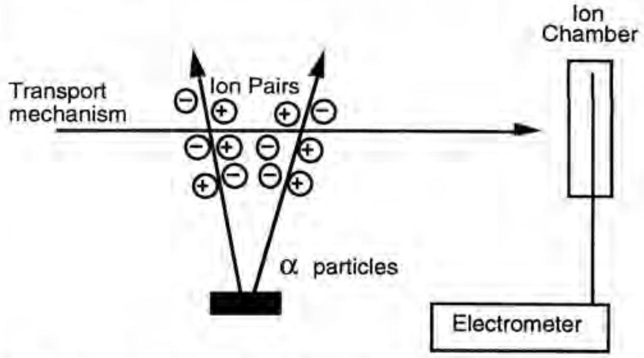

Fig. 2. LRAD concept for detection of alpha contamination.

LRAD OPERATION

The LRAD can be configured in one of two basic designs: airflow, where the ions are transported to the collection grid by means of air movement through the detection volume; and electrostatic, where the ions are attracted to a collection grid be means of an applied electric potential.

Figure 3 shows LRAD response to various common gases. Although in terms of ionization nitrogen is the more efficient detector gas, air, because of its convenience, is the detector gas of choice (2). However, some care must be exercised in order to eliminate background signals due to such

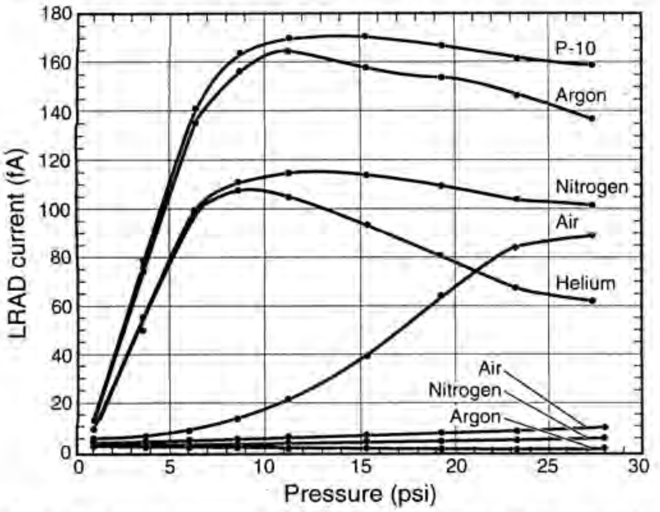

Fig. 3. Detector response to a 1100-disintegrations-per-minute source for various gases.

environmental factors as airborne particulates and relative humidity.

General Electrostatic LRAD

The soil-surface monitor (SSM) is an example of an electrostatic LRAD. It has an active detection area of 1 square meter and is mounted on the front of a tractor for fast and easy transportation over fields or across rough terrain. Figure 4 shows air ions within the detection volume of the SSM being attracted to the collection grid by the electrostatic field.

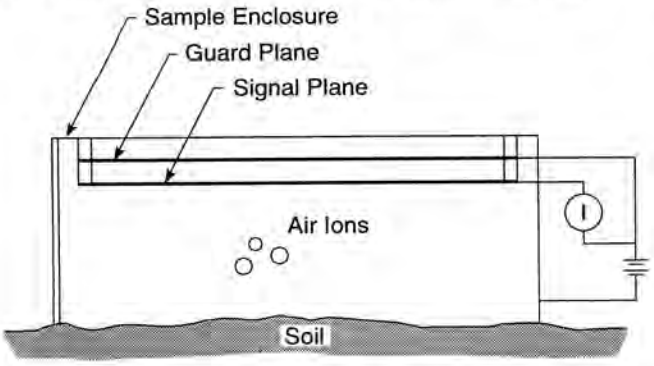

Fig. 4. Electrostatic LRAD technology applied to a Soil Surface Monitor.

A sensitive electrometer connected to the collection grid measures the current produced by these ions. The amplitude of this current is directly proportional to the energy deposited by the alpha particles stopping in the detector volume and is, therefore, a measure of the total alpha contamination enclosed by the detector. Again, care must be taken to insure a reasonably tight seal between the detector and the surface being monitored in order to prevent ions and other contaminants that are normally present in air from leaking into the detection volume. If outside contaminants are eliminated, the maximum sensitivity of the SSM can be realized and the entire surface beneath the detector can be characterized in less than 10 minutes.

The operating range of this detector is from 30 dpm/100 cm^2 to greater than 9000 dpm/100 cm^2 [3]. This detector design has been extensively field-tested in site-characterization studies of surface soil contamination at Los Alamos National Laboratory, Sandia National Laboratory, and Fernald, Ohio. The results indicate that large-scale site characterization can be accomplished by the LRAD with confidence. LRAD SSM detectors have been calibrated at large-area calibration pads at the Department of Energy (DOE) Grand Junction Projects Office in Grand Junction, Colorado, and at Grants, New Mexico.

Airflow LRAD

The airflow LRAD relies on a current of air moving through the detection volume, around and through the object being monitored, to transport the alpha-induced ionization to a collection grid. Figure 5 shows a schematic diagram of the airflow LRAD. The air current can be established in a number of ways: by small fans, by injecting pressurized gas into the detector intake, or by venting the detector exhaust into a vacuum. Once the ions arrive in the vicinity of the collection grid, they are attracted to the grid by means of an applied potential, in the same manner as the electrostatic LRAD. The advantage of the airflow LRAD is that it can transport ions over many meters with little loss in the total electrical current collected at the grid. To eliminate background signals associated with normal air ionization and radon progeny, an electrostatic ion filter and an airborne particulate filter are attached to the detector intake.

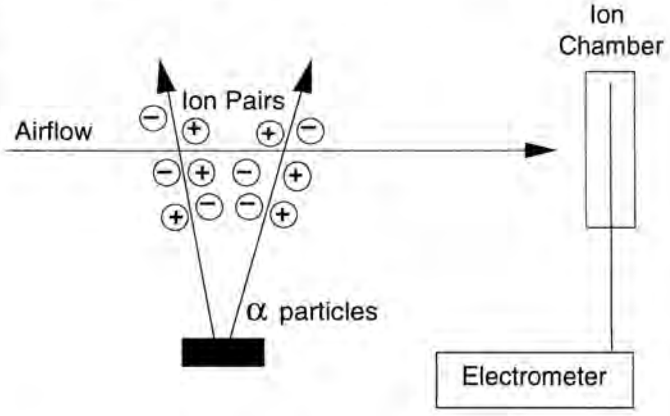

Fig. 5. Conceptual design of airflow LRAD.

Airflow LRADs have been built and tested in many configurations. These include LRADs that can monitor large and small objects, waste and waste streams, pipes, and human hands and arms. A new generation of radon gas and working-level monitors is also under development at Los Alamos National Laboratory.

The following sections give specific descriptions of the design and development of LRAD hand-and-arm monitors and radon monitors.

LRAD HAND AND ARM MONITORS

The LRAD hand-and-arm monitor is similar to the object monitor just mentioned. Their operation requires a conductive seal, such as a static dissipative glove, that is held around the hand/arm once the limb is placed inside the detector chamber. Once inside, a conductive iris valve will close around the appendage, creating a Faraday cage. Figure 6 shows a prototype of an LRAD hand monitor.

Figure 7 illustrates a prototype of an LRAD arm monitor, which is composed of two main stages. The first stage of this

Fig. 6. Prototype of LRAD hand monitor.

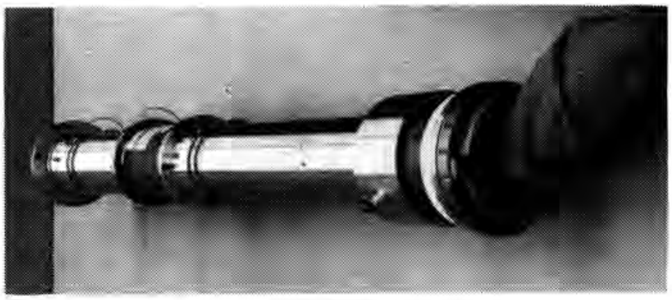

Fig. 7. Prototype of LRAD arm monitor.

monitor comprises the air intake, ion filter, arm-length volume, and detector grid. This is where potential alpha contamination is detected. The second stage is the particulate (HEPA) filter, decay volume and a second detector grid. In situations where the arm is contaminated, the second stage acts to prevent any existing alpha contamination from being blown out of the detector into the environment.

Signal response of the hand arm monitor was measured using calibrated surface sources, as shown in Fig. 8. The detector response to calibration sources is approximately 0.1 fA/dpm. Response time for both monitors is less than one minute with typical signal-to-noise ratios of 1::2.5 for a 100 dpm source.

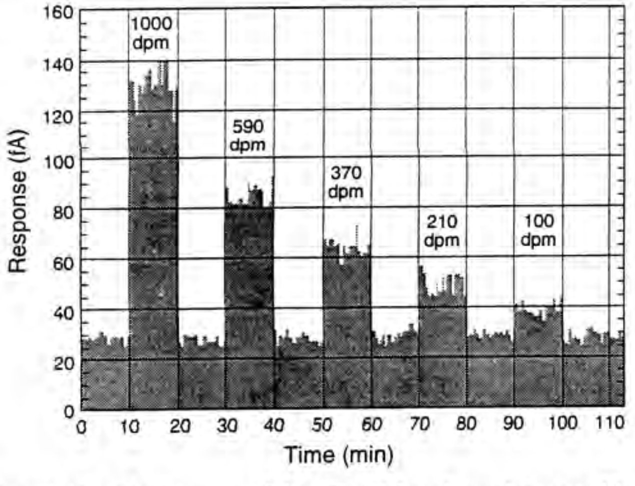

Fig. 8. Signal response of the LRAD hand monitor to calibration sources.

LRAD RADON MONITOR

The high sensitivity of LRAD airflow detectors to airborne alpha decays also makes them useful as radon monitors. A conceptual drawing of an LRAD radon monitor is illustrated in Fig. 9. Using such a monitor, radon concentration measurements can be performed in real time.

Two 23-liter LRAD radon detectors were tested in the calibration chamber at the DOE's Grand Junction Projects Office (GJPO). Data from this test is shown in Fig. 10.

The 23-l LRAD detectors gave 100 fA/pCi/L response. In addition, we measured a time response of less then one minute to changes in radon concentration over the test range of 0.1 to 320 pCi/L.

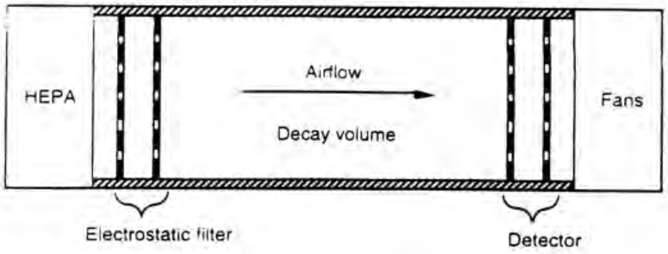

Fig. 9. Conceptual drawing of a radon monitor.

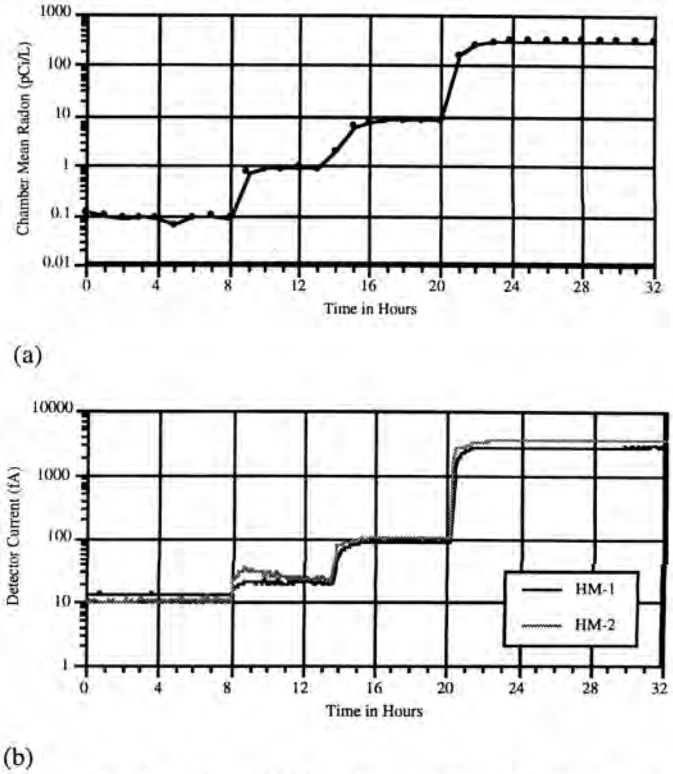

Fig. 10. Result of the LRAD radon response in comparison with the GJPO standard. (a) radon gas concentration as measured by GJPO monitors. (b) LRAD response to radon gas concentration levels; detector HM-1 draws in ambient air through a particulate filter, detector HM-2 draws in ambient air directly.

CONCLUSIONS

Prototypes of the LRAD hand, arm, and radon monitors have been built and are currently being tested at Los Alamos National Laboratory. Using a combination of the LRAD airflow and electrostatic methods, we can apply LRAD technology to the monitoring of possible alpha contamination of personnel, waste, and the environment. In this report we have presented the general design, construction, and results of testing for the LRAD hand, arm, and radon monitors.

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