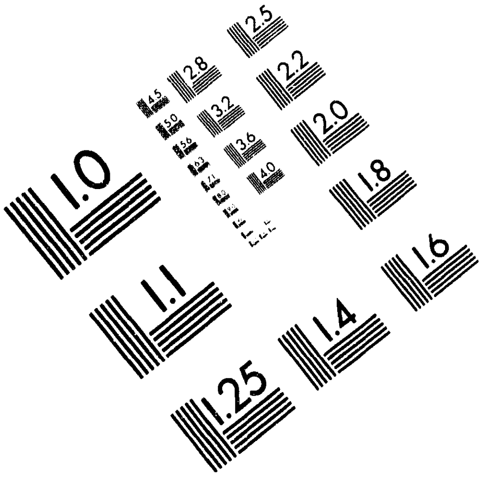

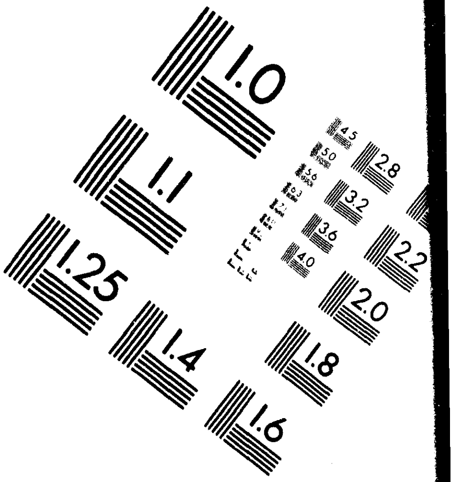

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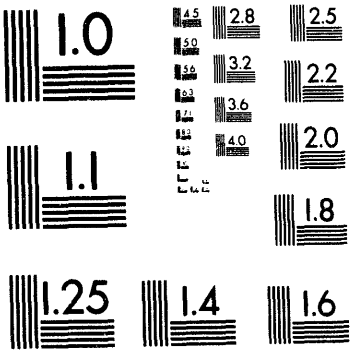

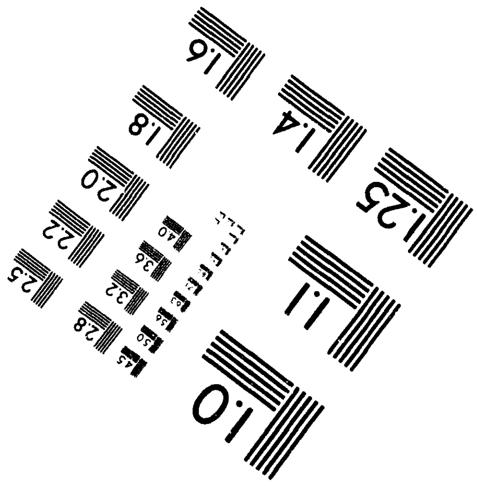

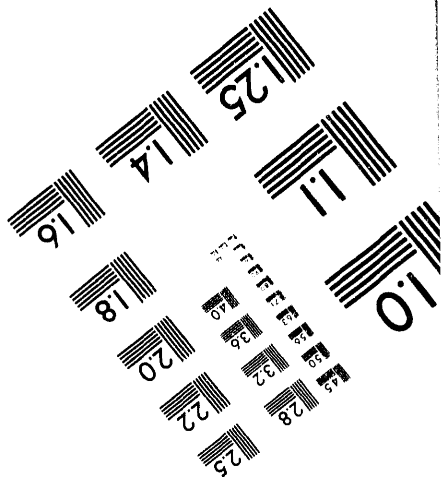

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The Development of an Innovative, Real-Time Monitor for Airborne Alpha Emissions

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Abstract

Los Alamos National Laboratory (LANL) is developing a technology for on-line, real-time monitoring of incinerator stacks for low levels of airborne alpha activity. Referred to as the Large-Volume Flow Thru Detector System (LVFTDS), this technology uses a unique design for sensitive, real-time measurements of alpha particle emissions. Scintillating plates are stacked close together so that alpha-particle emissions in the flowing gas stream strike a plate. The light pulses produced when the alpha particle strikes the plate are registered by photomultiplier tubes and processed to determine the concentration of alpha emitting radionuclides present in the air.

This technology directly addresses the public's demand for fast responding, high sensitivity effluent monitoring systems.

With Department of Energy (DOE) EM-50 funding LANL has fabricated a bench-top proof of concept detector system and is conducting tests to evaluate its performance. A second-generation prototype is being designed, based on requirements driven by potential field test sites. An industrial partner is being solicited to license the technology. Field trials of a full-scale detector system are planned for fiscal year 1995.

In this paper the LVFTDS technology is explained, including the measured performance of a prototype detector. The advantages, disadvantages, and other ramifications of applying this technology to incinerator effluent monitoring are also discussed. An overview of the development effort is also provided.

Background

This effort began in fiscal year 1992, when Los Alamos National Laboratory (LANL) group INC-13 was asked to survey the state of the art of real-time alpha monitoring technology that was currently, or could easily be adapted, for use in stacks. A primary motivation was acknowledgment of the desire of the public and regulators for improved real-time, continuous monitoring, particularly for alpha-emitting radionuclides.

In our survey of commercially available monitoring systems we found that, with some minor variations, nearly all commercial alpha monitoring techniques are based on a common approach. This approach involves the extraction of a sample of the gas being monitored and passing it through a filter placed close to a detector, sensitive to alpha decay radiation. Particulates bearing alpha emitting radionuclides are entrained on the filter and subsequent alpha decays are measured by the detection system.

This approach, while useful in many applications, is inherently an integrating technique and not well suited to real-time applications. Additionally, only a small sample (relative to the stack flow rate) is measured and assumed to be representative of the remainder of the stack.

With these problems in mind, Los Alamos then began evaluating other possible alpha monitoring technologies. Based on concepts being developed for a different application, we proposed the development of a new monitoring technology.

This new technology uses parallel plates of scintillating plastic constructed such that the entire stack gas stream flows directly through the inter-plate volume. Light from the scintillations produced by the alpha particles striking the plates is collected and processed to determine the concentration of alpha emitting radionuclides present in the air.

Enough experimental work was done in FY 92 to establish a basis for some performance estimates of a detector built from this new technology. These estimates were quite promising, indicating the potential for more than an order of magnitude improvement in sensitivity at short integration times.

Effort in FY 93 consisted of those steps needed to demonstrate the detector at the bench-top or lab-scale prototype level. This prototype detector was designed to allow us to test detector performance, on a scale that was large enough to demonstrate the concept, but small enough to be easily constructed, handled, and altered as needed. In concert with the technical development, market research was initiated and preparations made for finding an industrial partner.

Detector Concept

The LVFTDS detector is designed to quantitatively detect, in real-time, low concentrations (in the range of picoCuries/liter) of alpha-emitting radioactive materials potentially present in an off gas stream. The key obstacle to overcome in making this type of measurement is the short range of the alpha particles. For typical decay energies alpha particles travel only a few centimeters in air, making their detection difficult. Our detector overcomes this difficulty by using multiple alpha sensitive scintillating panels spaced closely together, but covering a large volume. Figure 1 illustrates this approach. With this arrangement approximately 75% of the alpha particles from radioactive decays in the detector active volume can reach a panel and generate a detectable light pulse. The light pulse is transmitted to a set of photomultiplier tubes by optical light guides.

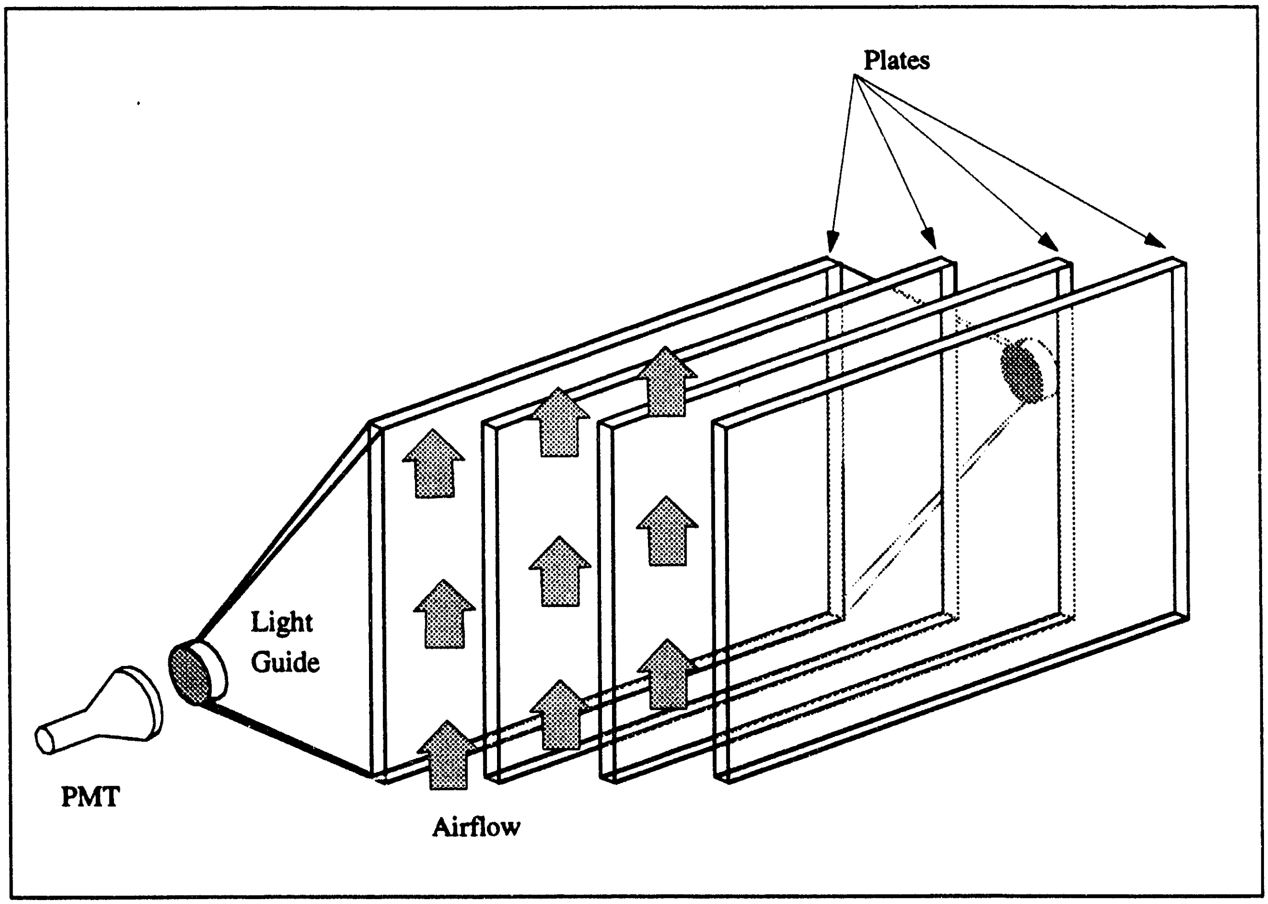

Figure 1. The LVFTDS Approach

A key feature of the LVFTDS is that the radioactive materials measured are not filtered, sampled, or otherwise removed from the primary gas stream in order to be detected. The radioactive materials are detected directly when they emit an alpha particle. The large active volume of the detector permits direct detection without using concentration techniques (such as filtering) that require substantial collection times and thus limit the real-time capability of the system. Also, concentration techniques lead to a reduction in sensitivity over time because of the accumulation of radioactive materials. For most flow conditions, the entire gas stream, or a substantial fraction of the stream, can be monitored directly with the LVFTDS. Its unique, real-time capability allows the LVFTDS to alarm essentially instantly in the event of airborne contamination.

The LVFTDS technology offers other advantages. Without a filter, the maintenance requirements are greatly reduced. The detector sensitive elements are easily cleaned, and with a modular design can be replaced easily should they be damaged. The inherent redundancy of the multi-plate design offers built-in fail safe operation.

Although designed for monitoring alpha radiation, experiments are being conducted to extend the detector into beta and gamma monitoring applications. While the ability of the detector to distinguish between alpha and some beta emitters may be poor, the detector should be able to provide the alarming feature on both alpha and beta radiation simultaneously. This 'total radiation monitoring' feature is an attractive possibility, providing incinerator operators comprehensive radiation alarming in a single device.

The basic concept has been successfully demonstrated on a laboratory scale, as is described in the following paragraphs.

Lab-Scale Prototype Detector

The goal in designing the lab-scale prototype detector was to allow us to test the detector concepts using a radioactive gas. The prototype needed to be large enough to be indicative of the design issues, but small enough to be easily fabricated, assembled, and modified. In the end, a detector built up of plates 930 cm^2 (1 ft^2) in area was designed. The plates were made from 1-mm thick BC404 scintillator from Bicron, Corp. The detector volume is dependent on the number and spacing of the plates. Most of the experiments were performed on a stack of five plates, with a 2 cm inter-plate spacing, giving a total detector volume of 10,230 cm^3 (~0.4 ft^3). With the volume of the 5 scintillation plates subtracted the active air volume of the detector is 9,765 cm^3. While small by our original performance estimates, a detector of this size would fit comfortably in the 25.4 cm (10") diameter stacks of some incinerators.

The lab-scale prototype uses the first generation of plate designs with a flat acrylic light guide. We performed a detailed comparative study of several different light guide designs. The light guide chosen is not the most optically efficient of those tested, costing around a factor of two in optical efficiency over the most efficient (but bulky and difficult to fabricate) design. Based on our experience with earlier tests we were confident that we could tolerate this loss, in favor of the mechanical benefits.

In order to test the prototype detector a commercially available NEMA type 4 enclosure, 152 cm (60") wide by 91 cm (36") deep by 52 cm (21") high, was modified for use as the detector enclosure. With steel walls to provide shielding, and a gasket on a hinged lid, this light and air tight box proved to be ideally suited to our needs.

Figure 2 is a phantom view of the finished detector enclosure. A set of internal walls was designed to allow the recirculation of air over the detector plates, using the fans below the detector plates. The walls and the ceiling restricted the volume of recirculating air to the minimum needed to flow past the detector plates. The fans selected provided ~200 cubic feet per minute of air flow through the detector, with an overall air cycle rate of slightly more than once per second.

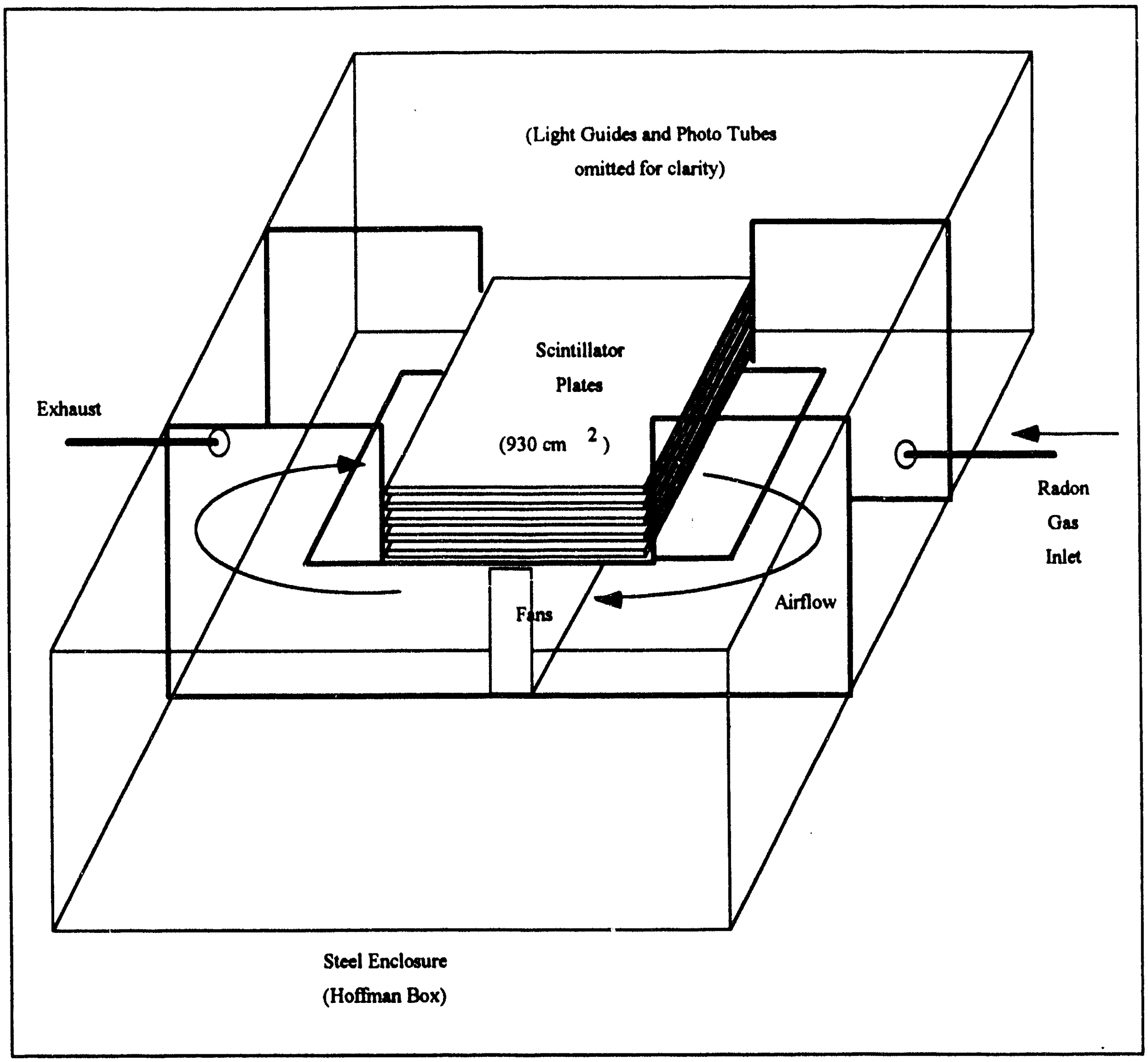

Figure 2. Detector Enclosure Phantom View

A series of electrical connectors were installed on the ends of the box, to connect the high voltage and signal cables to the data acquisition system. An plumbing inlet was installed on the front of the box to allow the introduction of the radioactive gas source, and an exhaust was provided to vent the box to a chemistry hood.

We purchased a commercial radon source supplied by Pylon Electronic Development Co., Ltd. (Model TH-1025) to test the detector. The source contains ^{228}Th that decays to ^{224}Ra and then to ^{220}Rn. The radon emanates from the solid source and is swept from the source with nitrogen carrier gas. The concentration of ^{220}Rn in the carrier gas is determined by the ^{228}Th activity in the source, the flow rate and the volume of the system. At the time we ran the tests, the activity in the source was 0.460 μCi, with a concentration of ^{220}Rn delivered to the test detector of 0.325 μCi/l. This resulted in an equilibrium radon concentration in the circulating air of the detector box of about 3.8 nCi/l.

To maximize flexibility, while minimizing the time and effort spent on experimental configuration changes, the data acquisition system was assembled out of a combination of NIM and CAMAC electronic modules, with an IBM-PC AT computer for control and data logging.

Experimental Results

The main goal of the experiments performed in FY 93 was to demonstrate the detector concept.

A number of test were conducted in which the radon was introduced into the detector box for a short time and then stopped. We continued to circulate the air in the box while the contained radon decayed. During these tests the detector count rate was measured every 5 seconds using the data acquisition system. When the radon flow was stopped, the counting rate decayed with the half-life of ^{220}Rn. The decay portion of a test run, with the background subtracted, is plotted and displayed in Figure 3. The slope of the line, hand fit to the decay curve data, gives a half-life of ~53s, in close agreement with the published half-life of ^{220}Rn.

The average equilibrium counting rate of the detector, corrected for background, was measured to be about 2000 c/s. The active volume of the detector is calculated to be 9765 cm^3, representing 12.7% of the circulating air volume. When the circulating air is at equilibrium with the radon being supplied by the source, the active detector volume contains about 37 nCi of radon with a decay rate of 1369 d/s. Since the ^{220}Rn decays to ^{216}Po with a 0.145s half-life, ^{216}Po is essentially in secular equilibrium with its Rn parent and the total alpha decay rate in the detector is double the rate calculated for Rn alone. This results in a total alpha rate in the detector of 2740 d/s. If we compare this rate with the measured rate of 2000 c/s, we estimate the detection efficiency to be about 73%. This measured efficiency is in excellent agreement with our model predictions.

We found that the background in the detector was a good bit higher than we had hoped for based on the early work we had done. As it turns out this background is the main factor limiting the sensitivity. The background has not been well characterized as yet and we are conducting experiments investigating the nature of the background as well as approaches for significant background reduction.

If we scaled this detector up to 1m^3, our original design goal, with no reduction in the current background or other change in performance, we would predict a minimum detectable concentration of about 0.5 pCi/liter, based on 1 minute counting times.

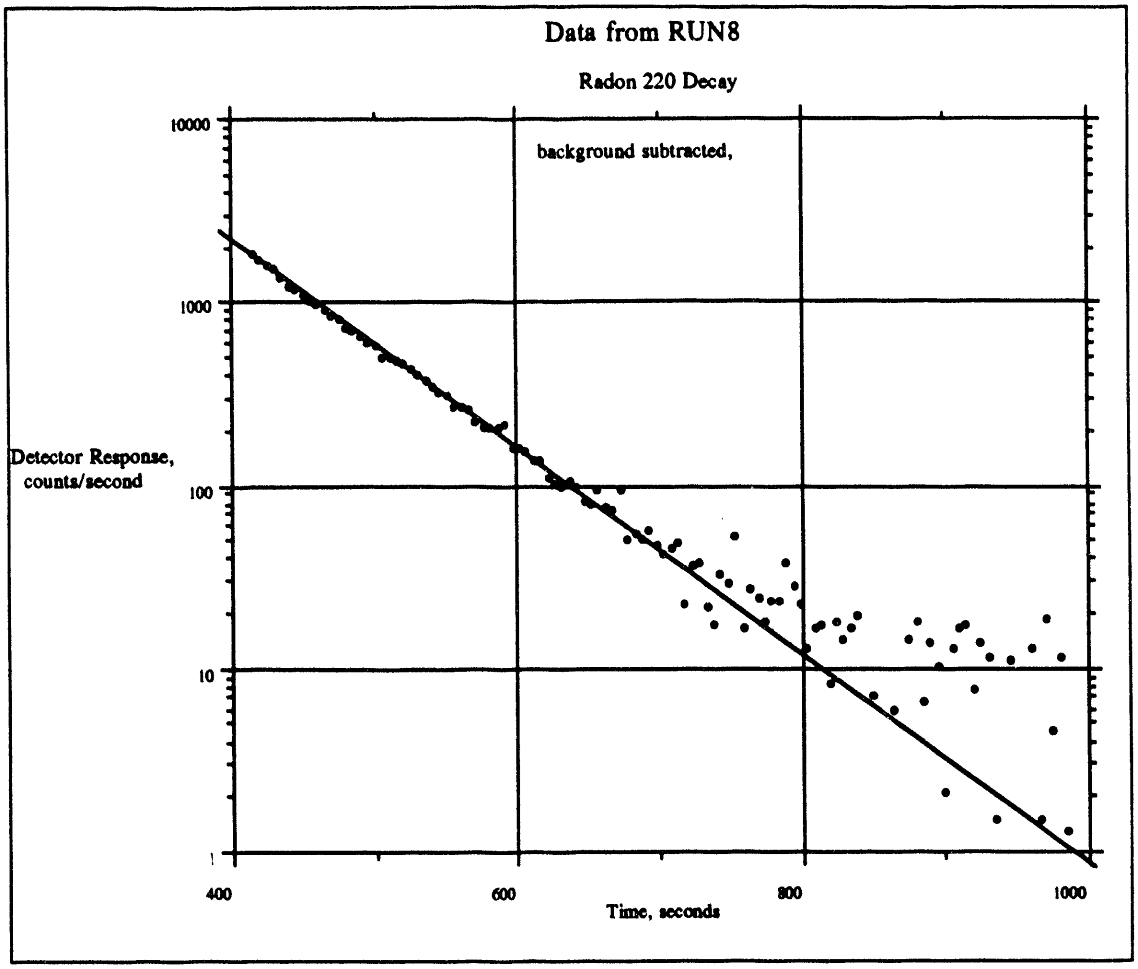

Figure 3. Radon Gas Decay

Development Program

Continued development of this detector system is being funded by the DOE under the Mixed Waste Integrated Program, culminating in a field test planned for late in FY 95.

In the current fiscal year we are concentrating on reducing the detector background, resolving some of the engineering issues concerning temperature and airflow, finding a suitable field test site, and finding a suitable industrial partner to commercialize the technology.

For the next fiscal year we plan to perform the detailed design of the unit for field test, and fabricate, install, and test this field test prototype.

At the conclusion of the field test a fully functional commercial prototype unit will have been installed and field tested. At this point LANLs role will be one of cooperating with the commercial partner to further develop applications and improvements by providing scientific expertise. It will be the responsibility of the commercial partner to bring the final commercial product to the market.

Other Applications

Although the research for this detector was prompted by the need to monitor alpha radiation in mixed-waste incinerator off-gases, we believe the base technology can be adapted for airborne alpha radiation monitoring in other applications.

Examples of applications within the DOE complex include monitoring of gas/ventilation systems such as those on high-level radioactive waste storage tanks or other storage areas, the monitoring of ventilation systems in buildings with combined labs and offices, and air monitoring during site remediation activities.

Commercial applications include some segments of the radon monitoring market, including large facilities or a trailer mounted mobile monitoring service. A final market which falls under this general category is the monitoring of mines and mine shafts. Given the dynamic nature of mining operations a single sampling type monitoring system is insufficient. The LVFTDS would be used in the mine ventilation system, thus monitoring much more effectively the worker's exposure. As a real time monitor, this detector could be very effective in shutting down dangerous operations (ones that result in a high airborne alpha exposure) quickly.

Summary

The development of this new technology is being driven by the need for improved on-line monitoring technology for alarming in real-time at low levels. This directly addresses the public's concern about shortfalls in monitoring technology.

It must be emphasized that this new technology is intended to compliment, rather than replace, current monitoring techniques. The sampling and long integration times of conventional detectors are necessary for the ultimate in sensitivity for regulatory compliance. The fast response, large active volume, and complete stack gas measurement of the LVFTDS technology is necessary to adequately provide fast real time alarming.

We have successfully demonstrated the detector concept and the performance of a prototype unit. At this time, the need to reduce the detector background and ensure the survivability in the incinerator off-gas environment are the primary technical challenges.

With the promise of providing the incinerator site a comprehensive, fast responding, on-line alarm, the LVFTDS technology will soon establish the state of the art of incinerator monitoring for radioactive materials.

We wish to acknowledge and thank Paul Hart and Nina French of the DOE Mixed Waste Integrated Program, and Paul Williams of the Rocky Flats Fluidized Bed Incinerator project for their support of the development of this technology.

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