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Monitoring Airborne Alpha-Emitter Contamination

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Abstract

Facilities that may produce airborne alpha-emitter contamination require a continuous air monitoring (CAM) system. However, these traditional CAMs have difficulty in environments with large quantities of non-radioactive particulates such as dust and salt. Los Alamos has developed an airborne-plutonium sensor (APS) for the REBOUND experiment at the Nevada Test Site which detects alpha contamination directly in the air, and so is less vulnerable to the problems associated with counting activity on a filter. In addition, radon compensation is built into the detector by the use of two measurement chambers.

I. INTRODUCTION

Subcritical experiments such as at the Nevada Test Site (NTS) are performed in support of the Department of Energy program to maintain the safety and reliability of the U.S. nuclear weapons stockpile without nuclear testing. The REBOUND and HOLOG experiments are designed to examine the dynamic properties of plutonium. Data will be used to benchmark computer simulation codes. Approximately 1.5 kg of plutonium in several assemblies will be explosively driven to high compression by conventional high explosives.

The subcritical experiment is conducted in a sealed chamber to prevent dispersal of radioactive material [1]. The conventional method of monitoring air for airborne radioactive contaminants is a continuous air monitoring (CAM) system. Air is drawn through a filter media, and the accumulation of radioactive particulates over some period of time produces an energy spectrum. The spectrum is summed at various alpha peak energies to determine levels of contamination of various radionuclides such as Pu-239. These systems typically can determine air contamination at the level of 1 Derived Air Concentration (DAC) in 4 to 8 hours.

The filters in CAMs need to be changed on a regular basis to reset the counting period. In addition, the filter media are susceptible to build up of non-radioactive particulates such as dust and salt which degrades the energy spectrum, introducing counting problems. Los Alamos field tested a prototype airborne plutonium sensor (APS) for REBOUND which does not measure accumulated radioactive particulates on a filter, but rather alpha decays occurring directly in the air. This eliminates the problem of particulate buildup on filters in dusty or salty environments.

Filter material is used in the APS, but it has a high volume capacity for particulates, so even in dusty environments, filter changing is reduced. In addition, the APS filters are not directly part of the measurement technique, so even with large radioactive particulate accumulations, they need not be changed to reset the measurement period. This detector is based on the long-range alpha detection (LRAD) method [2].

Two of the instruments were field tested near the REBOUND experiment on July 2, 1997 and also near the HOLOG experiment on September 18, 1997. These experiments occurred in the U1a drift of the LYNER complex at the NTS. Work remains to refine the design and determine the feasibility of using this design in the LYNER environment.

II. LRAD BACKGROUND

The advantages of an LRAD-based volume monitor are its inexpensive simplicity, ruggedness, and its ability to assay air volumes and variously shaped surfaces much faster than traditional alpha detection methods such as Geiger-Muller, gas cell, or solid-state detectors. In addition, LRAD designs have been miniaturized to the size of portable hand-held devices for use as swipe monitors, surface contamination monitors, and ion “sniffer” devices for alpha-emitter radioactive leaks.

Alpha particles travel directly out from their source and have a very short range of about 5 cm. Within just a few centimeters of their source, the alpha particles lose all of their energy to collisions with air particles, creating many ions. Alpha-emitter contamination is therefore particularly difficult to assay.

However, the LRAD method detects air molecules ionized by alpha particles, rather than the alpha particles themselves. This is accomplished by allowing or forcing the ions into an electrostatic field produced by grids or parallel plates at high voltage (HV). In the presence of an electrostatic field, the ions can be collected to produce a measurable current. In addition, the ions can travel several meters through a volume and away from irregularly shaped surfaces. This method is extremely effective because a single 5-MeV alpha particle produces approximately 140,000 ions, so even a partial collection of the ions will produce a significant signal. In contrast, a traditional alpha detector produces a signal only if struck by individual alpha particles.

III. APS OPERATION

In the APS, detection of airborne plutonium is accomplished by comparing the signal from decaying particulates in the first LRAD chamber to the signal in a second LRAD chamber that has been filtered of ions and other particulates. Air is drawn into the APS by a fan and passes through four stages. A diagram of the APS is shown in Fig. 1. The detector is made of 4 6” diameter aluminum cylinder sections. This facilitates installation of the grids. Fig. 2 details the electrostatic grids for one LRAD chamber.

DISCLAIMER

LRAD chambers. One measurement used 18 sources arranged symmetrically around the interior of the chamber in 3 groups of 6 to simulate the even distribution of decays caused by radioactive particulates and gas. In each group of 6 sources, 3 were on the chamber wall and 3 were suspended in the center of the chamber facing the cylinder wall. This was repeated for two sets of sources. The first set totaled 6001 dpm and the second set totaled 58019 dpm.

Chamber response was 375 +/- 25 mV and 3600 +/- 52 mV, respectively, yielding a sensitivity of 0.061 +/- 0.005 mV/dpm. The errors in signal are single run statistics, but the sensitivity error is larger than statistics because the reproducibility of this number from run to run was 8%. The check sources are in dpm, but only $2\pi/4\pi$ are seen, so a factor of 2 is needed in the conversion to mV/pCi/l. With the volume of each chamber being 5.05 liters, the Pu-239 calibration is 1.38 mV/pCi/l. Detector efficiency with distributed sources is 33%.

A second calibration was done using single Pu-239 check sources of several strengths placed on the lower HV grid of each chamber alternately. This established the linear response of the detector to source strength. Fig. 3 shows this linearity check. Detector efficiency with these single sources was 43%.

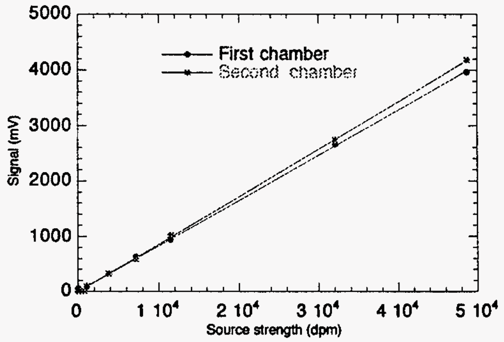

Fig. 3. Plot of singles Pu-239 check sources to verify linearity of the APS. The slight difference in slope was corrected by adjusting the gain of one electrometer.

Tests of the detector in conditions of actual air contamination are much more difficult and have not yet been performed. The ideal calibration of the APS would be in a calibrated environment of airborne plutonium. The next best calibration would be in a calibrated radon chamber. The radon chamber would verify the gain matching of the two electrometers and chambers more accurately than either of the above two calibrations. This would also give a radon calibration which would enable the detector to also be used as a radon detector. Tests with a similar LRAD design indicates a sensitivity to radon of < 1 pCi/l in 5 min. counting time.

Routine calibrations checks were done by NTS personnel using check sources to verify proper and consistent operation.

IV. RESULTS

The APS has been tested during the REBOUND and HOLOG experiments. Some of the detector response is not understood. The detector has shown a sensitivity to various activities preceding and following the subcritical experiments. For example, tunnel pressurization, combustion products of nearby operating machinery, and ventilation activities seem to cause fluctuations in the detector signals. These fluctuations occur mainly in the first chamber.

A. REBOUND-1

Fig. 4 shows the detector response in the hours just before and after the REBOUND experiment. The data plotted are the radon subtracted signals. One APS was placed just outside the zero room primary containment plug, and a second APS was placed outside the "anti-contamination plug" (see Fig. 5.). Notice the large spikes in both detectors just before the experiment. These spikes coincide with the drift over-pressurization. The pressurization is designed to help reduce the amount of gas diffusing through the alluvium from the zero room, where the experiment takes place, into other parts of the complex.

The nature of the anomalous signals is not known, but it is suspected that the activities mentioned above produce heavy and/or large quantities of ions which are not stopped by the Stage 1 filter. The second chamber shows smaller fluctuations, indicating a small number of ions are also passing through the filter media.

The signal of the detector near the "anti-C plug" drifts upward steadily after the experiment. If the detector were operating properly, this would indicate an increasing radioactive particulate atmosphere. However, measurements just outside the zero room indicated no sign of contamination. The drift is believed to be an electronics problem.

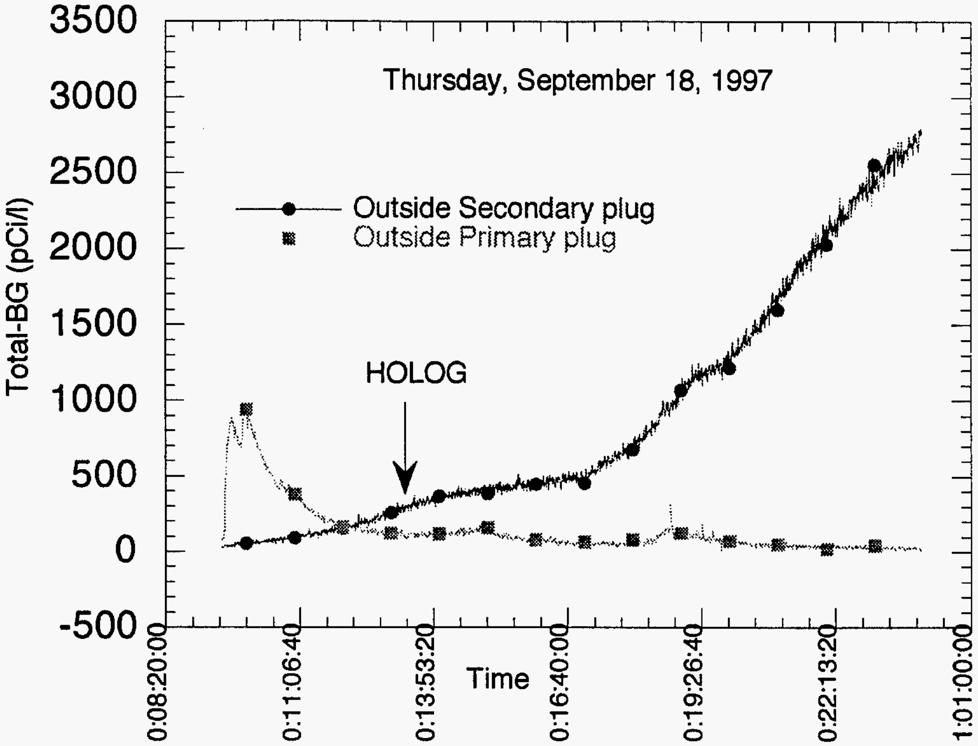

Fig. 6. The radon subtracted response of the two APS detectors just before and after the HOLOG experiment. The y-axis reads pCi/l according to the calibration, but the drift clearly does not have the contamination indicated.

As the averaging time is reduced, the uncertainty in the DAC level increases, but uncertainty in the total exposure, i.e. DAC-hr., decreases. Table 1 summarizes these results.

Table 1.
DAC and DAC-hr. uncertainties for various APS averaging times

Averaging time	DAC uncertainty	DAC-hr. uncertainty
1 hr. at NTS	520	520
5 min. at NTS	780	65
1.8 min. at NTS	1840	55
1 min. at LANL	860	14

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