LA-UR-01-3256
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Submitted to:

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Abstract

Los Alamos National Laboratory (LANL) is in the process of adding Long Range Alpha Detector (LRAD) technology to its established Green Is Clean (GIC) program. GIC material includes waste and material for recycle generated in radiological controlled areas (RCAs) that have been actively segregated as "clean" (i.e., nonradioactive) through the use of waste generator acceptable knowledge (AK). Properly segregated GIC material has a high probability of being free of radioactive contamination. LANL GIC operations provide a verification check on the AK-based determination for low-density and certain high-density items.

Introduction

Green Is Clean material that is verified clean can be disposed of at the Los Alamos County Landfill or recycled if it meets applicable DOE recycle criteria. It is estimated that 50-90% of the waste and recycle material from RCAs at LANL might be free of radioactive contamination. The cost of low-level waste disposal at LANL has been steadily increasing over the past ten years. Depending on the type of waste, recent disposal estimates for low-level waste have been from $550 to $4000 per cubic meter. By contrast, non-radioactive waste can be sent to the county landfill at a few dollars per cubic meter.

The LRAD system verifies that small, high-density items such as tools, circuit boards, and pipe fittings, are free of radioactive contamination. At LANL, these items are primarily from radiation areas that process plutonium and uranium.

On site testing of the LRAD is being performed to determine the range of background radiation counts and the sensitivity of the instrument to sources placed in various locations in the assay chamber. Real waste or items for recycle from LANL RCAs that have already been verified clean by the LANL Decontamination Facility are being assayed in the LRAD with and without added radioactive source material. The LRAD systems will detect radiation on irregular objects, and inside open surfaces that can be accessed by the air flow through the monitoring chamber, but not on closed surfaces. The on site testing includes placing radioactive source material in or on the items to help determine the practical limits of the instrument.

The completion of this testing phase will set the boundaries of the instrument capabilities for GIC waste and signal the formal addition of the LRAD technology to the LANL Green Is Clean program.

The LRAD Detector

LRAD type detection systems were developed at LANL and the technology has been transferred to several commercial companies to meet identified DOE and commercial radiation detection needs. The instrument used for this study is the Eberline LRAD-1™. This instrument (Figure 1 and 2) consists of a pre-filter for particulates, a static precipitator to remove existing ions before they enter the sample chamber, the sample chamber, the detector grid and electrometer circuits, a high efficiency particular air (HEPA) exhaust filter, a set of fans to pull air through the system, and an integrated computer and display.[1] The LRAD enclosure is about the size and appearance of a large microwave oven. The inner dimensions of the sample chamber are 13 inches (33 cm) high by 22 inches (56 cm) wide by 16 inches (41 cm) deep. This instrument is the most appropriate size for items such as the circuit boards, pipe fittings, and small tools that may be part of the LANL Green Is Clean program.

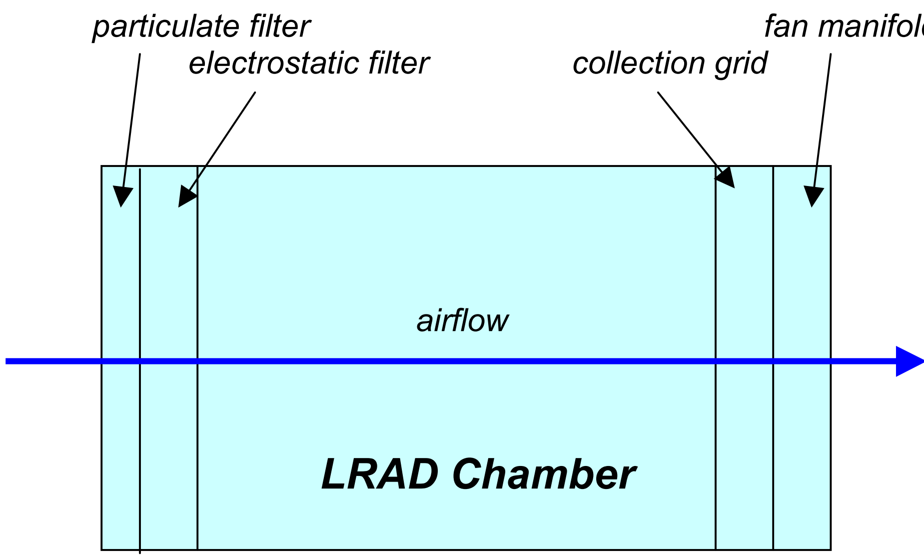

Figure 1. A schematic of the LRAD-1 System.

Other commercial LRAD products available include small and large chambered object monitors similar to the medium size instrument described above, pipe and duct monitors, and surface monitors.[2,3] Other instruments being studied or under development are personnel monitors, instruments that use a conveyor belt to monitor batches of material, and monitors for liquid radioactive waste streams.

Objects to be monitored are individually placed into the LRAD enclosure with no wrapping (Figure 3). The LRAD operates by detecting the ions created by alpha particles in ambient air rather than detecting the alpha particles directly. The LRAD system sweeps the ions to the grid where they are collected and then the charge associated with the ions is measured by electrometer circuits (in femtoamps). The instrument is actually sensitive to all forms of ionizing radiation, but is best suited to detecting alpha particles because they ionize heavily over a short range. Beta particles and gamma rays have a much longer range and deposit most of their energy in the chamber walls. Neutrons interact weakly and do not produce a large signal in the LRAD. In most cases, the contribution from these other types of radiation is negligible compared to the alpha contribution. The range of a 5-MeV alpha particle in air is about 4 cm under normal conditions.[4] In this short path length, the particle produces approximately 150,000 ion pairs at 35 eV per ion pair. The ion pairs have a mean lifetime of a few seconds, which is more than enough time for them to be transported to the ion collection grid of the instrument (the ions can be transported several meters).

Figure 2. The LRAD-1 System

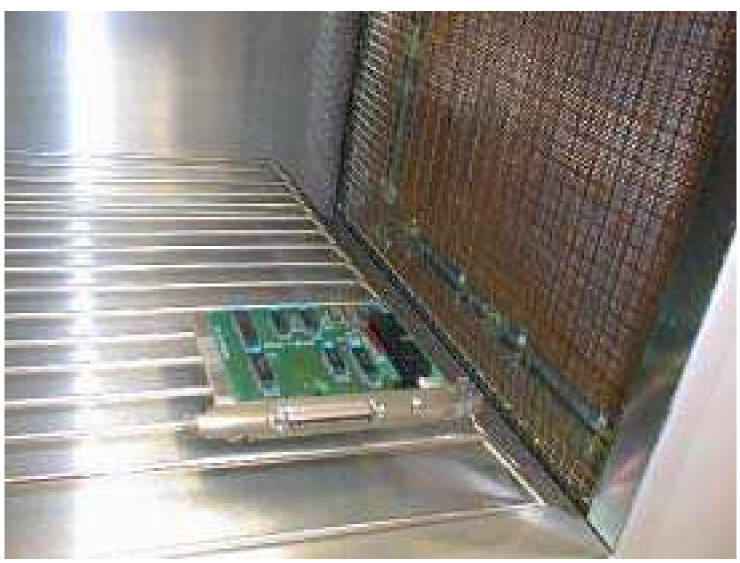

Figure 3. A circuit board in the LRAD chamber near collection grid.

The response of the LRAD to alpha radiation is linear. When the instrument is optimized, sources smaller than 100 disintegrations per minute (dpm) have been reliably detected. Factors affecting the detection limits consist of those set by the system configuration, by environmental factors, by operator choices, and by the objects being monitored. These factors include the stability of the background signal, the collection grid voltage, the configuration of the collection grid, the position of the object in relation to the collection grid, the airflow speed, the static charge and the geometry of the object being monitored. High radioactivity levels promote rapid recombination of the ion pairs created by the alpha radiation and give a false indication of the level of radioactivity present. However, for Green Is Clean materials, high radioactivity levels are not an issue.

Current Experiments

Doped Circuit Boards

Three circuit boards doped with uniformly distributed levels of a plutonium 239/240 mixture (both have 5.2 MeV alphas) applied to both sides of the circuit boards were used to determine the response of the detector to slightly contaminated circuit boards. Table 1 shows the known contamination levels of the boards.

Table 1. Pu239/240 Circuit Boards

board number	Board size (LxW) (inches)		total surface area (cm^2)	total activity (dpm)	activity/area (dpm/100 cm^2)
S-1	4.50	4.25	247	286	116
S-2	4.00	5.00	258	286	111
S-3	3.50	5.50	248	286	115

The last column of Table 1 is calculated as dpm/100 cm^2 because the DOE unrestricted release limits (DOE Order 5400.5) for surface contaminated objects are stated as contamination levels in dpm/100 cm^2. The current release limit for total contamination from transuranics is 100 dpm/100 cm^2. From uranium, it is 5000 dpm/100 cm^2. For removable contamination, the limit is 20 dpm/100 cm^2 for transuranics and 1000 dpm/100 cm^2 for uranium. Like direct survey instruments, the LRAD measures both fixed and removable alpha contamination.

The three doped circuit boards were used to make various counts in the LRAD to determine the optimum position for the boards in the instrument, whether the boards being right side up or up side down made a difference (due to air flow non-uniformities in the chamber), and the efficiency of the instrument in counting each board. A total of 177 measurements were used to make these determinations. More measurements were made, but the first several were discarded because it was determined through trial and error that the application of Static Guard® (or a comparable antistatic product) to both sides of the circuit boards prior to the measurement was absolutely essential to achieve adequate collection of the ions produced by the alpha contamination. The high static charge of the untreated circuit boards strongly attracts the ions and prevents them from traveling to the collection grid.

Table 2 shows the results of the measurements. The boards were placed right side up for 125 counts and up side down for 52 counts. It was found that the efficiency of the detector was greater when the boards were facing right side up. This could be attributed to uneven application of the radioactivity when the circuit boards were prepared for the experiment. Alternatively, it could be due to some air flow difference between the two positions which is a combination of the effect of the circuit board components and the positioning rack at the bottom of the LRAD chamber.

The boards were placed in three vertical and three horizontal segments within the LRAD chamber (Figure 4). Twelve or more counts were made in each of the segments, with each of the three boards being placed in each segment approximately the same number of times.

Table 2. LRAD Test Data Summary

count	average dpm detected	% efficiency (vs. known 286 dpm)	1 sigma uncertainty (dpm)
overall (board up)	194.5	68.02	52.17
overall (board down)	137.2	47.96	47.18
S-1 board	197.1	68.90	56.17
S-2 board	185.7	64.95	39.03
S-3 board	203.1	71.00	61.31
segment A1	199.1	69.61	49.75
segment A2	184.1	64.36	46.41
segment A3	185.1	64.73	82.59
segment B1	197.2	68.94	47.56
segment B2	238.8	83.48	38.04
segment B3	210.4	73.58	35.52
segment C1	163.8	57.26	35.51
segment C2	188.8	66.03	42.67
segment C3	185.0	64.69	52.95
all vertical 1	184.4	64.47	45.96
all vertical 2	203.9	71.29	48.30
all vertical 3	195.9	68.51	58.83
all horizontal A	189.0	66.08	63.04
all horizontal B	214.4	74.98	41.84
all horizontal C	177.7	62.11	43.86

Note: Averages for vertical and horizontal positions, and for the individual boards, are based only on counts performed with the board facing up.

Top view looking down on LRAD

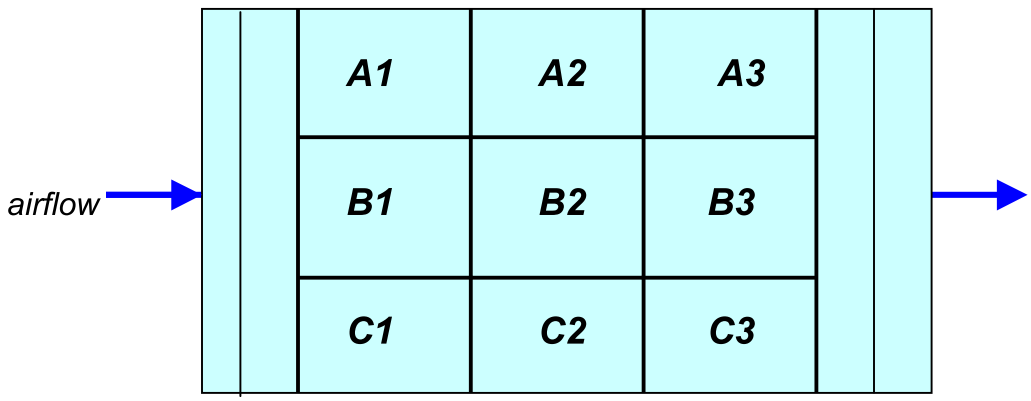

Figure 4. Vertical and horizontal segments within the LRAD chamber.

From these data it appears that the most efficient position for placing the circuit boards in the LRAD chamber is in the middle of the chamber. This is true for the horizontal position because the airflow should be most consistent at the center of the chamber. However, for the vertical position, since the third vertical segment (B3) is closer to the collection grid, that would logically be the most efficient position. In fact, the averages for sections B2 and B3 are very close and the uncertainties with these low activity sources are large.

The average efficiencies calculated for the three circuit boards were 65%, 69%, and 71%. These efficiencies were calculated using the counts made in the right side up position only. The average efficiency for all of the boards was 68%.

Background Counts

The background count information is presented below in Table 3 and Figure 5. 229 one-minute background counts were made over the course of six days, for both consecutive and non-consecutive days. The background count information is presented to the operator in Hertz. The current calibration conversion for this instrument from Hertz to dpm is a factor of 5.87. The average and standard deviations of the 10-minute background counts were nearly the same as the average and standard deviations of the one-minute background counts. Four additional 10-minute background counts were made and not included in this data. These four counts were the last four counts made and were significantly elevated (239 Hz – 313 Hz) compared to the first 50 counts. This was probably due to an incoming thunderstorm. Large changes in air pressure can change the background counts radically. Low atmospheric air pressure brings radon out of the ground. Radon daughters raise the alpha background level in the chamber.[5] The average of the one-minute background counts varied from 165.37 Hz to 215.25 Hz over the experiments. The background counts are automatically subtracted from the sample counts, so the operator needs to be aware of the potential for a changing background. During weather front activity, the background counts can raise or fall rapidly (over the course of a half-hour for example) and give a false positive or negative result from the LRAD. We chose not to operate the instrument during thunderstorm activity. The operator can set the instrument to use only the latest background or to average several background counts together. For these experiments, the latest background count was used for comparison with the sample count. The background counts were checked at least hourly and sometimes after every sample count to make sure that the operator was aware of background changes.

Table 3. LRAD Background Summary

count time (min.)	number of counts	average (Hz)	1 sigma (Hz)	average (dpm)	1 sigma (dpm)
10	50	188.08	12.07	1104	71
1	229	188.81	12.69	1108	74
1 – 5/8/01	50	210.00	22.81	1233	133
1 – 5/17/01	28	215.25	18.63	1264	109
1 – 5/21/01	41	176.80	19.57	1038	115
1 – 5/22/01	41	165.37	10.32	971	61
1 – 5/23/01	29	185.14	5.77	1087	34
1 – 5/24/01	40	182.80	9.16	1073	54

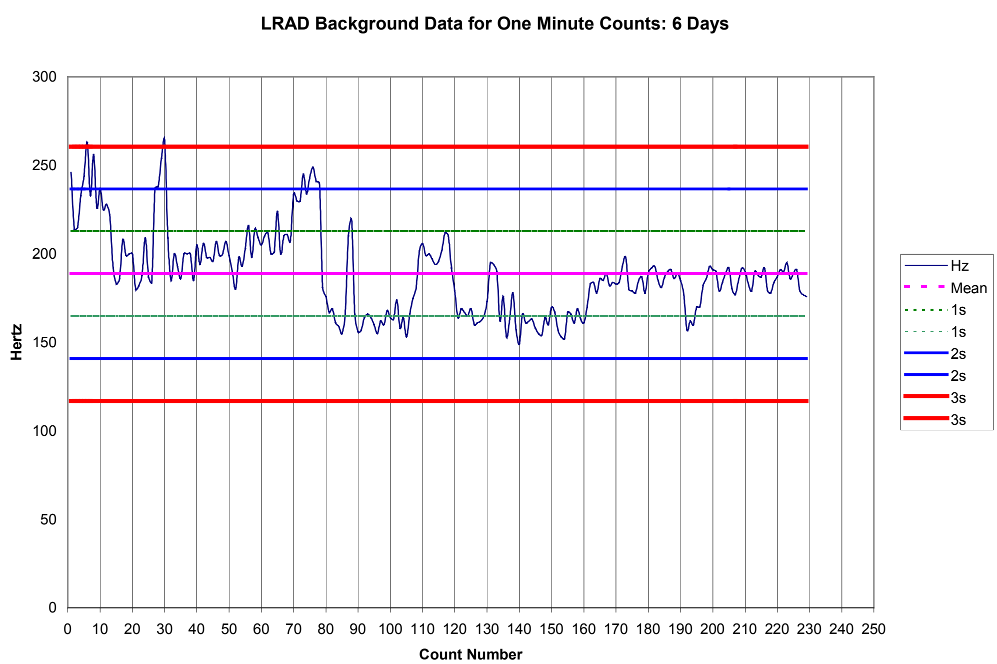

Figure 5. 229 one-minute background counts on the LRAD.

Radiation Sources

Two standard alpha radiation sources were used to check the response of the LRAD instrument. The sources were placed in same segment of the LRAD chamber for all counts. One Th-230 and one Am-241 source were used. The detector response was very consistent with these higher strength (compared to the doped circuit boards) sources.

Table 4. Response of LRAD to Alpha Sources

source	alpha energy (MeV)	number of counts	average (dpm)	1 sigma (dpm)	%RSV
Th-230	4.7	50	20,288	536	2.64
Am-241	5.5	50	2,968	136	4.59

Green Is Clean Circuit Boards

The final phase of these experiments involved using the LRAD to assay Green Is Clean circuit boards from LANL RCAs where alpha materials are processed. Over four hundred circuit boards were assayed in the LRAD. These circuit boards had been removed from electronic equipment that had been used in the RCAs. The generator's declared that the material was not contaminated. The outside of the equipment was surveyed by radiation control technicians (RCTs) prior to leaving the RCAs. It was dismantled at LANLs Decontamination Facility, then the circuit boards were individually surveyed by RCTs and placed in drums for recycle. These drums were sent to the GIC facility and the circuit boards were counted in the LRAD. Each board was sprayed with an anti static spray. Each board was counted at least twice. They were counted individually and in sets laid out on the LRAD rack. They were counted right side up and up side down. They were placed in all segments of the LRAD. No radiation was found on any of the boards. The LRAD did alarm several times and indicate that radiation was present, however, upon investigation, it was found that the background had been changing rapidly, causing a false alarm.

Conclusion

The Long-Range Alpha Detector was found to be a reliable instrument when used with care. Doped circuit boards with low levels of contamination (around 100 dpm/100 cm^2) were consistently identified as contaminated objects. The standard deviation for low level contaminated objects was high, but the presence of contamination was detected. Frequent background checks were necessary to assure that the background had not changed significantly, which would result in either false positive or false negative readings. The application of an antistatic agent is required when counting items with the potential for a high static charge. High strength alpha sources were counted with low relative standard deviation.

References

1. Eberline, "Long Range Alpha Detector Technical Manual," January 1, 1993.

2. Caress, R.W., et. al, "LRAD-Based Airflow Monitors," LA-12742, March 1994.

3. Conaway, J.G., M.W. Rawool-Sullivan, and D.W. MacArthur, "Alpha Contamination Assessment for D&D Activities: Technology Overview," LA-13062-MS, February 1996.

4. Knoll, G. F., Radiation Detection and Measurement, 2nd ed., John Wiley & Sons, Inc., New York, 1989.

5. MacArthur, D.W., K. S. Allander, J.A. Bounds, and K.B. Butterfield, "Small Long-Range Alpha Detector (LRAD) with Computer Readout," LA-12199-MS, December 1992.