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TITLE THE CONTINUING SAGA OF ALPHA CAM DEVELOPMENT AT LOS ALAMOS

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The Continuing Saga of Alpha CAM Development at Los Alamos

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Abstract

Monitoring requirements for airborne plutonium are becoming increasingly stringent as regulations require progressively lower limits of detection. The current requirement of 8 DAC-hours reflects the limitations of today's technology for workplace monitoring. Simultaneously, closed-ventilation systems and massive concrete buildings are concentrating radon and its daughter products. The daughter products produce a spectrum that degrades the ability of a continuous air monitor (CAM) to make accurate low-level determinations of plutonium. Los Alamos has been working on improved methods for detecting airborne alpha emitters in the presence of radon daughter products for the last 2 years.

These efforts were recently coordinated into a program to examine all facets of CAM operation including aerosol collection, detection, signal processing, computation, alarming, communications, and, finally, instrument cost.

Introduction

The initial steps were taken when Unruh[1] joined a small multi-channel pulse height analyzer (MCA) to an existing CAM and developed an algorithm to separate plutonium and radon background spectra. Current instruments reflect this heritage. Recently, Los Alamos submitted specifications and a request for quotation to the marketplace for CAMs and received prototypes from three vendors. The prototypes were evaluated and all were rejected for numerous reasons, including poor collection efficiency, instability, and cost. It was apparent to us that current technology can produce a better CAM. A meeting of Dept. of Energy contractors at the Rocky Flats plant in April 1989 reached similar conclusions.

At the same time, Wolf[2] developed a prototype MCA board while new ideas on CAM head design emerged as a result of our testing. These developments indicated that it is possible to produce a new generation CAM, which offers improved performance at significantly reduced cost.

The development is progressing systematically starting with the head design. Close attention is being paid to aerosol collection efficiency, uniformity of deposition, flow regulation, and detector/filter geometry. Satisfactory

performance requires the head to collect and deposit on the filter no less than 50% of the particulates whose sizes range up to 10 microns. The geometric relationship of the filter and the detector affects the resolution of the spectrum. It is a compromise between a close spacing for improved spectral resolution and a wider spacing to avoid flow restriction and distortion.

Next comes the detector. There are differing opinions about detector sizes and the resulting resolution, sensitivity, and cost effectiveness. We are examining detectors ranging up to 2 in. in diameter. As of this meeting, we do not know the best combination of detector size and filter geometry.

Instrumentation is one area primed for enhancement. Microprocessor technology is a "must do" and offers the ability to perform local data reduction and to use intelligent algorithms. Additionally, microprocessors that contain integrated analog to digital (A/D) converters allow the construction of fast, inexpensive, and accurate MCAs. This factor alone will have a major impact on the cost of a CAM. Present A/D converters which are integrated with a microprocessor lack sufficient linearity for a good MCA design. However, Wolf[2] has demonstrated a compensation technique that makes these devices suitable.

The system requirements are as important as the instrument itself. Applications range from a stand-alone CAM and progress through several CAMs linked to a desktop computer and can become an entire facility containing several hundred CAMs networked to a central control room environment. A successful CAM design should adapt itself to all these situations without major changes. How can all these requirements be condensed into an effective design?

We have addressed these needs and come up with a system that should meet all requirements. This development is currently under way.

Head Design

Our testing of commercial CAM heads for aerosol collection efficiency has convinced us to undertake a new design. Close attention was paid to efficiency and uniformity of aerosol deposition. The resulting design uses a radial sample inlet and preserves laminar flow as much

as possible. Disturbances in the flow pattern have a strong effect on the loss of larger size aerosols. Part of this effort is a study to determine the optimum detector size and the detector-to-filter geometry. One interesting item reported by Little[3] is that detector sizes above 25 mm offer little or no improvement in sensitivity.

The head design is well under way and prototypes are being prepared at this time. The design includes flow monitoring and regulation to compensate for varying house vacuum. This simplifies the calculations for isotope concentration. The detector is shielded from ambient light and requires no surface protection beyond normal passivation. An outline of the CAM head is shown in Figure 1.

Our collection head continues to use filters for aerosol extraction. There is interest in the ability of impactors to provide greater sensitivity because of their larger sample flow capability. However, numerous questions exist about this new technology. How well does an impactor reject radon daughter products under various operating conditions? How frequently is detector maintenance required in dusty areas? How sensitive is an impactor's "cut point" in size discrimination to changes in sample flow? By using an impactor, are some dangerous assumptions being made about the aerosol sizes that will be present under accidental release conditions? These and other questions need to be resolved before impactor CAMs can be realistically compared to filter CAMs.

Detectors

Detectors have received relatively little attention so far because existing detectors are low in cost and the best size appears to be in the vicinity of 25 mm. Additional work to prolong detector life in harsh environments needs to be done and the issues of optimum detector size and its geometric relationship to the filter need to be verified.

Instrumentation

The greatest effort to date involves the electronics package that we have located in the head assembly. The low-cost MCA described at last year's meeting has been augmented by alarm outputs (contact closure, audible, & visual) and an interface to a second card containing an intelligent adaptive alarm algorithm. This optional second card ("smart card") will also be located within the head assembly.

At present, our smart card is programmed in BASIC and uses EPROM storage. Its purpose is to perform low-level release calculations by applying an algorithm which adapts itself to the data then being seen by the detector. This algorithm can compensate for gain drifts in the detector preamplifier and changes in filter loading with

time. Its presence within the CAM is optional but, if used, yields a fully functional and stand-alone CAM. The smart card is optional and can be omitted for those situations in which external intelligence replaces the algorithm's capabilities.

Because this card is programmed in a high level language, it is easy to implement changes in the coding of the algorithm. It will not be necessary to replace EPROMS or require factory assistance because all changes will be done in the field at the installed location. Thus, as operating experience grows, updates will involve new software, whereas the hardware will remain unaffected.

Finally, our development includes a removable liquid crystal display (LCD) panel, which presents graphical spectral and isotope concentration data. This unit is expected to be located in a corridor outside the CAM's installed location.

The installed configuration will have the CAM detector head and its electronics package located as close to the area of interest as is possible. The LCD panel and keyboard will be remotely located for convenience.

Algorithms

Improved data reduction methods are a major component of our effort. Unruh's[1] work in 1986 was the first step in this process. The major hurdle is still the overlapping of the low-energy side of the 6-MeV radon daughter peak into the plutonium spectrum. Additional problems include electronic gain drift with time and the effects of inert material that is deposited onto the filter. Figure 2 shows a sample spectrum of a low-level plutonium sample with accompanying radon background.

The background compensation algorithm in present instruments uses a ratio approach to predict how much of the low-energy tail of the 6-MeV peak will extend into the spectral region occupied by plutonium. Because instrument calibration is fixed, this method is very sensitive to anything which causes a change or drift in the peak location. Whereas good electronic design can minimize amplifier gain shifts, nothing can be done to compensate for changes in filter loading or a calibration error with this method. Our approach uses an adaptive algorithm which calibrates itself to the data being seen and makes adjustments to those MCA channels being summed for plutonium as filter loading and peak shapes change. This has the added benefit of allowing simpler circuitry to be used and compensates for gain drifts in the preamplifier. After background compensation has been applied to the data, the resulting concentration from the last instrument update is analyzed using statistics. For concentration levels near the alarm threshold, a statistically significant majority ("N" alarms in "M"

intervals) must exist before an instrument alarm occurs. This minimizes false alarms. In addition, the statistics of the plutonium totals are examined and used to determine what the minimum alarming level can be for the data being seen at that time. This means the lowest detection limit of the CAM is not fixed. Instead, it changes with time and filter conditions to reflect that which can be accomplished under the current operating conditions.

on Nuclear Science, vol. NS-36, No. 1, pp. 723-725, Feb. 1989.

[3] J. Little, "Sensitivity of Alpha Continuous Air Monitors," Presented at the August 22, 1989 Meeting of the Fine Particle Society, August 1989.

Networking

In facilities containing many CAMs, it is necessary to deliver CAM data to a central computer located in a control room. In the past, this was done by wiring from each CAM to the computer or to a nearby data concentrator. The overhead in this approach is enormous. Additions or changes in an existing facility are very expensive.

Our approach is designed with a flexible and versatile interface. Each CAM contains an RS-485 serial communications port and a unique identification code. RS-485 allows over thirty CAMs to attach to a single twisted pair in a party-line fashion and the wiring can be several thousand feet long. This communication bus can connect to anything from a personal computer to a mainframe and supports high data rates. Commands issued by the computer are addressed to a specific CAM and only that unit responds. Health check polls issued by the controlling computer result in messages identifying the CAM's presence and alarm status. This method allows workplaces to be easily wired and for CAMs to be quickly rearranged as needs change.

Conclusions

By approaching the CAM design systematically, we have started the development of a new generation of continuous air monitors which combine low cost, improved sensitivity, and versatility in preparation for the needs of the next decade.

Acknowledgments

It is appropriate to acknowledge Wes Unruh for pioneering the use of an MCA combined with a compensation algorithm, John Umbarger and Lee McAtee for funding support, and Mike Wolf for yet another MCA design.

References

[1] W. P. Unruh, "Development of a Prototype Plutonium CAM at Los Alamos," Unpublished internal report, Los Alamos National Laboratory, Dec. 15, 1986.

[2] M. A. Wolf, "Differential Non-Linearity Compensation Enables the Design of a Low-Cost Networked MCA," IEEE Transactions

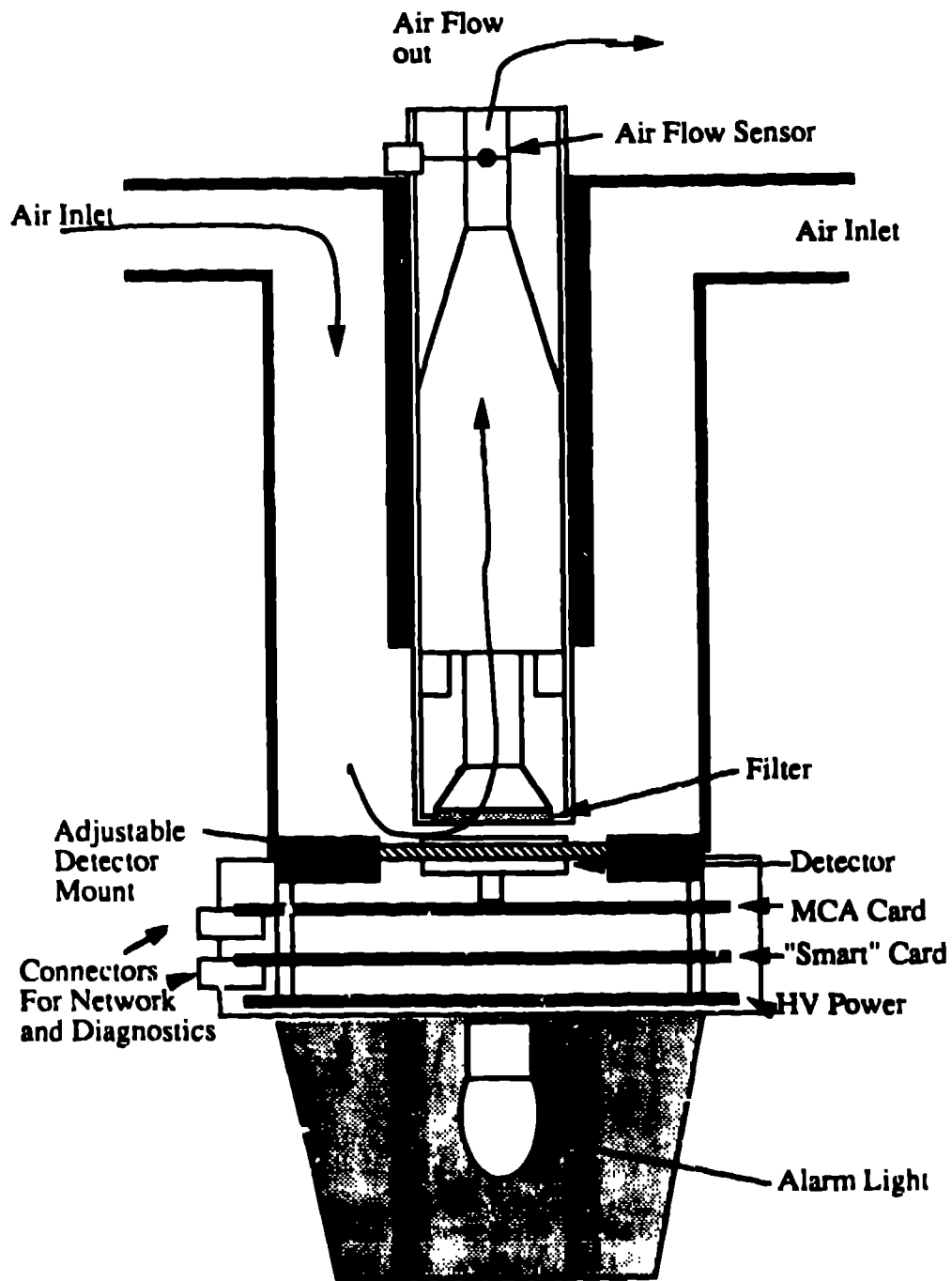


Figure 1. Prototype Los Alamos CAM

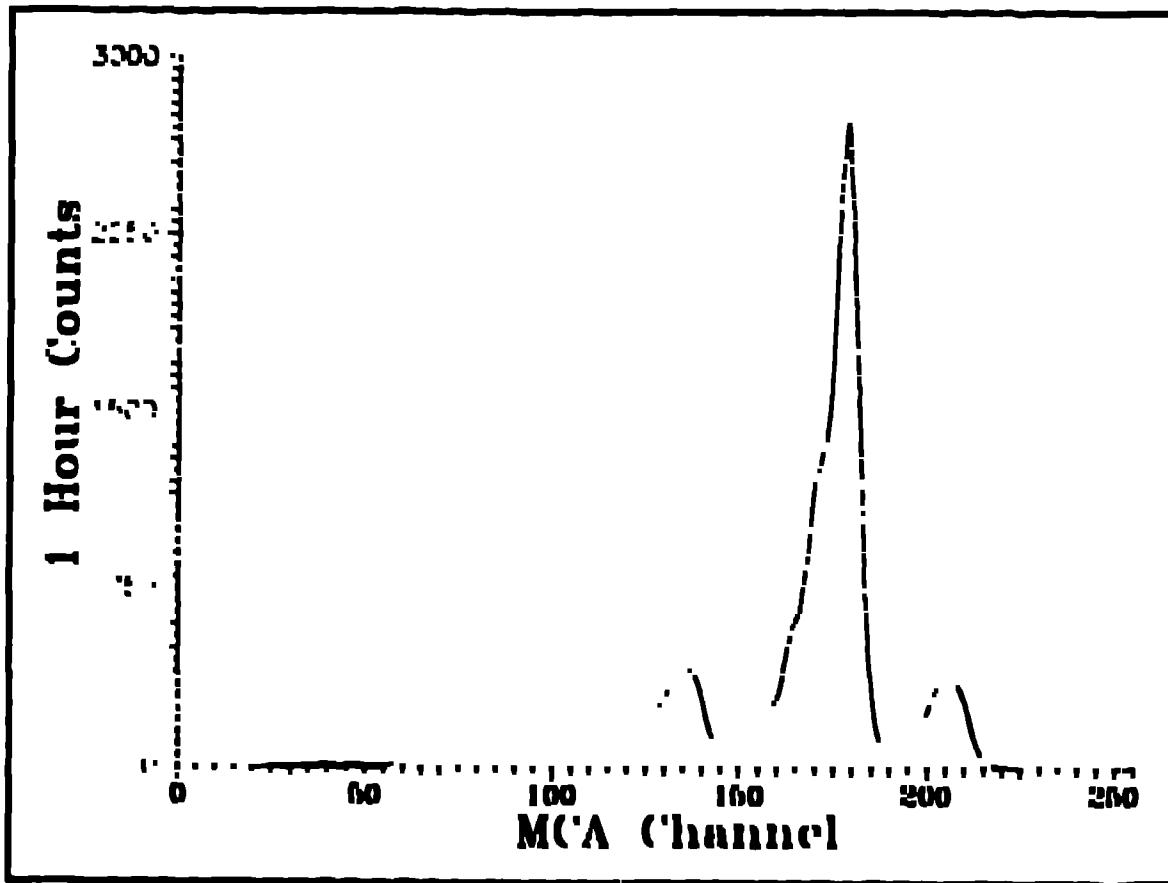


Figure 2. Plutonium and Radon Daughter Spectrum