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SUMMARY OF SECOND GENERATION ALPHA CAM TESTING PERFORMED AT HANFORD

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SUMMARY

Pacific Northwest Laboratory and Westinghouse Hanford Company tested six models of commercially available alpha continuous air monitors (CAMs): the Canberra Alpha Sentry, Eberline Alpha 6A-1, Merlin Gerin A-CAM, NE America CAM1A, SAIC/RADeCO Model 452, and Victoreen Model 758. The CAMs were tested for calibration and workmanship, performance in various environments, and human factors for field use.

CONTENTS

SUMMARY iii

1.0 INTRODUCTION 1.1

2.0 BASIS FOR AND SUMMARY OF EVALUATIONS 2.1

2.1 CALIBRATION EVALUATION 2.1

2.2 WORKMANSHIP EVALUATION 2.1

2.3 ENVIRONMENTAL EVALUATION 2.2

2.4 FIELD AND HUMAN FACTORS EVALUATION 2.7

3.0 CANBERRA ALPHA SENTRY 3.1

4.0 EBERLINE ALPHA 6A-1 . . . . . 4.1

4.1 SUMMARY 4.1

4.2 CALIBRATION EVALUATION 4.1

4.3 ENVIRONMENTAL EVALUATION 4.1

4.4 FIELD EVALUATION 4.2

5.0 SAIC/RADeCO 452 . . . . . 5.1

5.1 SUMMARY 5.1

5.2 CALIBRATION EVALUATION 5.1

5.3 ENVIRONMENTAL EVALUATION 5.2

5.4 FIELD EVALUATION 5.3

6.0 MERLIN GERIN A-CAM 6.1

6.1 SUMMARY 6.1

6.2 CALIBRATION EVALUATION 6.2

6.3 ENVIRONMENTAL EVALUATION 6.2

6.4 FIELD EVALUATION 6.2

7.0 NE AMERICA CAM1A 7.1

7.1 SUMMARY 7.1

7.2 CALIBRATION EVALUATION 7.1

7.3 ENVIRONMENTAL EVALUATION 7.2

7.4 FIELD EVALUATION 7.4

8.0 VICTOREEN 758 . . . . . 8.1

8.1 SUMMARY 8.1

8.2 CALIBRATION EVALUATION 8.1

8.3 ENVIRONMENTAL EVALUATION 8.2

8.4 FIELD EVALUATION 8.4

9.0 REFERENCES 9.1

APPENDIX - TESTING OF CONTINUOUS ALPHA AIR MONITORS AGAINST CRITERIA IN ANSI N42.17B

1.0 INTRODUCTION

Pacific Northwest Laboratory (PNL)[a] and Westinghouse Hanford Company (WHC) recently evaluated six models of commercially available alpha continuous air monitors (CAMs): Canberra Alpha Sentry, Eberline Alpha 6A-1, Merlin Gerin A-CAM, NE America CAM1A, SAIC/RADeCO Model 452, and Victoreen Model 758 (see Figure 1.1). The evaluation was conducted in three phases: a calibration and workmanship evaluation, environmental testing, and field and human factors evaluation. The first two phases were completed by PNL, the third by WHC. This report summarizes the results.

Since the CAMs were prototypical and were, at the time of the evaluation, undergoing fairly continuous design changes, more exact descriptions of the models evaluated are given in Sections 3.0 through 8.0. The tests were performed to examine several new developments in alpha CAM technology, including microprocessor-based CAMs with background subtraction algorithms, radial inlet sample heads, and menu-driven user interfaces. The results of the testing were used to develop purchase specifications for procuring second-generation alpha CAMs for use at Hanford.

This project did not include evaluating particle size collection characteristics of the sample head or the network capabilities of the CAMs. These two areas were evaluated by Inhalation Toxicology Research Institute (ITRI) and EG&G Rocky Flats, respectively.

The CAMs evaluated underwent fairly constant design changes before and during the course of the evaluations. Some modifications were extensive. The design changes made it difficult to maintain current and accurate calibration and evaluation procedures. In addition, changes to the CAM technical manuals typically lagged considerably behind changes to the CAMs. Modifications to the CAMs were allowed until the start of the environmental evaluation, at which time no further modifications were accepted. The CAMs have continued to evolve, so the test results presented in this document may not reflect the CAM models currently available.

None of the CAMs met all the criteria. However, the extent of noncompliance varied widely from CAMs that failed to comply primarily because of information lacking from the manufacturer's literature to CAMs that suffered functional failures during testing.

When practical, the tests began with three CAMs of each model. The consistency or lack of consistency in performance among the three CAMs of the same model indicates a related consistency or lack thereof in instrument manufacture and design.

(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

One of the more important criteria, minimum detectable activity (MDA), could not be evaluated because the vendors and the test manager could not agree upon an acceptable method for testing MDA. As a default, the MDA was calculated using the equation given in ANSI N42.17B (see Equation 2.1). Further information on the MDA calculations is provided in the appendix.

The basis for comparison to standards and method of analysis are described in Section 2.0. Then, the evaluations of each CAM are summarized in Sections 3.0 through 8.0. The appendix contains more detailed information on the environmental evaluation. Data sheets used to record the test information are not included.

FIGURE 1.1. Four of the CAMS Tested — (l. to r.) Victoreen Model 758, SAIC/RADeCO Model 452, Eberline Alpha 6A-1, and NE America CAM1A (Canberra Alpha Sentry and Merlin Gerin A-CAM not pictured)

2.0 BASIS FOR AND SUMMARY OF EVALUATIONS

This section provides the bases and summary of the evaluations. With the exception of the workmanship evaluation, more information on each evaluation can be found in the applicable section for each CAM model.

2.1 CALIBRATION EVALUATION

The bases for the calibration evaluation were the manufacturers' calibration procedures and ANSI N323, *Radiation Protection Instrumentation Test and Calibration*. The instruments were also evaluated on operational and maintenance characteristics and system documentation. In compliance with ANSI N323, CAMs were calibrated with NIST-traceable sources. The calibration evaluation was performed on all the CAMs except the Canberra Alpha Sentry, which was available for only a short period that did not allow time for a full evaluation.

Several factors of the CAMs were notable in conducting the calibration evaluations. The most significant observation was that several of the instruments use radon progeny collected by the filters to verify the gain. Although the use of radon progeny to establish the system gain during calibration is an acceptable practice, using radon progeny activity on the filter to verify the system gain during operations is unacceptable since the filter may have confusing and/or interfering activities. Moreover, the use of thoron progeny for calibrating the system gain is difficult to implement since it requires a thoron generating source.

One of the CAMs evaluated could not be calibrated with a NIST-traceable source since placing the source over the filter location put the CAM into a fault mode, disabling the detector. This occurred because the CAM required correct air flow to operate properly, a condition that cannot exist when an electroplated source is in the filter position.

A typical characteristic of the CAMs evaluated (with the exception of the Canberra CAM) was that the source-to-detector distance was shorter than the filter-to-detector distance because of the thickness of the source. Several were not designed to use calibration sources of standard design. The filter holder opening on the SAIC CAM sample head was too narrow to readily accept an electroplated source. Also, the SAIC CAM uses a nonstandard-sized detector (44-mm diameter). The NE America CAM requires a doped filter. Use of either of these CAMs would require procuring nonstandard calibration and performance check sources.

2.2 WORKMANSHIP EVALUATION

The basis for the physical and electronic workmanship evaluation was ANSI IPC-S-815A, *General Requirements for Soldering Interconnections*, and ANSI IPC-CM-770B, *Printed Board Component Mounting*.

The workmanship evaluation was completed on the Eberline Alpha 6A-1, Merlin Gerin A-CAM, NE America CAM1A, SAIC/RADeCO 452, and the Victoreen 758. All five CAMs exhibited workmanship deficiencies that would be cause for rejection (e.g., poor solder flow, inadequate solder, contaminated solder connection). With the exception of the Eberline CAM, there was evidence of engineering alterations on the CAM circuit boards. This is expected in a prototype instrument but is unacceptable in a standard production model.

2.3 ENVIRONMENTAL EVALUATION

The environmental evaluation was performed on the Eberline Alpha 6A-1, NE America CAM1A, SAIC/RADeCO 452, and Victoreen 758. The Canberra Alpha Sentry CAM and Merlin Gerin A-CAM were not received until after the testing was completed.

The purpose of the environmental evaluation was to test the alpha CAMs against the requirements given in ANSI N42.17B, *Performance Specifications for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*. Though ANSI N42.17B does not have a requirement for vibration, a vibration requirement from ANSI N42.17A, *Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions*, was adapted to the CAMs. The vibration requirement developed was that the CAM response shall not vary by more than 15% from the reference value after the CAM has been exposed to vibrations of 2 G for 15 minutes in a frequency range of 10 to 33 Hz. Since alpha CAMs at Hanford are frequently transported relatively long distances by truck to a central calibration facility, the vibration testing was judged applicable.

The CAMs were tested to the criteria given in ANSI N42.17B with the following exceptions. The CAMs were not tested to the air in-leakage or filter pressure drop criteria (ANSI N42.17B, Sections 9.2 and 9.4, respectively). No practical method of connecting the air flow meter to the radial air inlets of the Eberline, Merlin Gerin, or SAIC/RADeCO CAMs could be devised. The Victoreen and NE America CAMs also use nonstandard air inlets that prevented a reliable connection between the air flow meter and the CAMs. The CAMs were not subjected to the 100-kHz ring wave transient, the 400-Hz radio frequency (RF) field, or magnetic fields (ANSI N42.17B, Sections 5.5, 7.1.2.1, and 7.4) since the capability to generate these conditions was not available. In addition, the CAMs were not tested to the criteria applicable to direct current (DC) or battery-powered instruments nor to the particle and gas collection requirements (ANSI N42.17B, Sections 4.7.2, 4.8, 9.7, and 9.8, respectively). Particle collection testing was conducted by the ITRI and is not addressed in this report.[a]

(a) Information on particle collection characteristics of alpha CAMs can be obtained by contacting Mark Hoover, Inhalation Toxicology Research Institute, Albuquerque, New Mexico.

Table 2.1 lists the specific tests conducted and the ANSI N42.17B section from which the test was derived. The tests are listed in the approximate order in which they were conducted.

Table 2.1. Tests Conducted for Environmental Evaluation

Test	Applicable Section of ANSI N42.17B
Flow rate meter accuracy	9.1
Microwave fields	7.2
Radio frequency fields	7.1
Flow rate meter stability	9.3
Sampler design	4.2
Units of readout	4.3
Markings	4.4
Alarm threshold	4.5
Protection of switches and controls	4.6
AC supply voltage	4.7.1.2.1 and 9.5
AC supply frequency	4.7.1.2.2 and 9.6
Minimum detectable activity	6.1
Response time	5.3
Stability (24 h)	5.2
Coefficient of variation	5.4
Alarms	5.1 (except 5.1.1.2, Alarm Threshold Drift)
Ambient pressure	8.3
Temperature	8.1
Humidity	8.2
Response to unwanted radiations	6.5
Electrostatic fields	7.3
Vibration	(criteria derived from ANSI N42.17A)
Accuracy	6.2

Table 2.1. (continued)

Test	Applicable Section of ANSI N42.17B
Radiation type and energy	6.4
Line noise susceptibility	5.5
Stability (500 h)	5.2

A majority of the environmental testing was performed by comparing a CAM's reference response or flow rate to the CAM's response or flow rate when subjected to an environmental influence. The reference values for response and flow rate were obtained by establishing standard test conditions (see Table 2.2), placing an appropriate source (^{239}Pu) in the filter holder, establishing air flow, and allowing the instrument response to stabilize. Small-diameter sources were used to prevent the source from completely obstructing the air inlet.

Table 2.2. Standard Test Conditions

Influence Quantities	Acceptable Range for Standard Test Conditions
Warmup time	
Electronic devices	> 10 minutes
Air or gas circuit	> 10 minutes
Relative humidity	Ambient ±10%, up to a maximum of 75%
Ambient temperature	20°C to 24°C
Atmospheric pressure	70 to 106 kPa
Line voltage	Nominal ±1%

Descriptions of the test procedures are given in the appendix.

All CAMs were noncompliant with two of the criteria. ANSI N42.17B requires the manufacturer to provide information on response time and MDA of the instruments. None of the vendors provided the required information. Where possible, empirical MDAs were calculated for each of the CAMs. Empirical MDAs could not be calculated for the Eberline CAM because it reports, at times, negative background. The MDA for the NE America CAM could not be calculated due to an inability to calibrate the CAM and determine its efficiency. The results are given in Table 2.3.

Table 2.3. Measured Minimum Detectable Activities in Disintegrations Per Minute

Group 1	MDA (dpm) Period 1	MDA (dpm) Period 2	Group 2	MDA (dpm) Period 1	MDA (dpm) Period 2
SAIC/RADeCO			SAIC/RADeCO		
CAM 1	730.0	350.0	CAM 2	740.0	1020.0
Victoreen			Victoreen		
CAM 2	18.0	8.0	CAM 1	72.0	90.0
CAM 3	117.0	56.0			

Empirical MDAs were calculated using the following equation from ANSI N42.17B:

$$MDA = \frac{4.65\ S_b}{k} \tag{2.1}$$

where S_b is the square root of the background and k is the efficiency. The background count rates at the end of two 24-h periods were obtained during the flow rate meter stability testing.

A summary of the test results for each instrument is shown in Table 2.4.

Table 2.4. Compliance of the Alpha CAMs with the Individual Requirements of ANSI N42.17B

	Eberline Alpha 6A-1			SAIC/RADeCO Model 452			Victoreen Model 758			NE America CAM1A		
	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3
Test												
Sampler design	P	P	P	P	P	P	P	P	P	P	P	P
Units of readout	C	C	C	C	C	C	C	C	C	C	C	C
Markings	C	C	C	P	P	P	P	P	P	P	P	P
Alarm threshold	P	P	P	P	P	P	P	P	P	P	P	P
Protection of switches and controls	C	C	C	C	C	C	P	P	P	C	C	C
AC supply voltage	C	C	C	C	C	NT	C	NT	NT	C	N	C
AC supply frequency	C	C	C	C	C	NT	C	NT	NT	C	N	C

Table 2.4. (continued)

	Eberline Alpha 6A-1			SAIC/RADeCO Model 452			Victoreen Model 758			NE America CAM1A		
	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3	CAM 1	CAM 2	CAM 3
Alarms	C	C	C	C	C	NT	P	NT	P	P	NT	P
Stability	C	C	C	C	N	NT	P	NT	NT	P	N	P
Response time	N	N	N	N	N	N	N	N	N	N	N	N
Coefficient of variation	C	C	C	P	P	NT	C	NT	NT	C	C	C
Line noise susceptibility	C	C	C	P	N	NT	NT	NT	NT	C	NT	C
Minimum detectable activity	N	N	N	N	N	N	N	N	N	N	N	N
Accuracy	C	C	C	C	C	NT	C	NT	NT	NT	NT	NT
Radiation type and energy	C	C	C	C	C	C	C	C	C	C	C	C
Response to unwanted radiations	C	C	C	C	C	NT	C	NT	NT	C	NT	C
Fields												
Radio frequency	NT	NT	N	P	NT	N	N	NT	NT	NT	N	NT
Microwave	NT	NT	C	NT	P	NT	C	NT	NT	NT	NT	NT
Electrostatic	NT	NT	C	NT	C	NT	C	NT	NT	C	NT	NT
Temperature	C	C	P	P	C	NT	P	NT	NT	P	NT	N
Humidity	C	C	C	P	P	NT	P	NT	NT	C	NT	C
Vibration	C	C	C	P	P	NT	P	NT	NT	C	NT	P
Ambient pressure	C	C	C	C	P	NT	P	NT	NT	P	NT	NT
Flow rate meter accuracy	N	P	C	N	N	N	C	N	N	N	C	N
Flow rate meter stability	C	N	C	C	C	NT	C	N	N	N	N	N

C = compliant
P = partially or marginally compliant
N = noncompliant
NT = not tested

2.4 FIELD AND HUMAN FACTORS EVALUATION

Requirements for alpha CAMs were identified early in the project and were compiled in WHC-SD-GN-FDC-301, *Functional Requirements for Alpha CAMs*. This document included calibration, maintenance, design, and human factors requirements. The purpose of the field and human factors evaluation was to address those requirements that were not covered in the calibration and environmental evaluations.

The field evaluation was conducted on the Eberline Alpha 6A-1, SAIC/RADeCO Model 452, Victoreen Model 758, and Merlin Gerin A-CAM. The NE America CAM1A was not field tested because, as a wall mounted unit, it is not easily transported. The evaluation was performed by placing the CAMs in an operating facility for four weeks and having the facility technicians perform filter changes, alarm responses, and performance tests on the instruments. Though the large amount of information available from the CAMs was initially confusing, the technicians preferred reviewing the CAM's operating history in the field rather than using separate computers or other equipment to obtain information. There was generally a distrust of CAMs that provided minimal information locally or that alarmed frequently.

3.0 CANBERRA ALPHA SENTRY

The Canberra Alpha Sentry CAM evaluated was a beta test version. The CAM has two components: an electronics chassis and a sample head. The electronics chassis monitors for chronic releases, provides trending data, and monitors multiple sample heads. The sample head has a radial inlet with a diffusion screen to remove unattached radon daughters; the sample head also performs the calculations necessary to monitor for acute releases. This CAM uses a cartridge-mounted filter. The cartridge is provided with a notch to align the filter barcode with a barcode reader inside the CAM. The barcode reader was not provided on the beta test version provided.

The Canberra Alpha Sentry is available with a 450-mm^2 or 1700-mm^2 passivated implanted planar silicon (PIPS) detector. The model evaluated had the 1700-mm^2 detector.

The Canberra CAM uses a diffusion screen to remove unattached radon daughters from the sampled air. At Hanford, CAMs are operated in relatively dusty (nonlaboratory) environments, which results in only a small fraction of unattached daughters. Since the screen offers no benefit in an environment with primarily attached daughters and because there is a potential for the screen to become contaminated during use, a diffusion screen is not recommended for use at Hanford. Consequently, the screen was removed from the CAM during the testing.

The Canberra Alpha Sentry was available for only a limited evaluation. The evaluation focussed on human factors requirements since the CAM's software was not fully developed. The evaluation produced the following observations:

- The use of inexpensive, reusable filter cartridges made filter changes a relatively easy operation.

- During the evaluation, the CAM's display scrambled and the CAM became unresponsive to keyed entries. After being turned off for a few minutes, the CAM responded normally although all the calibration data were lost. The cause of the incident was not apparent; however, the facility where the CAM was operated has "dirty power" so the incident may have been caused by a power spike or switching transient.

- The operating manual for the Canberra Alpha Sentry was incomplete. This is expected for a preliminary release. The vendor was receptive to suggestions on information that should be included in the final version of the manual.

Because of the potential for the CAM to lose all calibration data, the Canberra design evaluated is unacceptable for use at Hanford. However, Canberra has continued to develop the Alpha Sentry CAM and its software. Only a full environmental evaluation would indicate if the potential memory loss was an anomaly of the beta test version or characteristic of the CAM design.

4.0 EBERLINE ALPHA 6A-1

The Eberline CAM evaluated was an Alpha 6A-1 with V1.0 software. The "6A" designates a radial inlet sample head. The model number was changed to 6A-1 when the original flash analog-to-digital (ADC) converter was replaced with a Wilkinson-type ADC. The model evaluated was one component with the sample head and electronics sharing the same chassis.

The Eberline Alpha 6A-1 is a lightweight (15-lb) unit. A 25-mm-diameter silicon diffused junction alpha detector is used to monitor a 25-mm-diameter active area on a 47-mm-diameter filter paper. Air enters the sample head from 360° and makes a right-angle turn to pass through the filter paper.

Eberline also manufactures an Alpha 6A-1 with an inline head; however, that model was not evaluated.

4.1 SUMMARY

The Eberline Alpha 6A-1 was compliant with a majority of the test criteria. Most concerns could be resolved with software modifications. Specifically, it should be possible to performance test the CAM and review history files without accessing the calibration parameters. The calibration procedure should be revised to require standard electroplated sources rather than radon progeny.

4.2 CALIBRATION EVALUATION

The Eberline Alpha 6A-1 requires the use of natural radon progeny collected on a filter to verify the system gain during operations. This presents quality assurance problems since the composition of operational air filters is not fixed and may contain interfering activities. It is recommended that Eberline develop a method for verifying the system gain with a standard electroplated source.

The flow calibration of the Alpha 6A-1 uses a mechanically adjusted orifice to regulate a low but proportional air flow to the flow rate sensor. The physical characteristics of the orifice may change when subjected to corrosives or aerosols if a defective air filter is used. This method of sensing air flow may be less reliable than submerging the air flow sensor in the main flow stream and using software to correct for changing system characteristics.

A number of errors were noted in the technical manual (which was stamped "PRELIMINARY"). These errors were communicated to the vendor.

4.3 ENVIRONMENTAL EVALUATION

During the environmental evaluation, it was noted that under normal operating conditions, the Eberline CAM background subtraction algorithm frequently calculated negative values for the ^{239}Pu

activity. This could cause the CAM to underestimate the ^{239}Pu activity. The use of negative values prevented calculating the MDA for the Eberline CAM.

The Eberline CAM was at least partially compliant with all requirements in the standard with the exception of the response time, MDA, flow rate meter stability, flow rate meter accuracy, and RF interference requirements.

ANSI N42.17B requires the manufacturer to state the instrument response time and MDA in the instrument's literature. Since the information was not provided, the CAM was noncompliant with the requirements. The estimated source response time of the Eberline CAM was approximately 55 seconds. An empirical MDA for the Eberline was not calculated since a significant number of background count rates displayed by the CAM were negative.

Over a period of 100 hours, the flow rate readings on two of the Eberline CAMS remained within 5% of the nominal value. The third Eberline CAM had a maximum deviation of 5.9% which did not comply with the standard.

The accuracy of the flow rate meters of the Eberline CAMs was evaluated at five points within the specified range of the CAM. The three Eberline CAMs had maximum deviations of approximately -20%, -15%, and -12.5%. Only the third CAM complied with the requirements in the standard.

Only one CAM was tested to the interfering RF field criteria. The CAM performed well under all conditions except when exposed to RF fields of 0.3 to 1.0 MHz. During this period, the CAM displayed 0.0 cpm. The CAM's response returned to normal at 2.0 MHz. The flow rate reading remained stable until 25.0 MHz, where it increased steadily to a maximum increase of approximately 60% at 35 MHz.

4.4 FIELD EVALUATION

The Eberline CAM appeared to operate without fault during the entire field evaluation. Two observations were made:

- The aerosols collected on the filter were not confined to the active filter area. The CAM uses 47-mm filters with a 25-mm active area. After a week of sampling, the area between the retaining ring and the active area was a uniform light brown color. The center 25-mm-diameter active area had collected a majority of the aerosol but the edges of the active area were irregular and not clearly defined. Discoloration of the filter indicated that some aerosol had been collected over the entire 47-mm diameter of the filter.

- Toward the end of the test period, the Eberline CAM alarmed on high concentration. An analysis of the filter paper showed that there was about 30-cpm long-lived alpha on the filter paper. A second count of the filter performed two weeks later indicated no long-lived alpha

activity. None of the other filter papers pulled that day had indications of long-lived alpha. A review of the laboratory data concluded that the relatively short sample time (24 hours) and statistical errors in counting the sample may have caused an erroneous report from the laboratory. A second possibility was that the filter contained a hot particle that was dislodged from the filter between counts.

During both the environmental and field evaluations, it was noted that the Eberline Alpha 6A-1 does not have a clearly labelled alarm acknowledge button. This presented some confusion during the field testing when the Eberline CAM alarmed and the technicians were unclear on how to silence the audible alarm.

5.0 SAIC/RADeCO 452

The SAIC/RADeCO Model 452 CAM with a remote head uses a 44-mm-diameter ion-implanted silicon detector. The model purchased from SAIC had a mass flow meter that was a separate unit from the electronics chassis and the sample head. Prior to the evaluations, the CAM was returned to SAIC for modifications. The mass flow meter was replaced with a meter that was an integral component of the sample head. In addition, SAIC updated the CAM's firmware and installed a postproduction collimator in the sample head. The new software was version 452_G3.

The CAM uses a radial inlet head. Air flow enters the head from all 360°, parallel to the filter. At the filter, the air flow makes a right-angle turn and passes through the filter.

5.1 SUMMARY

The SAIC 452 Alpha CAM presents some unusual calibration challenges. First, the manufacturer recommends calibrating the instrument gain with thoron progeny collected on a filter. Hanford does not have the capability of generating calibration-quality thoron daughters. Second, the active area of the SAIC filter is smaller than the active area of standard alpha-calibration sources. Use of this CAM would require procuring special, nonstandard calibration sources.

Two of the tests given in ANSI 42.17B (RF and line noise) permanently damaged two of the test CAMs.

The SAIC 452 was preferred by several of the technicians who performed the field testing. The menus are generally easy to understand, and instrument operations proceeded fairly smoothly. The default menu was confusing to some since it does not include units for the various parameters that are displayed.

During the field testing, the SAIC 452 exhibited a high false alarm rate.

5.2 CALIBRATION EVALUATION

The SAIC Model 452 requires the use of short-lived thoron progeny to calibrate the gain and to verify the system gain during operations. The use of thoron progeny to calibrate the gain is acceptable but not preferred since Hanford does not have a facility for generating thoron sources. A calibration procedure requiring radon progeny or electroplated sources is preferred. The use of thoron progeny for verifying system gain during operations is unacceptable since the composition of operational filter samples is not fixed and may contain confusing or interfering activities.

The active area of the SAIC filter was not compatible with the active area of standard alpha calibration sources. The active area of the SAIC filter is about 42.5 mm in diameter (the active area

of standard alpha calibration sources is about 45 mm in diameter). To correctly reproduce the filter to detector geometry, special-size sources would have to be manufactured for performance testing the CAM.

5.3 ENVIRONMENTAL EVALUATION

The environmental evaluation began with three SAIC Model 452 CAMs. One of the three was permanently damaged during the RF testing. This CAM was removed from further testing, so a majority of the environmental tests were conducted on only two CAMs. A second CAM was permanently damaged during the line noise susceptibility testing. Since this test was performed last, the CAM was included in all of the other tests.

Because the 0.3 to 35 MHz RF testing destroyed one SAIC Model 452, the remaining two CAMs were not tested to the full extent of the RF testing. One CAM was tested in 60-Hz and 140-MHz fields and complied with that portion of the criteria.

Of the two CAMs subjected to the temperature testing, one was fully compliant. The flow rate on the second CAM remained within the allowed variation of the reference value but the count rate did not. This CAM was judged partially compliant. The same two CAMs were judged partially compliant with the humidity requirement because the count rate stayed within the allowed variation but the flow rate did not.

The SAIC CAMs were only partially compliant with the vibration and ambient pressure criteria. The flow rates, after the CAMs were vibrated, were within the allowed range. However, the count rate on one CAM increased approximately 55% after the vibration. The second CAM was only partially compliant because a circuit board and the mounting nut for the detector bias adjustment came loose. The CAM operated normally after the board was reinserted and the nut tightened. The ambient pressure testing generated flow rates within the allowed deviation but the count rate on one CAM was outside the allowed variation.

None of the SAIC CAMs complied with the flow rate meter accuracy requirement. The measured flow rate versus the actual flow rate was tested under standard environmental conditions at six points over the range of the flow rate meter. The measured flow rate deviated from the actual flow rate by greater than 20% for at least one point on each CAM.

ANSI N42.17B requires the manufacturer to state the instrument response time and MDA in the instrument's literature. Since the information was not provided, the CAM was also noncompliant with these requirements. The estimated source response time of the SAIC CAMs range from approximately 8.4 seconds to 8.8 seconds. Empirical MDAs were calculated based on the CAM's efficiency and the background count rate for two 24-hour periods. The calculated MDAs are listed in Table 2.3.

The SAIC Model 452 was noncompliant with the coefficient of variation criterion although this was attributed to the short count times used for collecting data. The CAM has two fixed count times: 6 seconds and 720 seconds. Because of time constraints, the 6-second count time was used. A lower coefficient of variation would be expected if the longer count time were used.

The CAM was compliant with the low-voltage transients given in the line noise susceptibility criterion. One of the CAMs failed during the high-voltage transients and was judged noncompliant. To prevent damaging a second CAM, no other SAIC CAMs were subjected to the high-voltage transients.

5.4 FIELD EVALUATION

The SAIC/RADeCO CAM was run with three different filter assemblies. The first had a membrane filter permanently mounted in a card. A second similar assembly had a pellon backing for the membrane filter. The third filter assembly had two layers: the bottom layer of cardboard and the top layer of a spongy, gasket-like material. The two layers were glued together at one end so the gasket could be lifted up and a filter placed between the two layers, allowing users to load the card with their own filters. The hole over which the filter was centered was backed with pellon.

When removing the card with a gasket, there was a tendency for the gasket to catch and bunch up on the collimator.

Several problems were noted with the card-mounted filters. Pinhole defects were apparent in several filters and appeared to be caused by large particles getting pulled through the filter. Also, some filters had scrapes and small tears when removed from the sample head. The scrapes and tears appeared to be formed when the filter was removed since the pellon backing was not discolored. The cause of the scrapes was not immediately apparent. Later, it appeared that the scrapes were caused by a post-production collimator installed by SAIC. Finally, the filters exhibited nonuniform deposition. The deposited material formed a starfish-shaped area of greater (darker) deposition off-center on the filter. This was also attributed to the collimator.

The CAM will alarm if the scatter exceeds normal limits (e.g., if the spectral resolution exceeds normal limits) and will alarm on filter defects. A paper-punch-size hole was torn in one filter on insertion. The CAM alarmed within just a few minutes. However, the CAM did not alarm on the filters that developed pin-prick holes.

The SAIC head has a thin metal filter clamp that is operated by a knob on the side of the head. Operation of the filter clamp and control knob are not immediately clear. Several technicians attempted to insert the filter card on top of the metal clamp instead of under the clamp. Also, at least one technician inserted the source on top of the clamp. The tight fit caused the collimator to scrape the source, damaging the source and potentially contaminating the CAM. These actions loosened the top of the head so there was quite a bit of play between the top and the bottom of the head.

The SAIC 452 CAM does not readily accept a standard 47-mm electroplated source. The head could not accommodate a source fitted in the hinged (gasketted) filter card. The source could be inserted into the head by cutting an open area larger than the source in a filter card and taping the source in the opening. Even then, the source thickness interfered with easily inserting the source into the head, and there was potential for activity to be scraped from the source by either the collimator or the filter clamp. It was not possible to source check the CAM with a source-to-detector distance that was equal to the filter-to-detector distance due to the thickness of the source.

There was a 3-hour power failure during the second week of the test. After the power failure, the SAIC CAM alarmed repeatedly. The manufacturer said that the problem was characteristic of a sudden step increase in background activity. Since the ventilation to the room was shut off during the power failure, a significant concentration of radon could have built up. It was postulated that the CAM responded to this dramatic increase in radon activity between the time the CAM lost power and the time power was restored as a sudden increase in background activity. After several hours, the CAM settled down and performed normally.

The first SAIC CAM installed in the test facility failed because of unstable gain. This fault was noted before the CAM left the calibration facility, but the project manager was not told of the problem until after the CAM was installed. A second SAIC CAM was installed on the second day of the test. After installations, the audible alarm (bell) was disconnected and, on powering up the CAM, the liquid crystal display (LCD) was dead. The instrument technician repaired the CAM and it appeared to function correctly for the remainder of the test.

After the first three weeks of testing, three of the CAM models were returned to the field for a fourth week of testing. The SAIC appeared to function normally for the first five days of the test period (Monday through Friday). Over the weekend, the CAM repeatedly went into alarm. On Monday (the seventh day of the test), the CAM was in alarm and would not clear. The history file indicated that the calculated airborne concentration varied between 158 and 11050 DAC-h. The vendor representative could not immediately explain the inordinately high readings. Later, he suggested that the high readings may have been caused by unusually low air flow readings although the air flow meter appeared to be functioning correctly. There was an Eberline CAM operating within 2 feet of the SAIC CAM during the period of the high readings. The Eberline CAM's history files did not indicate any diurnal increases greater than those noted on previous days.

6.0 MERLIN GERIN A-CAM

Merlin Gerin manufactures large, installed alpha air-monitoring systems, commonly referred to as EDGAR, for use in France. The Merlin Gerin A-CAM evaluated was a portable version of the EDGAR system and is sometimes referred to as a Mini-Edgar. The portable CAMs are configured for alpha detection (A-CAM), beta detection (B-CAM), or noble gasses (NG-CAM). The A-CAM is a small, relatively lightweight CAM with an integral pump. The remote head is equipped with a 22-mm-diameter detector that is insensitive to ambient light. The unique characteristic of the Merlin Gerin CAM is the 11-mm gap between the detector and the filter. A combination of the relatively large gap and a collimator degrades the CAM's efficiency but improves spectral resolution.

The sample head is essentially two small boxes separated by a 11-mm gap. The upper box contains the detector and electronics; the lower, smaller box is connected to the vacuum hose. The filter, which is placed on top of the lower box, is essentially open to the environment in all directions. The detector, located on the bottom of the upper box, is also fully exposed to the environment.

The firmware version was HSCU 0791A.

6.1 SUMMARY

It was not possible to perform a defensible operational check of the Merlin Gerin CAM. This was because the CAM would not operate with a standard electroplated source in the source holder without placing a paper clip or similar device under an edge of the source to allow air flow. The CAM also does not positively position the source in the correct place under the detector, so the source-to-detector geometry may vary.

The CAM provides little information to the user. The instrument output consists solely of an uncalibrated analog scale with three regions: green, yellow (alert), and red (alarm). The amount of information provided to the user was judged unacceptable since it was insufficient for evaluating alarm conditions. More information is available through a RS-232 port, but this requires connecting the CAM to a network or carrying a computer to the CAM. Unfortunately, during the course of the testing it was difficult to establish the computer link with the CAM. Consequently, little information could be collected during some of the evaluations. Merlin Gerin later upgraded the communications software; the upgraded software seemed more reliable. A preferable solution would be to allow the user to gain information from the CAM without using an external computer.

This Merlin Gerin CAM used a carbon vane pump with an unfiltered exhaust. When used in a confined area or with the sample head near the pump, the filter paper clogged rapidly with carbon particles emitted by the pump. The use of HEPA filters on vane pumps is preferred.

The Merlin Gerin CAM does not measure the air flow rate. Instead, the nominal air flow rate is entered in the software during calibration. The air flow rate is monitored through the use of two preset differential pressure switches which initiate a fault alarm if the flow rate exceeds the high flow limit (e.g., a broken filter) or falls 10% below the calibrated flow rate value. A preferable method is to have the CAM measure and integrate the air flow rate so the concentration is calculated from the actual sample volume collected.

6.2 CALIBRATION EVALUATION

The original Merlin Gerin CAM required an external count rate meter to calibrate the gain and efficiency. The count rate meter was connected to a 9-pin port on the sample head. The firmware was later upgraded to version 2592A BETA and software was provided to calibrate the CAM through the serial port.

Calibration still requires tricking the CAM into believing that the air flow is within the range of the low- and high-differential pressure alarms. The vendor representative recommended disconnecting the vacuum hose and placing an air filter over the free end. It is preferable to place the CAM in a test mode that would allow the detector to operate without air flow and wire the pump with a separate power switch.

The CAM head does not provide for positive positioning of the calibration source. The active area of the source must be visually aligned with the detector.

6.3 ENVIRONMENTAL EVALUATION

The Merlin Gerin CAMs were received after the environmental evaluations on the other CAMs were completed so were not tested.

6.4 FIELD EVALUATION

During an attempt to perform an efficiency check on the Merlin Gerin CAM by inserting a 5000-dpm ^{239}Pu source under the collimator, the CAM's alert and high radiation alarms both tripped. The source was then removed. Twenty minutes after removing the source, the alarms had not cleared. The CAM was shut off, power restored, and the alarms still did not clear. The CAM was left on and, apparently, remained in alarm overnight since it was still in alarm the following morning. Again, the CAM was shut off for a minute and power restored. At this time, the alarms cleared. The inability to establish communications with the CAM prevented any analysis of the CAM's response.

The vacuum hose must be disconnected from the sample head when performing the efficiency check. The pump does not have a separate power switch and placing the source in the filter's position blocks all air flow through the sample head (potentially destroying the pump). However, with the vacuum

hose disconnected, the CAM activates a fault alarm (high flow) and the detector no longer counts activity. In order to get the detector to count the source, the air flow through the vacuum hose has to be artificially constricted (we used a thumb) to keep the CAM out of the fault mode. This was not an easy task since too little air flow caused a fault alarm for low flow. The vendor representative initially recommended leaving the vacuum hose connected and placing a small object (i.e., a paper clip) under one edge of the source to allow air flow under the source. This is not acceptable since it does not provide a fixed repeatable geometry and the source-to-detector distance then does not equal the filter-to-detector distance. The vendor later recommended removing the vacuum hose and placing an extra filter paper over the inlet, which constricts the air flow to within the acceptable range.

Given the location of the pin that is provided to hold down the edge of the filter paper, a source cannot be inserted into the head with the activity centered under the detector unless the source has a significantly off-center active area. If sources with off-center active areas were manufactured, there would then be the problem of assuring that the active area was centered under the detector.

The thin metal collimator presents a hazard to the surgical gloves worn by technicians. This is significant since the surgical gloves are protective clothing for entering surface contamination areas, and the CAMs are frequently located in surface contamination areas. The sharp edges of the collimator may also damage electroplated sources placed in the sample head.

It was not possible to obtain any information of value from the CAM without connecting the CAM to a computer. Given the potential for contamination within the test facility, a portable computer was not used to collect test data. Following the field testing, the Merlin Gerin was connected to a computer in an attempt to download the historical data and verify the operating parameters. The computer program VD4S supplied by Merlin Gerin was used but it was not possible to establish communications between the CAM and the computer. The VD4S program scans a matrix of CAM identification numbers and attempts to locate CAMs that may be connected to the computer. Despite numerous attempts, the VD4S program would not recognize the Merlin Gerin CAM. Therefore, there is only limited test data for the Merlin Gerin CAM.

7.0 NE AMERICA CAM1A

The NE America CAM evaluated was the model CAM1A. It is a large unit (19.5-kg, 43-lb) designed as a wall-mounted CAM and not intended for use as a portable instrument. The CAM1A uses a 22-mm-diameter solid-state alpha detector monitoring a 25-mm-diameter active area on a card-mounted filter.

This CAM uses a nonradial inlet sample head. The air flow enters the sample head through a short section of pipe (7.5 mm long, 4.5 mm in diameter). A solid tear-drop-shaped piece, concentric with the pipe and placed in front of the filter, is used to control the air flow turbulence and achieve even deposition on the filter.

The NE America CAM design was relatively stable with only one modification during the course of the evaluation. NE America recommended installing an augmenter tube in the air flow inlet to provide a more laminar flow. The modification was made although it was later learned that it prevented calibrating the instrument. Therefore, the evaluated units were calibrated with default parameters.

7.1 SUMMARY

The immediately obvious disadvantage of the NE America CAM1A at Hanford is that it is not designed for use as a portable CAM. Hanford uses CAMs as portable instruments that are frequently transported between the field and a central calibration facility. Both the weight and the components that project from the electronics chassis make lifting and carrying the CAM a difficult and awkward task.

None of the NE America CAMs survived the environmental evaluation and so were not included in the field evaluation.

7.2 CALIBRATION EVALUATION

Due to the modification of the CAM sampling head, it was not possible to electronically align the flow sensor. NE America was unable to provide a solution, so the CAM flow sensor was configured with its default settings.

The manual as written is unacceptable as a user's guide since it provides little information on operating the instrument and too much information that the user would not need.

The NE America CAM uses a card-mounted filter. The CAM reads coded holes on the cards to determine if the card carries an operational filter or a source (doped filter). Performance tests for the CAM would require specially configured, nonstandard alpha sources.

7.3 ENVIRONMENTAL EVALUATION

The NE America CAM was not calibrated prior to performing the environmental evaluation due to a postproduction modification made to the sample head. The NE America representative claimed to be developing a procedure for calibrating the instrument but failed to produce a workable procedure. Consequently, the NE America CAMs were not calibrated but were instead set up with the default settings.

During the AC supply voltage and frequency testing, one of the NE America CAMs exhibited an abnormally fluctuating count rate. The cause of the fluctuations could not be determined and the CAM was removed from the testing. A second CAM failed during the RF testing. The NE America CAMs were noncompliant with requirements for alarms, AC supply voltage, and frequency fluctuation, stability, accuracy, RF interference, temperature, and flow rate meter accuracy and stability.

ANSI Standard N42.17B requires different audible alarm signals for fault and high concentration alarms. The NE America CAM does not comply since it uses the same annunciator for both alarms.

One NE America CAM overresponded by 77% when the AC power supply was adjusted from a nominal 120-V AC to 135-V AC (in 5-V increments). The same CAM underresponded by 36% when the frequency of the power supply was adjusted from 60 Hz to 57 Hz in 1-Hz increments.

The count or count rate stability of the alpha CAMs was evaluated over two separate periods. The duration of the first test period was 24 hours and the duration of the second test period was 500 hours. The NE America CAMs had variations of approximately +6.1%, +52.1%, and +6.7% over the 24-hour period. The compliance of the first and third NE America CAMs with the 24-hour requirement was marginal. The second CAM did not comply with the 24-hour requirement. The first and third CAMS complied with the 500-hour requirement with maximum variations of approximately 12.8% and 10.4%, respectively. The second CAM was not evaluated over the 500-hour period because of failure of the CAM prior to the test.

Because the NE America CAM could not be calibrated, its accuracy could not be measured and it was judged noncompliant with the ANSI N41.17B accuracy requirement.

During RF testing, the count rate of the NE America CAM increased by approximately 175% above the reference value at 7.5 MHz. The count rate returned to a value near the reference at 15.0 MHz. The count rate increased again to approximately 245% and 196% of the reference at 30.0 MHz and 35.0 MHz, respectively. Normally, the count rate from a ^{239}Pu alpha source is displayed in the 2.5- to 5.0-MeV window on the CAM. At 0.3 MHz, the count rate shifted to the adjacent window of 5.0 to 6.0 MeV. The flow rate reading decreased to approximately 62% and 71% of the reference at 5.0 MHz and 15.0 MHz, respectively. The flow rate reading dropped below the low end of the scale at 7.5 MHz and 10.0 MHz.

During the temperature testing, the maximum changes in count and flow rate reading for one of the NE America CAMs occurred at 30°C and -20°C, respectively. The changes in the count and flow rate reading at these temperatures were approximately +43.6% and -92.1%, respectively. The maximum change in count rate for the second NE America CAM occurred at 30°C and was approximately +4.3%.

The maximum change in flow rate reading occurred at -20°C and was approximately -95.0%. For both NE America CAMs, the flow rate readings decreased steadily to their minimum values from 0°C to -20°C. Large changes in flow rate reading were also observed at 40°C for both NE America CAMs. One of the CAMs had a change of approximately +24.7%; the other a change of approximately +21.8%. The former CAM does not comply with the requirements in the standard in either temperature range. The count rate of the latter CAM complies with the standard in both temperature ranges while the flow rate reading does not comply in either range.

While testing the influence of ambient pressure on the flow meter, the NE America CAM flow meter had a maximum overresponse of 29% over the pressure range of 100 kPa to 106 kPa (air flow meter readings were corrected for changes in air density as allowed by ANSI N42.17B).

The accuracy of the flow meter was checked at three points over the stated range. At one data point, one the CAMs displayed a flow rate reading approximately 60.8% greater than the actual value. At the remaining data points, the flow rate reading displayed by the CAM went off the high end of the scale.

ANSI N42.17B requires the manufacturer to state the instrument response time and MDA in the instrument's literature. Since the information was not provided, the CAM was noncompliant with these requirements. An empirical MDA for the NE America CAM was not calculated since it was not possible to determine the CAM's efficiency. An attempt was made to measure the response time but it could not be measured because the display on the CAM would revert to the fault display when the source was inserted or removed. The display would remain in this condition too long to permit an accurate measurement of the source response time.

The NE America CAM was not tested to the microwave field criteria because it was too large to fit in the test chamber.

7.4 FIELD EVALUATION

After completing the environmental evaluation, the NE America CAMs were returned to NE for repair and modifications. The CAMs were irreparably damaged during the shipment to NE America and were removed from any further testing.

Although not included in the formal field evaluation, some observations on the human factors design were made during the calibration evaluation. The primary concerns were the CAM's size, weight,

and configuration. At Hanford, CAMs are used as portable instruments; they are routinely moved about a facility and are calibrated at a central facility. The weight and size of this CAM would make transport difficult. Also, the NE America CAM1A must be wall-mounted; it cannot stand on a table or cart.

In addition, other features of the NE American CAM1A would make its use problematic:

- The function of the menu keys on the NE America CAM is not clearly identified. It was not clear how to advance through the menus or how to return to the default display.

- The alarm threshold on the NE America CAM is adjusted through an external computer. This protects the alarm threshold from inadvertent adjustment but also makes field adjustments of the threshold difficult.

- The NE America CAM flow rate indicator had a fullscale reading of 50 lpm even when the flow rate exceeded this value. There was no overrange indicator, high flow alarm, or indication of actual air flow rate when the flow rate exceeded 50 lpm.

8.0 VICTOREEN 758

The Victoreen CAM evaluated was composed of two components: a sample head and an electronics chassis. Victoreen offers two detector sizes, 450 mm^2 or 1700 mm^2. The evaluated CAM had a 1700-mm^2 silicon-dioxide passivated ion implant detector. Originally, the CAM head had a filter drawer that was removed from the CAM for filter changes. A metal retaining ring mated with magnets in the filter drawer to hold the filter in place. The difficulty of removing the filter drawer from the sample head and of removing the metal retaining ring from its magnetic grip prompted Victoreen to redesign the filter holder. The modification involved removing the handle from the filter drawer and cutting a slit in the drawer face. The filter, mounted in a sheet-metal holder, is slid through the slit into position under the detector. A gasketted door was provided to hold the sheet-metal holder in position.

Victoreen also upgraded the firmware. The modified firmware, Rev. F, requires the use of a stand-alone software package for calibrating the air flow sensor.

8.1 SUMMARY

The testing of the Victoreen CAM was largely inconclusive. Only one CAM was subjected to the environmental evaluation due to early failures, and it failed to meet nearly half the performance requirements given in ANSI N42.17B. The Victoreen CAM used during the field evaluation failed to collect a valid sample during the entire 4-week test period due to sloppy design and construction of the air sample head. In spite of the inability to collect a sample, the CAM frequently alarmed on high airborne activity even though air samples pulled in the area had no indications of airborne long-lived alpha activity.

8.2 CALIBRATION EVALUATION

The calibration procedure for the Victoreen 758 requires the use of radon progeny collected on an air filter for adjusting the system gain. This presents quality assurance problems since the composition of operational air filters is not fixed and may contain confusing and/or interfering activities.

During the calibration evaluation it was noted that the sheet-metal filter holder was difficult to use and presented a safety hazard because of the sharp edges. It was also noted that replacing the filter drawer with a source drawer was a task better suited for an individual with three hands rather than one with only two.

During the calibration, the instrument was operated with no air flow. The low-flow alarm tripped repeatedly even when the trip point was set for 0 cfm. It was also noted that the instrument does not have a power switch, an omission which creates operational difficulties.

The technical manual omitted important information such as performance and accuracy limits and failed to address size-dependent particle collection efficiencies. Several errors in the technical manual were communicated to the vendor.

8.3 ENVIRONMENTAL EVALUATION

A majority of the environmental evaluation was conducted on only one Victoreen CAM. To allow access to the CAM while it was in the environmental chamber, a remote keypad was added. During attempts to interface the remote keypad to the CAMs, the displays on two CAMs malfunctioned. One of the two CAMs could not be repaired and was removed from the testing. The second CAM was repaired and appeared to be functional, but upon checking it with a ^{239}Pu source, no counts appeared in the appropriate region of interest. Because of uncertainties in operating this CAM, it too was removed from the testing. The third CAM failed during the line noise susceptibility test, so was tested neither to that criterion nor to the long-term stability criterion.

The Victoreen CAM will send data over a serial communications line in response to certain commands entered at the front panel of the unit. The capability of the CAMs for remote communication was exploited where possible to simplify the collection of data during the testing. A remote keypad was assembled and interfaced to the Victoreen CAMs to permit the operator to send data from the CAM to a computer from a remote location. The data sent by the Victoreen CAM include the times that collection of data started and stopped, cumulative air volume, and a channel-by-channel listing of the alpha energy spectrum. The count rate over the measurement period can be calculated from the start and stop times and from the spectral data. Flow rate could not be accurately calculated from the data transmitted by the Victoreen CAM to the computer. Because of this difficulty, only the Victoreen CAM's count rate data was recorded during tests where the computer was used to record data.

The Victoreen CAM was either partially compliant or noncompliant with the following criteria; sampler design, markings, alarm threshold, protection of switches and controls, alarms, stability, RF fields, temperature, humidity, vibration, flow rate meter accuracy, flow rate meter stability, and ambient pressure.

The Victoreen CAM failed the requirement for sampler design because of the loose filter holder that allowed the filter to slip from position and sampled air to bypass the filter.

The connections on the back of the Victoreen CAM were not identified, causing confusion when connecting the CAM to a computer or printer. This was noncompliant with the requirement that all controls, etc., shall be labelled according to function.

The alarm threshold on the Victoreen CAM is easily adjusted from the CAM's front panel. Therefore, the CAM is noncompliant with the requirements that the threshold and other controls shall be protected from inadvertent adjustment.

The fault alarm on the Victoreen CAM used the same annunciator as the high radiation alarm. Therefore, it was noncompliant with the requirement that the fault alarms shall sound different from radiation alarms.

The count or count rate stability of the alpha CAMs was evaluated over two separate periods. The duration of the first test period was 24 hours and the duration of the second test period was 500 hours. The Victoreen CAM was marginally compliant with a variation of approximately +6.5% over the 24-hour period. The Victoreen CAM could not be tested over the 500-hour period because of failure of the CAM prior to the testing.

At a frequency of 0.3 MHz during the RF testing, the elapsed time displayed on the Victoreen CAM incremented only 1 second for every 10.5 seconds of real time. The count rate calculated using the time displayed on the CAM was 22% below the reference value. The CAM became unresponsive between 0.3 and 0.543 MHz. The count rate returned to near reference values for the remainder of the test. The flow rate reading dropped to 34% of the reference between 30.0 and 35.0 MHz. The alarm on the CAM sounded between 25.0 and 35.0 MHz.

Due to failures in two of the Victoreen CAMs, only one was subjected to the temperature testing. During the testing, the Victoreen CAM count rate changed approximately +4.5% at 40°C. The count rate changed approximately -36.5% at -30°C. The flow rate reading could not be determined using the computer. The count rate of the Victoreen CAM is in compliance with the standard in the temperature range of 10°C to 40°C but not in the range of -20°C to 50°C.

The Victoreen CAM was only marginally compliant with the humidity requirement from ANSI N42.17B because the flow rate on the CAM could not be measured during the testing.

The vibration testing was conducted in two stages. The Victoreen CAM indicated a maximum change in response of approximately -2.1% after the first vibration. After the second vibration, the ribbon cable connected to the display board became loose. The CAM did not function after the cable was reattached. Apparently, permanent internal damage to the CAM had occurred. Compliance with the requirement could not be determined.

The accuracy of the flow rate meters of the Victoreen CAMs was evaluated at three points. The maximum deviation in flow rate reading of the first CAM was approximately -11.4%. The flow rate reading of the second CAM deviated by as much as +61.2%. The maximum deviation in flow rate reading of the third CAM was approximately -30.6%. Therefore, the first CAM complied with the requirements in the standard while the remaining CAMs did not.

During the 100 hour flow rate stability test, two of the Victoreen CAMS had maximum flow rate deviations of 9.4% and 6.1% and did not comply with the requirement.

During ambient pressure testing, the flow rate on the Victoreen CAM dropped 24% even after corrections were made for changes in air density as allowed by ANSI N42.17B.

ANSI N42.17B requires the manufacturer to state the instrument response time and MDA in the instrument's literature. Since the information was not provided, the CAM was noncompliant with these requirements. Empirical MDAs were calculated based on the CAM's efficiency and the background count rate of two CAMs for two 24-hour periods. The calculated MDAs showed a wide variation, from 8 to 117 dpm. Further information is included in the appendix.

The Victoreen CAM complied with the units of readout, AC supply voltage and frequency, coefficient of variation, accuracy, radiation type and energy, response to unwanted radiations, microwave fields, and electrostatic interference.

8.4 FIELD EVALUATION

There were two primary observations from the field evaluation. First, on the Victoreen 758 efficiency checks cannot be performed in the field. Even if two people are available to remove the filter drawer (a minimum of three hands is required), the detector voltage is shut off when the source drawer is in place, making it impossible to check the CAM's efficiency. Since one technician at the test facility has only limited use of one hand, that technician could not, under any circumstances, perform an efficiency check on this CAM. Second, the CAM evaluated would not collect a valid sample since the filter paper would not stay correctly positioned in the filter paper holder. The filter would slip out of position either while being inserted in the CAM or vibrated out of position by the vacuum pump. When the filter was out of position, there was a 1-mm to 3-mm gap between the filter and the filter holder along one edge of the filter. Consequently, during the entire 4-week test, it was not possible to collect a valid sample with the Victoreen CAM. The same filter paper was used for the first 3 weeks and the dirt on the filter at the end of 3 weeks was barely discernable.

In addition, various other observations made during the field evaluation:

- Although the Victoreen CAM is designed to alarm if the filter door is open, this alarm does not operate as expected and prevents efficiency-checking of the instrument. When the sample door is opened and the filter holder removed, the door-open alarm should trip but does not. When the filter holder drawer is removed, the door-open alarm is activated, as expected, and the detector voltage is shut off. When the source holder drawer is inserted, the drawer-open alarm does not clear, voltage to the detector remains off, and the detector will not count, making it impossible to check the detector efficiency in the field.

- The technicians are required to wear surgical gloves when performing efficiency checks. They also wear protective clothing, including surgical gloves, when entering many of the areas that have alpha CAMs. Consequently, the CAM's sheet-metal filter holder is

unacceptable since there is a high potential for tearing surgical gloves on the sharp edges of the holder.

- Victoreen also provided a card-mounted filter with a bid submitted on a separate procurement. When the card-mounted filter was inserted in the sample head without using the sheet-metal holder, the card fit too loosely to prevent inleakage. The accompanying literature illustrated the card placed in the sheet metal holder. When this approach was tried, the size of the card prevented centering the filter paper over the hole in the filter holder.

- The Victoreen CAM generally reported 1.00E-14 μCi/mL of activity in region A (the region of interest). On the last two days of the test, the CAM was reporting 3.7E+04 μCi/mL of activity in region A, and the CAM was in alarm. However, there was still no discoloration on the filter and the filter paper was not correctly positioned in the filter holder (indicating that a valid sample had not been collected). Later analysis of the filter showed no long-lived alpha activity on the filter.

- The flow rate indicated on the CAM display decreased slightly when the filter was removed, which is the opposite of what was expected.

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APPENDIX

TESTING OF CONTINUOUS ALPHA AIR MONITORS AGAINST CRITERIA IN ANSI N42.17B

APPENDIX

TESTING OF CONTINUOUS ALPHA AIR MONITORS AGAINST CRITERIA IN ANSI N42.17B

This appendix describes the procedures used for evaluating continuous air monitors for alpha radiation (alpha CAMs). The testing was performed in accordance with American National Standards Institute (ANSI) Standard N42.17B *Performance Specifications for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*. The instruments evaluated in this testing were microprocessor-based CAMs configured for measurement of workplace air concentrations of ^{239}Pu. The testing was performed on commercial alpha CAMs from four manufacturers: an Eberline model ALPHA 6A-1, a Victoreen model 758, a SAIC/Radeco model 452, and a NE America model CAM1A. Three of each model of alpha CAM were available for testing. The testing included all applicable tests listed in the standard. The following tests were performed:

- sampler design
- units of readout
- markings
- alarm threshold
- protection of switches and controls
- power
- alteration and modification
- alarms
- stability
- response time
- coefficient of variation
- line noise susceptibility
- minimum detectable activity
- accuracy
- radiation type and energy
- response to unwanted radiations
- radio frequency fields
- microwave fields
- electrostatic fields
- temperature
- humidity
- vibration
- ambient pressure
- flow or flow rate meter accuracy
- flow rate stability.

The standard also states requirements for filter pressure drop and air in-leakage. The ability of the alpha CAMs to meet these requirements could not be verified. No practical method for connecting the flow meter to the radial air inlet of the Eberline and SAIC/RADeCO alpha CAMs could be determined. The air inlet of the Victoreen and NE America alpha CAMs was also nonstandard and a reliable connection could not be established.

A.1 METHODS AND MATERIALS

Testing of the alpha CAMs was performed in accordance with procedures drafted prior to the testing. This appendix does not give the procedures but instead provides a general description of the some of the test methods. Tests that were conducted, but are not listed in this appendix, used the procedures given in ANSI N42.17B. In general, except for the inspection tests, the reference response of the CAMs was measured prior to the test after a sufficient stabilization time, as required by the standard. Response data was then measured during the test and/or after the test and compared to the data measured prior to the test. Changes in response are calculated as a percentage change from the reference response. A positive change indicates an increase from the reference response while a negative change indicates a decrease. Compliance with the requirements in the standard was determined by comparing the responses measured during and/or after the test to the reference response. Response of the alpha CAMs refers collectively to the count or count rate and flow rate reading. Both quantities were recorded where possible and applicable and both were interpreted to determine compliance with the requirements in the standard. For example, if the count rate of an alpha CAM remained within the limits stated in the standard and the flow rate reading did not, the CAM was judged noncompliant.

All of the units, except for the Victoreen CAM, are capable of bidirectional communication to a remote computer via a serial communications line. The units can be interrogated from the remote computer to obtain count and flow rate information. The Victoreen CAM will send measured data over a serial communications line in response to certain commands entered at the front panel of the unit. The capability of the CAMs for remote communication was exploited where possible to simplify the collection of data during the testing. A remote keypad was assembled and interfaced to the Victoreen CAMs to permit the operator to send data from the CAM to a computer from a remote location.

A.2 AC SUPPLY VOLTAGE

The alpha CAMs were connected to a variable AC power supply. The voltage supplied to the alpha CAMs was varied ± 20 Volts in 5-V increments with respect to the nominal operation voltage. The mean response at each voltage was compared to the mean response at the nominal operating voltage. The standard allows a maximum variation in response of 5%.

A.3 AC SUPPLY FREQUENCY

The AC supply frequency was varied from 57-61 Hz in 1-Hz increments; voltage remained constant at approximately 115 V. The mean response at each voltage was compared to the mean response at 60 Hz. The standard allows a maximum variation in response of 5%.

A.4 ALARMS

The alarm activation delay was measured with a 20,000-dpm ^{239}Pu alpha source because a 50-dpm source (as required by ANSI N42.17B) was not available. With the NE America CAMs, the source area was reduced so that the detector was exposed to only a small portion of the source.

A.5 STABILITY

The count or count rate stability of the alpha CAMs was evaluated over two separate periods. The duration of the first test period was 24 hours and the duration of the second test period was 500 hours. The requirements in the standard allow a variation in counts or count rate of not more than 6% over the 24-hour period and a variation of not more than 15% over the 500-hour period.

A.6 RESPONSE TIME

None of the operating manuals for the CAMs stated the response time of the CAM. Therefore, the CAMs do not comply with the requirements in the standard. Response time is the time it takes the CAM response to increase from 10% of the nominal response to 90% of the nominal response. The count rate and flow rate response time were measured. The former is termed the source response time and the latter is termed the flow response time. The activity of the ^{239}Pu source used to measure source response time was approximately 20,000 dpm. The SAIC/RADeCO CAM displays concentration in DAC-hours instead of displaying a count rate. The 10% and 90% source responses were difficult to determine for the Eberline and SAIC/RADeCO CAMs because the CAMs update their source response every 5 and 6 seconds respectively. As a result, the source response will change in relatively large, discontinuous jumps when a source is first placed in the CAM. Attempts were made to estimate the source response time. The Victoreen CAM does not display a real time count rate. The only other indication of response to a source is the concentration. However, the displayed concentration does not reflect the actual value until at least 1 hour of steady state operation.

A.7 COEFFICIENT OF VARIATION

The measurement of the coefficient of variation of the alpha CAMs was performed with two ^{239}Pu alpha sources with activities of 1,110 and 20,000 dpm. The requirements in the standard allow a coefficient of variation of 15% for alpha sources below 2,000 dpm and 10% for sources at or above 2,000 dpm.

A.8 LINE NOISE SUSCEPTIBILITY

The requirements in the standard dictate that the response of the CAM not vary by more than 15% when the CAM is exposed to the power transients listed in the standard. In addition, the system alarms cannot be triggered by the transients. In this test, the CAMs were exposed to all the transients listed in the standard except the 100-kHz ring wave. The capability to generate this transient was not

available. The CAMs were first exposed to the low voltage transients and then exposed to the high voltage transient.

A.9 MINIMUM DETECTABLE ACTIVITY

To determine MDA, the CAMs were run continuously for at least 24 hours with filters and no check sources. Background data was acquired after this 24-hour period and after a second period of at least 24 hours. The data was acquired during the flow rate stability test, for which the CAMs were split into two groups and one group was tested at a time. Each group consisted of at least one CAM from each vendor. The formula for calculating MDA is given in ANSI N42.17B as

$$\mathrm{MDA} = \frac{4.65\ S_b}{k} \tag{A.1}$$

where S_b is the standard deviation of the background count rate in counts per minute and k is a conversion constant in units of counts per minute (cpm) per disintegration per minute (dpm). The conversion constant, k, is equivalent to the efficiency and is obtained from calibration. The standard deviation of the background count rate was approximated by the square root of the average background count rate.

A.10 ACCURACY

The requirements in ANSI N42.17B dictate that the indicated value be within 40% of the conventionally true value. In this test, only the accuracy of the count rate was evaluated. The testing was performed with three ^{239}Pu sources of the following approximate activities: 2,380 dpm; 20,000 dpm; 40,000 dpm. The sources were approximately 7/8 in. in diameter and were originally uncalibrated. To certify the sources, the sources were counted in a 2π gas flow proportional counter. The measured count rate from the sources was compared to the count rate of a calibrated standard. The activities of the sources were calculated based on the comparison. The calibrated activities were: 2,421 $\pm$ 18 dpm; 21,546 $\pm$ 311 dpm; 44,770 $\pm$ 303 dpm, respectively.

The count rates measured by the CAMs were converted to dpm using the efficiency factors determined during calibration of the CAMs.

A.11 RESPONSE TO UNWANTED RADIATIONS

The alpha CAMs were exposed to gamma rays (^{137}Cs) at approximately 100 mR/h and neutrons (^{252}Cf) at approximately 300 mrem/h to determine their response to unwanted radiations. A requirement in ANSI N42.17B states that any sensitivity to unwanted radiations be noted. The operating manuals for the CAMs made no statements as to the sensitivity of the CAMs to unwanted

radiations. However, the methods used to subtract for background were discussed in the manuals of all the vendors.

A.12 RADIO FREQUENCY FIELDS

One alpha CAM from each vendor was tested for radio frequency sensitivity. The CAMs were tested in unison for the fields of 60 Hz and 0.3 to 35.0 MHz. The RF fields had a strength of approximately 100 V/m. The 140-Mhz radio frequency field was generated with a hand-held transceiver and applied to the CAMs individually. The capability to generate a 400-Hz field was not available.

A.13 MICROWAVE FIELDS

The CAMs were tested in a 2,450-MHz microwave field of approximately 100 mW/m^2.

A.14 TEMPERATURE

The requirements in ANSI N42.17B allow a change in response of not more than 15% between 10°C and 40°C and a change of not more than 20% between -20°C and 50°C. The CAMs were allowed to stabilize at room temperature (nominally 22°C) and reference readings were recorded. The temperature was then increased at a rate of 10°C/h until the temperature reached 30°C. The CAMs were allowed to stabilize for 1 hour at the new temperature and then the responses were recorded. The temperature was again increased to 40°C and 50°C allowing a 1-hour stabilization at each temperature before recording the instruments' responses. The CAMs were then returned to room temperature and allowed to stabilize. The process was repeated for the temperature range of 22°C to -20°C.

A.15 HUMIDITY

The requirements in ANSI N42.17B the standard state that the change in response of the CAM will not exceed 15% over the relative humidity range of 40% to 95% at 22°C with respect to the reference response at 40% RH (22°C).

A.16 VIBRATION

ANSI N42.17B does not include requirements for vibration. The requirements for vibration for this study were adapted from ANSI Standard N42.17A, *Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions*. This standard states that the CAM response will not vary by more than 15% from the reference response after the CAM has been exposed to vibrations of 2 G for 15 minutes in the frequency range of 10 to 33 Hz. Vibration testing was performed near the end of the testing sequence in case the CAMs were physically damaged by the vibration. The procedures require vibration along three orthogonal

axes. However, the Eberline and Victoreen CAMs were only vibrated along two axes to prevent damage to the external surfaces by the mounting hardware.

A.17 AMBIENT PRESSURE

The requirement in ANSI N42.17B allows a change in response of not more than 15% over the pressure range of 70 to 106 kPa with respect to the response at 101 kPa.

A.18 FLOW RATE METER ACCURACY

The standard states that the CAM air flow rate meters be accurate to within ±15% of the actual value. The accuracy of the flow rate meters of the Eberline CAMs was evaluated at five points within the specified range of the CAM, of the NE America CAMs at three points, of the SAIC/RADeCO CAMs at six points, and of the Victoreen CAMs at three points.

A.19 FLOW RATE STABILITY

Requirements in ANSI N42.17B dictate that the manufacturers state the nominal flow rate for the type of filter that is used. In addition, it is required that the flow rate reading of the CAMs must not vary more than 5% from the nominal flow rate. Except for the Victoreen CAMs, the nominal flow rates were stated in the vendors' operating manuals. The nominal flow rate of the Victoreen was assumed to be 50 liters/minute. The test period was 100 hours.

A.20 REFERENCES

American National Standards Institute (ANSI). 1989a. *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*. ANSI N42.17B-1989, American National Standards Institute, Inc., New York.

American National Standards Institute (ANSI). 1989b. *Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions*. ANSI N42.17A-1989, American National Standards Institute, Inc., New York.

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