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Evaluation of the Eberline AMS-3A and AMS-4 Beta Continuous Air Monitors

M. L. Johnson
D. R. Sisk

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Operated for the U.S. Department of Energy
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Abstract

Eberline AMS-3A-1 and AMS-4 beta continuous air monitors were tested against the criteria set forth in the ANSI Standards N42.18, *Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents*, and ANSI N42.17B, *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation.* ANSI N42.18 does not, in general, specify testing procedures for demonstrating compliance with the criteria set forth in the standard; therefore, wherever possible, the testing procedures given in ANSI N42.17B were adopted. In all cases, the more restrictive acceptance criteria and/or the more demanding test conditions of the two standards were used.

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL)[a] evaluated the performance of two models of Eberline beta radiation continuous air monitors (CAMs). The two models tested were the AMS-3A-1 and the AMS-4. Instruments were tested against criteria in ANSI N42.18 (R 1980), *Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents*, and ANSI N42.17B (1989), *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation.* The following tests, as defined by ANSI N42.17B and ANSI N42.18, were performed:

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

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

2.0 Instrument Specifications

Two different Eberline beta CAM models were tested: model AMS-4 and AMS-3A. Each model of beta CAM was tested in two configurations. Specific models and configurations are described below.

2.1 Eberline Model AMS–4

The AMS–4 beta CAM is a microprocessor-based CAM with two types of sampling heads: a radial inlet head for workplace monitoring and an optional inline head for effluent monitoring. Both configurations have identical electronics with the exception of a longer cable between the modular detector board and the electronic chassis on the inline head. The two heads use different detectors. The radial inlet head uses a 2-inch-diameter, sealed argon-CO_2 gas proportional detector. The inline head uses a 1-inch-diameter, sealed gas proportional detector. The original 1-inch-diameter detectors were neon-CO_2 filled, as stated in the Eberline manual (Eberline 1993). The detector manufacturer changed the fill gas, and the 1-inch detectors used for the actual testing were argon-CO_2 filled. The two sample-head configurations also have different style anode clips.

During the testing, the detector manufacturer also changed the construction method for the detectors. Early detectors had an epoxied mica window. Later detectors used a glass-fused window (which is the same process used by the manufacturer for Geiger-Mueller tubes). The test results presented in this report were collected on the AMS–4 CAMs equipped with the detectors with glass-fused windows.

For some tests, the results were not expected to be affected by the differences between the two sample-head designs; these tests were performed on only one version of the AMS–4, typically the inline sample head. The remaining tests were performed on both versions of the sample head except where indicated. The AMS–4 CAMs are identified in the report as AMS–4 numbers (1), (2), and (3). The serial numbers of the actual instruments tested are given in Table 2.1.

Table 2.1. Serial Numbers of Eberline AMS-4 Instruments Tested

Identification Number	Electronics	Inline Head	Radial Head
AMS-4 (1)	130	319	130
AMS-4 (2)	325	338Y	325
AMS-4 (3)	338	338X	338

2.2 Eberline Model AMS-3A

The Eberline AMS-3A beta CAM is an analog instrument. Two configurations are used at Hanford: the standard AMS-3A and a modified, modular AMS–3A–1 designed at Hanford and manufactured by Eberline. The instruments are identical except that the modular AMS–3A–1 separates the CAM into two components, an electronics module and a lead-shielded detector module. The only electronic difference between the AMS-3A and the AMS-3A–1 is a longer cable between the electronic chassis and the detectors on the modular AMS–3A–1. Because the AMS-3A is large and awkward to work with, some tests were difficult or impossible to perform. Therefore, all tests were performed only on the AMS–3A–1. Because the instruments are functionally equivalent, the results for the AMS–3A–1 are applicable to the AMS-3A. The AMS–3A–1 CAMs are identified in the report as AMS-3A-1 numbers (1), (2), and (3). The serial numbers of the actual instruments tested are given in Table 2.2.

Table 2.2. Serial Numbers of Eberline AMS-3A-1 Instruments Tested

Identification Number	Serial Number
AMS-3A-1 (1)	146
AMS-3A-1 (2)	145
AMS-3A-1 (3)	142

3.0 General Test Protocol

A majority of the tests in this study were performed using the test criteria and methods described in ANSI N42.17B (1989); additional tests were defined by PNNL to further evaluate the performance under conditions given in ANSI N42.18. Where criteria from ANSI N42.17B and ANSI N42.18 overlapped, the test was performed to comply with the most restrictive criteria from both standards. The requirements or objectives and the procedures followed for all the tests are described in the following sections. Requirements obtained from ANSI N42.17B and ANSI N42.18 are summarized as they relate to CAMs.

Attempts were made to arrange the tests from least damaging to most damaging to prevent the loss of test results from damaged instruments. Where practical, tests were performed simultaneously on all the instruments to reduce redundant effort and ensure that test conditions were identical. For example, the temperature test was conducted with all instruments placed in the environmental chamber at the same time.

3.1 Data Collection Methods

A data acquisition system for automated collection of test data was employed when practical to expedite testing and reduce labor.

When the data acquisition system was not practical for the AMS-3A-1, count rate data were collected using a digital scaler connected to the CAM's "Signal Out" connection. During other tests, count rate data were collected using a computer connected to the 4-20 mA remote output. The computer converted the signal to an equivalent count rate.

For the AMS-4, beta and gamma channel count rates and flow data were collected by querying the CAM's history log using the data acquisition system or communication software provided by Eberline. Eberline provided PNNL with a communication software, titled *WINAMS*, for use during the testing. *WINAMS* is proprietary software developed and provided by Eberline that can be used to manually obtain data from individual AMS-4 CAMs, and perform plateau measurements, calibrations, and other utility functions. For other tests, the count rate and flow data was read from the CAM's front panel using the "Test Inputs/Outputs" option. The response of the AMS-4 alpha channel was not monitored.

Unless otherwise identified, a 7-mCi ^{137}Cs source was used to irradiate both background and beta detectors of all CAMs during a test. The detector/source geometries were maintained constant for the duration of a given test. A sufficient number of instrument readings was recorded to satisfy statistical requirements. Guidance on the number of readings required is found in Section 3.3 of ANSI N42.17B. In general, after several readings were taken, the coefficient of variation (CV) of those readings was calculated. The variance in instrument response allowed under the test conditions (e.g., the temperature test allows a 5% variance in response over the temperature range), the CV, and the table in Section 3.3 of ANSI N42.17B were used to determine the number of required instrument readings.

Changes in response with respect to a reference response are typically reported as a signed percent change (e.g., -10%). The sign indicates the direction of the change; a negative sign represents a decrease from the reference response, and a positive sign represents an increase.

Data sheets were written and completed in accordance with PNL-MA-68, "Records Management and Document Control," Section 6.8. Data sheets were reviewed for technical content by the project manager.

The standard test conditions defined by ANSI N42.17B, other than the conditions meant to be adjusted, were maintained to the extent possible during testing. The heating and ventilation system in the test facility failed for several weeks during the testing. Therefore, some tests were performed outside the standard test conditions. Actual conditions under which the tests were performed are noted in the "Results" for tests that were performed outside the standard test conditions.

The conditions for each test, e.g., temperature and humidity, were monitored using instruments that have a current calibration traceable to the National Institute of Standards and Technology (NIST) through the Hanford Standards Laboratory, which is operated by the Westinghouse Hanford Company.

3.2 Tests Not Performed

Several tests listed in ANSI N42.17B were not performed. The tests listed below are not required by ANSI N42.18, so the lack of test results does not affect the determination of whether or not the CAMs comply with ANSI N42.18. The tests not performed were as follows:

- *400-Hz electric field* - The CAMs were not subjected to a 400-Hz electric field because the equipment to generate the field was not available.

- *In-leakage and filter pressure drop on AMS–4* - The AMS–4 was not tested for in-leakage or filter pressure drop because a satisfactory method for connecting a standard air-flow device to the CAM's air inlet (i.e., filter holder) was not available.

- *Particle collection* - Particle collection testing was not completed on the CAMs because the equipment to perform the testing was not available.

3.3 Corrections for Air Density

The ANSI standard N42.17B allows correcting an instrument's response for changes in air density when performing some tests (such as temperature and ambient pressure) when appropriate. A representative from Eberline stated that the mass flow meter used as a flow sensor for the AMS-4 has a response that is independent of temperature and pressure, and that corrections were not necessary. By definition, mass flow meter responses are independent of temperature and pressure. However, when the volumetric flow rate is derived from the mass flow rate, the derived volumetric flow rate is dependent on the temperature and pressure at the time of calibration.

The results for the ambient pressure testing and the temperature tests include uncorrected and corrected flow sensor readings.

4.0 General Criteria

Evaluation of general characteristics included visual inspection of the instrument features, such as sample-head design and instrument labelling, and comparison of the features to the requirements of ANSI N42.17B.

4.1 Instrument Inspections

Compliance or noncompliance with a majority of the requirements in ANSI N42.17B classified as "General Characteristics" is determined by visual inspection of the instrument. The applicable requirements and the results are summarized in Table 4.1. Requirements from ANSI N42.17B that are not specifically listed were determined to be not applicable.

4.2 Alternating Current Power Supply

Requirement

Both ANSI N42.17B and N42.18 require that the manufacturer state the operating voltage range for the instrument. In addition, ANSI N42.17B requires that the range shall be, at minimum, 117 ± 15 VAC (or 208 ± 30 VAC) at a nominal frequency of 60 Hz (i.e., 57 to 61 Hz).

ANSI N42.18 requires that the instrument's response vary not more than ±5% at voltages and frequencies over the range of ±15% of the manufacturer's design values. Similarly, ANSI N42.18 requires that the manufacturer state the effect on the instrument's accuracy of line voltage and frequency variations of ±15% from the design value.

Results

The AMS–4 complied with the ANSI N42.17B requirement that the minimum operating range of the instrument be 117 ± 15 VAC. The AMS–3A–1 is marginally compliant (the stated operating range is 115 VAC ± 10%).

Both the AMS–3A–1 and the AMS–4 complied with the ANSI N42.18 requirement that the response vary not more than ±5% over the voltage range.

Neither the AMS–3A–1 nor the AMS–4 complied with the ANSI N42.18 requirement for the frequency range. The response of AMS–3A–1 (1) decreased 8% at 69 Hz. The response of one AMS–4 decreased 10% (beta channel) and 7% (background channel). The results, though, indicate that the change in response on the AMS–4 may be due to a shift in the source position during the course of the testing.

Table 4.1. Applicable N42.17B "General Characteristics" Requirements for Eberline AMS-3A-1 and AMS-4

Requirement	Result
The distance between the inlet and the collection media shall be minimized.	Complied
The collection media should be specified by the manufacturer.	Complied
Easily removed parts for decontamination. The design should minimize internal contamination.	Complied
In-leakage that allows flow to bypass the collection media shall be eliminated.	Complied
Readings should be expressed in units of activity per unit volume or in units of directly measured quantities.	Complied
All external instrument controls, displays, and adjustments shall be identified as to function.	Complied
Markings listed in ANSI N42.17B shall appear on the exterior of each major subassembly, as appropriate. Markings shall be readable and permanently fixed.	Complied
Analog meters shall have scale markings in accordance with ANSI N42.17B. Readouts shall display the readout units. Abbreviations shall be consistent with ANSI Y1.1 (1984).	Partial compliance[a]
The range shall be specified and shall be at least 10^4 times the minimum detectable level.	Partial compliance; minimum detectable activity not specified.
The alarm threshold shall be adjustable over the range of the instrument and shall be given as percentages of scales or decades or in terms of the units of the display. Controls shall be protected from inadvertent adjustment.	AMS-3A-1 not compliant,[b]; AMS-4 complied.
Controls shall be protected from inadvertent deactivation or improper operation of the instrument.	Complied

(a) Not all abbreviations used on the AMS-3A and AMS-4 monitors are consistent with ANSI Y1.1 (1984). However, they were consistent with commonly used health physics abbreviations.
(b) The AMS-3A alarm threshold control is not protected from inadvertent adjustment.

In addition, neither CAM model complied with the ANSI N42.18 requirement that the manufacturer shall state the effect on the instrument's accuracy of varying the line voltage and frequency over the operating range.

ANSI N42.17B allows a 15% variation in response over the voltage and frequency ranges, and both model CAMs complied with the less stringent ANSI N42.17B requirement.

Because the nominal operating range for the AMS–3A–1 is 115 VAC ± 10% at 60 Hz, the AMS–3A–1 was tested over the range of 98 to 127 VAC. A calibrated pulser was used as an input signal in place of a detector to provide more consistent counting statistics. A calibrated scaler was used to collect the count rate data. The count rate on the pulser was selected to be sufficiently high to achieve good counting statistics with a 1-minute count.

The nominal operating voltage for the AMS–4 is stated in the manufacturer's literature as 85 to 264 VAC at 50 to 60 Hz. Because the manual states a voltage range rather than a nominal operating voltage, a nominal operating voltage of 115 VAC was assumed. The AMS–4 was tested over the range 115 VAC ± 15% (98 to 133 VAC). During the testing, the beta, background, and flow channels were monitored.

The facility air conditioning had failed during the period in which the voltage testing was performed on the AMS–4 models. The actual temperature in the laboratory was 27°C, which exceeds the temperature range for standard test conditions.

The results are summarized in Tables 4.2 through 4.5. The results for the AMS–4 flow channel are not included because the flow was essentially unchanged for all variations of line voltage and frequency. The results for AMS–4 (2) indicate that the instrument response decreased 10% when the frequency was varied. However, a final reference reading taken at the end of the test was also 10% less than the original reference reading. This indicates a potential change in the instrument/source geometry between the first reference reading and the frequency testing. Normally, this test would be repeated. However, in this case it was not possible because the instrument in question was permanently damaged by subsequently performed AC line transient testing.

Table 4.2. Results of Line Voltage Test for Eberline AMS–3A–1

Line Voltage	Response, cpm		
	AMS–3A–1 (1)	AMS–3A–1 (2)	AMS–3A–1 (3)
115 (reference)	15058	60563	75700
98	14966	59596	77486
100	15657	60961	76841
105	14802	60889	76571
110	15277	60400	76747
120	14993	58898	76630
125	14612	59633	76355
127	15288	60462	76674
115 (Reference 2) [(a)]	85949	87719	66280
133	85857	86615	67273
Maximum variation from reference	+4%	-3%	+2%

(a) Reference 2 and the 133-V data point were collected after the initial testing. Reference 2 is used with only the 133-V data point.

Table 4.3. Results of Power Frequency Test For Eberline AMS-3A-1

Frequency, Hz	Response, cpm		
	AMS-3A-1 (1)	AMS-3A-1 (2)	AMS-3A-1 (3)
60 (reference)	15584	59555	76551
59	15108	59623	77251
58	14846	59101	76137
57	15001	60434	76710
56	15581	60012	78291
55	15136	60213	76189
54	15175	59188	77646
53	15560	59876	77058
52	14956	59527	77059
51	14968	58688	76659
61	14864	60185	75895
62	15285	59689	77539
63	15072	58772	77583
64	15633	59535	76228
65	14998	59438	76943
66	15825	59605	76192
67	15106	58868	77180
68	15580	58994	76530
69	14348	58900	76447
Maximum variation from reference	-8%	+1%	+2%

Table 4.4. Line Voltage Test Results for Eberline AMS–4 Beta and Background Channels

	Response, cpm					
	AMS–4 (1)		AMS–4 (2)		AMS–4 (3)	
Voltage	Beta	Background	Beta	Background	Beta	Background
115 (reference)	5389	5800	3456	4218	3353	3623
98	5352	5820	3396	4195	3374	3560
103	5395	5815	3420	4239	3427	3624
108	5433	5788	3445	4150	3361	3604
113	5344	5800	3424	4154	3356	3563
118	5415	5747	3422	4145	3424	3617
123	5464	5739	3418	4161	3361	3620
128	5386	5822	3435	4146	3380	3607
133	5371	5833	3366	4155	3368	3616
118	5378	5736	3418	4095	3409	3594
Maximum variation from reference	+1.4%	-1.1%	-2.6%	-2.9%	+2.2%	-1.7%

Table 4.5. AC-Line Frequency Test Results for Eberline AMS–4

	Response, cpm					
	AMS–4 (1)		AMS–4 (2)		AMS–4 (3)	
Frequency, Hz	Beta	Background	Beta	Background	Beta	Background
60 (reference)	6163	7092	4452	5078	7232	8837
51	6138	7141	4044	4741	7169	8705
53	6146	7135	4028	4709	7248	8800
55	6226	7148	3993	4713	7215	8732
57	6184	7100	4026	4745	7240	8785
59	6189	7141	4025	4749	7248	8697
61	6197	7117	4033	4753	7323	8760
63	6213	7104	4015	4709	7331	8802
65	6233	7245	3993	4732	7300	8808
67	6180	7159	4022	4772	7272	8839
69	6167	7164	4052	4734	7294	8778
60	6253	7195	4010	4816	7324	8761
Maximum variation from reference	+1.5%	+2.2%	-10.3%[(a)]	-7.3%[(a)]	+1.4%	-1.6%

(a) This variation was possibly due to a change in instrument/source geometry during the test. The CAM was permanently damaged during other testing (AC power supply transients) before the frequency test could be repeated.

4.3 Alteration and Modification

ANSI N42.17B requires repeating tests if any alterations or modifications are made to the instrument. No alterations or modifications were made to the Eberline AMS-3A nor the AMS–3A–1 during the course of the testing. Therefore, no repeat testing was needed for the AMS-3A or the AMS–3A–1.

Several modifications were made to the AMS–4. New detectors and new detector designs were used as well as a revised (higher beta threshold) calibration procedure. The results in this document reflect the performance of the CAM with the final design and calibrated with the most recent calibration procedure. All tests performed before the detector design was changed and the calibration procedure revised were repeated.

5.0 Electronic Criteria

The Eberline AMS-3A-1 and AMS-4 were tested to several electronic test criteria from ANSI N42.17B and ANSI N42.18. A comparison of the requirements and results are included for the following tests:

- high radiation alarm
- alarm reset
- alarm activation delay
- alarm threshold drift
- fault alarms
- audible alarm intensity
- visual alarms
- stability
- response time
- coefficient of variation
- line noise susceptibility.

5.1 High Radiation Alarm

Requirement

ANSI N42.18 requires that the high radiation alarm shall be externally selectable to any point over the range of the instrument.

Results

Both the AMS-3A-1 and the AMS-4 complied with the requirement.

5.2 Alarm Reset

Requirement

ANSI N42.17B requires that latching and nonlatching alarms shall continue to operate in radiation fields greater than the selected alarm points. In addition, it should be possible to interrupt an audible alarm by deliberate action without interrupting an accompanying visual alarm. Latching radiation alarms shall continue to operate on reduction of exposure rate below the alarm level until manually reset (i.e., acknowledged). Nonlatching radiation alarms shall clear automatically on reduction of exposure rate below the alarm level. Radiation alarms shall be both audible and visual.

Results

The AMS-4 complied with the criteria; the AMS-3A-1 partially complied with the criteria.

Both models had visual and audible high airborne radiation alarm indicators that were continuous for at least 5 minutes when exposed to a source of radiation sufficient to activate the alarm. The high radiation alarm on both model CAMs is nonlatching, and all instrument responses returned to typical background values after the sources were removed. Alarms remained off for at least one minute after sources were removed. It was possible to interrupt the audible alarm by deliberate action without interrupting the visual alarm.

5.3 Alarm Activation Delay

Requirement

ANSI N42.18 requires that the failure and the high radiation alarms be described in the manufacturer's literature. Information provided on the alarms should include the time to alarm.

Result

Both the AMS-3A-1 and the AMS-4 were marginally compliant.

The operating manuals for the instruments included thorough discussions of the fault alarms and high radiation alarms. Alarm activation delay was not stated in the manuals. Therefore, neither CAM complies with the requirement that the manufacturer provide the alarm activation delay time.

Alarm activation delay times for the AMS-3A-1 CAMs were measured and were between 25 and 30 seconds.

High radiation alarm activation delay times for the AMS-4 varied depending on the values set for parameters such as "Net Beta Alarm." Measured alarm activation delay times were consistent with the values set for "Net Beta Alarm." Fault alarms on the AMS-4 had an alarm activation time of 5 to 20 seconds (depending on the type of fault).

5.4 Alarm Threshold Drift

Requirement

ANSI N42.17B states that under standard test conditions, the actual exposure rate trip level shall not deviate from the set point level by more than $\pm 10\%$ over a period of 24 hours and $\pm 20\%$ over a period of 500 hours. ANSI N42.18 does not have similar criteria for alarm threshold drift.

Result

This test is not applicable to digital instruments such as the Eberline AMS-4. Although it is applicable to the AMS-3A-1, the test was not completed on the AMS-3A-1 because of budget constraints.

5.5 Fault Alarms

Requirement

ANSI N42.17B requires a fault alarm capability to give appropriate notification when the CAM is incapable of monitoring radiation or if a failure occurs in any component or circuit which would affect the accuracy of the readout. The sound of fault alarms shall differ from that of high radiation alarms.

Similarly, ANSI N42.18 requires that the fault alarms identify when there is a loss of detector signal or loss of power to the detector circuit. ANSI N42.18 also requires that fault alarms be latching.

Result

The AMS-3A-1 partially complied with the criteria. AMS-3A-1 fault alarms are not latching. The AMS-4 partially complied with the criteria. The AMS-4 does not alarm on a failed background detector.

Fault alarms were activated on the AMS-3A-1 CAMs within 40 to 42 seconds of disconnecting either of the CAM detectors from its high voltage power supply. Fault alarms reset on the AMS-3A-1 once the high voltage supply was restored. One AMS-3A-1 re-initiated the fault alarm about 40 seconds after power was restored to the background detector. The AMS-3A-1 met the requirement that the fault alarm sound different from the high radiation alarm. However, it did not meet the requirement that the fault alarm be a latching alarm.

Fault alarms were activated on the AMS-4 within 2 to 20 seconds of the fault (depending on the type of fault). Fault alarms were latching. The AMS-4 has the capability of alarming if the count rate from the beta detector decreases below a user-settable minimum. However, this alarm feature may be disabled by the user by setting the "Min Beta Count Rate" equal to 0.0. The AMS-4 does not alarm on low count rates from the background detector. Therefore, the AMS-4 may have a damaged background detector without initiating a fault alarm.

5.6 Audible Alarm Intensity

Requirement

NSI N42.17B requires that the intensity of an audible alarm shall be at least 75 dB in the frequency range 500 to 3000 Hz at a distance of 15 cm (6 in.) from the exterior case of the instrument over a solid angle of 15°.

Results

The design of the sound pressure level meter did not allow testing the CAMs over the continuous frequency range of 500 to 3000 Hz. Therefore, the CAMs were tested over two frequency ranges: 500 to 1500 Hz and 2000 to 3000 Hz. The results for each range were compared to the acceptance criteria given in ANSI N42.17B.

Because of their different physical construction, both the AMS-3A and AMS–3A–1 were tested. Both models complied with the requirement with an average audible alarm intensity greater than 80 dB over the frequency range of 500 to 3000 Hz. The results are summarized in Table 5.1.

The AMS–4 did not comply with the requirement over the frequency range 500 to 1500 Hz; the audible alarm intensity over that frequency range was less than 60 dB. However, the AMS–4 did comply over the range of 2000 to 3000 Hz, with an average audible alarm intensity greater than 80 dB. The results are summarized in Table 5.2.

The AMS–4 has two sonalerts to provide audible alarms. One sonalert is in the electronics chassis, with a second in the remote sample head. The intensity of the audible alarm on the AMS–4 was measured when the instrument was in a "detector failure" alarm, which activates both sonalerts. In this alarm, the sample head alarm has a continuous tone, and the electronics chassis audible alarm has a pulsed tone.

The audible alarm intensity for the AMS–4 was measured at +15°, 0°, and -15° with the sound meter parallel to and on the same plane as the bottom of the instrument (the location of sonalert). Because the AMS–4 did not comply at these points, the remaining points of the solid angle were not tested. The electronics chassis and the sample head were placed in close proximity to each other (approximately 12 inches apart). Two octave bands were used: 500 to 1500 Hz and 1000 to 3000 Hz. The sound level was measured using a linear (unweighted) scale.

Table 5.1. Minimum Audible Alarm Intensity for Eberline AMS–3A–1

Instrument Tested	1-kHz Octave Band, 500 to 1500 Hz		2-kHz Octave Band, 1000 to 3000 Hz	
	Intensity	Angle	Intensity	Angle
AMS-3A (1)	86 dB	-15°	97 dB	+15°
AMS-3A (2)	84 dB	0°	95 dB	-15°
AMS-3A (3)	82 dB	-15°	93 dB	-15°
AMS–3A–1 (1)	87 dB	0°	92 dB	-15°
AMS–3A–1 (2)	83 dB	-15°	94 dB	-15°
AMS–3A–1 (3)	88 dB	-15°	94 dB	+15°

Table 5.2. Minimum Audible Alarm Intensity for Eberline AMS–4

	AMS–4 (1)	AMS–4 (2)	AMS–4 (3)
Intensity of 1-kHz Octave Band, 500 to 1500 Hz			
Inline head	49.2 dB at 0°	47.2 dB at 0°	52.13 dB at 0°
Radial head	54.5 dB at 0°	55.2 dB at 0°	49.7 dB at -15°
Intensity of 2-kHz Octave Band, 1000 to 3000 Hz			
Inline head	81.4 dB at 0°	76.8 dB at 0°	82.2 dB at 0°
Radial head	84.9 dB at 0°	85.4 dB at 0°	82.7 dB at -15°

5.7 Visual Alarms

Requirement

ANSI N42.18 states that the CAM shall have a visual high radiation alarm. ANSI N42.17B allows visual alarms to be flashing or steady-state.

Results

Both the AMS–3A–1 and AMS–4 have flashing, visual high radiation alarms and steady-state visual fault alarms. Therefore, both models meet the criteria.

5.8 Stability

Requirement

The mean instrument response at constant temperature and pressure shall not vary more than 6% from the mean of a set of reference readings over a period of 24 hours for alternating-current-powered (AC-powered) units after a warmup period specified by the instrument manufacturer. A maximum change of 15% over a period of 500 hours is allowed for AC-powered units.

Results

The AMS-3A-1 complied with the criterion. Of the three AMS-4 beta CAMs tested, one complied with the criterion, one failed to comply, and the third CAM complied marginally.

The CAMs were operated continuously for 500 hours. The AMS-4 CAMs were connected to vacuum pumps during the testing. Because the stability of the AMS-3A-1 rotameter was not a concern (and because the resolution of a rotameter precludes discerning a 15% variation in response), the AMS-3A-1 CAMs were not operated with a vacuum pump.

The data on one AMS-3A-1 CAM was discarded when it was discovered that the reference source had shifted position during the course of the test. Therefore, results are provided for only two of the AMS-3A-1 CAMs.

The results are summarized in Tables 5.3 and 5.4.

Table 5.3. Results of Stability Test for Eberline AMS-3A-1, cpm

Test Point	AMS-3A-1 (1)	AMS-3A-1 (2)
Reference	77622	70083
1 hr	78031	68764
10 hr	77372	69446
24 hr	77195	69816
Maximum Variation at 24 hr	-0.5%	-2%
100 hr	77000	68178
200 hr	76303	67994
500 hr	76610	68497
Maximum Variation from Reference	-2%	-3%

Table 5.4. Results of Stability Test for Eberline AMS-4, cpm

Test Point	AMS-4 (1)		AMS-4 (2)		AMS-4 (3)	
	Beta	Background	Beta	Background	Beta	Background
Reference	1655	3301	1722	5306	1286	702
1 hr	1608	3314	1711	5350	1292	700
10 hr	1659	3325	1738	5365	1313	709
24 hr	1693	3372	1720	5385	1321	716
Maximum Variation at 24 hr	-3%	+2%	+1%	+1%	+3%	+2%
100 hr	1961	3833	1785	5487	1417	720
200 hr	2137	3849	1762	5449	1411	735
500 hr	2436	3861	1784	5559	1463	745
Maximum Variation from Reference	+47%	+17%	+4%	+5%	+14%	+6%

5.9 Response Time

Requirement

ANSI N42.17B requires that the instrument response time shall be stated by the manufacturer for each scale or decade of the unit.

ANSI N42.18 requires that the instrument response time shall be not less than that required to maintain background readings within the required accuracy.

Results

Neither CAM model complied with the ANSI N42.17B requirement that the manufacturer state the response time for each scale or decade of the instrument.

The AMS-3A-1 complied with the ANSI N42.18 criterion that the response time shall be sufficient to maintain background within the desired limits.

The Eberline operating manual (Eberline 1991) for the AMS–3A–1 states that the response time "varies with count rate to provide constant statistical fluctuation." Therefore, the AMS–3A–1 does not strictly comply with the requirement that the manufacturer shall state the response time.

The Eberline operating manual for the AMS–4 does not state a response time. Because the AMS–4 is a digital instrument with, essentially, a user-selectable response time, the criteria are not applicable to the AMS–4. By adjusting variables such as "Slow Alarm Interval" and "Net Alarm Interval," the user can adjust the time required for the AMS–4 to achieve equilibrium after a change in the detector signal.

The rise time and fall time for the AMS–3A–1 was measured using a calibrated pulser as a signal source. After the instrument stabilized, its response was recorded as the reference reading. The pulser was then turned off and back on. The time required for the meter to respond from 10% of the reference reading to 90% of the reference reading (rise time) was recorded. Similarly, the pulser signal was removed and the time required for the meter to respond from 90% to 10% of the reference reading (fall time) was recorded. Table 5.5 records the response times of the AMS-3A-1.

Table 5.5. Response Time of the Eberline AMS–3A–1

	Response Time, seconds					
	AMS–3A–1 (1)		AMS–3A–1 (2)		AMS–3A–1 (3)	
Range, cpm	Rise	Fall	Rise	Fall	Rise	Fall
10 - 100	>180	>180	>180	>180	>180	>180
100 - 1,000	20.2	18.8	22.6	19.1	19.7	19.0
1,000 - 10,000	3.1	3.5	2.5	2.7	3.0	2.9
10,000 - 100,000	2.9	1.2	2.7	1.0	2.9	1.1

To determine if the AMS-3A-1 met the criterion from ANSI N42.18, it was assumed that the isotope of interest was ^{90}Sr(Y), which has the most limiting derived air concentration (DAC) for beta-emitting isotopes generally of concern at Hanford. The DAC for ^{90}Sr(Y) is 2.00 x 10^{-6} μCi/cm^3. DOE Order 5480.11 requires that air monitors be capable of alarming on 8 DAC-hours. This is equivalent to 1.2 x 10^8 dpm for ^{90}Sr(Y) (assuming a 2-cfm sample collection rate). The average ^{90}Sr(Y) efficiency of the three AMS-3A-1 CAMs tested was 21%, which, when multiplied by the desired detection limit of 8 DAC-hours, results in a signal count rate of 2.5 x 10^7 cpm (the count rate equivalent to 8 DAC-hours of ^{90}Sr(Y) activity on the filter). Therefore, the response time of the AMS-3A-1 must be sufficiently long to allow detecting 2.5 x 10^7 cpm under typical background conditions. The background count rate of the three CAMs tested was typically 300 to 400 cpm. Using the equation provided in ANSI N42.18 (and reproduced below) and an average response time of 20 seconds (from Table 5.4., 100 - 1000 cpm range), the resultant signal count rate is less than 100 cpm, which is far less than the required detection limit:

$$n_s = 2\sqrt{\frac{n_b}{2RC}} \quad (5.1)$$

where n_s = the net signal count rate
n_b = the net background count rate
RC = the electronic time constant.

5.10 Coefficient of Variation

Requirement

ANSI N42.17B requires that the coefficient of variation of 20 instrument readings shall not be more than 10% for detectors exposed to radiation intensities greater than or equal to 2000 dpm. When the instrument is exposed to radiation intensities less than 2000 dpm, the coefficient of variation shall not be more than 15%. The ANSI standard requires performing this test on each scale or decade. However, the CAMs tested do not have separate calibration controls for each scale, so the criterion was revised to require testing at only two points over the instrument's range.

The criterion is directly applicable to analog instruments that have a resistance/capacitance (RC) time constant and was written as a test for erratic meter/instrument response. The criterion is less applicable to digital instruments that do not have a true RC time constant and that do not have an analog meter.

Results

The AMS-3A-1 complied with the requirement. Although the criterion is not directly applicable to the AMS-4 because the AMS-4 is a digital instrument, when the test was performed, the AMS-4 complied for sources greater than 2000 dpm but did not comply for sources less than 2000 dpm.

Twenty readings were taken for each CAM. The coefficient of variation was calculated by dividing the standard deviation by the mean instrument response.

Readings on the AMS-3A-1 were taken at least 30 seconds apart. The results are given in Table 5.6.

The AMS-4 was tested by monitoring the beta count rate, which was selected because it is the basic value from which all other values are calculated. The results are also shown in Table 5.6.

Table 5.6. Coefficient of Variation Test Results for Eberline AMS–3A–1 and AMS-4

Count Rate	AMS–3A–1 (1)	AMS–3A–1 (2)	AMS–3A–1 (3)
< 2,000 cpm	10.9%	6.5%	9.7%
> 2,000 cpm	3.7%	1.3%	1.6%
	AMS–4 (1)	AMS–4 (2)	AMS–4 (3)
< 2,000 cpm	63%	38%	46%
> 2,000 cpm	0.6%	0.6%	0.6%

5.11 Line Noise Susceptibility

Requirement

ANSI N42.17B requires that the mean instrument response of AC-powered units vary not more than 15% from the mean of a set of reference readings during or after exposure to voltage sags, surges, and transients on the power line. System alarms shall not be triggered by sags, surges, or transients. The voltage sags, surges, and transients are listed in Table 5.7.

Results

The Eberline AMS–3A–1 did not comply with the criteria. AMS–3A–1 underresponded by 21% following transient 5. All three AMS-3A-1 CAMs were damaged by either transient 5 or 6. The fuses on all three instruments were blown. In addition, the main transformers on two of the AMS–3A–1 CAMs were damaged and required replacement. The results are listed in Tables 5.8 and 5.9.

The AMS-4 also did not comply with the criteria. Two AMS-4 CAMs were tested to the sags and surges listed as transients 1 through 4. The remaining AMS-4 was not tested because it was permanently damaged during previous testing. The AMS-4 did not comply because the flow response on AMS-4 (1) decreased 20% during transient 1. The response of the beta and background channels on both AMS-4 CAMs tested complied with the criteria when subjected to transients 1 through 4.

The AMS-4 CAMs also did not comply with the criteria when tested against the ring-wave transients (transients 5 through 8). The communication link with AMS-4 (3) was lost after transient 5. The communication link was restored after cycling the instrument power. Transient 6 permanently damaged AMS-4 (2) and blew the fuse on AMS-4 (1).

Table 5.7. Power Transients for Line Noise Susceptibility Test

Transient ID Number	Number of Pulses	Rise Time, ms	Duration, ms	Decay, ms	Pulse Amplitude and Sign[(a)]
Surges					
1	10	10	10	10	+40%
2	10	10	500	10	+20%
Sags					
3	10	10	10	10	-100%
4	10	10	500	10	- 40%
Transients					
5	5	0.0005	100-kHz ring wave		6 kV[(b)]
6	5	0.0012	100-kHz ring wave		6 kV[(b)]
7	10	0.0005	100-kHz ring wave		2.5 kV[(b)]
8	10	0.0012	100-kHz ring wave		2.5 kV[(b)]

(a) Percentage of nominal voltage (root-mean-square [RMS] voltage).
(b) Absolute peak amplitude.

Table 5.8. Results of Line Noise Test for Eberline AMS-3A-1

Transient ID Number	AMS-3A-1 (1)		AMS-3A-1 (2)		AMS-3A-1 (3)	
	Response, cpm	Variation from Reference	Response, cpm	Variation from Reference	Response, cpm	Variation from Reference
Reference	14,993	--	59,602	--	75,834	--
1	14,805	-1%	59,447	0%	75,773	0%
2	15,053	0%	59,094	-1%	76,249	+1%
3	15,526	+4%	59,092	-1%	77,767	+3%
4	15,828	+6%	58,988	-1%	78,529	+4%
5	--	-100%	5,000	-90%	60,000	-21%
6	-- (b)	-- (b)	-- (a)	-100%	-- (a)	-100%
7	-- (b)	-- (b)	-- (b)	-- (b)	-- (b)	-- (b)
8	-- (b)	-- (b)	-- (b)	-- (b)	-- (b)	-- (b)

(a) The instrument's response dropped below the zero indication on the meter (off-scale low).
(b) The instrument was not tested to this transient because the CAM was permanently damaged (no indicated response) during a previous transient.

Table 5.9. Results of Line Noise Test for Eberline AMS–4 with Remote Inline Head

Transient ID Number	Response, cpm					
	AMS–4 (1)		AMS–4 (2)		AMS–4 (3)	
	Beta	Background	Beta	Background	Beta	Background
Reference	1055	2151	-- (a)		2134	2752
1	1084	2228	-- (a)		2158	2709
2	1076	2203	-- (a)		2139	2680
3	1094	2190	-- (a)		2132	2702
4	1092	2175	-- (a)		2142	2654
Reference	29891	17831	10469	10025	2174	2651
5	29748	17796	10349	10054	-- (d)	
6	-- (b)		10384	10006	-- (d)	
7	-- (c)		-- (a)		-- (c)	
8	-- (e)					

(a) The CAM was permanently damaged during transient 7 and was not tested to subsequent transients.
(b) The fuse was blown by transient 5 and no further testing was done.
(c) AMS-4 (1) and AMS-4 (3) were not tested because of the potential to permanently damage the instruments.
(d) Communication with the CAM was lost and no further testing was done.
(e) The AMS-4 CAMs were not tested to transient 8 because of the potential to permanently damage the CAMs (as indicated by the response of AMS-4 [2] during transient 7).

6.0 Radiation Response

The Eberline AMS-3A-1 and AMS-4 were tested against various radiation response criteria. The radiation response criteria, comparison requirements, and results are reported for the following tests:

- minimum detectable activity/sensitivity
- accuracy
- beta/photon radiation overload
- radiation type and energy
- response to unwanted radiations.

6.1 Minimum Detectable Activity/Sensitivity

Requirement

ANSI N42.17B requires the manufacturer to state the minimum detectable activity (MDA) for specific radionuclides or radiation types over a given energy range. The standard states that the radionuclides and background conditions used in testing shall be agreed upon between the instrument manufacturer and user. However, PNNL procedures were used to determine the instrument's MDA.

ANSI N42.18 has a similar requirement: The sensitivity should be stated in terms of signal count rate associated with a specific nuclide detectable at the 95% confidence level in the presence of a specified background count rate.

Results

Eberline operating manuals (Eberline 1991 and 1993) do not state MDAs or sensitivities (as defined by ANSI N42.18) for the AMS-3A-1 nor the AMS-4. Therefore, neither model meets the criterion that the manufacturer shall state the MDA.

The MDA for the AMS-3A-1 was estimated by placing a clean filter in the filter holder and then operating the CAM several days at a nominal flow rate. The average background count rate was recorded and, in conjunction with the detector efficiency for ^{90}Sr(Y), used to calculate the MDA using the equation below, which is from ANSI N42.17B:

$$MDA = \frac{4.65\ S_b}{K} \tag{6.1}$$

where S_b = the standard deviation of the background
K = the efficiency, cpm/dpm.

Although the average background for the AMS-3A-1 recorded in the testing laboratory was 30 cpm, background count rates in the field may be as high as 100 cpm. Therefore, MDAs for both background count rates were calculated and are listed in Table 6.1.

Table 6.1. Minimum Detectable Activity for Eberline AMS-3A-1

Background, cpm	Minimum Detectable Activity of $^{90}Sr(Y)$, dpm
30	120
100	220

The firmware for the AMS-4 calculates a minimum detectable concentration as a function of the background count rate, the detector efficiency, and several user-defined variables, including the alarm time interval and the sigma factor. The AMS-4 CAM was calibrated to a $^{90}Sr(Y)$ source (the isotope of concern with the most limiting DAC). A fresh filter was placed in the CAM, and the CAM was operated at a nominal flow rate.

The minimum detectable activity for the AMS-4 is calculated using Equation 6.2:

$$MDA = \frac{SF\sqrt{\text{beta background counts}} + 3}{K * \text{alarm time interval}} \tag{6.2}$$

where SF is the sigma factor (4.65) and K is the efficiency, cpm/dpm).

The alarm time interval is selectable by the user. The default values are 30 minutes for the slow alarm and 60 seconds for the fast alarm.

The beta background count is an estimate of the number of counts accumulated by the beta detector during one alarm interval due to background radiation. It is a function of the count rate of the background detector and the gamma factor. The gamma factor is the ratio of the count rate in the beta detector to the count rate in the background detector and is set during calibration.

The calculated MDAs for the Eberline AMS-4 are summarized in Table 6.2.

Table 6.2. Minimum Detectable Activity of Eberline AMS-4, Nominal Gamma Background of 30 μR/h

	Inline Head	Radial Head
Average efficiency for ^{90}Sr(Y), cpm/dpm	0.13	0.17
Average background, cpm	19 cpm	58 cpm
Fast alarm (60-second) estimated beta background count	19 counts	58 counts
Slow alarm (30-minute) estimated beta background count	570 counts	1740 counts
Estimated fast MDA	179 dpm	226 dpm
Estimated slow MDA	29 dpm	39 dpm

6.2 Accuracy

Requirement

ANSI N42.18 states that the ratio of the indicated to the conventionally true value shall fall within the range of 0.80 to 1.20 at the 95% confidence level, or

$$0.80 \le \frac{\overline{r_i}}{CTV_{ref}} \le 1.20 \qquad (6.3)$$

where $\overline{r_i}$ is the mean indicated value and CTV_{ref} is the conventionally true value.

ANSI N42.17B has a similar criterion, which includes a requirement to perform the testing at 25% and 75% of each range and allows a 40% variance over the range. The CAMs were tested at the points specified in ANSI N42.17B, but the more restrictive acceptance criterion from ANSI N42.18 was applied.

Results

Both the AMS–3A–1 and the AMS–4 complied with the criterion. The maximum deviation on the Eberline AMS–3A–1 was a 12% underresponse. Similarly, maximum overresponses and underresponses on the AMS–4 were each 12%. The results are given in Table 6.3.

Table 6.3. Results of Accuracy Tests for Eberline AMS–3A–1 and AMS–4

	AMS–3A–1			AMS–4		
	(1)	(2)	(3)	(1)	(2)	(3)
Reference	20 cpm			20 cpm		
Measured, cpm	19.3	17.6	19.5	19.3	17.6	19.5
% Difference	-4%	-12%	-3%	-4%	-12%	-3%
Reference	50,000 cpm			50,000 cpm		
Measured, cpm	53,612	54,560	54,819	53,611	54,559	54,819
% Difference	+7%	+9%	+10%	+7%	+9%	+10%
Reference	80,000 cpm			80,000 cpm		
Measured, cpm	86,273	89,232	87,680	86,272	89,232	87,679
% Difference	+8%	+12%	+10%	+8%	+12%	+10%

To reduce statistical uncertainties associated with using a radioactive source, thus improving the statistics of each count, a calibrated pulser was used in place of a source. The pulser was connected to the "Main Signal" connection on the AMS–3A–1, which effectively bypasses the detectors. The pulser was connected directly to the detector anode clip on the AMS–4.

6.3 Beta/Photon Radiation Overload

Requirement

ANSI N42.17B states that when exposed to radiation levels greater than that corresponding to the highest scale or decade maximum, the instrument shall continue to operate, and the readout of an analog instrument shall be offscale or at the higher end of the scale or decade and shall remain so until the radiation field is reduced to below full-scale or decade value. Digital readouts shall convey that the radiation levels present exceed the upper detection limit of the instrument in a manner described by the manufacturer. When the radiation field is removed, the instrument reading shall return to the correct downscale reading, within the time interval stated by the instrument manufacturer. Saturation and other irregular responses at concentrations above the upper detection limit shall be stated.

ANSI N42.18 does not have a criterion for radiation overload response.

Results

The AMS–3A–1 complied with the requirement. The AMS–4 complied with the requirement provided that the "Beta Max Count Rate" alarm limit is less than the maximum value for the beta channel count rate.

When exposed to an overrange condition, the AMS–3A–1 responds offscale high. When the overrange source was removed, the AMS–3A–1 returns to normal operation.

The AMS–4 has an alarm parameter called "Beta Max Count Rate." The default value is 6.00×10^5 cpm. The maximum value to which the alarm may be set is 1.00×10^8 cpm. The maximum display value for the beta count rate is 3.93×10^6 cpm. As long as the "Beta Max Count Rate" parameter is set to a value lower than the maximum display value for the beta count rate, the AMS–4 overrange response meets the criterion. The AMS–4 displays an overrange condition by alarming on "Max Beta Count Rate" and displaying "Out of Service." When the overrange source is removed, the alarms clear and the AMS-4 returns to normal operation.

6.4 Radiation Type and Energy

Requirement

Both ANSI N42.17B and ANSI N42.18 state that the manufacturer shall state the radiation type and energy range which the instrument measures. Instruments for measurement of specific nuclides or beta energy ranges shall be tested for those nuclides or ranges and the results shall be stated.

ANSI N42.17B includes an additional criterion that instruments for gross beta activity shall respond to beta particulates with energies between 0.08 and 3 MeV. Curves of detector efficiency versus beta energy should be provided. The curve shall be based on efficiency measurements made with the sources listed in Table 1.4 of ANSI N42.17B. The minimum particle energy detected and the density of the detector window shall be stated.

Results

Because the manufacturer's literature was incomplete (with respect to the criteria of ANSI N42.17B), both the AMS–3A–1 and the AMS–4 are partially compliant.

The Eberline technical manuals (Eberline 1991 and 1993) list the window density thicknesses as 1.4 to 2.0 mg/cm^2 for the AMS–3A–1 and 2 to 3 mg/cm^2 for the AMS–4. For both instruments, efficiency values for ^{99}Tc and ^{90}Sr(Y) are provided. For neither instrument does the manufacturer state the minimum particle energy detected nor are energy response curves provided.

The instruments were tested for response to isotopes with average beta energies from 50 keV (^{14}C) to 2.2 MeV [$^{90}Sr(Y)$]. A source emitting a 3-MeV beta particle was not available, so the response to the 3-MeV beta particle was not determined.

All the CAMs were calibrated before the efficiency measurements. The AMS–4 CAMs were calibrated using the WINAMS software provided by Eberline. The high voltages for the AMS–4 were set at the points recommended by the software. The AMS–4 beta thresholds were set at 15% of the maximum in accordance with Eberline's recommendation. (The default value given in the technical manual for the beta threshold is 6%. At the time of this testing, Eberline was recommending a higher beta threshold to improve the instrument's performance.) Beta energy response measurements were made for both sample heads for the AMS–4 because the two sample heads each use a different-sized detector. The results are listed in Tables 6.4 and 6.5.

Table 6.4. Beta Energy Response for Eberline AMS–3A–1

	AMS–3A–1 (1)	AMS–3A–1 (2)	AMS–3A–1 (3)
Background, cpm	15	7	13
Efficiency, 4π			
^{14}C	4%	10%	10%
^{99}Tc	15%	19%	18%
$^{90}Sr(Y)$	27%	26%	23%

Table 6.5. Beta Energy Response for Eberline AMS–4

	AMS–4 (1)		AMS–4 (2)		AMS–4 (3)	
	Inline	Radial	Inline	Radial	Inline	Radial
Background, cpm	7	125	14	29	35	21
Efficiency, 4π						
^{14}C	3.7%	4.0%	3.8%	4.0%	3.9%	4.4%
^{99}Tc	9.8%	12.7%	10.1%	11.6%	9.8%	12.4%
$^{90}Sr(Y)$	13.4%	19.3%	13.2%	16.3%	13.0%	16.3%

6.5 Response to Unwanted Radiations

Requirement

ANSI N42.17B requires the manufacturer to state the ability of the instrument to reject unwanted ionizing radiations, including natural background. The manufacturer shall also state the method for testing the ability of the instrument to reject unwanted radiations. In addition, the manufacturer shall state the response of the instrument to ionizing radiations other than those for which measurement capability is claimed.

ANSI N42.18 requires that if the air monitoring system uses a radiation background-subtract circuit or process, the operation of such shall be evaluated and documented.

Results

The AMS–3A–1 responded significantly in the presence of neutron and gamma radiations. In addition, the response of the three AMS–3A–1 CAMs under identical test conditions varied widely.

The AMS–4 responded to alpha radiation but did not respond significantly (less than 10% variation from reference) to the neutron or gamma radiation fields.

During the interfering radiation testing of the AMS–3A–1, the background-subtraction circuit was turned on.

The responses to interfering gamma radiation were measured using a high activity, ^{137}Cs reference source. The source was placed in a position to irradiate both the background and the beta detector. The AMS–4 gamma factor was calculated with the reference source in place. Without disturbing the instrument/source geometry, reference readings were taken. The instrument was then exposed to an additional 100-mR/h ^{137}Cs gamma field and additional readings were taken. During the testing of the AMS–4, only the sample head was placed in the gamma field. The entire AMS–3A–1 was placed in the gamma field. The results indicate that the AMS–3A–1 is sensitive to gamma background.

The responses to interfering alpha radiation were measured by determining the detector efficiency for alpha radiation. A background count was taken as the reference value. The detector was then exposed to a calibrated, National Institute of Standards and Technology (NIST)-traceable alpha-emitting radioactive source. Because ANSI N42.17B does not state specific isotopes for the interfering radiation test, an alpha-emitting isotope recommended by ANSI N42.17A (specifically, ^{239}Pu) was used.

The CAM responses to interfering neutron radiation were measured using an unmoderated ^{252}Cf source. The dose rate of the field during the test was 300 mrem/h. ANSI N42.17B states that the test method should be agreed upon between the manufacturer and the user. However, the manufacturer's literature does not include instructions for neutron interference testing. ANSI N42.17B does not specify sources for neutron interference, so the sources stated in ANSI N42.17A for interfering radiation testing were used.

The results of the interfering radiation tests are listed in Tables 6.6 and 6.7.

Table 6.6. Interfering Radiation Test Results for Eberline AMS–3A–1

	AMS-3A-1 (1)	AMS-3A-1 (2)	AMS-3A-1 (3)
Neutron reference, cpm	568	589	650
300-mrem/h neutron exposure, cpm	384	694	2099
% Difference	-32%	+18%	+223%
^{239}Pu efficiency, cpm/dpm	14%	13%	14%
Gamma reference, cpm	495	704	464
100-mR/h gamma exposure, cpm	583	989	4964
% Difference	+18%	+41%	+970%

Table 6.7. Interfering Radiation Test Results for Eberline AMS–4

	AMS-4 (1)	AMS-4 (2)	AMS-4 (3)
Neutron Reference, cpm	395,000	387,000	375,000
300-mrem/h neutron exposure, cpm	399,000	393,000	386,000
% Difference	+1.0%	+1.6%	+2.9%
^{239}Pu efficiency, cpm/dpm	23%	53%	67%
Gamma reference, cpm	386,000	383,000	376,000
100-mR/h gamma exposure, cpm	403,000	395,000	344,000
% Difference	+4.4%	+3.1%	-9.3%

7.0 Interfering Responses

The criteria for interfering responses, with comparisons of requirements and results, involved performance tests in the following environments:

- specified radio frequency fields, 0.3 to 35 MHz and 140 MHz
- 60-Hz fields
- microwave fields
- electrostatic fields
- magnetic fields.

7.1 Radio Frequency Fields 0.3 to 35 MHz and 140 MHz

Requirement

ANSI N42.17B states that the mean instrument response for each detector, obtained when the instrument is exposed to a radio frequency field that is $\leq$100 V/m in intensity in the frequency range of 0.3 MHz to 35 MHz and/or at a nominal 140 MHz[a], shall not vary more than 15% from the mean instrument response obtained with no radio frequency field present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields.

The criterion from ANSI N42.18 states that the response shall vary less than 5% when exposed to radio frequency fields less than 10 μW/cm^2.

The more intense field strength from ANSI N42.17B was used for the exposures, and the acceptance criterion from ANSI N42.18 was used to determine compliance.

Because previous experience indicated that the radio frequency test could damage a microprocessor-based instrument, this test was performed on only one model each of the AMS–4 inline sample head and AMS–4 radial sample head.

(a) Approximate frequency of a portable transceiver unit.

Results

Neither the AMS–3A–1 nor the AMS–4 complied with the criteria for the 0.3 to 35 MHz fields. AMS–3A–1 (3) did not comply with the criteria at 35 MHz, the response being 28% higher than the reference reading; a decrease of 15% in response was also noted at 25 MHz. The AMS–4 displayed multiple failures at several frequencies, typically communication failures but also underresponses, overresponses, and no response.

The AMS-4 complied with the criteria for the 140 MHz field with no significant change in response during the exposure to the nominal 140-MHz radio transceiver. The AMS-3A-1 did not comply with a maximum variation of -14%. The actual transmitting frequency of the transceiver used in this test was 163 MHz.

As a result of the testing, sensitivity of the AMS–4 to radio frequency fields was identified at multiple frequencies. The sensitivity was such that the CAM could be rendered inoperable in certain fields. In addition, communications between a remote CAM and a central computer could be disrupted.

Reference readings from the AMS-4 were recorded by the computer with the radio frequency field at zero intensity. The radio frequency was then scanned, beginning at 0.3 MHz. Near 10 MHz, the computer stopped collecting data for about 2 minutes. The probable cause was a communications failure resulting from radio frequency interference. During this interval, the CAM appeared to be functioning normally. At approximately 26.7 MHz, the CAM alarmed and the display changed from the concentration to "TIME = 17:05:02" on the top line and a garbled spelling of the word "MONITORING" on the bottom line. The radio frequency field was then turned off, and the CAM's power was cycled. Scanning of the radio frequency field resumed at 8.5 MHz. The computer stopped data collection at approximately 13 MHz (probable communications failure), and the display on the CAM froze. At approximately 19 MHz, the display on the CAM began regular updating but data collection by the computer did not resume. Data collection by the computer resumed at approximately 24 MHz but stopped again at approximately 25 MHz. At approximately 25 MHz, the display on the CAM became erratic and began rapidly alternating from the "Enter Password" display (where zero to four asterisks would appear on the second line as if entered by a user), to the "Instrument Status Normal" display, to the display showing DAC-hours, to the display showing concentration. A garbled display was also observed on the CAM at approximately 26.8 MHz and the acquisition of data on the computer did not resume. The display on the CAM returned to normal above 26.8 MHz up to 35 MHz, but data collection on the computer did not resume. The radio frequency field was then turned off and the CAM's power was cycled. The radio frequency field was restored at 35 MHz and data collection on the computer resumed. However, as the radio frequency field was scanned down to 33 MHz, data collection on the computer stopped again. The CAM appeared to operate normally. Radio frequency scanning was terminated at that point and no further measurements were made until the next day.

A second set of reference readings from the CAM were recorded by the computer with the radio frequency field at zero intensity on the second day of testing. Radio frequency scanning was repeated, starting with 0.3 MHz. The computer stopped collecting data from the CAM at approximately 6.4 MHz. The CAM appeared to be operating normally. At approximately 7.8 MHz, the computer began collecting data from the CAM again. The computer stopped collecting data at approximately 11.5 MHz. Whenever the computer was observed to stop collecting data (on both the first and second day of testing), there was no indication that the computer was malfunctioning. The display on the CAM appeared to cease updating (freeze) at approximately 20 MHz. The CAM remained in this state even after the radio frequency field was removed. The CAM's power was then recycled and the radio frequency scanning was resumed at 18 MHz. A status of "Com Fail" was immediately indicated by the computer software communicating with the CAM.

7.2 60-Hz Radio Frequency Fields

Requirement

ANSI N42.17B states that the mean instrument response for each detector, obtained when the instrument is exposed to a 60-Hz radio frequency field that is ≤100 V/m in intensity, shall not vary more than 15% from the mean instrument response obtained with no radio frequency field present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not operate properly in such fields. The more restrictive acceptance criteria of ±5% from ANSI N42.18 was used to determine compliance.

Results

Both the AMS–3A–1 and the AMS–4 complied with the criteria.

Because previous experience indicated that the radio frequency test could damage a microprocessor-based instrument, this test was performed on only one AMS–4. Both the inline head and radial sample heads were tested. The results are summarized in Tables 7.1 and 7.2.

Table 7.1. Results of Testing Eberline AMS–3A–1 in 60-Hz Field

	AMS-3A-1 (1), cpm	AMS-3A-1 (2), cpm	AMS-3A-1 (3), cpm
Reference	58300	64598	10168
Exposure	57429	65306	10597
Variation from reference	-1%	+1%	+4%

Table 7.2. Results of Testing Eberline AMS–4 in 60-Hz Field

	AMS-4 (2) Inline			AMS-4 (2) Radial		
	Beta, cpm	Background, cpm	Flow, cm^3/min	Beta, cpm	Background, cpm	Flow, cfm
Reference	1.4E+5	2.2E+5	11494	1917	1818	0.31
Exposure	1.4E+5	2.2E+5	11494	1896	1911	0.31
Variation from reference	0%	0%	0%	+1.1%	+5.1%	0%

7.3 Microwave Fields

Requirement

ANSI N42.17B states that exposure to microwave fields $\leq$100 W/m^2 in intensity at 915 MHz or 2450 MHz shall not alter the mean response of the instrument to ionizing radiation by more than 15% from the mean response of the instrument obtained when no field is present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and may not operate properly in such fields. The test for this requirement may be performed on a single instrument.

ANSI N42.18 states that microwave signals of less than 10 $\mu W/cm^2$ shall not cause the instrument response to vary more than 5%.

The more intense field strength from ANSI N42.17B was used in the test, and the more restrictive acceptance criteria from ANSI N42.18 was used to determine compliance.

Results

The manufacturer's literature does not mention a sensitivity to microwave fields for either model of CAM.

The AMS-3A-1 was not tested because the instrument was physically too large to place it in the microwave exposure chamber.

The AMS-4 complied with the criteria from both ANSI N42.17B and ANSI N42.18 with a maximum change in response of 4% during the microwave exposure. Two AMS-4 CAMs were tested with radial heads and one AMS-4 was tested with an inline head. Both the sample head and the electronic chassis were in the exposure chamber during the exposure.

7.4 Electrostatic Field

Requirement

ANSI N42.17B has no criterion for CAM response to electrostatic fields. For the sake of completeness, the criterion from ANSI N42.17A was adopted and applied to the CAMs.

ANSI N42.17A states that exposure to electrostatic fields ≤5000 V/m in intensity shall not alter the mean response of the instrument to ionizing radiation by more than 15% from the mean response of the instrument obtained when no field is present. Alternatively, the manufacturer may specify in the documentation that the instrument may be sensitive to and may not properly operate in such fields. The test for this requirement may be performed on a single instrument.

Results

The Eberline AMS–3A–1 and the AMS–4 complied with the criterion. The results are given in Tables 7.3 and 7.4.

Both the radial inlet head and the inline head were tested for the AMS–4. Because of the potential to damage the AMS–4, only one AMS–4 was subjected to the electrostatic fields.

Table 7.3. Results of Electrostatic Field Test for Eberline AMS–3A–1

	AMS-3A-1 (1), cpm	AMS-3A-1 (2), cpm	AMS-3A-1 (3), cpm
Reference	58052	66259	10022
Exposure	58440	65506	10661
Variation from reference	+1%	-1%	+6%

7.5 Magnetic Field

Requirement

ANSI N42.17B states that exposure to magnetic fields ≤800 A/m (~10 Oersteds) shall not alter the mean response of the instrument by more than ±15% from the mean response of the instrument obtained when no field is present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and may not operate properly in such fields. The test for this requirement may be performed on a single instrument.

Table 7.4. Results of Electrostatic Field Test for Eberline AMS–4

	AMS-4 (2) Inline			AMS-4 (2) Radial		
	Beta, cpm	Background, cpm	Flow, cm^3/min	Beta, cpm	Background, cpm	Flow, cfm
Reference	1.4E+5	2.2E+5	11752	1818	1917	0.31
Exposure	1.4E+5	2.2E+5	11494	1888	1955	0.31
Variation from reference	+0.7%	0%	-2.2%	+3.9%	+2.0%	0%

The criterion from ANSI N42.18 simply states that the effect of magnetic fields on the instrument's accuracy shall be stated by the manufacturer.

Results

Both the AMS–3A–1 and the AMS–4 complied with the performance requirement from ANSI N42.17B. However, the literature did not state the effects of magnetic fields on either model of CAM, as required by ANSI N42.18. Nevertheless, because there was no effect (and no effect mentioned in the literature), the CAMs were considered compliant with the ANSI N42.18 criteria.

This test was not performed on the integral AMS–3A–1 because the instrument did not fit in the test chamber. The modular AMS–3A–1 was tested by first putting the electronics portion in the test volume with the sample head outside the test volume, completing the test, and then switching the components and repeating the test.

Similarly, both portions of the AMS–4 did not fit in the chamber at the same time; therefore, the magnetic field test on the AMS–4 was performed on the electronics body and the sample head separately. Both the inline head and the radial head were tested. Because the two heads use the same electronics body, each AMS–4 was tested with the electronics body in the magnetic field only once (with the inline head). During the tests of the radial inlet head, the electronics body was partially in the field. Only the responses of the beta channel and flow sensor were monitored on the AMS–4.

The results from the magnetic field testing are summarized in Tables 7.5. and 7.6.

Table 7.5. Results of Magnetic Field Test for Eberline AMS–3A–1

Axis	AMS-3A–1 (1)		AMS-3A–1 (2)		AMS-3A–1 (3)	
	Meter	Head	Meter	Head	Meter	Head
Reference, cpm	11569	13458	14923	15144	14708	14624
X-axis, cpm	10531	13056	14817	15476	15050	14169
Y-axis, cpm	11357	13112	15652	14739	14802	14861
Z-axis, cpm	11496	13183	14777	14973	14668	14676
Maximum variation from reference	-9%	-3%	+5%	-3%	+2%	-3%

Table 7.6. Results of Magnetic Field Testing for Eberline AMS–4

	AMS–4 (1)	AMS–4 (2)	AMS–4 (3)
Radial Sample Head in Magnetic Field			
Reference, cpm	5349	6810	6727
X-axis, cpm	5284	6785	6680
Y-axis, cpm	5293	6808	6715
Z-axis, cpm	5351	7024	6638
Maximum variation from reference	-1.2%	+3.2%	-1.1%
Inline Sample Head in Magnetic Field			
Reference	10626	10007	10065
X-axis, cpm	10553	9946	10082
Y-axis, cpm	10385	10015	10221
Z-axis, cpm	10475	9792	10314
Maximum variation from reference	-2.0%	-2.2%	+1.4%
Electronics Body in Magnetic Field			
Reference	6151	7843	10015
X-axis, cpm	6156	7867	9989.8
Y-axis, cpm	6113	7951	9980
Z-axis, cpm	6095	7922	10055
Maximum variation from reference	-0.7%	+1.1%	+0.7%

8.0 Environmental Criteria

The criteria for environmental conditions, comparing requirements and results, are presented in this section and include testing for the following conditions:

- temperature ranges and variations
- humidity ranges and variations
- vibrations
- ambient air pressure.

8.1 Temperature Ranges and Variations

Requirement

ANSI N42.18 states that the mean instrument response shall not vary more than 5% in the temperature range of 0° to 60°C. ANSI N42.17B states a criterion for a broader temperature range, including a requirement that the CAM response shall not vary more than 20% in the temperature range -20° to 0°C from the mean instrument response of 22°C. Instrument responses were not corrected for changes in air density because the instruments use a sealed detector. The instrument shall have the capability to withstand changes in temperature of 10°C/h. Based on the requirements, the instruments were tested over the range of -20°C to 60°C. The CAMs were considered compliant with the criteria if the response did not vary more than ±5% from the reference over the temperature range of 0°C to 60°C nor more than ±20% over the range of -20°C to 0°C.

ANSI N42.17B allows correcting the instruments' response to compensate for changes in air density, when appropriate. Because the detectors used on the AMS-3A-1 and AMS-4 are sealed, the response of the detector is independent of ambient air density. Therefore, the detector responses were not corrected. However, the volumetric flow derived from the flow sensor response on the AMS-4 is dependent on the ambient pressure and temperature. Therefore, the flow sensor readings were corrected to account for the changes in air density. The correction factor used is given in Equation 8.1:

$$\text{Correction Factor} = \frac{P_{reference} * T(°K)}{P * T(°K)_{reference}} \quad (8.1)$$

where P = ambient air pressure
$P_{reference}$ = ambient air pressure for reference instrument responses
$T(°K)$ = temperature in degrees kelvin

Results

The instruments were tested by placing them in an environmental chamber stabilized at 22°C. After an equilibrium period (at least 1 hour), reference readings were taken. The temperature was then increased at a rate of 10°C/h until the temperature in the chamber was 30°C. The chamber was again allowed to reach equilibrium (for at least 1 hour) and the instrument responses were recorded. This process was repeated for all the temperature data points of interest.

None of the AMS-3A-1 CAMs complied with the criterion. Two of the AMS–3A–1 CAMs underresponded by greater than 5% at 40°C with underresponses of greater than 40% at 50°C and 70% at 60°C. Therefore, the AMS-3A-1 does not comply with the criterion.

The flow sensor on AMS–4 (2) had a maximum deviation of +12.5% at -20°C from the reference reading. Therefore, the AMS–4 is partially compliant with the criterion because the count rate meter complied but the flow sensor response did not. The results of the temperature test are listed in Tables 8.1. and 8.2.

Table 8.1. Results of Temperature Test for Eberline AMS–3A–1

	AMS–3A–1 (1)		AMS–3A–1 (2)		AMS–3A–1 (3)	
Temperature, °C	Response, cpm	Variation from Reference	Response, cpm	Variation from Reference	Response, cpm	Variation from Reference
22	63793	Reference	16571	Reference	83499	Reference
30	63542	0%	16884	+2%	81978	-2%
40	60070	-6%	14538	-12%	80295	-4%
50	35298	-45%	7456	-55%	79494	-5%
60	16873	-74%	3772	-77%	76421	-8%
25	63966	Reference	16509	Reference	83128	Reference
13	64138	0%	17275	+5%	86266	+4%
3	64461	+1%	17928	+9%	88347	+6%
-13	63809	0%	18754	+14%	88663	+7%
-20	64411	+1%	18870	+14%	89505	+8%
24	63278	-1%	16305	-1%	83039	0%

Table 8.2. Results of Temperature Test for Eberline AMS–4

	AMS–4 (2)				AMS–4 (3)			
Temperature, °C	Beta, cpm	Background, cpm	Flow, cfm	Corrected Flow, cfm	Beta, cpm	Background, cpm	Flow, cfm	Corrected Flow, cfm
22 (reference)	645	767	0.50	0.50	583	573	0.38	0.38
30	669	782	0.49	0.51	576	574	0.37	0.38
40	669	779	0.48	0.50	560	577	0.37	0.39
50	666	795	0.46	0.50	580	557	0.37	0.40
60	661	812	0.45	0.50	591	576	0.36	0.40
20	666	789	0.48	0.48	567	557	0.38	0.38
10	666	774	0.50	0.49	581	565	0.38	0.37
0	651	758	0.51	0.49	569	547	0.39	0.37
-10	652	772	0.53	0.48	554	533	0.39	0.36
-20	673	758	0.54	0.48	571	532	0.40	0.36
Maximum variation from reference	+3.7%	+5.9%	+13%	-4%	-3.9%	-4.5%	+5.3%	-5.3%

8.2 Humidity Ranges and Variations

Requirement

ANSI N42.17B states that the mean instrument response shall not vary more than 15% over the relative humidity range of 40% to 95% relative humidity noncondensing at a temperature of 22±2°C from the mean instrument response at 40% relative humidity and ~22±2°C. The test was performed by placing the CAMs in an environmental chamber stabilized at 40% relative humidity. The CAMs were allowed to equilibrate for 4 hours and a reference reading was recorded. The relative humidity was then increased to 95%. This condition was maintained for 8 hours and the CAM responses then recorded. The relative humidity was then decreased to 40% and maintained at this level for 4 hours. After the instrument responses were recorded, the humidity was decreased to 10% relative humidity, where the CAMs again stabilized for 4 hours. The final instrument responses were then recorded.

Results

Both the AMS–3A–1 and the AMS–4 complied with the criterion. The results are summarized in Tables 8.3 and 8.4.

Table 8.3. Results of Humidity Test of Eberline AMS-3A-1

Relative Humidity	AMS-3A-1 (2), cpm	AMS-3A-1 (3), cpm
40% (reference)	8680	64969
95%	8563	66024
40%	8316	65683
10%	8530	66389
Maximum variation from reference	-4.2%	+2.2%

Table 8.4. Results of Humidity Test of Eberline AMS-4

Relative Humidity	AMS-4 (2)			AMS-4 (3)		
	Beta, cpm	Background, cpm	Flow, cfm	Beta, cpm	Background, cpm	Flow, cfm
40% (reference)	624	746	0.52	574	.542	0.38
95%[(a)]	642	770	0.51	558	570	0.37
40%	650	752	0.51	577	551	0.37
10%	639	777	0.50	576	570	0.38
Maximum variation from reference	+4.2%	+4.2%	-2.5%	-2.8%	+5.2%	-2.6%

(a) During the 8-hour exposure at 95% relative humidity, CAM responses were recorded every hour. The value reported is the maximum value observed during the test. The responses listed for 40% and 10% relative humidity are the responses recorded at the end of a 4-hour exposure to these conditions.

Only two of the AMS-3A-1 CAMs were tested to the humidity criterion, both of which complied. AMS-3A-1 (1) was damaged by the line noise transient test and was not repaired in time to include it in the humidity test.

Because of a lack of operable detectors, only two AMS-4 CAMs were subjected to the humidity test. The AMS-4 CAMs tested had the inline heads.

The maximum variation observed of a flow sensor was observed on AMS–4 (2), which had a 4% under-response at 10% relative humidity. The maximum variation of the beta and background detectors was a 5% overresponse on AMS–4 (3). Therefore, both detector responses and flow rate sensor on the AMS–4 complied with the criterion.

8.3 Vibrations

Requirement

ANSI N42.17B does not include criterion for response to mechanical vibrations. ANSI N42.18 has a criterion that the minimum vibration level (of loading) or acceleration that perturbs readings or damages components shall be specified over a frequency range of 1 to 30 Hz.

The criterion from ANSI N42.18 provides a frequency range but does not state an acceleration range or criterion for acceptable performance. Therefore, for the purposes of testing, the criterion from ANSI N42.17A was adopted.

ANSI N42.17A states that the mean instrument response shall vary not more than 15% following harmonic loadings of 2 g applied for 15 minutes in the frequency range of 10 to 33 Hz. Because the frequency range in ANSI N42.18 is broader, the test was actually performed over the range of 1 to 33 Hz.

Results

Both the AMS–3A–1 and the AMS-4 complied with the criterion.

The CAMs were vibrated along three mutually orthogonal axes (a vertical and two horizonal axes). Two AMS–3A–1 CAMs and one AMS–4 CAM were tested. The AMS-4 that was tested had an inline sample head. Both the sample head and the electronics of the AMS-3A-1 were tested at the same time. For the AMS-4, the electronics section was vibrated separately from the sample head. Instrument response information was recorded after each set of vibrations.

Physical effects were noticed on both CAMs during the vibration testing. The bells on the AMS-3A-1 CAMs became loose and eventually fell off the CAMs entirely. During the actual vibrations, the AMS-4 CAM demonstrated a flickering and/or flashing display that occasionally included garbled characters. The display function returned to normal when the vibration was stopped. In these cases, the physical effects observed did not affect the post-vibration performance of the instruments.

Another physical effect was observed that would affect the operability of the AMS-3A-1. While the AMS-3A-1s were being vibrated along the horizonal axis, the 4-20 mA signal decreased to near zero on one AMS-3A-1. The meter response continued to indicate approximately the reference value. The action pack was removed and reinstalled and the CAM functioned correctly. Throughout the test, the meter continued to respond correctly. In this case, the action pack appeared to have become loose, which would have resulted in a loss of remote signal from the instrument.

The results for the AMS-3A-1 are summarized in Table 8.5. The results for the AMS-4 are given in Table 8.6.

Table 8.5. Results of Vibration Testing for Eberline AMS-3A-1

	AMS-3A-1 (2)			AMS-3A-1 (3)		
Axis	1	2	3	1	2	3
Reference, cpm	8504	8544	8616	82698	82777	82207
Post-vibration response, cpm	8434	8317	8318	83073	82207	82909
Variation from reference	-0.8%	-3%	-3%	+0.5%	-1%	+0.9%

Table 8.6. Results of Vibration Testing for Eberline AMS-4

	Response of AMS-4 (3)		
	Beta, cpm	Background, cpm	Flow, cm^3/min
Reference	23123	30834	36824
Post-vibration (electronics)	23128	30861	36824
Post-vibration (inline head)	25198	33346	36824
Maximum variation from reference	+9%	+8%	0%

8.4 Ambient Air Pressure

Requirement

ANSI N42.17B states that the mean instrument response shall not vary more than 15% from the mean instrument response at 101 kPa over the ambient pressure range of 67 to 107 kPa. Corrections to instrument readings for air density changes were not made because the instruments do not use detectors that are open to the atmosphere (e.g., vented ion chambers or air proportional detectors).

ANSI N42.18 states that the instrument shall be capable of continuous operation under ambient pressures from 500 to 800 torr (66 kPa to 107 kPa). ANSI N42.18 includes a requirement for testing the CAMs at higher pressures (up to 333 kPa) if they are used in containment vessels. The CAMs tested in this report will not be used in containment vessels at Hanford and were not tested over the higher pressure range.

Flow sensor readings for the AMS-4 were corrected to compensate for changes in air density, as described in Section 8.1. Equation 8.1 was used to calculate the correction factor.

Results

The AMS-3A-1 did not comply with the criterion, with AMS-3A-1 (2) underresponding 51% at 525-mm Hg. AMS-3A-1 (1) also underresponded at 525-mm Hg, though only by 7.8%. The maximum variation for AMS-3A-1 (3) was a 5.8% increase at 500-mm Hg.

The response of the AMS-4 beta detector and background detector complied marginally with the criteria, but the response of the air flow sensor did not comply. Two AMS-4 CAMs were tested with inline sample heads. The third AMS-4 was not tested because it was permanently damaged during previous testing.

The AMS-4 CAMs tended to overrespond at lower pressures. AMS-4 (1) overresponded by 10% (beta detector) and 12% (background detector) at pressures of 500-mm Hg (66.6 kPa) and 563-mm Hg (75 kPa), respectively. AMS-4 (3) showed a similar overresponse, with a maximum response of 13% (beta detector) and 15% (background detector) at 500-mm Hg (66.6 kPa).

The air flow sensors responded significantly to changes in ambient air pressure. Air flow sensors on both tested AMS-4 CAMs overresponded at increased ambient pressure and underresponded at decreased ambient pressure. Maximum underreponses of -47% and -26% were observed for AMS-4 (1) and AMS-4 (3), respectively, at 500-mm Hg (66.6 kPa).

The flow rates measured during the testing were corrected for air density changes to facilitate comparison to the reference flow rates. The correction for air density compensates for the effect of air density changes on flow rate that normally accompany changes in temperature and pressure.

The data indicate that corrected flow rates for AMS-4 (3) measured at low ambient pressures exceed the reference response by as much as 22% at 500-mm Hg (66.6 kPa). Apparently, flow rates measured by the CAM at low ambient pressures are higher than would be expected based on known themodynamic relationships. This indicates that the CAM will overestimate the actual flow rate, resulting in underestimating the actual concentration of radioactive particulates.

It is significant that the sealed proportional detectors used in the AMS-4 beta CAMs did not appear damaged by the ambient pressure test.

9.0 Air Circuit Criteria

Tests of the air flow examined the instruments' air flow meter or flow rate meter accuracy and flow rate stability.

9.1 Flow or Flow Rate Meter Accuracy

Requirement

Airflow rate meters shall be accurate to within ±15% of the conventionally true flow rate values. This test was not completed on the AMS-3A-1 because the AMS–3A–1 flow rate data is not used by the CAM to make concentration calculations. Nor does the AMS–3A–1 CAM monitor the flow rate to verify that the flow rate is within tolerances.

The accuracy of the AMS-4 flow meter was tested by comparing the flow rate indicated on the front panel of the instrument to the flow rate indicated by a mass flow meter placed upstream of the sample head. Because the design of the AMS-4 radial sample head does not allow placing a mass flow meter upstream of the sample, the test was performed on only the inline head. However, both sample heads use the same flow sensor; therefore, the results for the inline head are applicable to the radial inlet head.

Results

The flow sensor was tested at three points over its operating range. At the nominal flow rate (28 lpm), the response of the AMS-4 was marginally compliant with the criterion. All three CAMs tested underresponded 13% to 25% to actual flow rates of 28 to 60 lpm.

The flow sensors were also tested at one point above the nominal flow rate and at one point below the nominal flow rate. The results are shown in Table 9.1.

Table 9.1. Flow Rate Accuracy Test Results for Eberline AMS-4

Nominal Actual Flow Rate, lpm	Percent Difference Between CAM Flow Rate and Actual Flow Rate		
	AMS-4 (1)	AMS-4 (2)	AMS-4 (3)
11	+7%	+9%	+8%
28	-15%	-14%	-13%
60	-22%	-25%	-20%

9.2 Flow Rate Stability

Requirement

According to ANSI N42.17B, the manufacturer shall state the nominal flow rate for the type of filter that is used. After the warm-up time specified by the manufacturer for the monitoring unit, the measured flow rate shall not vary more than 5% from the nominal flow rate. The flow rate shall be measured after 1, 5, 10, and 100 hours of operation.

This test was conducted only on the AMS–4. Testing of the AMS–3A–1 was not performed because it uses a rotameter. Also, the AMS–3A–1 does not use the actual flow rate in its calculations to determine if alarm set points have been exceeded.

Results

The AMS-4 complied with the criteria with a maximum variation of 3% over the first 100 hours of the test. Although the standard requires completing the test over a period of 100 hours, the test was continued for 500 hours. The maximum variation over the 500-hour test was -5%.

10.0 References

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