PNNL-11527
UC-606

Pacific Northwest National Laboratory

Operated by Battelle for the
U.S. Department of Energy

Performance Testing of Eberline Alpha 6 and Alpha 6A Continuous Air Monitors

M. L. Johnson

January 1998

Prepared for the U.S. Department of Energy
under Contract 25632A

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PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

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Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

This document was printed on recycled paper.
(9/97)

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Waste Isolation Pilot Plant
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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Eberline Alpha 6 and Alpha 6A continuous air monitors (CAMs) were tested against the performance criteria of the International Electrotechnical Commission standard 761-6, *Equipment for Continuously Monitoring Radioactivity in Gaseous Effluents, Part 6: Specific Requirements for Transuranic Aerosol Effluent Monitors,* and against ANSI N42.17B, *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation.* The performance criteria require the CAM's response to a radioactive source to remain within a tolerance while the CAM is exposed to an external influence such as temperature, electromagnetic fields, or ionizing radiations. The CAMs complied within specified tolerances with a majority of the performance specifications. The most significant problems with CAM performance were noted during exposures to external nonionizing radiation fields (radio frequency fields). At numerous frequencies, the CAMs did not respond to radioactive material in the filter holder. At other frequencies and in some orientations, the CAMs overresponded by orders of magnitude. In addition to sensitivity to external nonionizing radiation fields, the CAMs exhibited sensitivity to electrostatic discharges.

Also of significance, the four CAMs provided by the Waste Isolation Pilot Plant (WIPP) from their inventory were all different. The CAMs showed evidence of modifications (some by Eberline and some, apparently, by WIPP). These modifications make it difficult to apply the test results provided in this report to the entire pool of Eberline alpha CAMs in use at WIPP because the affect of the various modifications on CAM performance could not be determined. Though one CAM failed during the humidity test, this may not be a significant finding as high temperature/high humidity conditions are not common in the salt caves of WIPP.

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Performance Testing of
Eberline Alpha 6 and Alpha 6a Continuous Air Monitors

1.0 Introduction

Eberline Alpha 6 and Alpha 6A continuous air monitors (CAMs) are used at the Waste Isolation Pilot Plant (WIPP) to monitor for airborne transuranic material. The CAMs may be used to monitor ambient work place air or to monitor air released to the environment through stacks or vents. Their function is to alarm when the concentration of airborne transuranic material exceeds limits established for protecting the worker or the public. The CAMs are expected to perform this function reliably under a variety of environmental conditions (e.g., temperature, humidity) and external influences (e.g., magnetic fields, radio frequencies). To ensure that the CAMs function correctly in the environment at WIPP, they were tested to the performance criteria given in the International Electrotechnical Commission (IEC) standard 761-6, *Equipment for Continuously Monitoring Radioactivity in Gaseous Effluents, Part 6: Specific Requirements for Transuranic Aerosol Effluent Monitors,* and in ANSI N42.17B-1989, *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation.* In general, the CAMs experienced the most difficulty functioning correctly when exposed to radio frequency fields at frequencies frequently used at the WIPP.

1.1 Instrument Description

A total of four Eberline Alpha CAMs were tested. Two were Eberline model Alpha 6A with remote radial inlet sample collection heads which are used for workplace monitoring. The other two were Eberline model Alpha 6 with remote inline sample collection heads which are used for stack or effluent monitoring. Although there are several differences between the Alpha 6 and the Alpha 6A, the most significant is the analog-to-digital converter. The Alpha 6 model uses a flash analog-to-digital converter; the Alpha 6A uses a Wilkinson analog-to-digital converter. The display module and sample heads were calibrated as sets and, in all cases, the display module/sample head pairs were maintained for all tests. In this report, the CAMs are identified by the serial number of the readout (display) unit.

The Alpha 6 and 6A CAMs tested had gold-plated silicon diode detectors, which are less sensitive to salt corrosion than the standard silicon diode detector used with these alpha CAMs (salt corrosion is a concern at WIPP where air monitoring is performed inside salt caves). Another variation between standard Eberline Alpha 6A CAMs and those tested was that the inline sample heads tested did not have mass flow meters.

One CAM, serial number 109 with an inline sample head, failed during the humidity test, which was conducted early in the test sequence. The CAM did not resume normal operation at the end of the test. As a result, this CAM was not included in subsequent testing.

1.2 Test Protocol

In general, testing is performed to determine if an instrument's response to radioactive material will vary as a result of some external influence such as an external radio frequency field or changes in ambient temperature. To measure whether or not an instrument's response varies, it is necessary first to establish a reference response. For these tests, the reference response was obtained by placing electroplated ^{239}Pu in the filter holder; the user variable, ^{239}Pu count rate (cpm), was monitored. Data collected during testing would then indicate two things: if the detector's efficiency had changed and if the CAM's energy calibration had shifted (a shift in the energy calibration would result in the ^{239}Pu peak drifting in or out of the region of interest).

Two of the CAMs have mass flow sensors. Flow data from the mass flow meter is used by the CAM algorithm to determine if the concentration alarm set point has been exceeded. Therefore, response data from the flow sensors was also monitored to determine if the mass flow sensors were affected by the influence quantities. The CAMs were connected to a vacuum pump and a standard mass flow meter placed inline between the vacuum pump and CAM.

Most test procedures were based on IEC 761-1, *Equipment for Continuously Monitoring Radioactivity in Gaseous Effluents, Part 1: General Requirements.* For some tests, IEC 761-6 states that tests should be performed to determine the instrument's response to the influence variable without providing specific performance criteria or test conditions. For these tests, the criteria and procedures from ANSI N42.17B were adopted.

1.3 Calibration

Prior to testing the CAMs, calibration as-found data for the CAMs was recorded. The as-found data recorded was ^{239}Pu peak channel, ^{239}Pu efficiency, and flow meter response at 28 lpm (1 cfm).

The following sections describe the tests conducted: external radiation from ^{137}Cs, warm-up time for detection and measurement assembly, power supply voltage and frequency variations, power supply transients, ambient temperature, relative humidity, atmospheric pressure, electromagnetic fields of external origin, magnetic induction of external origin, and electrostatic discharge. Each section describes the criterion used for evaluation and the procedure and the results of the test.

2.0 External Radiation from ^{137}Cs

Criterion

The Alpha 6A CAM responses to variations in background gamma radiation were determined. The criterion for this test was taken from IEC 761-1, Section 26.4. The criterion states that the manufacturer shall specify the instrument's response when the detector is exposed to a 1-mrad/h gamma field. The response to a 1-mrad/h gamma field under any orientation, and for any energy photon, shall not exceed twice the value specified by the manufacturer.

Procedure

To ensure that any variations in CAM response were due to the CAM detecting photons (and not due to the CAM detecting radon progeny on the filter paper), the CAMs were operated without vacuum pumps for this test.

After allowing time for the CAMs to warm up, the ^{239}Pu count rate and total ^{239}Pu count were recorded. The CAM sample heads were then placed over a ^{137}Cs source well. The source depth in the well was adjusted to provide exposure rates of 1 mR/h, 130 mR/h, and 200 mR/h at the sample head location. These exposure rates were selected at the direction of the WIPP technical representative who indicated that the highest exposure rates in areas where CAMs may be used is 200 mR/h.

The sample heads remained in the radiation field at each exposure rate for approximately 5 minutes. At that time, the ^{239}Pu count rate and total ^{239}Pu count were again recorded. During the irradiations, the CAM display was monitored so that if counts registered in regions other than the ^{239}Pu region, they could be recorded.

Results

The Eberline Technical Manual for the Alpha 6A-1 does not specify a response to gamma backgrounds. Therefore, the results could not be compared to the manufacturer's specification.

Only three of the four CAMs were tested. One CAM with an inline sample head was damaged during prior testing and could not be included in this test.

The results for all three CAMs, for all orientations and exposure rates tested, show that none responded to gamma radiation. No counts were recorded by any of the Eberline Alpha 6A CAMs during any of the gamma irradiations.

One purpose of this test is to estimate the CAM's detection limit, which is a function of the background count rate. In the case of alpha CAMs, the background count rate does not come from photons; it comes from alpha-emitting radon progeny that accumulate on the filter paper. Therefore, a more meaningful test is to determine the radon background in the area where the CAMs will be used. The CAM detection limit is a function of other factors as well, including particle size of ^{239}Pu aerosol and collection efficiency of the sample head. Because of the number of variables involved, a discussion of the detection limit for the Alpha 6A CAM is beyond the scope of this report.

Another reason for completing this test is to identify if the CAM's performance is adversely affected by external ionizing radiation fields. The results indicate that Eberline Alpha 6 CAMs are insensitive to external gamma fields up to 200 mR/h.

3.0 Warm-up Time for Detection and Measurement Assembly

Criterion

The time required for a CAM to transition from a cold start to stable performance was measured and compared to the criteria of IEC 761-1, Section 27.2. For warming-up time, the criterion is that the instrument's response 30 minutes after it is turned on shall be within ±10% of the response after 10 hours of operation.

Procedure

To ensure that any change in instrument response was due strictly to the lapsed time since the instrument was turned on, electroplated ^{239}Pu sources were placed in the filter holders to provide a stable reference response. The vacuum connection to the sample holder was disconnected to allow the vacuum pump to be operated while the electroplated source was in the filter holder. The absence of a filter paper ensured that normal variations in radon concentrations would not bias the test results. A standard mass-flow meter was placed inline between the vacuum pumps and the CAMs to provide a reference response for the flow rate.

The CAMs were disconnected from the AC power supply for more than 12 hours. The CAMs and their pumps were then reconnected to the AC power supply and turned on. Response data (^{239}Pu count rate and flow rate) were immediately collected. Data were collected continuously for the first hour that the CAMs were in operation. The CAMs were then allowed to operate, undisturbed, for another 9 hours, when response data was again collected.

Results

All three CAMs complied with the criterion. The maximum variation observed between the average response for the first 30 minutes and the response after 10 hours was 3%. The average variation in response for all three instruments was less than 1%.

The flow sensors on the two CAMs with radial inlet sample heads showed essentially no variation in response over the 10-hour test period.

4.0 Power Supply Voltage And Frequency Variations

Criterion

The performance criterion for response to variations in the AC power supply was taken from IEC 761-6, which states that the CAM's response shall vary not more than ±10% from the reference when the voltage is varied over the range of 88% to 110% of the nominal supply voltage. Similarly, the performance criterion for response to power supply frequency fluctuations is that the CAM's response shall vary not more than ±10% when operated over the range of 57 Hz to 61 Hz.

Procedure

The test procedure was based on IEC 761-1, Section 27.4, which requires performing the test twice. The test is performed once with a radioactive source that provides a reading of approximately 20% of the maximum of the least significant decade. The second time a higher activity source is used sufficient to provide a response of approximately two-thirds of the maximum full scale reading. The sources available for use during this test provided count rates of less than 100 cpm (generally, 40 to 60 cpm) and count rates greater than 1000 cpm (generally, 3000 to 4000 cpm).

Because electroplated sources were placed in the filter holders, the vacuum supply line to the sample holder was disconnected so that vacuum pumps could be used during the test. A standard mass-flow meter placed inline between the vacuum pumps and the CAMs provided a reference response for the flow rate.

The instruments were connected to an AC power supply that had a variable voltage and frequency control. Reference readings were taken at the nominal operating voltage and frequency (120 V, 60 Hz). With the frequency maintained at 60 Hz, the voltage was adjusted to 105 V and then to 132 V (88% to 110% of the nominal operating voltage). Instrument responses at both voltages were recorded. Similarly, with the voltage held fixed at 120 V, the frequency was adjusted to 57 Hz and then to 61 Hz, and instrument responses at both frequencies were recorded.

Results

Three CAMs were included in the AC voltage and frequency test. Two of the CAMs had remote radial inlet sample heads; the third CAM had a remote inline sample head. A fourth CAM with a remote inline head was not available for testing because it was damaged during previous testing.

Two of the CAMs complied with the criterion for response to variations in the voltage of the AC power supply. The third CAM had a maximum over-response of 15% when subjected to the voltage fluctuations and when operated at low count rates (<100 cpm). The same CAM complied with the criterion when operated with a source that provided a higher count rate (i.e., >1,000 cpm).

All three CAMs complied with the criterion for response to variations in the frequency of the AC power supply.

There was no significant change in the response of the flow sensor for the voltage nor for the frequency variations.

5.0 Power Supply Transients

Criterion

The performance criterion for response to power supply transients given in IEC 761-6 is that the CAM shall withstand a short interruption in power supply of duration less than 10 ms without interruption of normal operation and without raising any alarm indications. Specific transients from IEC 761-1 are listed in Table 1. Of these, only the 10-ms transient could be generated using Battelle's equipment. The CAMs were not tested to the other transients listed. The performance of the CAM when exposed to the 10 ms, 100% of amplitude transients is not indicative of the CAM's performance to the other transients.

Table 1. Power Supply Transients from IEC 761-1

Amplitude (% of supply)	Duration
100	10 ms
200	1 ms
300	0.02 ms
500	0.005 ms
Shaded transients not included in test.	

Procedure

The test procedure given in IEC 761-1, Section 27.5, was used to perform this test. The CAMs were connected to a AC power supply transient generator. Reference readings were taken with the power supply set at 60 Hz, 120 V. Vacuum pumps were connected to the CAMs and standard mass flow meters placed inline between the pumps and the CAMs. The vacuum pumps and standard mass flow meters were on a separate power supply and were not subjected to the voltage transients. High activity (>1000 cpm) electroplated ^{239}Pu sources were placed in the CAM filter holders, and reference count rate and flow rate data was recorded. Transients of +100% and −100% of the supply voltage were introduced. The duration of each transient was 10 ms. Each transient was repeated 10 times for each CAM. Post-transient count rate and flow rate data were recorded after each set of 10 transients.

Results

The CAMs complied with the criteria. No anomalies in CAM response were noted during the transients, and no alarms were generated by the transients. The CAMs' post-transient responses varied less than 2% from the reference response recorded prior to the transients. In addition, none of the CAMs appeared to be damaged by the transients.

6.0 Ambient Temperature

Criterion

The IEC standard 761-6 provides temperature response criteria for instruments used indoors and for instruments used outdoors. The criterion for outdoor use was selected because of the environments in which the CAMs will be used at WIPP. The performance criterion for outdoor use is that the instrument's response shall vary not more than ±20% over the temperature range of -10°C to 40°C and not more than ±50% over the range of -25°C to 50°C.

Procedure

The temperature test procedure was based on IEC 761-1, Section 28.1.2. The standard states that the instrument should be placed in an environmental chamber and the temperature maintained at each of the extreme values for at least 4 hours. The response at the end of each 4-hour exposure period is compared to the reference response taken under standard test conditions. IEC 761-1 does not require controlling the humidity during the temperature test. However, the humidity was maintained at 40% to 50% RH for this test.

Low-activity, electroplated ^{239}Pu placed in the CAM filter holders provided a reference response. The CAMs with integral flow sensors (i.e., those with radial inlet sample heads) were connected to vacuum pumps to provide flow through the CAMs and a flow rate response for the CAMs. In addition to the CAM's integral flow sensor, a second flow sensor (a calibrated mass flow meter) was placed upstream of the vacuum pumps to provide a reference flow rate. Both the vacuum pumps and the standard mass flow meter were placed outside the temperature chamber so that the environment in the chamber would not influence their performance. The flow rate recorded by the CAM at each temperature was compared to the flow rate recorded by the standard mass flow meter. This ensured that any drift in the true flow rate (e.g., drift in the vacuum pump's performance) would not bias the test results.

The temperature in the environmental chamber was ramped at a rate of not more than 10°C per hour until the temperature reached the desired value. The CAMs operated at each temperature for at least 4 hours, and response data was collected at the end of each exposure period. The ^{239}Pu count rate and flow rate were recorded at 22°C, 10°C, -25°C, 40°C and 50°C. The response at each temperature was compared to the reference response at 22°C.

The CAMs with inline sample heads were tested without instrument covers. An environmentally sealed enclosure provided by WIPP was not used because the enclosure was not sealed. The temperature/humidity inside the NEMA enclosure would quickly reach equilibrium with the temperature/humidity of the environmental chamber.

There was some difficulty in maintaining the temperature of the environmental chamber at -25°C for a 4-hour period. Therefore, CAM response data was collected at -20°C.

Results

The radiological response of all four alpha CAMs complied with the criterion. The performance of one CAM (SN 109) was marginal, with an over-response of 19% at 50°C.

Of the two CAMs tested for flow meter response, one CAM complied and one CAM failed. The flow sensor on the CAM that failed displayed a flow rate of 2.55 cfm at all test points (other than the reference point at 22°C) when the true flow rate was about 2.1 cfm. This was an apparent over-response of 21%. However, during a post-test calibration, the same flow sensor indicated 2.55 cfm at all flow rates including zero air flow. This indicates that the over-response noted during the temperature test could be due to a failed flow sensor. The performance of this particular flow sensor was questionable during later testing when it appeared, at times, to function correctly and, at other times, to indicate flow rate values that were independent of the actual flow rate.

7.0 Relative Humidity

Criterion

The performance criterion for the relative humidity from IEC 761-6 is that the instrument's response when subjected to 90% RH at 30°C shall vary not more than ±10% from the instrument's response under standard test conditions.

Procedure

The test procedure in IEC 761-1, Section 28.2, states that the test may be performed at a single temperature (30°C) and a single humidity (90% RH). No guidance is provided on how long the CAM should be held in this environment. Therefore, the 4-hour exposure period used for the temperature test was used for the humidity test.

After stabilizing the CAMs for 4 hours in an environmental chamber set for standard test conditions, reference readings for each CAM were recorded. The humidity and temperature were then ramped to 30°C, 90% RH over a period of 1 hour. The CAMs were then allowed to stabilize for 4 hours at the elevated temperature and humidity. After the second stabilization period, instrument response data were again recorded.

For this test, the CAMs with radial inlet heads were operated with a vacuum pump. The vacuum pump was placed outside the environmental chamber so that heat generated by the pump would not influence the controlled environment inside the chamber. A standard mass-flow meter provided a reference flow rate and was also placed outside the environmental chamber so that it was not influenced by the elevated temperature and humidity in the chamber.

For this test, low-activity ^{239}Pu sources (selected to provide count rates of less than 100 cpm) were placed in the CAM filter holders.

Results

Three of the CAMs complied with the criterion. The fourth CAM, SN 109 with an inline sample head, was damaged during the test such that data could not be collected for that CAM. After 4 hours of exposure at 30 °C, 90% RH, the CAM display was illegible and no data could be collected over the serial port. The CAM did not recover when it was returned to standard test conditions.

The three CAMs that survived the test each had an elevated response (3% to 5% over-reference), which was an acceptable variation.

8.0 Atmospheric Pressure

Criterion

The standard IEC 761-6 does not include criteria for response to changes in atmospheric pressure other than that the parameters of the test and limits of variation shall be specified where required. Because the CAMs use silicon diode detectors, changes in atmospheric pressure are not expected to affect the performance of the instruments. However, for the sake of completeness, the pressure test was conducted. The performance criteria given in ANSI N42.17B were used as a basis for this test.

ANSI N42.17B states that the CAM's response shall vary not more than ±15% from the instrument response at 101 kPa when the ambient pressure is varied over the range of 70 to 106 kPa.

Procedure

Sources to provide a nominal count rate of less than 100 cpm were installed in the CAM filter holders and the CAMs placed in the vacuum chamber. Test protocol requires that all parameters not under test shall be maintained within standard test conditions. Among other things, this means that the temperature inside the vacuum chamber had to be maintained between 18 °C and 22 °C. Placing vacuum pumps inside the chamber would add heat loading to the chamber such that the temperature would not be maintained at standard test conditions. Placing the vacuum pumps outside the vacuum chamber would make it difficult to maintain pressure in the vacuum chamber because the pumps would be continuously removing air from the chamber. Therefore, pumps were not used and the response of the flow sensors was not recorded for this test.

The CAMs were tested over the ambient pressure range of 67 to 107 kPa, which is a wider range than stated in ANSI N42.17B. Response data was collected at the reference pressure (755 mmHg), and at 107 kPa (803 mmHg), 92 kPa (690 mmHg), 84 kPa (630 mmHg), 75 kPa (563 mmHg), and 67 kPa (503 mmHg).

Results

It was expected that slight variations, inversely proportional to the ambient pressure, would be observed due to changes in air attenuation of the alpha particles emitted from the sources. This was not the case. Of the three CAMs tested, two failed to comply with the criterion given in ANSI N42.17B: SN 118 under-responded by 17% at 67 kPa and SN 138 over-responded by 29% at 67 kPa. The third CAM, SN 119, complied with the criterion with a maximum variation of -9% at 107 kPa. At 75 kPa, the CAM performance was marginal. Two CAMs had responses that were within ±15% of the reference, and one CAM's response was 16% lower than the reference. Though data were not collected at 70 kPa, the CAM performance was marginal at 75 kPa and failed to meet the criterion at 67 kPa, which indicates that at 70 kPa the CAMs would not have complied with the criterion.

9.0 Electromagnetic Fields of External Origin

Criterion

The IEC standard 761-6 does not provide general specification for CAM responses to electromagnetic fields. Instead, it states that the range of value of the influence quantity and limits of variation should be specified if required. To ensure that the test was pertinent, it was designed to cover frequencies emitted by equipment used at the WIPP facility (Davis 1996 and Attachment A). The criterion for acceptable performance from ANSI N42.17B was adopted: that is, the response, while the instrument is under the influence of the non-ionizing field, shall not vary more than ±15% from the response of the instrument when no field is present.

The fields to which the CAMs were subjected covered the frequencies 49.8 MHz, 100 to 200 MHz, 800 to 1,000 MHz, and 2,000 to 2,500 MHz. In most cases, field intensity was maintained at 100 V/m. The test at 2,450 MHz was repeated with a field intensity of 10 mW/cm^2 (194 V/m) because this is the frequency and field strength associated with microwave fields.

Procedure

This test was performed at the Brooks Air Force Base because equipment to generate the 800 to 2,500 MHz fields was not available at Battelle. To simplify shipping the equipment offsite, ^{239}Pu sources were not used to provide a reference response. Instead, thoron lantern mantles were used. The mantles were installed between the filter holder and the detector. The lantern mantle emits alpha particles with energies greater than alpha particles emitted by ^{239}Pu. The result was that the ^{239}Pu value calculated by the alpha CAM's algorithm was not a function of strictly the detector's efficiency and the energy calibrations. To ensure that the instrument response was independent of any variables other than the condition under test (radio frequency fields), the equation used to calculate ^{239}Pu cpm was rewritten to eliminate the radon subtraction. This ensured that the recorded data was simply the gross count rate in the ^{239}Pu region. After completing the test, the ^{239}Pu count rate equation was restored to the Eberline default.

The CAMs provided with inline sample heads were not tested for responses to RF fields. Alpha CAMs equipped with inline sample heads at WIPP are rack-mounted in a NEMA enclosure. The CAMs are installed in the enclosure without their covers (i.e., the internal circuit boards are exposed). They were provided to PNNL in the same condition (i.e., without covers). A NEMA enclosure was provided by WIPP for use during testing; however, the enclosure had several unsealed orifices. Presumably, these orifices are sealed when the enclosure is used at WIPP. However, the presence of holes in the NEMA enclosure compromises any RF shielding that may be offered by the enclosure. Therefore, the CAMs with inline sample heads were not tested in the radio frequency fields. This decision was supported by telephone discussions with WIPP personnel who indicated that the CAMs installed in NEMA enclosures are not expected to be exposed to radio frequency fields.

The two CAMs with radial inlet sample heads were tested at 49.8 MHz, and over the ranges of 150 to 175 MHz, 825 to 928 MHz, and 2,400 to 2,450 MHz. These frequency ranges covered all the radio frequencies emitted by WIPP equipment (Davis 1996). In most cases, the field intensity was 100 V/m. The exposures at 2,450 MHz were repeated at 10 mW/cm^2 to simulate exposure to microwaves. The frequency ranges were covered in 5-MHz increments. Flow data and count rate data were recorded at each frequency.

As received from WIP, the CAMs had damaged cables. The cables have multiple strands of conductors, not all of which are used. The unused conductors were not soldered into the connectors and, as a result, had come loose from the connector and were exposed. The CAMs were tested with a brand-new Eberline Alpha 6A-1 cable provided by PNNL to ensure that the damaged cables (with their unshielded conductors) did not affect the test results.

Results

CAM SN 118 was extremely sensitive to radio frequency fields. At various frequencies, the CAM's response dropped to zero cpm; at other frequencies, the response increased by orders of magnitude. Of particular note is the response at 49.8 MHz, the frequency of WIPP's FM wireless microphones, which are noted as being used daily. At this frequency, the CAM response dropped to zero even when the field strength was decreased to as low as 30 V/m. In addition to sensitivity at 49.8 MHz, the CAM's response dropped to zero at several frequencies between 825 and 885. At these frequencies, the CAM had frequent "P2 FAILURE" error messages. In the range of 150 MHz to 175 MHz, the CAM either had a zero response or a response that was orders of magnitudes higher than the reference response. In addition, communication with the computer was lost at 165 MHz. The CAM's response could not be determined at this frequency.

10.0 Magnetic Induction of External Origin

Criterion

IEC 761-6 provides no general specification for responses to electromagnetic fields. It states that the range of value of the influence quantity and the limits of variation shall be specified (by the manufacturer) if required. The ANSI N42.17B performance criterion was adopted for use in this test. ANSI N42.17B states that the instrument's response to 10-gauss magnetic fields shall vary not more than ±15% from the reference response measured with no magnetic field present.

Procedure

The test procedure was derived from ANSI N42.17B. The CAMs were placed in a three-axis Helmholtz coil and subjected to 10-gauss AC and DC magnetic fields. The test was repeated for each of the three axes. Both the sample head and the electronics package were placed in the magnetic field chamber.

The CAMs with radial inlet sample heads were operated with vacuum pumps, which were placed outside the magnetic field chamber. A standard mass flow meter, also placed outside the magnetic field chamber, was used to provide a reference flow reading.

Results

Two of the CAMs had minor response variations when exposed to the magnetic fields. The third CAM, SN 118, over-responded by more than 300% when exposed to AC fields along the z-axis (vertical axis). The flow sensors of the CAMs with two radial inlets showed no variation in response when subjected to the magnetic fields.

11.0 Electrostatic Discharge

Criterion

No criterion is provided in either IEC 761-6 or ANSI N42.17B for response to electrostatic discharges. However, static discharges can affect the performance of microprocessor-based instrumentation; therefore, this test was completed at the request of the WIPP technical representative.

For the purposes of this test, the instrument's performance was considered acceptable if no spurious alarms were initiated by the static discharges and if no counts that would affect the CAM's response were registered by the MCA.

The CAMs were tested for response to electrostatic discharges over the voltage range of 2.5 kV to 20 kV. For comparison, voltages generated by some common activities are listed below:

Walking across a carpet	1,500 to 35,000 volts
Walking over untreated vinyl floor	250 to 12,000 volts
Worker at a bench	700 to 6,000 volts
Vinyl envelope used for work instructions	600 to 7,000 volts
Picking up a common plastic bag from a bench	1,200 to 20,000 volts

The electrostatic discharge test was performed with the ambient humidity at 36% RH at a temperature of 24°C. The effect of an electrostatic discharge may be intensified at lower humidities.

Procedure

An electrostatic discharge generator was used to apply static discharges of various amplitudes to multiple locations on the CAM surface. The probe used to apply the discharges has a conical tip and is intended to simulate static discharges from a human body to the test instrument through a small, metal intervening object, such as a key or a coin.

Static discharges were focussed on parts of the CAM that personnel are likely to touch (e.g., keypad, display, sample holder, and cables). Discharges were also made to other areas of the CAM. Because the speed of the probe as it approaches the test object affects the shape of the ESD pulse, the rate of approach was quasi-randomly varied to simulate a variety of pulse shapes.

The amplitude of the discharges ranged from 2.5 kV to 20 kV in 2.5-kV increments.

Results

To avoid unnecessarily damaging instruments, only one CAM was tested for response to static discharges. The CAM selected had a radial inlet sample head because the electronics portion had a cover (the CAMs with inline sample heads were provided by WIPP without covers for the electronics unit). To avoid damaging the computer used for data collection, the computer was not connected to the CAM for this test. Data was collected manually by viewing the ^{239}Pu-cpm history file.

Static discharges with amplitude as low as 5 kV applied to the remote sample head triggered the sonalert in the remote sample head. Generally, alarms were not initiated in the electronics (i.e., the instrument status did not indicate the presence of an alarm). Higher-amplitude discharges (e.g., >10 kV) to the electronics section also triggered the sonalert in the remote sample head. Again, the electronics unit did not indicate an alarm condition.

In all cases, the static discharge caused counts to register in channels 250 to 255. As these channels are well above the channels used by the CAM to monitor for alpha-emitting transuranics, spurious counts in these channels should not interfere with the CAM's operation.

Static discharges of greater than 10 kV affected the response of the flow sensor. The flow sensor's response tended to be zero when static discharges were applied to the remote sample head. The response recovered to the original value within a few seconds.

Grounding the case of the remote sample head reduced the sensitivity of the remote head to static discharges but, even when grounded, the sonalert in the remote sample head alarmed when the CAM was subjected to a static discharge (to either the sample head or the electronics unit). Grounding the sample head did not appear to make the flow sensor less sensitive to static discharges.

12.0 References

ANSI N42.17B-1989, American National Standards Institute, *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*; Approved September, 1989.

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Report Number (14) PNNL--11527

Publ. Date (11) 199801

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