DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

7 February 2006

MEMORANDUM FOR SEE DISTRIBUTION LIST

FROM: AFIOH/SDR
2350 Gillingham Drive
Brooks City-Base, TX 78253-5103

SUBJECT: Consultative Letter, IOH-SD-BR-CL-2006-0017, Minimum Air Sample Volume for the RADēCO® High Volume Air Sampler Model H-809VII

1. Introduction: The Air Force Institute for Operational Health (AFIOH), Radiation Surveillance Division (SDR), Health Physics Consulting Branch (SDRH) identified a need to address the air sample volume for radionuclides in a contingency operation. AFIOH/SDRH has received inquiries regarding the RADēCO® High Volume Air Sampler (HVAS), Model H-809VII, procured under the WMD medical first responder program. The DoD 3150.8-M, Nuclear Weapons Accident Response Procedures (NARP), February 2005 recommends a minimum air sample volume of 1,000 cubic feet (ft^3). An alternate air sample volume may be needed if the 1,000 ft^3 sample is impractical when using the RADēCO® HVAS. This letter is a follow-up to Consultative Letter, IOH-SD-BR-CL-2005-0081, Alpha Correction Factor for New Bioenvironmental Engineering Radiological Air Sampling Equipment - RADēCO® Model H-809VII written by AFIOH/SDRH which provided a conversion factor for the RADēCO® HVAS.

2. Background: The NARP recommends a minimum air sample volume of 1,000 ft^3. The Staplex®, and other high volume air samplers, can draw a sample at rates of 50-70 cubic feet per minute (cfm) depending on the filter type. The RADēCO® HVAS has a maximum flow rate of 30 cfm. The manufacturer recommends an optimum flow rate of 20 cfm when using the 4" diameter LB5211 filter paper and a maximum run time of 1.5 hours for the air sampler. The lower flow rate with the RADēCO® HVAS greatly increases the sample time based on the following equation:

$$\underline{V = AFR \times t}$$

Where:
- V = Sample volume in units of ft^3 or liters
- AFR = Average flow rate in units of lpm or cfm
- t = Time in minutes

$$\textit{Example: } \underline{1000\,ft^3 = 20 cfm \times 50 \min}$$

3. Findings: If time or dust-loading constraints do not allow the collection of 1000 ft^3, an air sample volume of 100 ft^3 can be substituted for the RADēCO® air sampler to meet analytical

requirements for the AFIOH Radioanalytical Laboratory (AFIOH/SDRR). The volume of 100 ft^3 is based on the minimum detectable activity (MDA) by AFIOH/SDRR with the criteria that the

MDA represents 10% of the derived airborne concentration (DAC) for ^{239}Pu. ^{239}Pu is used in this calculation as it is the limiting radionuclide for most potential AF incidents, which allows this minimum sample volume to apply to all Broken Arrow events. An air sample volume of 100 ft^3 also enables a technician to measure a minimum concentration of 10 DAC using field counting instruments, such as the ADM-300 AP-100 probe with ratemeter. Refer to appendix A for calculations specific to laboratory and field counting. Also, appendix A provides a discussion on derived air concentration and minimum detectable activity.

4. Conclusion:

a. Collect a 1000 ft^3 air sample per the NARP when a longer sample time can be accommodated. If sampling time is limited or dust loading is a problem, a minimum sample volume of 100 ft^3 can be used to quantify airborne contamination from a nuclear weapon accident when using RADēCO® HVAS.

b. Although the calculated minimum air sample volume for the air sampler is a conservative 28 ft^3, a sample volume of 100 ft^3 has better sensitivity for counting samples. This sample volume applies to alpha and beta emitting radionuclides as the calculation for the minimum air sample volume necessary to detect ^{239}Pu is most conservative. The sample collection time must be calculated by the bioenvironmental engineer depending on the desired flow rate and collection volume. When using equipment or sample media other than those described in this letter, consult the equation listed in appendix B and make appropriate changes to the parameters.

c. It is important to note that after counting air samples in the field, the appropriate correction factor for converting counts per minute per cubic foot (cpm/ft^3) to disintegrations per minute per cubic meter (dpm/m^3) should be applied as shown in appendix B of this letter.

d. Collection of 100 ft^3 air samples with the RADēCO® HVAS will also meet the requirements specified in the NARP to determine if respiratory protection (100 dpm/m^3) is required when sampling media is analyzed using the ADM-300 with AP-100 alpha detector.

e. The 100 ft^3 sample volume is also applicable to air sampling in response to a radiological dispersal device (RDD) event.

5. If you have questions concerning this report, please contact Capt Krystyn Clark at DSN 240-4297 or krystyn.clark@brooks.af.mil or the ESOH Service Center at 1-888-232-ESOH.

//signed//

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Attachments:
1. Appendix A: Sample Volume for Counting Air Samples in: (1) the SDR Radioanalytical Laboratory and (2) the Field using ADM-300 with AP-100 detector.
2. Appendix B: CPM to DPM Correction Factor

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Appendix A: Sample Volume for Counting Air Samples in: (1) the SDR Radioanalytical Laboratory and (2) the Field using ADM-300 with AP-100 detector.

When collecting an air sample with the intent of measuring the concentration of airborne radioactivity, the following principle applies: radiation detection instrumentation is able to detect smaller concentrations of airborne radioactivity as the air sample volume increases. The recommended air sample volume of $100 ft^3$ is considered a minimum. If field conditions allow, larger sample volumes should be collected.

Radioanalytical Laboratory

Due to variations in instrument response, instrument efficiency, and variations in background radiation, uncertainty is inherent to the process of measuring low levels of radiation. The minimal detectable activity (MDA) is the smallest quantity of activity above background at which an instrument can detect a nuclide with a 95% confidence. The MDA is calculated as follows per NUREG 1400:

$$\text{MDA} = \frac{2.71 + 3.29\sqrt{R_b T_b (1 + T_s / T_b)}}{T_s \times E_c}$$

Where: R_b = AFIOH/SDRR background count rate (alpha = 0.08 cpm; beta = 1.1 cpm)
T_s = Sample count time (100 min)
T_b = Background count time (100 min)
E_c = Efficiency of counting instrument (0.3)

$$\text{MDA} = \frac{2.71 + 3.29\sqrt{(0.08 cpm)(100\,\text{min})(1 + 100\,\text{min}/100\,\text{min})}}{100\,\text{min}(0.3)} = 0.529 \text{ dpm alpha}$$

Convert from dpm to µCi

$$0.529 dpm \times \frac{1 \mu Ci}{2.22E6 dpm} = 2.38E - 7 \mu Ci$$

In the laboratory, AFIOH/SDRR is able to detect an activity of 2.38E-7 µCi with a 95% confidence. The minimum sample volume is based on the Derived Air Concentration (DAC) for ^{239}Pu from 10 CFR 20, Appendix B. One DAC is the concentration of a given radionuclide in air which, if breathed by reference man for one hour, would result in a committed effective dose of 2.5 millirem (10 CFR 20.1003). The DAC for ^{239}Pu is 3E-12 µCi/ml. To be conservative, 1/10 of a DAC (3E-13 µCi/ml) was used to calculate the sample volume by solving for 'X' in the following equation:

$$0.1 DAC = \frac{3E - 13 \mu Ci}{ml} = \frac{2.38E - 7 \mu Ci}{X ml}$$

Solve for X to calculate the volume needed to detect 0.1 DAC

Minimum sample volume = 7.93E5 ml

Convert sample volume from ml to ft^3 ($1\ ft^3 = 28{,}317$ ml):

$$\text{Minimum sample volume} = (7.93E5 \text{ ml}) \times (1ft^3/28{,}317 \text{ ml}) = 28.0 \text{ ft}^3$$

<u>Field counting using the ADM-300 with the AP-100 (alpha) detectors</u>

Using the same equation from NUREG 1400:

$$\text{MDA} = \frac{2.71 + 3.29\sqrt{R_b T_b (1 + T_s / T_b)}}{T_s \times E_c \times F \times E_f}$$

Where:
- R_b = Background count rate (alpha = 1 cpm)
- T_s = Sample count time (1 min)
- T_b = Background count time (1 min)
- E_c = Efficiency of counting instrument (0.17 4π geometry)
- F = Alpha absorption factor of 0.5 (Consultative Letter, IOH-SD-BR-CL-2005-0081, Alpha Correction Factor for New Bioenvironmental Engineering Radiological Air Sampling Equipment - RADēCO® Model H-809VII)
- E_f = Collection efficiency of filter used (95% or better use 1) (Consultative Letter, IOH-SD-BR-CL-2005-0081)

$$\text{MDA} = \frac{2.71 + 3.29\sqrt{(1\,cpm)(1\min)(1 + 1\min/1\min)}}{(1\min)(0.17)(0.5)(1)} = 86.6 \text{ dpm alpha}$$

Convert from dpm to μCi

$$86.6\,dpm \times \frac{1\,\mu Ci}{2.22E6\,dpm} = 3.9E - 5\,\mu Ci$$

Finally, the minimum sample volume is based on the DAC for Pu-239 from 10 CFR 20, Appendix B. The DAC for Pu-239 is 3E-12 μCi/ml. Ten DAC is used for field conditions (3E-11 μCi/ml). A one hour exposure in a 10 DAC environment will result in a committed effective dose of 25.0 mrem. To calculate the MDA by solving for X in the following equation:

$$10\ DAC = \frac{3E - 11\,\mu Ci}{ml} = \frac{3.9E - 5\,\mu Ci}{X\ ml}$$

Solve for X to get volume needed to equal 10 DAC
X = 1.3E6 ml

Convert sample volume from ml to ft^3 ($1\ ft^3 = 28{,}317$ ml):

$$1.3E6\text{ml x } 1ft^3/28{,}317\text{ml} = 45.9 \text{ ft}^3$$

Although a minimum air sample volume of 46 ft^3 is sufficient, a minimum air sample volume of 100 ft^3 provides better sensitivity for counting samples. It should also be noted that this minimum air sample volume (46 ft^3) is sufficient to measure an airborne alpha activity concentration of 100 dpm/m^3, which is the trigger level for recommending respiratory protection in the field per Table AP11.T1 in the NARP.

Appendix B: CPM to DPM Correction Factor

The equation for converting cpm to dpm for alpha is referenced in AFIOH consultative letter IOH-SD-BR-CL-2005-0081. The beta values are inserted when they are different from the alpha values.

$$\frac{dpm}{m^3} = \frac{cpm \times A_f}{0.5 \times m^3 \times F \times E_f \times E_c \times A_c}$$

Where:

- cpm = Alpha or beta meter reading on air filter in counts per minute
- 0.5 = Constant used to correct detector 2 π efficiency to a 4 π efficiency
- A_f/A_c = Alpha only: area of filter used (approximately 62 cm^2 [4" diameter reduced to a 3.5" diameter in the filter holder])/ Area of filter actually counted by the instrument (same units as A_f) = 1 (Note: When the filter paper is smaller than the detector, no correction is necessary, therefore, A_f/A_c = 1.)
- A_f = Beta only: area of filter used (approximately 62 cm^2 [4" diameter reduced to a 3.5" diameter in the filter holder])
- A_c = Beta only: area of filter actually counted by the detector (same units as A_f) = 15.5 cm^2 for the BP-100 (Note: For the BP-100, A_f/A_c = 62/15.5 = 4.)
- m^3 = Total volume of sampled air in cubic meters (conversion 1 m^3 = 35.3 ft^3 =1000 liters)
- F = Alpha or beta absorption factor for filter used (approximately 0.5 for alpha particles and 0.1 for beta particles, based on conservative estimate with a maximum energy of 300 kev)
- E_f = Collection efficiency of filter used (0.95 per manufacturer) (Note: If the collection efficiency of the filter is > 95%, E_f = 1 per NUREG 1400.)
- E_c = Efficiency of counting instrument (2 π efficiency for the detector, use a conservative value of 0.3 for the AP-100 or BP-100)

Substituting the new values for the RADēCO® Type LB-5211, Model 0750-49 4" diameter filter paper into the equation, the assessed air concentration for alpha becomes:

Alpha:

CF to Becquerel

$$\frac{Bq}{m^3} = 10 \times \frac{cpm}{ft^3}$$

or

CF to dpm/m^3

$$\frac{dpm}{m^3} = 500 \times \frac{cpm}{ft^3}$$

Beta:

CF to Becquerel

$$\frac{Bq}{m^3} = 200 \times \frac{cpm}{ft^3}$$

or

CF to dpm/m^3

$$\frac{dpm}{m^3} = 10{,}000 \times \frac{cpm}{ft^3}$$

Where:

- cpm = Beta meter reading on air filter in counts per minute
- ft^3 = Total volume of sampled air in cubic feet (35.3ft^3=1m^3)