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# A CASE STUDY ON DETERMINING AIR MONITORING REQUIREMENTS IN A RADIOACTIVE MATERIALS HANDLING AREA

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## Abstract

A technical, defensible basis for the number and placement of air sampling instruments in a radioactive materials handling facility was developed. Historical air sampling data, process and physicochemical knowledge, qualitative smoke dispersion studies with video documentation, and quantitative trace gas dispersion studies were used to develop a strategy for number and placement of air samplers. These approaches can be used in other facilities to provide a basis for operational decisions. The requirements for retrospective sampling, personal sampling, and real-time monitoring are included. Other relevant operational decisions include selecting the numbers, placement, and appropriate sampling rates for instruments, identifying areas of stagnation or recirculation, and determining the adequacy and efficiency of any sampling transport lines. Justification is presented for using a graded approach to characterizing the workplace and determining air sampling and monitoring needs.

## Introduction

Health protection professionals are frequently called upon to evaluate the adequacy of programs for monitoring airborne radionuclides in the workplace. A number of general approaches are typically used, but there are no definitive procedures or check lists for doing such an evaluation. In this paper, we summarize the methods we used to establish a technical basis for the appropriate number and placement of air sampling and monitoring instruments in a hot cell facility at Sandia National Laboratories (SNL). We offer this information as an option for use in other U.S. Department of Energy (DOE) facilities.

## Approach

Our approach involved a series of activities:

- Reviewing current regulatory requirements for retrospective sampling, real-time monitoring, and personal sampling for airborne radionuclides within DOE facilities.

- Reviewing historical air sampling data for the facility to determine the location and frequency of releases in the past.

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- Combining historical information with current process and physicochemical knowledge to estimate the likely location and frequency of releases in the future.

- Developing a general understanding of the type of sampling and monitoring that would be needed.

- Using standard anemometry methods to measure inlet and exhaust flows to each room, and to estimate the average air change rates in the work areas.

- Using standard smoke dispersion studies to provide qualitative information on the directions of air flow from the likely release points in the work areas, and to confirm that there were no major areas of stagnation or recirculation.

- Including video tape documentation of the smoke studies to provide a record for subsequent evaluation, and to provide a record for use in later audits of the program.

- Using the qualitative smoke study information to select an array of potential locations for sampling and monitoring instruments.

- Determining whether any past sampling locations should be included in the evaluation for continuity with historical sampling records.

- Evaluating potential sampling locations based on accessibility and mechanical stability, avoidance of work obstruction, and minimization of any requirements for sample transport lines.

- Using highly sensitive tracer gas dispersion tests to compare air concentrations as a function of time at each of the likely release points with air concentrations at the potential sampling locations.

- Selecting a set of sampling locations that provide adequate coverage for the potential release locations.

- Including some considerations for redundancy, and providing for appropriate use of portable instrumentation or personal sampling for special activities.

- Balancing the air monitoring program with adequate worker training and awareness, well-designed and functioning engineered controls, adequate procedures and work practices, and prudent use of other early-warning indicators such as surface swiping and hand and foot monitoring.

For operations involving large particle sizes such as particles produced from grinding or coarse particle handling, it would be prudent to include tests for gravitational settling of particles. These tests might involve controlled releases of tracer particles whose aerodynamic diameters are larger than 5 $\mu$m. The current study included only smoke and tracer gas releases because process knowledge indicated that particle sizes were likely to be predominately less than 5 $\mu$m aerodynamic diameter. Selected information and highlights from the evaluation are included below.

Criteria for Air Monitoring Requirements

Criteria for monitoring airborne radionuclides in DOE facilities are listed in several sources including the DOE Radiological Control Manual (DOE/EH-0256T), and in the DOE order and the federal rule on Radiological Protection for Occupational Workers (DOE Order 5480.11 and Title 10 of the Code of Federal Regulation Part 835). We have summarized the basic requirements in Figure 1. The different air sampling and monitoring requirements are based on both historical measurements and on the future likelihood of airborne releases.

We consider **air sampling** to involve retrospective or fixed air samplers (FASs) or personnel samplers that collect an air sample for subsequent off-line analyses by a variety of analytical techniques. Some of these techniques include simple radioactive counting of filter samples, alpha spectroscopy of filter samples, and radiochemical analyses. These analyses can include simple chemical separations or complex, low-level analyses involving alpha spectroscopy.

We consider **air monitoring** to involve continuous air monitoring systems (CAMs) that determine airborne radionuclide concentrations in real time and provide an alarm at preset airborne concentrations. Both alpha and beta CAMs are examples of monitoring instruments that can be used in the workplace and in effluent gaseous stream monitoring applications.

Strategy for Establishing an Air Sampling Program

Figure 2 shows a strategy to decide location and numbers of air samplers and air monitors. The strategy assumes that there are three levels of consequences for releases. First, consider activities that have high consequences. Second, consider activities that have low consequences. Third, consider activities that have very low consequences. Next, consider whether the activities can be classified as infrequent or frequent. These analyses identify six possible combinations as shown in the boxes in Figure 2. Inside each box is a suggested air sampling strategy ranging from FASs for infrequent work with little potential consequence for a release to frequent work with a high potential consequence for release requiring a portable CAM at the work station. These types of analyses can guide the placement of air sampling or air monitoring instruments in the workplace.

Table 2 shows other factors that an operational health physicist should consider when making decisions concerning an air sampling program in the workplace. Because of the sensitivity requirements for plutonium, the need for networking alpha CAMs has become more critical. The health protection professional must be able to examine on-line alpha spectra from an alarming monitor to determine if the alarm is really due to low levels of airborne plutonium or is due to false alarms from 110 volt power surges or other types of false alarms. Also included in Table 2 are several important considerations ranging from vacuum sources to FASs.

The Sandia National Laboratories Hot Cell Facility

A floor plan of the Sandia National Laboratory (SNL) underground Hot Cell Facility (HCF) is shown in Figure 3. The figure includes the original locations of CAMs in the HCF, and release points for the smoke visualization tests.

Radionuclides of Interest

The HCF handles short-term irradiated nuclear fuel (enriched $^{235}U$) where the alpha-emitting radionuclide of concern is $^{234}U$. If the $^{235}U$ is enriched above 93%, even though the mass fraction of $^{234}U$ is only about 1%, more than 99% of the alpha-emitting radioactivity will come from $^{234}U$. Table 1 lists the DACs for several radionuclides of concern within the SNL Hot Cell Facility. The Class Y form of enriched $^{234}U$ is the most restrictive chemical form, and its DAC is $2 \times 10^{-11}$ $\mu$Ci/mL. Thus, 1 DAC for the Class Y form of $^{234}U$ is equivalent to 44.4 dpm/m$^3$, an order of magnitude higher than the DAC for $^{239}Pu$, 4.44 dpm/m$^3$. This required sensitivity must be achieved in the presence of naturally occurring, alpha-emitting radon progeny, $^{218}Po$ and $^{214}Po$, that can range from about 400 to 130,000 dpm/m$^3$, (0.1 to 30 pCi/L). Although the required sensitivity is not easy to demonstrate, there are no technical reasons that this sensitivity cannot be achieved with the new generation of alpha CAMs.

There is also concern for beta-emitting radionuclides in the Hot Cell Facility. For health protection concerns for beta-emitters, the limiting radionuclide is Class Y $^{90}Sr$-$^{90}Y$ and has a DAC of $2.0 \times 10^{-9}$ $\mu$Ci/mL. The $^{90}Sr$ DAC is 8.75 times more restrictive than the DAC for $^{137}Cs$-$^{137}Ba$. Electroplated sources of either $^{137}Cs$ or $^{90}Sr$ are typically used for field calibrations. One can use an electroplated $^{137}Cs$ source if the relative counting efficiencies are known for both $^{90}Sr$ and $^{137}Cs$ and the alarm setpoint on the CAM is set for $^{90}Sr$-$^{90}Y$.

Review of Historical Data

Air sampling data, collected from alpha and beta CAMs in the underground HCF from April

1983 through December 1990, were entered into a spread sheet (Plan Perfect, WordPerfect Corp., Orem, UT), and the DAC values were calculated for $^{234}U$ and $^{90}Sr$-$^{90}Y$.

Results of calculating the DACs for $^{234}U$ and $^{90}Sr$-$^{90}Y$ suggested that at no time during the periods considered, did the concentration exceed 0.02 DAC for either $^{234}U$ or $^{90}Sr$-$^{90}Y$. A strict interpretation of the results of these calculations suggests that only retrospective air sampling is required. However, we did not advise SNL to remove CAMs from the HCF because (1) conservative health physics practices would require a combination of retrospective air samples and alpha and beta CAMs because of process knowledge and inventories of radionuclides; and (2) the existence of technically defensible, conservative, health physics approaches reassures SNL staff about their protection and serves to demonstrate to oversight and regulatory groups that SNL has more than adequate health protection programs.

## Ventilation Studies

### Air Flow Measurements

The ventilation study consisted of three different parts. The first part of the study, conducted by a SNL contractor, consisted of air volume measurements at all ventilation registers (inlet and outlet) throughout the Hot Cell Facility. Results of these studies were summarized in a report by the contractor and were used to guide subsequent studies.

### Visible Smoke Releases

The second part of the ventilation study was a visible smoke release campaign conducted by SNL and ITRI personnel. The purpose of these studies was to visualize air currents in the HCF. Visualization and videotaping of the movement of the smoke cloud provide a permanent record of the study. Visualization also addresses the concern that dead air cells or areas of slow clearance could exist in the HCF. Figure 3 shows a partial floor plan of the HCF and the locations where smoke was released. Smoke release points are indicated by circles with letters A through L. These points also correspond to potential airborne release points for fugitive emissions of radioactive aerosols.

Visible smoke releases and videotaping of the smoke dispersion studies indicated that the air flow patterns in the HCF were adequate to disperse the smoke within a few minutes. Only insignificant volumes of smoke suggested recirculation cells or dead air volumes. The smoke release studies suggested that CAMs and FASs placed in the general work areas of the HCF would provide a satisfactory time-to-alarm in most areas. A single air sampler or air monitor placed near the main exhaust register would provide the quickest response for all scenarios for potential airborne releases of radionuclides.

Tracer Gas Dispersion Studies

The third part of the study was determination of the ventilation characteristics of the HCF by a $SF_6$ tracer gas release study. Tracer gas ventilation studies with $SF_6$ has become an accepted method for characterizing ventilation within the buildings. In fact, ASTM Standard E-741 has been promulgated to provide a standard method for measuring air-leakage (ventilation) rates within structures. This technology was used at the HCF by personnel from SNL/Industrial Hygiene and ITRI. Studies were conducted to measure the clearance of $SF_6$ tracer gas from room air. A small volume (2-10 mL) of pure $SF_6$ gas was released at the locations shown in Figure 4. At various times post release, 10 mL syringe samples of the atmosphere were taken simultaneously at the locations also shown in Figure 4. Syringes were capped and taken to the election capture gas chromatograph (Lagus Applied Technology, Inc., Model 215BGC, San Diego, CA), and analyzed by injecting the air sample into the instrument. Figure 5 shows the locations of $SF_6$ releases and concentration measurements in the Glove Box Laboratory.

Results of the dilution and dispersion of gaseous $SF_6$ concentration measurements were displayed on a strip chart recorder. These data are plotted on the graphs shown in Figures 6 and 7. These results and other graphs not included here demonstrated that the number of CAMs in the HCF can be reduced without loss of coverage.

Recommendations

We determined that the total number of alpha CAMs in the SNL HCF could be reduced. Based on the air flow studies, visible smoke releases, and $SF_6$ dispersion studies, any release in the rooms would be detected by a CAM located in a downstream area of any potential release within 10 min. Therefore, we recommended that alpha and beta CAMs be placed at the locations shown in Figure 8.

We also recommend use of portable CAM stations consisting of an alpha and a beta CAM. The movable CAM stations would normally be deployed as shown in Figure 8 to satisfy a desire for a level of redundancy in CAM stations. During higher risk operations, the remotely locatable alpha and beta sampling heads could be strategically placed to monitor these higher risk operations. We also recommended that the portable CAM systems be equipped with remotely locatable sampling heads to reduce contamination of the more expensive electronic packages if airborne releases of radionuclides occurs.

The total **minimum** number of alpha CAMs was, therefore, reduced from 10 to three, plus three alpha CAMs on each of three portable sampling stations. The total **minimum** number of beta CAMs remained at three plus one beta CAM on each of three portable sampling stations. Placement and number of FASs in the future will be based on operational experience and will depend, in part, on the vacuum pump capacity.

## Conclusions

Air sampling programs that include CAMs and FASs are part of a comprehensive health physics protection program. The first line of defense against airborne radioactivity should be: (1) a well-trained staff; (2) engineered controls such as containment structures, glove boxes, and "hot cell facilities" that can incorporate shielding and remote handling devices; (3) written operating procedures and guidelines that control actions for personnel handling radioactive materials; and (4) an air sampling program including the use of CAMs and FASs. In addition, surface surveys for workplace contamination such as swipe surveys are very important. All of these considerations apply when developing a defendable air monitoring program for a nuclear facility.

The approach we have described in this paper could be used for any facility that must establish a defendable air sampling program for health protection purposes.

## Acknowledgments

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U.S. DOE, *Radiological Control Manual*, DOE/EH-0256T, N5480.6, U.S. Department of Energy, Washington, DC, 1992.

U.S. DOE, *Radiation Protection for Occupational Workers*, Order 5480.11, U.S. Department of Energy, Washington, DC, 1988.

10 CFR 835, *Radiation Protection for Occupational Workers*, Title 10, Code of Federal Regulation, Part 835, Washington, DC, draft December 9, 1991.

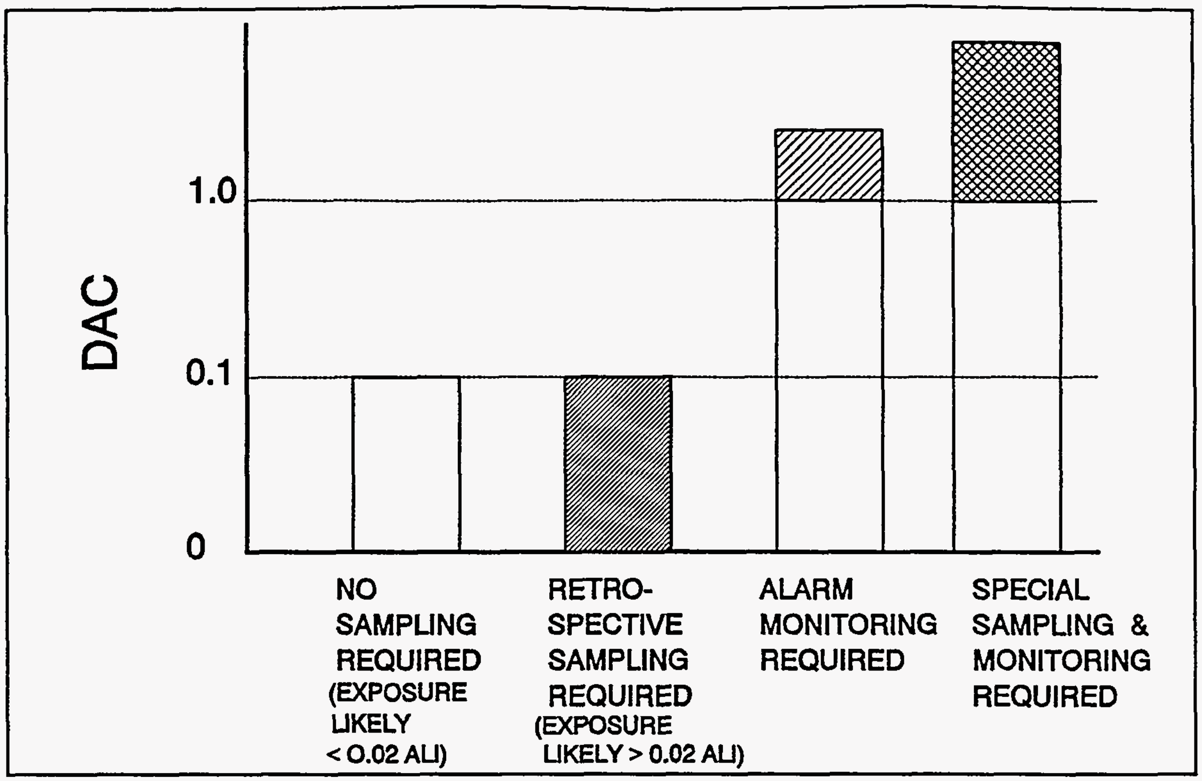


**Figure 1:** Requirements for air monitoring as a function of DAC v.s. action levels defined in the DOE RadCon Manual based on historical air sampling data.

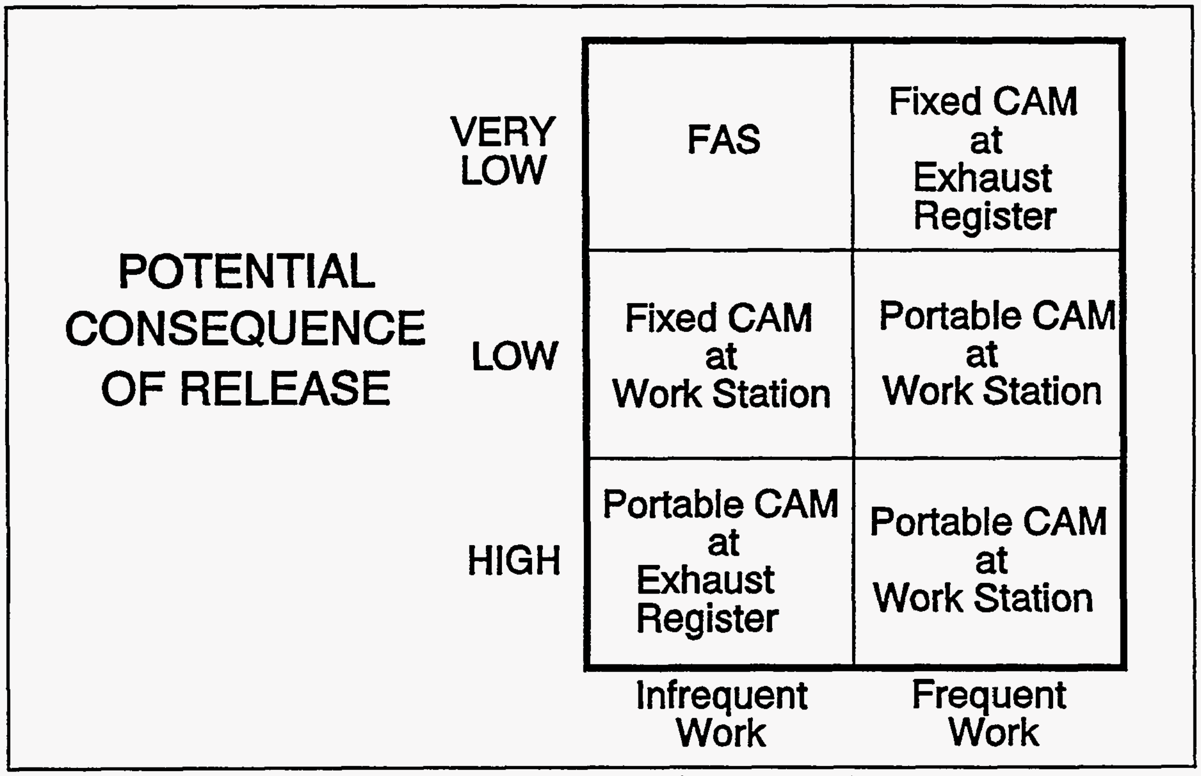


**Figure 2:** Strategy for placement of air samplers in the workplace.

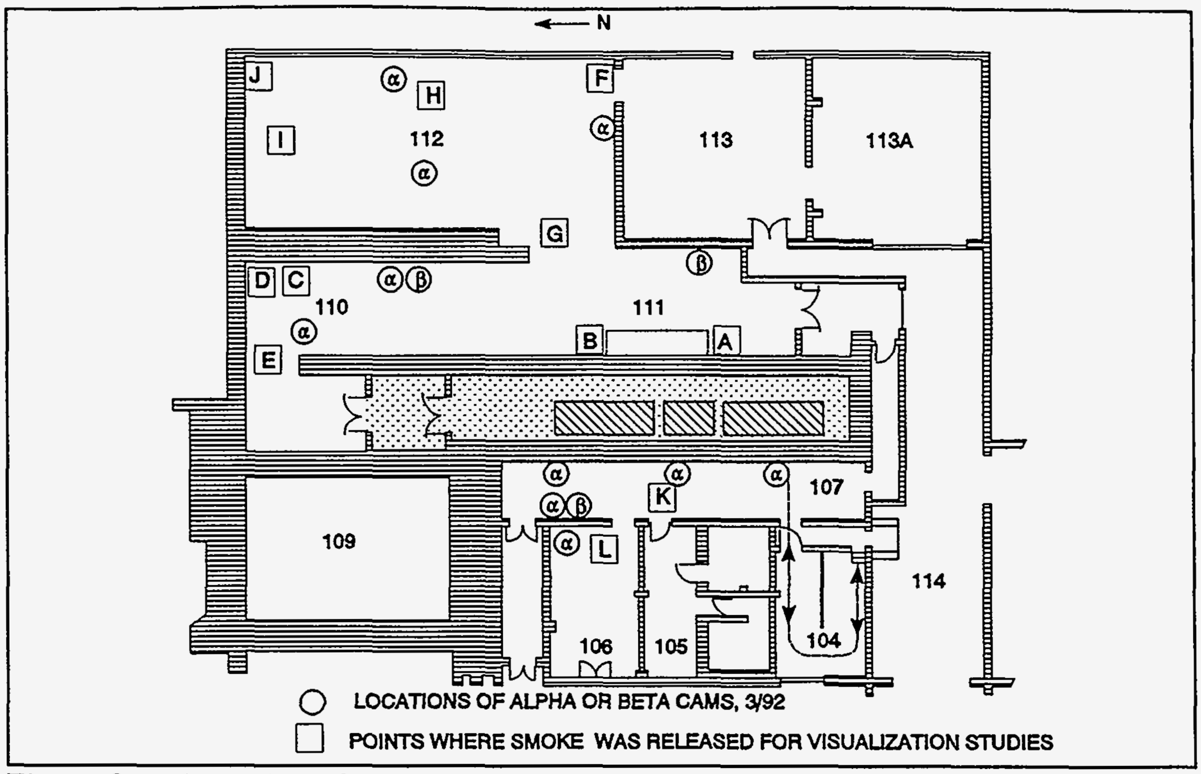


**Figure 3**: Floor plan of the underground HCF in the SNL Technical Area V showing laboratories, locations (3/92) of alpha and beta CAMs, and smoke release points for the visualization studies.

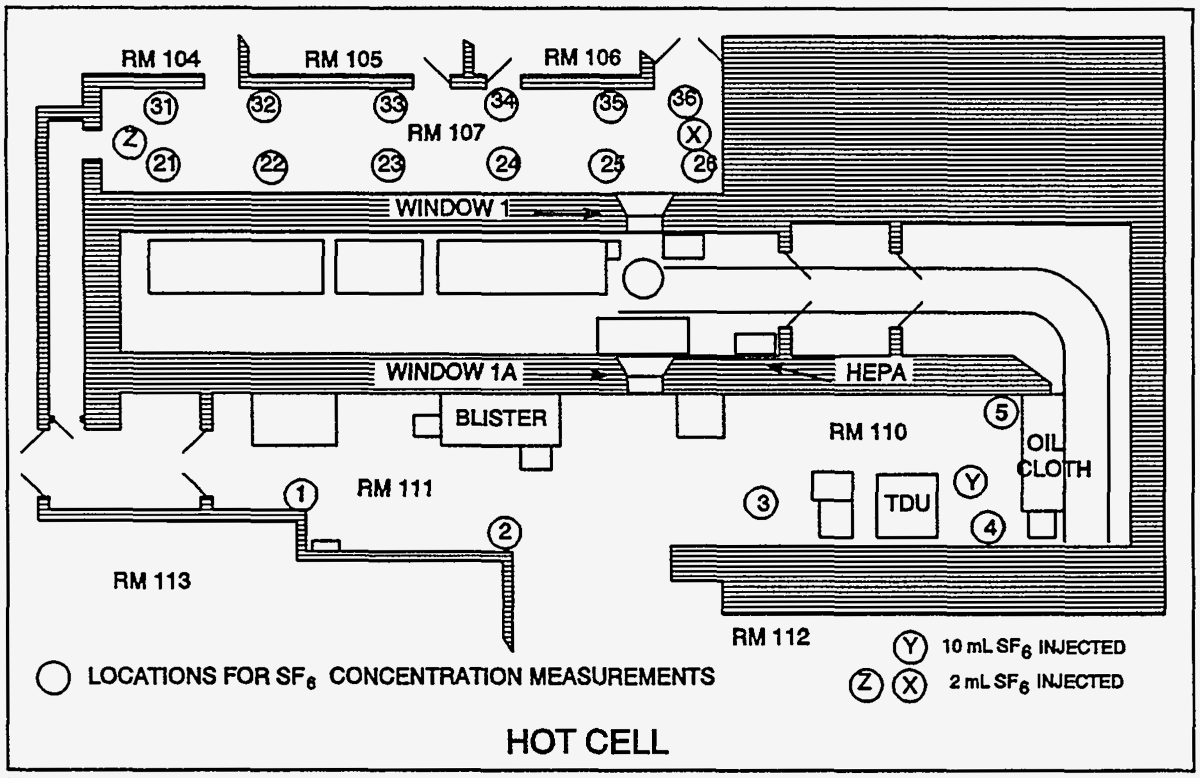


**Figure 4**: Floor plan of the SNL HCF. $SF_6$ was released at the locations denoted by circumscribed letters T-Z. Air samples were obtained at the locations denoted by the circumscribed numbers.

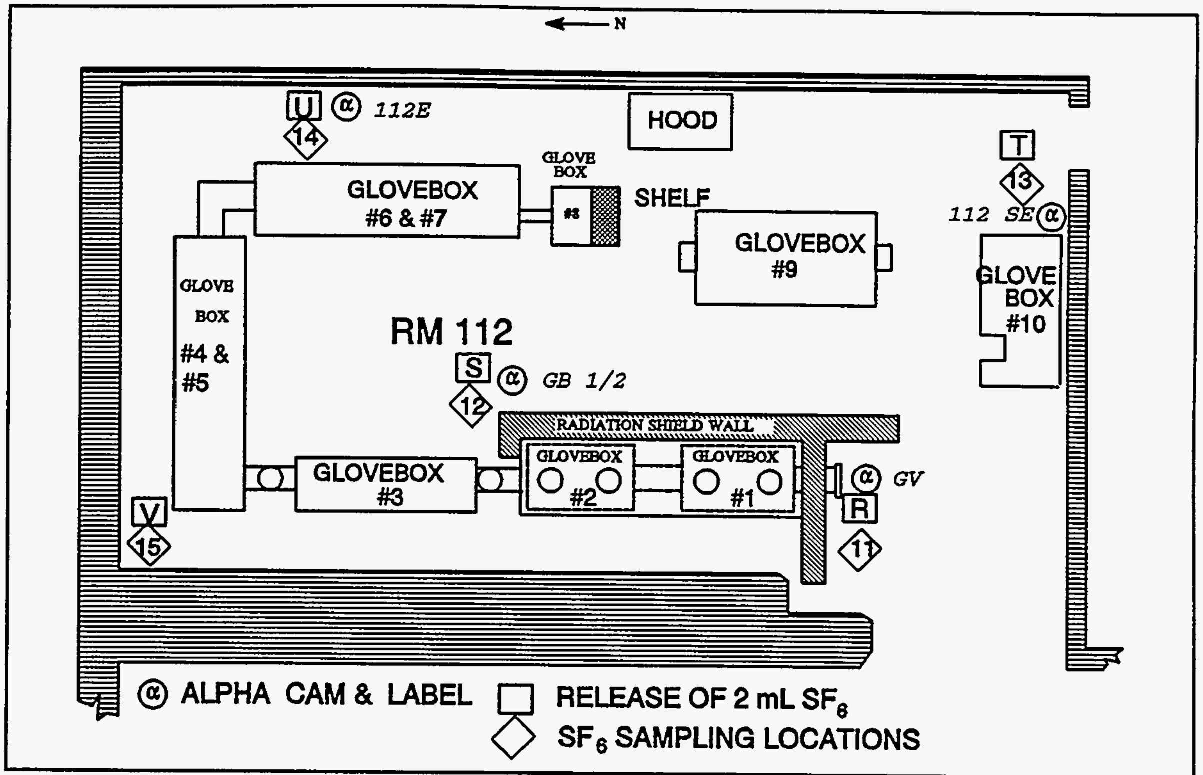


**Figure 5:** Floor plan of Rm. 112 showing original locations of CAMs, release points for $SF_6$ (R-V in a square, and air sampling locations (numbers 11-15).

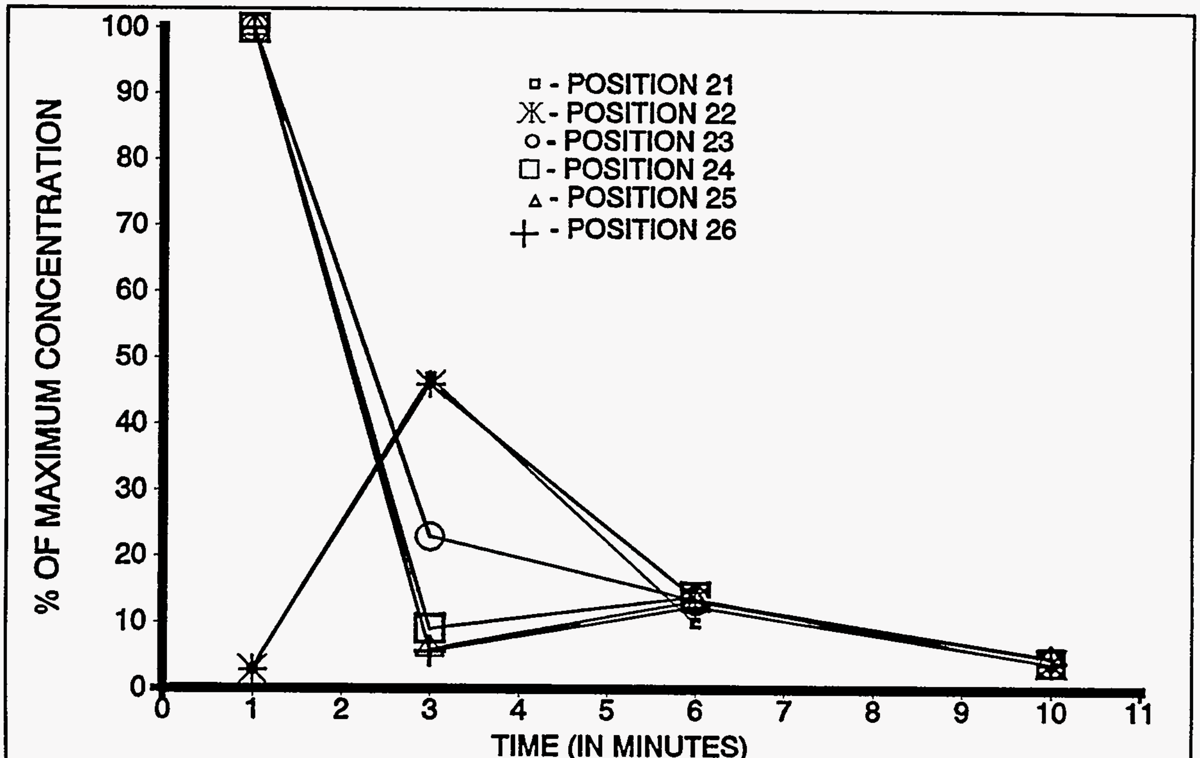


**Figure 6:** Concentration of $SF_6$ gas in Rms. 110-111 as a function of time and position after release of $SF_6$. Positions are shown in Figure 4.

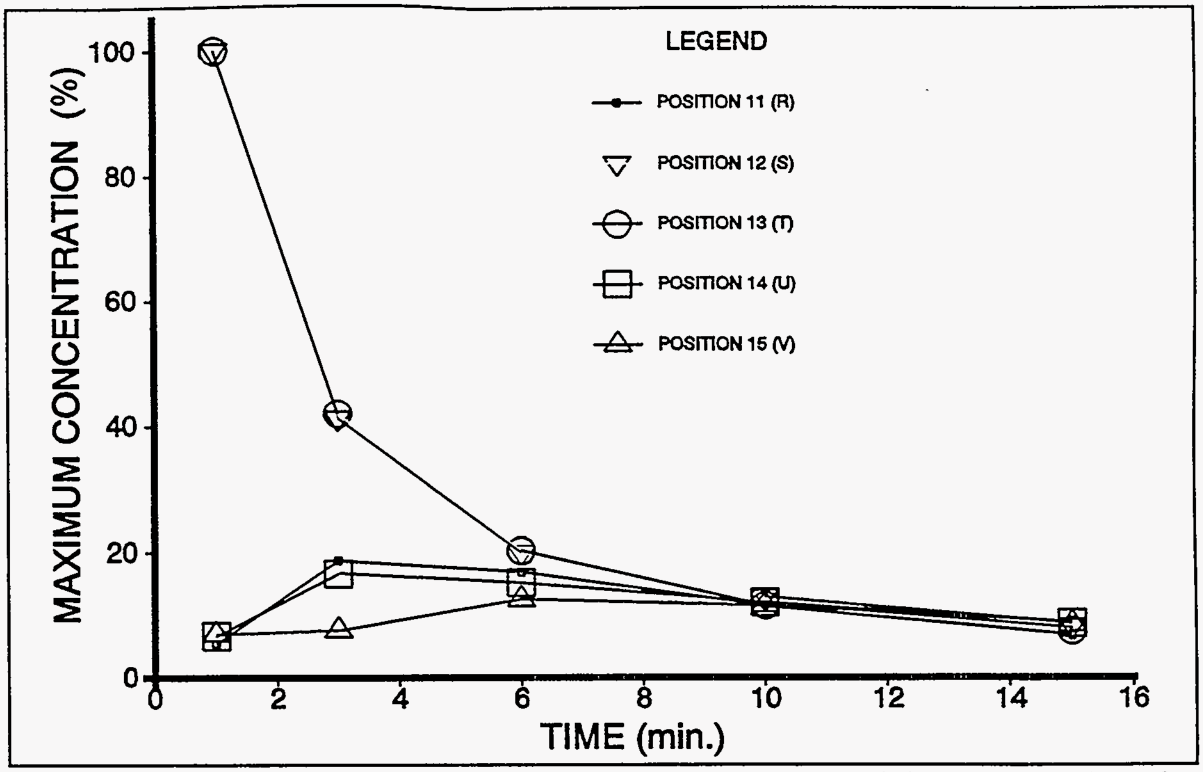


**Figure 7**: Concentration of $SF_6$ gas in Rm. 112 as a function of time and position after release of $SF_6$ at point T. Positions are shown in Figure 5.

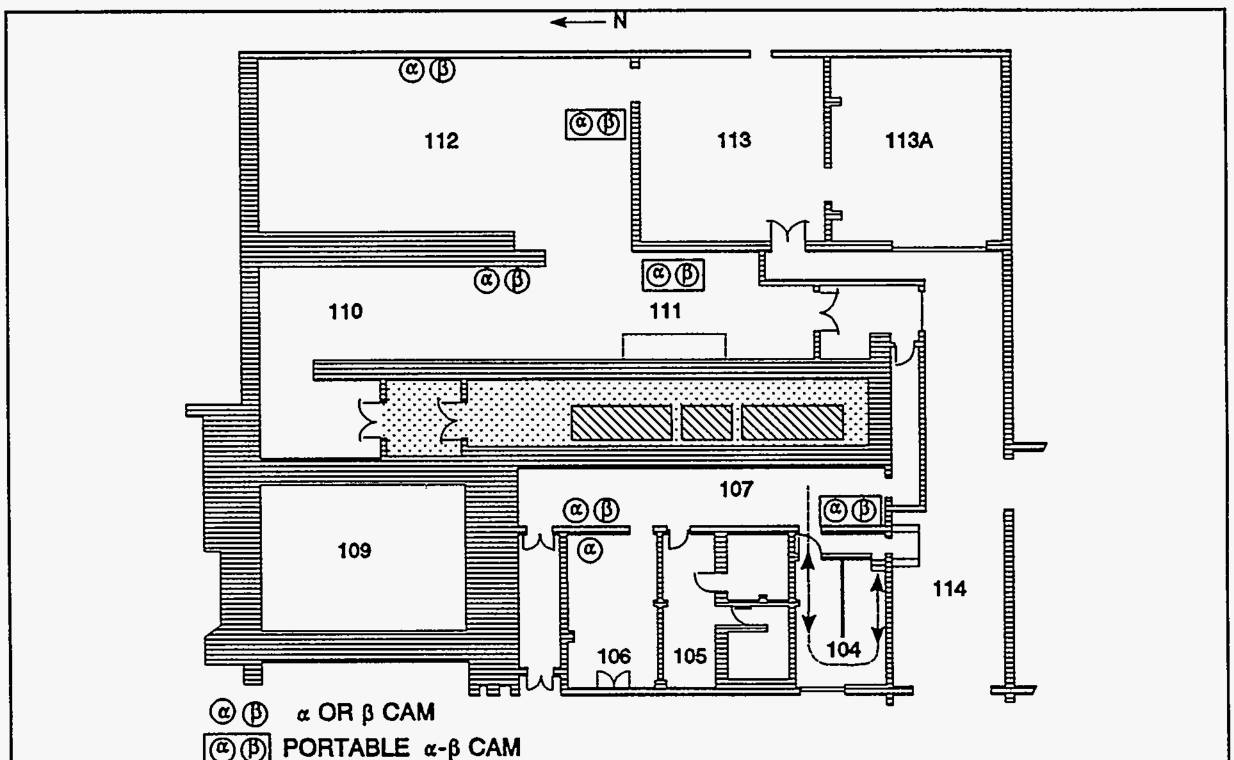


**Figure 8**: Floor plan of the HCF (Rooms 110-111, 112, and 107) areas showing recommended locations for alpha and beta CAMs.

TABLE 1

Derived Air Concentrations (DACs) for Radionuclides of Interest in the Sandia National Laboratories Hot Cell Facility (from 10 CFR 835, draft 12/9/91)

| Radionuclide | Solubility Class | | |
|---|---|---|---|
| | D (days) | W (weeks) | Y (years) |
| $^{137}Cs$-$^{237}Ba$ | 7.0 x $10^{-8}$ $\mu$Ci/mL | -- | -- |
| $^{134}Cs$ | 4.0 x $10^{-8}$ $\mu$Ci/mL | -- | -- |
| $^{90}Sr$-$^{90}Y$ | 8.0 x $10^{-9}$ $\mu$Ci/mL | -- | 2.0 x $10^{-9}$ $\mu$Ci/mL |
| $^{234}U$ | 5.0 x $10^{-10}$ $\mu$Ci/mL | 3.0 x $10^{-10}$ $\mu$Ci/mL | 2.0 x $10^{-11}$ $\mu$Ci/mL |

Table 2

Other Considerations for Design of a Technically Defensible Air Monitoring Program.

| ITEM | COMMENTS |
|---|---|
| VACUUM SOURCE | Vacuum source must be adequate for all sampling or other applications and should have a capacity about 1.5 times the maximum envisioned flow rate. Site specific requirements dictate whether the vacuum system is central or has a local pump. |
| DATA ACCESS | There are several important considerations for data access. Is the system (1) a local stand alone, (2) remote stand alone, (3) a local network, and (4) setup for remote access to a network? |
| NETWORKING | Network systems can have a wide range of designs, some of which are: (1) hard wired, (2) fiber optic, and (3) spread spectrum radio. |
| STEPPING FILTER | Use of stepping filters in air sampling instruments can result in several improvements that include saving worker involvement and improving reliability. |
| FIXED AIR SAMPLERS (FAS) | Use of FASs should balance the regulatory requirements for the type of sampler indicated versus costs of CAMs. Other factors that need to be considered are the numbers of CAMs and aerosol losses in transport lines. |
| PROBABILITY OF RELEASE | Central to the establishment of an air sampling program in the workplace is an estimate of probability of an airborne release of radioactive materials. This consideration should guide the placement and number of air samplers in an individual site. |