Pacific Northwest National Laboratory

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Automated Particulate Sampler Field Test Model Operations Guide

Dr. Sonya M. Bowyer
Dr. Harry S. Miley

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

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Preface

The Automated Particulate Sampler Field Test Model Operations Guide is a collection of documents which provides a complete picture of the Automated Particulate Sampler (APS) and the Field Test in which it was evaluated. The collection of documents consist of three main components. The first component is the Field Test Plan which provides a motivation for the test and specifies the type and criteria for each test case. The second component is the description of the APS Field Test Model and its operating instructions along with instructions for installation for the field test. The third component describes the findings of the field test and the changes that were made to the Field Test Model or that will be made in the subsequent Bid Model. This final component also includes a description and drawing of the Bid Model.

The original version of this document included only the description of the APS Field Test Model and its operating instructions. Its purpose at that time was to provide detailed information about the design and the operation of the Field Test Model for the individuals involved in the field test evaluations. The second version contained additional information that addressed the findings of the Interim Test Report by describing changes made during the field test and the changes to be made to the Bid Model. This final version has updated all the information in version two and has added the Field Test Plan and the evaluations found in the Final Field Test Report. Hence, this document provides a complete description of the APS Field Test Model and all the activity related to its evaluation and progression.

Upon final submission of this document, work on the bid model referred to as the Radionuclide Aerosol Sampler/Analyzer (RASA) Mark 4 has advanced substantially. Documentation on the RASA Mark 4 is underway and listed below. In light of these new developments, this document now serves a more historical than utilitarian role.

RASA Mark 4 Documentation:

Dr. Harry S. Miley, Mr. John E. Smart, and Mr. Robert C. Thompson. 1997. *The DOE CTBT Radionuclide Aerosol Sampler/Analyzer RASA Mark 4 Schematics and Drawings*. PNNL-11368, Pacific Northwest National Laboratory, Richland, Washington.

Dr. Harry S. Miley. 1997. *The DOE CTBT Radionuclide Aerosol Sampler/Analyzer RASA Mark 4 User Documentation*. PNNL-11369, Pacific Northwest National Laboratory, Richland, Washington.

Dr. Harry S. Miley. 1997. *The DOE CTBT Radionuclide Aerosol Sampler/Analyzer RASA Mark 4 Test Plan and Test Report*. PNNL-11370, Pacific Northwest National Laboratory, Richland, Washington.

Dr. Harry S. Miley, Mr. Rodney M. Savard and Mr. Charles W. Hubbard. 1997. *The DOE CTBT Radionuclide Aerosol Sampler/Analyzer RASA Mark 4 Software Documentation*. PNNL-11371, Pacific Northwest National Laboratory, Richland, Washington.

1. Field Test Plan

This chapter contains the Field Test Plan prepared by HQ AFTAC/TN released 30 June, 1995. The document has been reformatted only. The cover page appeared as:

Field Test Plan
for the
Comprehensive Test Ban Treaty
Prototype Particulate Samplers

30 June 1995

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1.1 INTRODUCTION

1.1.1 Identification

This test plan addresses field testing of prototype radionuclide particle samplers from the Department of Energy's Environmental Measurements Laboratory (EML) and the Pacific Northwest National Laboratory (PNNL). It provides guidance for preparing and conducting the tests stated in the following sections. The sources used to prepare this test plan are attached. It defines the necessary Air Force resources and environment in which to conduct the test. Finally, this test plan identifies the groups responsible for conducting specific tasks and the schedule for performing the tasks.

1.1.2 Purpose

The purpose of these tests is to provide early cooperation and feedback between the Department of Energy and AFTAC organizations responsible for CTBT verification, as well as to smooth and speed the development and acquisition processes. These tests will identify strengths and deficiencies of the prototypes and to the best of our ability characterize the emerging operational capabilities of the samplers. These tests will provide the user perspective to the instrument developers to ensure that the desired product is provided. Also, since EML and PNNL have already begun acquiring data, we want to gather more mean time between failure data and system characterization data. Lastly, we want to study the samplers to identify possible maintenance and logistical shortcomings and suggest potential improvements.

1.1.3 Background

The Comprehensive Test Ban Treaty (CTBT) has been under discussion for the past several years. Typically, members of the Conference for Disarmament meet in Geneva at least once a year, sometimes more. These members, 30-40 different nations, discuss arms control and how to implement it. As early as the Reagan era, there was dialogue between many conference members for a treaty that would ban all nuclear testing by signatory nations. Between 1991 and 1992, the idea of a CTB began collecting momentum in the US, which spawned serious research efforts for monitoring such a treaty. In 1993, investigation was underway specifically for real time analysis of radionuclide particles. By late 1994, two Department of Energy Laboratories, EML and PNNL, had developed prototype particle samplers. The Department of Energy, AFTAC, EML, and PNNL were all desirous of an early demonstration of the sampling and analysis technologies. This would permit cooperation and constructive comments in the development and commercialization of the instruments for the international CTBT monitoring market, accelerating delivery of the final product. A field demonstration, as part of ongoing cooperative research, was agreed to in principle by DOE and AFTAC early in 1995. In February of 1995, AFTAC/TOD was notified by AFTAC/TN that it would conduct field testing of the two prototype samplers beginning 6 July 95.

1.1.4 Scope

The field test will span a 6-month period, beginning 6 July 1995 and ending 6 January 1996. During that time, the samplers will transmit daily raw gamma spectra data to HQ AFTAC. The first two months of the test will consist of those experiments that can easily confirm a majority of the requirements established by HQ AFTAC. Also, the first two months of experiments will be aimed at defining some of the characteristics of the samplers. The latter four months of tests may consist of more difficult and time consuming experiments, which characterize the samplers and confirm requirements. Additionally, the last four months will also provide needed mean time between failure data.

1.1.5 Roles and Responsibilities

1.1.5.1 DOE

Provide oversight responsibility and fiscal support for DOE laboratories in the development and fielding of their samplers for this demonstration. Ensure that efforts of the laboratories are directed to the goals of the demonstration, and that corrective actions (as needed) are accomplished and potential system improvements are considered. Provide high-level coordination of sampler technology development with AFTAC/TN.

1.1.5.2 AFTAC/TN

Provide oversight responsibility for AFTAC participation in the field demonstration, including efforts at headquarters and tasking for AFTAC/TOD. Collect and transmit electronic data from the samplers by acting as the National Data Center, and disseminate the data for evaluation by the other participants. Provide high-level coordination of sampler technology development with DOE.

1.1.5.3 AFTAC/TOD

Provide logistical support for the field demonstration at McClellan Air Force Base, CA. Provide evaluations of the samplers in light of the specifications; suggest potential deficiencies and improvements in light of experience. See also Sections 1.3.2.1 and 1.3.3

1.1.5.4 EML/PNNL

Provide a field prototype of their particulate samplers/analyzers for demonstration and testing. Provide for shipment of the samplers to McClellan AFB. Install the samplers at the test site (July 6 - July 14), and provide initial inspection, fine-tuning, and TOD training (July 14 - July 21), culminating in the transfer of the units to TOD care July 21. As necessary, provide documentation or other information as requested by TOD in support of the testing and evaluation. If necessary, should field repairs be necessary, provide technical staff or detailed written technical instructions to TOD. Provide for pickup of the samplers at the conclusion of the test. See also Section 1.3.2.2.

1.1.6 Reference Documents

Tasking memorandum from AFTAC/TN, Mr. Charles F. McBrearty, Jr. Subject: Aerosol Sampler Field Test. Date: 31 Mar 95. Attachments. Test Objectives, Evaluation Criteria.

1.2 TEST CASES

1.2.1 General Philosophy

The particle samplers are new technology. Therefore, the test experiments should be conducted to gather as much information as possible without causing harm to these prototypes. Any tests that may cause sampler malfunction would preferably be conducted in the presence of the samplers' design engineers. A majority of the tests will be conducted to validate the samplers' fulfillment of the requirements listed in the tasking document mentioned in paragraph 1.6. However, some tests will be conducted to gather information which team members believe will help them to identify possible maintainability or logistical deficiencies. For many of the tests, the performance of the samplers will be compared to the performance of a typical Ground Filter Unit (GFU), since the GFU is proven equipment. TOD has installed a GFU at the test site to run concurrent with the particle samplers. Since the detectors will arrive in early July, some test procedures and validity will not be completely clear until we can inspect the samplers.

1.2.2 Test Cases versus Requirements

This section explicitly shows how each of the requirements will be addressed by the test plan. Table I gives a brief description of the requirement, indicates where the requirement is located in the tasking memorandum, provides an evaluation method, and notes a name for the applicable test. The following is a list of the evaluation methods used in Table I. Because TOD will not receive the samplers until after publication of this document, some evaluations have been given multiple evaluation methods to account for possible changes in the scope of the evaluations.

Not Applicable (N/A) - an evaluation, or verification, which is not necessary or is not concerned with these particular samplers.

Inspection (I) - an evaluation that can be accomplished through visual inspection.

Demonstration (D) - an evaluation that can be accomplished through operation of the equipment.

Test (T) - an evaluation that can be accomplished through operating the equipment and relies on collection and subsequent examination of data.

In Table I below, test requirement names are abbreviated as Collection Requirements (CR), Analysis Requirements (AR), and so on.

Table I. Requirements Testing Cross Reference Table

Requirement Description	Requirement Location: table number and row	Evaluation Method	Test Case Name
<i>Collection</i>	1		CR
continuous collection	1,1	D	CR1
removable filter	1,2	D	CR2
min. SCM/per day	1,3	T	CR3
filter efficiency	1,4	I	CR4
filter capability	1,5	I	CR5
filter documentation	1,6	I	CR6
flow rate	1,7	D/T	CR7
<i>Analysis</i>	2		AR
on-site measurement	2,1	T	AR1
cooling	2,2	I	AR2
background analysis	2,3	I	AR3
energy/ch. pairs	2,4	D	AR4
sensitivity for Mo99	2,5	N/A	AR5
sensitivity per SCM	2,6	T	AR6
precision	2,7	N/A	AR7
spectrum range	2,8	D	AR8
background reduction	2,9	I	AR9
radon daughter reduction	2,10	N/A	AR10
collection cycle time	2,11	D	AR11
<i>Data Storage and Communication</i>	3		DCR
background storage	3,1	D	DCR1
energy/ch. storage	3,2	D	DCR2
spectral storage	3,3	D	DCR3
start/stop time	3,4	T	DCR4
start/stop analysis time	3,5	T	DCR5
collection/analysis correlation	3,6	D	DCR6
serial port comm.	3,7	D	DCR7
protocol changes	3,8	D	DCR8
software updates	3,9	D	DCR9
intermediate analysis	3,10	D	DCR10
<i>Operation and Logistics</i>	4		OR
modular design	4,1	I	OR1
easy operation	4,2	T	OR2
unattended operation	4,3	D	OR3
easy to repair	4,4	D	OR4
service interval	4,5	D	OR5
restocking interval	4,6	I	OR6

degradation self-diagnostic	4,7	T	OR7
state-of-health	4,8	D	OR8
off-the-shelf components	4,9	I	OR9
reporting time	4,10	D	OR10
data availability	4,11	D	OR11
self-calibration	4,12	D	OR12
filter shipment	4,13	I	OR13
remotely activated calibration	4,14	I/D	OR14
mean time between failure	4,15	D	OR15
power failure recovery	4,16	D	OR16
<i>Physical Requirements</i>	5		PR
surface mounted	5,1	I	PR1
power	5,2	T	PR2
dimensions	5,3	I	PR3
volume	5,4	N/A	PR4
weight	5,5	I	PR5
component weight	5,6	D/T	PR6
noise	5,7	T	PR7
integration	5,8	I	PR8
indoor operation	5,9	I/D	PR9
indoor operating temperature	5,10	T	PR10
overall operating temperature	5,11	T	PR11
shipping	5,12	I	PR12
stand alone capability	5,13	I	PR13
General	6		GR
No LN	6,1	I	GR1
ozone depleters	6,2	I	GR2
unit cost	6,3	I	GR3
installation manpower	6,4	I	GR4
operation cost	6,5	I	GR5

1.2.3 Test Case Identification

Table II below provides an explanation of the test cases from Table I. The purpose of Table II is to illustrate why the tests are being conducted, how the tests will be conducted, and what a theoretical positive test outcome may be. The table also identifies additional tests, demonstrations, and recommended changes in requirements (which are not indicated in Table I) that will be performed on the samplers. Recommended changes are indicated in italics.

Table II. Test Descriptions

Test Case Name	Objectives	Execution	Verification
CR1	The system should automatically change filters without any instrument downtime between samples.	Operate the system under normal conditions. Note the time taken for the filter change and compare samplers' change times.	The system automatically changes filters; downtime is compared between samplers.
CR2	Filter medium shall be removable	Conduct normal operations of the system and note any problems the system has with removing filters throughout the testing period. Determine if it is possible to track the used filters.	Old filters are removed without incident, for further analysis.
CR3	The system should have a minimum flow rate of 10,000 SCM per day.	While the system is operating, a calibrated flow meter should be placed on the system. CR7 should also be satisfied to compare the flow meter reading with the system's internal measurement. The flow meter should then be removed and the flow rate should be noted using the system's internal measurement.	The flow meter and the system's internal measurement agree, within manufacturer's specifications, and the flow rate is determined to be at least 10,000 SCM per day.

CR4	The filter medium should have an efficiency greater than 98% for particles of 1 to 5 microns and greater than 90% for particles of 0.1 to 1.0 microns.	Reference filter medium test results from an independent lab.	The lab results indicate that the medium meets the specified efficiencies.
CR5	The filter medium should be capable of an efficiency greater than IPC paper efficiency for particles less than 0.1 microns.	Reference filter medium test results from an independent lab.	The filter medium has an efficiency greater than IPC paper.
CR6	Documentation shall be provided concerning the trapping efficiency and durability of the filter medium.	The documentation for the filter medium should be referenced.	The documentation is available and contains information valuable to verifying trapping efficiency requirements and filter durability quantification.
CR7	The system should have a built-in flow rate measuring device that is capable of transmitting the flow rate data.	Conduct normal operation of the system. Record the flow rate information for the demonstration and confirm HQ has received the same values. Execution is accomplished with CR3	The flow rate data provided by the system is the same as the flow rate received by HQ. Calibrated flow meters agree with the reported value. Verification is accomplished with CR3.
CR8	Quantify how rugged the filter medium.	Conduct normal operations of samplers. Randomly choose a used filter and inspect it for any abnormality Document the normal operating flow rate and, if possible and applicable, measure the normal operation tensile stress on the filter medium. Compare these results to data provided by independent lab results and/or filter medium documentation	Filters consistently maintain their integrity throughout the experiment and, if applicable, normal operations show filter stress to be well below breaking points.

CR9	Attempt to measure particle size distribution present on footprint of sample.	Conduct normal operation of sampler through one full cycle. Remove filter medium and analyze particle sizes. Compare size distribution for both samples and GFU. Document results. Repeat procedure up to 3 times.	N/A
CR10	Daily particulate matter dispersion across filter medium remains consistent.	Conduct normal operation of system through one full collection cycle. Inspect sample for noticeable deposition of particulates. Note the relative placement. Repeat procedure several times and note any changes of particle footprint.	Particulate matter is consistently deposited across the same footprint.
AR1	The system should be capable of on-site radionuclide measurement	CR4 and 5 are verified with positive results. Measure a source, such as the daily standard, for a specified period; HQ transmits results back to TOD.	The samplers' results indicate proper energies and activities.
AR2	The detector should not require any non-self-contained coolant such as liquid N ₂ .	The detector system should be inspected for any non-self-contained coolants.	No non-self-contained coolant found.
AR3	The system should measure and analyze background spectra with a justifiable recommended period between measurements.	PNNL and EML provide written detailed explanations of background analysis schemes, such as frequency of measurement, use of blanks, and method of spectrum background subtraction.	TOD reviews explanation and approves methodology.

AR4	The system should provide an energy/channel calibration.	PNNL and EML provide written detailed explanations of how energy/channel calibration is accomplished, especially the calibration curve calculations and the isotopes used. Operate the system through one full cycle. HQ transmits results back to TOD.	TOD confirms that energy/channel pairs, as well as the curve parameters, are properly calculated and received.
AR6	The system should be sensitive to 30 micro-Bq/SCM of Ba-140.	AR 12 is satisfied. Samplers collect background gamma spectra. TOD generates a theoretical 0.3 Bq (per 10,000 SCM) Ba-140 spectrum. Add estimated spectrum to background spectrum. Perform a peak location procedure with a significance threshold of 2 sigma.	TOD confirms that sufficient fresh fission isotope species could theoretically be identified at the level of two sigma above background.
AR8	There should be a spectrum range of 50 keV to 2 MeV, or if extrapolation will be sufficient.	Reference the off-the-shelf manuals for the gamma ray detector. Operate the system and adjust the voltage if necessary. In both cases, inspect the system's channel/energy pairs.	Manuals and actual channel/energy pairs confirm energy range.
AR9	The system should have some emphasis on reducing/eliminating background.	Request figure of merit equation from both EML and PNNL. Determine which equation should be used, or how to equate the two equations. Using equations, compare the two samplers to each other and both to typical TOD gamma ray detectors.	

AR11	The system shall have the capability to adjust the test cycle for each filter from 24 hrs. to 72 hrs.	EML and PNNL provide instructions for adjusting the cycle period. Operate system at 24 hrs. and 72 hrs. per cycle.	The resulting cycle correlates with the selected setting.
AR12	Precise efficiency curves as a function of energy shall be supplied for the sampler's geometries.	Along the curve calculation technique, PNNL and EML shall specify isotopes, paper salting procedures, and recommended frequency of efficiency calibrations. TOD evaluates methodology.	TOD accepts methodology.
AR13	If necessary, a periodic efficiency correction factor shall be calculated from the daily energy calibration standard intensities.	TOD evaluates methodology for calculating and correcting for periodic shifts in the detector efficiencies.	TOD accepts methodology.
DCR1	The system should be capable of recording background spectral information and associating it to each sample cycle.	AR3 is satisfied. Conduct normal operation of sampler through one full cycle. The system memory should then be examined to see if the background spectral information is retained.	The background spectral information is found during the search, is correct, and is properly associated to the normal sample information.
DCR2	The system should be capable of recording energy/channel calibration information and associating it to each sample cycle.	AR4 is satisfied. Conduct normal operation of sampler through one full cycle. The system memory should then be examined for energy/channel calibration information.	The energy/channel information is found, is correct, and is properly associated to the normal sample information.
DCR3	The system should be capable of recording sample spectral information for each cycle.	DCR 1, 2 and 11 are satisfied. Conduct normal operation of sampler through one full cycle. The system memory should then be examined for sample spectral information.	The sample spectral information is found, is correct, and properly associated to the background, energy/channel calibration, efficiency calibration, and daily efficiency correction.

DCR4	The system shall record the collection start and stop time for each sample.	Conduct normal operation of sampler through one full cycle. Time the collection interval. The system memory should then be examined for sample collection start and stop time.	The start and stop times are found and they correspond with the demonstration's start and stop times.
DCR5	The system should record the analysis start and stop count times for each sample.	Conduct normal operation of sampler through one full cycle. Time the analysis interval. The system memory should then be examined for sample analysis start and stop time.	The start and top times are found and they correspond with the demonstration's start and stop times.
DCR6	The system should correlate the collection and analysis times with the proper sample information.	DCR4 and DCR5 are satisfied. Conduct normal operation of sampler through one full cycle. The system memory should then be examined for proper correlation of times to sample information.	The collection and analysis times are properly associated to the sample information.
DCR7	The data stored in the system should be provided to a serial port for communication.	Conduct normal operation of sampler through one full cycle. Request HQ confirm receipt of sample information.	The information sent by the system is properly received by HQ.
DCR8	The system should be capable of changing the analysis protocol via com link.	HQ changes the analysis protocol, for example, from a 24-hour count time to 72 hours, or to a background count (no airflow collection), and they inform TOD of the change	The protocol from HQ is properly executed.
DCR9	The system should be capable of updating the software via com link.	HQ accesses the system root directory.	HQ confirms access to the system root directory.

DCR10	Intermediate analysis data should be provided via com link, without sample collection or count interruption.	During an other than normal reporting time, HQ will access and retrieve analysis data through the com link.	The analysis data is properly retrieved by HQ.
DCR11	The system should be capable of recording efficiency calibration information and daily efficiency correction information and associating both to each sample cycle.	AR4 and AR13 are satisfied. Conduct normal operation of sampler through one full cycle. The system memory should then be examined for efficiency calibration information and daily efficiency correction information.	The efficiency calibration information and daily efficiency correction information is found, is correct, and is properly associated to the normal sample information.
OR1	The system should be a modular design.	Either during installation or removal, the system should be disassembled and inspected to see if the components meet the OSHA weight requirement for one person lifting. Any questionable part of the system should be weighed to make sure it does not exceed the one person lift limit. As an alternative, pending a disassembly or assembly, the system drawings and the system itself should be examined to evaluate against this requirement.	All parts of the system are modular and do not exceed OSHA individual lift standards.
OR2	The system should be designed to be easily operated by an unskilled operator.	EML and PNNL provide documentation, such as a theory of operation or an owner's manual. Using the documentation, an operator, having no more than a high school education, will operate the system. The level of training required will	The amount of education required, as determined through observation of the individuals, is of high school equivalent.

		then be determined and documented by observing the individual operating the system. Repeat this procedure several times.	
OR3	The system should be capable of unattended operation for 12 months (see OR5).	Throughout the test, the system will be observed to note whether it needs to be assisted during operation. Such observations will be documented to permit system improvement.	The system operates without assistance for the extent of the test period.
OR4	The system should have an easy to repair configuration.	The system should be inspected, to include possible disassembly, in order to ensure that it is maintainable by one on-site technician with no special tools, it has no hard to reach parts, it provides the location of failed modular components through a diagnostic system, and it can be serviceable within a four-foot clearance around the system. Additionally, PNNL and EML provide software explanations, to include the operating system, languages contained in the code and number of lines in the code.	The inspection proves the maintenance requirements.
OR5	The system should have a service interval of 12 months.	EML and PNNL provide documentation on anticipated service and intervals. Also, EML and PNNL will supply the manufacturer's information on mean time between failure.	The system does not require servicing during the demonstration. Documentation also supports a 12-month service interval for those parts that could not be exercised during the simulation.

OR6	The system restocking interval is determined.	The system should be inspected in order to obtain the filter capacity of the system. The restocking interval should then be determine for various operating scenarios such as 8, 24, or 72 hour reporting times.	A restocking interval for normal operations and special operations is documented.
OR7	The system should have self-diagnostics for degradation.	Obtain the location of diagnostic sensors, develop sensor specific tests, such as ripping paper or blocking filter compartments. Conduct sensor specific tests	Faults are designated by the diagnostic system and correlate to the test being conducted.
OR8	The system should provide (both on-site and off-site) state-of-health information, which must be clearly defined by the contractors.	TOD reviews state of health metrics. OR7 is satisfied. An on-site check by TOD and an off-site check by HQ is done to see whether state-of-health information is available both off-site and on-site.	TOD validates the state-of-health parameters provided by the contractors. The information is found both on-site and off-site.
OR9	The system should be constructed with off-the-shelf components.	Inspect the parts list. Document those, if any, of the parts that require customizing.	Each part is found to be off-the-shelf.
OR10	The final report and data should be forwarded to HQ preferably within 6 hours of detector count stop time, but no later than 24 hours.	Conduct normal operation of the system. HQ reports time of receipt of information.	An analysis time length is determine through observation to be at most 24 hours after end of collection.
OR11	Raw spectra will be available for HQ at the conclusion of the sample count time.	Normal operation, HQ requests raw spectra by DSN at the conclusion of a sample count.	The raw spectrum is available by DSN at sample count conclusion.

OR12	The system should have a form of self-calibration (energy vs. channel number).	AR4 is satisfied.	The calibration system is found to be self operating.
OR13	It should be possible to ship the filter medium from the test site to the laboratory.	Remove and inspect a specifically identified filter paper after is use. Identify a suitable shipping medium. Research possible safety issues and document them.	A filter can be identified, removed, prepared, and shipped.
OR14	The system should permit field calibration of the detector.	AR12 is satisfied.	Methodology satisfied in AR12 accounts for field calibration.
OR15	The expected mean-time-between-failure for the system should be greater than 12 months. Proof shall be provided in data, documentation and explanations.	OR5 is satisfied. Continued monitoring is conducted throughout testing period. Documentation and data previous to the testing period are referenced.	The system operates throughout the simulation without any failures. Documentation supports at least a 12-month mean time between failure.
OR16	The system should not lose any collected data due to a power failure.	A demonstration, including at least one analysis and collection cycle, must be conducted with data stored throughout the cycle noted. The power should then be removed from the system. Upon re-supply of power, the data storage must then be check to ensure that none of the data were lost during the power loss. Conduct this test several times with varying time intervals.	The system does not lose any collected data.
PR1	The system should be surface mounted.	The system should be inspected to ensure that it is surface mounted.	It is confirmed that it is surface mounted.
PR2	The system is required to operate using a value within the range 100-260 VAC, 50-60 Hz	A Test must be conducted to ensure that the systems use the required power sources.	The test confirm that the suggested power source will be sufficient for the system and the

	and using less than 2500 W.	The system must then be connected to the appropriate power sources and checked for basic operation. Internal components of the system should also be checked to see if there are any points in the system where there is a dangerous voltage level. The current should also be measured at different points and noted.	system will not draw an excessive amount of current. The internal voltages are noted in case of dangerous voltages within the system.
PR3	The overall size will be within the approximate limit of 6'x3'x3'.	The system must be measured in order to note the overall size of the system.	The system complies with required dimensions.
PR5	The system as a whole should be weighed in order to analyze the shipping requirements.	The system weight is noted by some method, such as the shipping documentation or use of a scale.	The weight is noted.
PR6	The system should contain modular components that do not require more than a one-person lift, except during installation.	N/A	OR1 is satisfied.
PR7	The system should operate under an 80 dBA limit, but a limit between 50 and 60 dBA is preferred.	A measuring device should be used to determine the noise level of the system periodically throughout the test period. Results should be documented.	The noise level is below 80 dBA.
PR8	The system should be an integrated unit.	The system should be inspected.	It proves to be an integrated unit.
PR9	The system should operate indoors with an external inlet and outlet.	The system should be inspected to ensure that it has both an external inlet and outlet.	The inspection confirms that there is an external inlet and outlet.
PR10	The system should be capable of operating at a temperature of 60° to 100°F.	Determine a schedule of temperature settings in which the sampler shall operate, to range over	The system operates between 60° and 100°F without any noticeable effects.

	<i>[Recommend extending upper and lower temperature ranges. LSM feels 50 °F is appropriate.]</i>	temperatures between 60° and 100°F. Implement schedule and monitor any noticeable differences in the sampler operation, such as analysis degradation.	
PR11	The system should have a nominal operation temperature.	Throughout the testing period, a thermometer should be placed in the system in order to check the operating temperature to determine if it is excessive. The operating temperature should be noted.	N/A. Operating temperature will be periodically noted; no verification will be performed.
PR12	There should be no special shipping requirements for the system.	PNNL supplies a written concept of how the sampler will be shipped for TOD's critique. EML ships its sampler to TOD. The shipping requirements of both systems are given proper oversight to determine any special requirements.	There are no special shipping requirements.
PR13	There should be no special environmental requirements for the system. <i>[Recommend placing humidity operating ranges; this requirement may be prohibitive to test, however.]</i>	The system should be inspected to determine whether or not special environmental requirements are necessary. Also, humidity within the test site and local weather conditions will be noted throughout the testing period.	There are no special environmental requirements.
GR1	The system should not use liquid nitrogen.	The system should be inspected for the presence of liquid nitrogen.	The system has no liquid nitrogen.
GR2	The system should not use any ozone-depleting substances.	The system should be inspected for the presence of ozone-depleting substances.	The system has no ozone-depleting substances.

GR3	The acquisition cost of each unit should be less than \$60K.	The acquisition cost should be provided by the manufacturer.	It is less than \$60K.
GR4	The installation requirements for the system should be determine.	PNNL supplies a written concept of how the sampler will be installed for TOD to critique. The installation of both systems should be observed in order to note the requirements.	A record of the requirements is created. See paragraph 3.2.1. *It will not be possible to do this with PNNL's detector if they ship it assembled and in a trailer.
GR5	The annual operation cost per sample, additional materials and supplies, technician time, and number of visits per year should be determine for the system.	All information for determining this requirement will be supplied by both EML and PNNL and/or gathered throughout the testing period.	A record of the results is completed.

1.2.4 Features Not to be Tested

Since these machines are prototypes, and not yet directly under normal Air Force acquisition procedures, it is reasonable to assume that TOD will not test every aspect of the samplers. However, this test plan attempts to address the majority of concerns held by both HQ AFTAC and TOD. Any further testing will take place once the prototypes are deemed ready for normal Air Force acquisition procedures.

1.2.5 Approach

Testing will be conducted in several phases, each phase focusing on specific aspects of the samplers' capability versus technical requirements. Listed below are the phases in which the test plan will be conducted. On the following page, Table III lists how each test case fits into the phases and provides an approximate order for conducting the tests.

Verification: The verification tests include those items that can be research and verified without the equipment, such as reference documentation, equipment specifications, etc.

Sample Setup: This phase of testing will include test that validate ease of equipment installation and physical requirements, but they do not require operation of the system.

Operation/Sample and Data Collection: This phase of testing will demonstrate actual equipment operations, sample collection capability, and data presentation versus requirements.

Sample Analysis: Here, testing concentrates on each of the analysis requirements.

Sampler Disassembly: This phase of testing will include tests that validate ease of equipment disassembly and physical requirements.

1.2.6 Item Pass/Fail Criteria

The pass/fail criteria are based both objective and subjective, and these criteria are reflected in the *Verification* block of Table II. For those cases with explicit requirements, such as voltage or mean time between failure, there is no subjectivity. Either the samplers will meet the requirements or they will not. For those cases with subjective requirements, such as "easily operated on-site by unskilled operator," the expertise of team members was relied upon to make an initial pass/fail determination. However, since we cannot be certain of the exact composition of tests to be conducted until we receive the samplers, final subjective pass/fail criteria will be determined before each test is performed. For both cases, the team will attempt to provide in its reports written feedback on inadequacies, pass/fail criteria, and how to improve performance.

Table III. Testing approaches

Verification	Set-up	Collection	Analysis	Disassembly
CR 4,5,6	PR 5	CR 1-3,7	AR 1	OR 1
OR 9	OR 1,4,9	OR 6	AR 4	OR 4
PR 13	PR 6,8,12	AR 11	AR 5,6	PR 12
GR 1-3	GR 1,2,4	OR 5,15	AR 8	GR 4
AR 3,4,9,12,13	AR 2	DCR 1-6,11		PR 5
	PR 1	DCR 7-10		PR 6
	PR 3	OR 2,3		
	PR 8	OR 7,8		
	PR 2	OR 11		
	PR 9	AR 4, OR 12		
		OR 13		
		OR 14, AR 12		
		OR 16		
		PR 7,10,11,12		
		GR 5		

1.3 TEST REQUIREMENTS

1.3.1 Suspension and Resumption Criteria

There are several instances in which the tests may be suspended: safety concerns, special activities, or Headquarters notification. Under such circumstances, all or part of individual tests may not be conducted. In most instances, data from the samplers will most likely continue to be transmitted to HQ AFTAC, since the systems are designed to be totally automated. Once the situation becomes normal, testing will resume, and as much effort as possible will be applied to completing all tests.

1.3.2 Test Deliverables

1.3.2.1 TOD Deliverables

In addition to this document, HQ AFTAC will receive the following from TOD:

- 1) A 2-month test report citing observations, results, analysis, and recommendations from the installation and tests conducted during the first 2 months of testing. Also, we will include any proposals for revisions or additions to the remainder of the test plan. The 2 month report will be delivered to HQ AFTAC approximately 90 days after testing begins.
- 2) A comprehensive test report citing observations, results, analysis, and recommendations from the latter 4 months of testing, and a brief synopsis of the previous report. Additionally, TOD will provide an overall assessment of the performance of each sampler, completed evaluation matrices, and any recommendations for future actions in support of commerciali-

zation, acquisition, and deployment of the systems. The comprehensive test report will be delivered to HQ AFTAC approximately 30 days after test conclusion.

3) Copies of experiment logs, experimental data, and any pertinent documentation (i.e., shipping records, safety documents, receipts, etc.)

1.3.2.2 Contractor Deliverables

TOD requires the support of PNNL and EML during the test period to properly verify the compliance with certain requirements.

1) Supporting documentation from the contractors relating to safety, particularly drawings, schematics, and existing manuals, will be provided, at the latest, prior to the start of installation of the systems at the test location.

2) Supporting documentation addressing test requirements in the following list should be provided, with as many as feasible settled by beginning of the test

AR 2, 3, 4, 8, 9, 12, 13
 OR 2, 12, 14
 DCR 4, 5, 6, 7, 11
 PR 2
 and GR 1, 2, 4.

3) Supporting documentation for the following test requirements should be provided within 30 days of the start of operations:

AR 11
 OR 5, 9, 15
 DCR 1, 2, 3, 8, 9, 10
 and PR 12.

4) Supporting documentation for the following test requirements should be provided within 60 days of the start of operations:

OR 7, 8
 CR 4, 5, 6, 8
 and GR 5.

5) To verify the bulk of the Analysis Requirements section, TOD must receive the DSN data stream provided to AFTAC HQ. Also included should be all necessary analysis components such as daily standards, background, and efficiency spectra (in the form of both raw data and the eventual curve fit parameters), as well as any daily standard factors.

The field demonstration and evaluation will not be considered successfully completed until these documentation issues are addressed.

1.3.3 Environmental Needs

The following is a listing of sampler necessities which TOD must satisfy upon installation.

- 1) Climate controlled shelter.
- 2) Unclassified DSN lines with ensured 2-way communication capability.
- 3) Power to properly operate both systems simultaneously.
- 4) Independent intake and exhaust ports to avoid cross contamination between the two samplers.
- 5) Security: the entire project is unclassified, but will be maintained in a controlled area. Thus, the normal security requirements applied to any TOD equipment in building 626 will be applied to these samplers.

1.3.4 Responsibilities - Field Test Objectives and Responsibilities

A. The current schedule for the field test is:

1. Site location and evaluation criteria meeting: 6 April
2. Site visit and logistics evaluation: May
3. Equipment installation: 6-14 July
4. Start of test: 21 July
5. Observation period: 24-28 July
6. End of test: 22 Sept.

B. Evaluation criteria:

1. Does the system operate continuously in an automated fashion without human intervention?
2. Does the system produce results consistent with the GFU?
3. Are the results from the automated system consistent with the lab analysis of the papers?
4. Does the system recover from a power loss?
5. Does/can the system meet the requirements (see attachment)?

C. AFTAC

1. Coordinate field test with TOD and HQ DOE.
2. Collect data reported by equipment and forward to interested parties

D. TOD

1. Provide room for both samples.
2. Provide a telephone line with DSN capability and power for each sampler.
3. Analyze random samples from each sampler.
4. Log the performance of each sampler.
5. Evaluate the maintainability of the system.
6. Inlet and outlet placement and installation.
7. Collect observations and write final report for each sampler.
8. Evaluate compliance of each sampler with the evaluation criteria.

E. EML & PNNL

1. Provide technical support on the samplers.
2. Install and remove the equipment.
3. Coordinate with TOD on inlet and outlet modifications.
4. Provide equipment to transmit data to AFTAC.

F. HQ DOE

1. Coordinate field test with EML, PNNL, and AFTAC.

1.3.5 Particulate Sampler Technical Requirements

Table 1: Collection Requirement

Description	Hard/Soft	Yes	No	Value	Comments
Continuous collection ^a (deadtime between samples)	H				
Removable filter medium (mechanism)	H				
Minimum continuous 10000 SCM per day (Actual value)	S				
High efficiency for 0.1 to 5.0 microns ^b	S				
Capability for less than 0.1 microns ^c	S				
Documentation of trapping efficiency ^d	H				
Flow rate measurement/data transmitted	H				

^a No required instrument downtime between samples.

^b 1 to 5 microns: >98% retention: 0.1 to 1 microns >90% retention.

^c Capability to retain particles <0.1 microns should not be precluded by design of components. Performance guidance is IPC paper, but no specific retention is implied.

^d Manufacturer's specifications for filter medium will be sufficient

Table 2: Analysis Requirements

Description	Hard/Soft	Yes	No	Value	Comments
On-site radionuclide measurement (method)	H				
No cooling required for detector ^a					
Background spectra analyzed ^b	H				
Energy/channel number data provided (method)	H				
Sensitivity 7 Bq Mo99 per 10000 SCM ^c	H				
Sensitivity 10 micro-Bq fission product per SCM ^d (actual)	S				
Measurement precision ^e					
Spectrum range 50 KeV to 2 MeV	H				
Emphasis on reducing/eliminating background (figure of merit)	S				

Emphasis on reducing/eliminating radon daughter interference (figure of merit)	S				
Collection/analysis cycle time adjustable between 24 and 72 hours (range)	H				

^a information only: no correct answer.

^b Background defined as all material/processing except air flow.

^c Defined as 2 sigma above background.

^d Reflecting latest discussion at CD: defined as 2 sigma above background.

^e Greater definition needed: AFTAC action item.

Table 3: Data Storage and Communication Requirements

Description	Hard/Soft	Yes	No	Value	Comments
Capability to record background spectral information each cycle	H				
Capability to record energy-channel calibration information each cycle	H				
Capability to record sample spectral information each cycle (storage medium)	H				
Record start/stop collection time	H				
Record start/stop collection analysis time	H				
Correlate collection/analysis times with medium	H				
Data provided to serial port for communication	H				
Changes in analysis protocol via com link	H				
Software updates via com link	H				
Intermediate analysis data via com link	H				

Table 4: Operation and Logistics

Description	Hard/Soft	Yes	No	Value	Comments
Modular design ^a	H				
Easily operated on-site by unskilled operator ^b	H				
Emphasis on unattended operation	H				
Easy to repair configuration ^c	H				

Recommended service interval 12 months	H				
Restocking interval	H				
Self-diagnostics for degradation (description)	H				
State-of-health information on-site	H				
off-site	H				
Off-the-shelf components ^d	H				
Reporting time within 24 hours of end of sample collection.	H				
Data availability following counting (time)	H				
Self-calibrating (energy vs. channel number, method)	H				
Allow shipment of selected filter media (instrument - mail laboratory)	H				
Permit field calibration of detector (dpm to cpm) mechanism interval remotely activated	H				
Expected mean-time-between failure > 12 months data expectations, documentation	H				
No loss of collected data on power failure (recovery time)	H				

^a Modular components can be removed and replaced by single technician within OSHA guidelines for single person lift.

^b High School education or equivalent.

^c One technician on-site, no special tools, avoid hard to reach parts. System diagnostics should be able to locate failed modular component. Serviceable within 4 foot clearance around system.

^d No high level custom components.

Table 5: Physical Requirements

Description	Hard/Soft	Yes	No	Value	Comments
Surface mounted	H				
Power requirements <2.5 KW (S), 50-60 Hz (H), 100-260 VAC (H)	S/H				
Size < 6 (w) x 3 (d) x 3 (h) ^a width depth height	S				
Volume					

Weight					
Individual components < 1 person lift (except at installation)	H				
Noise level < 80 dBa ^b	H				
Integrated Unit	H				
Operate indoors with external air inlet and outlet ^c	S				
Indoor operating temperature range 60-100°F	H				
Nominal operating environmental temperature	H				
No special shipping requirements	H				
No special environmental requirements (global deployment)	H				

^a Reasonable footprint in a standard room required.

^b Goal: 50-60 dBa limit 80 dBa. Source: AFOSH-STD-48.19.

^c Hole positions are a free parameter.

Table 6: Other Requirements

Description	Hard/Soft	Yes	No	Value	Comments
No use of liquid nitrogen	H				
No use of ozone-depleting substances	H				
Unit acquisition cost < \$60K (base model)	S				
Installation requirements number of technicians technician time					
Annual operating cost per sample other materials and supplies technician time Number of visits					

2. Basic Operation Instruction Checklists

This chapter contains basic operation instructions in a checklist format. These checklists will be most effectively used by persons unfamiliar with the APS system if they are used in conjunction with the detailed explanations given in subsequent chapters of this operations guide. For persons that are very familiar with the system, the checklists serve as succinct instructions to be followed sequentially thus ensuring that all procedures have been correctly and fully completed.

2.1 Installation Checklist

(Refer to Chapter 5 for installation details.)

1. Verify that the installation area has cleared floor space adequate for the APS trailer (at least 10 feet by 18 feet with a 10 foot ceiling.).
2. Verify that two 20 Amp, 60 Hz, 120VAC outlets are available for powering the system.
3. Verify that there is access to outside air (via a window or outside wall hole) for the intake air duct.
4. Verify that a phone line is available for communications.
5. Maneuver the trailer containing the APS system into the desired location.
6. Level and support the trailer so that it is stable and free standing.
7. Remove all travel securing equipment.
8. Remove ducting materials, toolbox, and system consumables from the trailer and set aside.
9. Lift the main body of the APS onto the two support frames.
10. Install outside air intake duct and exhaust duct.
11. Set up the Supervisor Computer on the table adjacent to the main structure.
12. Install the HPGe detector under the HPGe detector counting area and securely support it via the couplings mounted in the support stand.
13. Position the cooling unit on the floor under the sample head.
14. Interconnect all wiring.

15. Assemble lead brick casing around HPGe detector counting area.
16. Connect trailer power to main power.
17. Connect the phone line to the modem.
18. Load the filter paper.
19. Turn on the Supervisor Computer.
20. Verify that the filter advances and the blower starts up, beginning an air sample.
21. Check through the State of Health Window (See the Normal Operations Checklist) to confirm that all sensors are operating properly.

2.2 Routine Operations Checklist

(Refer to Section 6.2 for more detailed instruction.)

1. Bring up the APS Main Window if it is not already visible. Do this by typing *xaps* at the prompt in an xterm window.
2. Click on the State of Health button in the Main Window.
3. Verify that the date, time, and Site ID are correct.
4. Note the state and the description reported. Verify that the physical state of the system is consistent with this information.
5. Under the window area labeled Op. State:
 - a. Check that the Air Volume is reading a number ranging from 0 - 24,000 m³.
 - b. If the blower is running, verify that the Air Volume reading is increasing as the Update button (located in the lower left hand side of the State of Health Window) is clicked on.
 - c. If the blower is running, verify that the Intake Vel. reading is greater than 600 m³/hr.
 - d. If the blower is running, verify that the Filter Press. reading is greater than 2.5 in. water.
 - e. If the blower is running, verify that the Blower state reading in "on".
 - f. Verify that the Cooler status is reported as "on" unless the State Description is reported as "Detector warming up".
 - g. Verify that the Ge HV state reading is "on" unless the State Description is reported as "Detector warming up" or "Detector cooling down".
6. Under the window area labeled Op. Mode:
 - a. Note the sample duration time.
 - b. Note if Decay, Blank, or Calibrate are "true".
7. Under the window area labeled Voltages:
 - a. Verify that the Battery voltage reading is at least 11.5 volts.

- b. Verify that the Sensors voltage reading is at least 4.5 volts.
 - c. Verify that the Logic voltage reading is at least 4.5 volts.
 - d. Verify that the CPU voltage reading is at least 4.5 volts.
 - e. Verify that the Motors voltage reading is at least 22 volts.
 - f. Verify that the NIM +24 voltage reading is at least 22 volts.
 - g. Verify that the NIM -24 voltage reading is less than -22 volts.
 - h. Verify that the NIM +12 voltage reading is at least 11 volts.
 - i. Verify that the NIM -12 voltage reading is less than -11 volts.
8. Under the window area labeled Temperatures:
- a. Verify that the NaI temperature reads in the range of 4 to 40°C.
 - b. Verify that the FlatPac temperature reading is at least as high as but no more than 50°C above the NaI temperature reading.
 - c. Verify that the Air Cond. temperature reading is at least as high as but no more than 10°C above the NaI temperature reading.
 - d. Verify that the Blower temperature reading is at least as high as but no more than 40°C above the NaI temperature reading.
 - e. Verify that the CPU temperature reading is at least as high as but no more than 15°C above the NaI temperature reading.
 - f. Verify that the Ge Amp temperature reading is at least as high as but no more than 10°C above the NaI temperature reading.
9. Under the window area labeled Power Status:
- a. Both the Battery and AC power status should be reported as "good".
 - b. Note that the AC Off status is not "true".
10. Verify that the Temperature, Bar. Pressure, Humidity, Dew Pt., Wind Speed, and Wind Dir. readings found in the window area labeled Met. Data are reasonably consistent with external environmental conditions.

3. Introduction

The Pacific Northwest National Laboratory (PNNL) Automated Particulate Sampler (APS) was developed for the purpose of radionuclide particulate monitoring for use under the Comprehensive Test Ban Treaty (CTBT). Its design was directed by anticipated requirements of small size, low power consumption, low noise level, fully automatic operation, and most predominantly the sensitivity requirements of the Conference on Disarmament Working Paper 224 (CDWP224).

3.1 Intention of Guide

This guide is intended to serve as both a reference document for the APS and to provide detailed instructions on how to operate the sampler. Chapter 4, which provides an overview of the system, contains the majority of the mechanical reference material. It describes the physical components of the system and the operations concepts. Chapter 5 provides information on installation requirements, including physical components and procedures. Chapter 6 contains a description of how automation is achieved via computer controlled hardware and it gives instructions for the computer based operation procedures. Finally, Chapter 7 provides mechanical maintenance instructions.

3.2 Description of Device

The Automated Particulate Sampler is capable of ultra-sensitive field measurements of short-lived fission products in near real time. The ultra-sensitivity of this sampler allows for the detection of fission products at large distances from nuclear detonations. The in-field, near real time measurement capabilities of the APS result in drastically reduced elapsed time between detonation and radionuclide detection confirmation.

A diagram of the basic conceptual elements of the APS is given in Figure 2-1. The APS passes air through a large-area, 0.25m², low pressure-drop filter at high flow rate. This is achieved by running twelve separate filter strips into an air sampling head designed to expose all twelve filter strips to the drawn air. A high volume, direct-drive blower is used to pull air through the filter strips. After the air sampling period, the filter strips are extracted from the sampling head, arranged one on top of the other, and then sealed by mylar on each side to form a continuous filter packet. This filter packet is then bar-coded for later identification purposes, folded, placed in front of a high purity germanium detector (HPGe), and counted. After counting, the acquired gamma-ray spectrum is transmitted to a designated data center via modem. All of the processes described above proceed automatically with no human intervention. Due to its filter paper roll loading capability (twelve 16 inch diameter rolls) the APS can operate unattended for up to 16 months on a standard one sample per 24 hours cycle. Automation is accomplished via computer control, and operation parameters such as sampling time can easily be changed by the user either at the deployment site or anywhere else via dial-in to the APS modem. User friendly graphical user interfaces (GUI's) have been implemented and allow easy access to state-of-health information, presently accumulating and archived gamma-ray spectra, and an operator's control panel. The operator's control panel reduces changing system parameters and schedules to the click of a button and/or the entry of a number where prompted.

Figure 3-1 Basic flow diagram of the APS system. The multi-colored arrows indicate the movement of the twelve individual filter strips into the air sampling head. The large blue arrows indicate the movement of the filter paper packet across the face of the HPGe detector upon exiting the air sampling head. The red arrows indicate the direction of air flow in the air sample head.

4. Overview of System

This Chapter presents descriptions of all components of the APS and an explanation of how the various parts of the sampler operate. The capabilities and limitations of the APS are discussed at the end of this chapter.

4.1 Description of Physical Components

4.1.1 Filter Paper and Dispensing Rack

The filter paper media used in the APS is obtained from 3M. It is designated by 3M as SBMF-40VF. This 3M brand Substrate Blown Microfiber (SBMF) filter media is an electret filter media which uses electrostatics and a combination of mechanical capture mechanisms to "collect" airborne particles. It consists of a durable round fiber that is bound to a substrate. It is important to note that this configuration results in two distinct sides of the filter paper, the fiber side and the scrim (substrate) side. The microfiber media is made of polypropylene fibers that will not support the growth of mold, mildew, fungus or bacteria and resists degradation over time. SBMF can withstand temperatures as high as 70°C (158°F) and 100% relative humidity levels, hence its strength is affected very little by water. The UL classification of the microfiber media is UL 900 Class 2.

The filter paper is packaged in rolls of 16 inch diameter and 5 inches in width. Twelve of these rolls are loaded onto the APS filter paper dispensing rack. This rack is comprised of two 38 inch long aluminum center support rods positioned horizontally, one on top of the other, with each rod holding six filter paper rolls where every other roll is oriented with the scrim side down (The configuration of the rolls is necessary for proper orientation in the air sampling head. See paper loading description in Section 5.2). Seven aluminum brackets, standing vertically, support the rods and separate the rolls. (See Figures 4-1 and 4-2) . The filter paper dispensing rack, fully loaded, measures 38" wide by 22" high by 34" deep, and it is mounted on sliding brackets which allow it to be retracted for ease of loading/unloading.

4.1.2 Filter Feed System

As the filter paper is drawn off the filter paper rolls on the dispensing rack, it must be turned and guided into the air sampling head. This is achieved by the Filter Feed System. (Refer to Section 5.2 and Figures 5-4 and 5-5 for details on loading the filter paper into the feed system.) Attached to the top and bottom of six of the aluminum brackets that support the 38" aluminum rods are sets of aluminum rollers that guide the filter paper off of each roll and towards the front of the APS. At about four inches from these rollers, the filter paper encounters a low friction nylon rod, measuring 1" in diameter and 10" in length, that is mounted on the aluminum brackets at an angle of 45 degrees. As the filter paper passes around one of these nylon rods, it changes direction by 90 degrees and comes off the nylon rod headed straight towards the air sampling head.

Figure 4-1 APS filter paper dispensing rack. The seven vertical brackets support two horizontal rods that sit in the hooks seen above. Each rod supports six filter paper rolls.

Figure 4-2 APS filter paper dispensing rack loaded with filter paper.

4.1.3 Air Sampling Head

The air sampling head is a semi-circular shaped aluminum structure measuring 18" in radius and 34" in depth. (See Figure 4-3). Paired slots are cut through the left side of the sampling head at intervals of 10" starting at the top and proceeding to the bottom. The filter paper strips are drawn through these slots and over wire gratings which serve to support the paper as air is drawn through it. These gratings measure 8" by 4" and thus, result in a collection area on the filters of the same dimensions. Looking at the front of the sampling head, these areas of paired filter strips over wire gratings appear as pie shaped cavities measuring 5" wide by 7.5" long. An intake pipe is located at the top of the air sampling head. This pipe extends to an outside air source. Behind the area containing the pie shaped cavities, an aluminum box is connected to the air sampling head. Air flows through the filters and into the volume of this box. The blower intake is coupled to the middle, right side of this box, and hence, air is exhausted through this coupling and on through the blower. (See Figure 4-4). The velocity of the air flow is continuously monitored by a Sierra Instruments Co. resistive thermal device, RTD, model number 600-V1-L13. (See Figure 4-5). This sensor is located in the inlet piping. The pressure drop across the filter is measured by a differential pressure gauge manufactured by Micro Switch, model number 164PC01D37. The gauge itself is mounted on the top of the APS enclosure directly above the air sampling head. Two tubes extend from this gauge and are exposed to the air flow on either side of the filter strips within the air sampling head at the top.

4.1.4 Blower

The APS uses a direct-drive high volume blower made by Dayton. This blower is especially well suited to small exhaust systems. The blower is comprised primarily of a one horsepower motor that turns a wheel on which fins are mounted. These fins serve to push the air through the housing scroll in which the wheel is mounted. An outlet pipe is attached to the outlet of the housing scroll and, hence, air is expelled through this pipe to the outside.

4.1.5 Filter Extrusion and Packaging Components

Three motors control the movement of the filter paper strips through the APS. They are designated as Motor 1, Motor 2, and Motor 3. Motors 1 and 3 are permanent magnet, 24 volt DC motors made by Pittman (model number GH9413G235). Motor 1 is located at the exit of the air sampling head and Motor 3 is located above the lead shielding. Motor 2 is a rotor nut, 24 volt stepping motor made by Applied Motion Products, Inc. (model number 5023-205-11). The filter paper movement is accomplished by an advance cycle which is broken into three separate and distinct combinations, or phases, of motor movements (these phases will be described in more detail below). During the execution of the three movement phases, the filter paper strips are moved off of the wire gratings and directed towards a single slot cut through the right side of the air sampling head, directly across from the paired slots through which the strips enter the sampling head. All twelve filter strips exit the air sampling head through this one slot and are thus aligned one on top of the other as they are extruded to the outside of the air sampling head. Upon exiting through the slot, the aligned filter strips proceed through two rollers, Roller Set 1, powered by Motor 1, using a spur gear. Two rolls of mylar tape are mounted above and below the rollers. The measurements of the mylar tape

Figure 4-3 Air sampling head.

Figure 4-4 Coupling of blower to sample head exhaust box.

Figure 4-5 Sierra Instruments Co. resistive thermal device used to measure air flow.

rolls are 6" in width and 6.25" in diameter when full. The mylar tape strips are fed through the rollers, one on top with the adhesive side down and one on the bottom with the adhesive side up, in order to encapsulate the aligned filter strips. Also mounted above the rollers is a roll of paper printed with heavy lines and bar-code numbers. The printed paper is fed into the rollers as if it were the top filter paper strip. The twelve filter strips, the printed paper, and the two mylar tape strips then compose a completely enclosed, sealed filter packet. (See Figures 4-6 and 4-7). This packet then proceeds through the rest of the APS system.

4.1.6 Filter Positioning and Counting Placement Components

Once the filter packet travels through Roller Set 1, it needs to be folded to a 4" by 4" area and positioned on top of the high purity germanium detector for gamma ray counting. In order to achieve this the heavy black lines, called position verification bars, which appear on the top side of printed paper are used. These bars are printed at 15" intervals. Sets of three optical sensors are located just below the top mylar tape roll and just before Motor 3. (See Figure 4-8). When the position verification bars are detected by these sensors, the motors are instructed to discontinue movement. Hence, an exact length of filter packet is maintained between these two sets of sensors. The bar-code number between each set of position verification bars is read by a bar-code reader (Symbol Technologies model # LS1220) located above Roller Set 1, and recorded by the Supervisor Computer just before a new exposed filter area is encapsulated by the mylar tape. Hence, all exposed filter areas are uniquely specified by their bar-code number which can be read by an operator to identify selected areas for further analysis.

The filter packet passes over a folding rod that is held in place by a bracket which is connected to a threaded rod at a right angle. (See Figure 4-9). These three components are referred to as the folding assembly. This threaded rod is coupled to Motor 2 and pulls in and out of a rectangular cavity with an opening of 1", referred to as the HPGe detector counting area. The exposed filter area is centered on the folding rod, via the position verification bars. As the folding rod is pulled into the rectangular cavity by Motor 2, the filter packet is pulled from its center and folded on top of itself as it proceeds into the cavity. The in and out position of the threaded rod is determined by two sets of optical sensors. A white nylon disk is attached to the threaded rod and the sensors are located at the positions where the disk is present when the folding rod is fully in and fully out. When the disk is detected by the sensors, Motor 2 is instructed to discontinue movement.

Once the gamma-ray counting has been completed, the rod is pushed back out of the HPGe detector counting area and Motor 1 and Motor 3 advance the filter packet strip to the next exposed filter area.

4.1.7 Detector System and Associated Electronics

The bottom of the rectangular cavity comprising the HPGe detector counting area is made of a 1/32" aluminum sheet. A Canberra Industries Inc. 90% High Purity Germanium (HPGe) detector is located about 1/4" below this aluminum sheet. The HPGe crystal measures 2.97" in length and 2.95" in diameter. (See Figure 4-10). It is mounted on a Freoelectric cooler which uses an environmentally friendly coolant (non-flammable, non-toxic, non-CFC, gas-based, mixed refrigerant used in an auto-cascade system) to cool the detector to a temperature

Figure 4-6 Cross-section of filter paper packet showing the mylar tape on both the top and bottom, the printed paper (with the bar-code and position verification bar) just below the top mylar, and the twelve separate filter strips labeled as the paper bundle.

Figure 4-7 Section of filter paper packet showing bar-code labels and position verification bars.

Figure 4-8 Location of optical sensors, bar-code reader, Roller Set 1, printed paper and mylar tape rolls.

Figure 4-9 HPGGe detector counting area and folding assembly. The counting area is the volume within the aluminum box. The threaded rod of the folding assembly can be seen extending from the counting area on the far right. The folding rod over which the filter packet passes is seen in the right part of the top circular opening. The folding assembly is viewed here in its "in" position.

Figure 4-10 HPGGe detector and cooler used in the APS. See text for detailed description.

of about -100°C . This is the optimal operating temperature for an HPGe detector. The HPGe crystal is contained in a protective and insulating housing which also contains high voltage circuitry and a preamplifier for the detector signal. Bias is supplied to the detector via an EG&G Ortec 660 Bias Supply. The output of the preamp is connected to a Canberra Industries Inc. 2024 High Rate Amplifier. The output of the amplifier goes into a Canberra Industries Inc. 8713 Analog to Digital Converter (ADC). The ADC is read out by a digital IO board, manufactured by Diamond Systems, connected to CPU 1. The Bias Supply, Amplifier and ADC are all standard NIM modules. (See Figure 4-11).

4.1.8 Power System

DC Voltages of 5, ± 12 , 15, and ± 24 volts are needed within the APS system hardware. The NIM modules require ± 12 and ± 24 volts. All three motors require 24 volts. The optical sensors and CPU 1 and 2 require 5 volts. The anemometer and differential pressure sensor require 15 volts. The HPGe detector cooler and the blower run off of 120 Volts AC as does the Supervisor Computer, a Gateway PX-100. In order to supply the necessary DC voltages, a Vicor FlatPac (model number VI-MA1-CS) converts the incoming 120 VAC to 48 VDC. This is then directed into a Vicor Bat Mod (model number VI-231-CU-BM) which serves as a DC to DC converter, outputting 12 VDC. The Bat Mod is also connected to a 12 volt, car type battery. The Bat Mod will charge the battery if it detects that the battery is depleted and will maintain a slow trickle charge if the battery is not depleted. The 12 volt output of the Bat Mod is run into several converters: 12 volt to 5 volt DC-DC converters (Vicor Mega Mod jr model number VI-LJ00-CZ), 12 volt to 15 volt DC-DC converters (Vicor Mega Mod jr model number VI-LJ02-CY), 12 volt to 24 volt DC-DC converters (Vicor Master Mod jr model number VI-PJ033-CYY, and a Vicor Mega Module model number VI-M03-EV), and 12 volt to 12 volt DC-DC converters (Vicor Master Mod jr model number VI-PJ011-CYY). The 12 volt to 12 volt DC-DC converters are necessary to maintain the proper 12 volt levels when running off the battery. The ± 12 volt and ± 24 volt outputs are run into ripple attenuation modules (Vicor model number VI-RAMC1) to ensure that the power supply to the NIM electronics is of the highest quality.

In order to prevent the loss of a sample or data due to power brown-outs or short (<20 minute) black-outs, the APS power system has substantial battery back-up components. As discussed above, the Bat Mod is connected to a 12 volt battery. If the incoming 120 VAC is interrupted, the 12 volt output of the Bat Mod is maintained by the battery which will last up to 2 hours. The Supervisor Computer, the external hard disk and the modem power runs through a Smart-UPS (uninterruptible power source) made by American Power Conversions (APC). In the event of a power failure, this unit will run the computer for over two hours.

4.1.9 Computer Systems

The APS computer system is an embedded system that utilizes 3 CPU's. CPU 1 is concerned with data acquisition. CPU 2 is involved with motor control and sensor information acquisition and processing. The third CPU is in the Supervisor Computer which oversees data transfer from the other two CPU's and handles communications with the outside world including file transfer operations.

Figure 4-11 Example of some standard NIM modules used in the operation and readout of the HPGe detector. See text for details.

4.1.10 Electronics Module Panel Displays

In the leftmost section in the front of the APS, three white panels (labeled Electronics Module 1, Electronics Module 2, and Electronics Module 3) display various information about the state and operation of the APS system and contain switches for controlling power states and motor motion. (See Figure 4-12). The leftmost panel, Electronics Module 1, contains switches to turn off and on the AC MAIN, the DC MAIN, the cooler, and the blower. In addition, fuse sockets for the AC MAIN, the DC MAIN, the cooler, the blower, the battery, and the A bus are present and easily accessible. Electronics Module 2 contains power switches and indicator lights for CPU 1&2, NIM electronics, logic circuitry, detector high voltage, the position sensors, the bar-code scanner, and the differential pressure sensor/anemometer. Fuses for the NIM electronics and the CPU main are also present on this panel. Electronics Module 3 contains a diagram of the filter feed system with sets of triplet indicator lights at positions designated as POS 1, 2, 3 or 4. Each set of lights represents an optical sensor set which is comprised of three separate optical sensors, hence the three indicator lights. These sensor sets are operated in majority logic mode (see Section 4.2.3) so when at least two of the three lights are lit, either a position verification bar (as in the case of POS 1 and POS 3) or a nylon disk (as in the case of POS 2 and POS 4) has been detected. These lights are extremely helpful when operating the motors manually. Electronics Module 3 also contains switches for running the three motors right on the panel, as well as a Motor Control Interface into which is plugged a motor control pod with a 10 foot cable enabling a single person to operate the motors while simultaneously observing their motion. The temperature status of the HPGe detector is reported on this panel via a green indicator light for "cold" and a red indicator light for "warm".

4.1.11 Metstation

The Metstation (short for Meteorological Station) is a commercial stand alone unit made by Qualimetrics Inc. which measures temperature, wind speed and direction, barometric pressure, and humidity. (See Figure 4-13). It is comprised of two units connected via cable. The first unit contains the actual measurement hardware which includes a thermometer, a hygrometer, a barometer, an anemometer, and a wind vane. The second unit is the control box which contains an embedded microcontroller, an LCD display, and a key pad. The control box has an RS-232 port which is used to interface with the APS CPU.

4.2 Principles of Operation

In the previous section, descriptions of APS components were presented but, little explanation of the philosophy behind component design or the idea behind component function was given. These concepts are discussed below.

4.2.1 Filter Paper Translation

In order to achieve the desired sensitivity to gamma-emitting isotopes that can be filtered from the air, a large volume of air needs to be sampled. This can be done in several ways but, due to restrictions on power consumption and noise levels, the APS system employs a high-volume, low-pressure-drop blower to move air through the filter media. Due to this low-pressure-drop property, a large area of filter paper is needed to pass the required volume of air through the system in 24 hours. The APS uses 0.25 m² of SBMF-40VF which is divided into 12 strips with an active area measuring 8" by 4".

Figure 4-12 Electronics Module Panel Displays.

Figure 4-13 APS Metstation.

The general idea behind the filter paper translation through the APS system is that filter paper must be drawn off of twelve rolls, fed into the air sampler head in the correct orientation, with the scrim side in contact with the wire gratings, and then the exposed twelve strips must be combined and sealed into a compact packet. This packet is then folded in half and moved in front of the HPGe detector. The packaging and folding functions are performed in order to minimize the volume of the exposed filter and to place it as close to the HPGe detector face as possible. By doing this, the efficiency of the HPGe crystal is effectively increased since it covers a relatively larger solid angle from the perspective of the exposed filter media. After the filter has been counted, the filter packet is removed from the HPGe detector counting area and the next filter is positioned and folded.

4.2.2 Air Sampling

The twelve filter strips are drawn into the air sampler head and over the wire gratings as described in Section 4.1.3. It is important to note that the scrim side of the filter paper has high tensile strength (but low friction), and must be placed against the wire grating. Thus, every other filter paper strip is loaded into the air sampling head in alternating orientations. Once the filter advancement is completed, the blower is turned on and air flows through the filter strips. The scrim, although strong, is sufficiently flexible to conform to the wire grating and effectively seal the filter under the pressure of the drawn air thereby restricting air to flow through the filter as opposed to around it. The air velocity and pressure drop across the filter are continuously monitored. The total air volume filtered is determined by integrating the air flow, using the known intake duct dimensions, over the duration of the draw. All three of these parameters, air velocity, pressure drop and total air volume, are continuously reported in the state-of-health display and stored on the Supervisor Computer. (See Section 6.1.3.)

4.2.3 Sample Positioning

The positioning of the sample in the HPGe detector counting area is critical to achieve the highest efficiency possible for the detector. As described in Section 4.1.6, sets of three optical sensors are located just below the top mylar tape roll and just before Motor 3. These sensors look for the position verification bars which are printed on the paper strip which can be seen through the top layer of mylar tape. The sensors come in sets of three and operate in majority logic mode. That is, at least two of the three sensors must return a positive signal before detection of a position verification bar is made. This eliminates problems with noisy sensors or occasional misreads due to surface reflection variations inherent in this type of dynamic system. The in and out positions of the filter in the HPGe detector counting area is determined by an additional two sets of optical sensors which detect a white nylon disk attached to the translating threaded rod as explained in Section 4.1.6. These two sets of sensors are also comprised of three individual sensors operating in majority logic mode.

The movement of the filter proceeds in three phases and results in a filter packet translation of 15". In phase 1, the folded, exposed area of the current filter is pushed out of the HPGe detector counting area by translating the threaded rod to the out position via Motor 2. Motor 3 runs forward in this phase to keep the filter paper packet taut throughout its entire length. Phase 2 begins with both Motor 1 and 3 running forward. Motor 2 remains inactive throughout this entire phase. When a position verification bar passes under the optical sensors located near Motor 3, both Motor 1 and Motor 3 discontinue moving. At this point, the filter paper packet is still taut throughout its entire length. During phase 3, Motor 2 pulls the filter

packet into the HPGe detector counting area. At the same time, Motor 3 runs backwards slowly and Motor 1 runs forward slowly to provide the extra length of filter packet needed to feed into the HPGe detector counting area. All three motors stop their motion based on independent criteria. Motor 1 discontinues motion when a position verification bar is detected by the optical sensor set located directly above it. Motor 2 discontinues motion when the threaded rod is detected in the full in position. Motor 3 discontinues its motion when the motor has turned a set number of turns, i.e., the filter paper packet has been pushed back through the last set of rollers 7.5". With these three criteria met, the exposed filter area of the subsequent sample is properly centered above the HPGe detector.

4.2.4 Sample Counting

As stated previously, the twelve filter strip packaging and filter packet folding functions are performed in order to minimize the volume of the exposed filter and to place it as close to the HPGe detector face as possible. By doing this, the efficiency of the HPGe crystal is effectively increased since it covers a relatively larger solid angle from the perspective of the exposed filter media. In order to reduce the background observed by the gamma-ray detector, a 4" lead shield surrounds the HPGe detector counting area.

Once the exposed area of the filter packet is positioned in front of the HPGe detector, gamma-ray counting commences. A program, denoted COLLECT_DATA, reads ADC values and fills an array of energy values by incrementing the appropriate energy array element for each ADC readout.

4.2.5 Automated Operations Control

Because the APS may be deployed in remote locations, and because labor costs must be kept to a minimum, the system has to operate on a day-to-day basis without direct operator intervention. To accomplish this, all filter advancement functions, sensor readouts, and data acquisition are computer controlled. These controls are done from two embedded PC/104 format CPU's. CPU 1 controls the data acquisition while CPU 2 controls all motor functions and all sensor readouts. CPU 3, the Supervisor Computer, runs the system control programs which instruct CPU 1 and CPU 2 to perform various tasks. These three CPU's communicate via an Ethernet connection. A detailed discussion of CPU layout and design and existing software and its operation is given in Section 6.1.

4.2.6 Automated Communications Control

Once data has been collected for a sample, it must be automatically sent over intercontinental distances to a central data repository. At the end of a data collection period, the acquired gamma-ray spectrum information file is copied to an archive directory and a second directory called TOBESNT. A communications script runs every 10 minutes to determine if files exist in the TOBESNT directory. If so, they are sent to the data repository via a modem using internet standard File Transfer Protocol, FTP.

The other very significant component of the APS automated communications control involves remote dial-in to the Supervisor Computer. This allows a remote user to view all the APS X-Windows just as they are seen on the monitor connected to the Supervisor Computer. Hence, all operations information, state-of health information and the gamma-ray spectra can be viewed remotely. Additionally, all operation parameters, such as sample draw interval, can

be changed remotely via the Operators Control Panel window, just as it is done on the monitor connected to the Supervisor Computer.

4.2.7 Power Failure Recovery

Since remote deployment may result in the use of external power which may not be reliable or "clean", the APS has been prudently designed to gracefully deal with power spikes, power brown-outs and short duration (<20 min) power failures.

Section 4.1.8 describes the power backup hardware in detail. The basic design has the outside power for the motors, NIM electronics, CPU 1 and CPU 2 in parallel with a 12 volt battery. Current is drawn from the battery only when the external power fails. The Supervisor Computer receives its power through an American Power Conversion Smart-UPS system. This system has a dual function. The UPS conditions the external power to the computer to prevent power fluctuations which could potentially take down the computer. The UPS also contains a large battery which can run the computer for over two hours in the event of a power outage.

The blower and the HPGe detector cooler are run off of external power through solid state relays. In the event of a power failure, both the blower and the cooler turn off. If the power failure is of short duration, less than 20 minutes, then the cooler can simply be restarted when the power is restored and no significant warming of the detector occurs. If the power failure duration is longer than 20 minutes, then the HPGe detector will warm-up enough that a complete thermal cycle will have to be performed. (The HPGe crystal and/or Preamplifier can be damaged if voltage is applied when the detector is not completely cooled.) A complete thermal cycle includes a 24 hour warm-up period and a 24 hour cool-down period. Of course the cool-down period can not commence until power has been restored. If power is interrupted at any time during a cool-down period, a complete thermal cycle is performed thus, preventing any possible damage.

4.3 General Information

The APS system design and principles of operation are optimized for the specific group of criteria exacted. Hence its performance in a particular category could be improved significantly if a different group of criteria were imposed. As a simple example, filter paper rolls of much larger diameter could be used to extend the stocking interval of the APS to a multiple number of years, as opposed to about one year, if size restrictions were not of great concern. Additionally, if power and noise restrictions were not of great concern, a higher pressure drop blower could be used resulting in a larger volume of air filtered in 24 hours. Hence, greater sensitivity would be achieved.

4.3.1 Capabilities and Options

The APS system is designed to be deployed in the field. This dictates that the system must be able to deal with severe environmental and climatic conditions. All components of the APS will function over a temperature range of 40°F to 100°F. The APS is completely protected within an aluminum enclosure and, hence, the filter paper and mylar tape stock remain unexposed to the outside elements at all times. The air intake duct is covered with screen to prevent debris from entering the air sampling head. Sections 4.1.8 and 4.2.7 have detailed the APS power system which is designed to operate under unstable external power conditions.

The APS Field Test Model was specifically prepared for operation in the climate/weather conditions of Northern California. Systems deployed throughout the globe will include site specific options that will enable the systems to function optimally in all sorts of climates and weather conditions such as environments of high strength windstorms, heavy rains and snow-fall. Available options can be found in Appendix 3.

5. Installation

5.1 Installation Procedure

The prototype APS system undergoing evaluation at McClellan AFB was delivered and is operated in a self-contained trailer, as was agreed by all parties prior to the commencement of the evaluation. (See Figure 5-1 and 5-2.) Installation of this prototype system involved a number of steps which are outlined in the Installation Checklist found in Section 2.1. Also, refer to the installation diagram in Figure 5-3. First, the Building 626 C-Bay (referred to as the warehouse) that would be housing the trailer was prepared. A space of appropriately cleared area near a window (for ducting in outside air) was chosen as the trailer placement site. This area was supplied with 220 VAC, 15-Amp power.

To begin the actual system installation, the trailer was backed up the ramp at the end of the Building 626 and down the dock in front of the building to the set of doors nearest the installation site. The trailer was then maneuvered into the warehouse and into the desired location. Once the trailer was properly positioned, it was then leveled and securely supported. The trailer was then open and system setup within the trailer began.

All support equipment used to secure the system components during travel were removed. The toolbox, ducting, and system consumables were removed from the trailer and laid aside. The two support stands were then properly placed in the desired position and the main body of the APS was lifted onto them. Next, the duct work for the air intake and the air exhaust was installed. The Supervisor Computer was set up on a table located to the left of the APS main body. The next step consisted of properly positioning and supporting the HPGe detector under the HPGe detector counting area. This was accomplished by carefully guiding the detector through the carefully positioned cutout in the aluminum directly under the counting area. Once the detector was all the way through the hole it was secured with its own screw down handles by screwing through a bracket in one of the support frames. The mechanical cooler was then placed adjacently on the floor just to the left of the detector. With the detector in place, all wiring was then interconnected.

Lead in the form of 4" by 8" by 2" bricks were used to build a shield around the HPGe detector counting area allowing for provisions to permit the filter paper packet to move into and out of this area. After the lead shield was built, power was connected to the trailer and the phone line was connected to the APS modem. The next step was to load the filter paper into the filter paper dispensing rack and thread it through the filter feed system and through the air sampling head. A detailed explanation of how to load the filter paper is given in the following section. The Supervisor Computer was then turned on and software tests were conducted to check the operation of the filter feed system, the blower, and the HPGe detector.

5.2 Filter Paper Loading

Locate the filter paper dispensing rack. Remove the retaining nut and withdraw the empty filter reel support structure. (See Figure 4-2.) Remove the filter reel assemblies by withdrawing the center support rod while holding the filter reel assembly farthest from the retraction end. Once the reel assembly is no longer supported by the rod, remove it from the

Figure 5-1 APS prototype test trailer.

Figure 5-2 APS system inside trailer.

Figure 5-3 Basic installation diagram for the APS Field Test Model.

reel support structure and place it on the floor. Repeat these steps until all twelve reel assemblies have been removed. Load each reel assembly with a filter paper roll by pushing the two disks together at the center while turning in a clockwise direction. Separate the two unlocked halves and insert a filter paper roll. Reassemble the loaded reel assemblies by joining the two halves together and turning counter clockwise to lock them. Now all reel assemblies are filled with filter paper and ready to be loaded back onto the filter reel support structure.

The filter paper filled reel assemblies must be loaded back onto the reel support structure in a particular orientation such that the scrim side of the filter paper strips are always facing the wire gratings once they get to the air sampling head. The two available orientations are scrim side up or scrim side down. The scrim side up orientation is achieved by placing the reel assembly on its support rod in such a way that the filter paper is drawn off the top of the roll. The scrim side down orientation is achieved by placing the reel assembly on its support rod in such a way that the filter paper is drawn off the bottom of the roll. Figure 5-4 illustrates the desired orientation of each reel.

The filter paper threading is best explained via the drawing given in Figure 5-5. Each strip follows a unique path to occupy its designated slot in the air sampling head. Once each strip has been positioned correctly, they are all collected together and feed out through the exit slot in the air sampling head. Load the bar-coded and position verification bar printed paper strip into its holder and thread it down to Roller Set 1. Do the same for both rolls of mylar tape. The manual motor control box can then be used, by advancing Motor 1 in the forward direction, to move the twelve filter strip, the paper and the tape through the roller resulting in a filter paper packet at the exit of Roller 1. This filter paper packet is threaded through the folding assembly and Roller Set 3. Once the filter paper packet is extruded through Roller Set 3, filter paper loading is complete.

To properly orient the position verification bars, a filter paper advance cycle should be run. This is automatically done when the MASTER_CONTROL process (see Section 6.1.3) is run for the first time. Turn the Supervisor Computer power switch to the "on" position. The computer will automatically initiate the MASTER_CONTROL process as part of its start-up instructions and hence, the filter paper will be properly positioned and air sampling will commence.

Figure 5-4 Orientation of filter paper rolls as seen when looking from the front of the APS system.

Figure 5-5 APS filter paper threading diagram. Each filter strip is color coded so that its unique path to the air sample head can be traced.

6. Automation and Functional Operation Procedures

The operation of the APS is fully automatic. All day-to-day function are performed via instructions issued by the Supervisor Computer to CPU 1 (data acquisition) and CPU 2 (sensor readout and motor control) at specific times and in specific sequences. A group of windows has been created which facilitates the interaction of the operator, whether located locally or remotely, with the system through the Supervisor Computer.

6.1 Automated Computer Control

Automated computer control of the APS is accomplished via multiple, embedded CPU's running under the QNX operating system and communicating with each other through an ethernet network.

6.1.1 QNX Operating System

The design of the computer hardware and software heavily depends on what operating system is used. The APS operating system was chosen to be QNX OS, based on the features it provides and the advantages it offers. The QNX operating system is a 32-bit, protected mode, multitasking operating system designed specifically for embedded, real-time applications by Quantum Software Systems LTD. To best accommodate these applications, the QNX operating system is necessarily small, i.e., it takes up little disk space, and it is very robust with emphasis on low overhead, as in low interrupt latency and fast context switches. The QNX operating system is designed specifically for industrial applications and, as such, it provides a level of integration and reliability not possible on DOS based machines.

The QNX operating system also provides integrated network support which makes multi-CPU implementations easy to design and maintain. Also, the QNX operating system supports the universally expected TCP/IP network protocol which makes interfacing with dissimilar architectures, i.e. different computer platforms such as IBM/IBM compatible Personal Computers, Macintosh Computers, Sun Microsystems Computers, etc., very straightforward.

6.1.2 CPU Design and Layout

The APS is designed around three Central Processing Units, designated as CPU's. CPU 1 provides HPGe detector data acquisition. CPU 2 provides hardware control functions and sensor readout while the Supervisor Computer (CPU 3) provides high-level system event scheduling, data storage and transmission, and the user interface. All CPU's are connected together through a thin-net ethernet interface and they can also be accessed remotely via modem. CPU1 and CPU 2, the two hardware interface computers, boot over the network and transparently use the hard disk drive on the Supervisor Computer as if it was their own. Although neither system has a keyboard or video display monitor, they can be completely remotely controlled from either the Supervisor Computer or a computer on the network, including remote modem systems.

CPU 1, the HPGe detector data acquisition computer, is an embedded computer and is an industry standard PC/104 format PC based on a 25 MHz 80386 CPU. It functions as a Multi-channel Analyzer (MCA) for the HPGe detector. It uses a simple digital I/O card, made by Diamond Systems, to interface with a Canberra 8713 NIM mounted analog to digital con-

verter (ADC) which digitizes the signal pulses as they arrive from the detector. Separating the Multichannel Analyzer functions of the APS from the rest of the hardware control facilitates possible conversion to a commercial Multichannel Analyzer in the future if a commercial unit were desirable. (See Appendix 3).

CPU 2, the hardware control functions and sensor readout computer, is also a PC/104 format PC based on a 25 MHz 80386 CPU. CPU 2 uses digital Input/Output (I/O) boards from Diamond Systems and analog input boards from Real Time Devices to provide control over all other hardware sub-systems including the thermal sensors, voltage sensors, airflow sensor, pressure sensor, bar-code reader, filter advance motors, blower, and cooler.

The Supervisor Computer, so named because it provides the event scheduling for the overall system, is based on a standard desktop 486 computer. This architecture was chosen because it was readily available and inexpensive. Certainly, any Intel based computer system with a video display and keyboard could be used. Future versions of the APS will use an industrial rack-mounted CPU which will be physically located in the same chassis where CPU 1 and 2 reside.

The Supervisor Computer provides all functions which do not involve direct hardware interfacing such as the graphical user interface, data storage, sensor status monitoring, system event scheduling, and modem communications.

6.1.3 Software Description

The ability of the QNX operating system to efficiently support concurrent processes running on multiple CPU's has greatly reduced and simplified the task of software development for the APS. The entire control system is client/server based and is implemented as a series of small, specific processes which communicate with each other via a simple but powerful message passing scheme. These specific processes are of two type; (1) the processes that are required, core processes that run continuously, and (2) utility processes that may be started and stopped as the user desires. Table 6-1 lists all the processes of type 1. Table 6-2 lists all the processes of type 2.

TABLE 6-1 - Required, core processes that run continuously.

Process	CPU	Description
POWER_SYSTEM	CPU 2	Keeps track of the current AC power status
AIR_VOLUME	CPU 2	Accumulates total air volume drawn
MASTER_CONTROL	Supervisor	Coordinates all system events
LOG_BOOK	Supervisor	Logs status and error messages to disk
COLLECT_DATA	CPU 1	Operates the HPGe detector data acquisition
CLIMATE_MONITOR	CPU 2	Interfaces to the weather station
MOTOR_MANAGER	CPU 2	Controls the filter advance motors 1, 2 & 3
SENSOR_MANAGER	CPU 2	Manages all other sensor and hardware control

TABLE 6-2 - Utility processes that are run when desired.

Process	CPU	Description
CALIBRATE_DATA	Any	Generates calibration data based on radon peaks
CONFIGURE_SYSTEM	Any	Text based system user interface
VIEW_LOGS	Any	Displays system error and status logs
MONITOR_SYSTEM	Any	Text based system status display
XWINDOWS_MENUS	Supervisor	X-windows based user interface

By implementing a set of small client processes, a number of benefits are realized. For instance, the code for each client is small and is dedicated to only a few well defined tasks. This makes the system highly modular and easy to maintain. Also, unless servicing a request, client processes spend their time in a suspended state. Hence, even though they are continuously ready to run, they don't actually use CPU time until they are being actively accessed.

A feature that is extremely important and central to the software architecture is that the clients can process server requests from multiple sources simultaneously. As an example, the SENSOR_MANAGER client process handles the hardware interface to all of the systems status sensors. The MASTER_CONTROL process requires certain pieces of sensor data as part of its normal operation. Rather than reading the data directly from the sensors itself, MASTER_CONTROL sends a request to SENSOR_MANAGER to provide the necessary sensor data. SENSOR_MANAGER then interfaces with the relevant sensor hardware, acquires the needed data and sends it to the MASTER_CONTROL process. At the same time that MASTER_CONTROL is making its request to SENSOR_MANAGER, other processes such as AIR_VOLUME, POWER_SYSTEMS, XWINDOWS_MENUS, and MONITOR_SYSTEM may also be requesting sensor data. All of these requests are automatically handled by the SENSOR_MANAGER process on a first come, first serve basis. The advantages of this structure are two-fold. First, hardware access collisions can not occur because only one process at a time actually has direct access to the hardware (SENSOR_MANAGER in the above example). Indeed, it is often the case that multiple copies of the same process, usually the MONITOR_SYSTEM status reporter, are running at the same time- one copy on the Supervisor Computer, one copy on a temporary debugging station and one copy running on a remote computer accessing the APS system via modem. Disaster would most certainly result if all of these processes were competing to access the hardware simultaneously. Second, new processes requiring sensor data can be added to the system at any time without having to make changes to SENSOR_MANAGER.

This multiple access capability is not unique to the SENSOR_MANAGER process used in the example. It is a common feature of all processes running on the APS system. Besides averting the disaster of hardware access collisions, this feature allows for control versatility. For instance, the state of the blower motor (either off or on) is normally controlled exclusively by the MASTER_CONTROL process. However, since the blower motor is actually controlled by SENSOR_MANAGER, other processes can be added to the APS system which also control the blower motor. This allows the user, through a user interface or other process, to manually turn the blower off and on allowing for diagnostic activities such as observation

of air flow and pressure sensor response to sudden air flow changes. This "manual override" capability applies equally well to all processes in the APS software.

Another, slightly more sophisticated, example which illustrates the versatility of the multi-process client/server approach involves the COLLECT_DATA process. Normally, MASTER_CONTROL requests a gamma-ray spectrum from the COLLECT_DATA process typically every 24 hours. If the user was interested in seeing how the spectrum changed over smaller time intervals during the entire 24 hour count, under the client/server approach the user could trivially start a new process which requested the gamma-ray spectrum from COLLECT_DATA every 15 minutes, hour, or whatever time interval was desired. These requests would be handled naturally by the COLLECT_DATA client and would, in no way, interfere with other data acquisitions (i.e., MASTER_CONTROL's). Note that this new spectrum logger process can be developed remotely, uploaded to the system via modem, and then started remotely. It is not necessary for the user to be physically located at the APS to change or add software.

The real "brains" of the APS software is the MASTER_CONTROL process. It runs on the Supervisor Computer and is responsible for coordinating all system activities. The MASTER_CONTROL process is based on a 13 node state machine. (See Appendix 1 for a diagram and description.) Each of the 13 nodes represents one of the possible states that the sampler can be in at any time (Detector Cooling Down, High Voltage Coming Up, etc.). From each state there are one or more possible transitions to other states. Associated with each transition is a set of conditions and a set of actions. At an interval of one per second, MASTER_CONTROL tests the set of conditions associated with each possible transition from the state in which the APS is currently running. When one of these tests results in a set of conditions for a possible transition being met, the corresponding actions to that transition are executed and a state change occurs. Transition conditions are mutually exclusive so that no two transitions can have a valid set of conditions simultaneously.

6.1.4 Automated Filter Movement and Air Sampling

Central to advancing the filter packet is the MOTOR_MANAGER process. Operating through a Diamond Systems digital Input/Output card, it can enable or disable any of the three DC motors. Speed control is achieved by rapidly pulsing the motors on and off in software (software pulse width modulation). Encoders on each motor generate pulses which MOTOR_MANAGER counts to determine how far each motor has turned. This information is saved for troubleshooting purposes but is not actually used for filter positioning confirmation. All position information is gathered from the optical sensors which detect the position verification bars or the position of the white nylon disk on the threaded rod connected to Motor 2. Relying on optical sensors as opposed to counting pulses prevents any positioning inaccuracies that might occur because of irregularities in the filter bundle or by roller slippage.

A complete filter advance is done in three phases as dictated by the MASTER_CONTROL process. These three phases were outlined in Section 4.2.3. Phase 1 unloads the counted filter from the HPGe detector counting area by running Motor 2 at 100% velocity in the unload direction while running Motor 3 at 100% velocity in the forward direction. Hence, in this phase Motor 2 runs the filter folding assembly to its full out position while Motor 3 pulls up the slack. Motor 1 is not turned on at any time during this phase. Phase 1 is considered com-

plete 2.5 seconds after the folding assembly reaches its full out position. This extra time allows Motor 3 to take up any remaining slack.

In Phase 2, Motor 1 runs at 80% velocity in the forward direction, Motor 2 remains off, and Motor 3 runs at 100% velocity in the forward direction. Motors 1 and 3 run forward in order to advance the filter packet through the system. The Motor 1 on-time duty cycle is set to 80%, while Motor 3 is on continuously, to ensure that the filter paper remains taut during the advance. Phase 2 is considered complete when the optical sensor set mounted just before Motor 3 detect a position verification bar. The next exposed filter area is now centered on the folding assembly bar.

Phase 3 consists of Motor 1 running at 10% velocity in the forward direction, Motor 2 running at 100% velocity in the load direction, and Motor 3 running at 10% velocity in the reverse direction. In this phase, Motor 2 retracts the filter folding assembly back into the HPGe detector counting area while Motors 1 and 3 pay out slack. Motors 1 and 3 are both operated at an on-time duty cycle of only 10% so as not to overrun the relatively slow retraction of the folding assembly.

Air sampling is controlled and monitored by several processes. The air draw schedule is handled by the MASTER_CONTROL process as dictated by its state machine (see Appendix 1). MASTER_CONTROL indirectly starts, stops, and monitors air drawing by sending messages to the SENSOR_MANAGER and AIR_VOLUME processes. The blower motor power is controlled by a high-current solid state AC relay which is manipulated by SENSOR_MANAGER through a Diamond Systems digital Input/Output card. Monitoring of the air draw is accomplished through an RTD anemometer in the intake air stream and a differential pressure sensor which measures the pressure drop across the filter media (see Section 4.1.3). Both of these sensors return analog voltages which are digitized by a Real Time Devices Analog to Digital board and converted to appropriate units (meters per second for the air draw velocity and inches of water for the pressure drop). The AIR_VOLUME process maintains a software air volume accumulator which MASTER_CONTROL resets at the start of each sample cycle. AIR_VOLUME requests the instantaneous air draw velocity from SENSOR_MANAGER once per second and by integrating this velocity over one second for the given intake pipe cross-sectional area, an accumulated air volume is maintained. The total air volume drawn at any point in a cycle can be requested from AIR_VOLUME by any other process (MASTER_CONTROL, MONITOR_SYSTEM, XWINDOWS_MENUS, etc.) at any time.

6.1.5 Data Acquisition and Analysis

Data acquisition is handled by the COLLECT_DATA process which is responsible for servicing the detector's analog to digital converter (ADC). COLLECT_DATA incorporates an interrupt service routine (ISR) which is triggered with each detector pulse. When the ISR is triggered it reads the ADC information and then resets the ADC allowing it to begin accepting potential pulses to digitize. Once the ADC begins digitizing a new pulse, it once again triggers an ISR. All of the ADC information read by the ISR is packaged into an "event record" and placed in a large ring buffer. Once a second the COLLECT_DATA process checks to see if any new information has been added to this ring buffer. If so, each new digitized

pulse height value is used to construct spectral histograms which are stored in local memory buffers.

The COLLECT_DATA process responds to three service requests. These are: (1) start new acquisition, (2) stop current acquisition, and (3) transmit current accumulated spectral histogram. Note that a request to transmit the spectral histogram **does not** stop data acquisition nor does it reset the local memory buffer in which the spectral histogram accumulates. During normal operation the COLLECT_DATA process is started, stopped, and serviced by the MASTER_CONTROL process as dictated by its state machine. At the end of a normal counting cycle, the MASTER_CONTROL process requests the spectral histogram from COLLECT_DATA and saves it to the hard disk. An analysis process called CALIBRATE_DATA is then spawned to analyze the data to determine an energy versus channel conversion. Extensive calibration information for the spectrum is written to a temporary file on the hard disk. MASTER_CONTROL uses this information to construct the final data files, using the standard IEEE file format for single parameter gamma-ray spectra, which are written to the hard disk.

6.1.6 Automated Communications

As new gamma-ray spectrum files are created by MASTER_CONTROL, copies of these files are placed in a local archive directory as well as into a directory from which all files are transmitted called TOBESSENT. Once every ten minutes a process running on the Supervisor Computer checks to see if files are present in the TOBESSENT directory. If so, a series of TCL/Expect scripts are run which attempt to establish a point-to-point (PPP) connection via modem link to a designated off-site service provider. Once this connection is established, each file in the TOBESSENT directory is transmitted via File Transfer Protocol (FTP) to a designated off-site location such as the National Data Center (NDC). If a file's transmission is successful the file is then removed from the TOBESSENT directory.

This approach to transmitting files has several clear advantages. First, all file transmissions occur using standard internet File Transfer Protocol. File Transfer Protocol is an error free protocol which guarantees file delivery with no missing or corrupted data packets. Second, if, for whatever reason, a given attempt to establish a modem connection fails (perhaps a local phone line is busy, a remote computer system is down, etc.) the phone line is simply put back on-hook. Since no files were transmitted, no files were removed from the TOBESSENT directory and another attempt to transmit them will automatically occur in ten minutes. Third, if a point-to-point connection is established but not all files are successfully transferred (perhaps the phone line becomes noisy and the connection is lost, the FTP service is not available, etc.) only those files that were completely transferred are removed from the TOBESSENT directory. Any files only partially transferred and all files for which no transfer attempt was made remain in the TOBESSENT directory and another attempt to transmit them will automatically occur in ten minutes.

Note that the system can easily be configured to send data to a single site or to several different sites and that, although the current system is setup for file transfer only, it would be a relatively straight forward matter to extend the APS automated communications abilities to include e-mail. For example, daily status reports, unusual event occurrence messages, error

condition messages, etc., could be automatically e-mailed to all concerned parties. Most of the required functionality for this ability presently exists in the current scripts.

6.2 Functional Operation Procedures

All software necessary for running the APS is started automatically whenever the system is activated. Hence, the user need never be involved with starting up processes critical to the basic operation of the system. There are, however, of particular utility interest, three processes that the user may start and stop as desired. The first process is XWINDOWS_MENU. It is the X-windows based interface which lends itself to extremely friendly interaction with the user. XWINDOWS_MENU sets up various windows which allow the user to check the status of the APS, change operating parameters, view gamma-ray spectra, and shut down the system. A lengthy description of the windows associated with the XWINDOWS_MENU process is given in Section 6.2.2. The second process is MONITOR_SYSTEM and it is a text based status reporter. This process is started by typing *snoop* at the command prompt. The process can be exited at any time by pressing the <Esc> key. Once per second MONITOR_SYSTEM requests status information from SENSOR_MANAGER and other client processes and displays them in a simple text list on the display screen. Due to the long list of status items, MONITOR_SYSTEM should be run on displays that support at least 50 lines. Terminals displaying text under the QNX operating system, such as the Supervisor Computer, can be set to 50 line display mode by pressing the <Ctrl>, <Alt> and <.> keys simultaneously. The status information provided by MONITOR_SYSTEM is identical to that displayed in the State of Health Window which can be accessed through XWINDOWS_MENU (Section 6.2.2). However, MONITOR_SYSTEM offers a lower overhead (i.e. uses fewer computer resources) alternative to the graphical user interface. MONITOR_SYSTEM can be accessed via modem with only a terminal emulator. To run XWINDOWS_MENU remotely, a user needs to support point-to-point connections and have X-windows installed on the remote system.

The third process is CONFIGURE_SYSTEM. This process is started by typing *config* at the command prompt. The process can be exited at any time by choosing the "exit program" selection on the display menu. The CONFIGURE_SYSTEM process implements a simple text based menu which allows the user to request various system status items, make changes in the system operation parameters, and perform an orderly system shutdown. CONFIGURE_SYSTEM status items are also contained in MONITOR_SYSTEM and if the user is only interested in the current status of the APS then the MONITOR_SYSTEM process would be the better choice for status display. All the functionality of the CONFIGURE_SYSTEM process is contained in the Operators Control Panel which can be accessed through XWINDOWS_MENU (Section 6.2.2). However, just as was the case for the MONITOR_SYSTEM process, the CONFIGURE_SYSTEM process offers a lower overhead alternative to the graphical user interface and thus may be preferable to some users connecting to the APS via modem.

6.2.1 Initial Start-Up

When the APS Supervisor Computer is first powered up or after a reboot, a start-up script is automatically run which starts all of the processes required to run the system. No user intervention is required to get the computer system up and running or to establish automated control of the hardware. Because certain processes depend on other processes for information

(e.g., AIR_VOLUME requests its air draw volume information from SENSOR_MANAGER) it is necessary to start up processes in groups; lowest level groups first and then the next higher level group. A delay period of at least 10 seconds is provided between each group start-up to insure that all processes of a lower group have sufficient time to register their services with the operating system. The current start-up order for the APS is shown in Table 6-3.

Table 6-3 - Start-Up Order of Processes

Group	Processes
1	LOG_BOOK
2	SENSOR_MANAGER, MOTOR_MANAGER, COLLECT_DATA, CLIMATE_MONITOR
3	POWER_SYSTEMS, AIR_VOLUME
4	MASTER_CONTROL
5	CONFIGURE_SYSTEM, MONITOR_SYSTEM

6.2.2 APS X-Windows

In order to make interaction with the computer software as user friendly as possible, X-windows has been employed in the APS software. X-windows is a standardized Graphical User Interface (GUI) environment which runs under practically all major operating systems. Hence, operators accessing the system from computers running a variety of operating systems, will encounter the same visual set-up of the APS windows. APS windows are windows that have been created specifically for the system and each has a specific function. Once the operator has brought up the main window, all other windows appear when their associated buttons are clicked on. Most windows have a "Dismiss" button and a "Help" button. When the "Dismiss" button is clicked on, the window associated with it goes away (closes). When the "Help" button is clicked on, a new Help window appears. This Help window contains text that should aide the operator in understanding what the associated window is about and what courses of action are available

6.2.2.1 Main Window

The main APS window is brought up by typing *xaps* in an xterm window. A window frame then appears with its upper left hand corner attached to the mouse pointer. The window can be positioned by placing the pointer in the desired position and clicking on the left mouse button. (See Figure 6-1). The Main Window is composed of a picture of the APS system on the left side and a row of five buttons on the right side. When the pointer is placed over a button, the button border becomes highlighted. If the left mouse button is then depressed, a new window frame appears. This new frame is positioned in the same manner as the Main Window frame was positioned.

The button on the top of the column is the Operator Control Panel. Below that is the State of Health button. Below that is the Gamma-Ray Spectrum Display button followed by the Help button. The Quit button is at the very bottom of the column and if this button is clicked on

the Main Window closes. By once again typing *xaps* in an xterm window, the Main Window can be brought back up.

6.2.2.2 Operator Control Panel

When the Operator Control Panel button is clicked on in the Main Window, the Operator Control Panel Window comes up. (See Figure 6-2). This window is divided into two main sections. The left section has the heading "System Control Parameters". This section reports the current sample cycle period next to the Sample Duration label. By clicking and continuing to depress the left mouse button on the right part of the box containing the sample duration number, a small menu appears. Chose the desired sampling time from this menu by highlighting the desired number and lifting up on the left mouse button. Hence, by choosing 12, the operator can change the sample duration period for the next cycle to twelve hours. It is important to note that these changes will not occur until the next filter advancement. This means that the next air draw, the next decay period and the next counting period will all be of the same new duration. Hence a filter in the air sampling head set to draw for 24 hours when the operator changes the sample duration period to 12 hours, will complete its 24 hour draw but then decay and be counted for only 12 hours. Likewise, the filter decaying for 24 hours when the operator changes the sample duration period to 12 hours, will complete its 24 hour decay but will only be counted for 12 hours.

Below the Sample Duration appears three, vertically aligned boxes labeled "Decay", "Calibrate", and "Blank". By clicking the left mouse button on the "Decay" raised box, the operator can request that the sample is decayed before being counted by the HPGe detector. By clicking the left mouse button on the "Calibrate" raised box, the operator can request that a detector calibration be carried-out upon completion of the current air draw. A detector calibration involves expelling the filter paper packet from the HPGe detector counting area via Motor 2. A small calibration source is embedded in the folding assembly (see Section 4.1.6) in a region of the threaded rod. As the folding assembly moves forward, expelling the filter paper packet, the source moves from its usual position behind the lead shielding to a position in front of the HPGe detector. Once the source is in position, data acquisition ensues for a duration of 5 minutes. The resulting calibration data is archived and automatically sent to the specified data repository.

If the raised box labeled "Blank" is clicked on with the left mouse button, the operator has then requested that an unexposed filter paper packet be counted. This means that the sample duration schedule will remain unchanged but when the next group of filter strips are moved into place in the air sampling head, the blower is simply not turned on. After the sample duration period, the unexposed filter strips continue through the APS normally, and are counted in the HPGe detector counting area, in exactly the same manner that an exposed filter packet would be counted. Note that if the operator has designated that the APS is allowing the samples to decay, results from the blank will not be available until three complete sample duration periods have passed since one period is spent in the air draw position, the second period is spent in the decay position, and the third period is spent counting the blank filter. At the end of the last period, the resulting "blank" data is archived and automatically sent to the specified data repository. If no decay is being done then the results are available in two sample duration periods. Counting a "blank" is done to take into account all the sources of

Figure 6-1 APS Main Window.

Figure 6-2 APS Operator Control Panel.

radiation present in the HPGe detector counting area that are not associated with the particulates filtered from the air.

When either the sample duration is changed or the states of one of the three raised boxes are changed, the button "Accept the Changes" must be clicked on with the left mouse button in order for any of the changes to go into effect. If any of the above mentioned changes are made and the "Accept the Changes" button is not depressed but rather the "Dismiss" button is depressed, the Operator Control Panel closes and the changes designated do not take place. When the "Accept the Changes" button is depressed, a new, small Operator Control Panel Notice window comes up. This window informs the operator that the changes made will not go into effect until the next sample change. The operator must click on the "Acknowledge" button to proceed.

The right section of the Operator Control Panel is labeled "System Shutdown". This section allows the operator to perform an orderly and safe shutdown by clicking on the "Shut Down" button. When this button is depressed, a new, small System Shutdown window appears which says, "If the APS system is not restarted within 20 minutes the system will go through a complete detector warm-up/cool-down cycle that will take 48 hours to complete". The shutdown can be aborted by clicking on the "Cancel the Shutdown" button at which time the System Shutdown window will close. The operator can elect to proceed with the shutdown by clicking on the "Shutdown Now" button. Once this button is depressed, a small System Restart window appears which says, "Restart will reboot the computer and then bring the APS system back on-line". Quit will only exit this program and the computer will not reboot". The operator then has the option to click on the "Restart" button or the "Quit" button. When either button is depressed, the screen will go blank. If the "Restart" button was depressed, the screen will come back up momentarily. Once the computer has completed its reboot, the Main APS window can be brought up by typing *xaps* at the prompt in an xterm window.

6.2.2.3 State of Health Window

When the State of Health button is clicked on in the Main Window, the State of Health Window comes up. (See Figure 6-3). This window contains identification information, operational state information, operating mode information, current voltage readouts, temperatures, power status, and meteorological information. A checklist for reviewing the State of Health window, including alarm values for readings of voltages and temperatures, is given in Section 2.2. The State of Health window is divided into seven main sections. The top section primarily provides identification information including the current date and time, the site identification designation (Site ID) which uniquely distinguish one APS from another, the current state of the APS (State) and the time associated with that state commencing, a text description of the current state (Description), and the sample number of the filter packet being counted in the HPGe detector counting area (Det. Sample ID). Just below the top section to the left, the Op. State section appears. This section reports the amount of air, in m^3 , filtered thus far in the draw (Air Volume), the velocity of the air, in m/s , as it enters the air sampling head (Intake Vel.), the pressure difference across the filter, in inches of water, (Filter Press.), and whether the blower and the cooler and the HPGe detector high voltage (Ge HV) are on or off. Below the Op. State section is the Op. Mode section. The sample duration period (Sample Dur.) is presented here as well as true or false indicators as to whether or not the

State of Health			
Site ID: TIME OUT		Wed Jan 10 11:05:09 pst 1996	
State: 3 (started Wed Jan 10 10:17:44 1996)			
Description: Detector cooling down			
Det. Sample ID: TIME OUT			
Op. State Air Volume: 2.4 m ³ Intake Vel.: 0.0 m/s Filter Press.: 0.0 in. water Blower: off Cooler: on Ge HV: off	Voltages (V) Battery: 13.79 Sensors: 5.00 Logic: 4.98 CPU: 4.94 Motors: 23.99 NIM +24: 23.99 NIM -24: -24.00 NIM +12: -12.00 NIM -12: 11.99	Temperatures (C) Nal: 20.5 FlatPac: 0.0 Air Cond.: 25.0 Blower: 19.0 CPU: 30.5 Ge Amp.: 26.5 View Temp. History	Power Status Battery: good AC: good AC On: 01/10/96 10:17:11 AC Off: n/a
Op. Mode Sample Dur.: 10 Decay: true Blank: false Calibrate: false	Met. Data Temperature: 15 C Bar. Pressure: 1021 mB Humidity: 58 % Dew Pt.: 7 C Wind Speed: 0 m/s Wind Dir.: 0 deg		
Update	Dismiss		Help

Figure 6-3 APS State of Health Window

sampler is set up to decay the samples before counting (Decay), whether or not a "blank" is being done (Blank), and whether or not a calibration is being done (Calibrate).

The section to the right of the Operating State and Mode has the heading Voltages (V). All voltages reported in this section are given in units of volts. The Battery voltage refers to the backup battery for the power to all the APS systems other than the Supervisor Computer. In addition to the Battery, the voltages for the Sensors, the Logic circuits, CPU 1 and 2, the three motors, and the power levels required for the NIM electronics (± 12 and ± 24) are presented. The Temperature section appears to the right of the Voltages section. Temperatures recorded here include the temperature of the Vicor FlatPac (FlatPac), the room temperature in the vicinity of the air conditioner (Air Cond.), the temperature of the blower unit (Blower), the temperature of CPU's (CPU), and the temperature of the HPGe detector amplifier (Ge Amp). A "View Temp. History" button is located at the end of the Temperature section. When this button is clicked on, a new window opens that displays a graph of the above mentioned temperatures over time. This graph can be used to identify trends in temperature fluctuations.

In the middle of the far right area of the State of Health window is the Power Status section. The status of the battery is reported here as "good" or "bad". Below that the status of the incoming AC is reported. The last time the AC was turned on (AC On) and the last time the AC was cut off (AC Off) are also listed there. Below the Power Status section is the section where various environmental (meteorological) information is presented (Met. Data section). The temperature (Temperature) listed here is the temperature of the environment outside of the APS enclosure. The outside barometric pressure (Bar. Pressure), humidity (Humidity), dew point (Dew Pt.), speed of the wind and its direction (Wind Speed and Wind Dir.) are also included in this section.

For the purposes of easily recording information from the State of Health window, an "Update" button is located in the lower left hand corner of the window. When the State of Health window is brought up, all information is "frozen". No information will change until the "Update" button is clicked on. All information will again be frozen until the next time the button is depressed.

6.2.2.4 Gamma-Ray Spectrum Display Window

When the Gamma-Ray Spectra Display button is clicked on in the Main Window, the Gamma-Ray Spectra Window comes up. (See Figure 6-4). This window is comprised primarily of two buttons, the "Current Spectrum" button and the "Archived Spectrum" button. When the "Current Spectrum" button is clicked on, a new window appears and displays the gamma-ray spectrum currently being acquired by the data acquisition system. When the "Archived Spectrum" button is clicked on, a new window appears which lists the file names of all the archived gamma-ray spectra. By double clicking on a file name in this list, a new window will appear and display the indicated spectrum.

6.2.3 Changing System Parameters

System parameters are changed from the Operator Control Window or from the text based menu generated by the CONFIGURE_SYSTEM process. Parameters that can be changed include the sample duration period and whether or not a decay is to occur before a filter is

Figure 6-4 Gamma-Ray Spectra Display Window

counted. Also, the operator can require that a calibration is to be done or that a "blank" is to be counted. Detailed instructions for changing system parameters from the Operator Control Panel are given in Section 6.2.2.2.

6.2.4 APS System Shutdown

Shutdown procedures for the APS system are carried out from the Operator Control Panel or from the text based menu generated by the CONFIGURE_SYSTEM process. Detailed instructions on how to perform a shutdown from the Operator Control Panel are given in Section 6.2.2.2. From whichever process is used to initiate a shutdown a request is sent to MASTER_CONTROL to shutdown at the next available opportunity. Note that a shut down does not necessarily occur immediately upon request since the system will only shutdown if it is currently in the "collecting/counting filter" state (state 10). In practice, since the system is almost always in this state, a shutdown request is usually granted immediately. If a shutdown request is issued during a filter advance, for example, the shutdown will be delayed until other operations have completed and the system has returned to the "collecting/counting filter" state.

To execute a shutdown, the system goes through a number of steps designed to ensure that no collected gamma-ray spectral data is lost. Additionally, the system state information is saved so that, in the event that the Supervisor Computer is turned off, the MASTER_CONTROL process can figure out what state the system was suspended in during the shutdown. The shutdown occurs as follows: (1) stop data acquisition, (2) record "count stop" time for the exposed filter in the HPGe detector counting area, (3) store the gamma-ray spectral data, (4) turn off the blower and the cooler, (5) record "decay started" time for the exposed filter in the air sampling head, (6) record total air volume for the exposed filter in the air sampling head, (7) carry out the analysis on the gamma-ray spectral data, (8) copy appropriate files to the archive directory, (8) copy appropriate files to the TOBESSENT directory, (9) save the system state information, and (9) terminate the MASTER_CONTROL process. Note that it is necessary to terminate the MASTER_CONTROL process only since it orchestrates the operation of the entire system. All other processes continue to run.

7. Maintenance

The APS system is designed to require general maintenance and restocking at most annually. Restocking includes filter paper and mylar tape, the APS consumables. Maintenance on the various APS components involve varying schedules and levels of effort.

7.1 General

A reasonable level of cleanliness is desirable. Hence, any dirt around the premises or in the intake, any insects, and any spider webs should be cleared away. Depending on the location of the APS, general checks of existing heating and/or cooling systems should be performed. Also, if dehumidifiers are in use, they should be checked as well.

7.2 Filter Paper Reloading

Filter paper reloading proceeds in the same manner as initial filter paper loading which is described in Section 5.2. If the reels are not completely empty, it may be easier to cut the filter strips away from the old rolls very near to the rolls and splice the end of the newly loaded roll onto the old strip. Since the old strip is already threaded through the system, it will drag the new strip through the threading process automatically.

7.3 Bar-Coded Paper and Mylar Tape Loading

Mylar tape loading proceeds as described in Section 5.2. Again, the easiest way to thread the new paper or tape through the feed system is by attaching it to the old paper or tape near the roll and letting the new strip follow the old.

7.4 Motors

The motors require, at most, lubricating of the drive gears and for Motor 2, lubricating of the threaded rod connecting the motor and the filter folding assembly. All rollers should be cleaned to ensure that their surfaces remain tacky.

7.5 Blower

The Dayton blower is essentially maintenance free requiring, at most, lubrication of its bearings.

7.6 Cooler

The Freoelectric cooler requires no maintenance except for cleaning of the condenser if the system is operated in a dirty environment.

7.7 Battery

The battery requires no maintenance. The battery in use in the prototype system is a car-type lead-acid one and requires replacement after about five years. A single APC UPS will be used in the future to back up all systems. (See Appendix 3).

Appendix 1 – 13 Node State Machine

The MASTER_CONTROL process is based on the 13 node state machine described below. Refer to the diagram in Figure A1-1 at the end of this section.

STATES:

- 0 - Power on start up
- 1 - Determine power-fail status
- 2 - Detector warming up
- 3 - Detector cooling down
- 4 - HPGe high voltage ramping up
- 5 - Advancing filter (Phase 1)
- 6 - Advancing filter (Phase 2)
- 7 - Advancing filter (Phase 3)
- 8 - Counting calibration
- 9 - Analyzing calibration data
- 10 - Collecting / Counting filter
- 11 - Analyzing filter data
- 12 - Power failure / Counting filter

STATE TRANSITION CONDITIONS AND ACTIONS:

A:

- 1) AC power is good
- IF (initialization file exists) THEN
 - Load initialization info into state variables
- ELSE
 - set state variables to default values
- ENDIF

B:

- 1) AC power is bad
- OR
- 1) User requested shutdown pending
- turn off the blower
- save state info to power-up initialization file
- IF (user requested shutdown) THEN
 - exit program
- ELSE
 - kill battery power
 - reboot Supervisor
- ENDIF

C:

- 1) AC power is good
- 2) No user requested system shutdown pending
- 3) Detector cooler has been off for more than MAX_COOLER_OFF_TIME
- no action

D:

- 1) AC power is bad
- no action

E:

- 1) AC power is good
- 2) No user requested system shutdown pending
- 3) Detector cooler has been off for less than MAX_COOLER_OFF_TIME
- turn on HPGe cooler

F:

- 1) AC power is bad
- no action

G:

- 1) AC power is good
- 2) Detector has warmed up for at least DETECTOR_WARM_TIME
- turn on HPGe cooler

H:

- 1) AC power is good
 - 2) Detector cooler has been off for less than MAX_COOLER_OFF_TIME
- OR
- 1) AC power is good
 - 2) HPGe detector has cooled for DETECTOR_COOL_TIME
 - ramp up the HV on the HPGe detector

I:

- 1) HPGe HV is fully ramped up
- set power failure flag = FALSE
- reset advance count to 0
- start filter advance Phase 1

J:

- 1) filter advance phase completed without error
- 2) Calibrate flag = FALSE
- start filter advance Phase 2

K:

- 1) filter advance phase completed without error
- start filter advance Phase 3
- "advance" <FilterStrip> object

L:

- 1) filter advance phase completed without error
- 2) Sample decay flag = FALSE
- 3) Advance count < NUM_DECAY_INTERVALS
- record "sample started" time for filter at sample position
- record "count started" time for filter at detector position
- record bar-code ID for filter at bar-code position
- update state "sampleID" field
- increment "number of advances for this cycle" counter
- increment "total number of advances" counter
- record "decay started" time for filter at sample position

- record "count stopped" time for filter at detector position
- start filter advance Phase 1

M:

- 1) filter advance phase completed without error
- 2) Calibrate flag = TRUE
 - set "do calibrate" flag to FALSE
 - start taking histogram data
 - record "sample started", "decay started" and "count started" times in calibration times record
 - set count expired flag to FALSE
 - start count interval timer

N:

- 1) Calibration counting interval expired
 - stop data acquisition
 - record "count stopped" time in calibration times record
 - store histogram data to disk
 - perform analysis on calibration data set

O:

- 1) Calibration data analysis is complete
 - copy appropriate files to archive directory
 - copy appropriate files to "to be transmitted" directory
 - delete files from "new data" directory

P:

- 1) AC power is bad
- OR
- 1) user shutdown is requested
 - copy appropriate files to archive directory
 - copy appropriate files to the "to be transmitted" directory
 - delete files from the "new data" directory

Q:

- 1) AC power is good
- 2) no user shutdown is requested
- 3) Filter data analysis is complete
 - copy appropriate files to archive directory
 - copy appropriate files to the "to be transmitted" directory
 - delete files from the "new data" directory
 - reset advance count to zero
 - start filter advance phase 1

R:

- 1) filter advance phase completed without error
- 2) (advance count == NUM_DECAY_INTERVALS) || (sample decay flag == TRUE)
- 3) count blank flag = TRUE
 - set "do blank" flag to FALSE
 - record bar-code ID for filter at bar-code position
 - update state "sampleID" field
 - reset air volume accumulator
 - increment "total number of advances" counter

- DO NOT turn blower on
- record "sample started" time for filter at sample position
- start taking histogram data
- record "count started" time for filter at detector position
- set "count expired" flag to FALSE
- start count interval timer

S:

- 1) filter advance phase completed without error
 - 2) (advance count == NUM_DECAY_INTERVALS) || (sample decay flag == TRUE)
 - 3) count blank flag = FALSE
- record bar-code ID for filter at bar-code position
 - update state "sampleID" field
 - reset air volume accumulator
 - increment "total number of advances" counter
 - turn blower on
 - record "sample started" time for filter at sample position
 - start taking histogram data
 - record "count started" time for filter at detector position
 - set "count expired" flag to FALSE
 - start count interval timer

T:

- 1) AC power is good
 - 2) counting interval expired
- OR
- 1) AC power is good
 - 2) user shutdown requested
- stop data acquisition
 - record "count stopped" time for filter at detector position
 - store histogram data to disk
 - turn off blower
 - record "decay started" time for filter at sample position
 - record total air volume for filter at sample position
 - set "analysis finished" flag to FALSE
 - start analysis on filter data set

U:

- 1) AC power is bad
- turn off blower
 - record "decay started" time for filter at sample position
 - record total air volume for filter at sample position

V:

- 1) AC power is good
- turn on blower

W:

- 1) AC power is bad
 - 2) Counting interval expired
- OR
- 1) AC power is bad

2) MAX_COOLER_OFF_TIME exceeded

OR

1) AC power is bad

2) Battery power is critically low

- stop data acquisition
- record "count stopped" time for filter at detector position
- store histogram and list mode data to disk
- set "analysis finished" flag to FALSE
- start analysis on filter data

Figure A1-1 State Machine for MASTER_CONTROL Process.

Appendix 2 – Final Test Report Evaluation And System Modifications During Field Test And For Bid Model

Test Case: CR1

Test Objectives: The system should automatically change filters without any instrument downtime between samples.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR2

Test Objectives: The filter media should be removable.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Any filter which has been exposed and counted may be removed at any time. To access the most recently counted sample may require a forced sample advance, which can be done using software or hardware overrides..

Test Case: CR3

Test Objective: The system should have a minimum flow rate of 10,000 SCM per day.

Final Test Report Evaluation: Passed - exceeded specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR4

Test Objective: The filter medium should have (a) an efficiency greater than 98% for particles of 1 to 5 microns and (b) greater than 90% for particles of 0.1 to 1.0 microns.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Failed - will require additional or replacement equipment to pass.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Substitution of thicker media will easily meet CDWP requirements.

Risk: None. The proposed change has been laboratory tested to reduce air flow from 27,000 SCM/day to 22,000 SCM/day, still a factor of 2 above AFTAC and CDWP standards.

Test Case: CR5

Test Objective: The filter media should be capable of an efficiency greater than IPC paper efficiency for particles less than 0.1 microns.

Final Test Report Evaluation: Difficult to determine.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR6

Test Objective: Documentation shall be provided concerning (a) the trapping efficiency and (b) the durability of the filter media.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Failed - could pass with simple modification.

Changes Made During Field Test: No

Changes For Bid Model: Documentation on tensile strength will be obtained from the manufacturer.

Test Case: CR7

Test Objective: The system shall have a built-in flow rate measuring device that is capable of transmitting the flow rate data.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR8

Test Objective: Quantify how rugged the filter media is.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR9

Test Objective: Attempt to measure particle size distribution present on footprint of sample.

Final Test Report Evaluation: No grade given for this test case.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: CR10

Test Objective: Daily particulate matter distribution across filter media remains constant.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR1

Test Objective: The system should be capable of on-site radionuclide measurement.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR2

Test Objective: The detector should not require any non-self-contained coolant such as liquid N₂.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR3

Test Objective: The system should measure and analyze background spectra, with a justifiable recommended period between measurements.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR4

Test Objective: The system should provide an energy/channel calibration.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR6

Test Objective: The system should be sensitive to 30 microBq/SCM of Ba-140.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes, substitution of thicker media will increase filter efficiency substantially while decreasing total air volume only slightly.

Risk: None. The proposed change has been laboratory tested to reduce air flow from 27,000 SCM/day to 22,000 SCM/day, still a factor of 2 above AFTAC and CDWP standards. Filter efficiency for a triple layer increases by more than a factor of 2 over a single layer in the particle size range between .1 and .2 microns.

Test Case: AR8

Test Objective: (a) There should be a spectrum range of 50 keV to 2 MeV. (b) Justify whether actual resolution data needs to be provided for up to 2 MeV, or if extrapolation will be sufficient.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR9

Test Objective: The system should have some emphasis on reducing/eliminating background.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The HPGe detector counting area in the bid design will allow for shadow shielding of the filter paper entrance gap. This will result in even further reduction of background.

Test Case: AR11

Test Objective: The system shall have the capacity to adjust the test cycle for each filter from 24 hrs. to 72 hrs.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR12

Test Objective: Precise efficiency curves as a function of energy shall be supplied for the sampler's geometry.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: AR13

Test Objective: If necessary, a periodic efficiency correction factor shall be calculated from energy calibration standard intensities.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC1

Test Objective: (a) The system should be capable of recording background spectral information (b) and associating it with each sample cycle.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Failed - could pass with simple modifications.

Changes Made During Field Test: No

Changes For Bid Model: Yes, background file information will be included in the header of spectral files.

Test Case: DRC2

Test Objective: (a) The system should be capable of recording energy/channel information (b) and associating it with each sample cycle.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Energy/channel calibration data can be recorded in the header of each spectrum.

Test Case: DRC3

Test Objective: The system should be capable of recording sample spectral information for each cycle.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC4

Test Objective: The system shall record the collection start and stop times for each sample.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC5

Test Objective: The system should record the analysis start and stop count times for each sample.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC6

Test Objective: The system should correlate the collection and analysis times with the proper sample information.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC7

Test Objective: The data stored in the system should be provided to a serial port for communication.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC8

Test Objective: The system should be capable of changing the analysis protocol via com link.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC9

Test Objective: The system should be capable of updating the software via com link.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC10

Test Objective: Intermediate spectral analysis data should be provided via com link, without sample collection or count interruption.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: DRC11

Test Objective: (a) The system should be capable of recording efficiency calibration information (b) and periodic efficiency correction information (c) and associating both to each sample cycle.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Passed - met specifications/expectations. (c) Failed - could pass with simple modifications.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Efficiency information can be associated with each sample cycle.

Test Case: OR1

Test Objective: The system should be a modular design.

Final Test Report Evaluation: Fail - will require major engineering modification effort to pass.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The Bid Model will be comprised of standard equipment racks and off-the-shelf electronic components. In addition, unique mechanical components have been re-packaged into two main modules for ease of assembly and maintenance. Hence, the system will be modular in design.

Risk: None. The proposed electrical components have already been tested at PNNL. The redesigned mechanical components are currently undergoing testing.

Test Case: OR2

Test Objective: The system should be designed to be easily operated by an unskilled operator.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: Yes. The X-windows based graphical user interface was added to the system. This interface allowed for easy operation of the system by unskilled operators.

Changes For Bid Model: Yes. Many controls have been eliminated, resulting a simpler, easier-to-understand system which can be easily controlled by software or manually overridden and controlled with three simple thumb-switches.

Risk: None. These controls have already been tested at PNNL.

Test Case: OR3

Test Objective: The system should be capable of unattended operation for 12 months.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR4

Test Objective: The system should have an easy to repair configuration.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Standard mounting systems and rack mounted hardware will be employed.

Risks: None. Selection of easily available commercial components reduces/eliminates the need for USAF supported subsystems.

Test Case: OR5

Test Objective: The system should have a service interval of 12 months.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: Yes. Most of the reliability problems associated with the field prototype centered around the slippage of the drive rollers. Resolution to this problem is discussed above in reference to Section 2.4.2 of the Interim Test Report.

Changes For Bid Model: Yes. The Bid Model will have rubber coated rollers (like Prototype 2), a simplified paper path with a single drive motor, fewer filter paper strips, and no folding of the filter paper packet. All of these simplifications will provide for a service interval of 12 months.

Risk: None. Prototype 2 moved over 200 samples without slippage. The field-modified PNNL system has moved 85 consecutive samples without difficulty.

Test Case: OR6

Test Objective: The system restocking interval is determined.

Final Test Report Evaluation: Passed - exceeded specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR7

Test Objective: The system should have self-diagnostics for degradation.

Final Test Report Evaluation: Failed - will require additional or replacement equipment to pass.

Changes Made During Field Test: No

Changes For Bid Model: Yes. While the nuclear measurements will be the same, the Bid Model will have improved filter positioning feedback via the addition of 2 quadrature encoder wheels which report the distance traveled by the filter paper to an accuracy of 0.05 inch. This will be an additional self-diagnostic for motion

control, and will allow the elimination of 11 of the 12 optical sensors now in the system. In addition, current monitors will measure the electrical current drawn by the motors (blower and drive).

Risk: None. The additional sensors will simply provide more system diagnostic information and as such, do not constitute a technical risk.

Test Case: OR8

Test Objective: (a) The system should provide (both on-site (b) and off-site) state-of-health information, which must be clearly defined by the contractors.

Final Test Report Evaluation: (a) Passed - needs improvement. (b) Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Additional temperature sensors will be incorporated. This will provide additional state-of-health information.

Risk: None. The additional sensor will simply provide more system diagnostic information and as such, does not constitute a technical risk.

Test Case: OR9

Test Objective: The system should be constructed with off-the-shelf components.

Final Test Report Evaluation: Failed - will require major engineering modification effort to pass.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The Bid Model will be comprised of standard mounting systems and off-the-shelf electronic components. In addition, unique mechanical components have been re-packaged into two main modules for ease of assembly and maintenance. Hence, the system will be modular in design.

Risk: None. The proposed electrical components have already been tested at PNNL. The redesigned mechanical components are currently undergoing testing.

Test Case: OR10

Test Objective: (a) The final report and data should be forwarded to HQ preferably within 6 hrs. of the detector count stop time, (b) but no later than 24 hrs.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (a/b) Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR11

Test Objective: Raw spectra will be available for HQ at the conclusion of the sample count time.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR12

Test Objective: The system should have a form of self-calibration (energy vs. channel number).

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR13

Test Objective: It should be possible to ship the filter media from the test site to the laboratory.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: OR14

Test Objective: The system should permit field calibration of the detector.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The calibrator will be a separate mechanism designed to introduce a calibration source on demand.

Test Case: OR15

Test Objective: (a) The expected mean-time-between-failure for the system should be greater than 12 months. (b) Proof shall be provided in data, documentation, and explanations.

Final Test Report Evaluation: (a) Failed - will require major engineering modification effort to pass. (b) Difficult to determine.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The Bid Model will have rubber coated rollers (like Prototype 2), a simplified paper path with a single drive motor, fewer filter paper strips, and no folding of the filter paper packet. All of these simplifications will provide for a service interval of 12 months.

Risk: None. Prototype 2 moved over 200 samples without slippage. The field-modified PNNL system has moved 85 consecutive samples without difficulty.

Test Case: OR16

Test Objective: The system should not lose any collected data due to a power failure.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Instead of two-tiered commercial/lab-built uninterruptable power supply (UPS), the Bid Model will have one fully commercial (APC UPS) power backup system. This commercial unit will ensure that no collected data will ever be lost due to a power failure.

Risk: None. The Field Test System passes this test case. The proposed change is a simplification to eliminate lab-designed components.

Test Case: PR1

Test Objective: The system should be surface mounted.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR2

Test Objective: (a) The system is required to operate using a value within the range 100-260 VAC, 50-60 Hz (b) and using less than 2500 W.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR3

Test Objective: The overall size of the system will be within the approximate limit of 6'x3'x3'.

Final Test Report Evaluation: Failed - will require major engineering modification effort to pass.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR5

Test Objective: The system as a whole should be weighed in order to analyze the shipping requirements.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR6

Test Objective: The system should contain modular components that do not require more than a one person lift, except during installation.

Final Test Report Evaluation: No grade given for this test case.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The proposed Bid Model would require only a two-person lift DURING installation and no lifting at restocking or maintenance visits. See also OR1 changes.

Risk: None. See OR1 risk.

Test Case: PR7

Test Objective: (a) The system should operate under an 80 dBA limit, (b) but a limit between 50 to 60 dBA is preferred.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Failed - will require additional or replacement equipment to pass.

Changes Made During Field Test: No

Changes For Bid Model: Yes. The SPL (sound pressure level) is 72 dBA at the system front, 75 dBA at the rear. With a sonic enclosure, is 65 dBA at the rear, less at the front. At the exhaust the SPL is 75 dBA at 3 meters. With an active noise cancellation system, this drops to 68 dBA. A passive exhaust noise suppression system is on order for testing.

Test Case: PR8

Test Objective: The system should be an integrated unit.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR9

Test Objective: (a) The system should operate indoors with an external inlet (b) and outlet.

Final Test Report Evaluation: (a) Passed - met specifications/expectations. (b) Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR10

Test Objective: The system should be capable of operating at a temperature of 60° to 100° F.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: PR11

Test Objective: The system should have a minimal operation temperature (i.e., heat emission from the system should have a negligible affect on room temperature).

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: No. The heat load is simply determined by the energy usage, which is <2500W.

Test Case: PR12

Test Objective: There should be no special shipping requirements for the system.

Final Test Report Evaluation: Failed - current available modifications/replacements will not increase rating performance.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Since the Bid Model will consist of modular components and knock-down racks, there will be no special shipping requirements. In addition, a lower level calibration source which adheres to the 0.002 microCi per gram standard will be used requiring no special shipping requirements.

Risk: No technical risk involved with modular design or lower activity calibration standard.

Test Case: PR13

Test Objective: There should be no special environmental requirements for the system.

Final Test Report Evaluation: Passed - needs improvement.

Changes Made During Field Test: No

Changes For Bid Model: Yes. Field-grade data acquisition equipment allows a wider range of temperatures without signal degradation.

Test Case: GR1

Test Objective: The system should not use liquid nitrogen.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: GR2

Test Objective: The system should not use any ozone-depleting substances.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: GR4

Test Objective: The installation requirements for the system should be determined.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Test Case: GR5

Test Objective: The annual operation cost per sample, additional materials and supplies, technician time, and number of visits per year should be determined for the system.

Final Test Report Evaluation: Passed - met specifications/expectations.

Changes Made During Field Test: No

Changes For Bid Model: No

Appendix 3 - Bid Model

Description of Bid Model

The development of the automated particulate system has flowed from proof-of-principle to commercialization. Along this path many hundreds of individual samples were automatically analyzed and data sent to a data center. In addition, field testing was performed to evaluate the performance of various components. Finally, only those system components deemed most valuable have been judiciously packaged as a Bid Model; a design ready for manufacturing by private industry.

The design of the Bid Model, referred to as the Radionuclide Aerosol Sampler/Analyzer (RASA) Mark 4, has resulted from efforts to meet USAF desires concerning logistics and reliability. To achieve the aim of increased reliability, the filter path has been simplified and shortened, the number of strips cut in half, the number of motors, sensors, and switches drastically reduced. As a result, the system is easier to construct, maintain, operate, and is cheaper to buy, thus easing logistical effort in placing a number of the systems in the field for long duration operation.

The central component of the system is a filter area of 0.25 m^2 divided into segments. The RASA Mark 4 features six strips of triple thickness 3M SBFM-40-VF filter paper which are brought together, sealed, and wrapped *around* a germanium detector for gamma-ray counting. The hardware needed to perform this function has been grouped into two main modules, a segmented sample head and a filter transport bracket. This grouping allows easy installation and provides easy-to-achieve alignment of the filter path. An additional consequence of this filter path arrangement is that the filter-handling modules can be easily removed from the enclosure to allow servicing of the two components (detector and blower) which are behind them. The other major system components are all directly accessible from the front panel: the CPU, the power supply, the nuclear data acquisition system, and the display monitor. While rear panel access would simplify servicing of the detector and blower, with some disassembly all components can be accessed from the front of the unit.

Of particular importance to note is the critical change in the design philosophy of the filter path. An exercise in the justification of each turn of the filter paper path in the Field Test Model resulted in a new filter paper path design with only two turns in the RASA Mark 4. Only one turn is now needed to position the filter paper from the filter storage rolls into the sample head and the second turn results in the formation of a loop around the re-oriented detector. See Figure A3-1.

The nuclear data acquisition system is a stand-alone commercial design which processes the signals from the detector into a high-resolution spectrum under the control of the system computer. The system computer has been selected for long MTBF, 19" rack mounting, easy parts swapping, and front-panel connections for easy access. An uninterruptible power supply with 2200 V-A rating and 19" rack mount has been selected to power the system logic which draws less than 75 watts.

Filter restocking has been simplified with a six-roll rack placed against the left wall of the system. With full extension slides the rack can be fully accessed for reloading with only front panel access. The output samples are automatically deposited into a sample depository box/bag for shipment.

The RASA Mark 4 represents the culmination of a system design process which began with the validation of the nuclear measurement technique, moved through drawing board design of a fully automated system, continued through critical testing of prototype designs for ruggedness and ease of operation and maintenance, incorporated full computer control and network capability, and is currently proceeding to commercialization and finally to field operation.

Figure A3-2 shows the updated drawing of the PNNL Bid Model, the RASA Mark 4.

Figure A3-1 Paper path design for the RASA Mark 4.

Figure A3-2 Drawing of RASA Mark 4.

Glossary

AC	Alternating Current.
ADC	Analog to Digital converter.
AIR_VOLUME	Process that accumulates total air volume drawn.
APS	Automated Particulate Sampler.
BID MODEL	Subsequent APS system resulting from lessons learned in test.
CALIBRATE_DATA	Process that generates calibration data based on radon peaks.
CLIMATE_MONITOR	Process that interfaces to the weather station.
COLLECT_DATA	Process that operates the HPGe detector data acquisition.
CONFIGURE_SYSTEM	Process that provides a text based system user interface.
CTBT	Comprehensive Test Ban Treaty.
DC	Direct Current.
FTP	File Transfer Protocol.
GUI	Graphical User Interface.
HPGe	High Purity Germanium.
LOG_BOOK	Process that logs status and error messages to disk.
MASTER_CONTROL	Process that Coordinates all system events.
MCA	Multichannel Analyzer.
MONITOR_SYSTEM	Process that provides text based system status display.
MOTOR_MANAGER	Process that controls the filter advance motors 1, 2 & 3.
PNNL	Pacific Northwest National Laboratory.
POWER_SYSTEM	Process that keeps track of the current AC power status.
PPP	Point-to-Point.
RASA	Radionuclide Aerosol Sampler/Analyzer
SBMF	Substrate Blown Microfiber.
SENSOR_MANAGER	Process that manages all other sensor and hardware control.
UPS	Uninterruptible Power Source.
VAC	Volts of Alternating Current.
VDC	Volts of Direct Current.
VIEW_LOGS	Process that displays system error and status logs.
XWINDOWS_MENU	Process that provides X-windows based user interface.