Title: Technical Statement of Work for the Attribute Measurement System with Information Barrier (AMSIB)

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Submitted to: Defense Threat Reduction Agency

Los Alamos
NATIONAL LABORATORY

Technical Statement of Work

for the

Four-Attribute Measurement System with Information Barrier (AMSIB)

Designated for Implementation at the Russian Fissile Material Storage Facility

June 28, 2001

Prepared by

Nonproliferation and International Security (NIS) Division
Los Alamos National Laboratory

in conjunction with

Lawrence Livermore National Laboratory (LLNL)

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Department of Defense

As Work For Others by

US-DOE AL

EXECUTIVE SUMMARY

The Attribute Measurement System with Information Barrier (AMSIB) is designed to protect classified information related to a classified object being measured. At the same time, the AMSIB must generate confidence with the monitoring party that the unclassified outputs are representative of the unseen classified measurements. An attribute measurement system relies on standard radiation detector systems, in this case a neutron multiplicity counter (NMC) and a high-resolution gamma spectrometer (HRGS). Since both of these detectors can generate classified information, an information barrier (IB) is used to protect the classified information while allowing monitoring party confidence in the results.

The raw data from the NMC and HRGS are used to generate four quantities—the presence of plutonium, the isotopic ratio of that plutonium, the mass of plutonium and an indication of whether the plutonium is in metallic form. These are compared with unclassified threshold values to generate four unclassified attributes of the object being measured. The only display, when classified objects are being measured, is a series of green and red lights indicating whether or not the object is consistent with the specified attributes. When unclassified items are being measured, additional video display connections are available. These displays can indicate all of the intermediate data processing steps (for unclassified objects only) to increase the confidence of the monitoring party that the AMSIB is operating correctly.

This document describes the steps that are required to build a AMSIB. The AMSIB will be built in the Russian Federation for use at the Mayak Fissile Material Storage Facility (MFMSF). This Technical Statement of Work (TSOW) can be broken down into five distinct sections: Statement of Work; Introductory material; System information; System functions; and Physical basis.

Section 1 introduces the AMSIB concept and provides the Statement of Work that the buyer, Bechtel National Incorporated (BNI), will use for contracting the design and development work for the system.

The introductory material is covered in Sections 2 and 3. Section 2 is a functional definition of the system. Section 3 defines the system requirements, both functional and operational, in more detail.

In Section 4, we describe in technical detail what is required to build a AMSIB system. This section includes information related to specific requirements for each element of the AMSIB. The software requirements for operating the detector systems (NMC and HRGS) are described in this section. The IB and its requirements are described in Section 4. Section 4 also includes more information about other AMSIB elements.

Fabrication requirements are listed in Section 5.

Sections 6-9 describe the anticipated operation of the AMSIB and specify the resources that will be required for this operation. Section 6 contains the operations description as well as the training plan. The test plans required for the AMSIB and its elements are defined in Section 8.

Additional information about the AMSIB as well as recommendations are contained in the appendices, Section 9. The physical basis for the attributes is discussed in Section 9.1 as well as the concept behind the information barrier. Section 9.2 includes specific recommendations with respect to individual elements (NMC, HRGS and IB) of the AMSIB. These recommendations are based on the attribute measurement systems that have been built and demonstrated in the US. Section 9.3 lists the recommended spare parts based on the US demonstration.

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ACRONYM LIST

AMSIB ....Attribute Measuring System with Information Barrier

ADC ....Analog to Digital Converter

AMSR ....Advanced Multiplicity Shift Register

BNI..Bechtel National Incorporated

CETAC..................................(US) Corps of Engineers Trans-Atlantic program Center

CoK ....Continuity of Knowledge

CPU.......................................Central Processing Unit

CTR.......................................(US) Cooperative Threat Reduction (program directorate)

DOE ....(US) Department of Energy

DOS.......................................Disk Operating System

DTRA....................................(US) Defense Threat Reduction Agency

FAT ....Factory Acceptance Test

FIFO......................................First In First Out

FMSF ....Mayak Fissile Material Storage Facility

FWHM ....Full Width Half Maximum

FWTM...................................Full Width Tenth Maximum

HPGe.....................................High Resolution Germanium (Detector)

HRGS ....High Resolution Gamma Spectrometer

IB...Information Barrier

INCC......................................IAEA Neutron Coincidence Counting

LNMC ....Large Neutron Multiplicity Counter

MSR ....Multiplicity Shift Register

NMC......................................Neutron Multiplicity Counter

PROM ....Programmable Read Only Memory

QA...Quality Assurance

QC..Quality Control

RC ....Resistance Capacitance Circuit (used in pulse shaping)

RFP..Request For Proposal

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SAT ....Site Acceptance Test

TSOW ....Technical Statement of Work

TTL ....Transistor-Transistor Logic

US...United States

1   STATEMENT OF WORK

1.1   Background

The Cooperative Threat Reduction (CTR) Program Directorate of the Defense Threat Reduction Agency (DTRA) has tasked the Los Alamos National Laboratory to develop this technical statement of work (TSOW) for a Attribute Measurement System with Information Barrier (AMSIB) to be built in the Russian Federation for use at the Mayak Fissile Material Storage Facility (FMSF). This document describes the general technical requirements and functional design specifications for a AMSIB. It also describes the full scope of a project to build and field a AMSIB system at the FMSF. The system description is based on work done in the United States to develop a prototype attribute measurement system that was successfully demonstrated to a delegation from the Russian Federation in August 2000.

1.2   System Overview

The AMSIB will be designed to measure certain specific physical attributes associated with nuclear materials to be stored the Mayak site. This system is intended to be used on randomly selected containers at Mayak. Attribute measurements will be performed as part of an overall technical and policy strategy to help ensure that storage objectives are met. The AMSIB will consist of electronic and computer hardware, radiation detectors, and software in an integrated configuration to measure the following attributes:

- presence of plutonium;
- isotopic ratio, 240 Pu /239Pu (the quantitative value of this ratio is to be less than or equal to 0.1);
- presence of plutonium metal; and
- threshold mass.

The AMSIB will incorporate an integrated information barrier that will ensure that classified information is not revealed while providing accurate system unclassified output.

1.3   Scope of Work

1.3.1   General Description of Work

The contractor shall design and fabricate two (2) identical Attribute Measurement Systems with Information Barrier to meet the requirements and specifications as defined in this document. At the completion of factory acceptance testing, the buyer and the buyer's technical representatives shall randomly select one system to be installed at the Mayak Fissile Material Storage Facility, Building 560, Room 358. The second Attribute Measurement System with Information Barrier shall be shipped to Los Alamos National Laboratory for independent testing and for use in training U.S. monitoring parties.

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Shipping Address:

Los Alamos National Laboratory
Attn: Noah Pope, NIS-7 / Diana Langner, NIS-5
Bikini Atoll Rd., SM 30
Los Alamos, NM 87545

1.3.2 Task Description

The Contractor shall perform the following tasks:

Task 1.0 Prepare and deliver an equipment certification plan. Design the U.S. Attribute Measurement System with Information Barrier in accordance with the system technical requirements, system design requirements and other sections of this Statement of Work.

Subtask 1.1 Review the U. S. supplied Technical Statement of Work, reach agreement with the buyer and the buyer's technical representatives on any changes, and use the revised requirements in the design.

Subtask 1.2 Prepare and deliver project timeline listing expected costs, effort and travel expenses, and resources to complete the project by [date to be determined]. A preliminary project timeline shall be submitted with the Contractor's proposal as a basis for its evaluation.

Subtask 1.3 Submit a comprehensive, integrated, resource-loaded baseline schedule. The schedule shall define all major activities, milestones, and deliverables for the AMSIB task and be used as the basis for monthly reporting.

Subtask 1.4 Prepare and deliver and issue conceptual system design documents at the 35% design stage. The contractor may proceed with the design while the buyer and the buyer's technical representatives review the documents submitted for the conceptual design.

Subtask 1.5 Prepare and deliver a preliminary equipment list to be used by the buyer to review and procure any long lead time items.

Subtask 1.6 Prepare and deliver a detailed material and components list complete with detailed specifications to include spare parts and test equipment inventory.

Subtask 1.7 Prepare and deliver and issue draft detailed design documents for review and comment by the buyer and the buyer's technical representatives. The contractor shall then incorporate the agreed upon comments and issue the final design documents. Include software manuals.

Subtask 1.8 Prepare and deliver and issue approved design documents for the final design.

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Task 2.0. Fabrication, software development, assembly of components, installation of components, material, and associated wiring in the recommended four-attribute measuring device enclosure.

Subtask 2.1 Procure all of the elements assigned to the contractor for procurement and assemble these as well as all elements purchased by the Buyer for the US Attribute Measurement System with Information Barrier (AMSIB).

Subtask 2.2 Develop the US Attribute Measurement System with Information Barrier software package including configuration, interface control, and data analysis programming along with all executable files, complete source code (in electronic format) and complete documentation.

Subtask 2.3 Develop a factory acceptance test (FAT) plan and perform or cause to perform, a complete set of FATs for the AMSIB to be observed by the buyer and the buyer's technical representatives at a location to be agreed upon. This FAT shall include two complete systems.

Subtask 2.4 Develop a site acceptance test (SAT) plan.

Task 3.0 Attribute Measurement System with Information Barrier installation.

Subtask 3.1 Direct and assist the FMSF construction contractor in all phases of the installation of the AMSIB in Room 358 at the Mayak FMSF including inspections for shipping damage, enclosure installation and orientation, cabling and power connections, enclosure tie-downs, and any other system check lists and/or modifications required before power-up of the components (see Section 7.2).

Subtask 3.2 Perform a complete set of Site Acceptance Tests for the AMSIB in Room 358 at the Mayak FMSF.

Subtask 3.3 Provide the U. S. Attribute Measurement System with Information Barrier operations and maintenance training for personnel at the Mayak FMSF site.

Subtask 3.4 Prepare and deliver a final set of as-built drawings, installation, maintenance and operations manuals, FAT and SAT results, and any additional documentation as required by this Statement of Work.

1.4 General Tasks

- The contractor shall issue monthly reports, engineering deliverables, and documentation on the dates specified in the contract.

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- The contractor shall provide photos (bmp, jpg, etc. format) and videotapes (avi files) to the buyer's specification to highlight and document work associated with this contract. The contractor shall include those items as attachments to the monthly reports.
- All US Attribute Measurement System with Information Barrier documentation originally created in the Russian Language shall be provided in the Russian language. All documents originally printed in English will be provided without retranslation. For all documents originally printed in a language other than English or Russian, both the original language version and the Russian translation will be provided to the buyer.
- The buyer is solely responsible for the cost associated with translation services required for submittals and deliverables.
- The contractor shall be responsible for providing interpreters at their site meetings, but the buyer reserves the right to supply its own interpreters to these meetings. The buyer will supply interpreters for Moscow meetings, meetings in the US, and for Mayak FMSF Site meetings
- All contractor produced US Attribute Measurement System with Information Barrier drawings, wiring diagrams, deliverables, and documents shall be provided to the buyer in both electronic and hardcopy formats. Any document released by the contractor shall have all the required Russian approvals for release to the buyer to meet the deliverable dates contained elsewhere in the contract documents. The number of copies of documents will be developed by the buyer and the contractor on specific basis for each deliverable (see section 10.3). Buyer reserves the right at its discretion to send the Contractor some U. S. originated information that is not perceived essential or critical to the Contractor in English (e.g. Manufacturer's catalogs). However, in all such instances, any such information will be still be translated into Russian by the Buyer at a specific request by the Contractor.
- The buyer's representatives shall have access to visit the Russian contractor's site and the Mayak FMSF for periodic quality assurance /quality control (QA/QC) during fabrication, configuration, programming, FAT, and SAT certification.
- The contractor shall receive approval from the buyer prior to the contractor subcontracting any portion of the assembly and manufacturer to another entity.

1.5 Submittals and Deliverables

1.5.1 Submittal Process

Submittals are documents, plans, drawings, reports, lists, or other media required that describe technical or other project information. Submittals are generally required to allow technical reviewers, contracting agents or other project personnel to make judgments into the validity, completeness, or other criteria of a project deliverable. Submittals are referenced to project subtasks as described in section 1.3.2

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Submittals shall be transmitted in a completed state and with all required predecessor documents to facilitate understanding of the information. Out-of-sequence or incomplete documents are not acceptable and will be returned without review, and no additional contract performance time will be allowed because of delays associated with incomplete submittals. Submittals that are not approved will be returned to the AMSIB contractor for revision. The contractor shall not proceed with the final design until the buyer has approved the documents submitted for the detailed design. Do not deliver or install equipment without a complete sequence of approved documentation for that equipment.

All AMSIB task documentation shall be provided in Russian. All submittals shall be provided in electronic form and hard copies. These submittals shall be provided to the buyer on the dates specified. The buyer shall be solely responsible for translation services as agreed to for their deliverable documents and products.

Some submittal documents are made for the purpose of obtaining review comments from the US Technical Team, who will return comments to buyer for transmittal to the Russian Contractor. In these cases, the Russian Contractor will be responsible for formally determining the outcome of each comment. This process, known as "comment disposition," shall be conducted using a formal process, and the results of the process shall also be submitted to the US Technical Team. Under the disposition process, comments may be (1) included as stated, (2) included with modification, or (3) rejected. Comments included with modification and rejected comments shall be done so with written justification with an approval signature from a Russian Contractor authority.

1.5.2 Submittals List and Timeline

AMSIB Milestones – Based on notional schedule sent to DTRA. Note: Number reflects duration of lead/lag from contract acceptance in contractor workdays. A submittal package shall consist of all documents as described for each submittal in Section 1.5.3 and shall be provided in Russian, in electronic form and hard copies. Two (2) copies of each submittal package shall be provided to the buyer on the dates specified.

Event	Schedule	Submittals due
Contract accepted by the Buyer, approval to start work issued.	0d	
Design Phase Begins	+10d	
Buyer to receive schedule and milestone documents	+10d	S1.3.1 S1.3.2 S1.3.3
Buyer to receive conceptual system design package	+30d	S1.4.1

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Buyer to receive preliminary equipment list	+30d	S1.5.1
Buyer review comments on preliminary design complete	+55d	
Buyer to receive detailed material and components list	+65d	S1.6.1
Buyer to receive detailed system design package	+80d	S1.7.1 S1.7.2
Buyer to receive certification plan	+80d	
Buyer Review Comments on detailed system design package complete	+95d	
Buyer to receive final detailed system design package and review comments disposition worksheet.	+110d	S1.8.1 S1.8.2
Procurement Complete	+165d	
Buyer to receive preliminary factory test plans	+165d	S2.3.1
Buyer review comments on preliminary factory test plans complete	+180d	
Buyer to receive preliminary site functional acceptance test plans	+165d	S2.4.1
Buyer completes review and transmits comments to Contractor and meets with Contractor, if needed to resolve any issues	+180d	
Contractor makes agreed upon changes and issues Final report	+190d	
Buyer to receive final factory test plans and review comments disposition worksheet	+195d	S2.3.2 S2.3.3
Buyer to receive final site test plans and review comments disposition worksheet	+195d	S2.4.2 S2.4.3
Buyer to receive operational plans and procedures	+205d	S3.4.1
Fabrication Complete	+215d	
Software Development Complete	+215d	
Buyer to receive fabrication report	+225d	S2.1.1
Buyer to receive software development report	+225d	S2.2.1
Buyer to receive training plans and manuals	+230d	S3.3.1 S3.3.2 S3.3.3 S3.3.4
Buyer to receive for review and approval the appropriate list of Pu reference and calibration sources, including the entire certified source test equipment list	+230d	

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Factory testing complete	+235d	
Buyer to receive preliminary installation plan	+245d	S3.1.1
Buyer to receive factory test results	+245d	S2.3.4
Buyer review comments on manuals complete	+245d	
Buyer review comments on installation plan complete	+260d	
Buyer to receive AMSIB operating and maintenance procedures and documents	+275d	S3.4.2 S3.4.3 S3.4.4
Buyer to receive final installation plan and comment disposition worksheet	+280d	S3.1.2 S3.1.3
Site acceptance testing complete	+285d	
System Installation Complete	+285d	
Buyer to receive site acceptance test results documentation	+295d	S3.2.1
Buyer to receive installation results documentation	+295d	S3.1.4 S3.1.5

1.5.3 Submittal Description

Task 1 Submittals

S1.3.1   The contractor shall submit a comprehensive, integrated, resource-loaded schedule using Primavera Scheduling Software. The schedule shall define all major activities, milestones, and deliverables for the AMSIB task.

S1.3.2   Separate from the schedule, the contractor shall submit a list of project milestones including specific input, output, and other milestones.

S1.3.3   Separate from the schedule, the contractor shall submit a list of project "decision points".

S1.4.1   The Russian Contractor shall prepare and deliver a conceptual system design document. This document is to be a preliminary view of the AMSIB Detailed Design Document as outlined below. It is expected that the document will reflect the system design at approximately 35% completion.

AMSIB Detailed Design Document
System Design Overview
Block Flow Diagrams
Process and Instrumentation Diagrams (P&IDs)
System Electrical and Power Drawings
Electronic Element Drawings and Lists
Computer Element Drawings and Lists

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Wiring and Wire Harness Lists
System Mechanical and Assembly Drawings
Chassis and Shielding Drawings
User Interface and Display Drawings
Interlocks System Descriptions and Drawings
Software Coding Standards Description
Software Logic Diagrams
Facility Installation Drawings including:
    Electrical Hook-ups
    Piping Connections (if required)
    Mounting Connections
Engineering and/or Physics Calculations
Mean-Time-between-Failure Analysis
Maintenance Design Information
Test Plan and Procedures
Equipment Lists
Spare Parts Requirements

S1.5.1   The contractor shall prepare and deliver a preliminary equipment list to be used by the buyer to review and procure any long lead time items. This list will be as complete and detailed as possible with consideration for the early stage of design.

S1.6.1   The contractor shall prepare and deliver a detailed material and components list complete with detailed specifications. Also prepare and deliver lists showing the complete test equipment and spare parts inventory for five (5) years operation, along with complete test equipment tool box and a one (1) year supply of consumables. Determine which of the materials and components the buyer will procure and which the contractor will procure. This will be approved by the buyer.

S1.7.1   The contractor shall submit a detailed system design package incorporating comments received from the buyer's conceptual design review. A draft of the final design documents shall be furnished to the Buyer for review and comment. The Buyer's comments will be furnished to the Contractor and agreement reached on changes to be made. The Contractor will then incorporate agreed upon comments and issue the final documents. At the 90% stage, the design will be considered to be essentially complete with the exception of final review and revision. The contractor shall not proceed with the final design until the buyer has approved the documents submitted for the detailed design.

S1.7.2   The contractor shall submit a worksheet describing the disposition of each conceptual system design review comment with associated justification or explanation.

S1.8.1   The contractor shall submit the final detailed system design package incorporating comments received from the buyer's detailed system design review. The final detailed system design package shall contain the

complete documents as described for submittal S1.4.1. The buyer and the buyer's technical representatives will consider the final detailed system design package for final acceptance of the design.

S1.8.2   The contractor shall submit a worksheet describing the disposition of each detailed system design review comment with associated justification or explanation.

Task 2 Submittals

S2.1.1   The contractor shall submit final fabrication sketches and photographs documenting sub-assembly and final assembly fabrication of the system within two weeks of the completion of system fabrication. This shall include as-built documentation to include, but not limited to:

Detailed circuit schematics.
Detailed parts list for all circuit schematics.
Manufacturers data sheets for all components (integrated circuits, resistors, inductors, capacitors, etc.).
Detailed cabling and wiring interconnections diagrams.
Functional descriptions, operating procedures, calibrations procedures for all operational modules.
Firmware code for all custom programmable devices (micro controllers, PLDs, PROM, Flash, …).
Complete vendor documentation of all procured hardware such as operating procedures, calibration procedures, circuit diagrams, parts lists, embedded code in any programmable device, and packaging mechanical drawings.
Procurement history for all components, including lot numbers and production runs.
Circuit board layout files (e.g., Gerber Files).
Mechanical drawings of all electronic enclosures.
Circuit description of electrical feed, cabling, and UPS.
Schematics, layout, masks, and production run data for all ASICs custom manufactured for this system.
X-rays and high resolution photographs

S2.2.1   The contractor shall submit final software documentation within two weeks of the completion. This documentation shall include, but is not limited to:

List of system software including operating system, compilers, databases, etc.
List of computer hardware including CPU, hard drives, peripheral equipment, etc.
List of all proposed commercial, off-the-shelf and custom software with source code availability status
Functional description of proposed software modules
List of all proposed computer I/O connections and interrupt usage
Software coding standards document.

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Software installation and maintenance plan.

System's users guide document.

Commented source code in machine-readable format for all custom software packages.

Executable code identical to that loaded on the system for all custom software (machine-readable format).

Build instructions to generate an identical executable from the source code provided in electronic form.

All documentation provided with commercially purchased software.

NOTE: Sufficient copies of software documentation for commercially licensed and procured software shall be purchased with the software to allow provision of the original documentation to the buyer

S2.3.1   The contractor shall submit for review, test plans for all factory acceptance testing including, but not limited to (1) Factory Element Testing prior to vendor shipment, if required and (2) Factory Functional Testing.

S2.3.2   The contractor shall submit a final factory acceptance test plan incorporating comments received from the buyer's factory acceptance test plan review.

S2.3.3   The contractor shall submit a worksheet describing the disposition of each factory acceptance test plan review comment with associated justification or explanation.

S2.3.4   All factory acceptance test results shall be recorded by the contractor and delivered to the buyer within two weeks of completion of the tests.

S2.4.1   The contractor shall submit for review, test plans for all site functional acceptance testing.

S2.4.2   The contractor shall submit a final site functional acceptance test plan incorporating comments received from the buyer's site functional acceptance test plan review.

S2.4.3   The contractor shall submit a worksheet describing the disposition of each site functional acceptance test plan review comment with associated justification or explanation.

Task 3 Submittals

S3.1.1   The contractor shall submit for review, a preliminary installation plan detailing the required installation steps.

S3.1.2   The contractor shall submit a final installation plan incorporating comments received from the buyer's installation plan review.

S3.1.3   The contractor shall submit a worksheet describing the disposition of each installation plan review comment with associated justification or explanation.

S3.1.4   The contractor shall submit final installation sketches, as-built drawings, and photographs documenting installation of the system within two weeks of the completion of system installation.

S3.1.5   The contractor shall submit a final software package as described in Submittal 2.2.1 with documentation describing all changes and modifications to software made during testing and installation within two weeks of the completion of system installation.

S3.2.1   All site acceptance test results shall be recorded by the contractor and delivered to the buyer within two weeks of completion of the tests.

S3.3.1   The contractor shall prepare and deliver a training plan covering the training requirements for Russian system operators and maintenance technicians. The plan shall include the content of the training, responsibilities for providing training, cost estimates for conducting the training and schedules for a minimum of two classes.

S3.3.2   The Russian Contractor shall prepare and deliver a training plan covering the training requirements for US monitoring parties. The plan shall include the content of the training, responsibilities for providing training, cost estimates for conducting the training and schedules for a minimum of two classes.

S3.3.3   The contractor shall submit Training Manuals to support the Russian system operators and maintenance training.

S3.3.4   The contractor shall submit Training Manuals to support the training for US monitoring parties.

S3.4.1   The contractor shall submit a list of required Operational Plans and Procedures for key operations at the FMSF 16 weeks prior to completion of AMSIB installation. This document shall also include software maintenance plans; this includes software version control documentation.

S3.4.2   The contractor shall submit an operating procedure for each operation on that list 2 weeks prior to commencement of training.

S3.4.3   The contractor shall submit an Operator Logbook for use in operation of the system containing, at a minimum, the operator's name, date of operation, operation performed, comments, and results. The logbooks will be designed to require the user to make entries to the Logbook both before and after each operation.

S3.4.4   The contractor shall submit a Maintenance and Repair Logbook containing the operator's name, date of maintenance or repair task, maintenance or repair performed, comments, and results.

1.6   Requirements versus Recommendations

Engineering standards in the US specify different terms to communicate the degree of mandate that a requirement carries, and one such convention is observed below. These terms serve to distinguish firm requirements from recommendations, and are as follows:

- "shall" indicates a firm requirement.
- "will" indicates a highly desirable feature the system should have.
- "may" indicates a desirable feature that observes "best practices" but is not imperative.

1.7 Codes and Standards

All design and fabrication of the AMSIB shall be performed in accordance with internationally accepted standards. All design work shall be completed in accordance with good engineering practices.

The contractor shall provide the buyer with a list of all safety and manufacturing standards used in the design and fabrication of the AMSIB.

1.8 Authentication

Authentication is the process by which a Monitoring Party gains appropriate confidence that the information reported by a monitoring system accurately reflects the true state of the monitored item. This can best be achieved through a multilayered approach, with each level providing additional confidence.

The AMSIB shall be designed to be authenticatable, that is the design shall be optimized to enhance the effectiveness of authentication procedures. Authentication includes complete documentation; functional testing; operating procedures; and random selection and exchanging of elements. The system as a whole and each module individually, shall be designed to be difficult to tamper with and to indicate if tampering has been attempted. Design features that support authenticatability include:

- simplicity,
- modularity,
- easy physical and visual access to all elements of the finished AMSIB,
- clear separation of security functions from measurement functions,
- sealable enclosures,
- tamper indicating measures,
- electrical shielding of enclosures and exposed cables,
- mechanical design that facilities disassembly and re-assembly for inspection, and
- visually traceable electronic circuits (no wire-wrap or hard-wired boards)

Authentication of specific subsystems and modules is addressed in later sections of this document.

2 SYSTEM FUNCTIONS

2.1 Functional Description

During a monitoring period, the monitoring party shall be presented with one or more closed storage containers declared to contain a specified mass of plutonium. The AMSIB will verify the following attributes of these containers:

- presence of plutonium;
- isotopic ratio, ^{240}Pu $/^{239}$Pu (the quantitative value of this ratio is to be less than or equal to 0.1);
- presence of plutonium metal; and
- threshold mass (specific metric to be determined, but will be some percentage of declared mass).

The contractor shall specify the confidence level associated with each of these measurements.

No classified information shall be disclosed, released, or stored during the course of these measurements. At the same time, the monitoring party shall be convinced that the displayed unclassified results authentically reflect the unseen classified measurements.

2.1.1 Block Diagram

The proposed attribute measurement system (the AMSIB) consists of neutron multiplicity counter (NMC) and high-resolution gamma-ray spectrometry (HRGS) detection systems integrated within an information barrier. The interrelationship between these three elements is illustrated in Fig. 2.1.1. The analysis results from these detection systems are compared with the mutually agreed threshold values to indicate whether attributes of the item being monitored are or are not consistent with the declarations concerning that item.

2.1.2 High-Level Description

As illustrated in Fig. 2.1.1, all of the elements of the attribute measurement system can be divided into four groups. The elements shown in dotted (red) lines can potentially contain classified information. Dashed (violet) lines are used to denote elements that are not themselves classified but are protected because of their location within the information barrier. The elements of the barrier itself are shown in bold (blue). Finally, elements of the system that cannot contain classified information are shown in thin solid (green) lines.

The three data processing modules of the AMSIB, the two detector systems and the computational block, are completely contained within the barriers as illustrated in Fig. 2.1.1. All potentially classified information in the AMSIB is contained in these modules within the barrier. Furthermore, all of the software elements of the AMSIB are contained in these three modules.
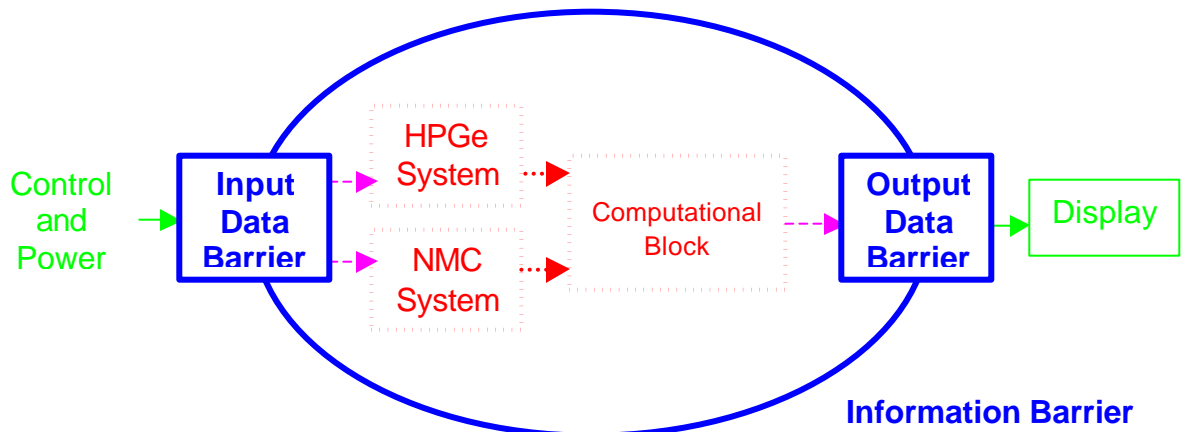
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Fig. 2.1.1 Block diagram of conceptual attribute measurement system.

All connections between the "potentially classified" modules and the barrier whether control input, power, or threshold output, are inherently unclassified. However, because these signals are within the information barrier, they are protected as if they were classified. Notice that classified information is never directly in contact with the barrier. Thus, failure of a single element cannot result in the loss of classified information.

All electronic signals (data, input signal, or power) that must be transmitted through the information barrier pass through one of the data barriers. The function of the data-barrier elements is to allow acceptable signals to pass while filtering out all other types of information.

Finally, the green elements of Fig. 2.1.1 cannot contain any classified information. This allows the use of AC power and other support directly from the facility and allows for archiving of the unclassified display information without compromising security.

Although only a single barrier is shown in Fig. 2.1.1, in reality this is a multi-layer barrier made up of hardware, software, and procedural elements. The failure of any one of these elements would not result in the failure of the entire barrier (see Section 3.3.2).

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2.2 Safety Functions and Requirements

2.2.1 Impact on Host Safety Systems

The AMSIB will not adversely impact the safety systems (fire, electrical, radiation, etc.) of the host facility.

2.2.2 No Implicit AMSIB Hazards

During operation, either routine or emergency, the AMSIB will not expose the monitoring parties to electrical, fire, or other hazards. Operation of the AMSIB will not expose the monitoring parties to excessive radiation. The radiation dose expected will be documented prior to system operation.

3　SYSTEM TECHNICAL REQUIREMENTS

3.1　AMSIB Functional Requirements

3.1.1　Neutron Multiplicity Counter (NMC) System

The NMC system shall be of robust design and be similar to those typically used for assay and analysis of unclassified plutonium. (See references)

The NMC system shall be optimized for the intended measurement application according to the requirements of the attribute measurement system and the facility. A suggested version of the NMC is described in the appendix, Section 9.

3.1.2　High-Resolution Gamma Spectrometry (HRGS) System

The HRGS system shall be of robust design similar to those used for assay and analysis of unclassified plutonium. (See references)

The HRGS system shall be optimized for the intended measurement application according to the requirements of the AMSIB and the facility. A suggested version of the HRGS system is described in the appendix, Section 9.

3.1.3　Information Barrier Elements

Appropriate shielding and other means shall be employed to prevent the transmission of any unintended electromagnetic and other data-carrying signals into or out of the attribute measurement system.

Commercial off-the-shelf equipment will be used (to the extent possible) in the data-acquisition, analysis, and control elements of the system. The selection and use of this (and all other) equipment will be consistent with the requirements for authentication and protection of classified information.

Nonessential system functionality shall be kept to a minimum.

All measurement data (**not** including background and calibration data) and intermediate results shall be purged after the completion of any individual measurement. In addition, all classified data shall be removed from the system if there is any indication of tampering and when power is removed or lost. The contractor shall provide a list of all actions that will automatically shut down the system (e.g., opening an access door).

The attribute measurement system will provide an indication of normal operation.

The detectors, equipment, and cabling making up the attribute measurement system shall be enclosed in sealable tamper-indicating enclosures.

The AMSIB shall be designed to protect against accidental damage to seals, seal wires, optical fibers, and other tamper indicating devices.

3.1.4 Data Acquisition and Processing

The system will require minimal operator intervention including minimal interaction for activation of pre-defined functions. All operator input will be via a measurement control panel that will be external to the enclosure containing the analyzers. It shall consist of a set number of control switches in a stand-alone shielded enclosure, and a shielded cable connecting it to the shielded cabinet.

The system shall acquire only the measurement data needed to verify the attributes.

The system shall erase or otherwise destroy the acquired data (other than background and calibration data) once the corresponding attribute has been verified for each individual measurement.

3.2 Operational Requirements

3.2.1 Sensitivity

The sensitivity of all detector systems incorporated in the AMSIB system shall be sufficient for the anticipated materials to pass the attribute thresholds with 3σ confidence within the mutually agreed measurement time.

3.2.2 Throughput

The operation of the AMSIB measurement system shall not adversely impact the normal operation of the facility in which it is used.

In particular, the sampling fraction and system throughput will be chosen so that the AMSIB is not the limiting factor during normal operations. Normal measurement time shall not exceed one hour.

3.2.3 Bar-Code Reader

The AMSIB system shall be equipped with a bar-code reader that is compatible with bar codes on the storage containers and calibration and reference material containers. These codes will be used to associate measured attribute outputs with the container being measured. However, the bar code reader shall in no way communicate to the information barrier.

3.3 Information Barrier Requirements

3.3.1 Data Security

The host country shall be convinced that the data acquisition and processing within the HRGS and NMC detector systems provide sufficient protection of its classified information.

The attribute measurement system shall be designed so that failure of any individual element (either hardware or software) cannot result in the release of classified information.

The information and protective barriers of the measurement system shall be implemented in hardware and software. These protections will be supplemented by administrative measures.

The measurement system shall be protected from unauthorized tampering. The methods of protection will be mutually agreed and fully documented.

3.3.2 Authentication Considerations

Because the monitoring country shall be convinced that the AMSIB is behaving as anticipated and that the unclassified display is truly representative of the classified measurement, the following conditions shall be met:

The AMSIB shall be designed to facilitate acceptance testing using unclassified reference materials.

The AMSIB shall be designed to facilitate initial authentication as well as reauthentication by the monitoring party. All software shall be either fully documented (including source code) or selected by the contractor with approval from the buyer.

Access to secured enclosures associated with the measurement system shall be controlled in accordance with mutually agreed procedures.

All elements of the attribute measurement system shall be protected against unauthorized access by either party. In normal use, there shall be no access to the software. In the event of necessary maintenance or upgrades, appropriate access controls and testing procedures shall be applied to provide assurance that the software is not modified in such a way that it would constitute a risk of revealing classified information or in such a way that its authenticity would be compromised. The integrity of the hardware shall also be assured in a similar manner.

The system shall be designed to allow all elements of the system to be easily swapped out as part of random selection and exchange.

3.4 Physical Requirements

The physical support requirements of the AMSIB (size, weight, electrical consumption, coolant consumption, etc.) shall be specified.

3.4.1 Environmental Requirements

The AMSIB shall be located inside a climate-conditioned building. The temperature range and humidity shall be specified for the conditions within the Mayak storage facility. Normal operating conditions are assumed to be the following:

```
Temperature:          10–38 degrees Centigrade
Pressure:             Atmospheric
Relative Humidity:    5–95% non-condensing
Atmosphere:           Air
```

Appropriate shielding shall be used around the AMSIB in order to reduce the radiation background so that radiation will not constitute a health risk and not adversely affect system operation. Radiation dose shall not exceed 2.5 μSv/hr neutron in contact or near the AMSIB equipment.

3.4.2 Seismic Requirements

The AMSIB shall meet seismic requirements similar to the MC&A Passport system installed at FMSF.

3.4.3 Power Stabilization

Power to the AMSIB shall be filtered and backed up by uninterruptible power supply so that power fluctuations and power line noise shall not interfere with normal operation.

3.5 Facility Interface Requirements

Operation of the AMSIB shall not adversely impact any requirements, safety or other, of the host facility.

The host facility shall provide the physical requirements discussed in 3.4.

3.5.1 Certification

It will be the responsibility of the host organization to obtain all certifications required for operation of the AMSIB in the host facility and to meet the agreed timetable.

3.5.2 Acceptance Testing

It will be the responsibility of the host organization to perform all agreed acceptance and functional testing as detailed in Section 7. This will include acceptance testing of individual modules as well as completed system testing. Additional testing activities specified by the US authentication team will be accommodated in the schedule.

4   SYSTEM DESIGN REQUIREMENTS

4.1   Detailed System Overview

Figure 4.1 illustrates the detailed relationships between the various elements of the AMSIB that are described in the remainder of this section. As described in detail in Section 4.4.4.2, the AMSIB utilizes two modes of operation. Measurements of unclassified objects can be performed either with the system open (Fig. 4.4.4.2.1: doors open and displays attached) or with the system secure (Fig. 4.4.4.2.2: doors closed and indicator display only). Measurements of classified objects shall only be performed with the displays disconnected and the system secure. In this section, a single complete attribute measurement system is defined. Two identical systems will be built; both shall meet the requirements of this section.

4.2   Data Flow

Although measurements that collect classified data are made by the detectors in the AMSIB, only unclassified results are displayed. Fig. 4.2 illustrates the flow of data within the AMSIB system that is illustrated in Fig. 4.1. The raw data generated in the two detectors pass into the shielded enclosure to data analyzers. Both the raw data from the detectors and the data in the analyzers will be classified if a classified item is being measured. The results of the analyses pass into the computational block where they are compared against stored threshold values. The results of the comparison, in the form of unclassified yes/no results, are sent from the computational block through the data barrier to the unclassified display. Although the outputs from the computational block are unclassified, these signals are inside the shielded enclosure and are protected as classified until they pass through the data barrier. In addition, all data flow within the AMSIB is as unidirectional as possible.

4.3   Neutron Detector Systems

4.3.1 ^{240}Pu Measurements

A neutron multiplicity counter (NMC) and associated electronics will be used to determine the ^{240}Pu effective mass. A schematic of the NMC system is shown in Fig. 4.3.1, below. The NMC will also be used via the measured (α,n) to (spontaneous fission, n) ratio and the measured multiplicity to test for the presence of metal attribute. The numbers of elements such as preamplifiers and ^{3}He tubes will be determined from an optimization study to meet the requirements below.

The NMC will be used to obtain three quantities:

- The mass of ^{240}Pu$_{effective}$ which is proportional to the spontaneous fission rate,

- alpha (α) which is a function of the rate of neutrons generated from (α,n) reactions, and

- multiplication (M) that is related to the neutrons from induced fissions.

Three types of measurements will be required for the NMC system:

- Measurement control to verify proper functioning.
- Background to establish a baseline for external neutron radiation.
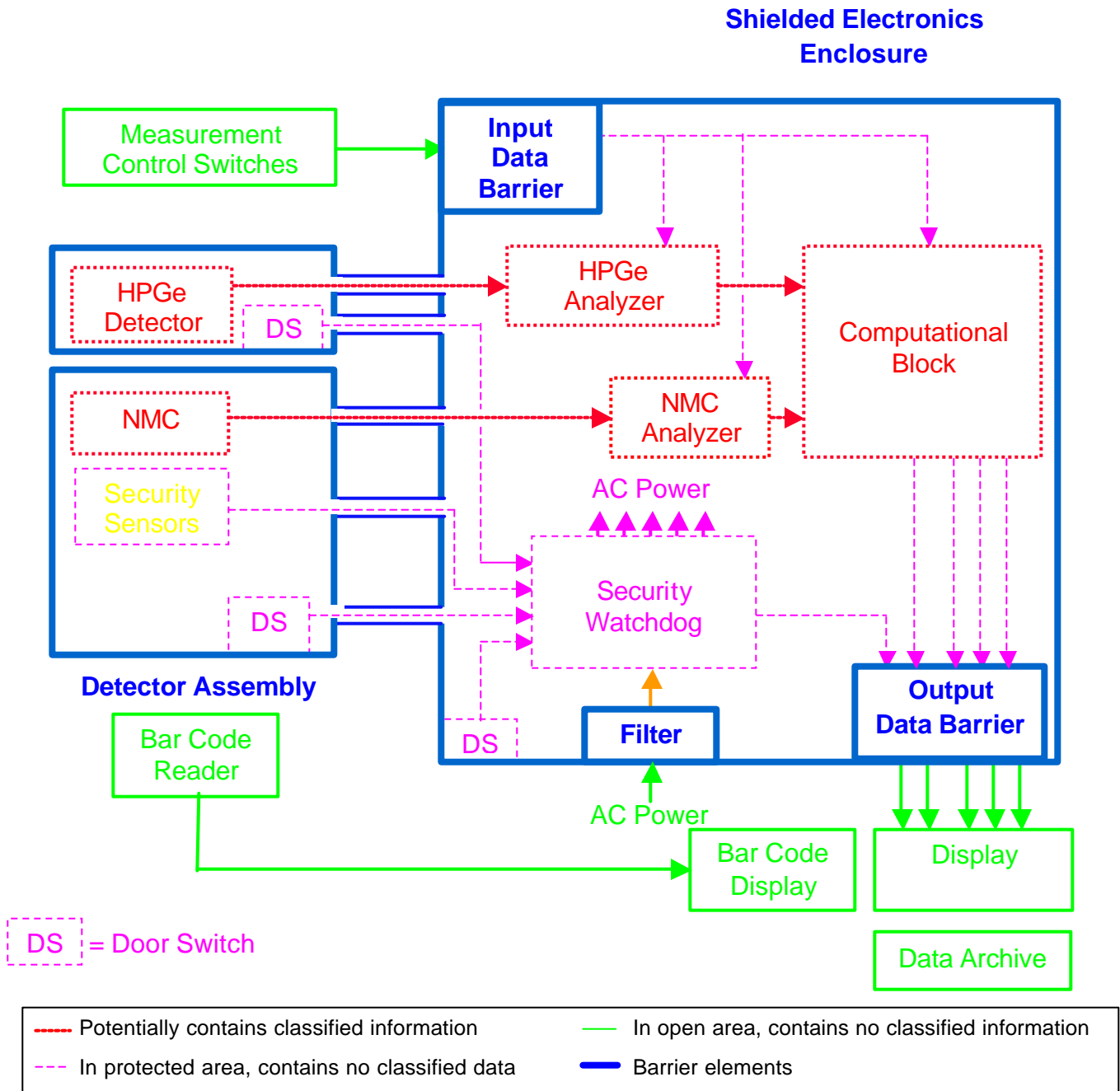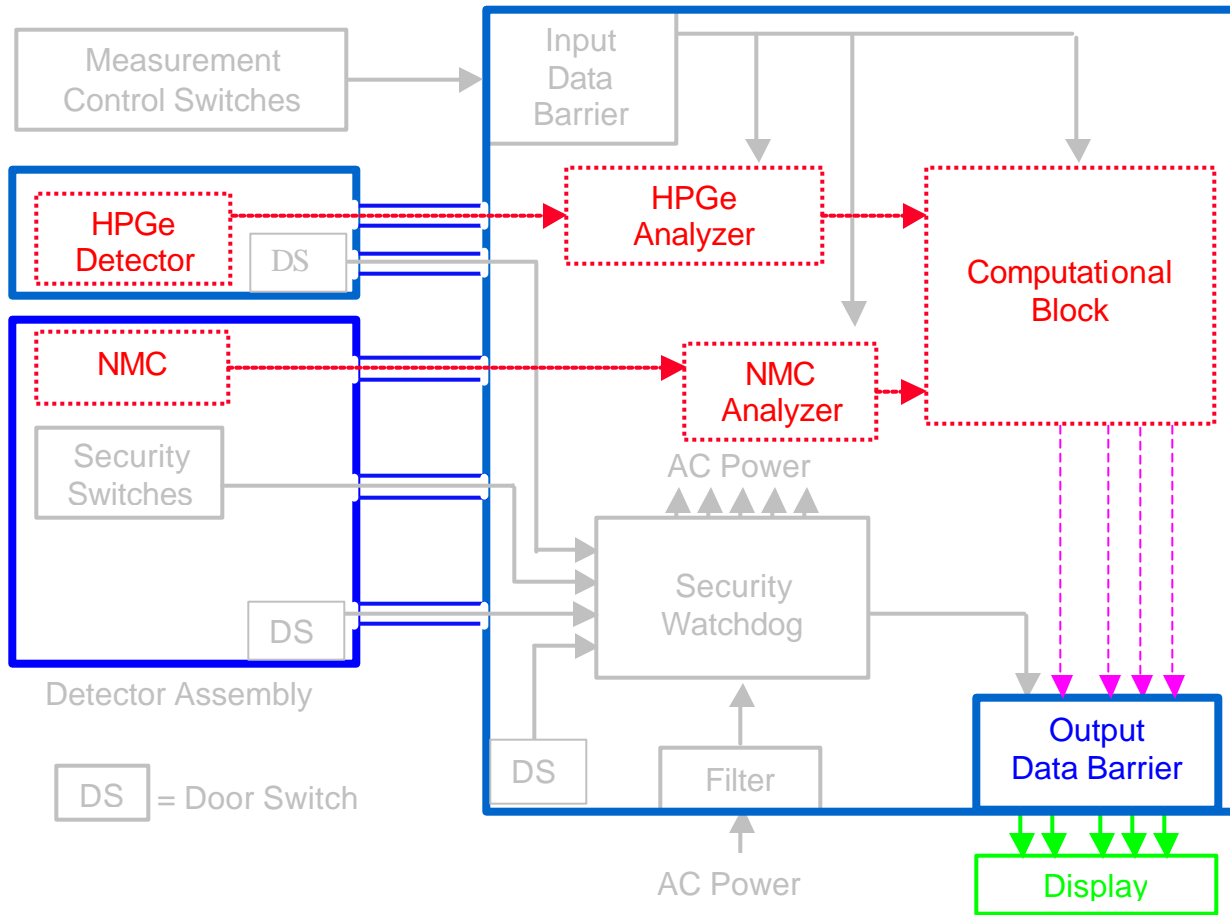- Assay measurement to determine the quantities of interest.

Fig. 4.2 The flow of measurement data between detectors, analyzers, computational block, data barrier, and display. The elements shown in gray are not part of the flow of measurement data.
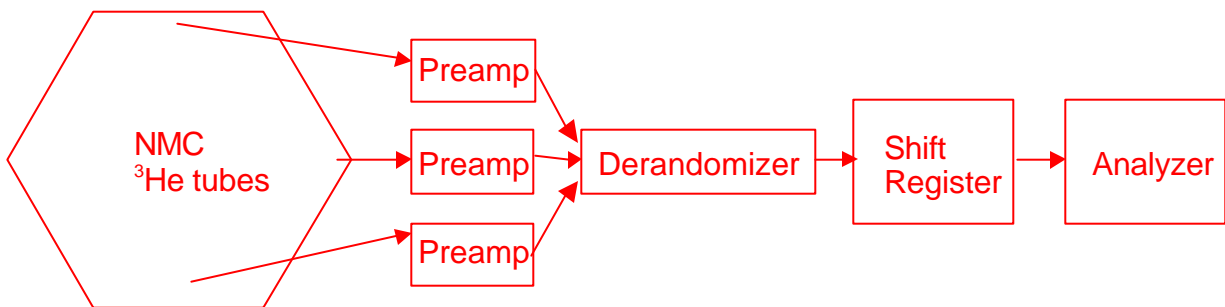
Fig. 4.3.1 Conceptual schematic diagram of the NMC measurement system.

4.3.2 NMC Detector

The detector shall be a standard thermal or epithermal neutron design with the following characteristics.

- It shall have a cavity size large enough to measure material packaged in an AT400R with at least a 5-cm clearance around all sides of the AT400R. The mechanical design will accommodate front loading.
- The efficiency, die-away time, and dead time shall be optimized to facility-specific operational requirements and constraints, including the packaging constraints, so that the system shall be able to complete measurements in reasonable count times with acceptable accuracy and precision. Reasonable count times and acceptable accuracy and precision shall be determined by the requirements given in Section 3.2.
- It shall be capable of operation over a minimum (α,n) to (spontaneous fission n) ratio range from 0 to 5. This range shall be extended as necessary based on host knowledge of the item characteristics.
- It shall provide, to the extent possible, uniform axial and radial response over the sample dimensions.
- It is preferred that the ^{3}He gas filled tubes have (1) 2.54 cm diameters, (2) pressures of 4–10 atmospheres, and (3) a maximum high voltage of 2000 V.
- The neutron detector preamplifier and high-voltage distribution enclosure (junction box) shall incorporate desiccant and desiccant holders sufficient for a two-year replacement cycle and be designed to make replacement of the desiccant easy.
- The NMC will have a metal exterior made of good electrical conducting alloy.
- All cables leaving the NMC shall be in a grounded, tamperproof enclosure.
- All electronic elements, including shielded cables, metal exterior, junction box, and ^{3}He tubes will have a solid, common electrical ground. This ground shall be in common with the general ground of the AMSIB system.
- While maintaining the NMC performance at an acceptable level, the neutron measurement system shall be designed to accommodate the gamma measurement system, the requirements of information protection, and procedures implemented for system authentication.

4.3.3 Electronics

- The overall count-rate capability shall be at least 2×10^6 counts per second. The required count-rate capability shall be revised as necessary based on host knowledge of the item characteristics.
- The required ^{3}He tube high-voltage supply and other necessary electronics power supplies shall be provided. The power supplies may either be incorporated in the coincidence electronics or be separate units.

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- The high-voltage power supply shall be capable of providing 0 to 2000 V with an accuracy of ±0.2%, ripple < 10 mV peak-to-peak, and a temperature coefficient <±50 ppm/°C.
- The preamplifier power supply shall provide +5 V ±1% with a maximum of 2 A. The power supply shall be short-circuit protected.

4.3.3.1 Preamplifiers
- The preamplifiers will convert the ^{3}He response to TTL standard signals.
- The Amptek Model A-111 is an example of an acceptable preamplifier.
- Sufficient preamplifiers will be used to not have excessive deadtime. System triples deadtime shall be less than 100ns. A triples deadtime less than 50ns is recommended. There shall be a maximum of six ^{3}He tubes per preamplifier.
- The preamplifiers shall be distributed among the ^{3}He tubes so as to equalize the count rates in each preamplifier to minimize deadtime.
- The sets of ^{3}He tubes associated with each preamplifier will be selected to facilitate measuring ratios of neutron rates at each ring of tubes.

4.3.3.2 Derandomizer
- Combines preamplifier signals into a single stream.
- Buffers as needed to separate signals that would otherwise overlap.
- The input pulse threshold for all signal inputs will be adjustable and set to 0.85 V relative to a 3.0 V trigger pulse.
- The input pulse width shall be greater than or equal to 50 ns.
- The pulse pair resolution shall be 15 ns or less giving an effective timing resolution of about 75 ns.

4.3.3.3 Multiplicity Shift Register
- The multiplicity shift register (MSR) shall collect data from the derandomizer.
- It shall have the parallel functions of a coincidence shift register and a multiplicity shift register.
- The MSR shall have a shift register frequency capacity of at least 4 MHz.
- The MSR signal input will be buffered in a 16-deep FIFO de-randomizer.
- The totals counter shall be 36-bit synchronous and the reals and reals plus accidentals counters shall be 48-bit synchronous.
- The MSR input pulses will be standard TTL pulses.
- The input pulse threshold for all signal inputs will be adjustable and set to 0.85 V relative to a 3.0 V trigger pulse.
- The input pulse width shall be greater than or equal to 50 ns.
- The pulse pair resolution shall be 15 ns or less.
- The coincidence elements shall extract the accidental rate and real plus accidental rate in selectable coincidence gate widths.

- It shall have selectable gate widths for both the multiplicity and standard coincidence shift register circuits, and these shall cover the range from 0.5 to 2 times the expected die-away time of the detector.
- The circuits shall also have selectable predelays in steps from 1 microsecond up to 5 microseconds.
- The reals plus accidental gates and the accidental gates shall be separated by a time delay of at least 10 times the die-away time of the detector system.
- The multiplicity shift register shall be able to accumulate coincidence information in the reals and reals plus accidental gates for pulses in the gates from 0 to 255 with 32 bits per channel.
- It shall present the extracted data to the NMC analyzer.
- It will incorporate fast accidentals sampling.

4.3.4 NMC Analyzer

Any NMC analyzer shall conform to the software, hardware, and operating system requirements delineated in Section 4.6. Additional NMC-specific constraints include the following.

4.3.4.1 Hardware–Additional Constraints

- It shall interface with the multiplicity shift register.
- It shall have only enough functionality to do the task of collecting and analyzing the neutron data, reporting results in open mode, and reporting to the computational block that does the threshold comparisons.

4.3.4.2 Software

- The software shall control communications with the shift register.
- The software shall use declared and defined data formats between shift register and NMC analyzer.
- The software shall, given shift register results, determine the following:
  - ^{240}Pu effective mass,
  - alpha, the ratio of (α,n) to (spontaneous fission n), and
  - item multiplication.
- The software will incorporate appropriate quality control tests on the individual measurement cycles to reject inconsistent cycles such as those affected by a cosmic ray.
- It shall flag error conditions including the following:
  - inconsistency between coincidence and multiplicity results, and
  - hardware failures.
- It shall report the measurement results and error conditions to the controlling hardware or software.
- It shall report intermediate results to an output device when the system is in open mode.

4.3.5 Overall NMC Considerations

- The anticipated radiation field to which the detector will be subjected after facility installation shall be estimated. All ele ments shall be designed to operate correctly over the anticipated 5-year lifecycle assuming a radiation field of 150% of the estimated field. Additional shielding shall be incorporated if necessary.
- The system shall be designed to be easy to repair within the constraints imposed by the required system performance.

4.3.6 Tamper Indication

- As appropriate, the system shall allow incorporation of seals and other tamper-indicating devices.
- The junction box and NMC exterior shall have tamper-indicating features that cannot be defeated in a time period shorter than any surveillance period.

4.3.7 Authentication

- It is anticipated that all of the individual elements will be subject to some form of inspection by the monitoring parties. Elements including the NMC and up to and including the shift register shall be constructed to enable visual inspection and functional testing for purposes of authentication.
- The NMC analyzer will need to be subjected to the same authentication techniques applied to other computer elements.

4.4 Gamma-ray Detection System

4.4.1 Measurements

Three types of measurements shall be performed: (1) energy calibration, (2) background, and (3) assay.

- Calibration measurement with energy calibration source. This operation shall include determining energy calibration of gamma detector system at specified time intervals.
- Background measurement (for monitoring of external gamma radiation). This operation shall include obtaining and storing background gamma-ray spectrum.
- Assay measurement (for reference sources and declared items). This operation includes the following.
  - o Performing background correction.
  - o Deciding plutonium presence from characteristic spectral lines, e.g., at 646.0 and 658.9 keV. The criterion for peak presence shall be five standard deviations above the continuum.
  - o Computing the ^{240}Pu to ^{239}Pu ratio.

4.4.2 Detectors

- Each AMSIB system requires two installed HPGe detectors, plus at least one additional detector as a maintenance backup.

- All HPGe detectors will have coaxial geometry.
- All HPGe detectors will be n-type to minimize neutron damage.
- All HPGe detectors shall have the following resolution characteristics:
    - < 1.50 keV FWHM at 186 keV
    - < 1.85 keV FWHM at 414 keV
    - < 2.00 keV FWHM at 662 keV
    - < 2.40 keV FWHM at 1332 keV.
- The HPGe detector shall have symmetrical Gaussian peak shapes with limited tailing (FWTM/FWHM < 2.3).
- The HPGe detectors may have an RC feedback type preamplifier.
- The HPGe detectors will have relative efficiency of 50–60%.
- To facilitate interchangeability and authentication, the HPGe detectors shall have performance characteristics as identical as reasonably achievable.
- The HPGe detectors will be energy calibrated no less frequently than once every 48 hours when in use.
- The HPGe detectors shall be appropriately shielded to prevent radiation from other sources present in the facility affecting the outcome of measurements.
- Measures shall be taken to protect the HPGe detector from damage from neutron fluence that could degrade measurements. (For example, a shield of cadmium one-millimeter thick would provide ample protection from slow neutrons.)
- Appropriate shielding shall be used around the AMSIB in order to reduce the radiation background so that radiation will not constitute a health risk and not adversely affect system operation.

4.4.3 Pulse Processing Electronics

- HPGe multichannel analyzer
  The HPGe multichannel analyzer will be a commercial unit with the following features:
    - 8192 channels or more,
    - fast ADC & store cycle (digital analyzer),
    - no rewritable persistent (power-off) data memory, and
    - integral nonlinearity < 0.05%, differential nonlinearity < 1%.
- HPGe amplifier
    - The HPGe amplifier may be incorporated into the multichannel analyzer.
- High-voltage bias supply
    - The high-voltage bias supply may be incorporated into the multichannel analyzer.
      Key features of the high-voltage bias supply may affect the resolution of spectral lines. Criteria for these features are as follows:
        - The output voltage of the high-voltage bias supply shall vary by less than 0.01%/hour and less than 0.02% over an 8 hour period for <0.001% ± 0.1% input voltage stability, and for equilibrium at ambient temperature after a 30 minute warm-up period.

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- The high-voltage bias supply shall have voltage ripple and noise of <3 mV peak-to-peak at a current of 300 µA.
- All elements of the pulse-processing electronics shall be extensively documented.

4.4.4 Gamma Analyzer

4.4.4.1 Hardware

4.4.4.1.1 General

- The gamma analyzer shall be designed with a high level of inspectability.
- The gamma analyzer shall receive no input indicating whether the mode of operation of the system is secure or open.
- The HPGe multichannel analyzer may be incorporated into the gamma analyzer as an internal element.
- The HPGe multichannel analyzer may be located external to but connected to the gamma analyzer as a discrete module.
- It shall have only enough functionality to do the task of collecting and analyzing the neutron data, reporting results in open mode, and reporting to the computational block that does the threshold comparisons.

4.4.4.2 Computer

The computer shall comply with all general computer requirements described in Section 4.6.

4.4.4.3 Software

All software shall comply with the general requirements in Section 4.6.
- Attribute Analysis Software—Detailed Functions
  The gamma attribute analysis software shall provide the following functions.
  o Control of data acquisition from the gamma detector.
  o Calibration measurement with energy calibration source. This operation shall include determining energy calibration of the gamma detector system at specified time intervals.
  o Background measurement (for monitoring of external gamma radiation.) This operation shall include obtaining and storing the background gamma-ray spectrum.
  o Assay measurement (for test samples and declared items). This operation includes the following.
    - Performing background correction
    - Deciding plutonium presence from characteristic spectral lines, e.g., at 646.0 and 658.9 keV. (Greater certainty derives from a larger set of confirmed lines.) The criterion for peak presence shall be five standard deviations above the continuum.

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- Computing the ^{240}Pu to ^{239}Pu ratio.
    - o Perform self-diagnostics at appropriate intervals on raw and analyzed data.
    - o Software will clear all spectral memory of the MCA prior to each acquisition.
    - o All the data transfer formats used shall be defined and open.
    - o Pass the data on to the computational block over an RS-232 or equivalent interface with a simple messaging format.

4.4.4.4 Authentication

- It is anticipated that all of the individual elements will be subject to some form of inspection by the monitoring parties. Elements of the HRGS shall be constructed to enable visual inspection and functional testing for purposes of authentication.
- The HPGe analyzer will need to be subjected to the same authentication techniques applied to other computer elements.

4.5 Information Barrier Systems

The goal of an information barrier (IB) integrated into an attribute measurement system is to allow meaningful measurements while preventing release of classified information. Thus, the output of the AMSIB system shall be unclassified data, the AMSIB shall be unable to display classified data, and there shall be no possible access to classified data. At the same time, the output of the system shall be authenticatable, so that the monitoring party can be assured of the validity of the measurements and that the unclassified output is accurate, authentic, and directly reflects the results of the classified measurements.

An IB is best implemented as a combination of hardware, software and procedural barriers. Key goals in the design of both the hardware and software portions of the AMSIB include:

- simplicity,
- modularity,
- minimizing the amount of classified data collected,
- minimizing the transmission of data between modules,
- minimizing amount of output,
- a design that facilitates visual inspection
- unidirectional data flow,
- minimizing barrier crossings,
- minimizing dependence on software,
- absence of single-point failure modes,[1]

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[1] Failure of the information barrier is defined as the release of classified data. A single-point failure (the failure of one element composing the Information Barrier) shall not allow the release of classified data.

- all modules designed to be fail-safe,
- minimizing operator functions,
- including the capability of performing unclassified authentication measurements with an open system, and
- accommodation of maintenance operations.

4.5.1 Computational Block

The analyzed attribute values passed from the analyzers to the computational block are compared to stored thresholds and a determination is made as to whether each attribute threshold has been met. The computational block then outputs the pass/fail results of these threshold comparisons to a display via the data barrier. The computational block will also send two additional signals to the display: these indicate *measurement complete* and *measurement error* (state of health). After a fixed period of time for measurement, the computational block sends a measurement complete signal to the display. A green *measurement complete* indicator on the output display denotes that measurements have been successfully completed. If an error of any kind occurs during measurement, then the red *measurement error* indicator on the output display denotes that an unspecified error has occurred and there are no measurement data.

The computational block will be implemented as a separate module. If a computer is used, it shall meet the requirements listed in Section 4.6.

4.5.2 Data Barriers

The data barriers provide an extra layer of protection between the modules containing classified information and the modules containing unclassified information. The AMSIB will contain two types of data barriers, one protecting the inputs into the information barrier and one protecting the outputs from the information barrier. In the event that either the measurement control switches or the display are located on the shielded electronics cabinet, the associated data barriers will not constitute barrier crossings. However, in this case, the functionality of the data barriers shall be retained in order to limit the data flow to and from these external connections. Both types of data barriers shall limit the type and amount of data that pass through the barrier. Both data barrier functions will be implemented in hardware with no software elements.

4.5.2.1 Input Data Barrier

The measurement control signals, which determine what operation the AMSIB will perform, are the only operator inputs to the AMSIB. These signals pass into the shielded electronics cabinet through the input data barrier. This simple, hardware-only module ensures that the data flows in only one direction—no output is possible. The input data barrier shall allow only simple "switch closure" information to pass. The input data barrier shall block all input during assays except that explicitly allowed by protocol.

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4.5.2.2 Output Data Barrier

The output data barrier provides protection against unauthorized data transmission between elements contained within the shielded electronics enclosure (that may contain classified information) and the unclassified display or other external systems. The output data barrier shall include a one-way optical isolation connection to allow for the connection to a data archiving device.

4.5.3 Security Watchdog

The security watchdog circuit will monitor and control the security status of the entire AMSIB. The security mode of the security watchdog is set by security sensors that are controlled by the security container itself, without human intervention. The security watchdog operates in the same manner whether in open or secure mode with a single exception. Following a removal of power by the security watchdog for any reason, and after a delay, power will be restored only if one of the specially devised unclassified containers is present in the detector cavity.

4.5.3.1 Functional Description

The security watchdog shall be a hardware module with the capability to terminate power to all other modules of the AMSIB.

4.5.3.1.1 Automatic Termination of Power

Power will be terminated automatically in case of the following:
- access door opening,
- classified material being introduced into the AMSIB incorrectly,
- tamper indication, or
- loss of ground connection.

There shall be no output indicating what triggered the watchdog. Any time the doors are opened, the security watchdog shall remove all power to the remainder of the AMSIB. Since no data shall be written into rewritable persistent power-off memory during AMSIB operation, removing the power will remove all classified data.

4.5.3.1.2 Manual Termination of Power

In addition, a manually operated switch, external to the information barrier and easily accessible by the operator, will be included. This switch will manually remove all power and, hence, purge all data from the system.

4.5.3.2 Logic of Security Watchdog

The security watchdog will be implemented with simple relays and use no silicon elements or software. All security functions shall be entirely separate from the data-analysis functions of the AMSIB.

4.5.3.3 Authentication

The only connection between the security watchdog and the measurement and analysis electronics shall be via the power line.

4.5.4 Switches and Interlocks

The AMSIB shall be designed with complete separation between security sensors and measurement control switches.

4.5.4.1 Security sensors and Interlocks

The security sensors will directly control the security watchdog. The security mode of the AMSIB will be controlled by the security watchdog. The security sensors will require no operator control, as they are actuated by the containers. The default condition, when no container is in the detector, will be to act as if a classified measurement is being made.

4.5.4.2 Modes

The AMSIB will operate in two modes: open mode or secure mode.

4.5.4.2.1 Open

The open mode may be used for background, measurement control, calibration, authentication measurements, and maintenance. When the system is in the open mode, video displays may be attached to the analyzers and the computational block so that output from the software on these computers may be viewed. The AMSIB shall be inoperable in open mode if a classified container is in the measurement cavity. Fig. 4.5.4.2.1 conceptually illustrates the AMSIB in the open mode (with doors open and display(s) attached).
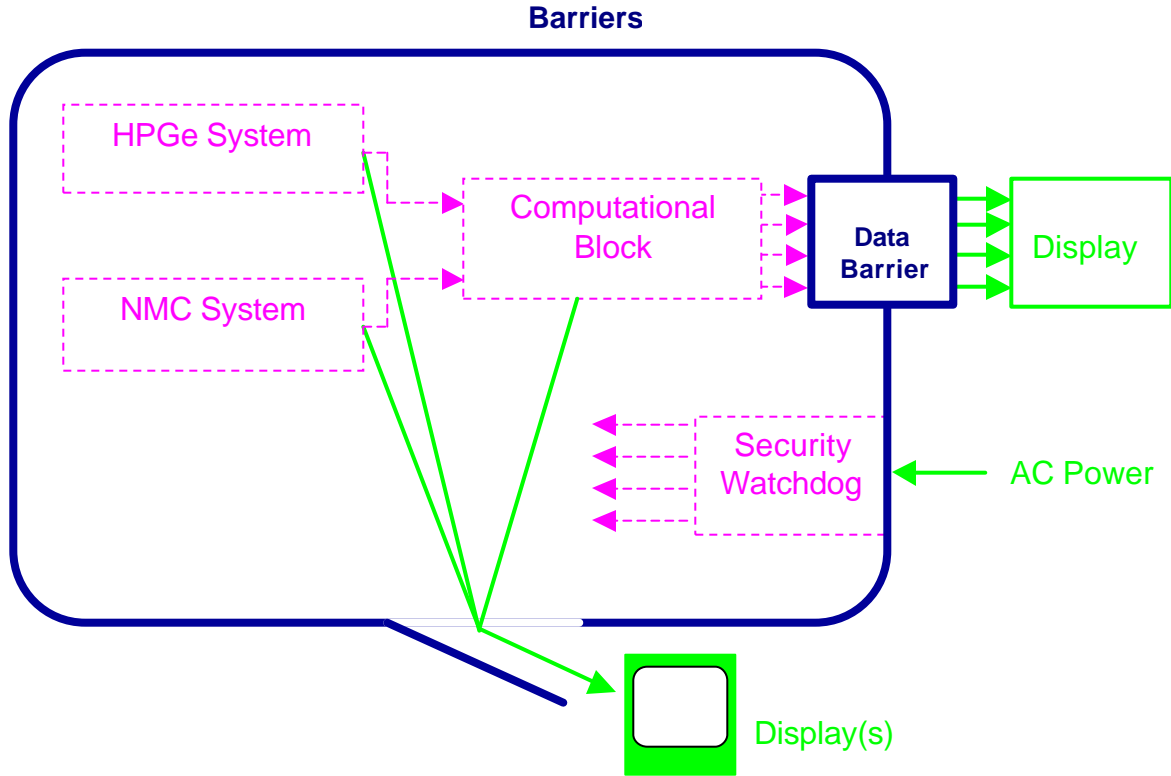
Barriers

Potentially contains classified information

In protected area, contains no classified data

In open area, contains no classified information

Barrier elements

Fig. 4.5.4.2.1 Simplified illustration of the AMSIB in the open mode with external display(s) attached. The doors are open in this mode, and no classified information can be processed.

4.5.4.2.2 Secure

The secure mode is used for all measurements of classified items. When a classified item is in the detector cavity, it shall be technically impossible for output to be displayed on any device other than the unclassified display. Background, measurement control, calibration, authentication measurements may also be performed in secure mode. Fig. 4.5.4.2.2 conceptually illustrates the AMSIB in the secure mode (with doors closed and the displays removed).

Barriers

HPGe System

NMC System

Computational Block

Data Barrier

Display

Security Watchdog

AC Power

---- Potentially contains classified information   —— In open area, contains no classified information
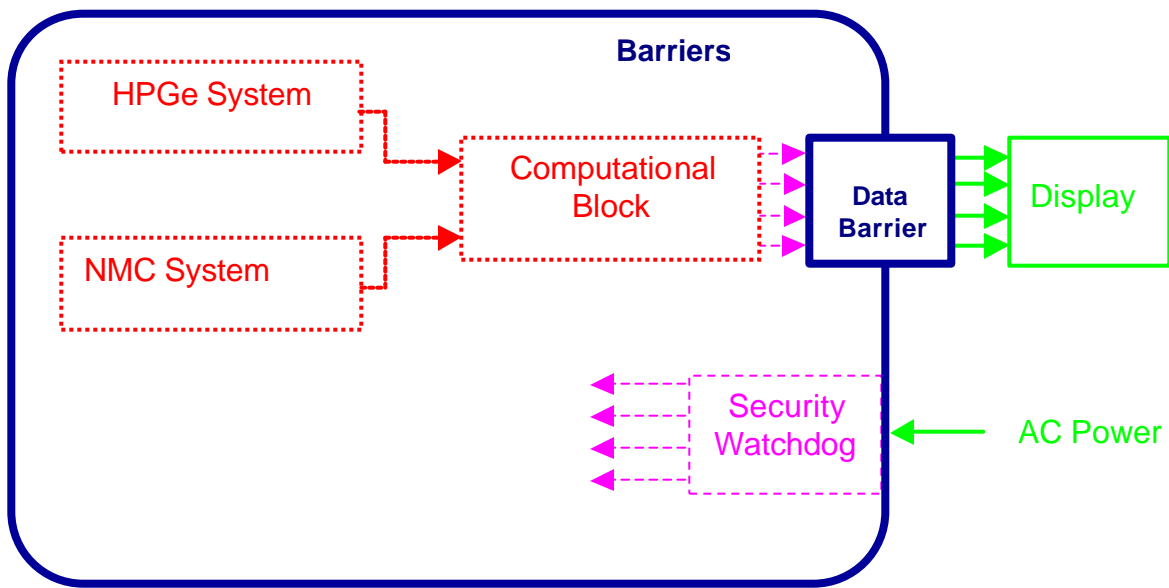
- - - In protected area, contains no classified data   ▬▬ Barrier elements

Fig. 4.5.4.2.2 Simplified illustration of the AMSIB in the secure mode. In this mode, external video display(s) cannot be attached and the doors must be closed. In secure mode, classified information can be processed.

4.5.4.2.3 Measurement Types

Two types of measurements can be made by the AMSIB, unclassified or classified. The measurement type is determined by the container holding the materials to be measured. The container type will be read by the security sensors located within the NMC detector.

4.5.4.2.4 Unclassified Measurements

Measurements of unclassified materials may be made in either the open or the closed modes. These measurements may include background, measurement control, calibration, and authentication.

4.5.4.2.5 Classified Measurements

Measurements of classified material shall be made only when all access doors are closed and the AMSIB is in the secure mode. In this mode, the red and green LED display is the only output from the system.

4.5.4.2.6 Container Designs

The 4AMS/IB system shall provide a means independent from its own radiation measurements for distinguishing between classified and unclassified items. Containers that hold known unclassified sources for calibration and authentication of the AMSIB system will be devised with a

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unique design. The container will be similar to the type of container that holds classified material, but distinguishable from it. The detector cavity will contain security sensors that distinguish these containers from containers holding classified materials. The AMSIB will operate in *open mode* only when the container devised for unclassified material is in the detector cavity. When in the detector cavity, a container that holds a classified item activates security sensor. Thus any container is assumed to contain classified material unless that container has been specifically devised so as not to contact the security sensor.

4.5.4.3 Measurement control Switches

The measurement control switches will be controlled by the system operator and shall be the only operator input mechanism in the AMSIB. These switches, located on the measurement control panel,[2] will control the data analysis systems to start background, calibration, measurement control, or assay. There shall be no connection from the measurement control panel to security sensors or to the security watchdog.

The measurement control panel may be a data input box external to the enclosure containing the analyzers. It consists of a set number of control switches, a stand-alone shielded enclosure, and a shielded cable connecting it to the shielded cabinet.

4.5.5 Enclosures

Both cables and cabinets shall meet the following requirements: all that are parts of the information barrier shall minimize the possibility of data transmission from inside to the outside and from the outside to the protected modules; all AMSIB elements will be shielded and tamper indicating. Cables between any cabinets and/or enclosures shall meet the same tamper indicating, sealable, EM shielding standards as the cabinets themselves.

4.5.5.1 Physical Control

Access controls shall be implemented to prevent unauthorized access to or tampering with the AMSIB. Procedures shall be in place covering all participant activities as well as system maintenance. Continuity of knowledge of system operation shall be achieved and recorded.

4.5.5.2 Seals

All enclosures or cabinets shall employ a mechanism to allow attaching multiple seals to every openable access point. Procedures shall be in place,

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[2] The measurement control panel may be a data input box external to the enclosure containing the analyzers. It consists of a set number of control switches, a stand-alone shielded enclosure, and a shielded cable connecting it to the shielded cabinet.

prior to operation, to record any authorized breech (e.g. attaching displays to the analyzers during unclassified testing of the tamper indicating devices and to reissue and affix seals before the system is placed back in service. Reauthentication shall be preformed to the satisfaction of all concerned parties before the reapplication of these seals. .

4.5.5.3 Electromagnetic Shielding

The AMSIB shall be shielded to prevent the transmission of any signal from inside of a cabinet or enclosure to the outside and to prevent the reception of any signals by the system from the outside of the cabinet or enclosure. The actual level of required shielding shall be jointly determined by the host and monitoring parties.

4.5.6 System Power

Upon entering the shielded enclosure, all power to the remaining AMSIB modules passes through the security watchdog. Ground sensing will be employed by the security watchdog, which will shut down the system if ground connection to shielded enclosures is lost. Any time an access door is opened, door switches will notify the security watchdog, and all power will be removed from the system. Since no data are written to persistent power-off memory during AMSIB operation, this operation removes all classified and unclassified information from the system.

4.5.7 Error Handling

The AMSIB system design shall include written procedures for handling system errors. These procedures shall address
- misidentification of an object under test,
- detection of an error condition, and
- rectification of errors without revealing classified information.

The AMSIB system design shall include written procedures for handling measurement errors. These procedures shall address
- identification of an error type or condition,
- a remeasurement protocol,
- false negatives, and
- false positives.

All modules shall be designed so that if they fail, they fail in a way that protects any classified data in the system. This will be included in Submittal 3.3.3.

4.5.8 Display

The output display reports completion of measurements, measurement results, and system state of health. It will be a simple hardware-only module with no capability of communicating back to the output data barrier. It shall be operational for both classified and unclassified measurements and capable of no more than "red/green" type outputs. The bar-code identifier on the container will be displayed simultaneously with the measurement results but on a separate display. The entire bar code system shall remain outside the shielded enclosures.

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Video or liquid crystal displays may be connected and viewed for display of additional output for unclassified measurements only. Connectors for display cables will be located on the analyzers, inside the shielded enclosure.

4.5.8.1 Archival Storage of Results

All AMSIB outputs are unclassified and may be archived as required. Printers, storage devices, and video displays may be connected to the unclassified display unit as long as such devices are incapable of changing the output of the unclassified display. The unclassified display outputs, along with the bar-code results, may be archived in a mutually agreeable storage medium. External connections to the IB system for archival data storage shall be protected by one-way (optical) isolation to preclude any electronic interactions with the system. Any unclassified data archives will be handled appropriately and will be protected against surreptitious modification.

4.5.8.2 Reconstruction of Lost Data

To protect classified data, the AMSIB shall be designed with no rewritable persistent power-off memory. Thus, once the power is removed or a new measurement is begun, all data from previous measurements are lost. The unclassified measurement results output by the display panel are transitory.

To prevent the loss of unclassified measurement results, a redundant archival system external to the AMSIB will be utilized.

4.6   Computer Systems

The computational block, the gamma analyzer, and the NMC analyzer will all be computer based.

All computers shall comply with the following requirements:

4.6.1 Hardware

- All computers shall be based on identical processing units. These processor units shall be identical, so that one will be replaceable by another.
- They shall employ no rewritable persistent (power off) memory, with the possible exception of small system-level rewritable persistent power-off memory. If BIOS memory is employed, the program will write a standard configuration into it at power-up.
- Each computer shall boot from a fixed (no moving mechanical parts), nonrewritable medium containing all software and constants, e.g. a solid-state PROM.
- The computers shall be capable of operating with or without a keyboard and display.
- The operation of each analyzer computer shall minimize the amount of data transferred to other modules.

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- The data flow between computers and also between computers and other elements (e.g. the NMC) shall be unidirectional, wherever possible.
- The computers will contain no hardware functions that are not required for proper operation. If such functions exist, they shall be hardware disabled. The computer shall be simple, having only enough functionality to perform its required task.
- The physical layout of the computers shall facilitate inspection.
- All computers shall easily recover from system disruption, for example, power failure.
- No processor shall be able to ascertain whether it is operating in open or sensitive mode.
- A means of reporting intermediate results in open mode shall be provided.
- Hardware selection shall be based on facilitating visual inspection.
- Hardware selection shall be based on the completeness, availability, and sharability of documentation.
- It is desirable to minimize extra computer boards and functionality.
- It is desirable to avoid reprogrammable logic.

4.6.2 Operating System
- The computer(s) need not use an operating system.
- If operating systems are employed, all computers within the AMSIB shall use the same operating system.
- Any operating system used shall be as simple as possible.
- Any operating system selection shall be based on completeness, availability, and sharability of documentation.

4.6.3 Software
- Software shall be as simple as possible, each program performing a single function.
- Extraneous functionality shall be avoided.
- Commercial off the shelf software selection shall be based on simplicity, completeness, and availability.
- Only one compiler for each language shall be used for building the entire system.
  - Software shall be written in a common programming language (assembly language, C, or Fortran).
  - Software shall flag error conditions.
- All software shall be robust and programmed to fail gracefully if unable to continue correctly.
- Source code, build instructions, and a golden copy of the executable code shall be provided in machine-readable format for all custom software.
- Hash functions may be used in open mode in situ.

4.7 Operator Interface

The entire operator interface shall be as simple as possible while still enabling the performance of the required functions of classified data protection and authenticated output.

4.7.1 Input

The operator input to the AMSIB shall consist of the minimum number of switches necessary to activate the required functions. These functions may include background measurement, HRGS calibration, NMC measurement control, and Assay.

The security function of the AMSIB shall not be controlled by the operator (or the monitoring party). All security functions shall be controlled by switches activated by the container itself. No operator intervention shall be required to inform the AMSIB as to the type of measurement being performed (classified or unclassified).

The systems that collect and analyze data or that display measurement results shall be unaware whether the item is classified or unclassified.

4.7.2 Output

The output of the AMSIB, when classified items are being measured, shall be limited to a series of red and green lights. These lights shall indicate whether (green) or not (red) each attribute is confirmed. Additional red and green lights shall indicate the operational state of the system.

When known unclassified measurements are being performed, computer displays may be attached to the computer-based modules within the AMSIB. These displays will indicate spectra and intermediate results from the analysis and threshold comparison modules.

4.7.3 Maintenance

There shall be no special maintenance mode of the AMSIB. If non-routine maintenance or element replacement is required, it shall be preformed in a mutually agreed fashion (possibly replacing modules from a "preauthenticated" stock). Reauthentication of the AMSIB may be required following any element replacement.

A mutually acceptable procedure for any required routine maintenance (such as filling cryogenic detector systems) shall be completed prior to operation of the AMSIB in the storage facility. This procedure will not require opening any of the equipment cabinets or shutting off power to the AMSIB.

5 FABRICATION

5.1 General

All procurement and assembly shall be performed in accordance with internationally accepted standards and practices. Any additional purchasing or procurement agreements, which are agreed to by both parties, shall be followed.

5.2 Labeling

In order to facilitate function identification, all major modules of the AMSIB system shall be labeled clearly and permanently in both Russian and English.

All switches and displays shall be permanently labeled in both Russian and English in letters that are large enough to be readable from the position of monitoring personnel during measurement of a classified item.

5.3 Cabinet Finishing

All cabinets and enclosures that form part of the information barrier will be constructed of light colored anodized aluminum. The exterior surfaces of these enclosures shall be unpainted.

All cabinets and enclosures that form part of the information barrier shall be furnished with appropriate locations and hardware to place seals and tamper indicating devices on all openable surfaces. These locations shall be sufficiently large to hold multiple seals and tamper indicating devices and shall be located on portions of the cabinets that will be accessible during operation. The seal locations shall be permanently affixed to the cabinets.

The interiors of information barrier enclosures and the exteriors of all other modules in the AMSIB will be finished according to good engineering practices. This may include removal of sharp corners, uniform painting of modules, etc.

5.4 Fabrication Facility Requirements

The contractor shall provide photos (bmp, jpg, etc. format) and videotapes (avi files) to the buyer's specification to highlight and document work associated with this contract. The contractor shall include those items as attachments to the monthly reports.
The buyer's representatives shall have access to visit the Russian contractor's site and the Mayak FMSF for periodic quality assurance /quality control (QA/QC) during fabrication, configuration, programming, FAT, and SAT certification.

6   SYSTEM OPERATIONS

6.1   Start-up

The system shall be designed so that start-up can be conducted in either open or secure mode. The system will initially have to be operated in open mode to place it into operation and perform initial functional testing.

6.1.1   Power-up

Power-up will be a simple procedure requiring minimal input from the operators. Upon initial power-up of the system, software shall auto-launch, and detection systems shall automatically take the steps necessary to reach operational status. This may include, but is not limited to, providing power to preamplifiers and amplifiers and applying bias voltage to detectors. The display panel shall provide an indication that the system powered up successfully and is ready to accept commands.

6.1.2   Background Measurements

Background measurements shall be taken at intervals sufficient to ensure that the background data stored in the AMSIB adequately represent the current background status. The AMSIB shall not allow assay measurements to be taken until a background measurement has been taken by each detector or measurement system that requires such information.

6.1.3   Calibration and Measurement Control

The system shall be designed to keep the calibration and measurement control requirements as time- and resource-efficient as is reasonably possible while still providing sufficient indications of system performance. Detectors and analysis systems shall be chosen to minimize the need for calibration standards. Detectors and analysis systems shall be chosen to minimize the time, radiation exposure, and other demands on the Mayak FMSF operating authorities.

6.2   Functional Testing

The subject of testing is covered in detail in Section 7.

The system shall be designed to incorporate self-diagnostic measures to minimize the need for functional testing wherever reliably and reasonably possible. While in open mode, normal functional information for each measurement system shall be available to the operators and monitoring parties. This shall include, but is not limited to, such parameters as bias voltage status, gamma-ray pulse shaping time, and input count rate for the HRGS, and ^{3}He tube voltage, neutron pulse accidental rate, neutron reals plus accidentals rate, and the neutron multiplicity distribution for the NMC. Standard functional testing procedures shall be provided with the system to ensure complete understanding by the operators and other parties to this contract. The operators and monitoring parties shall have the ability, while the system is operating in open mode, to compare attribute analysis indications with the detailed results of measurements of unclassified items.

6.3 Normal Operation

The system shall indicate when it is operating normally. The system shall be self-monitoring to determine that it is in normal operation. The self-monitoring shall cover measurement system functions, analysis functions, and security/IB functions. Failures or faults within any of these systems shall cause the system to stop indicating normal operation and indicate that it is not operating normally. The exact nature of and list of monitored functions and systems will be determined during development of the system. Monitoring of security/IB functions by the data-collection and analysis CPUs shall not occur. A separate method of monitoring will be developed.

6.4 Error Conditions and Reporting

As discussed above, when the system fails to operate normally, it shall indicate this fact. Such indication shall be provided both by the system ceasing to indicate normal operation and by a separate indication of an error condition. The specific nature of the error shall be determinable once any classified items have been removed from the system and the system placed in open mode. The system shall not indicate attribute analysis results when an error condition is reported. The system shall indicate an error only after the measurement is complete. The system may be designed for private access to more detailed error information by the Mayak FMSF operating authority provided the mechanism does not violate system authentication or information protection.

6.5 Authentication

The measurement system shall be designed to facilitate authentication and testing with the use of unclassified items. The system shall be designed to facilitate revalidation after the initial authentication and after maintenance and repair.

6.6 Maintenance and Repair

The system shall be designed to minimize requirements for periodic maintenance and support. The system shall be designed for a minimum life of 5 years, except for items routinely requiring periodic replacement. The number of such parts, and their cost, shall be minimized. Maintenance and repair plans shall be prepared and reviewed by all parties to this contract. For repair and maintenance of the system, the developer may rely on qualified, off-site personnel as agreed to by all parties to this contract. However, all maintenance and repair plans shall be designed to minimize downtime of the system.

6.6.1 Maintenance Procedures

The contractor shall develop maintenance procedures. These procedures shall be documented and provided to the parties to this contract. The design of the system shall simplify maintenance procedures as much as possible through the use of modular, easily replaced elements and other appropriate design features. A list of spare parts shall be provided by the contractor and approved by the buyer. This list shall include 5-10 spares beyond what is necessary to keep the equipment operational for the 5 years of operation. Maintenance procedures shall allow for reauthentication of correct operation.

6.6.2 Spare Parts

The developer shall recommend a list of spare parts requirements anticipated for 5 years operation with the addition of 5-10 spares per component. This list shall be approved by the buyer. This list may reflect projected obsolescence of some elements. To the extent reasonably possible, the number of elements that are projected to become obsolete over the design life of the system shall be minimized. This is of particular concern in critical elements whose obsolescence would impact the system as a whole. The spare parts list shall specify any parts that require a long lead-time for procurement. A list of potential spare parts is included in Section 9.3.

All spare parts shall be stored according to procedures agreed to by all parties to this contract. Storage of spare parts shall provide continuity-of- knowledge for the part and may include the use of an approved storage vault, surveillance, and tamper indicating tags or seals to provide this continuity-of-knowledge.

6.7 Training

Training will accommodate the need for routine operators of the system, personnel to provide routine maintenance of the system, and personnel to perform repair of the system. Training will be efficient but thorough.

6.7.1 Training Plan

The developer shall provide a detailed training plan for the system. The system shall be developed to function intuitively for individuals with radiation measurement experience on similar systems. The training necessary to operate, maintain, and troubleshoot the system shall be as minimal as reasonably possible. The training plan shall specify the initial training requirements, any ongoing or refresher training that may be necessary on a periodic basis, and who is qualified to provide and evaluate operator training.

6.7.2 Site Training

The developer shall minimize the requirements for training of on-site (non-operator) personnel. Such training may involve the support requirements for the HRGS and basic familiarity with handling of the system (ruggedness). The developer shall also design the system so that as little training as possible has to be conducted on-site. The designer may provide in the training plan for some training to be conducted at other facilities to reduce personnel radiation exposure or to provide more convenient access to specialized elements. The host nation shall provide the necessary site training to allow monitoring personnel access to the AMSIB operation site.

6.7.3 System Training

The developer shall provide training materials to familiarize technical and non-technical personnel (both host and monitoring parties) with the capabilities, limitations, and functional theory of the system.

6.7.4 Operator Training

The developer shall provide training materials for system operators. This training shall prepare the system operators to put the system into operation (power-up), take background and calibration measurements, operate the system in open and secure mode, move the system from open to secure mode (and back), determine normal operation, determine error conditions, perform basic troubleshooting, and take the system out of operation (power-down). This training shall also enable the operator to determine when expert consultation is necessary.

6.7.5 Expert Training

The developer shall provide training materials for system technicians. This training shall prepare the system technicians to perform detailed troubleshooting. The training shall prepare system technicians to anticipate possible problems or sources of error in the measurements. The training shall prepare the system technicians to train and approve system operators.

6.7.6 US Participant Training

The developer shall provide US participants with sufficient training to operate and maintain the duplicate system.

7 TESTING

7.1 Module Tests

Test procedures for all commercial modules and those constructed in-house shall be written by the contractor and approved by all parties to this contract. These shall include element level modules such as computers, HPGe detectors, multichannel analyzers, shift registers, etc. The tests will include sub-elements such as ^{3}He tubes and pre-amplifiers if these sub-elements are used in modules that are constructed in-house. Modules included in the AMSIB system shall be tested in accordance with documented procedures, and the results of these tests shall be reported in writing. Module test procedures shall be established by the contractor to minimize the burden involved in testing all modules. The procedures shall specify who will perform the tests, who will be present to observe testing, how the tests are to be documented, and procedures in case of module test failure. Module tests shall include the following.

7.1.1 Acceptance Tests

Acceptance testing shall be performed on all modules in accordance with procedures agreed to by all parties to this contract. Acceptance testing shall establish that modules are complete, undamaged, and operable. Procedures shall be approved regarding any modules that fail these tests.

7.1.2 Functional Tests

Functional testing shall be performed on all modules in accordance with procedures agreed to by all parties to this contract. Functional testing shall establish that all modules are functioning within their manufacturer-specified parameters and will perform adequately in the AMSIB. Functional tests shall not result in excessive wear on system components such that the functional life of the components is unduly shortened. Procedures shall be approved by all parties to this contract regarding modules that fail these tests.

7.2 System Tests

The complete AMSIB shall be tested in accordance with procedures agreed upon by all parties to this contract. The procedures shall specify who shall perform the tests, who may be present to observe testing, how the tests shall be documented, and procedures in case of test failure. Test procedures and results of these tests shall be provided to the buyer in accordance with the submittals defined in Section 1.

7.2.1 Factory Acceptance

The system shall be tested by the manufacturer to ensure that the AMSIB is correctly assembled and capable of functioning as specified. Factory acceptance testing shall demonstrate, as completely as possible, full functionality of the system. The system factory acceptance test shall include testing with isotopic neutron and gamma-ray sources such as ^{252}Cf and ^{137}Cs. All parties to this contract shall be given the opportunity to observe factory acceptance testing. The factory acceptance testing shall include a 100-hour continuous run of the system

without loss of any critical function, and without any software or hardware failure. The testing shall be fully documented, and the documentation shall be provided to all parties to this contract upon shipment of the system from the factory. The factory shall be responsible for correcting any deficiencies discovered during this testing before shipment, unless an alternative agreement has been reached, in writing, with the receiver. The factory shall provide for the health and safety of all participants during factory acceptance testing. This shall include adequate protection from electrical, mechanical, or radiation hazards that may be encountered during the course of this testing.

7.2.2 Functionality

The AMSIB shall be tested to ensure that it will function in accordance with specifications. This testing shall replicate, as closely as possible, the conditions under which it will operate in the host nation's facility.

7.2.3 Authentication

Testing for authentic performance of the AMSIB shall include the execution of all procedures agreed to by all parties to this contract. Each module or sub-element shall be sealed in a tamper indicating enclosure after authentication. Continuity of knowledge (CoK) of its integrity shall be maintained. Loss of such CoK will require complete reauthentication of the component. Authentication testing shall include functional testing of the system as described above. If agreed to by all parties, authentication of the AMSIB shall include authentication of individual modules or sub-elements. The manufacturer shall provide access for agreed authentication activities in a timely fashion. The manufacturer shall provide for the health and safety of participants during authentication activities. This shall include adequate protection from electrical, mechanical, or radiation hazards that may be encountered during the course of agreed authentication activities.

7.2.4 Site Acceptance

Once the AMSIB is installed in the final facility, the Mayak FMSF operating authority shall, with manufacturer support, conduct site acceptance testing. Procedures and results of this testing shall be fully documented by the contractor. The Mayak FMSF operating authority shall give other parties to this contract the opportunity to observe this testing. The testing procedures shall be approved by all parties to this contract. The procedures shall be based on the factory acceptance test procedures, but shall also include testing with unclassified SNM items. The Mayak FMSF operating authority shall report to all parties to this contract in writing when the system has passed site acceptance testing. The warranty shall begin on the date of issuance of such notification. The Mayak FMSF operating authority shall provide for the health and safety of participants during site acceptance testing. This shall include adequate protection from electrical, mechanical, or radiation hazards that may be encountered during the course of agreed acceptance activities.

7.3 Ongoing Tests

Procedures for ongoing, routine tests shall be approved by all parties to this contract. These tests will demonstrate that the system, having been accepted as functional and meeting performance specifications, continues to maintain full functionality and meet performance specifications.

7.3.1 Source

Ongoing tests shall include measurements of unclassified radioactive and SNM sources. The Mayak FMSF operating authority or the system manufacturer shall provide these sources, unless an alternative source is agreed to in writing by all parties to this contract.

7.3.2 Simulator

Ongoing tests may include simulated measurements of unclassified radioactive and SNM sources. These tests will be regarded as providing information about data analysis modules and the information barrier system only. These tests will not be regarded as providing any information about the functionality of the radiation detector elements of the AMSIB.

7.4 Other Tests

Procedures for other tests may be added as deemed necessary and approved by all parties to this contract.

7.5 Test Plan

The complete test plan (module tests, system tests, ongoing tests, and other tests) shall be made available to all parties to this contract by the manufacturer before initiation of the factory acceptance testing. The manufacturer shall seek and incorporate input from all parties to this contract as the test plan is written. The test plan may be modified after initiation of the factory acceptance testing if the approval of all parties to this contract is obtained. Operations conducted under the test plan shall be documented. Such documentation shall be available to all parties to this contract for review.

8 PACKAGING, SHIPPING, AND STORAGE REQUIREMENTS

8.1 Transportation and Handling

- Transport and handle products in accordance with manufacturer's instructions.
- Promptly inspect shipments to assure that products comply with requirements, quantities are correct, and products are undamaged.
- Document receipt and inspection of equipment

8.2 Storage

Store and protect products in accordance with manufacturer's instructions, with seals and labels intact and legible.

9 APPENDICES

9.1 Detailed Explanations

9.1.1 Physics Basis of the Attribute Measurement System

9.1.1.1 Introduction

US and Russian technical experts have been working together since 1994 to find effective means to measure attributes of plutonium removed from dismantled nuclear weapons. The physics basis of these measurements is, of course, well understood by these technical experts. For readers with a more general scientific background, we begin in Section 9.1.1.2 with a refresher description of the nuclear atom, radioactivity, and reactions. In the remainder of Section 9.1.1, we build on these fundamental concepts and discuss how the four plutonium attributes can be determined with radiation measurements.

9.1.1.2 About the Atomic Nucleus, Radioactivity, and Reactions

9.1.1.2.1 The Atomic Nucleus and Isotopes

Matter is composed of atoms. Atoms comprise a tiny nucleus with a positive electrical charge, which in turn is surrounded by a cloud of negatively charged electrons. Almost all of the atom's mass is in the nucleus, which contains two types of particles of roughly equal mass— neutrons and protons. Neutrons have no electrical charge and protons have positive electrical charge equal, in magnitude, to the electron charge. The number of protons in a nucleus (called its atomic number or Z) determines the chemical element. For example, all hydrogen atoms have one proton, all iron atoms have 26 protons, and all uranium atoms have 92 protons. Except for the very lightest elements, the nucleus has about twice as many neutrons as protons.

The nuclei of all of the chemical elements can have varying numbers of neutrons. These variations are called isotopes. The written symbol for an isotope is a superscript number that indicates the total number of neutrons and protons in the nucleus followed by the chemical symbol of the element that identifies its atomic number. An example is ^{239}Pu, an important isotope of plutonium (Z = 94), which has a total of 239 neutrons and protons.

9.1.1.2.2 Radioactivity and Reactions

- Radioactive decay
  For a nucleus to remain stable, it must have a proper balance of neutrons and protons. A nucleus with too many or too few neutrons is unstable and seeks stability by the emission of particles—the process of radioactive decay. All of the isotopes of the heavy elements above bismuth ($Z = 83$) are radioactive.

  Radioactive emissions from plutonium carry information from which many plutonium attributes can be determined. A variety of subatomic particles is emitted during radioactive decay processes. Because of their ability to penetrate from the interior of items and through thick storage containers for observation, two of these emissions are of particular interest—neutrons and gamma-rays.

- Neutron emissions
  For heavy elements, a particular form of radioactive decay of interest is spontaneous fission. This form of decay is particularly important for plutonium. Spontaneous fission is a decay mode in which the nucleus splits into two large fragments of nearly equal size accompanied with the emission of several energetic neutrons. Nuclear fission can also be induced. This commonly occurs when a neutron emitted from a fissioning nucleus interacts with another nucleus to induce another fission and release more neutrons. The production of neutrons from successive fission processes of this kind is called neutron multiplication. Fission neutrons are quite penetrating and can escape from plutonium in storage containers; they can then be observed with a neutron detector.

  Neutrons emitted from plutonium carry information about the properties of the source, among these are its mass and the presence of light elements.

- Gamma-ray emissions
  Gamma radiation is another emission associated with radioactive decay that is of particular interest. Following radioactive decay, the resulting nucleus is usually left with excess energy. This energy is typically released through the emission of gamma-rays. Gamma-rays are electromagnetic radiation, like x-rays, but are more penetrating. Moreover they have sharply defined energies, and the pattern of gamma-ray emissions is unique for each radioisotope—providing a nuclear signature. These signatures can reveal a wealth of information about the material emitting them. This includes such attributes as the presence of radioactive isotopes and isotopic composition.

- Another form of radioactive decay that is common among the heavy elements is the emission of alpha particles. An alpha particle is a tightly bound unit containing two neutrons and two protons. Alpha particles have short ranges and cannot escape from storage containers but are of interest because interactions of these particles with light impurity elements (called alpha-n or (α,n) reactions) also produce energetic neutrons. Alpha particle detection is not used in the AMSIB.

9.1.1.3 Gamma-Ray Measurements of Plutonium

9.1.1.3.1 The Gamma-Ray Signature of Weapons-Quality Plutonium

As already mentioned, gamma-rays have sharply defined energies, and the pattern of gamma-ray emissions is unique for each radioisotope—providing a nuclear signature. A portion of the gamma-ray signature measured from an unclassified US weapons-grade plutonium item is shown in Fig. 9.1.1.3.1. To expand the plot, the data in the figure have been folded in half, with the first 500 keV region shown at the top of the figure and the second 500 keV region shown at the bottom. The horizontal axis is calibrated in gamma-ray energy using customary nuclear energy units—kilo-electron-volts or keV. The vertical axis indicates the number of counts recorded by the measurement instrument—a high-resolution gamma-ray spectrometer.

The spectrum is complex and rich with characteristic peaks riding atop a continuum that is down-sloping with increasing gamma-ray energy. The item was 93.5% ^{239}Pu by weight, and its peaks dominate the spectrum. Peaks from the decay of other isotopes are identified by their isotopic symbols in their call-outs.

9.1.1.3.2 High-Resolution Gamma-Ray Spectrometers

The spectrum shown in Fig. 9.1.1.3.1 was obtained using an instrument called a high-resolution gamma-ray spectrometer. The sensing element is a solid cylindrical crystal of ultra-high-purity germanium kept at cryogenic temperature (~100 °K). The cryogenic temperature is necessary to obtain the high energy resolution (narrow peaks) shown.
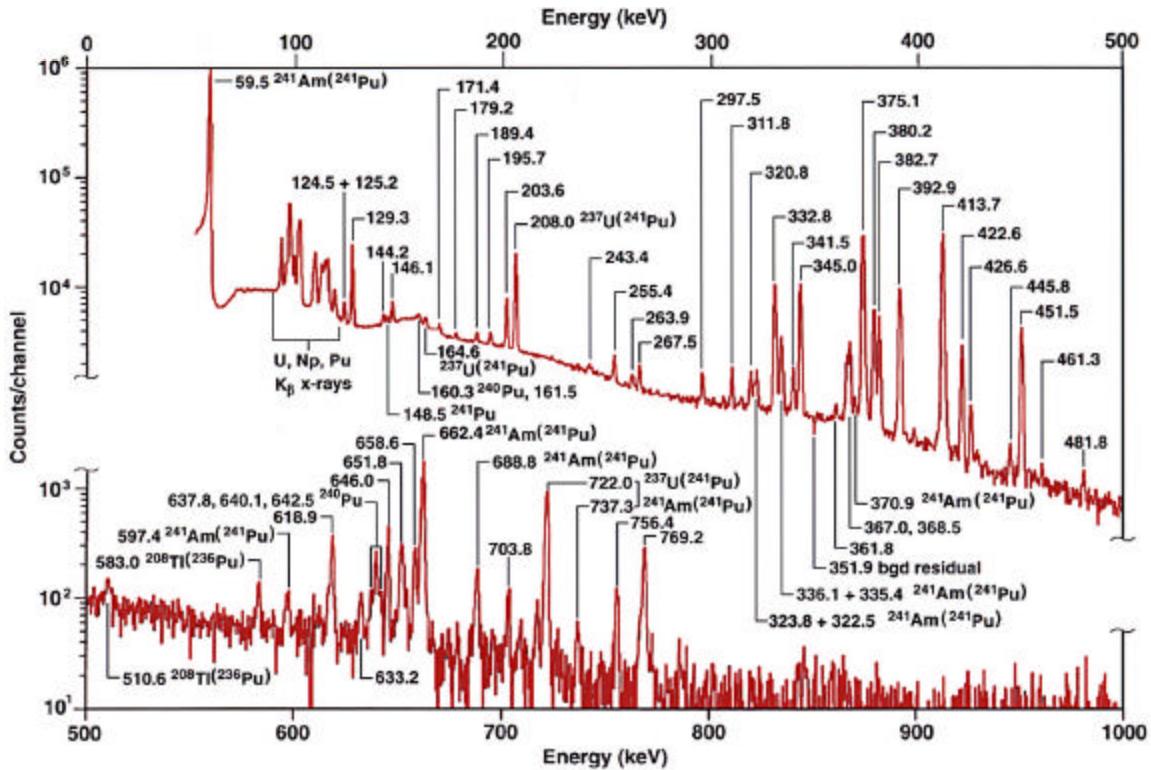
Fig. 9.1.1.3.1 The first 1000 keV of a net gamma-ray spectrum (background subtracted) from an unclassified 2.2 kg sphere of weapons-grade plutonium. The spectrum was acquired with a high-purity germanium detector of 40% relative efficiency. The source-to-detector distance was adjusted to 3.7 m to reduce system dead time to less than 5%. The foreground data acquisition time was 5300 s, and the background data acquisition time was 58,100 s. During the measurements, the detector was bare. No material was introduced to attenuate low-energy gamma-rays.

When a gamma-ray enters the spectrometer crystal, it may pass through unscathed or it can deposit all or part of its energy by ionizing the germanium atoms. If the gamma-ray succeeds in depositing all of its energy in the crystal, its count will appear in a full-energy peak, such as those in Fig. 9.1.1.3.1, that is characteristic of that gamma-ray. Often a gamma-ray will not deposit all of its energy. It may scatter, depositing some of its energy in the crystal and exiting the crystal at reduced energy. This Compton scattering is partly responsible for the down-sloping continuum in Fig. 9.1.1.3.1. Other gamma-rays that contribute to this continuum are those that Compton scattered before reaching the detector—in the plutonium item itself or other materials between the source and the detector (such as the storage container, in the case of the AMSIB).

The amount of electrical charge produced in the germanium crystal by gamma-ray ionization is directly proportional to the amount of energy deposited. A high-voltage bias, applied between the axis of the crystal and its outer surface, sweeps the charge into the input of a charge-

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sensitive preamplifier. The output of the charge-sensitive preamplifier is a voltage pulse with a height proportional to the amount of charge collected (and therefore proportional to the gamma-ray energy deposition). The low-level preamplifier output is further amplified and applied to the input of a multichannel analyzer (MCA).

In the MCA, the pulse is first passed through an analog-to-digital converter that determines its pulse-height to within a narrow incremental range. A count is then added to the contents of a memory register (channel) that corresponds to that particular pulse-height increment (and equivalent gamma-ray-energy increment). The MCA used for the spectrum in Fig. 9.1.1.3.1 was calibrated to accept a maximum pulse height corresponding to 3000 keV and was digitized over 8192 channels corresponding to 0.37 keV/channel. The data in Fig 9.1.1.3.1 are those that were accumulated into the first 2730 channels. Figure 9.1.1.3.2 shows an expanded view in a region spanning 630–670 keV that reveals the channel width by its "stair-step" character.
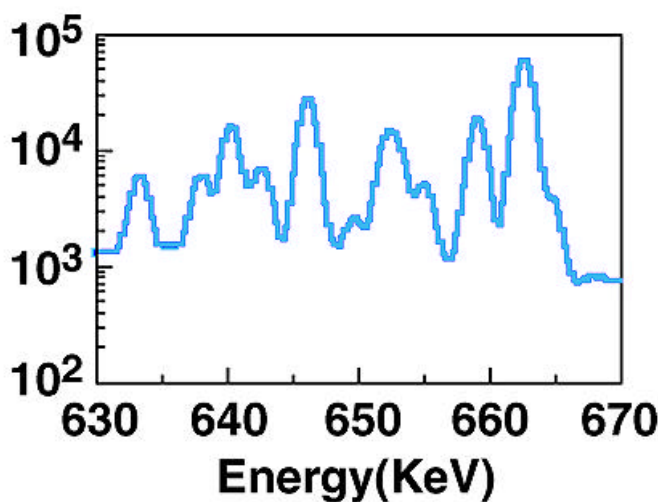
Fig. 9.1.1.3.2 The 630-670 keV region of a high-resolution gamma-ray spectrum of weapons-grade plutonium.

9.1.1.3.3 Full-Energy-Peak Analysis

Plutonium presence and isotopic information can be obtained from several regions of the plutonium gamma-ray spectrum. For measuring classified items in thick storage containers, both US and Russian scientists have developed methods that exploit a narrow energy region, 630–670 keV (Fig. 9.1.1.3.2). There are two advantages to using this region: (1) these relatively high-energy gamma-rays are easily able to penetrate thick storage containers and (2) only information concerning

the two plutonium isotopes ^{239}Pu and ^{240}Pu is present, an information barrier consideration.

Once the data in the 630–670 keV region have been acquired, they are then analyzed to determine the ^{240}Pu/^{239}Pu ratio. The first step in the analysis is to determine the shape of the underlying continuum and remove it. The next step is to resolve all of the peaks in the region. This is done by a statistical procedure called nonlinear regression analysis. The analysis determines the areas (counts) in all of the peaks in the region.

The result of such an analysis (sometimes called fitting) of a weapons-grade plutonium item is shown in Fig. 9.1.1.3.3. The net data (after removal of the continuum) is represented with dots. Colored lines indicate the contributions of the four isotopes present in the region. In addition to the plutonium contributions, there are also contributions from ^{241}Am and ^{137}Cs in this particular spectrum. ^{241}Am is the radioactive daughter formed from the decay of ^{241}Pu and ^{137}Cs is a nuisance source that was present in the measurement room.

Before a plutonium item is counted, a measurement is made of the background radiation in the room when no plutonium is present. The background spectrum is analyzed. Any peaks found in the 630–670 keV region can be fitted and these results saved in memory for inclusion in the subsequent analysis of plutonium items, as was the case for the data in Fig. 9.1.1.3.3. In the last few years US technical experts have surrounded the detector with a massive shield of machinable tungsten to eliminate peaks from background.
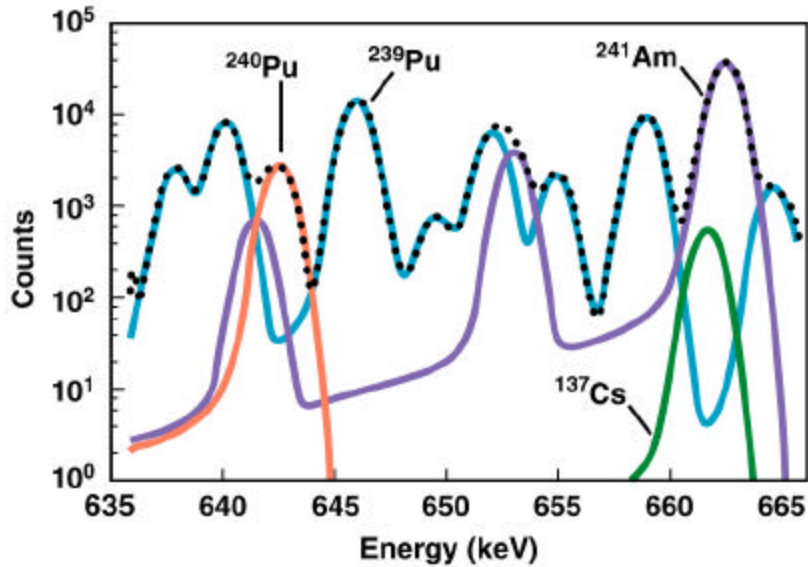
Fig. 9.1.1.3.3 Results of analysis of the 630-670 keV region. Black dots show the net measured data. The solid lines show the results of the analysis that resolves the measured data into its isotopic constituents. Note the small peak near 662 keV detected in the background measurement that resulted from ^{137}Cs contamination in the measurement facility.

9.1.1.3.4 Determining the Presence of Plutonium

Because the full-energy-peak analysis has determined the areas of all of the peaks in the 630–670 keV region, the determination of the presence of plutonium is straightforward. For example, the areas of the 646.0 and 658.9 keV ^{239}Pu peaks can be examined to confirm the presence of plutonium in the storage container. If they are both present, then plutonium is in the container.

9.1.1.3.5 Determining the Presence of Weapons-Quality Plutonium

The fact that plutonium is weapons-quality is determined by its isotopic mixture. The dominant isotope is ^{239}Pu with ^{240}Pu making up most of the rest. For the item used to produce Fig. 9.1.1.3.2, the isotopic makeup is as follows: ^{239}Pu 93.5%, ^{240}Pu 6.0%, ^{241}Pu 0.5%, and other minor isotopes that contribute tiny fractions of one per cent.

A low value of the ratio ^{240}Pu/^{239}Pu is a good indicator of weapons-quality material for materials composed almost entirely of ^{239}Pu and ^{240}Pu. The US and the Russian Federation have agreed that material with a measured value of the ^{240}Pu/^{239}Pu ratio below 0.1 will be considered weapons-quality.

The isotopic ratio is calculated by taking the ratio, corrected for emission intensity, of the areas of the 642.5 keV peak from ^{240}Pu and the 646.0 keV peak from ^{239}Pu.

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9.1.1.4 Neutron Measurements of Plutonium

9.1.1.4.1 The Neutron Signature of Weapons-Quality Plutonium

There are three sources of neutrons that make up the neutron signature for a given item: spontaneous fission, induced fission, and (α, n) reactions. The total rate of emitted neutrons and the proportion corresponding to each of the above sources is determined by item properties. The spontaneous fission rate is primarily a function of the amount of ^{240}Pu present. For analysis purposes, all of the spontaneous fissions are assumed to come from ^{240}Pu, leading to the use of the ^{240}Pu effective fission rate. Once an induced fission has occurred, the neutrons from it can induce further fissions in other nuclei. The total number of additional neutrons generated from induced fission reactions compared to the number from spontaneous reactions is the item multiplication. The induced fission rate is strongly dependent on the physical configuration and density of the item. An item with the plutonium nuclei relatively close together, such as in metal rather than oxide form, will provide an exiting neutron with more opportunities to interact with plutonium nuclei, leading to more induced fission reactions and, hence, to a higher multiplication. Finally, (α, n) reactions are much more common with lighter elements, like oxygen or fluorine, than with the heavy elements, like plutonium, so a large alpha (α), the ratio of neutrons from (α, n) reactions to spontaneous fission alphas, is an indicator of the presence of light elements. To summarize, the underlying neutron sources lead to three measurable quantities: the spontaneous fission rate (F), the multiplication (M), and alpha.

9.1.1.4.2 Neutron Multiplicity Counters

The primary tool for extracting the neutron-based quantities is a neutron multiplicity counter (NMC). Such a counter uses tubes filled with ^{3}He gas with a high voltage wire running along the central axis. Typically, many tubes (60–130) are arranged to nearly completely surround the measured item and are embedded in several inches of polyethylene. The polyethylene serves to slow down the neutrons to increase the probability that a neutron will interact with a ^{3}He nucleus when it passes through a tube. A neutron interacting with ^{3}He generates a pulse, and the timing information contained in the pulses from many neutron interactions is used to generate the multiplicity distribution for the item. The multiplicity distribution is essentially a summary of the number of coincidences that occurred between different neutron events.

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9.1.1.4.3 Multiplicity Analysis and Ring Ratios

The multiplicity distribution is summarized by the singles (S), doubles (D), and triples (T) rates where the singles are the individual neutron events, doubles are the two-way coincidences, and triples are the three-way coincidences. A mathematical model, the "point" model, is used to relate the singles, doubles, and triples to the spontaneous fission rate (F), the multiplication (M), and alpha (α). The necessary relationships are given by:

$$S = F\varepsilon M\nu_{s1}(1 + \alpha)$$
$$D = F(f_D/2)(\varepsilon M)^2 \{\nu_{s2} + [(M - 1)/(\nu_{i1} - 1)]\nu_{s1}(1 + \alpha)\nu_{s3}\}$$
$$T = F(f_T/6)(\varepsilon M)^3 \{\nu_{s3} + [(M - 1)/$$
$$(\nu_{i1} - 1)][3\nu_{s2}\nu_{i2} + \nu_{s1}(1 + \alpha)\nu_{i3}]$$
$$+ 3[(M - 1)/(\nu_{i1} - 1)]^2\nu_{s1}(1 + \alpha)\nu_{s1}^2\}$$

where

detector parameters are:

ε = detector efficiency

f_D = fraction of doubles in the coincidence gate

f_T = fraction of triples in the coincidence gate

nuclear parameters are:

(n=s $\Rightarrow$ spontaneous fission, n=i $\Rightarrow$ induced fission)

ν_{n1} = average number of neutrons produced per fission event

ν_{n2} = average number of neutron "pairs" produced per fission event

ν_{n3} = average number of neutron "triplets" produced per fission event.

The detector properties are determined by calibrating the detector after construction and may be expected to remain constant for the lifetime of the detector, barring hardware failure. The nuclear parameters are known for the types of material measured. Therefore, for all cases where the point model is sufficient, an NMC requires no further calibration with representative standards and F, M, and α may be determined from S, D, and T.

Another quantity that is useful is the ring ratio. Generally, the ^{3}He tubes in an NMC are arranged in a concentric ring, and the average neutron energy at each ring of tubes determines the relative rate at which the neutrons interact with the ^{3}He in that ring. The concept of "rings" is illustrated in Fig. 9.2.1.2. The ring ratio is defined as the rate of neutrons detected at the innermost ring compared to the rate at the outermost ring. The ring ratio will be a function of the average energy the neutrons have leaving the item and entering the detector polyethylene. The initial energy the neutrons have is a function of their source, however, if the item has been established to be plutonium, the primary factor affecting the energy the neutrons have leaving the item is the number and kinds of interactions they experience, which is a function of the item type and matrix material. Very impure items will have ring ratios significantly different from those of pure items.

9.1.1.4.4 Determining the Mass of Plutonium

The spontaneous fission rate is related to the ^{240}Pu effective mass (^{240}Pu$_{\text{effective}}$) by

$$F = 473.5 \text{ fissions/s/g} \times {}^{240}\text{Pu}_{\text{effective}}.$$

The final step required to determine the total Pu mass is to combine the ^{240}Pu effective mass with the isotopic information that provides the ^{240}Pu/^{239}Pu ratio.

9.1.1.4.5 Determining the Presence of Plutonium Metal

The neutron measurement provides three indicators of the presence of plutonium metal. Taken together, they can be used to provide assurance that the item measured is the expected metallic plutonium.

9.1.1.4.5.1 Alpha

An α of less than 0.5 indicates metal.

9.1.1.4.5.2 Multiplication

An estimated value of multiplication greater than 3 indicates metal assuming two 2 kg spheres are present.

9.1.1.4.5.3 Ring Ratios

The specific ring ratio threshold or window (R) will need to be determined by the final detector design.

9.1.1.4.5.4 Result combinations

Table 2 shows the possible combination of results and the conclusions that should be drawn from them.

Table 2: Determination of the Metal Attribute

Alpha	Multiplication	Ring Ratio	Conclusion
< 0.5	> 3	~ R	metal
< 0.5	< 3	~ R	non-metal
< 0.5	> 3	≠ R	likely metal
< 0.5	< 3	≠ R	likely non-metal or metal in low density state (powder)
> 0.5	< 3	~ R	likely non-metal
> 0.5	< 3	≠ R	non-metal
> 0.5	> 3	≠ R	metal with significant contamination
> 0.5	>3	~ R	indeterminate, likely significant non-plutonium contamination

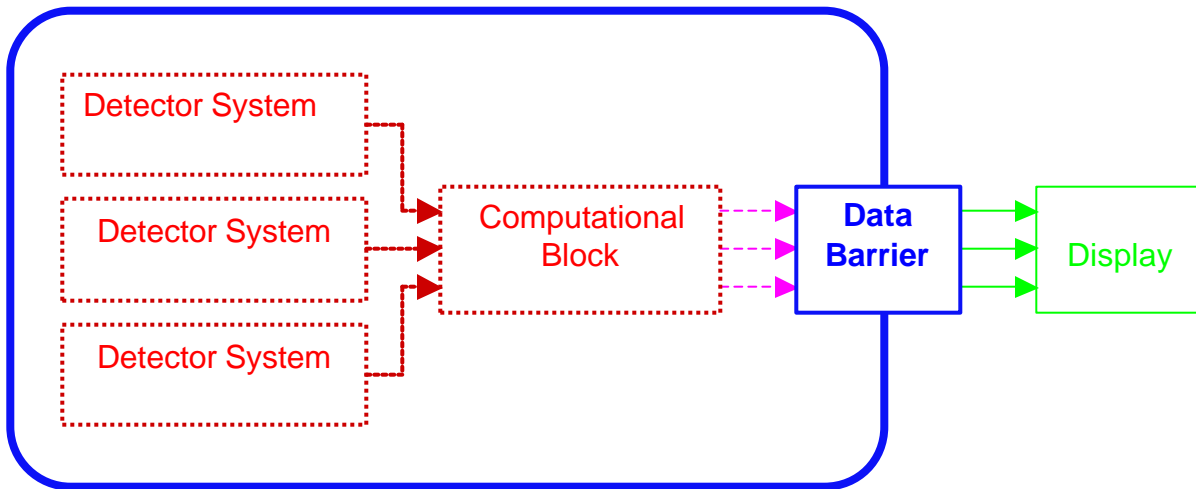### 9.1.2 Information Barrier Basis

Measurements made on classified items by the AMSIB will necessarily generate classified data. The information barrier (IB) integrated into the AMSIB allows meaningful measurements while preventing release of classified information. Specifically:

- only unclassified data are displayed,
- no access to classified data is possible, and
- unclassified output is accurate and authentic.

An information barrier concept is shown in Fig. 9.1.2.

The information barrier encloses and protects all of the "raw" classified data, and only unclassified yes/no threshold evaluations are shown on the unclassified display. An IB is best implemented as a combination of hardware, software, and procedural barriers. An IB uses the principle of defense-in-depth to reduce both the probability and consequences of any inadvertent information release. An IB uses a series of simple protective shells. Key features of the hardware and software of a measurement system with integrated information barrier include a combination of the following:

- Simplicity—simple elements are easier to authenticate, verify, and maintain.
- Modularity—each module performs a single function.

Detector System

Detector System

Detector System

Computational Block

Data Barrier

Display

- - - - Potentially contains classified information   —— In open area, contains no classified information

- - - In protected area, contains no classified data   ▬▬ Barrier elements

Fig. 9.1.2 Core information barrier concept.

- Minimization of the amount of classified data gathered. The system gathers no unnecessary classified data. The amount of classified data at each stage of the system will be reduced to the minimum required to allow correct functioning of the system.
- Minimization of the transmission of data between modules—restrict the number of modules that contain classified data and the amount of classified data in each.
- Minimization of the amount of output—with just a few outputs, it is more difficult for the system to display classified data.
- Unidirectional data flow—prevent modules from affecting other modules. Even if individual elements are secure, interaction between elements could create pathways for the loss or diversion of classified information.
- Minimization of barrier crossings. Each crossing is a potential route for information loss or covert manipulation.
- Minimize dependence on software—hardware is more inspectable.
- Absence of single-point failure modes.[3]
- All modules designed to be fail-safe.
- Minimize operator functions.
- Capability and allowability of performing unclassified authentication measurements with an open system.

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[3] Failure of the information barrier is defined as the release of classified data. A single-point failure (the failure of one element within the information barrier) must not allow the release of classified data.

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- Accommodation for maintenance operations. Do not allow hidden data paths.
- Perform classified measurements with secure system.

Another important feature of the demonstration AMSIB is the separation between the security sensors and the data switches. The security sensors control the security watchdog directly. The security watchdog, in turn, controls the power to all of the other elements of the AMSIB, but there is no other connection from the security watchdog to the computer-based modules. Thus, the computer-based modules, including the data analyzers, do not know the position of the security sensors and have no way of knowing whether they are processing classified or unclassified data. This adds assurance that the analyzers are operating similarly whether or not a classified item is being measured.

Although the IB "box" of Fig. 9.1.2 is a useful tool for locating and minimizing vulnerabilities, this concept is overly simplistic and prone to single-point failure. A complete AMSIB can incorporate a series of data-filtering stages followed by a final barrier to prevent the release of any classified information. The data filtering reduces the amount of classified information available throughout the detector system(s) through proper choice of detection methods, hardware discriminator settings, data processing methods, etc. Thus, the IB consists of several layers of protection rather than a single layer. The sum of all the layers ensures that no classified information can be released. The multilayer approach can provide the same amount of protection as a single layer, but without the single point failure mode inherent in a single-layer design. The end result is that no classified information is displayed in the open area.

A AMSIB based on this concept can explicitly contain examples of many of the types of controls mentioned above. Many of the information filters, particularly those relating to detector choice, eliminate the possibility of transfer of excess classified data by eliminating any method of collecting those data. Data filters that limit the collection or transmission of classified data in hardware (e.g., discriminator settings) are examples of hardware controls; data processing that generates quantities such as isotopic ratios is an example of a software control. The administrative and access-control elements of the IB also serve to prevent the release of classified information. Fig. 9.1.2 shows an extension of the simple AMSIB concept. Although only one layer of protection is shown, this represents multiple layers that shall be implemented in the AMSIB.

9.2 Subsystem Example

The rest of this document is designated as system recommendations only. There are no requirements listed in this section. Instead, this section explains what was used in prior demonstrations of technology.

9.2.1 Neutron

9.2.1.1 Measurements

As discussed in Section 9.1.1.4, neutron measurements will be used to determine the ^{240}Pu effective mass, which, in conjunction with the gamma measurement, will verify the mass attribute. Additionally, the neutron measurements will be used to confirm the metal attribute.

9.2.1.2 Detector

The core of the neutron measurement apparatus is a neutron multiplicity counter. Of existing designs, the most suitable is the large neutron multiplicity counter (LNMC), which is also known as the 30-gal. neutron multiplicity counter. The LNMC was developed in response to a need for an NMC that could accommodate the 30 gal. containers used by the US DOE, so it would easily accommodate an AT400R container. A schematic of the LNMC is shown in Fig. 9.2.1.2. The LNMC is a hexagonal detector that allows front loading. The six sides are composed of slabs of polyethylene each containing 21 ^{3}He tubes for a total of 126 ^{3}He tubes. The end plugs are composed of graphite. This system has been extensively field tested on both metal and oxide items.

The basic characteristics of the LNMC are
- efficiency = 41.7%
- die away time = 55 microseconds
- doubles gate fraction = 0.41
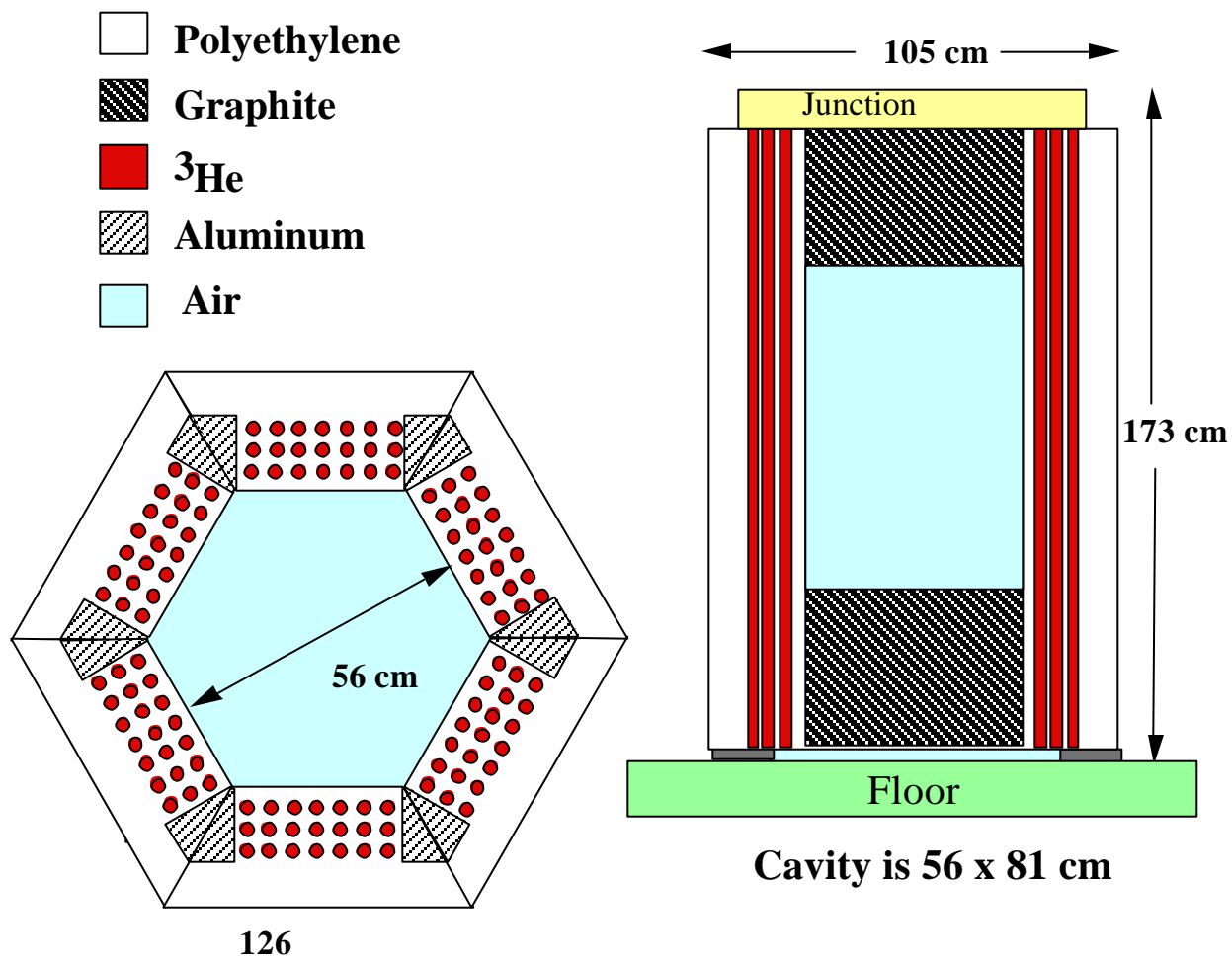- triples gate fraction = 0.18.

Polyethylene

Graphite

³He

Aluminum

Air

56 cm

126

105 cm

Junction

173 cm

Floor

Cavity is 56 x 81 cm

Fig. 9.2.1.2 A schematic of the LNMC

Based on experience since the LNMC initial development and because of the requirements of integration with the gamma systems and information barrier along with the overall requirements that the AMSIB be certifiable and authenticatable, some modifications are proposed.

- The efficiency could be significantly increased by using ³He at 10 atmospheres rather than the 4 atmospheres used in the initial design.
- Metal shielding appropriate to prevent the transmission of significant radio-frequency signals both in and out of the LNMC is needed. A regular 18-gauge stainless steel enclosure will be sufficient however the final selection will be determined by the NMC design.
- A hole at one corner of the LNMC is required to bring the gamma detector head close to the AT400R. This will also require modifying the ³He tube arrangement. To minimize the loss of efficiency, slightly shorter than half-length tubes will be used above and below the

gamma detector. Although the accommodations for the gamma detectors will lead to reductions in the NMC efficiency, the higher ^{3}He pressure will tend to offset that. Further, the modification will remove a small fraction of moderating material and only perturb a few tubes. The overall effect is expected to be small.

9.2.1.3 Pulse Processing Electronics

There exists currently a suite of standardized electronics available for use with an NMC for data acquisition and analysis. These are commercially available and in use worldwide. The selection of specific items of equipment is primarily driven by the information barrier and authentication of the system. In light of this, the following are recommended.

9.2.1.3.1 Preamplifier

The initial signal from the ^{3}He tubes requires processing and conversion to a TTL pulse. For this purpose, Amptek-based fast preamplifier/discriminator circuit boards (Canberra Model JAB-01) are recommended. The tubes will be wired so that there will be three tubes per preamplifier.

9.2.1.3.2 Derandomizer

The standard LANL design will be used for the derandomizer that combines the preamplifier signals. A commercialized derandomizer is available from Canberra. A simple OR circuit could be used, however, a substantial loss due to deadtime and pileup will occur. The derandomizer buffers the incoming signals to limit the signal overlap that may occur.

9.2.1.3.3 Shift Register

The shift register processes the output of the derandomizer and, in parallel circuitry, determines the reals plus accidentals rate and the accidentals rate and determines the multiplicity distribution. There are three models of shift register that could be used in the application, the PSR-B, the ISR, and the AMSR. (Similar models under different names and in different packaging are also available.) The PSR-B is has very limited functionality so would be the most suitable for use behind and information barrier. A better choice is the ISR, which has limited memory and functionality like the PRS-B, but also contains fast accidentals processing. The fast accidentals processing samples the events in the accidental gate faster than the events in the coincidence gate. As the real coincidence events must be separated from the accidental events, better accidentals values lead to better real values. This reduces the count time required for a given precision particularly for large items. Unfortunately, it is currently difficult to obtain either the PSR-B or the ISR commercially, especially in

the quantities that would be needed as spares for the anticipated lifetime of the AMS/IB. The state-of-the-art is the advanced multiplicity shift register (AMSR) which is readily available commercially. This would also be the best choice purely from the perspective of the neutron measurement. It should be noted however that the AMSR essentially has an onboard computer so care will be required in its incorporation behind an information barrier. Unless it becomes possible to acquire sufficient ISR units, the commercial availability of the AMSR makes it the best choice.

9.2.1.4 NMC Analyzer

The purpose of the NMC analyzer is to process the shift register results, calculate the ^{240}Pu effective mass, alpha, and multiplication, and communicate the results to the portion of the system making the final attribute determination. In addition, some degree of error checking will be done.

9.2.1.4.1 Hardware

Dedicated computer—It is recommended that the NMC analyzer be composed of a dedicated computer system that reports the NMC results to another computer for final evaluation. In particular, computer boards will be considered appropriate if they conform to an international standard while being adequately flexible for this specific application. The elements of the recommended hardware include the following.

- PC/104 386sx computer module (part #CM2-SXI-Q-74).
- MiniModule Video board (part #MM2-SVG-Q-72).
- Corrosion-Resistant Enclosures, Aluminum, COMPACT^{TM} Junction boxes, type 4X Enclosures (part #C-CA26169).
- 4 Port RS-232 + 48 Digital I/O PC/104 Module (part Emerald-MM-DIO-XT).
- 8 Megabit EPROM
- CondorPower 5V power supply (part #GSC20-5 [5.1V, 3.8A]).
- Connector Receptacle, 4 position 2.5mm shrouded (part # WM17405-ND).
- Crimp Contact 2.5mm 22-28AWG Part #WM17406-ND
- Snap-together mounting system for PC/104 boards, starter set (part #PRV912A-70).
- Maintained lighted pushbutton switch (EAO part #01.271.025; Newark #99F3198).

9.2.1.4.2 Software

The data-analysis and acquisition software will be functionally equivalent to INCC without the graphic user interface and with unused hardware types removed. A simple, small operating system will be used. A variation of MS-DOS or imbedded Linux is recommended.

9.2.2 *Gamma-Ray Subsystem*

In this section we share US experience gained in the assembly of a gamma-ray spectrometer subsystem used to demonstrate how an information barrier can protect classified information. The Fissile Material Transparency Technology Demonstration (FMTTD) was held in August 2000 and included a delegation of technical experts from the Russian Federation. The key element in the demonstration was the successful measurement, using an information barrier, of classified attributes of a US nuclear weapon component without revealing classified information. The system demonstrated was a prototype that would require improvements before it could be successfully fielded in an arms control regime. In the following paragraphs, we describe the gamma-ray subsystem that measured the presence of plutonium and the presence of weapons-quality plutonium, and we note areas where improvements could be made.

9.2.2.1 *Measurements*

The Pu-600 method measures two plutonium attributes: (1) the presence of plutonium in a sealed storage container, and (2) that the plutonium is of weapons quality. This analysis is carried out in a narrow energy region between 630–670 keV. The presence of plutonium is determined by the presence of two characteristic ^{239}Pu peaks. The ^{240}Pu/^{239}Pu ratio is measured to determine that the plutonium item is weapons quality.

The isotope ratio measurement serves two purposes. The first is to determine that the plutonium is weapons quality and the second is to allow the conversion of the effective ^{240}Pu value, as measured by a neutron multiplicity counter, to total plutonium mass. Weapons-quality determination was made when the value of the ^{240}Pu/^{239}Pu ratio was below the threshold value of 0.1.

The presence of plutonium was affirmed by the presence of the 646.0-keV and 658.9-keV ^{239}Pu gamma-rays. For the FMTTD, we required that these peaks exceed five standard deviations above the continuum for plutonium to be confirmed to be present.

The penetrating gamma-rays in the 630–670 keV region ensure that measurements can be made regardless of the configuration of the plutonium item or its storage container. Another advantage of using this region, from an information barrier standpoint, is that information is only available for the two plutonium isotopes of interest. As with traditional high-resolution gamma-ray isotopic measurements used in international safeguards, analysis of the closely spaced peaks in a narrow region minimizes effects due to variation of detection efficiency and differential attenuation. Because we are determining the ^{240}Pu/^{239}Pu ratio from two closely spaced lines, we have no requirement to determine the absolute detection efficiency.

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9.2.2.2 Detector

The hardware for the gamma-ray spectrometer comprised mostly commercial elements. The detector chosen was n-type to limit neutron damage in the germanium crystal. This detector had 50% relative efficiency, since, for this application, the detector will have good intrinsic full-energy-peak efficiency in the 600-keV region.

The manufacturer of the HPGe detectors provides two signal leads. These signals were sent to the data acquisition subsystem. A view of the detector, its iris, and the iris controller in the shielded enclosure is shown in Fig. 9.2.2.2.
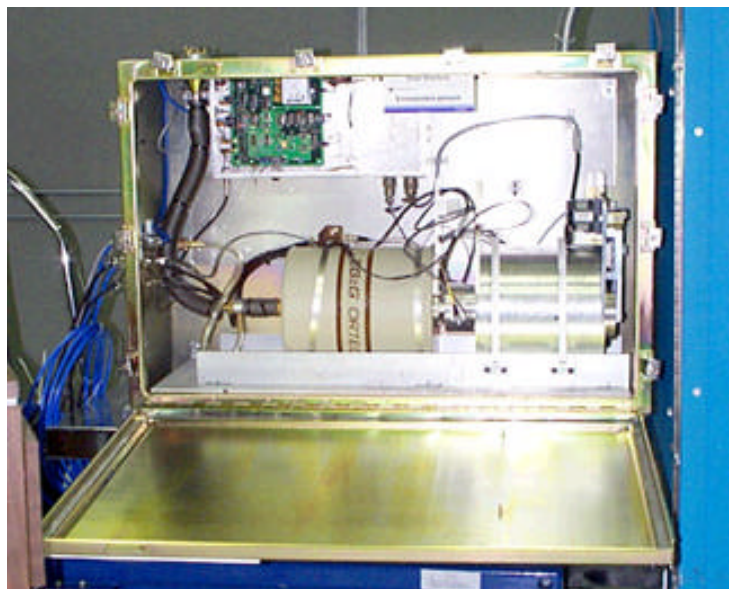

Fig. 9.2.2.2 The high-purity germanium detector used for the Pu-600 measurements at the FMTTD. The detector is housed in a radio-frequency-shielded enclosure. To the right of liquid-nitrogen dewar (tan object with brown writing) is a heavy shield of machinable tungsten that shields the detector's cryostat.

9.2.2.3 Pulse-Processing Electronics

The signal from the HPGe detector is used as input to a data-acquisition subsystem. This instrument combines a high-voltage bias supply, spectroscopy amplifier, and multichannel analyzer. We employed this instrument because our software was compatible with it. We are advocating the use of newer digital-data-acquisition systems since the FMTTD. The digital systems maintain good peak shape characteristics at much higher data rates than analog systems. The ability to handle high data rates is an important consideration for Pu measurements in the 600-keV region.

9.2.2.4 Gamma-Ray Analyzer

9.2.2.4.1 Computer, Operating System, and Control Software

The data-acquisition system is controlled by a computer program written in the C programming language. The controlling computer is based on a simple PC/104 single-board computer, assembled specifically for this application. Our control program allowed us to limit the collection of gamma-ray data to the narrow 630–670 keV energy region by use of the programmable upper- and lower-energy discriminators provided in the data-acquisition subsystem.

The computer runs under the MSDOS operating system and takes advantage of the Canberra MSDOS libraries. The control program was written especially for the demonstration so that all unnecessary features of the commercial software provided with the data-acquisition system would be eliminated. The single-board computer boots from a PROM and otherwise contains only volatile memory. In addition to the MSDOS operating system, the PROM contains the control and analysis software for the system. When the system is actuated, the push of a single button initiates completely automatic operation. This eliminates any ambiguity in the operation of the system. These features implement various elements of the information-barrier architecture, described elsewhere.

9.2.2.4.2 Energy Calibration

During the FMTTD, gamma-ray energy calibration was carried out over a broad energy range because other gamma-ray measurements were included in the demonstration. The calibration source used was ^{152}Eu. As described below, a very precise, and accurate local energy calibration, utilizing ^{239}Pu peaks, is performed in the 600 keV region during item assay.

9.2.2.4.3 Background Measurement

Following energy calibration, a background measurement was taken. A peak search was performed in the 600-keV region. If peaks are found, they are analyzed, and this information is passed on to be used in the analysis of the plutonium spectra.

9.2.2.4.4 Plutonium Item Assay

The Pu-600 analysis method was developed specifically to determine the presence of weapons-quality plutonium in heavy, sealed storage containers. The methodology is an adaptation of the MGA isotopic analysis code. Pu-600 was tailored to handle specific issues associated with the FMTTD analysis and numerous validity checks were included to aid automation.

9.2.2.4.4.1 Determining the Presence of Weapons-Quality Pu

During assay, the code acquires and analyzes data only in the 630–670-keV energy region of a high-purity germanium detector spectrum. From the analysis, the code calculates the $^{240}Pu/^{239}Pu$ isotopic ratio that is passed to the computational block. Pu-600 makes numerous validity checks on the spectral data and statistical checks on the analysis process. For example, gain calibration checks are made to insure the code processes the proper region of the spectrum. The linearity and dead time checks are made to verify that the peak shape has not been distorted by instrumental anomalies. Failures in the checks result in an error report.

Isotopic ratios are calculated by taking a ratio of peaks, corrected for emission intensity. The peaks used are the 642.5-keV peak from ^{240}Pu and the 646.0-keV peak from ^{239}Pu. To determine these peak areas, Pu-600 performs a response function analysis of the entire energy region from 630 to 670-keV. Local energy calibration is performed using the 646.0-keV and 662.4-keV peaks from ^{239}Pu and ^{241}Am as part of the response function analysis. The code makes no corrections for sample self-absorption or sample container absorption because these factors are unknown. Because absorption correction factors vary slowly as a function of energy in this region and the peaks chosen are quite close in energy, the correction factors would be in the range of a fraction of a percent. Because the Pu-600 uncertainty in determination of the $^{240}Pu/^{239}Pu$ isotopic ratio is typically in the neighborhood of 5%, ignoring sample self-absorption and container absorption correction factors has a negligible impact on the result.

Before the peaks can be analyzed, the underlying continuum has to be determined and removed. Fixed regions at the extremes of the analysis region are chosen to define the continuum. This approach is used, rather than a more accurate global continuum determination, because of the narrow constraint on the analysis region. Under good measurement conditions, these fixed regions will be free of any peaks. Nevertheless, any peaks found in the background measurement are accounted for. (This is illustrated in Fig. 9.2.2.4.4.1.1 where an unanticipated ^{137}Cs background peak was found.) The fitting procedure also makes small corrections to the continuum due to the low-energy tails from each of the peaks in the cluster. An empirically derived formula is used to interpolate the continuum region under the peak cluster.

As illustrated in Fig. 9.2.2.4.4.1.1, the relevant analysis peaks are clustered within a large number of other peaks from [239]Pu and [241]Am. This is especially true for the 642.5 keV peak from [240]Pu, which is in close proximity to peaks from both [239]Pu and [241]Am. To correctly calculate the individual peak areas requires a rigorous technique for unfolding the overlapping peaks. A model based on the work of Gunnink was developed that closely fits a single gamma-ray peak in a high-purity germanium spectrum. The model consists of a Gaussian element with two tailing terms on the low energy side of the peak, a short- and long-term element. The long-term tail is considered to be part of the continuum.
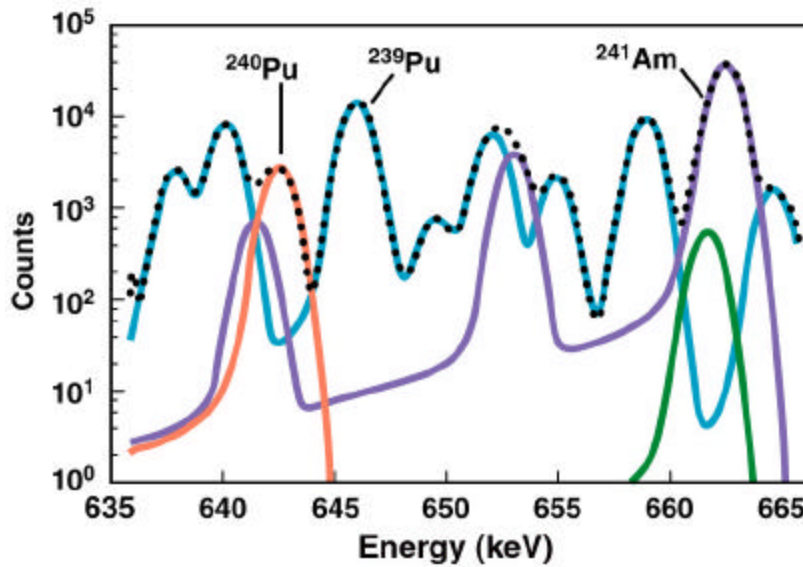

Fig. 9.2.2.4.4.1.1 The region of the gamma-ray spectrum analyzed by the Pu-600 method. Black dots show the net measured data. The colored lines show the results of the analysis that resolves the measured data into its isotopic constituents. Note the small peak shown in green near 662 keV that resulted from ^{137}Cs contamination in the measurement facility and was detected in the background measurement.

Using this model, peak groups are described for each spectral data point as the sum of the contributions from the individual peaks in the group. The Pu-600 analysis simplifies the model of the data—reducing the number of free parameters by exploiting well-known information about the peak region. The peak areas for all peaks from a given isotope can be related using their emission intensities and relative intrinsic detector efficiency. The energy differences between peaks can also be related because the energies are well known. A fit of the model to the data is accomplished by nonlinear minimization of the weighted

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residual sum of squares. The isotopic contributions and mass estimate are derived from the fitting coefficients.

Two goodness-of-fit estimates are derived from the fitting process—the value for chi-squared from the fit gives an estimate of the overall fit quality. Peak areas are derived from insertion of the fitting coefficients for the peak into the Gunnink model and integrating it over the full width of the peak. Estimates of peak area uncertainties are derived through propagation of individual uncertainties in the fitted coefficients through the integration process. The code uses this uncertainty to determine an estimated uncertainty in the isotopic ratio. This uncertainty estimate was not exploited for the FMTTD but probably will be for a more robust system.

Some previous results obtained with this method from a variety of items are shown in Fig. 9.2.2.4.4.1.2. The items were either "bare" or enclosed in US AT400A or AL-R8 containers. The data in this figure show the Pu-600 isotopic ratios normalized to certified values of the ratios. Data acquisition was typically 15 minutes. Results plotted in green are from US weapons-grade plutonium while results plotted in red are reactor-grade (e.g., the item designated PIDI-5 contained 22% ^{240}Pu). If the Pu-600 measurements were perfect, the results in the plot would be unity for all measurements. The average of these results is 0.99 $\pm$ 0.05.

9.2.2.4.4.2 Determining the Presence of Plutonium

The analysis determines the areas of all of the peaks in the 630–670-keV region. The areas of the 646.0 and 658.9-keV ^{239}Pu peaks are examined to determine that they both exceed five standard deviations above background to confirm the presence of plutonium in the storage container.
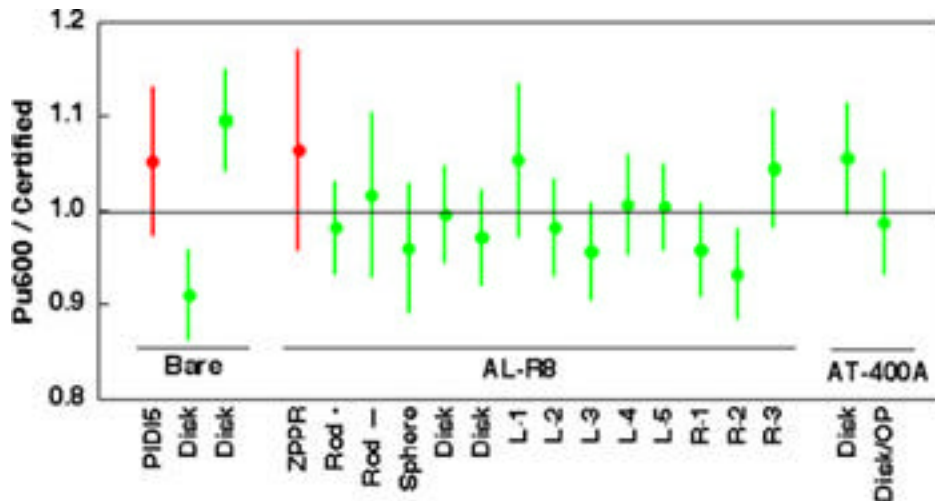
Fig. 9.2.2.4.4.1.2 A variety of measured Pu-600 isotopic ratios normalized to certified values of the ratios. Results plotted in light color (green) are from US weapons-grade plutonium. The items beginning with L- and R- were measurements of US weapons components at Livermore and Rocky Flats. The results plotted in dark color (red) were from small reactor-grade sources. The individual precision of these measurements, as indicated by the error bars, was typically 4% to 6%, with the exception of the small reactor-grade sources, which provided poor counting statistics. These measurements were made under a wide variety of conditions. The notations at the bottom of the plot show that they were made of "bare" objects not in containers as well as objects in AL-R8 and AT-400A storage containers. If the Pu-600 measurements were perfectly accurate, all of the results in the plot would fall on the line indicating unity. All of the measured results were within ± 10% of unity. The average of all of the measurements was 0.99 ± 0.05. Many of these measurements were made a number of years ago before many of the improvements in the Pu-600 method were made.

9.2.3 Information Barrier Systems

9.2.3.1 Computational Block

The computational block will be based on a very simple computer running a very simple operating system. A PC/104 specification CPU running a DOS operating system meets these requirements. As with the analysis CPUs, there will be no data connection between the security watchdog and the computational block.

9.2.3.1.1 Hardware

The computational block shall be located within a shielded enclosure. All communications through the shielded enclosure will be through either simple hardware switch controls (the data switches) or filtered through the (hardware) data barrier. There will be at least one "hardware only" element between each of the CPUs and the outside world. Thus, the software program running within the CPUs cannot affect the hardware elements of the information barrier. In particular, it shall be physically impossible for one of the CPUs to reprogram either the data barrier or the display to make it possible for the system to reveal classified information. In addition, all data flow within the

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AMSIB is as unidirectional as possible. No information can be passed from the display back to the remainder of the system or from the computational block to any of the analyzers.

9.2.3.1.2 Software

Classified data from the gamma analyzer and the NMC analyzer are input to a computational block where the DATA_ATT.C program performs the final calculations to determine whether the measured item exceeds or falls short of agreed-upon threshold values. The DATA_ATT.H program contains the unclassified attribute thresholds. Both of these programs are compiled and are stored in the computational block in read-only memory.

DATA_ATT.C performs the following functions:
- compares the oxide value from the Pu900 to the oxide receives and stores the isotopic ratio of the analyzed material;
- receives the ^{240}Pu effective mass of the analyzed material;
- computes the Pu mass from the ^{240}Pu effective mass and the isotopic ratio;
- compares the Pu mass to the mass threshold;
- compares the Pu ratio to the ratio threshold; and
- compares the oxide value from the NMC to the oxide threshold.

The four pass/fail results are then output to the data barrier as pass/fail indicators. These unclassified outputs indicate only whether the measured values meet or fail to meet the stored thresholds.

DATA_ATT.C executes the following steps.
1. Both the video card and the parallel I/O card are initialized.
2. The serial ports internal to the processor card are initialized.
3. The lights on the display panel are cleared.
4. A loop is entered, waiting for one of four switches to be pressed. The four switches are: background, measurement control, calibrate, and measurement.
5. After a switch is pressed and recognized by the software, another loop is entered, waiting for data to be received on the serial port.
6. Data received from the serial port are analyzed, compared to set limits, and appropriate lights are illuminated on the display panel.
7. Step 4 is executed again.

As one of the data-control switches is pressed, the computational block digital I/O card receives the "switch down" signal and changes one bit on a data word that is readable by the processor card. The program running on the processor card leaves the perpetual loop when the data word is non-zero, indicating one switch has been pressed. The program then determines which switch has been pressed and starts looking for

data to be placed in a null data string. An interrupt process is continuously running in the background, accepting all data that come in through the serial ports and placing the incoming data into a data string. As data enter the data string, the string is no longer null, and the program will recognize this fact. Data in the string are then analyzed. Based on that analysis, different lights are illuminated on the display panel. To accomplish this, a bit string is constructed with various "ones" placed in specific locations. A "one" indicates the light associated with the bit is to be turned on, and a "zero" indicates the light is to be turned off. This bit string is output to the digital I/O card and is held present on the inputs to the flip-flops located on the data barrier. This is followed by another bit string containing a single "one" bit to trigger a one-shot that will clock the data through the flip-flops on the data barrier and illuminate the lights on the display panel. The flip-flop/one-shot combination makes an extremely efficient low-pass filter that restricts data to low-frequency data pulses only, preventing information from being transmitted on a high-frequency data stream.

9.2.3.2 Data Barriers

As illustrated in Fig. 9.1.2, the AMSIB can be thought of as a box (the IB) with the measuring and computational systems on the protected side (inside) and the display on the open side (outside). All classified data generated by the measurement system will remain inside the box. There are three types of routes for unintentional classified information release across the IB.

1. Some data must be passed through the IB in order for the inspector to receive useful information about the inspected object. Although these data themselves are unclassified, care must be taken to ensure that classified information does not "leak" through this connection.
2. All other connections (e.g., power supply) or operations (e.g., maintenance) that pass through the IB are also potential conduits for classified information transfer or manipulation. The connections can be addressed by hardware controls and the operations by access controls. However, the most straightforward way of minimizing the potential for classified data leakage or modification is to minimize the number of barrier crossings.
3. Energy (e.g., acoustic, optical, or radio-frequency) radiated from the inside to the outside of the box could also carry classified information. Because there is no intentional transmission across the barrier, the simplest solution is elimination of all transmission. This can involve a combination of hardware and access controls.

9.2.3.2.1 Input

The only operator input to the AMSIB is through the measurement control box to determine the type of measurement to be made. Filters and/or flip-flops may be used to limit the number of allowable changes. A simple logic circuit could be used to disallow multiple button pushes. Procedures and/or the computer inputs could do all this.

9.2.3.2.2 Output

The output data barrier is a simple module residing on the IB whose only function is to ensure that no classified data are passed into the open area. Protected unclassified information passes from the computational block inside the shielded enclosure to the display outside the enclosure via the output data barrier, a simple hardware module that outputs 1 bit of data per input line. No information can be passed from the display back through the output data barrier to the remainder of the system.

As implemented in the demonstration system, the data barrier utilizes fiber-optics drivers and fiber-optic links to the display to ensure that no data can pass back into the shielded enclosure. The fiber-optic links also ensure that no extraneous electrical signal can be picked up or radiated by the links to the display. The fiber-optics drivers are controlled by the outputs of either flip-flops or low-pass filters. The flip-flops are clocked once each measurement cycle so that only one change of output state is allowed for each measurement. Ideally, all signals derived from the computational block would pass through flip-flops clocked by the computational block. However, in this implementation, all of the threshold data results do pass through flip flops, but the *system open* and *system secure* which are derived directly from the security watchdog will pass through low-pass filters.

9.2.3.3 Security Watchdog

The sole function of the security watchdog is to monitor the security status of the entire system and to remove all power from all other AMSIB elements if the access doors are opened or if classified material is introduced into the system incorrectly. The security mode of the security watchdog (and hence the entire AMSIB) is set by the door switches and other intrusion sensors.

An important feature of the AMSIB is the separation between the security and data processing functions. The security sensors and door switches control the security watchdog directly. The security watchdog, in turn, controls the power to all of the other elements of the AMSIB, but there is no other connection from the security watchdog to the CPUs. Thus, the CPUs do not know the position of the security sensors and have no way of

knowing whether they are processing classified or unclassified data. This adds assurance that the analyzers are operating similarly whether or not a classified item is being measured. Similarly the data switches are demonstrably not connected to the security watchdog. No manipulation of the data switches can change the security status of the system.

Because the only function of the security watchdog is to control the AC power to the rest of the AMSIB, the security watchdog can utilize simple relay logic with no silicon elements or software. There are two power relays in the watchdog. The first or main relay turns on AC power to the remainder of the AMSIB if and only if the doors to the shielded enclosure and any auxiliary enclosures are closed. In this case, power is applied to the AMSIB regardless of whether or not classified objects are present. If a door is opened, the main relay contacts open, and all power is removed from the remainder of the AMSIB. Following a delay of approximately 20 seconds, a second relay (K2) will close (re-energizing the AMSIB) only if a known unclassified container is present (as determined by the security sensors). In addition, the security watchdog incorporates a SCRAM switch that, if pressed by a system operator, will remove all power from the AMSIB regardless of whether classified material is present or not.

9.2.3.4 Switches and Interlocks

9.2.3.4.1 Security sensors

The security functions of the AMSIB are monitored by the security watchdog that will, in turn, be controlled by the security sensors, the door switches, and the SCRAM switch. All switches performing security functions will be normally closed switches operating in a "fail-safe" configuration, i.e., if any of the cables connecting these switches is not connected fully, then the switch is assumed to be open.

When the system is in a secure configuration, all door switches will be closed. Opening a door in the shielded enclosure or one of the auxiliary enclosures will open one or more of the door switches and remove power from the main relay.

Security sensors—The container that holds a classified item presses against a mechanical security sensor when the container is placed in the detector of the AMSIB. Thus any container is assumed to contain classified material unless that container has been specifically devised so as not to contact the security sensors.

The security sensors are pushbuttons located within the AMSIB detector cavity. In the AMSIB, the security sensor will consist of 2 sensors in series, either one of which is sufficient to indicate a classified container.

One of these switches (S1) is normally closed and the other (S2) is normally open. Both switches shall be closed in order for the AMSIB to be energized with the door(s) open. Thus a specially devised source container that presses switch S2 (closing it) but not switch S1 (leaving it closed) **must** be in place in order to make any measurements in open mode, with the door open. If a container containing a classified object (or any other similar container) is placed within the detector, security sensor S1 is also depressed, and the second power relay cannot be activated.

The security sensor S2 is used to check whether a container is in the system. If no container is the system, then S2 is open and relay K2 cannot be energized. Similarly, if a container with classified material is in the system, both S1 and S2 are pressed, again allowing measurements in the secure mode. Thus, the only time that open measurement s are permitted is when a container devised for unclassified materials is present in the system. Any attempt to remove this container will remove power from the AMSIB.

Door Switches—Both doors to the shielded enclosure as well as the doors to the HRGS detectors will be instrumented with interlock switches. Each door of the shielded enclosure will have 2 or more switches (top and bottom) and each smaller door of the HRGS detector enclosure will have at least one switch.

SCRAM Switch—In addition to the door switches, a SCRAM switch will be mounted on the shielded enclosure. The SCRAM switch is operable from outside the shielded enclosure. If the SCRAM switch is pressed, all power is immediately removed from the AMSIB (except for the security watchdog) regardless of the position of the other security sensor. The AMSIB cannot be restarted until the SCRAM switch is manually reset. The SCRAM switch also forms part of the active purging operation in the AMSIB.

All of these switches shall be closed (i.e., all doors shall be closed) before classified material can be measured in the AMSIB. The SCRAM switch is a large button accessible from the outside of the shielded enclosure. If the SCRAM switch is pressed, all power is removed from both relays in the Security Watchdog. Thus, all AC power is removed from all other elements of the AMSIB until the SCRAM switch is reset manually. The SCRAM switch will not reset itself.

9.2.3.4.2 Measurement control Switches

The data-analysis computers will be initialized by the measurement control switches, a set of mechanical switches separate from switches

used for the security functions. These data switches are used to start a background run, calibration run, or a measurement run. If the cables to the data switches are not connected correctly, no measurements can be initiated, and the system will not function until the connection is fixed.

These push-button switches, operated by the material handler (as opposed to an inspector or observer), control the starting of background, calibration, or measurement cycles within the AMSIB. Once any type of cycle has been started, additional switch closures have no further effect. These switches are simple hardware closures – no further electronics or processing capability is included in this part of the AMSIB.

9.2.3.4.3 Modes

The AMSIB can operate in two modes. In the Open Mode the access doors are open. In the open mode, the red and green display is active, and additional displays may be used to indicate the analysis results directly. In this mode, only unclassified materials (as determined by the security sensors) can be measured. The AMSIB can be operated in the Secure Mode only if all the access doors are closed. In the secure mode, the red and green display is the only output from the system. In this mode, either classified items or unclassified reference materials can be measured, but only the simple unclassified display is possible. Whenever an access door is opened, all power is immediately removed from the system. This, in addition to an active purge procedure, will ensure that no classified information can remain in the AMSIB after a door is opened. If, and only if, a specially devised container containing no classified material is present in the AMSIB, the security watchdog will restore power to the AMSIB following a delay of approximately 20 seconds. This will allow authentication measurements to take place using unclassified reference materials only. If a classified object is placed in the system while the door is open, all power to the system will be immediately cut off and will remain off until the classified item is removed or the access door is closed.

9.2.3.4.4 Measurement Types

Two types of measurements can be made by the AMSIB, unclassified or classified. The measurement type is determined by the container and the security sensors.

Unclassified measurements may be made with access doors open or closed. These include background, measurement control, calibration or authentication. In this mode, video displays may be connected to the system and detailed output from the analyzers and computational block may be viewed. Measurements of known, unclassified materials in this

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mode provide assurance to the monitoring party that the system is operating correctly.

Classified measurements may be made only when all access doors are closed. In this case, a red and green LED display is the only output from the system.

9.2.3.5 Enclosures

Although the AMSIB will be constructed of tested elements using good assembly procedures, the final proof of the effectiveness of the system shielding has to be an actual measurement of the entire AMSIB after assembly is complete. Following these measurements, a physical exclusion area around the AMSIB may be defined in order to meet RF power limits.

Shielded Enclosure—All of the CPUs and high-level signal (as opposed to detector output signal) wiring will be contained within a shielded enclosure. The enclosure for the demonstration AMSIB is a Hoffman PROLINE EMI/RFI high-performance enclosure. This enclosure includes spring finger contacts around all door openings and welded construction and is rated for 30 dB attenuation at 1 GHz. All door and ventilation openings in this cabinet will be as supplied by the manufacturer. All other penetrations in the enclosure will be made according to manufacturer recommendations. This enclosure or another with similar EMI/RFI characteristics will be used for the final AMSIB system.

The detectors for the AMSIB are not within the main shielded enclosure. The detectors will be connected to the shielded enclosure through cable bundles. These cables, as well as the detector enclosures, will be shielded to reduce electronic emanations. In addition, each bundle of shielded cables from a detector will be located within another shield, probably a braided tube. The exterior shield will not be carrying any signal information—i.e., this shield will not be used as a "return" for the signal wiring or to carry any other signal.

Physical Barrier—Most of the elements (and all of the elements incorporating memory) of the AMSIB are protected from physical interference by the shielded enclosure. However, the detectors and detector cabling are outside of this enclosure and require other protective measures. For the AMSIB system, the HRGS detectors will be enclosed in interlocked shielded enclosures that are connected to the security watchdog. The NMC will be enclosed in a shielded enclosure, but interlocking this enclosure is not possible. Thus, physical protection for the NMC detector and all cabling will be provided by procedural limitations on access.

9.2.3.6 Power Filtering

All power for the AMSIB will enter the shielded enclosure through a Corcom CDSRW-E series filter. This filter is mounted directly on the inner side of the shielded enclosure, and the AC socket is enclosed in the shielded volume of the filter. This type of filter is specified to have an insertion loss of > 100 dB from 14 KHz to 10 GHz as per MIL-STD-220A.

9.2.3.7 Error Handling

Because of the key position of the security watchdog in the AMS, it is important to consider failure modes of this circuit. In particular, the Security Watchdog will fail in the "safe" configuration (no power supplied to the remainder of the AMS) if common element failures occur.

- If the power supply or related wiring fails, then neither K1 nor K2 will be energized, and no AC power can be supplied to the remainder of the AMS.
- Both relays will be connected in a "fail-safe" configuration. An active connection to the coil is required in order for the watchdog to supply AC power to the rest of the AMS.
- Both sides of the AC line will be switched by relays K1 and K2. Thus, the failure of one contact will not prevent the watchdog from interrupting power.
- Each of the doors on the shielded enclosure has 2 interlock switches, either one of which is sufficient to de-energize K2 if the door is opened.
- The default mode for the door switches will be "closed." Therefore, if one of the cables connecting the auxiliary door switches to the main cabinet is not connected correctly, then the watchdog will act as if one of the doors were open.
- If the coil of either relay becomes open, that relay will not supply AC power to the AMS.
- The security sensors S1 and S2 will each be a pair of mechanical switches in the final implementation. Failure of any one of these four switches cannot cause the security watchdog to malfunction.
- The security sensor circuit requires closure for the system to make open measurements. Therefore, if one of the cables connecting the security sensors to the main cabinet is not connected correctly, the security watchdog will not allow open mode measurements.
- Both the "door open" and "system secure" displays will be driven directly from the relay coils in the watchdog. This is the best indication that the relays are actually in the configuration displayed.

9.2.3.8 Display

The unclassified display shall be a simple hardware circuit with no computer-controlled functions. Optical signals transmitted by the data barrier can be received in optical receivers. The optical receivers in turn

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will be connected to LED drivers, which are connected directly to the red and green LEDs. All power for the display is DC that is generated within the shielded enclosure and sent to the display through a shielded cable. Thus, the security watchdog also controls the display power.

Six pairs of LEDs (12 LEDs total) are necessary to indicate passing or failing the attribute tests and to provide the two security status indicators. The attribute tests are displayed on four pairs of red/green LEDs (8 LEDs). The remaining two pairs of LEDs are for the system "housekeeping" functions. One pair indicates the security status of the AMSIB, i.e. they indicate whether the system is open (red) or secure (green). An additional green LED indicates that a measurement has been completed and the final red LED is indicative of a hardware malfunction within the AMSIB. There shall be no other outputs from the AMSIB possible during classified measurements.

9.3 Recommended Equipment List

Below is a list of recommended equipment that could be procured by the buyer prior to the completion of design work and as deemed appropriate by the contractor. Before procurement, the contractor will certify that this equipment can be certified for use in Russia.

AMSIB Suggested Long-Lead Procurement Materials
For Development and Testing of A Single System

	Equipment Description	Quantity
1	Neutron Multiplicity Counter (NMC) This could be procured commercially -- lead time will be approximately 9 months	Depends on design- cannot procure until at least 35% design is complete.
2	NMC Parts—if NMC is built by contractor A. ^{3}He tubes – 70 cm active length, 1" diameter, 10 atmospheres gas pressure B. AMPTEK Type 111 Preamplifiers- (other similar optional options are available) C. Polyethylene – High Density (on the order of 0.98 g/cm^3) D. Cadmium Sheets	A. Quantity: 180 units B. Quantity: 60 units C. 6'x6'x6' block equivalent in various slab pieces and thickness' D. 6'x6' and 1/16" thick (Sufficient to surround an AT400R with a fair excess top and bottom)

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3	Multiplicity Shift Register: e.g. Ortec ISR, Canberra AMSR-150 without flash card	Quantity: 2 units
4	High Purity Germanium Detector – n-type at least 50% efficient and cryostat type 30 liter dewar	Quantity: 4
10	Digital Multichannel Analyzer: e. g. Canberra DSP 2000, Ortec DSPEC	Quantity: 4
11	Shielded electronics rack - Hoffman PROLINE EMI/RFI or similar	Quantity: 2

9.4 Recommended Spare Parts

The designer will specify the number and type of spare parts necessary to meet the requirements listed in Section 6.6.2. These may include:

Gamma detector(s)
Multichannel analyzer(s)
Complete gamma analysis module(s)
^{3}He neutron detector tube(s)
Shift register(s)
Complete neutron analysis module(s)
Complete computational block module(s)
Basic computer board(s) to be used in any of the computer-based modules
Input data barrier module(s)
Complete measurement control switch assembly(s)
Output data barrier module(s)
Complete display module(s)
Bar code reader(s)
Bar code display(s)
Data archiving system(s)
Interconnecting cables
Fuses

9.5 Recommended Technical References

9.5.1 Attribute Measurement System Descriptions

Many references can be found at the Fissile Material Transparency Technology Demonstration Web Site, http://www-safeguards.lanl.gov/FMTT/index_main.htm, LA-UR-01-1091, March 2001.

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9.5.1.1 Concepts

Duncan W. MacArthur and Rena Whiteson, "Functional Requirements for a Prototype Inspection System and Information Barrier for the Trilateral Initiative," Los Alamos National Laboratory document LA-UR-99-829 (February 1999).

Rena Whiteson, Duncan W. MacArthur, and Robert P. Landry, "Functional Specifications for a Prototype Inspection System and Information Barrier," Los Alamos National Laboratory document LA-UR-99-1174 (March 1999).

Rena Whiteson and Duncan W. MacArthur, "Fissile Material Technology Demonstration Attribute Measurement System with Information Barrier: Functional Requirements," Los Alamos National Laboratory document LA-UR-99-5634 (Rev) (February 2000).

9.5.1.2 Systems

Duncan W. MacArthur, Rena Whiteson, Diana Langner, and James K. Wolford, Jr., "Attribute Measurement System with Information Barrier for the Fissile Material Technology Demonstration: System Overview," Los Alamos National Laboratory document LA-UR-99-5611 (Rev) (February 2000).

Rena Whiteson, Robert P. Landry, Diana Langner, Duncan W. MacArthur, and James K Wolford, Jr., "A Prototype Inspection System with Information Barrier for the Trilateral Initiative," proceedings of the INMM 40th Annual Meeting, Phoenix, Arizona, July 25–29, 1999.

Duncan MacArthur, "Attribute Measurement Systems with Information Barriers," Los Alamos National Laboratory document LA-UR-3700 (Aug. 2000). (Viewgraphs only)

9.5.1.3 Software

Rena Whiteson, Diana Langner, Robert Landry, James Wolford, and Tom Gosnell, "General Description of Software for the PPIA/Mayak Demonstration," Los Alamos National Laboratory document LA-UR-99-5894, (Nov. 1999).

9.5.2 Detector Systems

9.5.2.1 Physics Basis

M. W. Johnson, "Physics Basis of the AMS/IB System," http://www-safeguards.lanl.gov/FMTT/presentations/pdf_docs/johnson_physics_basis.pdf, March 2001.

T. B. Gosnell, "Attributes and Thresholds," Los Alamos National Laboratory document LA-UR-00-5421 (Nov. 2000). (Viewgraphs only)

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9.5.2.2 Neutron Detectors

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