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SELECTION OF POTENTIAL IAEA INSPECTION STRATEGIES INVOLVING CASCADE ACCESS AT THE PORTSMOUTH GAS CENTRIFUGE ENRICHMENT PLANT (GCEP)

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1. INTRODUCTION

This report has been prepared as a U.S. contribution to Team 4 of the Hexapartite Safeguards Project. It provides to the Team 4 participants one example of an approach, which has been used in the United States, to developing a range of safeguards strategies involving differing degrees of access to cascade areas of centrifuge enrichment plants. Its purpose is to facilitate the work of other Hexapartite participants in completing Task II of Team 4's terms of reference. The scope of this report is limited to identifying safeguards approaches for the Portsmouth Gas Centrifuge Enrichment Plant (GCEP) which involve differing degrees of access to the cascade area. This report does not examine non-access safeguards approaches, which will be considered later in the work of Team 4, nor does it examine verification of the plant's nuclear material balance, which is the subject of Team 3's work. Furthermore, this report's selection of safeguards strategies involving differing degrees of access does not exhaust the possible motives for access (as discussed in Task I of Team 4's terms of reference, for example). Motivations for access which may arise in other circumstances, for example, in the investigation of anomalies, must be considered separately as the work of the Hexapartite Safeguards Project proceeds.

This report provides a method for selecting cascade access inspection strategies at GCEP which appear promising for more detailed evaluation. It is quite important to note, however, that the effectiveness and practicability of these strategies have not been established at the present. In addition, some strategies have been included on the basis of very preliminary calculations and considerations which have not been validated. Thus, some of these strategies may ultimately be rejected because they prove to be impracticable. Considerations of cost and the possible transfer of information and technology related to the production of enriched uranium will also be pertinent in considering the degrees and frequency of access to the cascade areas of centrifuge enrichment plants.

This report describes the process for combining technical measures, implementation approaches and objectives to arrive at the total number of theoretically possible combinations. It then describes how these combinations may be reduced in a series of steps to a number that is more manageable for detailed evaluation. The process is shown schematically in Figure 1.

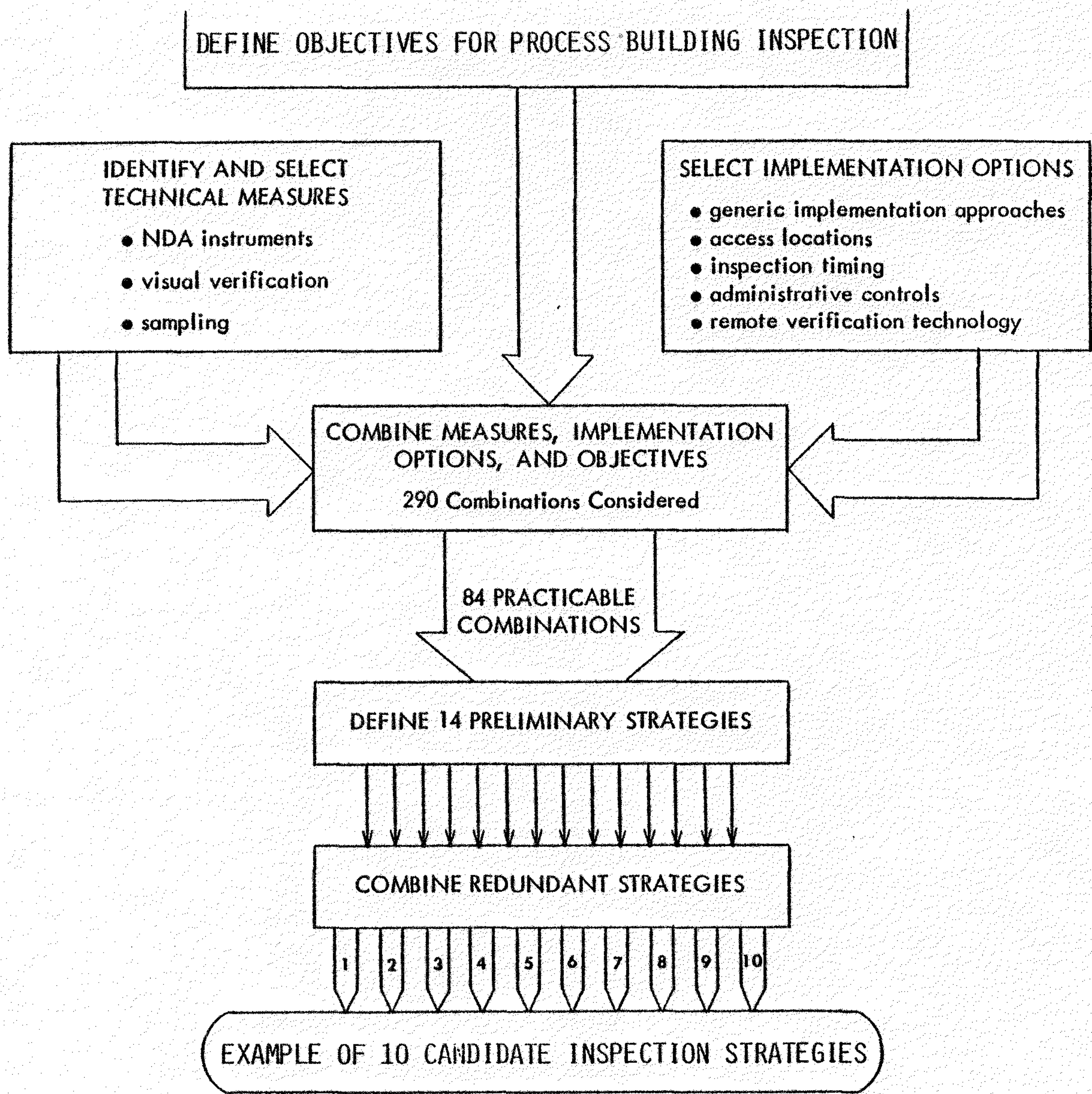

Figure 1

SCHEMATIC DIAGRAM OF THE METHOD USED TO SELECT IAEA INSPECTION STRATEGIES FOR THE GCEP

2. RELEVANCE OF ACCESS WITHIN THE PROCESS BUILDING

For the purpose of this report, effective international safeguards at GCEP are broadly defined as a set of measures that, if fully implemented by an inspectorate, could: (1) verify the declared nuclear material flows and inventories, (2) confirm that there is no possible production of HEU, and (3) confirm that there is no possible production of LEU in excess of or at enrichments higher than that reported. Confirmation that there is no possible production of HEU is generally regarded as the most important of the above 3 inspection activities because the other 2 do not relate to materials directly useable in nuclear explosives.

The specific activities required for HEU production, excess LEU production and the diversion of declared nuclear material and the relevance of access within the process building to detection of each activity are shown in Table 1. This table shows that inspector access to a process building would be relevant with respect to:

1. The presence of unverified feed and/or feed stations in the process building for either HEU or LEU production,

2. Accumulations of unverified tails or high-assay wastes from HEU production or unverified tails from excess LEU production,

3. Unverified cascade withdrawal stations and accumulations of HEU or excess LEU products,

4. Modifications or additions to the centrifuges or cascades for HEU production, and

5. The production of HEU.

All of these possibilities are relevant to confirming that there is no possible HEU production and the first three are relevant to confirming that there is no excess LEU production. Table 1 does not indicate the effectiveness of the methods in detecting each diversion activity.

In this report, the above five activities relevant to process building access are combined into three objectives:

1. Confirming that there is no possible presence of highly enriched uranium.

2. Confirming the correctness and completeness of the declared flows and amounts with respect to inventories of low enriched uranium.

3. Confirming the correctness and completeness of design information and the reported operating conditions.

These assumed objectives are used to categorize inspection measures in Section 3 and develop inspection strategies in Section 5.

Table 1

DETECTION OBJECTIVES AND RELEVANCE OF ACCESS WITHIN PROCESS BUILDINGS

Detection Objectives	Access Within the Process Buildings
1. HEU Production	
a. Introduction of Feed:	Not Relevant
	Relevant If[1]
b. Preparation of Separative Capacity	Relevant If[2]
c. Enriching Operation	Relevant
d. Withdrawal and Storage of HEU, Tails, or Waste	Relevant
e. Removal of HEU, Tails, or Waste	Not Relevant
2. Excess LEU Production	
a. Introduction of Feed	Relevant If[1]
b. Preparation of Separative Capacity	Relevant If[2]
c. Enriching Operation	Not Relevant
d. Withdrawal and Storage of LEU or Tails	Relevant If[1]
e. Removal of LEU or Tails	Not Relevant
3. Diversion of Declared Uranium	
a. Acquisition and Preparation of Uranium (feed, product, or tails)	Relevant If[1]
b. Removal of Uranium	Not Relevant

(1) Relevant if inspector observes cylinders.
(2) Relevant if inspector observes alteration from declared design information.

3. POTENTIAL TECHNICAL MEASURES FOR INSPECTION OF PROCESS BUILDINGS

This section identifies and selects the technical measures, such as nondestructive assay (NDA) equipment or visual inspection, that could be used to inspect process buildings. A list of inspection measures that includes all methods identified as potentially useful for process building inspection is presented in Table 2. These technical measures are evaluated with respect to their current state of development, feasibility, practicability,* and safeguards value if fully implemented. Based on this evaluation, a list of technical measures is selected for inclusion in inspection strategies. The selected measures are listed in Table 3. This table also identifies the relevant objective of each technical measure and whether the measure is a primary or supplemental method. Because the data required to make some of the assessments are not yet available, judgments on the likely feasibility and practicability of these measures were made in this report. The technical measures not included in Table 3 were rejected either because they would not be effective safeguards methods, they are infeasible, or there is a more practicable alternative.

It is important to note that the assessments in Table 3 were made by a small group of knowledgeable UCC-ND employees after discussions with technical experts at Los Alamos National Laboratory, Sandia National Laboratory and Brookhaven National Laboratory. The assessments are based in some cases on very limited experimental evidence and preliminary calculations. In Section 5, the selected technical measures are incorporated into inspection strategies for the process buildings.

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*In this report, feasibility is applied to methods that could be implemented with current or foreseeable technology; practicable methods are feasible methods that have reasonable impacts on safeguards costs.

Table 2

POTENTIAL TECHNICAL MEASURES
FOR INSPECTION OF PROCESS BUILDINGS

---

1. Radiation Monitors and Nondestructive Assay Instruments

   a. Stationary Monitors:
      - Neutron Monitor Array
      - Gamma Monitor Array
      - Gamma Monitor for Cascade Pipes
      - Collimated, High-Energy Gamma Monitor
      - Collimated, Low-Energy Gamma Monitor
      - Gamma-Imaging Camera

   b. Portable Monitors:
      - Gamma Monitor for Centrifuges
      - Gamma Monitor for Cascade Pipes
      - Gamma Monitor for Area Measurements
      - Neutron Monitor for Area Measurements
      - Cryodeposition Gamma Monitor
      - Collimated, High-Energy Gamma Monitor
      - Collimated, Low-Energy Gamma Monitor
      - UF_6 Trap Monitor

2. Visual Verification of Facility Configuration and Observation of Operations

   a. Direct Inspector Observations

   b. Indirect Observations:
      - Closed Circuit Television
      - Tamper Indicator
      - Location Verification Device
      - Wall Port

3. Cascade Sampling

   a. Sample Withdrawal from Cascade Headers:
      - Off-Site Analysis
      - At-Line Analysis

   b. On-Line Sampler/Mass Spectrometer (train product and tails)

4. Piping Continuity and Flow Measurements

   a. Tracers for Piping Configuration Checks

   b. Non-intrusive, Portable UF_6 Flowmeter

Table 3

RELEVANCE OF SELECTED TECHNICAL MEASURES TO MEETING OBJECTIVES OF INSPECTION WITHIN PROCESS BUILDINGS

Selected Measures	Confirmation Objective: No Possible Presence	Confirmation Objective: Completeness and Correctness of Uranium Inventories	Confirmation Objective: Completeness and Correctness of Design Information and Reported Operating Conditions
1. Radiation Monitors and Nondestructive Assay Instruments			
a. Stationary Monitors: - Neutron Monitor Array	Primary	Primary	Not Relevant
- Gamma Monitor Array	Primary	Supplemental	Not Relevant
- Gamma Monitor for Cascade Pipes	Primary	Not Relevant	Not Relevant
- Collimated, High-Energy Gamma Monitor	Not Relevant	Primary	Not Relevant
- Collimated, Low-Energy Gamma Monitor	Primary	Primary	Not Relevant
b. Portable Monitors: - Gamma Monitor for Centrifuges	Primary	Not Relevant	Not Relevant
- Gamma Monitor for Cascade Pipes	Primary	Not Relevant	Not Relevant
- Gamma Monitor for Area Measurements	Primary	Primary	Not Relevant
- Neutron Monitor for Area Measurements	Primary	Primary	Not Relevant
- Collimated, High-Energy Gamma Monitor	Not Relevant	Primary	Not Relevant
- Collimated, Low-Energy Gamma Monitor	Primary	Primary	Not Relevant
- UF_6 Trap Monitor	Supplemental	Not Relevant	Not Relevant
2. Visual Verification of Equipment Configuration	Not Relevant	Primary	Primary
3. Cascade Sampling — Sample Withdrawal with Off-Site Analysis	Supplemental	Not Relevant	Not Relevant

NOTE: Although the purpose of this table is to examine the objective for individual selected technical measures, the combination of an appropriate instrument from Item 1 with Item 2 would provide a primary method with the possibility of meeting all three objectives.

4. IMPLEMENTATION APPROACHES FOR INSPECTION

The technical measures discussed in Section 3 are divided into three main groups: (1) stationary radiation monitoring equipment, (2) portable radiation monitoring equipment, and (3) visual verification of the cascade configuration. The implementation of an inspection strategy using stationary measurement equipment is accomplished most directly by allowing the inspectorate to either install its equipment or supervise its installation by the facility operator, and by permitting the inspectorate to verify and service the installed devices at the required frequency. For portable instruments, the most direct implementation is to permit the inspector to move and use the portable equipment as required to achieve his performance objectives. If there were no issue of potential technology transfer within the process buildings, then the above implementation approaches would be used; the only concern of the facility operator would be interference with operations. Since inspector access does raise issues with respect to the potential transfer of technology, implementation approaches with differing degrees of access must also be considered. However, this seems to apply only to the first two technical methods; i.e., stationary and portable radiation monitoring.

4.1 RADIATION MONITORING EQUIPMENT

Three implementation approaches for stationary radiation monitors and two for portable monitors are considered. The practicability and feasibility of each of these approaches are considered later for specific combinations of objectives, inspection locations, and monitoring instruments. Each generic implementation approach describes the general manner in which specific technical measures will be installed, maintained, and operated.

4.1.1 Implementation Approaches for Stationary Radiation Monitors

4.1.1.1 Inspectorate Installation, Maintenance, and Verification of Safeguards Instruments. Safeguards equipment would be installed by the inspectorate at strategic points or by the facility operator under the direction and observation of inspectorate personnel. The equipment would be serviced and verified directly by the inspectorate. Verification procedures would include, for example, periodic calibrations and checks of seals or other tamper indicators. The safeguards equipment signals and any tamper-indicating signals would either be remotely monitored or recorded within the instrument. In this context "remotely monitored" means transmission of the signals to a location on the GCEP site that is continuously accessible to the inspectorate. Tamper indication might be augmented by CCTV or film camera observation of the equipment and its immediate environment. This approach is typified in current practice by the use of sealed camera units for monitoring spent fuel pools.

4.1.1.2 Inspectorate Installation and Remote Verification and Facility Maintenance of Safeguards Instruments. Safeguards equipment would be installed by the inspectorate or under its supervision and serviced by facility personnel by substitution of sealed instrument modules. Verification would be accomplished remotely by the inspectorate using remote monitoring of encoded output signals, CCTV or film cameras installed by the inspectorate and serviced by the facility, electronic instrument interrogation, source checks, or other methods. This implementation approach is aimed at reducing the required frequency of inspector access to sensitive areas. There is no inspectorate experience with this approach, but the U.S. Arms Control and Disarmament Agency's RECOVER (REmote COntinual VERification) Program has developed a system to accomplish some of the same objectives.

4.1.1.3 Inspectorate Remote Verification and Facility Installation and Maintenance of Safeguards Instruments. Safeguards equipment would be installed and serviced by facility personnel. Maintenance would be by substitution of sealed instrument modules. Verification of proper installation, operation, and maintenance would be accomplished remotely as in the second implementation approach. There is no inspectorate, or any other experience with this type of implementation approach.

4.1.2 Implementation Approaches for Portable Radiation Monitors

4.1.2.1 Inspectorate Direct Use of Monitors. Safeguards instruments are carried and used by inspectors as is the current practice at fuel fabrication plants.

4.1.2.2 Facility Use of Sealed Portable Instruments with Remote Verification. Sealed portable instruments provided by the inspectorate would be used by facility personnel, as agreed with the inspectorate. The inspector would remain outside of the sensitive area while the facility personnel made the measurements. This implementation approach would require a verifiable method of remotely locating the position of a portable instrument and a method of verifying the correct use of the instrument at each measurement location. The instrument output could be transmitted remotely during the measurements or recorded in the sealed instrument and be returned to the inspector at the conclusion of a measurement sequence.

This implementation approach was defined to determine whether portable instruments could be used effectively without inspector access. This approach would not require any significant advance notice of inspection because the inspector would not have access to sensitive areas. This implementation approach is the most technologically difficult and may not be practicable.

4.2 PROCESS BUILDING INSPECTION LOCATIONS

This section contains a summary description of a typical process building and divides the building into distinct areas for the consideration of inspection opportunities.*

*A full description of the GCEP can be found in the report K/OA-4783, Revision 1, that has been previously provided the Hexapartite participants.

The eight process buildings on the GCEP site will contain all the equipment necessary for the enriching process with the exception of UF_6 feed and withdrawal facilities. The first two process buildings are authorized for construction. Figure 2 shows these buildings and the terminology used to distinguish the areas of the buildings. The process building, as shown in Figure 3, is bisected by the transfer corridor (open central aisle) with four enriching trains located in each half of the building. A train consists of six parallel cascades. Each cascade consists of centrifuges arranged in rows with the service modules running between them. The service modules are arrays of piping, valves, electrical cabling, and instrument packages. The centrifuge machines and service modules make the floor level of the process building very crowded except in the central transfer corridor aisle.

One overhead crane, for moving and placing new and replacement centrifuge machines, is located in each crane bay. Each crane passes over the central aisle and the trains on either side of the aisle. The crane has a lifting mechanism so that the machines can be lifted from their mounts and moved over the service modules to the central aisle. Here the machines are placed on special intraplant transport vehicles that haul the machines along the transfer corridor between the process buildings and the Recycle/Assembly Building.

At each end of the process building is a utility bay that has a lower roof than the cascade crane bay. Each utility bay serves the four trains located in its half of the building. This area contains heating and ventilating equipment, electrical distribution equipment, emergency generators, vacuum pumps, heat exchangers, and chemical traps for UF_6. A small aisle separates this area from the ends of the cascades. The service module piping crosses this aisle overhead and connects to the train headers that are mounted along the wall at the inside edge of the low bay. The train headers connect to the building headers at one corner of the building. The product ends of the cascades are located at each end of the building and the tails are located at the center aisle.

The process building and adjoining structures are divided into five areas in order to determine the applicability of safeguards measures and the potential for technology disclosures in each area. In Section 5, where specific inspection strategies are defined, the areas described below will be considered.

4.2.1 Cascade Areas on the Floor of the Process Building

This is the primary area of safeguards interest and frequent access to this area would provide most of the relevant safeguards information. Access to this area could pose the chance of exposing the greatest amount of technology. This area is not subdivided because access to any corridors or service modules on the cascade floor probably would result in a similar chance of technology exposure and similar safeguards effectiveness.

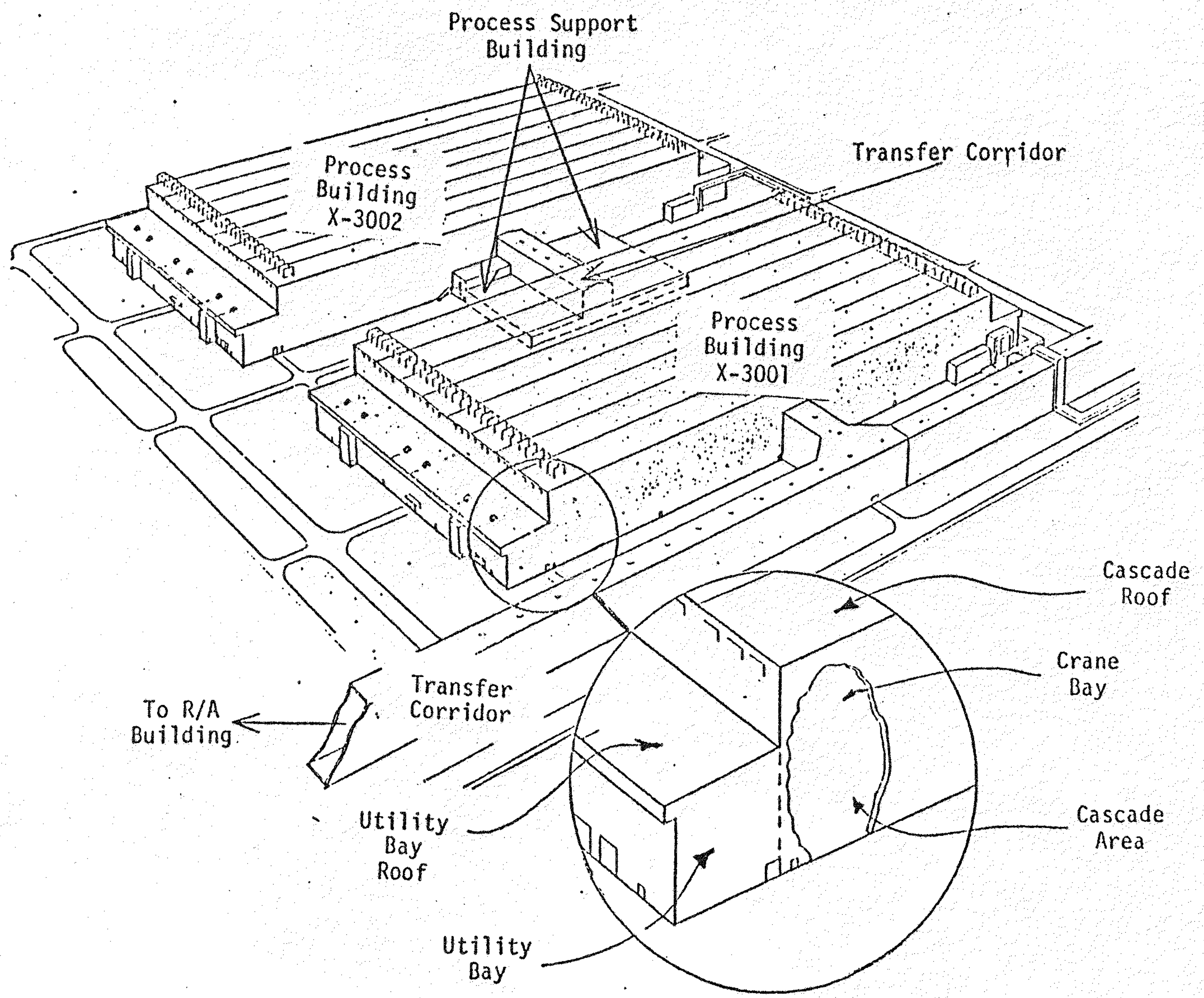

Figure 2

Process Buildings at the Gas Centrifuge Enrichment Plant

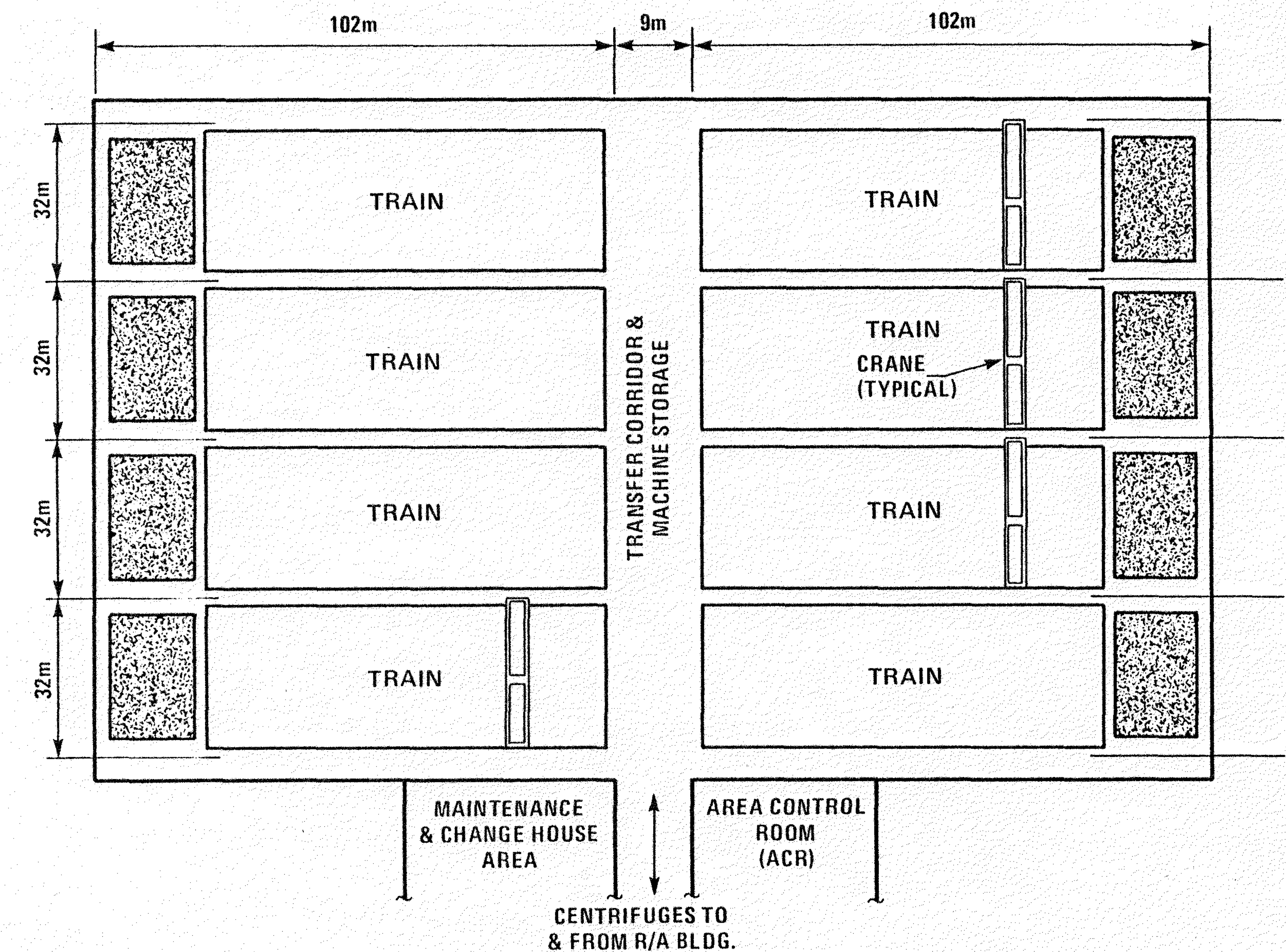

Figure 3

Floor Plan of a GCEP Process Building

4.2.2 Utility Bays

The chemical traps are located near the end walls of the process building on the ground floor of the utility bay. Access to the traps would require utility bay access. In the present design, such access could reveal important technology. Walls to separate the trap area from the remainder of the utility bay could be considered.

The train pipe headers are arranged vertically along the side of the second floor of the utility bay. Access to this area would permit pipeline measurements without access to the process building floor in the cascade area.

4.2.3 Crane Bays

Access to the overhead crane bays either for mounting stationary monitors or for use as mobile platforms for measurements by the inspector is considered because of the possibility for limiting technology disclosure. Because the crane and its bay can be viewed remotely with a limited number of CCTV cameras (1 to 2 per crane bay or 4 to 8 per process building), this area is very suitable for instruments that can be installed by the facility and monitored remotely by the inspectorate.

4.2.4 Process Building Roof

Access to the cascade area roof and to the utility bay roof would be required to install, service, and verify stationary rooftop monitors. Some measurements of LEU inventories with portable instruments, such as the collimated, high-energy gamma detectors for measuring the ^{238}U daughter nuclide ^{234m}Pa could possibly be made from the roof.

4.2.5 Wall Ports

Access to a utility bay roof permits access to the process building wall nearest to the product end of the trains and to the cascade roof. (See Figure 2.) Ports in this wall could be used for collimated, gamma area monitors, CCTV monitors for crane observation, crane position sensors, and neutron area monitors. All of these monitors could be installed and serviced from outside the process building, thereby limiting direct inspector access. Ports for this application are not now in the GCEP design.

4.3 SAFEGUARDS EQUIPMENT INTEGRITY VERIFICATION

Integrity verification is required for stationary safeguards equipment and for portable instruments that are used by the facility operator. Whether the facility or the inspectorate installs the equipment, the inspectorate must be able to verify, to its satisfaction, that the integrity of the equipment has not been compromised in his absence and that any portable equipment used by the facility is located and operated correctly. Three primary techniques that could be used for such verifications are: closed circuit television, tamper indicators, and location verification devices.

4.3.1 Closed Circuit Television (CCTV)

Safeguards systems must depend upon nuclear instrumentation to verify proper operation of the enrichment facility. Video equipment can be used to verify that no tampering with the instrumentation has occurred. Some possible uses of video equipment for this function are:

1. Portable cameras and recorders can be used to verify the operation or connections of installed monitoring equipment. A plant employee could carry the camera and recorder to various locations as agreed with the inspectorate. The sequence of recording could be dictated by the inspector and an internal time clock used to estimate travel time from one location to another.

2. A mobile cart, which would travel past marker points on its way to a location, could be used to carry equipment. As the cart passes a marker point, a coded passive transponder would be interrogated by the equipment on the cart. This marker system could be implemented with an electronic badge similar to one used for portal monitoring. The distance between markers would be measured from the revolutions of the cart's wheels. The combined distance measurement and marker points would serve to verify to an inspector that the TV equipment and any other monitor equipment had been moved to the proper location in the plant. The TV equipment could monitor the motion of the cart and show the inspector that the cart was actually being moved around the plant.

3. Video equipment could be installed in fixed positions to watch equipment such as in-line enrichment monitors. Video motion detectors would warn of possible tampering with equipment.

4. Video cameras could be mounted at the ends of each crane's travel to view the operation of monitors installed in the crane bays. The cameras could be mounted in special housings attached to the outside walls of the crane bay areas. The cameras could take periodic pictures of crane operation, could look for attempts to tamper with installed monitors, could verify the use of portable instruments on the crane, and could confirm positioning of the crane. Position of the overhead crane could be determined by laser distance-measuring equipment installed in the camera housing and aimed at reflectors mounted on the crane. The cameras and crane position monitors could be maintained by the inspectorate from outside the building.

The first two applications are not considered to be practicable since the cameras, measurement equipment, and recorders are all under the use, and hence control, of the facility. Scenarios are easy to visualize in which the location of the equipment or the identification of the item being measured could be misrepresented. Hence, only the last two applications, items 3 and 4, are considered to be practicable. Since both of these applications have fixed-position cameras, the inspector knows and can verify the location of the cameras and their visual fields.

Some equipment required for these surveillance tasks has already been developed for other programs. The video from the crane cameras could be recorded by some of the unattended video surveillance equipment developed for the IAEA. This equipment has motion detectors and the capability for recording periodic video frames. Some development would be required to adapt commercial distance-measuring equipment into the system. Protection against accidental or intentional power loss to the video equipment could be provided by emergency power sources within the equipment.

4.3.2 Tamper Indication and Verification

A variety of tamper indicators has been developed for safeguards and security applications. Inspectorates currently rely on seals as the primary method of verifying the integrity of the closure of a nuclear material container or a safeguards instrument. The U.S. DOE Enrichment Safeguards Program is developing data encryption technology to encode safeguards data so that their source is uniquely identified and so that the data can be transmitted on unsecured lines. Motion sensors, magnetic switches, electrical continuity checks, and special materials have been employed to make tamper-indicating instrument enclosures. The details of tamper-indication depend on the instrument's characteristics, function, and environment. It has been assumed that any installed monitor could be designed so that unauthorized penetration of the unit could be detected remotely. For area radiation monitors, it may be practical to use small radiation sources from outside the facility to remotely check their operation. Arrays of monitors may be inherently less susceptible to tampering because of their overlapping coverage. The feasibility of these measures is not yet established for each application and type of radiation monitor. The practicability and effectiveness of some of the inspection strategies selected in Section 6 will depend on the ability of the inspectorate to remotely verify radiation monitor integrity.

4.3.3 Location Verification Devices

Special problems arise in verifying the integrity of location verification devices and portable monitors used in strategies where the plant operator takes the measurements for the inspectorate. Verification is accomplished by using (1) tamper-indicating devices (i.e. motion sensors and a stressed-glass envelope) on the locator device, (2) encryption devices in both the locator device and the portable monitor, and (3) seals and a tamper-indicating/tamper-resistant enclosure on the portable monitor. Tamper safing the portable monitor is not difficult, since it is in the hands of the facility operator for only short periods of time. Requiring two-way encrypted communication between either stationary or mobile locator devices assures that the instrument being used to obtain the measurement is the device that was given to the operator, that the data are coming from the proper location, and that these data are valid. CCTV could also be used in conjunction with the portable monitor to provide additional verification during the time that measurements are being made.

5. SELECTION OF INSPECTION STRATEGIES FOR ACCESS WITHIN THE PROCESS BUILDINGS

This section describes the selection of candidate inspection strategies for the GCEP process buildings. The strategies are derived from combinations of the objectives in Section 2, the selected inspection measures in Section 3, and the generic implementation approaches and locations in Section 4. There was a conscientious effort to develop the smallest possible list that covers all practicable strategies so that the evaluation part of this study could avoid the confusion inherent in trying to evaluate the fine differences between many alternative strategies. Emphasis was given to including strategies that ranged in intrusiveness from full inspectorate access to the process buildings to no access for the inspectors.

All of the inspection strategies considered use radiation monitoring or NDA equipment as the fundamental safeguards tool. Discussions on UF_6 sampling of cascades concluded that at GCEP, sampling should be used only as a supplemental method. This conclusion is being further evaluated.

The effective use of visual inspection as the sole measure to verify the cascade configuration and operation would require direct, frequent physical access by the inspector. If the inspector has frequent access, he will be much more effective if he uses NDA equipment as the primary tool and supplements it with whatever he can see. Thus, visual inspections are assumed to be part of any strategy that involves internal access to the process buildings.

The candidate inspection strategies are selected by the following procedure:

1. Define the parameters which will be combined to describe the possible strategies (Table 4).

2. Construct matrices of all combinations of the above parameters and determine the relevance, practicability, and potential for effectiveness of every combination (Tables 5 and 6).

3. Derive a list of all practicable strategies from the matrices of inspection parameters (Tables 7 and 8).

4. Reduce this list of preliminary strategies by combining similar strategies (Table 9).

5. Complete the list of candidate strategies by adding combinations of strategies where these could be substantially more effective than single strategies (Table 9).

6. Estimate, subject to review, the required frequency of internal access.

Table 4

PARAMETERS USED TO DEFINE THE POSSIBLE STRATEGIES

Parameter	Values
1. Technical Measure	Stationary Monitor Portable Monitor
2. Objective	Confirm No Possible Presence of Highly Enriched Uranium Confirm Completeness and Correctness of Uranium Inventories
3. Location for Inspection	Cascade Area Utility Bay Crane Bay Process Building Rooftop Wall Ports
4. Generic Implementation Approach	
a. For Stationary Monitors	Inspectorate Installation, Maintenance, and Verification (S1) Inspectorate Installation and Remove Verification; Facility Maintenance (S2) Inspectorate Remove Verification; Facility Installation and Maintenance (S3)
b. For Portable Monitors	Inspectorate Direct Use (P1) Inspectorate Remote Verification; Facility Use of Monitors (P2)
5. Monitor Types	
a. Stationary	Neutron Monitor Array Gamma Monitor Array Gamma Monitor for Cascade Pipes Collimated, High-Energy Gamma Monitor Collimated, Low-Energy Gamma Monitor
b. Portable	Gamma Monitor for Centrifuges Gamma Monitor for Cascade Pipes Gamma Monitor for Area Measurements Neutron Monitor for Area Measurements Collimated, High-Energy Gamma Monitor Collimated, Low-Energy Gamma Monitor UF_6 Trap Monitor

Table 5

APPLICABILITY OF STATIONARY RADIATION MONITORS TO PROCESS BUILDING INSPECTION FOR THREE IMPLEMENTATION APPROACHES

Implementation Approach	Confirmation Purpose: No Possible Presence of Highly Enriched Uranium					Confirmation Purpose: Completeness and Correctness of U Inventories				
	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports
S1. Inspectorate installation, maintenance, and verification.										
Monitor Types										
Neutron Monitor Array	•	-	•	•	•	•	•	•	•	•
Gamma Monitor Array	•	-	•	•	•	-	-	-	-	-
Gamma Monitor for Cascade Pipes	•	·	-	-	-	-	-	-	-	-
Collimated, High-Energy Gamma Monitor	-	-	-	-	-	•	•	•	•	•
Collimated, Low-Energy Gamma Monitor	•	-	•	·	•	•	•	•	•	•
S2. Inspectorate installation and remote verification; facility maintenance										
Monitor Types										
Neutron Monitor Array	•	-	•	-	-	•	•	•	-	-
Gamma Monitor Array	•	-	•	-	-	-	-	-	-	-
Gamma Monitor for Cascade Pipes	o	o	-	-	-	-	-	-	-	-
Collimated, High-Energy Gamma Monitor	-	-	-	-	-	o	o	•	-	-
Collimated, Low-Energy Gamma Monitor	o	-	•	-	-	o	o	•	-	-
S3. Inspectorate remote verification; facility installation and maintenance.										
Monitor Types										
Neutron Monitor Array	o	-	•	-	-	o	o	•	-	-
Gamma Monitor Array	o	-	•	-	-	-	-	-	-	-
Gamma Monitor for Cascade Pipes	o	o	-	-	-	-	-	-	-	-
Collimated, High-Energy Gamma Monitor	-	-	-	-	-	•	•	•	-	-
Collimated, Low-Energy Gamma Monitor	•	-	o	-	-	•	•	o	-	-

Key:
- • Relevant as a fundamental method.
- · Relevant as a supplemental method.
- \- Method not relevant/applicable.
- o Method not feasible/practicable.

Table 6

APPLICABILITY OF PORTABLE RADIATION MONITORS TO PROCESS BUILDING INSPECTION FOR TWO IMPLEMENTATION APPROACHES

Implementation Approach	Confirmation Purpose: No Possible Presence of Highly Enriched Uranium — Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports	Completeness and Correctness of U Inventories — Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports
P1. Inspectorate direct use										
Monitor Types										
Gamma Monitor for Centrifuges	●	–	●	–	–	•	–	•	–	–
Gamma Monitor for Cascade Pipes	●	•	–	–	–	–	–	–	–	–
Gamma Monitor for Area Measurements	●	–	●	x	●	–	–	–	–	–
Neutron Monitor for Area Measurements	●	–	x	x	x	●	●	x	x	x
Collimated, High-Energy Gamma Monitor	–	–	–	–	–	●	●	●	●	●
Collimated, Low-Energy Gamma Monitor	●	–	●	•	●	●	●	●	●	●
UF_6 Trap Monitor	–	•	–	–	–	–	–	–	–	–
P2. Inspectorate remote verification; facility use of sealed monitors										
Monitor Types										
Gamma Monitor for Centrifuges	o	–	o	–	–	o	–	o	–	–
Gamma Monitor for Cascade Pipes	o	o	–	–	–	–	–	–	–	–
Gamma Monitor for Area Measurements	o	–	●	–	–	–	–	–	–	–
Neutron Monitor for Area Measurements	o	–	x	–	–	o	o	x	–	–
Collimated, High-Energy Gamma Monitor	–	–	–	–	–	●	●	●	–	–
Collimated, Low-Energy Gamma Monitor	●	–	●	–	–	●	●	●	–	–
UF_6 Trap Monitor	–	o	–	–	–	–	–	–	–	–

Key:
● Relevant as a fundamental method.
• Relevant as a supplemental method.
– Method not relevant/applicable.
o Method not feasible/practicable.
x Method not effective.

Table 7

IDENTIFICATION OF PRACTICABLE INSPECTION STRATEGIES FROM TABLES 5 AND 6

Implementation Approach	Monitor Location: Cascade and Utility Bays	Crane Bays	Building Roof	Wall Ports
S1	A	B	C	D
S2	E	F	-	-
S3	G	H	-	-
P1	I	J	K	L
P2	M	N	-	-

Table 8

DEFINITION OF PRACTICABLE, PRELIMINARY INSPECTION STRATEGIES

			Relevant Monitors												
			Stationary					Portable							
Preliminary Strategy	Implementation Approach	Monitor Location	Neutron Monitor Array	Gamma Monitor Array	Gamma Monitor for Cascade Pipes	Collimated, High-Energy Gamma Monitor	Collimated, Low-Energy Gamma Monitor	Gamma Monitor for Centrifuges	Gamma Monitor for Cascade Pipes	Gamma Monitor for Area Measurements	Neutron Monitor for Area Measurements	Collimated, High-Energy Gamma Monitor	Collimated, Low-Energy Gamma Monitor	UF_6 Trap Monitor
A	S1	Cascade and Utility Bays	+	+	+	+	+							
B	S1	Crane Bays	+	+		+	+							
C	S1	Building Roof	+	+		+	+							
D	S1	Wall Ports	+	+		+	+							
E	S2	Cascade and Utility Bays	+	+										
F	S2	Crane Bays	+	+		+	+							
G	S3	Cascade and Utility Bays				+	+							
H	S3	Crane Bays	+	+		+								
I	P1	Cascade and Utility Bays						+	+	+	+	+	+	+
J	P1	Crane Bays						+		+		+	+	
K	P1	Building Roof										+	+	
L	P1	Wall Ports								+		+	+	
M	P2	Cascade and Utility Bays										+	+	
N	P2	Crane Bays								+		+	+	

Table 9

EXAMPLES OF CANDIDATE INTERNATIONAL INSPECTION STRATEGIES
FOR THE GCEP PROCESS BUILDINGS

Strategy	Preliminary Strategy From Table 8	Estimated Frequency of Internal Access*
1. Stationary radiation monitors installed by the inspectorate in the cascade and utility bays.	A, E	Quarterly to Annually (remote verification might be required)
2. Stationary radiation monitors installed by the inspectorate in the crane bays.	B, F	Quarterly to Annually (remote verification might be required)
3. Rooftop radiation monitors.	C, K	**
4. Gamma monitors installed in building wall ports.	D, L	(CCTV viewing through the ports may be required)**
5. Stationary radiation monitors installed by the facility or portable instruments used by the facility in the cascade and utility bays with location verification devices.	G, M	(location verification device is required)**
6. Stationary radiation monitors installed by the facility or portable instruments used by the facility in the crane bays with CCTV verification from the wall ports.	H, N	(CCTV viewing of upper portion of cascade is required)**
7. Portable instruments used by the inspector in the cascade and utility bays.	I	Weekly to Monthly
8. Portable instruments used by the inspector from the overhead crane.	J	Weekly to Monthly
9. Stationary monitors and portable instruments installed, verified, and used by the inspectorate in the crane bays.	B, J	Quarterly
10. Stationary monitors and portable instruments installed, verified, and used by the inspectorate in the cascade and utility bays.	A, I	Quarterly

*Actual frequencies will depend on a number of variables, including effectiveness of remote verification, instrument reliability, relative effectiveness of stationary and portable monitors, access delay, and probability of detection required.

**Strategy emphasizes a verification approach which requires little or no internal access during its implementation. However, access may be required at other times in order to confirm that the strategy's assumptions are, or remain, valid. The needed timing and frequency of internal access is under investigation.

The parameters shown in Table 4 are used to form two matrices; one that describes the applicability of stationary radiation monitors and the other of portable radiation monitors to process building inspection. Tables 5 and 6 give the 290 possible combinations of the five parameters shown. Each combination of parameters is categorized as (1) relevant as a fundamental safeguards method, (2) relevant as a supplemental method, (3) not relevant, (4) not feasible, or (5) not effective. Because these categorizations are not mutually exclusive, the most pertinent category for each method is shown. The rationale for the classification of each combination in Tables 5 and 6 is given in Appendix A. Of the 290 possible combinations, 77 are judged relevant as fundamental safeguards approaches, 7 as supplemental approaches, 171 as not relevant, 9 as not effective, and 26 as not practicable for GCEP. It is important to recognize that the categorization of a combination as relevant does not imply anything about its effectiveness.

In the next step of the selection process, the 84 fundamental and supplemental methods are combined into a smaller number of strategies. The criteria for this step are: (1) to combine methods that have similar requirements for access and implementation approach and (2) to include methods that require access to the utility bays with those that require access to the cascade area. The first criterion tends to group the methods by degree of intrusiveness. The second criterion recognizes the fact that only supplemental safeguards methods for HEU detection can be employed in the utility bays; therefore, there is no substantial safeguards reason for granting access solely to the utility bays. If only utility bay access were granted, then a long, high wall would be needed between each utility bay and the cascade area to limit visual access to the cascades. A more limited wall would suffice if access were permitted solely to the alumina traps in each utility bay.

The effect of the application of these two criteria on Tables 5 and 6 is summarized in Table 7. The result is 14 potentially practicable inspection strategies. These 14 preliminary strategies are defined in Table 8 --using the implementation approach (defined in Section 4.1), the monitor location (defined in Section 4.2), and the relevant radiation monitors (identified in Tables 5 and 6).

The next two steps in the selection process are to reduce the list in Table 8 by combining similar strategies and to include combinations that might be more effective than single strategies. The final 10 candidate inspection strategies are given in Table 9. The access location and the estimated frequency of access into the process buildings are also shown for each strategy. The actual frequency required to achieve the objectives will be considered in a later study.

The rationale for selecting each of the 10 combinations from the 14 strategies given in Table 8 is as follows:

STRATEGY 1

Stationary Radiation Monitors Installed by the Inspectorate in the Cascade and Utility Bays.

Stationary radiation monitors (neutron or gamma monitor array, pipe monitors on the cascade product headers, or collimated gamma monitors) installed in the cascade are believed to be more practicable if they are periodically inspected and maintained by the inspectorate. This is Preliminary Strategy A. Monitors installed by the inspectorate and maintained by the facility (Preliminary Strategy E) have been included in this strategy because the extent of access for verification and maintenance will depend on the state-of-the-art in tamper indication and remote verification. Thus in Strategy 1, the degree of access will depend on the ability of the inspectorate to verify proper operation of the system and to maintain it. It is assumed that some access will be required to implement in-cascade fixed monitors. Such access may disclose important technology but not as much as Strategy 7.

STRATEGY 2

Stationary Radiation Monitors Installed by the Inspectorate in the Crane Bays

This strategy is similar to Strategy 1 except that the stationary radiation monitors (neutron or gamma monitor array or collimated gamma monitors) are located in the crane bays. It is a combination of Preliminary Strategies B and F. The technology disclosure is not as great as in Strategy 1, since access to the cascade floor is limited.

STRATEGY 3*

Rooftop Radiation Monitors

This strategy includes the potential use of stationary monitors (neutron or gamma monitor array or collimated gamma monitors) and portable monitors (collimated gamma monitors) on the roofs of the cascade area or the utility bays. This is a direct combination of Preliminary Strategies C and K. The strategies are combined because, if rooftop access is granted, then the inspectorate can use whatever methods are most appropriate or effective.

STRATEGY 4*

Gamma Monitors Installed in Building Wall Ports

This strategy includes the use of stationary monitors (gamma monitor array or collimated gamma monitors) and portable monitors (gamma area or

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*Strategy emphasizes a verification approach which requires little or no internal access during its implementation. However, access may be required at other times in order to confirm that the strategy's assumptions are, or remain, valid. The needed timing and frequency of internal access is under investigation.

collimated gamma monitors) in special purpose ports in the end walls of the process building above the utility bay roofs. This strategy combines Preliminary Strategies D and L because, if these ports are available, the inspectorate will have the option of using permanently installed and/or portable monitors.

STRATEGY 5*
Stationary Radiation Monitors Installed by the Facility or Portable Instruments Used by the Facility in the Cascade and Utility Bays with Location Device Verification

Preliminary Strategies G and M, which involve location verification of stationary or portable monitors in the cascade and utility bays, are combined into this strategy. It permits facility installation or use of IAEA instruments on the floor of the process building without granting access to the inspector.

STRATEGY 6*
Stationary Radiation Monitors Installed by the Facility or Portable Instruments Used by the Facility in the Crane Bays with CCTV Verification from the Wall Ports

Preliminary Strategies H and N, which involve remote CCTV verification from the wall ports of stationary or portable monitors in the crane bays, are combined into this strategy. It permits facility installation or use of inspectorate instruments in the crane bays without granting access to the inspector.

STRATEGY 7
Portable Instruments Used by the Inspector in the Cascade and Utility Bays

This strategy is the same as Preliminary Strategy I. This is the fullest access strategy considered and would involve frequent, short-notice inspections throughout the floor level of the process building. It poses the greatest chance of disclosing important technology. It also offers the greatest chance for successful detection of the misuse of the facility.

STRATEGY 8
Portable Instruments Used by the Inspector from the Overhead Crane

This strategy is the same as Preliminary Strategy J. The inspector would be escorted, perhaps through covered stairways or ladders, to one or more of the overhead cranes. The crane bridge and trolley would,

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*Strategy emphasizes a verification approach which requires little or no internal access during its implementation. However, access may be required at other times in order to confirm that the strategy's assumptions are, or remain, valid. The needed timing and frequency of internal access is under investigation.

during the inspection, be dedicated to the inspection effort and would be moved to the locations requested by the inspector. The gamma monitor would be positioned on centrifuges, with special handling equipment operated for the inspector from the crane. This strategy requires frequent, short-notice access by the inspector to be effective.

STRATEGY 9
Stationary Monitors and Portable Instruments Installed, Verified, and Used by the Inspectorate in the Crane Bays

This strategy is a combination of Strategies 2 and 8. It provides on-site, inspector-directed measurements as in Strategy 8, with the added capability of stationary monitors for measurements when the inspector is not present. Because of this, Strategy 9 requires less frequent inspector access than does Strategy 8.

STRATEGY 10
Stationary Monitors and Portable Instruments Installed, Verified, and Used by the Inspectorate in the Cascade and Utility Bays

This strategy is a combination of Strategies 1 and 7. It is similar to Strategy 9 except that access is to the cascade area rather than to the crane bays. If infrequent access is granted to verify in-cascade monitors, then the use of portable measurements on these visits should increase the effectiveness without substantially increasing the technology exposure.

COMMENTS ON CANDIDATE INSPECTION STRATEGIES

1. The intrusiveness of the selected strategies ranges from frequent inspector access throughout the process building (Strategy 7) to access only to the building roof (Strategy 3).

2. The technical complexity of the strategies ranges from the remote verification of installation, maintenance, and operation of large arrays of neutron or gamma monitors (Strategies 5 and 6) to the inspector's use of portable radiation monitors (Strategies 7 and 8).

3. The effectiveness of these strategies is not quantified in this section; however, all of the selected strategies should be capable of detecting some HEU production scenarios and some are capable of detecting accumulations of unshielded or lightly shielded, aged uranium associated with HEU or excess LEU production.

4. All of the strategies may be feasible to implement with technology already available or achievable before the startup of the first process building at GCEP. All of the strategies will require some instrument development and engineering.

5. Some strategies (2, 4, 6, 8, and 9) would involve modifications to the current design of the process buildings. Strategies 4 and 6 would require special ports in each of the buildings. The number of

ports would range from 1 to 6 per train or 8 to 48 per building. Strategies 2, 8, and 9 could require some additional ladders and catwalks in the crane bays to permit inspector access to all four bays to without general access to floor areas of the buildings.

6. For the strategies that involve access to the interior, some equipment changes will be necessary to protect technology.

7. The specific frequency or conditions of access were not examined. In the case of stationary monitors, the frequency of access will depend on the state-of-the-art in remote verification and on instrument reliability. In the case of portable instruments, the frequency of access will depend on the desired probability of detection and on the importance given to the deterrent effect of random, short-notice inspections.

8. Strategies 2, 3, 4, 6, 8 and 9 make use of building or cascade features unique to GCEP; therefore, these strategies may not apply to other centrifuge enrichment plants. The effectiveness of Strategies 1, 5, 7, and 10 will depend on the specific characteristics of the centrifuge cascades. In general, inspection approaches that are based on cascade inspection will be much more facility-specific than perimeter safeguards approaches.

APPENDIX A

RATIONALE FOR SELECTION OF PRACTICABLE COMBINATIONS

This appendix gives the reasons for the categorizations of each combination of the inspection methods shown in Tables 5 and 6 in Section 5. These tables are reproduced here as Tables A-1 and A-2, respectively. Each entry in these tables has a footnote which describes the reasons for classifying each combination of purpose, monitor type, implementation approach, and inspection location. For many combinations, when more than one identified footnote is appropriate, only the most important one is shown.

Table A-1
(Table 5 in Section 5)

APPLICABILITY OF <u>STATIONARY</u> RADIATION MONITORS TO PROCESS BUILDING INSPECTION FOR THREE IMPLEMENTATION APPROACHES

	Confirmation Purpose									
	No Possible Presence of Highly Enriched Uranium					Completeness and Correctness of U Inventory				
Implementation Approach	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports
S1. Inspectorate installation, maintenance, and verification.										
Monitor Types										
Neutron Monitor Array	● a/	– b/	● c/	● a/	● d/	● a/	● e/	● c/	● a/	● d/
Gamma Monitor Array	● f/	– b/	● c/	● g/	● g/	– h/	– h/	– h/	– h/	– h/
Gamma Monitor for Cascade Pipes	● i/	• i/	– k/	– k/	– k/	– ℓ/	– ℓ/	– ℓ/	– ℓ/	– ℓ/
Collimated, High-Energy Gamma Monitor	– m/	– m/	– m/	– m/	– m/	● n/	● e/	● c/	● o/	● o/
Collimated, Low-Energy Gamma Monitor	● p/	– b/	● c/	• g/	● d/	● n/	● e/	● c/	● g/	● d/
S2. Inspectorate installation and remote verification; facility maintenance										
Monitor Types										
Neutron Monitor Array	● q/	– b/	● r/	– s/	– s/	● q/	● q/	● r/	– s/	– s/
Gamma Monitor Array	● q/	– b/	● r/	– s/	– s/	– h/	– h/	– h/	– h/	– h/
Gamma Monitor for Cascade Pipes	o t/	o t/	– k/	– k/	– k/	– ℓ/	– ℓ/	– ℓ/	– ℓ/	– ℓ/
Collimated, High-Energy Gamma Monitor	– m/	– m/	– m/	– m/	– m/	o u/	o u/	● r/	– s/	– s/
Collimated, Low-Energy Gamma Monitor	o u/	– b/	● r/	– s/	– s/	o u/	o u/	● r/	– s/	– s/
S3. Inspectorate remote verification; facility installation and maintenance.										
Monitor Types										
Neutron Monitor Array	o v/	– b/	● w/	– s/	– s/	o v/	o v/	● w/	– s/	– s/
Gamma Monitor Array	o v/	– b/	● w/	– s/	– s/	– h/	– h/	– h/	– h/	– h/
Gamma Monitor for Cascade Pipes	o x/	o x/	– k/	– k/	– k/	– ℓ/	– ℓ/	– ℓ/	– ℓ/	– ℓ/
Collimated, High-Energy Gamma Monitor	– m/	– m/	– m/	– m/	– m/	● y/	● y/	● w/	– s/	– s/
Collimated, Low-Energy Gamma Monitor	● y/	– b/	o u/	– s/	– s/	● y/	● y/	o u/	– s/	– s/

Key: ● Relevant as a fundamental method.
• Relevant as a supplemental method.
– Method not relevant/applicable.
o Method not feasible/practicable.

Table A-1 (Continued — Footnote Explanations)

a. Preliminary technical conclusion based on preliminary calculations performed by Los Alamos National Laboratory.

b. No HEU production is possible in this area.

c. Monitors could be mounted on building support columns between and above trains or on the overhead cranes.

d. Monitors could be mounted on process building walls at ends of trains as primary method or as a supplement to rooftop monitors.

e. Monitors could be installed at selected locations in the utility bays.

f. Preliminary technical conclusion based on limited experimental studies by UCC-ND.

g. The effectiveness of this method is questionable because of low signal-to-background count rates. Special ports in the cascade area roof or process building wall above the utility bay roof would be required to minimize the attenuation of the U-235 gamma rays.

h. The gamma monitor array is designed to preferentially detect the low-energy U-235 gamma rays or uranium x-rays and this would not be applicable to the detection of higher energy gammas from the U-238 daughters in natural or low-enriched uranium.

i. Preliminary technical conclusion based on limited experimental results by Los Alamos National Laboratory and UCC-ND.

j. Train product headers are accessible from the 2nd floor level of the utility bays.

k. No cascade pipes are accessible from this location.

ℓ. Pipe monitor is not applicable to detecting accumulations of uranium.

m. The collimated, high-energy gamma detector, is designed to detect primarily the 767 and 1001 keV gamma rays from the U-238 daughter $Pa-234^m$ and not the low-energy (<200 keV) gamma rays from U-235 and is thus not applicable to the direct detection of U-235.

n. Monitors could be installed near the floor at the ends of the trains or between trains.

(continued)

Table A-1 (Continued — Footnote Explanations)

o. The relatively high penetrability of the U-238 daughter gamma rays should permit the detection of abnormal uranium accumulations with detectors on the rooftop or in wall ports.

p. Preliminary technical conclusion based on a preliminary Los Alamos National Laboratory evaluation of a UCC-ND experiment.

q. Remote verification can include (1) continuous remote monitoring of encoded background signal, (2) remote monitoring of array response to external stimuli such as routine movements of UF cylinders at the F/W Building or special low-level source movements on the exterior of the building, and (3) continuous monitoring of tamper-indicating sensors enclosed in the detector package.

r. Monitors could be mounted on building support columns between and above trains or on the overhead crane. Remote verification could make use of the methods listed in Footnote q above. In addition, viewing of the monitors with CCTV or film cameras should be feasible from outside the process building through special ports in the end walls of the building.

s. This implementation approach is not required on the outside of the process building.

t. Remote verification does not appear feasible for a monitor that is only sensitive to radiation originating from a small volume such as a cascade pipe.

u. Because the collimated gamma monitors are not used as members of an array, remote verification would be more difficult than in the case of neutron or gamma area monitors. Thus, this approach was judged to be impracticable.

v. For arrays of neutron or gamma monitors in the cascade area or in utility bays, remote verification of proper installation and maintenance by the facility of a credible safeguards system is not considered feasible.

w. See Footnote r. Remote viewing could be used in the crane bay to verify correct installation of detector packages provided by the Inspectorate.

x. Remote verification of the proper installation of a pipe monitor is not feasible. See also Footnote t.

y. For collimated gamma monitors in the cascade area or in utility bays, location verification devices will be required for remote verification of proper installation and maintenance by the facility of safeguards system.

Table A-2
(Table 6 in Section 5)

APPLICABILITY OF PORTABLE RADIATION MONITORS TO PROCESS BUILDING INSPECTION FOR TWO IMPLEMENTATION APPROACHES

	Confirmation Purpose									
	No Possible Presence of Highly Enriched Uranium					Completeness and Correctness of U Inventories				
Implementation Approach	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports	Cascade	Utility Bays	Crane Bays	Building Roof	Wall Ports
P1. Inspectorate direct use.										
Monitor Types										
Gamma Monitor for Centrifuges	● a/	– b/	● c/	– d/	– d/	• e/	– d/	• e/	– d/	– d/
Gamma Monitor for Cascade Pipes	● f/	• g/	– d/	– d/	– d/	– h/	– h/	– d/	– d/	– d/
Gamma Monitor for Area Measurements	● i/	– b/	● i/	x k/	● ℓ/	– m/	– m/	– m/	– m/	– m/
Neutron Monitor for Area Measurements	● n/	– b/	x o/	x k/	x o/	● i/	● i/	x o/	x o/	x o/
Collimated, High-Energy Gamma Monitor	– p/	– p/	– p/	– p/	– p/	● q/	● q/	● r/	● s/	● s/
Collimated, Low-Energy Gamma Monitor	● t/	– b/	● t/	• u/	● ℓ/	● t/	● t/	● r/	● u/	● ℓ/
UF_6 Trap Monitor	– v/	• v/	– v/	– v/	– v/	– v/	– w/	– v/	– v/	– v/
P2. Inspectorate remote verification; facility use of sealed monitors.										
Monitor Types										
Gamma Monitor for Centrifuges	o x/	– b/	o x/	– d/	– d/	o x/	– d/	o x/	– d/	– d/
Gamma Monitor for Cascade Pipes	o x/	o x/	– d/	– d/	– d/	– h/	– h/	– d/	– d/	– d/
Gamma Monitor for Area Measurements	o y/	– b/	● z/	– aa/	– aa/	– m/	– m/	– m/	– m/	– m/
Neutron Monitor for Area Measurements	o y/	– b/	x o/	– aa/	– aa/	o y/	o y/	x o/	– aa/	– aa/
Collimated, High-Energy Gamma Monitor	– p/	– p/	– p/	– p/	– p/	● bb/	● bb/	● cc/	– aa/	– aa/
Collimated, Low-Energy Gamma Monitor	● bb/	– b/	● cc/	– aa/	– aa/	● bb/	● bb/	● cc/	– aa/	– aa/
UF_6 Trap Monitor	– v/	o x/	– v/	– v/	– v/	– v/	– w/	– v/	– v/	– v/

Key:
- ● Relevant as a fundamental method.
- • Relevant as a supplemental method.
- – Method not relevant/applicable.
- o Method not feasible/practicable.
- x Method not effective.

Table A-2 (Continued — Footnote Explanations)

a. Preliminary technical conclusion based on preliminary experimental/calculational studies performed by UCC-ND.

b. No HEU production is possible in this area.

c. Gamma monitor could be positioned on centrifuges with special handling equipment operated for the inspector from the overhead crane. The inspector would be on the crane bridge during measurements.

d. There is no access to centrifuges or cascade pipes from this area.

e. This approach is relevant only if it is assumed that dummy centrifuges might be used as covert uranium storage locations.

f. Preliminary technical conclusion based on limited experimental studies performed by Los Alamos National Laboratory and UCC-ND.

g. Train product headers may be accessible from the second level of the utility bays.

h. Pipe monitor is not applicable to detecting accumulations of uranium.

i. Preliminary technical conclusion based on limited experimental/calculational studies performed by Los Alamos National Laboratory and UCC-ND.

j. Monitors would be used from the crane bridge or carriage. Effectiveness and practicability are questionable due to low count rates.

k. A portable gamma or neutron area monitor will not be effective on the building roof because the low count rates at roof height require a fixed array of detectors in order to interpret the signals. Also, counting times may be too long for a practicable portable system.

ℓ. It may be feasible to use portable gamma monitors to measure U-235 gamma rays through ports in the walls of the process building above the utility bays. Low count rates may make this method impracticable for portable monitors.

m. The gamma area monitor is designed to preferentially detect the low-energy U-235 gamma rays or uranium x-rays and thus would not be applicable to the detection of higher energy gammas from the U-238 daughters in natural or low-enriched uranium.

n. Preliminary technical conclusion based on limited calculational studies performed by LASL.

o. Inability to easily focus or collimate neutron detector will make it ineffective at this location. The signal-to-background ratio will be too low for interpretation with a portable detector.

p. The collimated, high-energy gamma detector is designed to detect primarily the 767 and 1001 keV gamma rays from the U-238 daughter Pa-234^{m} and not the low-energy (<200 keV) gamma rays from U-235 and is thus not applicable to the direct detection of U-235.

(continued)

Table A-2 (Continued — Footnote Explanations)

q. Technical conclusion based on a preliminary Los Alamos National Laboratory evaluation of a UCC-ND experiment.

r. Monitors would be used from the crane bridges or carriages.

s. The relatively high penetrability of the U-238 daughter gamma rays should permit detection of abnormal uranium accumulations with detector on the rooftop or in wall ports.

t. Preliminary technical conclusion based on a preliminary Los Alamos National Laboratory evaluation of a UCC-ND experiment.

u. The effectiveness of this method is questionable because of low signal-to-background count rates. Special ports in the cascade area roof or process building wall above the utility bay roof would be required to minimize the attenuation of the U-235 gamma rays.

v. All uranium traps are in the utility bays.

w. Trap monitor is designed for HEU detection only.

x. To verify this method when used by the facility requires that the location of measurements is verified and that the proper use of the instrument is verified for each measurement. No feasible approach to achieving both of these requirements has been identified.

y. To verify the proper use of this measurement only requires that the approximate location (within a few meters) of each measurement be verified. One approach has been identified that does not require access (see Section 4.3); however, the practicability of this approach is questionable and thus it is not considered feasible.

z. Monitors would be used from the crane by facility personnel. Verification measures that would be feasible but complicated include (1) direct or CCTV viewing of the measurements from ports in the walls at the ends of each crane bay, (2) a method of remotely measuring the location of the crane as a function of time, (3) a tamper-indicating monitor with internal recording of measurement and tamper-indicating signals as a function of time, (4) a method to assure that additional shielding was not placed around the sensor during measurements. The effectiveness may be limited due to low counting rates in this location.

aa. This implementation approach is not required on the outside of the process building.

bb. For collimated gamma monitors in the cascade area or in utility bays, locator boxes will be required for remote verification of proper use by the facility of a safeguards system.

cc. This monitor would be used as described in Footnote z. Counting rate should not be a limiting factor for this monitor.