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CONTAINMENT/SURVEILLANCE CONCEPTS FOR INTERNATIONAL SAFEGUARDS IN REPROCESSING PLANTS

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ABSTRACT

This paper examines the potential role of advanced containment/surveillance instrumentation systems for international safeguards in reprocessing plants. Several conceptual systems for the surveillance of containment boundary penetrations in a reference reprocessing plant are described and evaluated. The results of the evaluation aid in understanding the potential capabilities and limitations of containment/surveillance as an international safeguards concept in this type of facility.

INTRODUCTION

International safeguards measures for large-scale spent fuel reprocessing plants may include conventional materials accountancy, near-real time materials accountancy, and containment/surveillance, including process monitoring. In an effort to assess the feasibility of safeguards system designs to provide timely indication of diversion of nuclear material from reprocessing plants, the Office of Safeguards and Security of the U. S. Department of Energy has tasked Sandia National Laboratories and Los Alamos National Scientific Laboratory to jointly develop concepts for international safeguards of reprocessing plants. These safeguards concepts are based upon combinations of these containment/surveillance and materials accountancy techniques. Containment/surveillance concepts have been developed in a study by Sandia[1] in order to provide a basis for understanding the capabilities and limitations of containment/surveillance and to more clearly define the role of containment/surveillance in reprocessing plant safeguards.

One approach to the provision of safeguards through the use of containment/surveillance is based upon the enclosure of nuclear material within containment boundaries and the application of surveillance devices to detect possible movement of nuclear material through penetrations of the containment boundaries. Material movement could occur through penetrations associated with normal process streams or through penetrations which have no normal nuclear material flow. Movements of material along normal process streams would be detected to provide assurance that these movements are known to the materials accountancy system. The detection of material movement through other penetrations provides assurance that inventory changes occur only through the penetrations associated with normal process streams.

DEFINITION OF CONCEPTUAL CONTAINMENT/SURVEILLANCE SYSTEMS

A reference large-scale reprocessing/conversion plant was chosen which included the existing Allied General Nuclear Services' Barnwell Nuclear Fuels Plant and a conceptual conversion facility design developed by Savannah River Laboratory. Two containment boundaries were studied in the reference plant. The inner or primary containment boundary is composed of the biological shielding of the process cells, cabinets, and gloveboxes. Six distinct areas (spent fuel storage area, chemical separations area, plutonium nitrate storage area, plutonium conversion process area, plutonium oxide storage area, and the analytical laboratory), called primary containment zones, were found to exist within the primary containment boundaries of the reference plant. The building outer walls, roof, and floor provide the outer or secondary containment boundary. All penetrations of these boundaries were identified.

Appropriate containment/surveillance measures were identified for each penetration. These measures fall into five general classes:

- Seals
- Material Presence Indicators
- Containment Modification
- Item Surveillance
- Sample Surveillance

Seals are applied to containment penetrations in such a way that access to material requires a seal to be broken. Material presence indicators such as portal or pipe radiation monitors are instruments designed to signal the presence of material in a penetration. Containment modification refers to minor additions or changes to the containment boundaries which allow presence indicators or seals to provide surveillance of multiple penetrations or penetrations that would otherwise require special surveillance devices. Item surveillance systems for

detecting the movement of items were proposed for the spent fuel and plutonium product storage areas, and sample surveillance concepts were identified for the laboratory and sample transfer areas.

The entire spectrum of development is spanned by the proposed instrumentation. Some of the devices which have been identified are already in use for international safeguards. In some cases, prototype instruments have been developed specifically for international safeguards. Other surveillance concepts incorporate proven technology which could be adapted to international safeguards needs. Finally, some concepts are described for surveillance instruments which have not yet been developed.

In the process of identifying penetrations it becomes apparent that not all penetrations are equally suitable for diversion. For some penetrations, the difficulty of the tasks required in order to accomplish diversion raises the question of whether diversion through those penetrations is credible. In this study, a set of criteria were defined and used to evaluate and categorize the relative credibility of diversion through each penetration. A penetration was placed into one of the following four groups, depending on the operational impact of activities associated with diversion through that penetration:

1) Diversion would require no significant deviation from the normal plant operating configuration.

2) Diversion would require significant deviation from the normal plant operating configuration.

3) Diversion would require more significant and potentially disruptive changes in the plant operating configuration.

4) Diversion would require shutdown and decontamination of areas within the primary containment zone.

Although no absolute level of credibility was defined, conceptual C/S system designs were developed which address each of the four relative levels of credibility. A system designed for a particular level of credibility includes instrumentation on all penetrations through which diversion is considered to be credible under the criteria of that level of credibility. Thus, for systems with decreasing levels of credibility (labelled I, II, III, and IV), additional penetrations must be addressed by each system. The number of instrumented penetrations included in each system design for each primary containment zone is shown in Figure 1. System IV, with nearly 2200

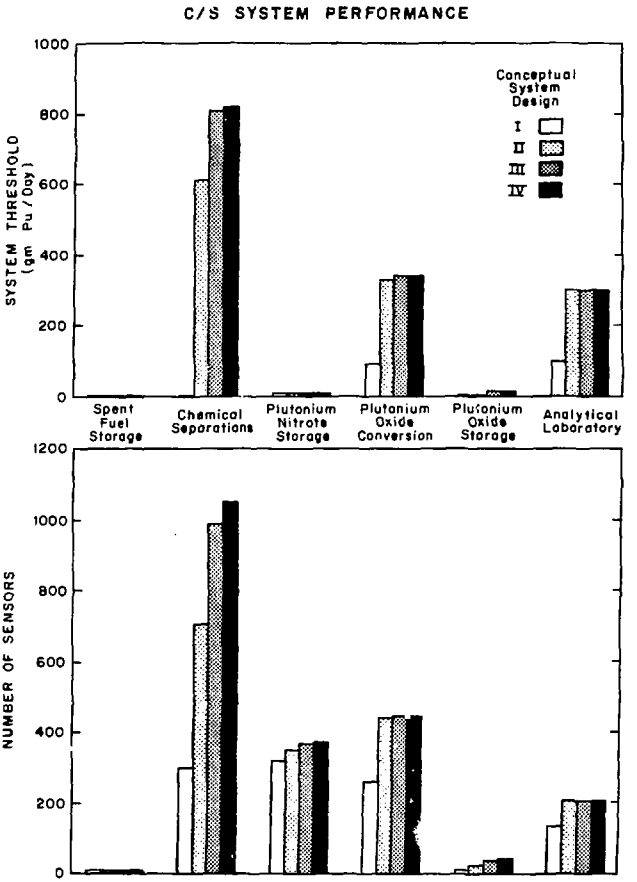
C/S SYSTEM PERFORMANCE
SYSTEM THRESHOLD (gm Pu / Day)
1000
800
600
400
200
0
Conceptual System Design
I
II
III
IV
Spent Fuel Storage
Chemical Separations
Plutonium Nitrate Storage
Plutonium Oxide Conversion
Plutonium Oxide Storage
Analytical Laboratory
NUMBER OF SENSORS
1200
1000
800
600
400
200
0

FIGURE 1

instrumented penetrations, has more than twice as many surveillance devices as System I which has over 1000 instrumented penetrations.

SYSTEM EVALUATION AND RESULTS

The potential performance of the conceptual containment/surveillance instrumentation systems was evaluated using a threshold approximation to describe instrumentation and systems sensitivity. A fundamental measure of effectiveness for both individual sensors and systems of sensors is the rate of nuclear material diversion that might take place without a high assurance of detection. For individual sensors, this measure is directly related to the threshold level of sensitivity of the sensors; it is the rate of diversion of nuclear material past a sensor that can occur without exceeding the threshold sensitivity of the sensor. For a system of sensors, a similar threshold may be easily calculated. This measure of effectiveness is referred to as a threshold rate (of diversion) and is the measure of effectiveness which is used to quantify system performance. The results of this analysis are shown in the upper portion of Figure 1. Threshold diversion rates for each of the six primary containment zones are shown.

In order to properly interpret these results, it is important that the effects of considering the various levels of credibility be understood. In designs II, III, and IV, the addition of penetrations associated with the various levels of credibility (II, III, and IV) means that more penetrations may credibly be used for diversion. It follows, then, that the performance of the various systems tends to be worse because additional sensors are required for the additional penetrations that must be addressed by those designs. The results for these systems indicate the relative success of C/S measures in addressing safeguards problems associated with the various levels of credibility.

One important feature of these results is that the containment/surveillance system instrumentation at the primary containment boundaries is more sensitive to diversion than the instrumentation at the secondary containment boundaries. Thus, the total system threshold is the sum of the thresholds for the primary containments, and it is the thresholds for the primary containments which limit the total undetected rate of diversion from the plant. The possibility of undetected diversion of nuclear material from the secondary containment is dominated by the number of expected exits by personnel through portals. With the large number of employees at the plant, potentially as much as 10kg/day could be diverted without detection.

A comparison of the results for the various primary containment zones indicates the potential effectiveness of containment/surveillance for the item handling areas -- spent fuel

and plutonium oxide storage -- where relatively few sensors are required and relatively low system thresholds are obtainable. In the process areas -- chemical separations and plutonium oxide conversion -- the large number of penetrations and the handling of plutonium in solution require many sensors and system thresholds are relatively high. In contrast for the plutonium nitrate storage area, in spite of the requirement for a fairly high number of sensors, a reasonably low system threshold may be achieved because of the types of penetrations and simplicity of operations in this area. In the analytical laboratory, little material is normally held, but the possibility exists for significant transfers of material to the laboratory in any given day. Containment/surveillance may be applied to this area with moderate success, but a fair number of sensors would be required.

POTENTIAL ROLE OF CONTAINMENT/SURVEILLANCE IN REPROCESSING PLANT SAFEGUARDS

The results of the evaluation of system performance indicate that surveillance of containment boundary penetrations is potentially an effective international safeguards measure in portions of large-scale reprocessing- conversion plants; however, the feasibility of plant-wide containment/surveillance systems of the size and scope described in this report is questionable. In particular, extensive systems of instruments could create unacceptable cost, and false alarm and reliability problems. These considerations suggest that it would not be practical to implement these containment/surveillance concepts throughout an unmodified, existing plant. The feasibility of implementing a system in a plant now being designed will depend on the success that the plant designers have in minimizing the numbers and types of penetrations through the containment boundaries.

The use of other safeguards measures could eliminate the need for portions of these extensive C/S systems. In a companion study by Los Alamos National Scientific Laboratory,[2] the effectiveness of conventional materials accounting systems augmented by near- real-time material accounting systems for the chemical separations and conversion facilities is considered. Since it is for these areas that containment/surveillance instrumentation requirements would be greatest, the use of near-real-time materials accounting as the primary safeguards measure for timely detection appears attractive.

Preliminary integrated safeguards concepts for a reprocessing plant (no Pu conversion facility) have been developed jointly with Los Alamos National Scientific Laboratory. The concept of surveillance of containment boundary penetrations would be applied in support of conventional accounting techniques in the spent fuel receiving and storage area and the plutonium nitrate storage area. These systems would provide

timely indications of unreported inventory changes in areas where timely inventory counts or measurements are impractical. Surveillance of containment boundaries would also be employed in the chop/leach area, where no effective accounting techniques exist, to provide a timely indication of potential diversion. Near-real time materials accountancy techniques would be applied to monitor in-process inventories in the chemical separations area, with the laboratory treated as part of the process material balance area. In addition, surveillance would be employed in the chemical separations area in order to detect the bypass of critical accounting measurements and to provide assurance that tampering with accounting measurements has not occurred. Process and operations monitoring concepts may be useful in accomplishing these tasks.

SUMMARY

The application of instruments in surveillance of containment boundary penetrations in a large scale spent fuel reprocessing/conversion plant has been studied to define the potential role of this containment surveillance technique in reprocessing plant safeguards. Four conceptual systems were defined based on different judgments of the credibility of diversions through containment boundary penetrations. These systems were evaluated using a threshold flow approach. The results suggest that penetration surveillance may be most effective in areas where timely inventory measurements are least practical, including the spent fuel, plutonium nitrate, and plutonium oxide storage areas. Safeguards concepts which integrate materials accountancy with containment/surveillance are now being developed jointly by Sandia and Los Alamos with the goal of identifying optimum combinations of materials accountancy and containment/surveillance for reprocessing plants.

REFERENCES

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