CONF-800655--17

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Paper for presentation
at the
1980 Annual Meeting of the Institute of Nuclear Materials Management
June 30 - July 2, 1980
Palm Beach, Florida

*Operated by Union Carbide Corporation for the U.S. Department of Energy.

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ABSTRACT

A viable approach has been developed for identifying those containment penetrations in a nuclear fuel reprocessing plant which are credible diversion routes. The approach is based upon systematic engineering and design analyses and is applied to each type of penetration to determine which penetrations could be utilized to divert nuclear material from a reprocessing facility. The approach is described and the results of an application are discussed. In addition, the concept of credibility is developed and discussed. For a typical reprocessing plant design, the number of penetrations determined to be credible without process or piping modifications was ∿ 16% of the penetrations originally identified.

Introduction

One of the safeguards concerns in a nuclear fuel reprocessing plant is ensuring that only authorized and declared flows of nuclear material cross defined containment boundaries. These containment boundaries have numerous penetrations that provide servicing and transfer capability for the chemical and operational functions of the plant. Each of these penetrations represents a possible diversion point for nuclear material. One approach to detecting a diversion is to monitor each penetration for the unauthorized or undeclared movement of material. However, due to the very large number of containment penetrations (i.e., over 2,000 in a typical commercial size reprocessing facility), the monitoring system required for full surveillance would result in a complex and costly design that may not be practical. A more practicable approach to monitoring for diversion involves determining which penetrations can be used to divert nuclear material at specified levels of effort following an evaluation of each penetration's engineering and design features. The result leads to a logical elimination of various types of penetrations as credible diversion paths, and results in a practical grouping of those credible penetrations for subsequent design and evaluation.

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*Research sponsored by the Nuclear Power Development Division, U.S. Department of Energy under contract W-7405-eng-26 with Union Carbide Corporation.

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Concept of Penetration Monitoring

To monitor penetrations in a reprocessing plant, containment boundaries must be selected to establish nested envelopes that contain all nuclear material from the time it is received as spent fuel through shipment of the product and off-site disposal of waste. With this concept of nested envelopes, a successful diversion of nuclear material requires the crossing of common or multiple containment boundaries. The multiple crossings alone result in an increase in the probability of detection. Once containment boundaries have been selected, the subsequent procedure involves identifying all penetrations of these containment boundaries to characterize and assess diversion possibilities. However, since penetrations in containment boundaries are designed for different functions, some penetrations are relatively more attractive for use in diverting nuclear material than are others. Consequently, for a specified level of effort (i.e. resources and expertise), each penetration can be examined from the perspective of engineering and technical features and/or limitations to judge its use in theft or diversion. Then when a safeguards designer considers what additional measures are available to detect diversion through the penetrations, the number of penetrations requiring direct monitoring can be reduced to a manageable quantity. However, in determining which penetrations are important to monitor it is necessary to identify which penetrations are credible diversion paths.

Crediblity Assessment

An assessment of the credibility of diverting through containment penetrations is important to safeguards system designers to provide maximum diversion detection capability at minimum cost and complexity. A practical approach to determining which penetrations are "credible" diversion routes (those through which diversion is believed to be possible and thus would require direct monitoring) requires the consideration of levels of effort necessary to accomplish the diversion. In addition, an evaluation of the engineering and technical limitations and the risk of detection provided by other safeguards measures is necessary to assess the credibility.[1,2,3] In this context, engineering and technical limitations include specific process equipment or plant design features which preclude the removal of nuclear material through a particular penetration.

To determine which penetrations require direct surveillance, each penetration must be examined initially to determine whether diversion is feasible or not through the given penetration. This concept is identified in Fig. 1. If diversion is possible at a specified level of effort, then the penetration being examined will be considered a "feasible" diversion path. For example, when a level of effort assumes that no changes in the normal operating configuration can occur, diversion will require modification of piping, pumps, etc. At this assumed level of effort the penetration is considered "non-feasible". The determination of which penetrations are feasible vs infeasible also requires the evaluation of engineering and technical features associated with the penetration (i.e. hydraulics, mechanics, piping, detailed component design, etc.).

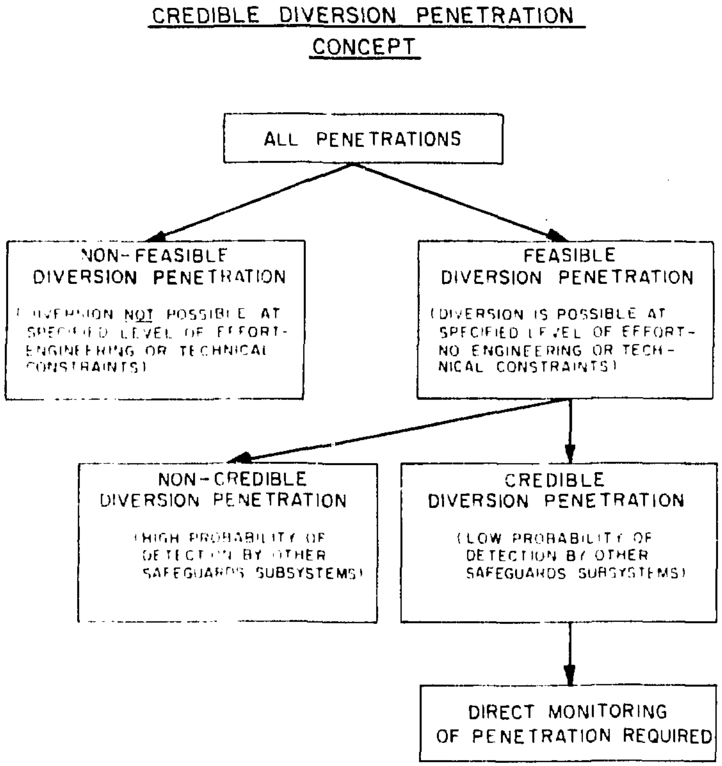

FIGURE 1

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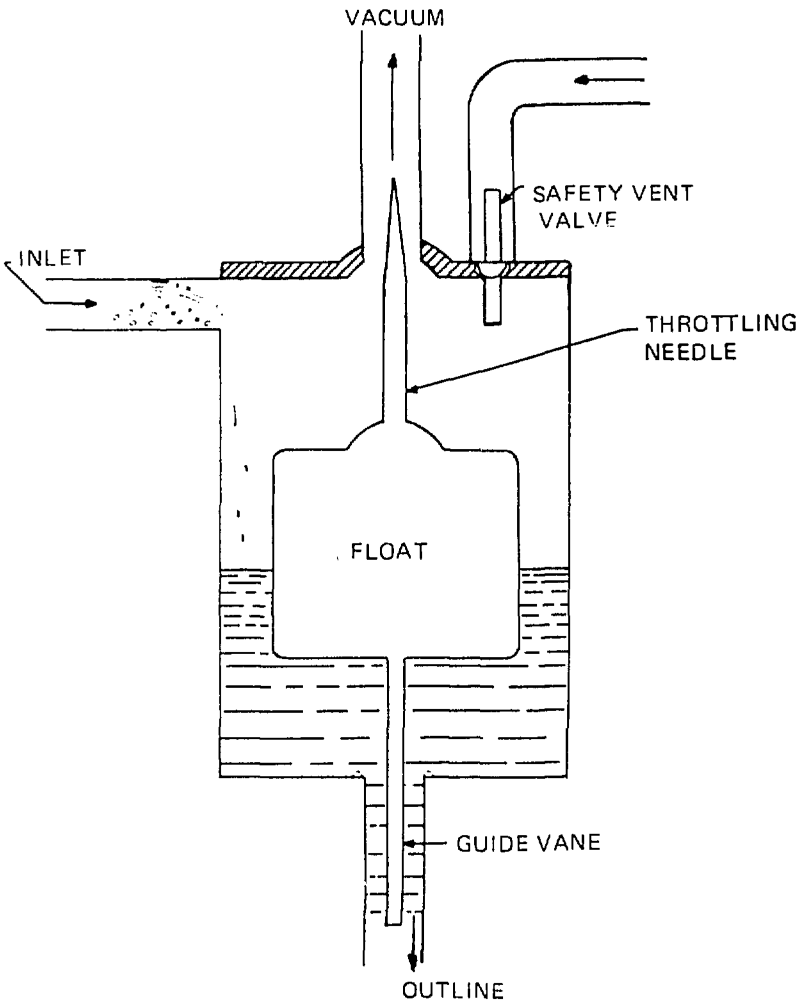

FIGURE 2: AIR SEPARATOR POT

When a subset of penetrations has been identified to be "feasible" diversion penetrations, an assessment must then be made on the risk of detection by additional safeguards measures. Principally in the case of penetration monitoring, this risk of detection could come from process monitoring or from the monitoring of plant operation and maintenance activities (i.e. "operations monitoring"). Therefore, if a high probability (i.e. risk is high) of detection by other safeguards measures exist for a set of penetrations, they can be considered "non-credible" diversion routes. The penetrations remaining would be considered "credible" diversion penetrations and as such will require direct monitoring to have a high assurance of diversion detection. Both the feasibility and credibility of a penetration type are directly dependent on the level of effort employed in the diversion attempt.

The remainder of the paper details the above mentioned procedures for identifying the penetrations in a reprocessing facility which require direct monitoring. In assessing individual penetrations as to the credibility of their use in diversion, the emphasis will be to evaluate the technical and engineering features rather than focus upon the detectability from other safeguards measures. Where applicable however, the consideration of risk of detection by other safeguards measures is included.

Containment Boundaries and Containment Penetrations

A representative containment boundary configuration for a reprocessing facility consists of a two level nested containment structure. The boundary of the innermost envelope (called the primary containment boundary) is comprised of the biological shielding surrounding the process area. The boundary of the outer envelope coincides with the outer structural walls of the process building. The primary containment area contains the process cells which house the process equipment and product storage areas, and the maintenance shops which service the process equipment. All nuclear material except during receipt (i.e. spent fuel assemblies) and during shipment (i.e. product or waste shipping casks) is located within these process cells. The secondary containment boundary has been selected such that it completely surrounds the primary containment area, thus minimizing direct access routes between the building exterior and the primary containment area.

Penetrations through the containment boundaries can be categorized as either service feedthroughs, service line penetrations, or transfer penetrations. The service feedthroughs furnish process liquids, gases, power, and instrumentation through the primary containment boundary as required by the in-cell equipment. Each line servicing the process equipment in-cell penetrates the cell wall individually. Approximately 95% of the containment boundary penetrations in a reprocessing facility consist of the primary containment utility line service feedthroughs.

The service line penetrations are located in the secondary containment boundary and provide pathways for on-site and off-site utilities servicing the various systems of the process building. These lines furnish electrical power, diesel fuel, water, air, steam, and process gases as well as remove exhaust, sewage, water, and condensate.

Transfer penetrations provide transfer pathways across both primary and secondary containment boundaries to satisfy the functional needs of the facility. Transfer penetrations include transfer hatches, gas locks, small equipment locks, bag-out ports, gravity tube ports, pneumatic transfer tubes, equipment doors, and personnel entry ways. Transfer penetrations provide transfer ways for fuel casks, product, waste drums, cold chemical canisters, equipment, tools, and personnel.

As discussed thus far, the approach to determining which penetrations are credible involves defining appropriate containment boundaries and identifying the penetrations through the containment boundaries. The next step involves assessing each individual penetration's usefulness in diversion. As was identified earlier, the relative credibility of diversion through specific penetrations depends upon the level of effort specified and the penetration's engineering or technical features.

Levels of Effort and Engineering/Technical Features

Four levels of effort for diversion through primary containment penetrations have been developed with Sandia Laboratories and are listed in Table 1.[4] Levels 1 and 2 restrict diversion attempts to efforts that do not rely on piping or transfer penetration modifications. Diversion scenarios under these categories include utilization of utility lines servicing nuclear material bearing vessels to siphon process material, or misoperation of the process to allow nuclear material transfer to areas where diversion through utility lines is probable. At these two assumed levels of effort, technical and engineering constraints cannot be challenged. For effort Levels 1 and 2, if diversion can be accomplished without piping or major process modifications, then diversion is "feasible" through the penetration being examined. For Levels 3 and 4, all in-cell handling equipment (i.e. remotely operated) is considered available for use in a diversion attempt. Under these conditions, engineering and technical constraints are no longer the limiting constraints, and all primary containment penetrations are considered feasible (i.e. susceptible) for use in diversion attempts. An example of a diversion scenario under these categories would be the conversion of an instrument air-line to an air lift which at Levels 1 and 2 would be deemed infeasible to diversion under normal conditions due to hydraulic limitations.

Levels of effort for diversion have also been developed for the penetrations through the secondary containment. Table 2 defines the two specified levels of effort that have been identified for the secondary containment boundary. Similar to the primary containment levels of effort, a Level 1 diversion is accomplished with no structural modifications of the facility. A Level 1 diversion scenario could involve the use

Table 1. Levels of Effort for Diversion through Primary Containment Boundary Penetrations

Level	Description to Accomplish Diversion
1	No significant changes from normal operating configuration.
2	Minor process modifications and/or unusual use of remote handling equipment.
3	Major process modifications and/or modifications of piping in remotely maintained areas.
4	Modification of piping in contact maintained areas.

Table 2. Levels of Effort for Diversion through Secondary Containment Boundary Penetrations

Level	Description to Accomplish Diversion
1	No significant changes from normal operating configuration.
2	Procedure or facility changes affecting normal plant operation.

of a door or sewer line to remove nuclear material from the process building. Diversion through either of these secondary containment boundary penetrations would have little or no effect on plant operations. A Level 2 diversion requires procedural or facility changes that would affect normal plant operation. Modifications for Level 2 diversions could occur either within or outside the building structure. Any type of equipment is considered available for use in modifications of these penetrations. An example of a Level 2 diversion would be the use of a water supply line to divert nuclear material from the building. This activity might involve radioactive contamination which would affect vital plant functions.

If the level of effort specified permits engineering and technical constraints to be binding, numerous primary containment penetrations can be eliminated from consideration as feasible diversion paths. The first of these technical constraints involve pipes which penetrate the top of process vessels but do not extend into the process solution. Examples of such lines would include recycle acid and cold chemical supply lines. Diversion through these lines requires that the tanks overflow and that nuclear material bearing solution reach these top lines. This situation can be prevented by ensuring that process vessels are designed with gravity overflow pipes. Overflowing a vessel of this design would require piping modifications to divert the material. Therefore, for Level 1 and Level 2 diversion scenarios, cold chemical and acid lines would not be considered feasible diversion paths.

A second technical constraint involves heat exchange lines. Heat exchange lines to individual process vessels are part of a closed loop system that do not directly contact the process solutions in the vessels. Piping modifications would be required to utilize these lines as diversion paths for nuclear material (assuming line failures are adequately prevented through periodic maintenance). Heat exchange lines to individual vessels include liquid cooling and heating lines as well as steam heating lines.

Another technical constraint that has been of use in assessing feasibility involves the sampling loops. A typical reprocessing plant sampling loop employs an air lift line to lift process liquids from the vessel to the level of a remotely operated needle block. An air jet then provides suction through a liquid-air separator pot to circulate the sample material through the needle block and back to the vessel being sampled. A float valve in the separator pot can prevent fluid reflux through the vacuum connection to the air jet (Fig. 2). This valve also prevents process material from being withdrawn by suction through the air-jet supply line. Thus, the air jet supply lines can be eliminated as potential diversion paths for Level 1 or 2 efforts.

A fourth technical constraint affecting feasibility is the elevation difference between the containment boundary penetration and the fluid level from which process liquid might be drawn. If the elevation difference exceeds the maximum suction lift height for the process material contained in the vessel, then even if the pipe extends into the process fluid, no material can be diverted through the containment penetration by applying suction. This assumes, however, the vessel is designed to prohibit pressurization and the lines are designed to prohibit conversion to an air lift.

Other Detection Measures

The risk of detection by other safeguards measures determines whether the set of feasible diversion paths are "credible" or not. The Reference Future Facility (RFF),[2] the reprocessing plant considered in this analysis is designed for remote maintenance of the process equipment. Many of the vessels associated with the process equipment, such as those involved in off-gas treatment, will never contain significant quantities of nuclear material under normal conditions. Thus the in-cell pipes which connect non-nuclear material bearing vessels to other process vessels can be monitored for nuclear material flow instead of monitoring containment boundary penetrations associated with the non-nuclear material bearing vessels. Such monitors on interconnecting lines would make it unnecessary to monitor individual penetrations servicing the normally non-nuclear material bearing vessels. For the RFF, monitors on 12 intervessel connections eliminate the need for individual penetration monitoring instruments on more than 900 primary containment penetrations.

Another safeguards system concept which can be of use in a reprocessing facility is the monitoring of maintenance operations (i.e. operations monitoring). In a remotely operated and maintained facility, sophisticated and versatile remote maintenance equipment must be installed in the process cells. Some system for monitoring this equipment will most likely be necessary to verify that maintenance equipment has not been used to remotely alter process piping for purposes of diversion. If an operations monitoring system is assumed effective, primary containment boundary penetrations requiring i.e. piping modifications in order to accomplish a diversion may be eliminated from consideration as credible diversion paths.

Results and Conclusions

The RFF as presented to the International Working Group on Reprocessing Plant Safeguards[2] contained 2,000 penetrations of the three types identified earlier, and was analyzed to determine which penetrations could be designated as being credible diversion paths. The analysis identified only 310 penetrations as being credible Level 1 and 2 diversion paths. That is, with the assumption that no piping or process modifications are feasible without detection, only 16% of the containment penetrations in the RFF require direct monitoring to have a high assurance of detecting diversion. Even if greater levels of effort for diversion are considered probable, this 84% reduction can be maintained provided operations and process monitoring are assumed to be effective safeguards measures.

In summary, by assessing the credibility of diverting nuclear material through the containment penetrations in a reprocessing facility, various types of penetrations can be eliminated as credible diversion paths for specified levels of effort. A penetration monitoring configuration can then be assigned to the group of credible penetrations with a subsequent evaluation of the detection capabilities of the monitoring system. By reducing the number of credible diversion paths, a safeguards system can be designed for a reprocessing plant to have maximum diversion detection capability at minimum cost and complexity.

Presently, this credibility analysis is being used to assist in the design of a penetration monitoring system for the Hot Experimental Facility (HEF), a pilot-scale experimental reprocessing facility being designed by the Consolidated Fuel Reprocessing Program at Oak Ridge National Laboratory. The analysis technique and approach will result in the identification of containment penetrations in the HEF that will require direct monitoring. Surveillance devices appropriate for the detection of nuclear material movement through these penetrations can then be assigned to the credible diversion paths. Finally, based upon the conceptual penetration monitoring system configuration, an evaluation will be conducted to determine the system's probability of detecting diversion. The technique used to evaluate the system performance was developed by Sandia Laboratories.[4] This evaluation involves correlating the sensitivity of individual monitors to the maximum concentration of nuclear material that could be withdrawn from each penetration. The evaluation, to be performed by Sandia during FY 1980, will be used to identify penetrations susceptible to mass quantity diversion. This could suggest either modifications to the facility design or the development of more sensitive penetration monitors.

In addition, this analysis has been used to define a penetration configuration for a reference facility to be analyzed by members of Subgroup 1 on Containment and Surveillance of the International Working Group on Reprocessing Plant Safeguards. The results of each analysis will then be compared to consider the relative merits of the various evaluation methodologies.

References

1. "Credibility Assessment," U.S. working paper submitted to Subgroup 1 on Containment and Surveillance, International Working Group on Reprocessing Plant Safeguards, March 1980.

2. D. W. Swindle, Jr., et al., "Conceptual Containment/Surveillance System Design for a Reference Future Facility," U.S. working paper prepared for Subgroup 1 on Containment/Surveillance, International Working Group on Reprocessing Plant Safeguards, March 1980.

3. J. Regneir, "Further Development of Criteria for Assessing the Credibility of Diversion through Specified Penetrations of Containment Boundaries," French working paper prepared for Subgroup 1 on Containment/Surveillance, International Working Group on Reprocessing Plant Safeguards, March 1980.

4. C. P. Cameron and M. E. Bleck, "A Containment/Surveillance System Evaluation Methodology," Sandia Laboratories, Albuquerque, New Mexico, September 1979.

5. J. T. Long, "Engineering for Nuclear Fuel Reprocessing," American Nuclear Society Monograph, 1978.

6. T. Shea et al., "Role of Containment and Surveillance in IAEA Safeguards," IAEA-SM-231/110, International Atomic Energy Agency. October 1978.

7. "Report on Advisory Group Meeting on Development of Containment/Surveillance Measures and Surveillance Instrumentation and Techniques for IAEA Safeguards," AG-190, International Atomic Energy Agency, June 1978.

8. J. W. Campbell and C. S. Johnson, "Containment and Surveillance Devices," IAEA-SM-231/63, International Symposium on Nuclear Material Safeguards, Vienna, Austria, October 2-6, 1978.

9. K. Nakajima et al., "Development and Demonstration of Safeguards Techniques in the Tokai Fuel Reprocessing Plant, IAEA-SM-231/34, International Symposium on Nuclear Material Safeguards, Vienna, Austria, October 2-6, 1978.

10. T. C. Piper, "Ultrasonic Liquid-in-Line Detectors: Development, Evaluation, and Implementation," ENICO-1014, Exxon Nuclear Idaho Company, Inc., October 1979.