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Methodology Development for The Evaluation of Proliferation Resistance

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1. Introduction

Nuclear fission reactors offer the possibility of meeting the world's energy needs for next generation. Further development of nuclear power will help to alleviate the environmental burden caused by other forms of energy production, particularly the burning of fossil fuels. Thus, nuclear energy can play an important role in meeting the expanding world energy demand. If nuclear systems are to make a major and sustainable contribution to world energy supply, future nuclear energy system must meet the specific requirements. One of the requirements is to satisfy the proliferation resistance condition in an entire nuclear system. Therefore, from the beginning of designing future nuclear system, it is important to consider the proliferation resistance to prevent the diversion of nuclear material. The misuse of nuclear system must be considered as well.

Historically, the study of proliferation resistance was initiated at INFCE (International Nuclear Fuel Cycle Examination) of IAEA and NASAP (Non-proliferation Alternative Systems Assessment Program) of DOE from 1970s. In 2000, the INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) program initiated by the IAEA proposed proliferation resistance (PR) as a key component of a future innovative nuclear system (INS) for fulfilling the energy needs in the 21st century along with a sustainability, economics, safety of nuclear installation and waste management[1]. The technical goal for Generation IV (Gen IV) nuclear energy systems (NESs) highlights Proliferation Resistance and Physical Protection (PR&PP), sustainability, safety, reliability and economics as well[2].

In this study, the evaluation procedure is introduced for the Korean methodology. In the methodology, the barriers and the pathway analysis for nuclear material are proposed. The evaluation parameters in each barrier are summarized. Fig. 1 shows the evaluation procedure for the Korean methodology. The assessment of PR is inherently qualitative and difficult to quantify the evaluation result. The Korean model will be revised as the study goes further.

1. Extrinsic Barrier

Extrinsic barriers are based on States' commitments and obligation and institutional arrangements related to nuclear energy systems. For States' commitments and obligation, there are several international treaties, convention and agreements[3]: for example, non-proliferation related treaties, nuclear weapon free zone treaties, export control. However, institutional arrangements consist of safeguards, access control and security, and location.

2. Intrinsic Barrier

The barriers are those qualities that make it more difficult to produce a nuclear explosive from a particular fissile or fertile material. Several factors from material itself influence on the use of nuclear material as an explosive, for example, critical mass, heat generation, spontaneous neutron generation and gamma emission[3,4]. Heat generation and radiation emission influence on the quality of weapon explosion. The barriers are divided into isotopic content, chemical, radiological, mass and bulk, heat generation, spontaneous neutron generation and detectability.

3. Safeguards Barrier

Safeguards apply facility information, nuclear material detection method, containment and surveillance, nuclear material accounting information, and inspection/in-field verification There are six indicators: accountability, amenability, detectability, difficulty to modify process, difficulty to modify facility design and detectability to misuse technology or facilities[3]. The "material unaccounted for" (MUF) is defined like below

$$MUF = (PB + X - Y) - PE$$

where PB is the beginning physical inventory, X is the sum of increases to inventory, Y is the sum of decreases from inventory, PE is the ending physical inventoryGenerally, for Pu and U233, 2~4 kg error has acceptance in the system. For U235 with high enrichment, 9~18 kg has acceptance limit[3].

The detectability of diversion of nuclear material can be enhanced by the installation of C/S measures and monitoring systems. The detectability of nuclear material is related to the easiness of identifying/recognizing the type and composition of nuclear material. The difficulty of modifying the process depends on the complexity of the modification, cost for the process modification, safety

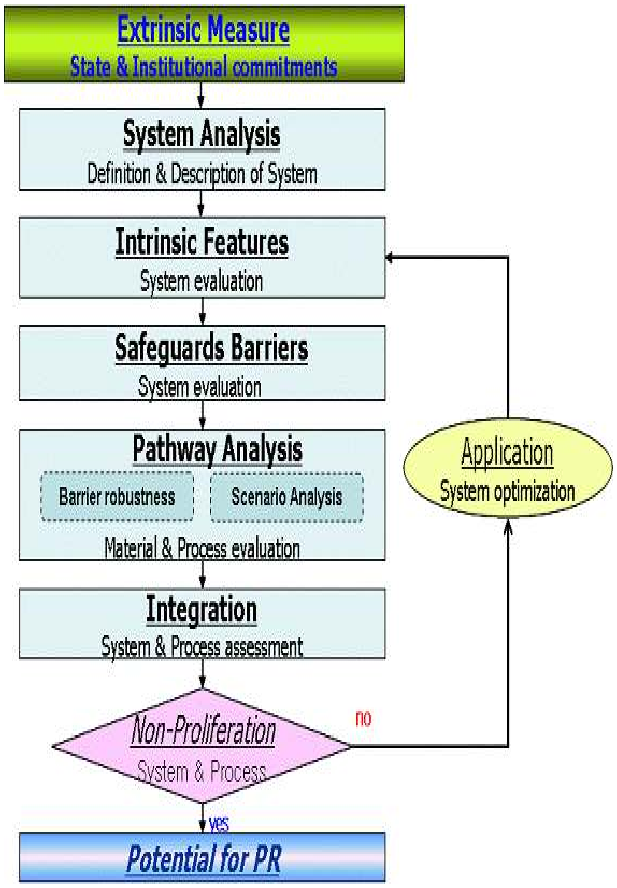

Fig. 1. Assessment procedure for the Korean model.

implication of such modification, and the time required to perform the relevant modification.

4. Pathway Analysis

Diversion pathway can be defined as a set of actions or tactics taken by the proliferator to divert nuclear weapons material. The systematic approach is suggested for the development of evaluation methodology, which is not the way of only using barrier itself but the way of combination of barriers and diversion pathway analysis for proliferation resistance.

Production of weapon material can be made directly in nuclear power plant, enrichment facility and reprocessing facility. Diversion of material can occur at a specific point in the material flow of nuclear system, for example, transportation, production facility and storage facility.
A nuclear energy system or a nuclear fuel cycle should be decomposed in order to describe proliferation actions in a given system element for the purpose of developing a set of proliferation diversion scenarios.

In reactor site, fuel storage site, fuel handling area, reactor irradiation report, spent fuel handling area, fuel pool storage area and dry storage area are the most important point for the pathway analysis. Once the pathway have been defined, the next step is the development of a representative list of options that might be available for implementing the events, conditions or tasks represented by each node.

The diversion of nuclear materials usually happens randomly and intentionally at the national or institutional level. From the analysis, relatively vulnerability points can be drawn in the material pathway of process to be needed to strengthen the robustness in resistance. Expert elicitation is basically helping to collect experts' subjective judgments on unknown or uncertain quantities and frequencies of the events.

5. Results and Conclusion

The conceptual design of methodology was setup for the evaluation of proliferation resistance as shown in figure 1. Several barriers are classified and the features are described for the evaluation of proliferation resistance. From the nuclear material pathway analysis, all feasible diversion scenarios are outlined for different systems and processes. The robustness is evaluated by the assessment of each scenario. PR analysis is intended to be performed from the earliest stages of the system design where initial flow diagrams and physical arrangement drawings are developed with safety analysis. The designer can introduce barriers that systematically make these pathways less attractive.

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