Methodologies and Properties of Safety Analyses for Pyroprocessing Facilities

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1. Introduction

KAERI is being developed pyroprocessing technology for a safe and an effective disposal of spent fuel. For the study and verification of this technology, it is necessary to develop the experimental facility with hot cells and auxiliary systems in the future [1]. In this paper, several safety analysis methodologies of Korea and the United States for the development of fuel cycle facilities are introduced, and the properties of the experimental pyroprocessing facility are practically analyzed using the associated safety analysis approaches.

2. Safety Analysis Methodologies

Safety analysis methodologies for a fuel cycle facility (including a pyroprocessing facility) are a traditional deterministic method (the Korean Nuclear Safety Act), an ISA method (the US NRC), a hybrid ISA-PSA method (developing by the US NRC) and a PSA method.

2.1 Korean Nuclear Safety Act (KNSA)

The Paragraph (3) of Korean Nuclear Safety Act article 35 requires that a person, who intends to carry on the spent fuel processing business, shall submit to the competent minister an application for the permit or the designation together with radiation environmental report, safety control regulations, explanatory statement of design and work methods, quality assurance program for the operation of the business and other documents as prescribed by the Ordinance of the Prime Minister. The Korean Nuclear Safety Act requires applicants to conduct a standard safety analysis methodology similar to that of nuclear power reactor, such as deterministic and defense-in-depth safety methodologies [2].

2.2 U.S. 10CFR70 (NUREG-1520, ISA)

NUREG-1520 provides U.S. NRC guidance for reviewing and evaluating the health, safety, and environmental protection aspects of applications for licenses to possess and use special nuclear material to produce nuclear reactor fuel. This guidance addresses the longstanding health, safety, and environmental-protection requirements of 10 CFR Part 20 and 10 CFR Part 70, as well as the accident safety requirements reflected in Subpart H, “Additional requirements for certain licensees authorized to possess a critical mass of special nuclear material,” of 10 CFR Part 70. Subpart H of 10 CFR Part 70 identifies risk-informed performance requirements and requires applicants and existing licensees to conduct an Integrated Safety Analysis (ISA) [3].

2.3 U.S. NRC SECY-0136 (an Enforced Risk Analysis and Hybrid ISA-PSA)

The NRC considers an ISA method required by 10 CFR Part 70 to be appropriate to address the types of hazards and accident sequences associated with existing fuel cycle facilities. However, the presence and processing of large quantities of fission products and TRU isotopes at reprocessing facilities have the potential to greatly increase consequences far above the 10 CFR Part 70 high-consequence thresholds for some accident sequences (e.g., fires, explosions), and, therefore, 10 CFR Part 70 is not appropriate for reprocessing facilities. The NRC concludes approaches that incorporate more quantitative risk assessment, including PRA, are needed to adequately address safety and risk at reprocessing facilities. The NRC is considering two basic approaches—a hybrid ISA-PRA approach and a PRA approach. The NRC considers the hybrid approach is a reasonable starting point at this preliminary stage of the NRC’s efforts in support of potential future rulemaking activities [4-6].

2.4 PSA

Recently NUREG/CR-7168 studied the possibility of using a PSA method for reprocessing facilities. This guidance concludes that the ISA approaches may identify potential weaknesses in a facility's design or operation for relatively simple nuclear fuel-cycle systems. However, since the approaches do not incorporate inter-system dependencies, nor provide an integrated assessment of risk, they could miss some essential risk outliers in more complex facilities. Varying degrees of PRAs for reprocessing facilities already have been carried out in several countries. Notwithstanding the limited data available for PRAs of this type of facilities compared to that for power reactors, the safety analyses of these facilities can benefit from the potential understanding gained by uncovering potential weaknesses in design and identifying dominant contributors to the risk of a plant or facility, such as human errors and dependencies [7].

3. Properties of Safety Analyses for Pyroprocessing Facilities

In Korea SF handling facilities are regulated as one of fuel cycle facilities under the Korean Nuclear Safety Act [2]. The act describes the safety requirements for the license and operation of fuel cycle facilities. Although the safety requirements for fuel cycle facilities show small differences compared to those of nuclear power plants, but a large parts of the requirements use the same technical criteria with nuclear power plants. The U.S. NRC is using an ISA safety analysis approaches and recently studied about an adaptability of a hybrid ISA-PSA [5,6] and a PSA to reprocessing facilities [7].

Table 1. Properties and ratings for each safety analysis methodology

Methodology / Property	KNSA	ISA (NUREG-1520)	Hybrid ISA-PSA (SECY-0136)	PSA (NUREG/CR-7168)
Simplicity	G	M	B	B
Safety Effectiveness to Pyro	M	G	G	G
Adaptability to Pyro	G	G	M	B
Event Analysis	B	M	M	G
Risk-Informed Performance	B	B	M	G
Necessity of Data (Fault & Likelyhood) for Pyro	B	M	M	G
Human errors and dependencies Analysis	B	M	M	G

G: Good, M: Medium good, B: Bad

For developing safer pyroprocessing facilities it is necessary to analyze the basic properties of these safety analysis methodologies. The table 1 shows some basic properties and ratings evaluated by authors for each safety analysis methodology.

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