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A Review of Safety Analysis Report Preparation Guidelines for Nuclear Fuel Cycle Facilities

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1. Introduction

Nuclear fuel processing business is regulated under the Nuclear Safety Act in Korea. According to Article 35 of the Nuclear Safety Act, a radiation environment report has to be submitted for designation application by a person who intends to engage in spent fuel processing business. The Nuclear Safety and Security Commission (NSSC) is currently preparing a bill to revise the designation system for nuclear fuel processing business to a licensing system and also require submission of a safety analysis report (SAR). However, the subordinate regulations (such as public notices) of the Nuclear Safety Act that deal with the preparation guidelines for safety analysis reports for spent fuel processing facilities have not been prepared, and it is urgent to establish them before the revised bill is enforced. This study investigated guidelines for the preparation of safety analysis report by reviewing two documents that the US- Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) issued for both regulatory staffs and licensees. The documents are saying that facility hazard categories has to be identified first and a series of detailed hazard analysis are performed to understand the risk of the hazards and finally hazard controls can be introduced to prevent and mitigate design basis accidents.

2. Nuclear Fuel Processing Business

The nuclear fuel processing business is subject to the provisions of Article 35 to 44 of the Nuclear Safety Act [1], Article 61 to 67 of the Enforcement Decree [2], and Articles 31 to 48 of the Enforcement Regulation [3]. The radiation environment report is one of the most important licensing documents for confirming the radiological safety of nuclear processing facilities at present. However, this is not necessary for integrated safety assessment. IAEA Integrated Regulatory Review Service (IRRS) [4] in 2014 recommended that the government and NSSC should develop the legal basis for the requirement of an integrated assessment for fuel cycle facilities, that includes chemical and industrial hazards and require an SAR as part of a license application.

3. Regulatory Basis in the US

In the US, safety analysis is a critical component of the regulatory framework for nuclear fuel cycle facilities, helping to ensure the safe and secure operation of these facilities while protecting public health and the environment. The US -NRC requires nuclear fuel cycle facilities perform safety analyses as part of their licensing process, and also requires that these analyses be updated and reviewed periodically throughout the facility's operation. The guidelines for NRC's SAR are well described in NUREG-1520 [5], and DOE also has a similar guideline with DOE-STD-3009 [6]. Both documents stress the importance of conducting safety analyses to identify and evaluate potential hazards and accident scenarios. Both documents also provide guidance on the use of risk assessments based on the likelihood and consequence of accidents. The most significant difference is their intended audience and the range of facilities they are applicable to. The DOE-STD-3009 is specifically intended for non-reactor facilities that are managed by the DOE and are subject to regulation under 10 CFR Part 830. This document is primarily aimed at applicants who are preparing SAR. Conversely, NUREG-1520 is designed to nuclear fuel cycle facilities that are regulated by 10 CRF Part 70, which pertains to the licensing of special nuclear material for domestic use. This covers facilities that are authorized to possess and use more than a critical mass of special nuclear material, or those that are seeking such authorization. In addition, NUREG-1520 provides information and guidance to assist the licensing staffs and the applicants in understanding the underlying objectives of the regulatory requirements and the licensing process.

4. Framework of Safety Analysis Report

This section summaries the safety basis content and format specified by DOE-STD-3009 and NUREG-1520. The first step in developing the safety basis for a fuel cycle facility is facility categorization [7]. Facility hazard categorization is necessary since the facility hazard category provides the regulatory basis for the amount of required accident analysis and selection of Safety Structures, Systems, and Components[1] (SSCs) and Technical Safety Requirements (TSRs). Hazard categorization is associated with the potential radiological hazards of a facility. The DOE-STD-3009 has a dose limit of 25 rem to the public and this guideline determines the strictness of safety controls.

Hazard and accident analysis, and control selection are addressed in SAR. This is the vital portion of the

[1] Safety SSCs are also commonly referred to as Items Relied on for Safety (IROFS) in the NRC term.

SAR because it identifies the safety class and safety significant SSCs as well as TSRs needed to protect the public and workers from radiological and chemical dose.

The result of hazards analysis includes a listing of events including their cause(s), qualitative estimates of event likelihood and consequences, preliminary identification of preventive and mitigative design features, and administrative controls. The estimation of likelihood category and consequence category is based on available data, operating experience, and/or engineering judgement. When there is significant uncertainty in the likelihood category or consequence category, a higher category is conservatively preferred. The risk is the combination of likelihood and consequence and commonly used to quantify the risk of accident sequences and identify acceptable and non-acceptable sequences as shown in Figure 1. When design basis events leads to consequences that go beyond an acceptable guidelines, the strategy for mitigation of consequences includes reduction of the available material at risk (MAR), passive safety SSCs, active safety SSCs, preventive administrative controls, and mitigative administrative controls. The control selection preference is influenced by the hierarchy as well as many factors including cost and operational impact.

Severity of consequence	Likelihood of Occurrence		
	Highly Unlikely(1)	Unlikely (2)	Not Unlikely(3)
High (3)	Acceptable Risk (3)	Unacceptable Risk (6)	Unacceptable Risk (9)
Intermediate (2)	Acceptable Risk (2)	Acceptable Risk (4)	Unacceptable Risk (6)
Low (1)	Acceptable Risk (1)	Acceptable Risk (2)	Acceptable Risk (3)

Fig. 1. Risk matrix with risk index values. The shaded blocks identify accidents for which the consequences and likelihood yield an unacceptable risk index and to which IROFS must be applied.

Following the hazard analysis, the accident analysis is performed to calculate dose consequence values for the bounding accident associated with each accident family (drop/impact, fire, criticality, non-radioactive material release, external events, and so on). When accident scenarios exceed the acceptable guidelines, controls must be selected and the accident analysis repeated with credit allocated to the selected controls to ensure the accident is prevented or sufficiently mitigated to ensure compliance with the dose evaluation guideline.

The safety or safety-significant SSCs identified are described to include the attributes, functional requirements and performance criteria. The specific administrative controls (SACs) are of sufficient importance that they are equivalent to safety SSCs and are thus described with safety SSCs. An example of SAC is an MAR limit.

Derivation of the TSRs is addressed in SAR. the process of preparing the TSR summary table leads to the identification of gaps in certain hazards mitigation strategies as well as helps guide the use of a mitigation strategy that addresses multiple hazards.

Prevention of inadvertent criticality is also addressed in SAR. For a high throughput Spent Fuel reprocessing or high-enriched fuel fabrication, criticality safety will be very high priority. The criticality safety program has to be approved by regulator but the criticality safety program documents can be satisfied by solely referring to the criticality safety program document approved by the regulator.

Safety management programs are also addressed in SAR to include radiation protection, fire protection, maintenance, procedures, training, conduct of operations, quality assurance, emergency preparedness and waste management.

5. Discussion

When considering regulations on Korea's nuclear facilities, we should take into account the following factors based on what can be inferred from the regulations in the US. Firstly, we urgently need to prepare not only laws, ordinances, and regulations, but also guidelines from the NSSC. A standard review plan like NUREG-1520 or an SAR preparation guidance like DOE-STD-3009 is urgently needed to minimize post-enforcement difficulties and resolve conflicts between businesses and regulators in advance.

We need a safety class-classification system to define so-called safety significant class. This class is not strictly classified as a safety class, but equivalent to a safety class in terms of safety controls for reactors. Concept of risk should be derived from both the consequence and likelihood of events, and based on this safety controls can be introduced to reduce the risk.

6. Conclusion

Korea's regulations on the fuel cycle facilities is not sufficient compared to international standard because it does not require SAR. Thus, the government is preparing the revision of the law to include SAR as a licensing document. However, the preparation of SAR for nuclear fuel processing business has not been started even though it is of great importance. From the investigation of the US documents related to SAR, we can get some insights. We need to do facility hazard identification, risk analysis based on likelihood and consequence, safety significant class identification, and introduction of safety controls to prevent and mitigate design basis accidents. It is also necessary to consider integrated safety analysis including not only radiological safety but also chemical safety etc., unlike in the case of nuclear reactors.

REFERENCES

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