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Safety Categorization and Design Consideration for Nonreactor nuclear facilities

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1. Introduction

In addition to research reactors, the Korea Atomic Energy Research Institute (KAERI) is conducting a variety of research related to the back-end nuclear cycle. As part of this, the KAERI has a number of nonreactor nuclear facilities such as nuclear fuel cycle facilities and radioactive waste treatment facilities, and utilized theses facilities to conduct various research projects such as pyroprocessing and waste reduction. Due to the increasing demand for research and the start of new research projects, the need to build new research facilities is also increasing. Nuclear facilities require more considerations in design and construction to ensure safe operation than other buildings. Various technical standards and guidelines have been developed and actively used to enhance safety at nuclear power plants with reactors, but nonreactor nuclear facilities, such as nuclear cycle facilities and waste treatment and disposal facilities, have many limitations compared to reactors.

In particular, due to the lack of clear guidelines related to safety classification, a lot of trial and error occurs to design and build these facilities. Therefore, this study analyzes the safety classification guidelines for nonreactor nuclear facilities and introduces various technical standards applicable to these facilities using references.

2. Safety Analysis and Classification for Nonreactor nuclear facilities

Various references have been developed for the safety evaluation of nonreactor nuclear facilities. In this study briefly introduces Integrated Safety Analysis (ISA) [1], which identifies Structures, Systems, Components (SSCs) performing safety functions through safety analysis, and ANSI/ANS-58.16 (Safety Categorization and Design Criteria for Nonreactor Nuclear Facilities) [2] which provides safety classification guideline that using the results.

ISA is a safety assessment technique that spans all aspects of a facility's processes, devices, structures, and worker activities. ISA improves facility safety by identifying all potential hazards with unacceptable consequence and identifying means to mitigate or prevent hazards. The results of an ISA typically provide the following information. (a) All information about the facility, including processes, equipment, facility structure, and work history (b) Identification of the hazards that are expected to occur in the facility and their scenario. (c) The expected consequence and likelihood of hazards. (d) The various hazard controls that could mitigate or prevent the hazard. (e) The means of verifying the reliability and availability of those controls.

ISA requires analysis across all disciplines of the facility (nuclear criticality, health physics, chemical hazards, and environmental safety), and the efforts of many people, including process engineer, facility designers, and others, not just the safety analysis team conducting the ISA. The evaluation flow is shown in Figure 1.

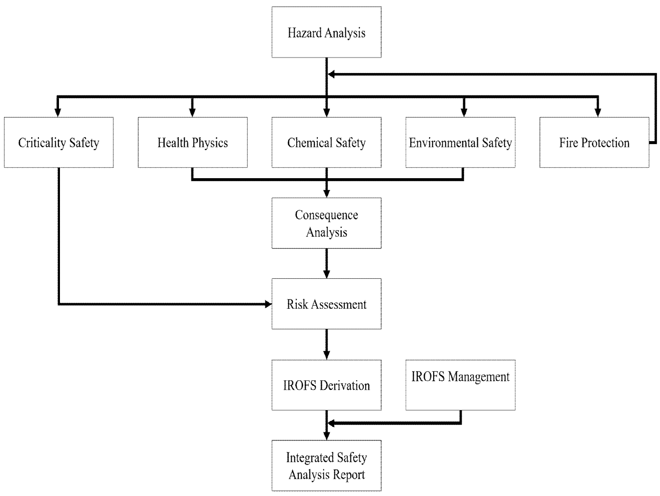

Fig. 1. Flow chart of ISA for nonreactor nuclear facilities

The accident scenario and results derived during the ISA can be used in the safety classification system of ANSI/ANS-58.16. That is, ANSI/ANS-58.16 identifies safety functions for the safety classification of safety-related SSCs and derives safety-related SSCs that perform specific safety functions. ANSI/ANS-58.16 provides quantitative or qualitative target values of the consequences of accident scenarios, and presents codes&standards suitable for the classification system. [2, 3] The quantitative consequence classification categories provided as examples in ANSI/ANS-58.16 are shown in the table below.

Table I: Safety categorization by consequence of accidents

Safety Category (SC)	Unmitigated Consequences		
	Facility Worker	Collocated Worker	Public
SC-1 (Low consequence)	Lesser radiological or chemical exposures to workers than those in SC-2 but above regulatory limits (workers will experience no permanent health effects)	Lesser radiological or chemical exposures to workers than those in SC-2 but above regulatory limits	Lesser radiological or chemical exposures to public than those in SC-2 but above regulatory limits
SC-2 (Intermediate consequence)	Dose > 1.0 Sv (100 rem) Toxic material concentration greater than AEGL-3/ERPG-3 or TEEL-3 levels	Dose > 1.0 Sv (100 rem) Toxic material concentration greater than AEGL-3/ERPG-3 or TEEL-3 levels	0.05 Sv (5 rem) < Dose < 0.25 Sv (25 rem) Toxic material concentration greater than AEGL-1/ERPG-1 or TEEL-1, but less than AEGL-2, ERPG-2, or TEEL-2 levels
SC-3 (High consequence)	If unmitigated consequence to workers exceed the SC-2 criteria by an order of magnitude or greater, more than one control should be provided at the SC-2 categorization level, or a control at the SC-3 categorization level should be considered	If unmitigated consequence to workers exceed the SC-2 criteria by an order of magnitude or greater, more than one control should be provided at the SC-2 categorization level, or a control at the SC-3 categorization level should be considered	Dose > 0.25 Sv (25 rem) Toxic material concentration greater than AEGL-2/ERPG-2 or TEEL-2 levels

3. Application case of Hot Cell Facility (HCF, US)

Hot Cell Facility (HCF) refers to a retrofit of an existing hot cell facility at Sandia National Laboratories (SNL) for the production and supply of medical isotopes needed in the United States (US), for which a Safety Analysis Report (SAR) [4] has been prepared and made publicly available in order to license to operate the facility. The published SAR do not formally state that ISA was ISA was used for the safety analysis by design, but the documentation format, flow, and results suggest that a similar methodology was used.

There are no safety class SSCs at the HCF because the safety analysis indicates that the radiation dose outside the facility would not exceed the criteria under all assumed accident scenario conditions, even without considering the safety-related SSCs of the mitigation. Nevertheless, considering safety-significant SSCs as a concept for defense-in-depth, the safety functions of SSCs are defined and functional requirements are established as shown in the table below.

Table II: Derived Safety-significant SSCs by Safety Analysis in HCF

Safety Function	SSC Performing Safety Function
Control of radioactive material releases	physical structures (walls and ceilings)
	Steel Confinement Boxes
	Ventilation exhaust systems (hot exhaust ducting, charcoal filters and plenums, and HEPA filters and plenums)
Protection of HCF personnel from potentially lethal radiation exposures	physical structures (concrete walls shield steel, shielding windows, ceiling, beam port shield plugs)
	Shield cask
	Hydraulic shield door controls
	Target Entrance System(TES) mechanical interlock

4. Conclusions

Unlike nuclear power plants, which have similar characteristics and purposes as described above, nonreactor nuclear facilities have a wide variety of design philosophies, forms, purposes, and functions. In consideration of these characteristics, overseas references are encouraging the gradual evaluation of the risk of harm in the facility by departing from the traditional deterministic safety evaluation method.

In particular, when designing nonreactor nuclear facilities, the design requirements and design criteria for major systems, structures, piping, utilities, etc., including the process equipment in the facility, can be established through sufficient discussions among researchers and engineers in the continuity of the design phase.

In other words, the applicability of many guidelines and codes&standards developed for nuclear power plants should not be applied or excluded at once, but rather the applicability of these codes&standards should be judged at the design stage by considering various factors such as design capability, safety assessment, construction capability, and manufacturing capability.

In addition, there is no safety classification system for nuclear fuel cycle facilities in domestic laws and regulatory guidelines. Therefore, it is expected that utilizing the classification criteria presented in ISA and ANSI/ANS-58.16 will help to establish a safety analysis methodology and classification system.

REFERENCES

[1] NUREG, Integrated Safety Analysis Guidance Document, NUREG-1513, 2001
[2] ANSI/ANS, Safety Categorization and Design Criteria for Nonreactor Nuclear Facilities, ANSI/ANS-58.16, 2014
[3] U.S. DOE, Facility Safety, DOE O 420.1C, 2012
[4] SNL, Hot Cell Facility (HCF) Safety Analysis Report, 200