A Study on the Application of Graded Approach in the Regulation of Nuclear Fuel Cycle Facilities in Korea

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Keywords: graded approach, safety classification, nuclear fuel cycle facilities, optimization, regulation revision

1. Introduction

In Articles 86 (location) to 102 (decommissioning of nuclear fuel cycle facilities) of the Regulations on Technical Standards for Reactor Facilities are applied to nuclear fuel cycle facilities in Korea. Accordingly, following to the classification system of reactor facilities, excessive regulations are applied even if there are no facilities, manufacturing process and components corresponding to safety class or the risk is low in the event of an accident.

There have been suggestions for improvement and related studies since about 20 years ago. The 157th Meeting of the Nuclear Safety and Security Commission (NSSC, '22.05.13) reconsidered the need to improve excessive regulations in accordance with the application of the reactor regulation related to the permission of Ara Research Building's nuclear fuel processing project of Korea Atomic Energy Research Institute (KAERI). Furthermore, NSSC recommended to establish safety grade classification standards and the standards for each grade in consideration of the characteristics of nuclear fuel cycle facilities, different from nuclear reactor facilities. Therefore, KINS aims to establish a definition classification system for safety functions of nuclear fuel cycle facilities within about two years from 2023 and to prepare standards for each safety level applied to structures, systems, and component, respectively.

For this, in this paper, the current status of regulations on nuclear fuel cycle facilities is studied, and cases of differential regulations in Korea and other countries are compared and investigated. Based on the results derived, the necessity of supplementing the safety regulations and research plans for graded approach will be devised. This can be used as basic data for promoting system for improvement operational and regulation efficiency of nonreactor nuclear facilities field.

2. Methods and Results

2.1 Current Regulation in Korea

Nuclear fuel cycle facilities in Korea are divided into refining facilities, processing facilities, conversion facilities, and spent nuclear fuel treatment facilities in accordance with Article 2 (Definitions) Subparagraph 15 of the Nuclear Safety Act. Facilities for refining, processing, and conversion nuclear raw materials or nuclear fuel materials and spent nuclear fuel treatment facilities shall comply with the technical standards prescribed in Article 36 of the Nuclear Safety Act and Chapter 3 of the Regulations on Technical Standards for Nuclear Fuel Cycle Facilities Article 86 to 102.

However, Chapter 3 of the Reactor Regulations does not clearly specify the classification requirements for facilities in nuclear fuel cycle facilities. Article 93 (Materials and Structures) requires only containers, pipes, pumps, valves, and the materials and structures of major structures supporting them to comply with the safety grade specifications stipulated in the NSSC Notice, but the corresponding NSSC Notice is absent.

None of the facilities of KAERI's fuel fabrication facilities for research reactor and Korea Electric Power Corporation Nuclear Fuel (KEPCO NF)'s reactor fuel fabrication facilities are classified into safety grades 1, 2, or 3 as stipulated in the NSSC Notice (2018-6, Regulations on Safety Classification and Specifications for Each Class of Reactor Facilities)

Fig. 1. Current status during operation and construction of major nuclear fuel cycle facilities in Korea. Data extracted from the 2023 KINS Nuclear Fuel Cycle Facility Workshop ('23.05.25). KAERI and KEPCO NF obtained permits and are building for new facilities for the first time in about 20 years.

Table I: KEPCO NF Fuel Processing Facility Classification

Installations	Safety Class	Seismic Category	Quality Class
Main-installation Building	N/A	II	A
Floor Structure of Cylinder Storage Area	N/A		
Sub-components Building	N/A	III	S
Measuring Station of Cylinder Storage Area	N/A		
Other Installations	N/A		

In the case of research reactor fuel fabrication facility, in the process of applying permission and evaluation, the safety classification (1 to 3, non-safety class) was graded as a technical basis for facilities subject to quality assurance. However, all related facilities are classified as non-safety class. Likewise, in the case of fuel fabrication facility for nuclear power plants, only seismic categories and quality classes are comprehensively applied as shown in Table I.

2.2 Graded Approach

In this study, graded approach is suggested as the concept that the level of analysis, verification, documentation, regulation, activities and procedures used to comply with a safety requirement, should be commensurate with the potential hazard associated with the facility without adversely affecting safety. International Atomic Energy Agency (IAEA) and some major countries operating overseas facilities such as the United States have established and applied their respective classes for nonreactor nuclear facilities.

Based on this concept, KINS intends to improve the regulation system in the direction of defining safety classes(functions) unique to Korea's facilities and establishing a safety class rating system. To serve as basic data and idea, this study identified Korea's regulatory and operational issues, discussed about the direction and process of the improvement, investigated and compared regulatory requirements, guidelines, and reports of IAEA, the United States Nuclear Regulatory Commission (NRC), American National Standards Institute (ANSI), and KINS.

2.3 IAEA

IAEA Specific Safety Requirements (SSR-4) for nuclear fuel cycle facilities partially cites General Safety Requirement (GSR) for each specific subject area. It is stipulated not by process or facility, by field as follows:

- Requirement 11: Use of a graded approach. It shall be commensurate with the potential risk of the facility and shall be based on safety analysis, expert judgement and regulatory requirements.
- Requirement 12: Proven engineering practices for the design. It shall be designed in accordance with the relevant national and international codes and standards.
- Requirement 13: Safety classification of items important to safety. It shall be identified and shall be classified on the basis of their safety function and their safety significance.
- Requirement 17: Design criteria and engineering design rules. Criteria corresponding to relevant physical parameters shall be specified for each operational state of the facility and for each design basis accident or equivalent. Engineering design rules shall be applied to provide for safety margins such that no significant consequences would occur even if the operational limits were exceeded within these margins.

On the other hand, Specific Safety Guides (SSG) are divided into general guidelines and each production processes or facilities, such as conversion, concentration, processing, reprocessing, and R&D as follows:

- SSG-5(2010), "Safety of Conversion Facilities and Uranium Enrichment Facilities"
- SSG-6(2010), "Safety of Uranium Fuel Fabrication Facilities"
- SSG-7(2010), "Safety of Uranium and Plutonium Mixed Oxide Fuel Fabrication Facilities"
- SSG-42(2017), "Safety of Nuclear Fuel Reprocessing Facilities"
- SSG-43(2017), "Safety of Nuclear Fuel Cycle Research and Development Facilities"

2.4 U.S. (NRC, ANSI)

The U.S. operate nuclear fuel cycle facilities include uranium conversion, enrichment/refining, and fabrication facilities. Laser enrichment/refining, gas centrifugation/refining, mixed oxide fuel fabrication, and other uranium conversion facilities are being approved and constructed. Their safety regulations are largely divided into facilities using special nuclear materials (SNM, 10 CFR Part 70) and facilities using source materials (10 CFR Part 40). Facilities using SNM include nuclear fuel fabrication and enrichment facilities, and facilities using source materials include uranium conversion and reconversion facilities.

In accordance with the U.S. NRC, the §70.62(a) 'safety program' and §70.62(d) 'Management measures' requirements stipulate and widely apply the use of graded approach with the reduction of potential risks attributable to that control or control system. This is based on IAEA requirements 11 presented earlier section. In addition, §70.61 (Performance requirements) (e) stipulates the availability and reliability of item relied on for safety (IROFS), which is the ultimate purpose of designation and classification, for each engineering or administrative control or control system required to comply with performance requirements.

Table II: NRC Safety Program

Elements	Requirements
Process safety information	Information pertaining to the hazards of the materials used or produced, technology, equipment in the process
Integrated safety analysis	Radiological, chemical, facility hazards and potential accident sequences, with adequate compensatory measures
Management measures	to ensure they are available and reliable to perform their function when needed, to comply with the performance requirements of § 70.61

Reg. Guide 3.14 presents guidelines related to seismic design classification for plutonium processing and fuel fabrication plants. Also, ANSI/ANS-58.16-2014(Safety Categorization and Design Criteria for Nonreactor Nuclear Facilities) presents industrial standards or codes corresponding to safety classification for structures, systems and equipment (SSCs) of nonreactor nuclear facilities, such as nuclear fuel fabrication, enrichment, radioactive material storage and treatment facilities, etc.

2.5 Research Reactors and the Other Nonreactor Nuclear Facilities

Furthermore, IAEA also presents the concept of graded approach regulation of research reactors through SSG-22(2023). It explains that the application of a graded approach is essential given the wide diversity among the regulated community of research reactors. Based on this, The U.S. NRC regulates 31 research reactors, some are located on federal government campuses, some are privately owned, but most are located at universities.

IAEA suggests to consider (1)the type of reactor, (2)the power level of the reactor, (3)the quantity and form of the special nuclear material possessed by the reactor, (4)the purpose and location of the reactor, and several more attributes:

- Hazard and potential impact (risks) associated with safety, health, and environment;
- Safety analysis and engineering judgement;
- Significance and complexity of each activity;
- Experiences of the staff involved;
- Possible consequences in case of failure;
- Maturity level of the technology and operating experience associated with the activities;
- And lifecycle stage of the facility.

Through IAEA TS-G-1.4(2008), the safety grade classification system of transport containers can also be referred to in three grades for each component.

- Grade 1: Critical. Directly affecting package leak tightness or shielding. Directly affecting geometry and criticality control, in packages of fissile material.
- Grade 2 : Major impact on safety. Failure could indirectly affect safety, in combination with a secondary event or failure. Example is impact absorber between primary and secondary containment systems.
- Grade 3 : Minor impact on safety. Affecting SSCs whose malfunction would not affect the effectiveness of the packaging and would be unlikely to affect safety. Examples include devices that indicate tampering e.g., security locks.

2.6 Process of Safety Classification

The process of establishing a foundation for graded approach can be referred to IAEA TECDOC-1787, ANSI/ANS 58.16. The APR-1400 Safety Classification process of KEPCO E&C, which recently succeeded in acquiring the European Utility Requirements (EUR) Assessment, is similar to them. The following processes can be benchmarked to implement grading, and to carry out evaluation and selection of standards and codes:

1. Understanding of plant and safety analysis
2. Identification of Functions & Design Provisions
3. Categorization of Function
4. Identifications & Classification of SSCs
5. Classification of Design Provisions
6. Verification of Classification
7. Selection of applicable engineering design rules

3. Conclusions

KINS is actively moving to improve regulation system of the nuclear fuel cycle facility by selecting "Research on the Application of Regulatory Requirements of Nuclear Reactor Facilities for Nuclear Fuel Cycle Facilities" as one of the fund projects in 2023. This institution will consult the opinions of operators or inspectors with a lot of experience in operating and responding to regulations so that they can reflect the actual issue and status.

In 2024, it is intended to conduct specific classification based on the above domestic and foreign regulations, guidelines, and additional research data. Additionally, in order to minimize confusion among existing facility operators, the use of the same term as the reactor facility will be avoided, and feedback is planned to be exchanged over a guidance period.

When the preparation of regulation with graded approach for the nuclear fuel cycle facilities is completed, the scope can be expanded to study and to utilize for regulation in Korea’s research reactors and other various nonreactor nuclear facilities that may be constructed in the future, which would have various manufacturing process, radioactive materials and function.

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