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Comparison on the IAEA Safety Requirements for Nuclear Fuel Fabrication Facility and the Requirements for Fuel Cycle Research and Development Facility

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1. Introduction

Domestic nuclear fuel cycle facilities can be categorized into three groups, according to the article 35 of the Nuclear Safety Act: refining facilities, fabrication facilities (including conversion process), and spent fuel processing facilities.

The status of nuclear fuel cycle facilities in Korea is as follows: (i) no refining facility, (ii) four nuclear fuel fabrication facilities (three are now operating and one is under review for its business permit), and (iii) one post irradiation examination facility (PIEF). Among three operating fuel fabrication facilities, two of them fabricate fuel assemblies for commercial reactors using UO_2 with low enriched uranium and one of them fabricates U_3Si-Al metal fuel for the research reactor, HANARO. The Figure 1 shows the typical fuel cycle process, and the shaded area in the figure means the facilities which have been operated in Korea.

Technical standards for nuclear fuel cycle facilities are described in the articles from the article 86 to the article 102 of "the Regulations on technical standards for nuclear reactor facilities etc." According to the article 86 (Location), the article 95 (Provisions Applicable Mutatis Mutandis), the article 100 (Provisions Applicable Mutatis Mutandis), and the article 102 (Decommissioning of the relevant nuclear fuel cycling facilities), most of provisions for nuclear reactor facilities are applied to nuclear fuel cycle facilities (see Table 1).

The safety of existing nuclear fuel cycle facilities in Korea have been guaranteed by applying substantial standards for nuclear reactor facilities because potential hazards of a nuclear fuel cycle facility is less serious than those of a nuclear reactor facility. However it is possible to be introduced various types of nuclear fuel cycle facilities in the future, so it is needed to prepare for standard development for nuclear fuel cycle facilities reflecting their design and operating characteristics. In this context, it might be meaningful to analyze IAEA safety requirements.

In this study, requirements in Appendix I "Requirements specific to uranium fuel fabrication facilities" and Appendix V "Requirements specific to fuel cycle research and development facilities" of IAEA Safety Requirements No. NS-R-5 (Rev.1), "Safety of nuclear fuel cycle facilities" [2] are compared to figure out different and/or stringent requirements for the fuel fabrication facility and for the fuel cycle research and development facility.

Although the NS-R-5 has been superseded by IAEA Specific Safety Requirements No. SSR-4 "Safety of nuclear fuel cycle facilities" [3], the NS-R-5 is used with the SSR-4 in this study. The reasons are as follows: (i) Most parts of the NS-R-5 are same in their technical content even though it have been revised to the SSR-4, and (ii) Requirements specific to each facility are separately provided in the appendix of NS-R-5, so it is much easier to figure out specific requirements of each facility.

Facilities subjected to this study are limited to the fuel fabrication facility and the fuel cycle research and development facility because they are existing facilities in Korea.

Table 1. Details of mutatis mutandis application in provisions for nuclear fuel cycle facilities [1]

Article No.	Provisions applicable mutatis mutandis
Article 86 (Location): Siting	Refer to Articles from 4 to 10: - 4. Geological Features and Earthquakes - 5. Limitation on Location - 6. Meteorological Conditions - 7. Hydrologic and oceanographic Conditions - 8. Impact of Man-Made Accident - 9. Feasibility of Emergency Plans - 10. Construction of Multi Units
Article 95 (Provisions Applicable Mutatis Mutandis): Design	Refer to Articles 13, 14, 34, and Subpar. 1 of Article 51: - 13. External Events Design Bases - 14. Protection against Fire Protection, etc. - 34. Radiation Protection Provisions - 51. Measures regarding Radiation Control Area, etc..
Article 100 (Provisions Applicable Mutatis Mutandis): Operation	Refer to Articles 51, 52, and from 64 to 66: - 51. Measures regarding Radiation Control Area, etc. - 52. Measures regarding Radiation Doses, etc. - 64. Transport at Place of Business - 65. Storage of Radioactive Materials, etc. at Place of Business - 66. Radioactive Waste Management Program
Articles 102 (Decommissioning of Nuclear Fuel Cycle Facility)	Refer to Articles 85-3 to 85-17 - 85-3. Organization and personnel in preparation in decommissioning - 85-4. Expenses and resources in preparation for decommissioning - 85-5. Strategies in preparation for decommissioning - 85-6. Actions for easy decommissioning - 85-7. Advance plan for decommissioning - 85-8. Decommissioning organization and personnel - 85-9. Decommissioning manual - 85-10. Decommissioning cost and resources - 85-11. Decommissioning strategies etc. - 85-12. Ensuring easy decommissioning - 85-13. Decommissioning safety assessment - 85-14. Protection from radiation during decommissioning - 85-15. Control of disassembly wastes etc. - 85-16. Assessment of impact of decommissioning on the environment - 85-17. Quality assurance of decommissioning

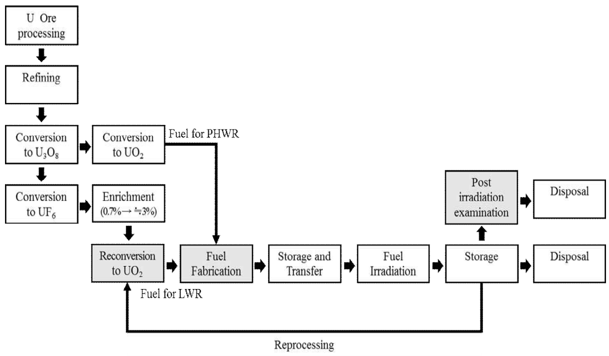

Fig. 1. Nuclear Fuel Cycle Process

2. Site Evaluation

In order to protect the public and the environment from the external hazards and the releasing impact of radiological and chemical materials, the following parameters are generally considered during site evaluation for nuclear fuel cycle facilities, and some of them should be monitored and controlled during life of the facility: geological characteristics, population distribution, methodological, hydrological and oceanographic conditions, man-made events, multi-units site and so on. Some of these parameters can be omitted if they do not have any significant effects on the safety of the nuclear fuel cycle facilities. The evaluation details (e.g. scope, method, acceptance criteria) can also be differentiated with applying the graded approach correspond to safety importance of each facility.

3. Design

3.1 Safety function

The design shall be such that the following main safety functions are met for all facility states of nuclear fuel cycle facilities: (i) Confinement and cooling of radioactive material and associated harmful materials, (ii) Protection against radiation exposure, and (iii) Maintaining sub-criticality of fissile material.

3.2 Engineering design

As with radioactive material, in the fuel fabrication facilities, protection against chemical hazards shall include the control of any route for chemicals into the workplace and to the environment.

In the fuel cycle research and development facilities, the design shall, as far as practicable, prevent hazardous concentrations of gases and other explosive or flammable materials, and consideration shall be given to the possible need for clean-up or recovery of radioactive material following an incident.

3.3 Criticality prevention

Common design requirements of criticality prevention for the fuel fabrication facilities and the fuel cycle research and development facilities are as follows: i) criticality safety shall be ensured by means of preventive measures, and ii) it shall be better to achieve criticality safety not by administrative measures but by engineering design.

For the fuel fabrication facilities, two specific requirements are added. One is maintaining several parameters (e.g. enrichment, mass, geometry, concentration, density and so on) within subcritical limit during normal operations and design basis accidents. The other is implementation of criticality safety assessment when the fissile material mass exceed a threshold. For the fuel cycle research and development facilities, the requirement about choice of fire extinguishing media (e.g. water, inert gas or powder) considering criticality is added.

3.4 Confinement of Radioactive Material

Means for the dynamic and/or static confinement of radioactive material and associated hazardous materials, as required by the safety analysis, to protect the personnel and the environment are commonly required in the design of nuclear fuel cycle facilities.

For the fuel cycle research and development facility, containment shall be the primary method for ensuring confinement against the spread of contamination. In addition, sampling devices, sample transfer methods, sample storage and the analytical laboratories shall be designed to keep exposures as low as reasonably achievable in the fuel cycle research and development facility.

3.5 Postulated initiating events

Postulated initiating events, including human induced events, that could affect safety shall be identified and their effects, both individually and in credible combinations, shall be evaluated. Postulated initiating events shall be identified on the basis of expert judgment, feedback from operating experience and deterministic assessment, complemented by probabilistic methods where appropriate.

Fires and explosions are commonly considered as the postulated initiating events for nuclear fuel cycle facilities. Moreover installing detection and suppression system is required commonly.

For the fabrication facility, the installation of automatic water spray shall be assessed for areas where uranium may be present, with account taken of the risk of criticality.

3.6 Instrumentation and control system

Instrumentation and control systems shall be provided for monitoring and control of all the process parameters that are necessary for safe operation in all operational states, commonly.

For the fuel fabrication facility, radiation and/or chemical release detector and/or alarms shall be installed in areas unless it can be demonstrated that criticality and/or chemical release is highly unlike to occur. In addition, detectors shall be installed in areas with a significant chemical hazard (e.g. due to UF_6, HF) and with limited occupancy, unless it can be demonstrated that a chemical release is highly unlikely. For the fuel cycle research and development facility, hot cells, glove boxes and hoods shall be equipped with instrumentation and control systems for fulfilling their requirements for static and dynamic confinement.

3.7 Radioactive waste and effluent management

The incorporation of provisions for radioactive waste management at the nuclear fuel cycle facility shall be considered at the design stage. The generation of radioactive waste shall be kept to the minimum practicable in terms of both activity and volume, by means of appropriate design measures. The predisposal management and disposal routes for waste shall be considered with the same aim of minimizing the overall impact on the workers, the public and the environment.

4. Commissioning

The commission requirements for the nuclear fuel fabrication facility are as follows: i) adequate commissioning program enough to demonstrate the facility meets the design objectives and the performance criteria shall be prepared and confirmed by regulatory body before the commissioning of the facility start, ii) the organization participating commissioning shall be composed with adequately qualified and trained people with clear identification of their responsibilities, iii) commissioning shall be divided into stages (depending on introduction of radioactive material and operation sequences), and all things specified in the commissioning program shall be checked at each stage, iv) the information about the commissioning shall be retained and reported in appropriate details.

The detailed items which have to be confirmed and/or demonstrated during commissioning and their acceptance levels are varied for each facility.

5. Operation

The operating organization of the nuclear fuel cycle facility, with enough number of personnel properly qualified and trained, shall have prime responsibility to guarantee safety of the nuclear fuel cycle facility during operation period. In addition, the operating organization shall establish an appropriate management structure for the facility and shall provide the necessary infrastructure for operations to be conducted safely.

5.1 Qualification and training of workers

Qualification and training of workers who deal with radioactive materials, firefighters and rescue staffs are required for the fuel fabrication facilities and the fuel cycle research and development facilities. For the fuel fabrication facility, qualification and training of workers for dealing with industrial hazard such as chemical release is additionally required.

5.2 Facility operation

Specific operational requirements for the fuel fabrication facility are as follows: (i) Manage fabrication process not to mix powders, pellets and rods of different enrichment, (ii) Minimize the number of events occurring in anticipated operational occurrences, non-routine operations and secondary operations such as decontamination, washing, preparation for maintenance or testing, through the attention to their prevention, (iii) Consider the impact of a fire on a solid UF_6 cylinder, and (iv) Pay attention to the confinement of uranium powders and the control of contamination of workplace.

For the fuel cycle research and development facility, it is required to develop and implement procedures to ensure that radioactive material received at the facility is appropriately characterized and is acceptable before it is allowed to be stored or used within the facility

5.3 Nuclear criticality safety

For the fuel fabrication facility and the fuel cycle research and development facility, only approved container shall be used when fissile material has to be removed from equipment.

For the fuel fabrication facility, the potential for the accidental transfer of two batches of fissile material instead of one (‘double batching’) shall be prevented, by means of administrative control measures.

The following requirements are specific to the fuel cycle research and development facility: (i) Collect waste and residue, which involve fissile material, in containers with a favorable geometry, and to record and store in dedicated criticality safe areas, and (ii) Pay attention to prevent unintentional mixing of chemicals which can increase criticality risk

5.4 Emergency planning and preparedness

For the fuel fabrication facility and the fuel cycle research and development facility, emergency arrangement shall be put in place for criticality accident, release of radioactive materials and chemical materials, and fires and explosions. It is also required for the both facilities that careful consideration should be paid to a fire fighting medium not to cause criticality hazard.

6. Decommissioning

The operating organization of the nuclear fuel cycle facility shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the facility, unless otherwise approved by the regulatory body, to show that decommissioning can be accomplished safely and in such a way as to meet the defined end state. In order to evaluate the safety of decommissioning of the fuel cycle facilities, the contamination effects on human health and environment due to decommission is required to be evaluated. For the fuel cycle research and development facility, special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry. In addition, criticality safety shall be ensured for the temporary storage of waste contaminated with fissile material, including plutonium that is generated from decommissioning, including the dismantling of glove boxes and their contents.

7. Conclusions

In this study, the safety requirements for the fuel fabrication facility and the fuel cycle research and development facility were compared.

Through comparison of the safety requirements for the nuclear fuel fabrication facility and the nuclear cycle research and development facility, it can be seen that most of the safety requirements are common but some are different. Most of the requirements are common because the nuclear fuel fabrication facility and the nuclear cycle research and development facility deal with radioactive materials in common. For the nuclear fuel fabrication facility, a large amount of UF_6 or UO_2 containing low enriched uranium 235 is treated in the process. The nuclear fuel cycle research and development facility deals with a variety of radioactive materials (e.g., uranium, other actinides and fission products, and activated materials in multiple physical forms such as powders, liquids and gases) with a small amount but high risk of radiation exposure. As a result, it is found that the major difference in some safety requirements reflects the nature of the potential risk due to the various physical characteristics and amounts of radioactive material treated depending on the operational purpose of each facility (see Table 2).

The results of this study is expected to contribute developing specific safety requirements for each nuclear fuel cycle facility in the future.

Table 2. Examples of the specific requirements reflecting the potential risk of the each facility

Facility	Specific requirements
Fuel fabrication facility	<u>3.3 Criticality prevention</u> ◦ Maintaining several parameters (mass, enrichment, geometry and so on) within subcritical limit during normal operations and design basis accidents ◦ Implementation of criticality safety assessment when the fissile material mass exceed a threshold <u>3.5 Postulated initiating events</u> ◦ Installing automatic water spray where uranium may present considering risk of criticality <u>5.2 Facility operation</u> ◦ Manage fabrication process not to mix items (powders, pellets and so on) having different enrichment, ◦ Pay attention to the confinement of uranium powders and the control of contamination of workplace. <u>5.3 Nuclear criticality safety</u> ◦ Preventing the potential for double batching by means of administrative control measures.
Fuel cycle research and development facility	<u>3.4 Confinement of Radioactive Material</u> ◦ Designing sampling devices, sample transfer methods, sample storage and the analytical laboratories to keep exposures as low as reasonably achievable <u>5.2 Facility operation</u> ◦ Developing and implementing procedures to ensure that radioactive material received at the facility is appropriately characterized and is acceptable before it is allowed to be stored or used within the facility <u>5.3 Nuclear criticality safety</u> ◦ Paying attention to prevent unintentional mixing of chemicals which can increase criticality risk

REFERENCES

[1] Regulations on Technical Standards for Radiation Safety Control, Etc., Nuclear Safety and Security Commission, Seoul, 2017.
[2] International Atomic Energy Agency, Safety of nuclear fuel cycle facilities, IAEA Safety standards series No.NR-R-5, IAEA, Vienna, 2014.
[3] International Atomic Energy Agency, Safety of nuclear fuel cycle facilities, IAEA Safety standards series No.SSR-4, IAEA, Vienna, 2017.