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Preliminary Conceptual Design for U-Zr Fuel Manufacturing Facility

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1. Introduction

Sodium-cooled fast reactors (SFRs) are under development as one of the most promising systems for electricity generation with an efficient utilization of uranium resources and a reduction in the generation of radioactive wastes [1-3]. According to the long-term SFR R&D plan authorized by the Korea Atomic Energy Commission (KAEC) in 2008, a Prototype Generation-IV Sodium Fast Reactor (PGSFR) will be constructed by 2028. In accordance with this project a U-Zr fuel fabrication facility (UFMF) which is obliged to provide PGSFR fuel is planning to apply for and acquire a license by 2018 and 2020 respectively. This facility also needs to complete the construction and commence operation by 2024.

As the first step to progress concerning the UFMF facility, KAERI has reviewed domestic and international regulations, codes, and standards of similar or related facilities to establish the design criteria for the UFMF. The UFMF facility includes the fuel slug fabrication process, sodium melting/bonding process, end-plug welding process, wire wrapping process, and fuel assembly process to manufacture the fuel for a PGSFR as a major function. It also needs to conduct cross-cutting functions such as safety management, quality management, confinement/release management, utility system, and safeguarding and physical security. In this study, the concept of the UFMF and the fuel manufacturing process are described. The design requirements for a major building of the UFMF are also derived by comparing and analyzing similar or related facilities.

2. Facility Concept of the UFMF

The UFMF should be designed in consideration of the economics, efficiency, safety, and safeguardability. The objective of safety is to protect workers, the public, and the environment from radiological and chemical risks. The main goal of safeguardability is to ensure that the facility satisfies the safeguard agreement between the Republic of Korea and IAEA.

The design characteristics of the UFMF are shown in Table 1. The annual processing capacity is about three tons on the basis of heavy metal and the facility is semi-independent in the nuclear science complex. The annual availability of the UFMF is 55% (200 days/year). U and Zr are the raw input materials and the fuel assembly is the output material provided to the PGSFR.

The major process in the UFMF is to manufacture fuel for a PGSFR, the process flow of which is shown in Fig. 1. A fuel rod consists of three fuel slugs, a cladding tube, and end-plug. The fuel slugs are contained in the cladding tube where sodium is charged in between. The fuel slug is made of U-10wt%Zr alloy with a length of 300 mm. A cladding tube with a diameter of 7.5 mm is fabricated using ferritic-martensitic steel. Sodium is covered up to the level of 25 mm higher than the upper end of the fuel slugs.

Table 1 Design characteristics of the UFMF

Capacity	Annual processing capacity : 3 tHM
Plant Type	Semi-independent facility in the Nuclear Science Complex
Input	U, Zr material
Output	U-Zr fuel assembly
Major Processes	Slug casting, Sodium melting/bonding, End-Plug welding, Wire-wrapping, Fuel assembly, Recycling process
Cross-Cutting Functions	Safety management, Safeguard and physical security, Quality management Utility system(compressed air, cooling water, HVAC, Instrumentation), etc.

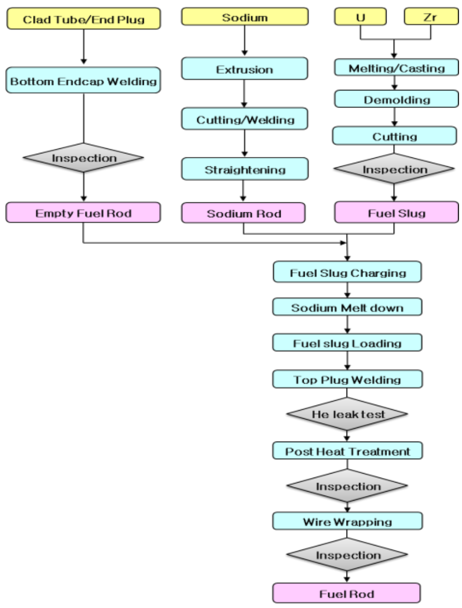


Fig. 1. Fabrication flow chart of fuel for a PGSFR

3. Design requirements of UFMF building

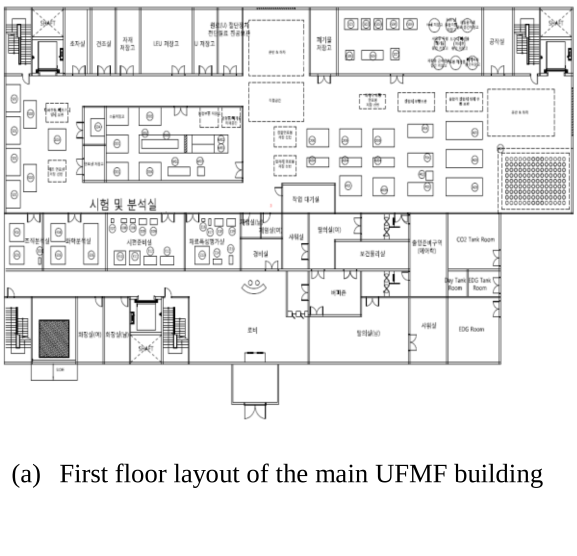
Figure 2 shows a preliminary conceptual layout of the first floor (Fig. 2(a)) and the basement (Fig. 2(b)) of the UFMF main building. The main building includes two truck bays for unloading and shipping materials or equipment, working areas, storages, test and analysis rooms, and facility operation rooms such as a machine room, electrical room, server room, and main control room. At the facility entry, the access control facility is installed with a change room for men and women, and health physics.

The radioactive waste arising from the UFMF consists of operation waste accrued from the fuel manufacturing process, job control waste accrued from the protective consumables of workers and decontaminated waste, and maintenance waste such as spent tools, spent equipment, and spent filters. Such waste should be collected and packed in the assigned containers, which are subject to relevant regulatory requirements.

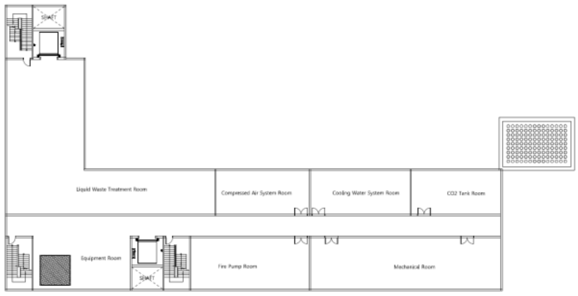
A radioactive waste liquid tank is installed in the basement, as shown in Figure 2(b). This should be built of corrosion resistant materials and be leak-tight. In case of any release causing the spread of contamination, the liquid tank also needs to be installed with a dike and sump. Waste is temporarily stored in the waste storage, and moved to a centralized waste management facility located at the same site.

The main building is divided into two areas, administered areas and non-administered areas. The administered areas should maintain an air flow from the higher contamination to less contaminated areas by adjusting the negative pressure. The access points of these two areas should be minimized as far as possible.

The UFMF building should provide safety functions to the workers against external loads and events, and radiation and other hazardous materials. This facility also needs to prevent hazardous materials from spreading to the outside.



(a) First floor layout of the main UFMF building



(b) Basement layout of the main UFMF building

Fig. 2. Preliminary conceptual design of the main UFMF building

4. Summary

The UFMF facility is obliged to supply fuel to a PGSFR, which will be operated in 2028. As the first step to progress, this report described the concept of the UFMF and the design requirements for a major building of the UFMF. This preliminary conceptual design will be upgraded to be more effective and feasible on an commercial basis during the subsequent design process.

5. References

[1] A Technology Roadmap for Generation IV Nuclear Energy Systems, Issued by the US DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum (2002) Available through the US Department of Energy.

[2] US Department of Energy Office of Nuclear Energy, Science and Technology (2003) The US Generation IV Implementation Strategy

[3] US Department of Energy, Press Release, Department of Energy Announces New Nuclear Initiative (2006)