# Evaluation of Applicability of LWR General Design Requirements to SFR

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## 1. Introduction

In Korea, design concepts of sodium-cooled fast reactors (SFRs) have been developed since 1997 by the Korea Atomic Energy Research Institute (KAERI). The 255th Atomic Energy Commission of Korea, held in Dec. of 2008, determined a long-term research and develop-ment plan for future nuclear systems including the SFR. According to the plan, it is scheduled to submit an application for licensing of an SFR demonstration reactor in 2017.

In order to prepare the licensing of the demonstration reactor, the general design requirements (GDRs) for the SFR should be established because they are used as rules in the safety evaluation of the design for the licensing by the regulatory body.

The current GDRs were developed based on the design of the LWR and enacted as the articles 12 to 49, including the article 2, in the “Regulations on Technical Standards for Nuclear Reactor Facilities, Etc” (hereafter referred to as “regulations on technical standards”), which is the Ordinance No. 1 of the Ministry of Edu-cation, Science, and Technology (see Table I).

In this paper, the applicability of the current GDRs for the LWR to the design of the SFR was evaluated as a part of activities to develop the GDRs for the SFR.

## 2. Design Characteristics of SFR

The design characteristics of the KALIMER-600, a demonstration burner reactor, were investigated, which is a sodium-cooled fast reactor being developed by the KAERI. Since the KALIMER-600 is a pool type of reactor, all the major components of the reactor coolant systems like reactor coolant pumps and primary heat exchangers are installed in the reactor vessel. The KALIMER-600 has such systems as reactor system, primary heat transport system, intermediate heat transport system, steam generation system, residual heat removal system, containment system, and etc. [1].

A ternary (U-TRU-Zr) metal fuel is used as a driver fuel. Each fuel assembly includes 271 fuel rods inside a hexagonal duct which channel reactor coolant flow. The core consists of 126 inner driver fuel assemblies, 198 outer driver fuel assemblies, 25 control rod assemblies, 75 reflector assemblies, 168 $B_4C$/radial shied assemblies, and 84 in-vessel storages. The reactivity control system consists of two independent systems and both systems adopt control rods. [2]

The reactor coolant temperature at the inlet and outlet of the core is 390℃ and 545℃, respectively. The pressure at the core is about 1atm. Since the melting point of the sodium is about 97℃, a sodium heating system is installed to prevent sodium solidification. Chemical reactions of sodium with air and water are so active that a closed intermediate cooling system is installed between primary cooling system and steam generation system, to minimize the potential releases of radioactive materials due to sodium leakages. Also, to avoid sodium reactions with the air, reactor vessel, intermediate cooling system, and steam generator are filled with inert cover gases. The decay heat produced at the core is removed by the primary cooling system, intermediate cooling system, and steam generation system in normal operations and anticipated operational occurrences (AOOs). During the postulated accident conditions, it is removed by the passive decay heat removal circuit system (PDRCS).

Table I: The current general design requirements

| Art. | Contents | Art. | Contents |
|---|---|---|---|
| 2 | Definitions | 31 | Ultimate Heat Sink |
| 12 | Safety Classes and Standards | 32 | Radioactive Processing & Storage Systems |
| 13 | External Events Design Bases | 33 | Fuel Handling & Storage Facilities |
| 14 | Fire Protection, etc. | 34 | Radiation Protection Provisions |
| 15 | Environmental Effects Design Bases, etc. | 35 | Reactor Core, etc. |
| 16 | Sharing of Facilities | 36 | Reactivity Control Material Drive Mechanism |
| 17 | Reactor Design | 37 | Overpressure Protection |
| 18 | Inherent Reactor Protection | 38 | Alarm Devices, etc. |
| 19 | Suppression of Reactor Power Oscillations | 39 | Prevention of Steep Slope Collapse |
| 20 | I&C System | 40 | Use of Qualified Equipment |
| 21 | Reactor Coolant Pressure Boundary | 41 | Testability/Inspectability/ Maintainability, etc |
| 22 | Reactor Cooling System, etc. | 42 | Design Bases Accidents |
| 23 | Reactor Containment, etc. | 43 | Protection during Startup, Shutdown, and Low Power Operations |
| 24 | Electric Power System | 44 | Reliability |
| 25 | Control Room, etc. | 45 | Human Factors |
| 26 | Protection System | 46 | Optimization of Radiation Protection |
| 27 | Diverse Protection System | 47 | Emergency Response Facilities and Equipment |
| 28 | Reactive Control System | 48 | Limiting Conditions for Operation |
| 29 | Residual Heat Removal System | 49 | Initial Tests |
| 30 | Emergency Core Cooling System | | |

## 3. Evaluation of Applicability of LWR GDRs to the SFR

For the development of GDRs for the SFR, it is necessary to evaluate the applicability of the LWR GDRs to the SFR, and identify (1) the requirements to be newly added due to the new systems adopted in the SFR, (2) the requirements to be modified due to the design differences between SFR and LWR, (3) the requirements not applicable to the SFR due to the design differences, and (4) the requirements applicable to the SFR as it is.

### *3.1 Requirements to Be Newly Added*

Since the SFR adopts new systems not installed in the LWR, new design requirements for such systems shall be added in the GDRs for the SFR to ensure the reactor safety. The sodium is used as coolants in the primary and intermediate cooling systems. A new requirement shall be added for the protection against the sodium reactions. Also, new requirements shall be added for sodium heating system, intermediate cooling system, and sodium & cover gas control systems. Fuel pin bundles of the SFR are located in a fuel assembly of a sealed duct type, reactor coolants flow into the fuel assembly through only the inlet port of the fuel assembly at the lower part. In order to assure core cooling, a new requirement shall be added to minimize a potential for flow blockage at the core assemblies. [3]

### *3.2 Requirements to Be Modified*

Since there exist design differences between SFR and LWR, some LWR requirements need to be modified considering such design differences. The total number of 13 requirements was identified as necessary to be modified and some requirements are discussed in the followings.

The SFR fuel handling facility operating at the reactor vessel has a leak-tightness function to prevent the sodium-air reaction during refueling activities. The components that are exposed to the reactor vessel cover gas or have a leak-tightness function shall be classified as a part of the reactor coolant pressure boundary. Therefore, the term “reactor coolant pressure boundary” defined in the article 2 shall be modified to include these components. Also, the term “specified acceptable fuel design limits (SAFDL)” shall be modified considering the damage mechanism of the metallic fuel used for the SFR.

Liquid reactivity control materials are not used in the SFR. The requirements for the liquid reactivity control system in the article 28 shall be replaced by those for the substituted reactivity control system. Especially, since the sodium void reactivity coefficient has a positive value, the requirement for one reactivity control system should be modified so as to have an independent and reliable capability that to cool the core is main- tained with appropriate margin for malfunctions such as a stuck-rod under conditions of normal operations, AOOs, and accident conditions.

The requirements for the residual heat removal systems specified in the article 29 and 30 were established based on the LWR that has two decay heat removal systems operating at low and high pressure conditions, respectively. However, since the SFR has low pressure conditions only, the article 29 and 30 should be combined into one article. And the requirements related to the oxidation and hydrogen generation in the fuel cladding in the article 30 shall be deleted because these can not be applied to the fuel of the SFR.

Besides the requirements discussed at the above, the requirements specified at the following articles shall be modified: article 22 (reactor cooling systems), article 24 (electric power system), article 25 (control room), article 31 (ultimate heat sink), article 33 (fuel handling & storage facilities), article 35 (reactor core), and article 36 (reactivity control material drive mechanism).

### *3.3 Requirements not Applicable*

The article 39 (prevention of collapse of steep slope, etc.) is related not to the design of nuclear reactor and its related facilities but to its site. Therefore, it is not applicable to the design of the SFR. Also, the article 30 (emergency core cooling system) will not be applicable anymore because the requirement will be incorporated into the article 29 (residual heat removal system).

## 4. Conclusions

For the preparation of the licensing of the SFR demonstration reactor, KALIMER-600, a study has been performed for the development of the general design requirements for the SFR. The design concept of the KALIMER-600 was investigated and the current general design requirements were evaluated for their applicability to the SFR. As a result, the followings were identified: 6 requirements shall be newly added; 13 current requirements shall be modified; 2 requirements are not applicable; and 18 requirements can be applied as it is. Based on the results, a draft of the general design requirements will be developed for the SFR in the future.

## REFERENCES

[1] Dohee Hahn et al., KALIMER-600 Conceptual Design Report, KAERI, KAERI/TR-3381/2007, p. 2-7, 2007.

[2] Young In Kim et al., Establishment of Advanced SFR Concepts, KAERI, KAERI/TR-4063/2010, p.99-101, 2010.

[3] U.S. NRC, Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor, NUREG-1368, p.3-58, 1994.