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Original Article

Safety Classification of Systems, Structures, and Components for Pool-Type Research Reactors

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ABSTRACT

Structures, systems, and components (SSCs) important to safety of nuclear facilities shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions. Although SSC classification guidelines for nuclear power plants have been well established and applied, those for research reactors have been only recently established by the International Atomic Energy Agency (IAEA). Korea has operated a pool-type research reactor (the High Flux Advanced Neutron Application Reactor) and has recently exported another pool-type reactor (Jordan Research and Training Reactor), which is being built in Jordan. Korea also has a plan to build one more pool-type reactor, the Kijang Research Reactor, in Kijang, Busan. The safety classification of SSCs for pool-type research reactors is proposed in this paper based on the IAEA methodology. The proposal recommends that the SSCs of pool-type research reactors be categorized and classified on basis of their safety functions and safety significance. Because the SSCs in pool-type research reactors are not the pressure-retaining components, codes and standards for design of the SSCs following the safety classification can be selected in a graded approach.

1. Introduction

The most important safety principle in a nuclear reactor facility is the reactor's ability to safely shut down and adequately cool following postulated accidents. To satisfy this principle, structures, systems, and components (SSCs) important to safety should be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to perform. The SSCs are classified according to their safety importance and/or significance using the appropriate classification guideline.

For nuclear power plants (NPPs), SSC classification guidelines have been well-established and applied [1–3]. The conventional SSC classification guideline has been based on the deterministic approach. The recent trend for the classification system is to determine the safety significance of SSCs based on deterministic methods as well as probabilistic methods [4,5] and to classify not only SSCs but also their parts [3]. In

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Korea, the SSC classification guideline has been also developed in accordance with American National Standards Institute standards [6].

For a research reactor, however, the minimum safety class guideline for SSCs was developed several decades ago [7] and was left as it is, probably due to the difficulties in establishing a generic guideline covering so many design features and power levels of the reactors. Among them, the most common design is the pool-type research reactor, in which the reactor is immersed in a large pool of water. The main design feature of the pool-type reactor is that the reactor is operating in an open and unpressurized pool. Considering the intrinsic design feature of the pool-type research reactor, the safety classification of SSCs should be differently determined from that used for power reactors. The International Atomic Energy Agency (IAEA) has been recently trying to establish safety standards and guidelines for research reactors [8,9]. Korea has already built a pool-type research reactor, High Flux Advanced Neutron Application Reactor (HANARO; 30 MWth). In addition to this, another pool-type reactor, Kijang Research Reactor (KJRR; approx. 20 MWth), is being built in Kijang, Korea. Therefore, it is time to establish an SSC classification system for pool-type research reactors in Korea.

2. Current status of safety classification for pool-type research reactors

Unlike power reactors, research reactors have various designs, wide range of maximum power levels, different purposes of utilization, etc. According to the BNL 50831-III design guide [7], research reactors can be categorized into several types as shown in Table 1. Among them, open pool-type reactor is a popular reactor because of easy accessibility to the reactor for experimental purposes. The reactor operates in an open and unpressurized pool, with cooling generally achieved by natural convection of light water.

The safety classification of SSCs is based on the facility's safety functions and the significance of the SSCs as in power reactors. The safety functions of a research reactor are as follows:

- Shutting down the reactor and maintaining a safe shutdown condition for all operational states or accident conditions;
- Providing adequate removal of heat from the core after shut down, including in an accident; and
- Containing radioactive material to minimize its release into the environment.

2.1. *Department of Energy guideline in the United States*

The Department of Energy (DOE) in the United States has already established a design guideline for pool-type research reactors [7]. The fundamental design philosophies for research reactors are similar to those applied to United States Nuclear Regulatory Commission (USNRC)-licensed power reactors. Both require the reactor to be capable of being able to safely shut down and adequately cooled following postulated accidents. In addition, the reactor facility is designed to provide a defense-in-depth against the uncontrolled release of radioactive materials into the environment. Because of the big difference between pool-type reactor and power reactor, however, it is possible to simplify the design of a research reactor while still adequately protecting public and environment. As a result, pool-type research reactors can be adopted to the reactor building (confinement concept), which does not control the release of radioactive material into the environment, unlike a containment generally utilized in power reactors.

The DOE guideline provides recommendations regarding the safety classification of SSCs as follows:

- The minimum safety classes are based on USNRC Regulatory Guideline 1.26 [2], "Quality Group Classifications and Standards for Water, Steam and Radioactive Waste Containing Components of Nuclear Power plants."
- Based on the accident analysis results, the final safety class should be determined. Alternatively, it may be necessary to increase the quality and reliability of the system by designing it to a higher than the minimum safety class.

For the pool-type research reactor, the DOE recommended the safety class of SSCs according to their safety importance as shown in Table 2. Note that there are no SSCs classified as SC-1, because of the characteristics of pool-type reactors (the reactor operates in an open and unpressurized pool).

Although the USNRC Regulatory Guideline 1.26 has been revised [2], the DOE guideline for research reactors has never

Table 1 – Research reactor categories [7].

Category	General reactor characteristics	
	Type	Subtype
I	Critical facilities	Solid fuel system Liquid fuel system Gaseous fuel system
II	Water-cooled reactor with a closed primary coolant system	Tank-type reactors Pressurized water reactors Water-cooled graphite reactors
III	Pool-type reactors	—
IV	Liquid-metal-cooled reactor	—
V	Transient reactors	Fast burst-type reactors Pulse type
VI	Air-cooled graphite reactors	—