Development of High-Level Safety Requirements for a Pyroprocessing Facility

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1. Introduction

One of the most important issues in Korea is the spent fuels (SFs) stored in nuclear power plants [1]. It is necessary to find a wide range of isolated area for a direct disposal or an interim storage of the SFs. However, a high population density in a relatively narrow land limits selecting an appropriate site for the SFs. Therefore, Korea Atomic Energy Research Institute (KAERI) has been developing a pyroproceesing technology to reduce the waste volume and recycle some elements [2]. The pyroprocessing includes several treatment processes which are related with not only radiological and physical but also chemical and electrochemical properties. Thus, it is of importance to establish safety design requirements considering all the aspects of those properties for a reliable pyroprocessing facility. In this study, high-level requirements are presented in terms of not only radiation protection, nuclear criticality, fire protection, and seismic safety but also confinement and chemical safety for the unique characteristics of a pyroprocessing facility [3].

2. Results

2.1 Radiation Protection Safety

Requirements of radiation protection toward facility workers and the public must be included in design safety requirements for a pyroprocessing facility.

Due to the fact that the main hot cell facility where pyroprocessing occurs is a facility which handles highly radioactive SF, a protective barrier should be installed to separate it from the surrounding work area using shielding material.

For the prevention of exceeding dose limits in nuclear workers, the facility must satisfy the clauses in the Nuclear Safety Act related to radiation protection and shielding technology on nuclear fuel cycle facilities as well as the Enforcement Decree and Enforcement Regulations of the same legislation. It must also comply with the base requirements in the Nuclear Safety and Security Commission Notification related to technology standards, regulations related to technology standards for radiation safety management, and regulations on technology standards for nuclear facilities.

In addition, it must satisfy the US NRC's radiation protection program on the radiological health and suitability of safety protection for workers in accordance with the regulation requirements in 10 CFR 19, 20, and 70.

2.2 Nuclear Criticality Safety

If nuclear materials reach critical mass while being handled in the pyroprocessing facility, large amounts of radiation will be released at one time leading to the exposure of the workers. In addition, it may release gaseous radioactive material due to the upsurge in temperatures or cause mechanical failures.

Since the pyroprocessing facility handles highly radioactive and thermal SF using high-temperature molten salts, special care must be taken into nuclear criticality safety in all processes from designing to operational management. Criticality must be prohibited in any case.

The nuclear criticality safety of the pyroprocessing facility must abide to the legal contents related to technology standards of nuclear criticality safety on nuclear fuel cycle facilities as stipulated in the domestic Nuclear Safety Law. In addition, it must include requirements related to nuclear criticality safety provided by the NRC of the US.

- Criticality accident alarm system
- The maintaining of all nuclear material handling processes in a subcritical state during normal conditions and certain abnormal conditions (application of the double-contingency principle)
- Criticality safety program

2.3 Fire Protection Safety

The facility handles SFs; therefore, unlike fires in conventional buildings or industrial facilities, fires within the facility do not only damage the building itself but leads to possible secondary hazards such as leakage of radioactive materials contaminating the external environment.

A defense-in-depth concept toward fire hazards and accompanying effects on items relied on for safety (IROFS) must be applied to the fire protection system of the pyroprocessing facility in order to prevent vital functions from being damaged from fires and to

minimize the risk of radiation being leaked into the environment.

Safety requirements that satisfy the related articles in the domestic Nuclear Safety Act must be set and they must satisfy the US NRC regulations on fire protection shown below.

- Alert of fire hazards in the facility
- Procedures to maintain the acceptable levels for fire safety
- Preparation of fast and safe countermeasures to extinguish fires
- Verification of safety requirements

2.4 Seismic Safety

The seismic safety requirements for the pyroprocessing facility, unlike conventional buildings, must be designed to be able to withstand strong earthquakes through the vibration analysis of the structure by calculating the maximum seismic value that may affect the building based upon earthquakes that have occurred in the past and fault lines near the site during the site survey phase. Moreover, they must be in line with domestic and US NRC nuclear safety standards related to seismicity.

2.5 Confinement Safety

There are hot cell facilities and related facilities using a high-level pyroprocessing process. Therefore, confinement safety is of utmost importance since it prevents leakage of high-level radioactive and toxic chemical materials.

The feed through which goes through the floor and walls of the hot cells must be operated as a confined structure capable of preventing beforehand accidents which can lead to radiation or toxic gas leaks during fires or cause gaseous radioactive materials from leaking outside during the process of processing SFs.

There should be means to measure the leakage rate of hot cells in order to verify their confinement safety.

2.6 Chemical Processing Safety

The chemical processes related to the pyroprocessing facility must satisfy the following safety requirements.

Explanation of chemical process: Explanations on the permitted materials verified through the integrated safety analysis, the chemical risk factors of the harmful chemical produced by them, and types of accident sequences must be provided.

Sequence of chemical accidents: The details of the accidents, including the chemical risks toward factory conditions which affect the safety of permitted chemicals or harmful chemicals which are produced from permitted, should be stated in the summary report on the integrated safety analysis.

Effect of chemical accidents: Whether it is due to permitted chemicals or the abnormal conditions of the facilities which can affect such chemicals, a valid assumption and suitable technology must be used to estimate the concentration of harmful chemicals that have been leaked.

The items relied on for safety (IROFS) toward chemical processing and the uniqueness of those criteria: During normal operations, the design requirements for chemical processing safety must be verified and the equipment and facility must prove that it is protecting the health and safety of the public as well as the environment.

The management method of chemical processing: When performing the safety functions of IROFS, a management method must be implemented to ensure the utility and reliability of the IROFS.

The requirements of new facilities at the existing facility or new process: Describe the design basis of new facilities or new processes on the application form. It must contain information related to chemical processing safety.

3. Conclusions

Several high-level safety design requirements such as radiation protection, nuclear criticality, fire protection, seismic, confinement, and chemical processing were presented for a pyroprocessing facility. The requirements must fulfill domestic and international safety technology standards for a nuclear facility. Furthermore, additional requirements should be considered for the unique electrochemical treatments in a pyroprocessing facility. Safety design requirements will be further developed for a designing process of the pyroprocessing facility.

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