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Technical Note

IDENTIFICATION OF SAFETY CONTROLS FOR ENGINEERING-SCALE PYROPROCESS FACILITY

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ABSTRACT

Pyroprocess technology has been considered as a fuel cycle option to solve the spent fuel accumulation problems in Korea. The Korea Atomic Energy Research Institute, Daejeon, Korea has been studying pyroprocess technology, and the conceptual design of an engineering-scale pyroprocess facility, called the Reference Engineering-scale Pyroprocess Facility, has been performed on the basis of a 10 ton heavy metal throughput per year. In this paper the concept of Reference Engineering-scale Pyroprocess Facility is introduced along with its safety requirements for the protection of facility workers, collocated workers, the off-site public, and the environment. For the identification of safety structures, systems, and components and/or administrative controls, the following activities were conducted: (1) identifying hazards associated with operations; (2) identifying potential events associated with these hazards; and (3) identifying the potential preventive and/or mitigative controls that reduce the risk associated with these accident events. This study will be used to perform a safety evaluation for accidents involving any of the hazards identified, and to establish safety design policies and propose a more definite safety design.

1. Introduction

Spent fuel (SF) is an inevitable byproduct of nuclear power generation. SF is highly radioactive waste which contains uranium, transuranic elements, and fission products. The direct disposal and interim storage of SF require wide and isolated areas, and thus it is not easy to find proper sites in Korea. Therefore, the development of an effective management or recycling technology for SF is essential to enhance nonproliferation and environmental friendliness.

In Korea, pyroprocess technology has been considered as a fuel cycle option to solve SF accumulation problems. Pyroprocessing is one of the key technologies used to recover actinide elements and long-lived fission products from the SF

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in LiCl or LiCl–KCl molten salt by an electro–chemical reaction. Korea Atomic Energy Research Institute, Daejeon, Korea has been developing a pyroprocess technology for the recycling of SFs. A hot cell facility for the demonstration of an electrolytic reduction process, named Advanced SF Conditioning Process Facility, was developed in 2005 [1,2]. PyRoprocess Integrated inactive DEmonstration facility (PRIDE) was developed in 2012. In this facility, a full pyroprocess flow can be tested and its integrated performance will be verified [3,4]. In PRIDE, depleted uranium is used for the process, and the maximum throughput is 10 tHM (ton heavy metal) per year. As the next stage of PRIDE, Engineering-Scale Pyroprocess Facility (ESPF), having radiation shielding capability to deal with SFs and the same SF treatment capability as PRIDE, was planned by 2016 but the plan was canceled. Instead of ESPF, a conceptual design of Reference Engineering-scale Pyroprocess Facility (REPF), of which design requirement was the same as ESPF's, was performed as a reference facility to be used for development of pyroprocess technology.

Idaho National Laboratory (Idaho Falls, ID, USA) conducted a conceptual design of an Advanced Fuel Cycle Facility and accident analyses for it to support the development of advanced technologies related to safeguards and security, instrumentation, process control, and integration, and to provide data on the reliability and scale-up for full-scale separations and fuel fabrication facilities [5–8]. In addition, Japan Nuclear Cycle Development Institute (Ibaraki, Japan) have proposed concepts for safety systems in pyrochemical reprocessing systems and performed safety evaluations [9].

In this paper, the concept of REPF was introduced, and a hazard evaluation was performed for identification of its safety structures, systems, and components (SSCs) and specific administrative controls (SACs).

2. Facility overview

REPF for the pyroprocess demonstration consists of: (1) processing equipment; (2) a hot cell facility and a building structure to shield and isolate the process equipment; (3) hot cell remote operation equipment for safety operation and maintenance; (4) an argon system to control the inert atmosphere of a process cell; (5) a utility supply facility; (6) material receipt and storage areas for SF; and (7) a waste treatment area and a shipping facility.

The main process involves the disassembly and rod cutting of SF assemblies, chopping and decladding, voloxidation, electrolytic-reduction, electro-refining, electro-winning, salt purification and recovery, waste form fabrication, off-gas treatment, and so on. Fig. 1 shows a flow diagram of REPF.

2.1. Design requirements

REPF can process a maximum of 10 tHM/yr of pressurized water reactor (PWR) fuel. The other top-tier requirements such as the operation rate, product and waste storage facility, reference SF, facility design life, and so on, are given in Table 1.

The safety class, seismic class, and quality class of the SSCs of a nuclear facility are classified according to their functions. The safety class is a criterion that should be applied to design the SSCs for PWR plants, and the classification criteria are presented in ANSI51.1 (nuclear safety criteria for the design of stationary PWR plants). In the case of REPF, there are no SSCs considered as safety classes 1 and 2. A hot cell structure and other SSCs requiring an equivalent structural integrity with the hot cell are classified in safety class 3, which can be assigned to the SSCs of which a loss of function can cause the radiological dose limit at the site boundary to be exceeded. In

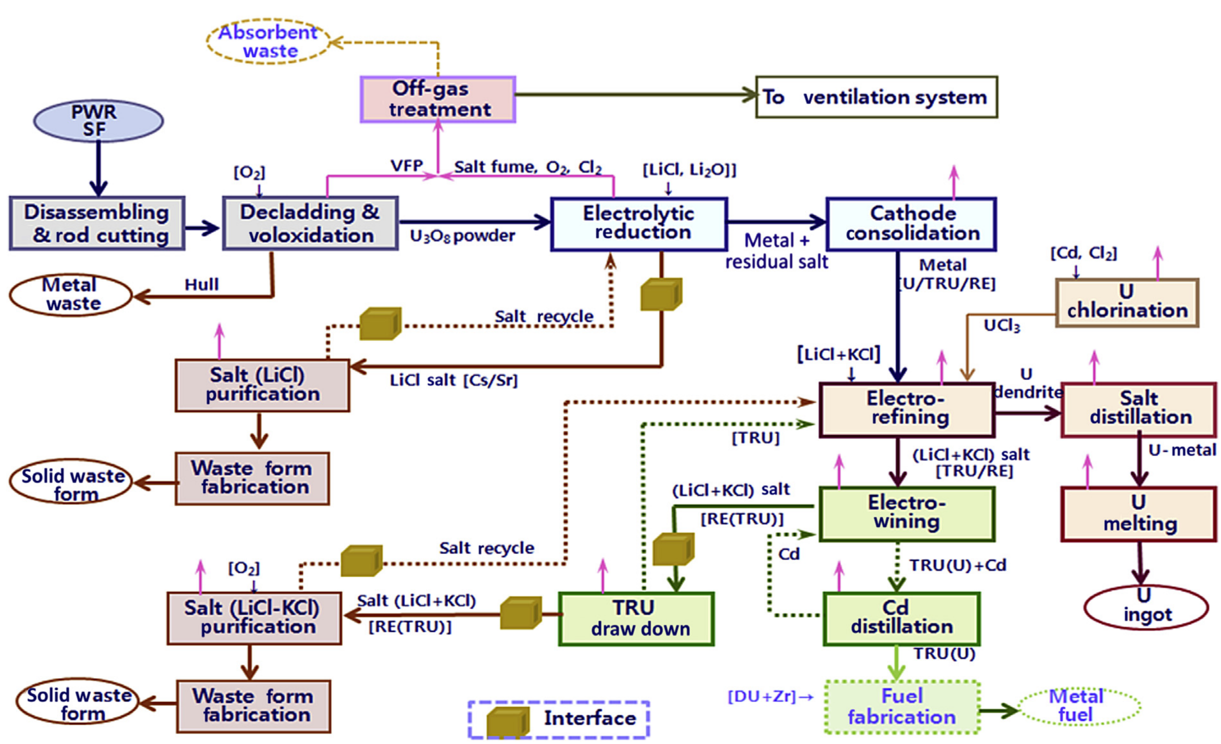

Fig. 1 – Process flow diagram of Reference Engineering-scale Pyroprocess Facility. TRU, transuranic elements; U, uranium.