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Repurposing a Spent Nuclear Fuel Cask for Disposal of Solid Intermediate Level Radioactive Waste From Decommissioning of a Nuclear Power Plant in Korea

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Operating and decommissioning nuclear power plants generates radioactive waste. This radioactive waste can be categorized into several different levels, for example, low, intermediate, and high, according to the regulations. Currently, low and intermediate-level waste are stored in conventional 200-liter drums to be disposed. However, in Korea, the disposal of intermediate-level radioactive waste is virtually impossible as there are no available facilities. Furthermore, large-sized intermediate-level radioactive waste, such as reactor internals from decommissioning, need to be segmented into smaller sizes so they can be adequately stored in the conventional drums. This segmentation process requires additional costs and also produces secondary waste. Therefore, this paper suggests repurposing the no-longer-used spent nuclear fuel casks. The casks are larger in size than the conventional drums, thus requiring less segmentation of waste. Furthermore, the safety requirements of the spent nuclear fuel casks are severer than those of the drums. Hence, repurposed spent nuclear fuel casks could better address potential risks such as dropping, submerging, or a fire. In addition, the spent nuclear fuel casks need to be disposed in compliance with the regulations for low level radioactive waste. This cost may be avoided by repurposing the casks.

Keywords: Radioactive waste storage, Decommissioning, Spent nuclear fuel cask, Repurposing

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1. Introduction

Nuclear energy is an excellent energy source from many aspects while it produces various types of radioactive waste. Good management systems for all levels of radioactive waste are needed, but specific disposal methods for higher level wastes are still under discussion in many countries. In Korea, disposal of intermediate level radioactive waste becomes more important since the country is facing present and future nuclear power plant decommissioning projects.

Dismantling itself produces large amount of intermediate level radioactive waste, and cleaning up existing radioactive wastes stored in the operating nuclear power plants is also required in the decommissioning. For instance, large sized intermediate radioactive level waste (ILW) such as irradiated components of the primary system can be generated in the dismantling process. Reactor vessel internals can be a typical intermediate level radioactive waste generated from decommissioning. Segmentation is one significant process in dismantling. Generally, many segmentation sequences are needed to put the waste in the conventional 200-liter drum. In addition, irradiated non-fuel assemblies such as control rod elements (CEAs) have been produced in operation and currently stored in the spent nuclear fuel pool (SFP). According to a sampling study, end part of CEA fingers which have been inserted into deep core can be classified as intermediate level waste [1]. The length of a finger is 6,213.48 mm in the case of APR-1400 [2]. As the length of the component is much greater than the height of the 200-liter drum, they should be cut into pieces to place in the drum. However, it would require too many segmentations. This is not desirable in decommissioning as it produces secondary radioactive waste and causes increased project cost.

As a solution, this letter proposes repurposing of no-longer used spent nuclear fuel (SNF) casks for solid ILW generated from decommissioning in Korea. It will be more efficient way to dispose large sized waste because it needs many segmentation process for conventional method.

2. Current Methods

Generally, concerned radioactive wastes can be categorized as high level waste (HLW), intermediate level waste, and low level waste (LLW). The classification criteria applied in Korea is shown in Table 1 [3]. The concept of the intermediate level waste and low level waste is often combined and called as low and intermediate level waste (LILW).

Currently, allowable LILW is transferred to Korea Radioactive Waste Agency (KORAD) for disposal. The waste acceptance criteria (WAC) is issued by KORAD. Specific acceptance criteria of waste packages for the cavern disposal facility is shown in Table 2. Also, the maximum allowable packaging size is 1.5 m (L) × 1.5 m (W) × 1.5 m (H) or 1.5 m (D) × 1.5 m (H) [4]. The criteria are identical to the concentration limit of radioactivity of low level waste of Nuclear Safety and Security Commission (NSSC) Notification No. 2020-6.

KORAD is the only company operating disposal facility in Korea. However, the radioactive concentration limits of the acceptance criteria are too low for disposal of the intermediate level waste. Therefore, it is virtually impossible to dispose the intermediate level waste now. It may take some time until new facilities become fully available for all kinds of radioactive wastes from operating and decommissioning considering capacity of the facilities planned. In this sense, temporary storage for the intermediate level radioactive waste has to be decided before decommissioning.

3. Concept of Repurposing

Repurposing of a SNF cask means utilizing a no-longer used SNF cask for different functions instead of disposing it. For example, no-longer used SNF casks may be repurposed for the storage of intermediate level radioactive waste. According to a study conducted by Oak Ridge National Laboratory (ORNL), dry storage cask (DSC) may be repurposed for disposal of radioactive waste. One precondition is

Table 1. Radioactive solid waste classification in Korea

HLW	LLW / ILW
• Alpha-ray-emitting nuclides with a half-life of 20 years or more • Alpha activity concentration ≥ 4,000 Bq·g^{-1} • Decay heat ≥ 2 kW·m^{-3}	• Restriction on disposal concentration for designated radionuclides (^{3}H, ^{14}C, ^{59}Ni, ^{60}Co, ^{63}Ni, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs and all alpha)

Table 2. Acceptance criteria per radioactive nuclide for cavern disposal facility of KORAD

Nuclide	Limit (Bq·g^{-1})	Nuclide	Limit (Bq·g^{-1})
^{3}H	1.11×10^{6}	^{94}Nb	1.11×10^{2}
^{14}C	2.22×10^{5}	^{99}Tc	1.11×10^{3}
^{60}Co	3.70×10^{7}	^{129}I	3.70×10^{1}
^{59}Ni	7.40×10^{4}	^{137}Cs	1.11×10^{6}
^{63}Ni	1.11×10^{7}	All alpha	3.70×10^{3}
^{90}Sr	7.40×10^{4}		

appropriate cutting activity for storage such as no jagged or diagonal cuts present. Also, DSC basket may be removed or reduced to secure enough space. No decontamination would be necessary for this. There still are some technical challenges such as setting up appropriate protocols for ensuring the integrity of the package. Otherwise, the casks would be disposed as low level radioactive waste after decontamination [5]. Similar case can be found in Connecticut Yankee decommissioning project. GTCC materials of 2.8×10^{16} Bq (750,000 curie) from reactor vessel have been segmented to fit into canisters, and stored at the ISFSI facility [6].

4. Application of Repurposing in Korea

4.1 General Description

Direct use of the repurposed SNF casks can be considered after removing unnecessary components for repurposing such as basket and impact limiter. A basket is installed to correctly arrange the spent nuclear fuels in the cask. Also, an impact limiter is installed to protect the transition sentence contents from excessive deceleration in the event of an accident [7]. A neutron shield is installed to protect the external environment from the radiation. These functions may not necessary and be removed for the repurposing of the SNF casks. However, the integrity of the modified casks has to be preserved. Fig. 1 shows the schematic of this application. Specification of KN-12; one type of transport

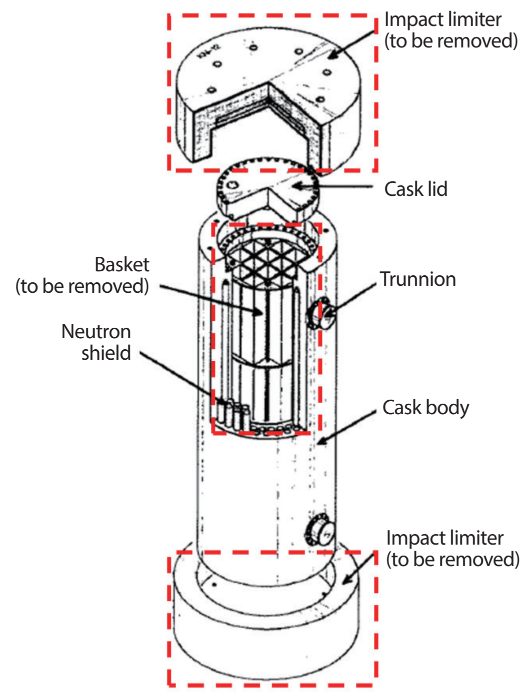

Fig. 1. Schematic of a repurposed cask proposed [8].

Table 3. Comparison in volume of modified KN-12 and conventional 200-liter drum

Parameter	Modified KN-12 [8]	200-liter drum
Inner diameter (m)	1.192	0.57
Inner length (m)	4.809	0.83
Volume (m^3)	5.36	0.21

cask in Korea, has been used [8].

Furthermore, the repurposed SNF casks can safely shield the radioactivity of the spent nuclear fuels inside. In this sense, the repurposed SNF casks may be directly located at a temporary storage such as an independent spent fuel storage installation (ISFSI) concept in the U.S. or a module concept disposal facility without further treatment.

4.2 Storage Functionality

The comparison of the inner space of a SNF cask without the basket and a conventional 200-liter drum is shown in Table 3. Larger size of radioactive waste can be stored without numerous treatment process in the modified casks as it suggests much greater space.

Reactor internals are composed of core support barrel (CSB), upper guide structure (UGS), lower support structure (LSS), and core shroud (CS) [9]. The dimensions of APR-1400 are 4,655 mm of inner diameter of cylindrical shell, 14,800 mm of total height inside, 3,810 mm of active core height, and 3,630 mm of core diameter [10]. A size comparison is shown in Fig. 2. This describes two lengthwise segmentation process is required to store in the repurposed casks while five segmentation process is required for the conventional 200-liter drums.

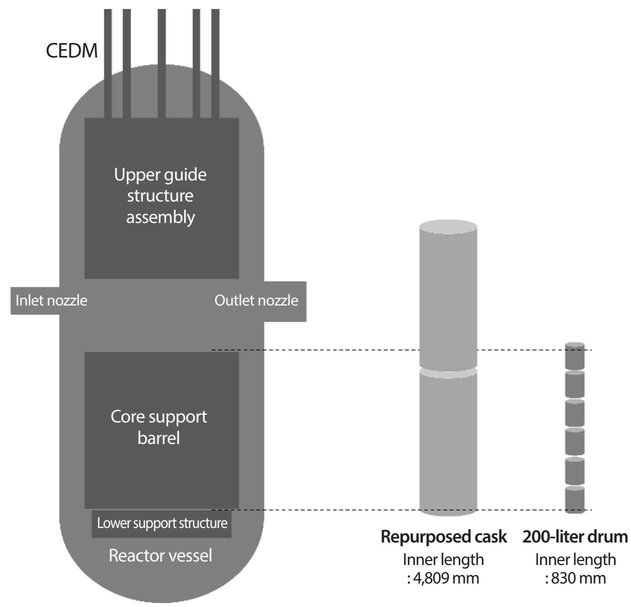

Fig. 2. Comparison of length of a CSB to inner length of a repurposed cask and a 200-liter drum.

4.3 Safety Functionality

In terms of safety, spent nuclear fuel cask can provide a great functionality from its superior design criteria compared to drums. NSSC 2021-21, Regulations on packaging and transportation of radioactive materials, regulates general requirements as well as technical requirements. B(U) type casks need to satisfy stricter requirement additional to the items from Article 22, General standard of transport casks. A document issued by IAEA shows more detailed requirements. For example, the SNF casks should withstand a free-drop impact of 9 m onto unyielding surface, 1 m onto a mild steel bar, fire up to 800ºC, and immersion to 200 m [11]. Hence, the transport casks like KN-12 can provide much higher level of safety quality compared to the conventional 200-liter drums.

5. Conclusion

This letter proposes repurposing of the no-longer used SNF casks for the storage of ILW. Repurposed SNF casks can provide a safe and economical mean for storing the ILW. In Korea, the repurposed SNF casks may be modified such as removing the basket, impact limiter, and neutron shield. The integrity of the cask should be preserved after the modification. Repurposing of the SNF casks would provide economic benefit as the casks not used will be disposed as another radioactive waste. Also, less segmentation process means smaller amount of secondary waste generated which results in lower disposal cost. Furthermore, repurposed SNF casks can provide safer environment storing radioactive wastes compared to using the conventional 200-liter drums because the casks are subject to severe tests to satisfy high level design requirements. More active discussions for developing detailed protocols, regulation amendments, and procurement plans are needed to realize this concept in Korea.

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