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Development of PWR Fresh Fuel Shipping Container

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1. Introduction

Over the last decade, IAEA has continuously recommended the enforcement of the radioactive material transportation regulations. South Korean government accepted these IAEA recommendations like other nuclear advanced countries in 2001. According to the revised Korean regulatory guide, KNF has to develop a fresh fuel shipping container which meets the enforced regulations. After due date, all the containers which have been manufactured with previous guide line will not be available any more. Under these circumstances, KNF has developed fresh fuel shipping container for pressurized light water reactors (PWR) since 2006 and is manufacturing the final pilot models to perform the enforced regulatory tests. This article presents the developing activities such as design and analysis of the PWR fresh fuel shipping container.

2. Design and Model Analysis

According to the enforced test regulations, the developed containers shall be sound in 9-m drop, 1-m drop (puncture), fire and water immersion tests, etc. Considering the above conditions, the new containers were designed and analyzed as follows,

2.1 Structure Design

New shipping containers are being developed for OPR1000 type (PLUS7) and Westinghouse type(ACE7, WH 14x14) fuel assemblies. The outer shape of containers is a cylindrical type which is to make structure strength better, and outer shell was designed with a double layer for strength and filling with thermal insulation which is able to protect fuel assemblies from a fire accident[Fig. 1]. It also has 26 special shock absorbers for the fuel integrity during normal and accident conditions of transport.

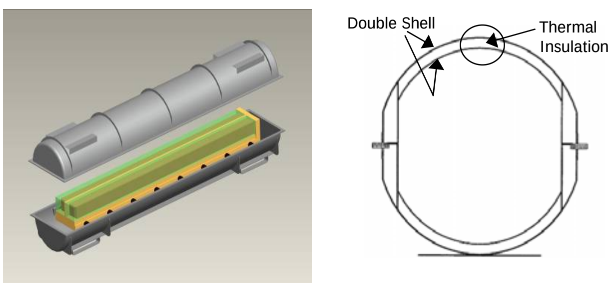


Fig. 1. Cylindrical shape and double layered outer shell

In addition, it has some more functions for easy handling in power plants. (e.g. cradle standing erection for loading/ unloading fuel assemblies with light cranes[Fig. 2])

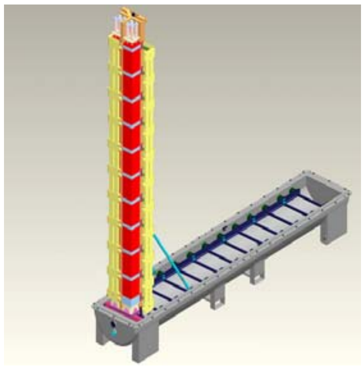


Fig. 2. Standing erection of internal structure

2.2 Structure Analysis

The structure has been analyzed in two phases according to IAEA and Korean regulations. Under the normal condition, stacking, lifting and tie-down analysis were performed and the result indicated that maximum normal stress vs. yield stress in most components are less than 15% except in the stacking analysis, which is almost 65%. 9-m drop and 1-m drop (puncture test) analyses were carried out under the hypothetical accident condition. The analysis indicates that the maximum yield displacement of the fuel assembly in 15° inclined drop reaches up to 233% compared to horizontal drop[Table 1]. In this analysis, the HGLS (Hourglass Deformation) appears less than 10%, which means this analysis is reliable.

Table 1: 9-m drop analysis (normalized stress)

Case	Comparison (Fuel Assembly)
	Y-stress ratio
Horizontal Drop	1.00
15° inclined Drop	2.33
75° inclined Drop	1.94
Vertical Drop	1.53

2.3 Criticality Analysis

Criticality analyses were performed to ensure the radiological safety of the shipping containers. All types of fuel assemblies (max. enrichment, 5.0 w/o) were modeled to calculate the effective multiplication factors (Keff) under the normal and accident conditions with SCALE and MCNP computer codes. A neutron absorber was applied to the shipping containers being compact and is the B_4C-Al material of a full metal matrix composite. Fig. 3 shows the model of the shipping container which is in the most severe case in the accident condition. and [Table 2] presents Keff in various conditions. In this model, the maximum Keff is limited up to 0.95.

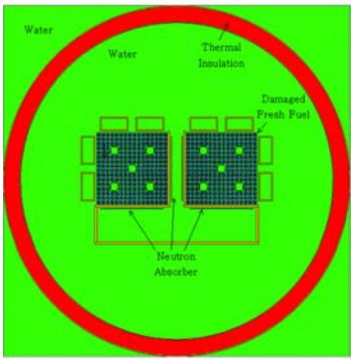


Fig. 3. Critical analysis model under accident condition

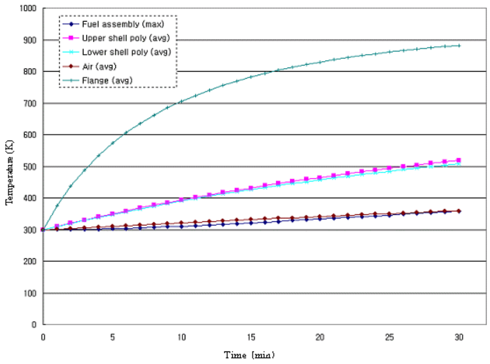
Table 2 : Keff as fuel types and conditions

Fuel Type	Condition		
	Normal	Sub-water	Accident
A	0.55690	0.87213	0.88483
B	0.58154	0.89628	0.90920
C	0.52045	0.84870	0.86145
C	0.51350	0.85942	0.86943

2.4 Thermal Analysis

The fresh fuels in the shipping container shall be safe in an aspect of thermal integrity in the fire which keeps 800℃ for 30 minutes. In our analysis, the highest temperature of the fresh fuels was less than 100℃[Fig. 4]. However, the temperature of the fuel claddings in reactors is up to 371℃ (700˚F), it means the fresh fuels and internal structures was estimated they are sound under accident conditions.

Fig. 4. Temperature curve of PLUS7 under accident condition



3. Conclusions

Fresh fuel shipping containers were designed to meet the domestic and overseas enforced regulations, and it was modeled and analyzed its integrity in severe conditions. It is expected that fresh fuels would be negligibly damaged and safe in criticality under accident conditions. Shipping containers were also analyzed in criticality in the most severe conditions, and it shows the all results were under the limited Keff. In the thermal analysis, it was estimated that the thermal insulator protected internal structures and fuels from high temperature of accident conditions. In conclusion, the design of fresh fuel shipping container meets the requirements of domestic and international regulations. A proto type container will be tested to confirm its integrity in 2009.

Acknowledgement

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