Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Conceptual Assessment of a Fresh Fuel Transport Package for KJRR

Ju-Chan Lee*, W.S. Choi, K.S. Bang, S.H. Yu, J.S. Park, Y.Y. Yang
KAERI, 111, Daedeok-daero 989Beon-gil, Yuseong-gu, Daejeon, Korea
**Corresponding author: sjclee@kaeri.re.kr*

1. Introduction

KAERI has been developing a fresh fuel transport package for Kijang research reactor (KJRR). This paper describes a conceptual design and preliminary safety analysis of the transport package for KJRR.

The transport package was designed for shipment of a fresh fuel and a FM (Fission Molybdenum) target. Low-enriched uranium (LEU) of U-Mo fuel with U-235 enrichment of 19.75 w/o is used as a research reactor fuel. And LEU of UAlx-Al with U-235 enrichment of 19.75 w/o is used as a FM target material. In the fresh fuel and FM target, the main isotope is U-235 and the A2 value for U-235 is unlimited in the IAEA[1] and domestic[2] atomic regulations. Therefore, the transport package is classified as a type AF package.

The IAEA and domestic regulations stipulate that the fissile material transport package be subjected to the cumulative effects of a 9 m drop, 1 m puncture, 800 ℃ thermal and water leakage tests. A fissile material transport package should be maintained the subcriticality during the normal and accident conditions for contingency of leakage of water into or out of package, rearrangement of the contents, reduction of spaces and temperature changes.

2. Conceptual Design of Transport Package

Through the preliminary analyses on the criticality, structural and thermal performances, the concept of the transport package was derived.

Fig. 1 and Fig. 2 show the configuration of the fresh fuel and FM target packages. The transport package is composed of an over-pack and a canister equipped with fuel baskets. The over-pack consists of steel casing and Balsa wood with 160 mm thickness for impact absorbing and thermal insulation under the hypothetical accident conditions.

Two types of canisters are loaded into an over-pack. One is for loading the fresh fuel assembly and the other is for loading the FM target. Two canisters have a same size but the internal structures are different from each other. The loading capacity of the package is 12 fresh fuel assemblies or 84 FM target assemblies.

Table 1 describes the general description of transport package. Outer diameter of the package is 970 mm and the overall length is 1,430 mm including the over-pack. The gross weight of the package is approximately 861 kg.

Table 1. General description of transport package

Item	Description
Type	A(F)
Loading capacity	- Fresh fuel : 12 fuel assemblies - FM target : 84 FM target (7 Baskets x 12 Ass'y)
Dimension	- Canister : Φ730 x 1,063 mm(H) - Overpack : Φ970 x 1,400 mm(H) - Basket . Fresh fuel : 90 x 90 x 1,028 mm(H), 4t . FM target : 158 x 175 x 1,028 mm(H), 3t
Weight	- Fresh fuel package : 861 kg . Canister 475 kg, Overpack 386 kg - FM target packaeg : 771 kg . Canister 385 kg, Overpack 386 kg
Material	- Canister . Canister, disk, basket : SA240 Type304 . Gasket : silicone rubber - Overpack . Absorber/insulation : Balsa wood (160t) . Case : Stainless steel SA240 Type304

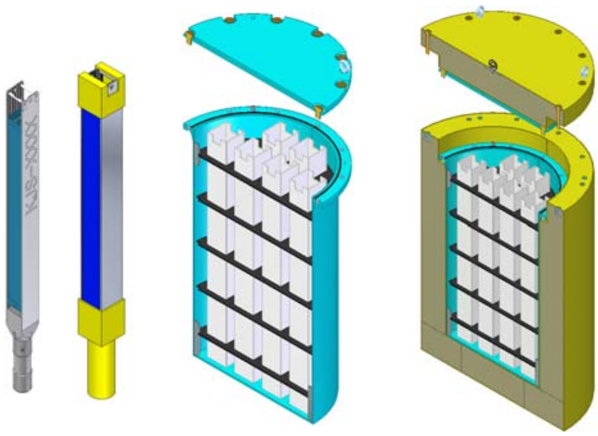


Fig. 1. Overview of fresh fuel transport package

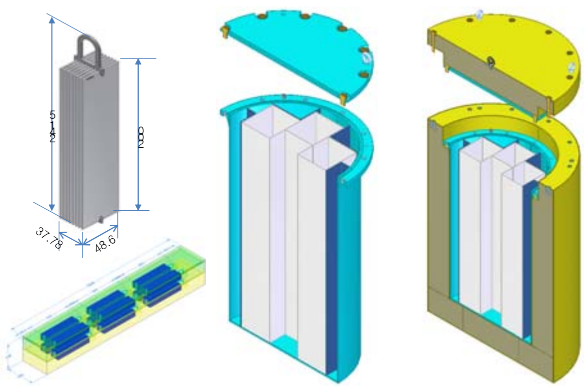


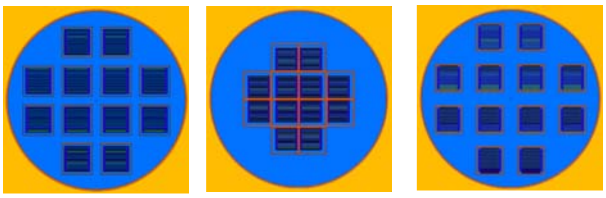
Fig. 2. Overview of FM target transport package

3. Safety Analysis of Transport Package

3.1 Criticality Analysis

Criticality analysis was conducted using the MCNP6 Ver.1.0[3] code, which is a Monte Carlo transport code that offers a three-dimensional geometry modeling capacity. Criticality analyses of the package were performed for normal and accident conditions. The accident condition was assumed to be leakage of water into the canister. In addition to the leakage of water condition, concentration of fuel assembly in the fuel baskets or damaged side plates of fuel assembly was assumed for accident conditions as shown in Fig. 3.

Effective neutron multiplication factors (keff) were calculated as 0.04299 under normal condition and 0.89641 under accident condition for water immersion and concentration of fuel assembly. These are below the criticality safety limit of 0.93226 including all biases and uncertainties. Therefore, the subcriticalities were maintained under normal and accident conditions.



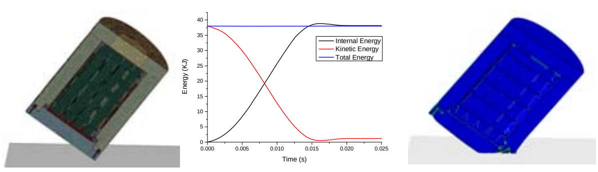
▲ Only water immersion ▲ Concentration of fuel ▲ Damaged fuel plate

Fig. 3. Accident conditions for criticality analysis

3.2 Structural Analysis

Structural analyses for the package were performed under normal and accident conditions specified in regulations using the ABAQUS/Explicit 6.14-1[4] code. Hypothetical accident conditions include a 9 m free drop and 1 m puncture. A three-dimensional cylindrical half model was used for the analysis of the package. The analysis model consists of 1,200,000 nodes, 910,000,000 elements.

The calculated stresses were lower than the stress limits stipulated in the ASME code. It shows that the package is structurally intact under normal and hypothetical accident conditions. After 9 m free drop and 1 m puncture test, there was no gap between the canister and canister lid and a significant deformation of fuel basket to cause a criticality. Water in-leakage was considered in the criticality analysis of the package, therefore the submersion test was not performed.



▲ FE Model ▲ Energy time-history ▲ Stress contour

Fig. 4. Drop analysis for corner drop

3.3 Thermal Analysis

Thermal analyses were conducted for fire accident condition with an average flame temperature of 800 ℃ for a period of 30 minutes. For the pre-fire phase, the hot-normal condition was assumed with solar insolation and an ambient temperature of 38 ℃.

In the thermal analysis results, all safety related components of the package did not exceed their safe operating temperatures. The maximum temperatures of fresh fuel and FM target are calculated within 75 ℃, which is below the allowable temperature of 570 ℃ under accident condition. Therefore, it is shown that the thermal integrities of the package were maintained under normal and hypothetical accident conditions.

4. Conclusions

Conceptual assessment of the fresh fuel transport package for KJRR was performed. The transport package was designed for shipment of a fresh fuel and a FM target. Safety analyses were conducted on all areas, including criticality, structural, and thermal fields. In the criticality analysis, effective neutron multiplication factors were below the criticality safety limit. In the structural analysis, the maximum stress satisfied the stress requirement stipulated in the ASME code. After 9 m free drop and 1 m puncture test, there was no significant deformation of fuel basket to cause a criticality. In the thermal analysis, the maximum temperatures at each part were lower than the allowable values. Therefore, it was found that the integrity of the package would be maintained under normal and hypothetical accident conditions. The results of this study will be used with basic data for the approval of package design.

REFERENCES

[1] IAEA Safety Standards Series No. SSR-6, 2012 Edition, Regulations for the safe transport of radioactive material, 2012.

[2] NSC Notice No. 2014-50, Regulation for packaging and transportation of radioactive materials, Nuclear Safety and Security Commission Notice, 2014.

[3] ABAQUS User's Manual for Revision 6.14-1, Hibbit, Karlson & Sorenson Inc., 2014.

[4] MCNP6TM User's Manual, Version 6.1.0, LA-CP-13-00634, Los Alamos National Laboratory, 2013.