Development of a Fresh Plutonium Fuel Container for a Prototype Fast Breeder Reactor

T. Ohtake[1], S. Takahashi[1], T. Mishima[2], J. Kurakami[2], Y. Yamamoto[2], Y. Ohuchi[2]

[1]*Power Reactor and Nuclear Fuel Development Corporation, Tokyo*
[2]*Tokai Works, Tokyo, Japan*

1. Introduction

Japan gives a good deal of encouragement to development of a fast breeder reactor (which is considered as the most likely candidate for nuclear power generation) to secure long-term energy source. And, following an experimental fast breeder reactor "Joyo", a prototype fast breeder reactor "Monju" is now under vigorous construction.

Related to development of the prototype fast breeder reactor, it is necessary and important to develop transport container which is used for transporting fresh fuel assemblies from Plutonium Fuel Production Facility to the "Monju" power plant. Therefore, the container is now being developed by Power Reactor and Nuclear Fuel Development Corporation (PNC).

Currently, shipment and vibration tests, handling performance tests, shielding performance tests and prototype container tests are executed with prototype containers fabricated according to a final design, in order to experimentally confirm soundness of transport container and its contents, and propriety of design technique.

This paper describes the summary of general specifications and structures of this container and the summary of preliminary safety analysis of package.

2. Summary of general specifications and structures of container

This container is designed as packaging for BU type fissile class I package, and can accommodate two fresh fuel assemblies.

As shown in Figure 1, this container is cylindrical in shape and mainly consists of containment vessel, overpack and two fuel holders.

This container has a structure to keep the containment vessel safe by absorbing drop energy with shock absorber in the overpack, in order to lighten the weight as much as possible.

Furthermore, in order to reduce the radiation exposure level, the container is designed to automatically load and unload the fuel assembly into or from the container by remote operation.

The summary of general specifications of this container is shown in Table 1.

Table 1 General specification of container

Type of Package	BM Type Fissile Class I Package
No. of Accommodated Fuel Assemblies	Max. 2 Assemblies
Weight of Package	Approx. 2.63 ton
Size of Package	
· Whole Length	Approx. 5,000 mm
· Outer Diameter	Approx. 630 mm
· Height	Approx. 730 mm
Main Materials	
· Structure	Stainless Steel
· Shock Absorber	Balsa Wood
· Neutron Shielding	Resin
· Thermal Insulator	Mortar

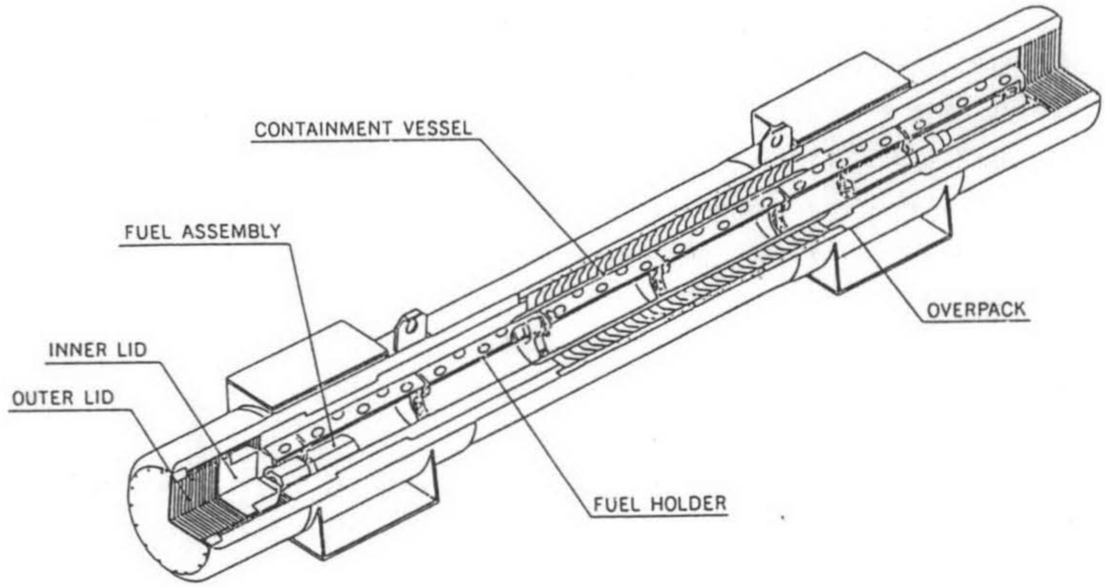

Figure 1 Schematic diagram of container

2.1 Containment Vessel

The containment vessel (made of stainless steel) accommodates two fuel holders and two fuel assemblies, and forms a containment system of the container.

The containment vessel is necessary to have containment performance which is required for making leakage rate of housed radioactive materials satisfy a design criteria under both general and special accident test conditions set to the package. Therefore, double O-rings are equipped between the upper lid and the flange of the containment vessel (which can be opened and closed automatically by remote operation).

Considering work efficiency, the upper lid of the containment vessel is also equipped with an inspection hole leading to the space between O-rings so as to be able to test a leakage, and with a valve which leads to the inside of the containment vessel so as to be able to monitor easily the air contamination by α radioactivity.

2.2 Overpack

The overpack is a general term for the whole part outside the containment vessel, and mainly consists of neutron shielding, heat transfer fins, heat insulator and shock absorber.

There are neutron shielding (resin) around the middle part of the containment vessel. Disk-type heat transfer fins (copper) are inserted in this shielding at stated intervals to transfer the heat discharged from fuels outwards.

And in order to prevent heat from coming in at the fire accident, the heat insulator (mortar) is incorporated in the outside of the heat transfer fins. For other parts, the balsa is filled up as the shock absorber to absorb a shock upon falling. The outer lid is designed to form a cover of the overpack so as to be able to be loaded and unloaded.

The lifting devices used for the handling such as lifting the container, the base plates to set up the container at a level, and bases to pile up the container, are equipped on the outer shell (stainless-steel) of the overpack.

2.3 Fuel Holder

The fuel holder is mainly made up of stainless steel, and resin is used for some places touching the fuel assembly. Fuel assembly is vertically loaded into the fuel holder or unloaded from it.

Considering efficiency of accommodating a hexagonal assembly, a self-orientation guide to determine the direction is incorporated in a inlet of the fuel holder.

Two fuel assemblies are individually held in the fuel holder by built-in holding system automatically and mechanically operated by means of the weight of fuel assembly itself.

3. Summary of Preliminary Safety Analysis of Package

As for design of the transport container, it is necessary to confirm, with safety analysis, that the design meets to design criteria stated in laws and regulations for transporting nuclear fuel materials and others.

Upon designing this container, the structural, thermal, containment, shielding, and criticality safety analyses have been executed in order to secure safety as the package not only under the normal conditions of transport but under the general and special accident conditions assuming an accident with a rare possibility, and their soundness have been confirmed.

3.1 Structural Analysis

In structural analysis, first of all, degree of stress or deformation which occurs in the above situations was calculated from the relationship between impact energy and absorption energy of the container itself. Then margin of safety [(Value of design criteria)/(Result from analysis)-1] was calculated, and finally the evaluation to confirm soundness of the containment vessel was made.

Here, a value based on the mechanical properties of materials and result of the heat analysis was used as the design criteria. For this container, yielding stress was mainly used.

As results from this analysis, all of impact energy of the transport container were absorbed by the overpack, and there was no damage on the containment vessel.

3.2 Thermal Analysis

In thermal analysis, considering heat discharged from two fuel assemblies and heat coming from the outside of the container, etc., temperature distribution inside the container was evaluated with a multi-dimentional heat transfer calculation code (based on the finite difference method), "TRUMP".

Under the general accident conditions, the evaluation was made to confirm soundness of materials constituting the container.

Under special accident conditions, the evaluation was made to confirm soundness of the package under the fire-test conditions (with consideration of drop test).

The results of this analysis meet to requirements of domestic and IAEA regulations, and temperatures were within the limitation for use of materials constituting the container.

3.3 Containment Analysis

In containment analysis, the leakage of radioactive materials was evaluated by using the results of an experiment on leakage of PuO_2 by Battelle Memorial Institute.

This container has two containment systems. One is fuel element in the fuel assembly and the other is the containment vessel. According to this evaluation, it was found that the fuel elements which are sealed up with welding, were solely confirmed to maintain the required performance of containment. Furthermore, the required performance of containment was confirmed to be maintained for the containment vessel.

3.4 Shielding Analysis

In shielding analysis, the "ORIGEN" Code was used for calculation of intensity of radiation source from radioactive materials included in two fuel assemblies, and a one dimensional transportation code ("ANISN") was used for calculation of dose rate.

Because this package is considered as a neutron multiplication system, the intensity of neutron source was multiplied by factor 1/(1-keff). As to keff, the result of criticality analysis was used.

As the results of this analysis, the shielding performance of this container fully satisfied the requirements of the regulations.

3.5 Criticality Analysis

In criticality analysis, keff was evaluated under the normal conditions of transport and both general and special accident conditions, using the Monte Carlo calculation code, "KENO- IV".

This container prevents the water from penetrating into the containment vessel, as performance of containment is ensured under each condition. However, upon this analysis, considering penetration of water into the containment vessel, keff was evaluated when such water density was changed.

The results were sufficiently below the critical level, even when keff was the largest.

4. Conclusion

This container was designed to transport fresh fuel assemblies for a prototype fast breeder reactor, "MONJU", of which criticality is planned in 1992.

Two prototype containers were fabricated to be subjected to various tests for verifying the design, and now prototype container tests such as drop, fire, and immersion tests are under preparation.

This transport container is designed to correspond with automatization in the Plutonium Fuel Production Facility. Therefore, it enables fuel assemblies to be loaded and unloaded automatically by remote operation. The reduction of radiation exposure level for workers can be expected as a significant merit.

As the results of preliminary safety analysis, soundness of package has been already confirmed and package has been found to meet all the requirements of the domestic and IAEA regulations.

An approval certificate for package design in Japan is intented to be acquired after the final safety analysis reflecting results of all tests in the near future.