Development of Fresh Fuel Packaging for ATR Demonstration Reactor

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1. Introduction

Japan gives a good deal of encouragement to development of an advanced thermal reactor (ATR) to secure long-term energy source. And, following a prototype advanced thermal reactor "Fugen", a demonstration advanced thermal reactor is now planned to be constructed.

Related to development of the demonstration advanced thermal reactor, it is necessary and important to develop transport packaging which is used for transporting fresh fuel assemblies. Therefore, the packaging is now being developed in Power Reactor and Nuclear Fuel Development Corporation (PNC).

Currently, PNC is fabricating two prototype packagings based on the final design, and land cruising and vibration tests, handling performance tests and prototype packaging tests will be executed with prototype packagings in order to experimentally confirm the soundness of packaging and its contents and the propriety of design technique.

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

2. Summary of general specifications and structures of packaging

This packaging is designed as type B fissile package, and can accommodate fresh MOX fuel assemblies.

As shown in Figure 1, this packaging is cylindrical in shape and mainly consists of containment vessel and overpack. This packaging has a structure to keep the containment vessel safe by absorbing drop energy with shock absorber installedin the overpack. The structure leads to weight reduction.

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

Table 1 General specifications of packaging

Type of Package	Type B Fissile Package
Weight of Packaging	Approxi. 7.51 ton
Size of Packaging • Total Length • Width • Height	 Approxi. 5.6 m Approxi. 1.7 m Approxi. 1.5 m

2.1 Containment Vessel

The containment vessel accommodates fuel holders and fuel assemblies, and forms a containment system of the packaging. 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 imposed to the package. Therefore, double O-rings are installed between the upper lid and the flange of the containment vessel. 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 around the middle part of the containment vessel. Disk-type heat transfer fins are inserted in this shielding at stated intervals to transfer the heat discharged from fuels outwards.

And 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 (trunnion) used for the handling such as lifting the packaging and the base plates to set up the container at a level are provided on the outer shell of the overpack.

3. Summary of Preliminary Safety Analysis of Package

As for design of the transport packaging, 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 packaging, 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 packaging 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 packaging, yielding stress was mainly used.

As results from this analysis, all of impact energy of the transport packaging 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 fuel assemblies and heat coming from the outside of the packaging, etc., temperature distribution inside the packaging 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 packaging. 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 the requirements of domestic and IAEA regulations, and temperatures were within the limitation for use of materials constituting the packaging.

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 package 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-2" Code was used for calculation of intensity of radiation source from radioactive materials included in 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 result of this analysis, the shielding performance of this packaging 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 packaging 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 packaging is designed to transport fresh fuel assemblies for a demonstration advanced thermal reactor, of which criticality is planned in 2000.

Two prototype packagings are fabricated to be subjected to various tests, such as drop, fire, and immersion tests for verifying the design.

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.

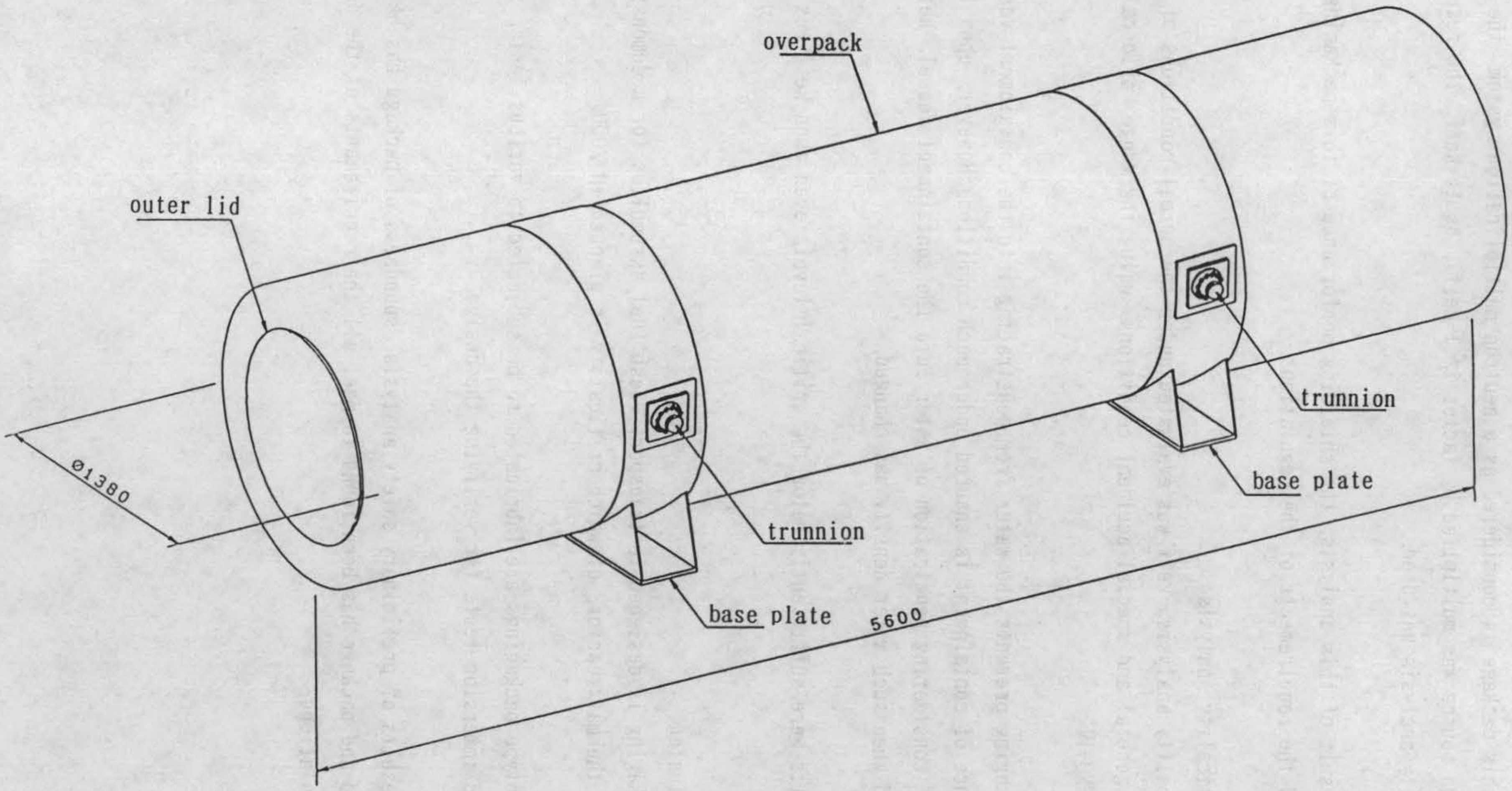

Figure 1 ATR Demonstration Reactor Fresh Fuel Packaging