DEVELOPMENT OF FRESH FUEL PACKAGING FOR ATR DEMONSTRATION REACTOR

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1. INTRODUCTION

Japan had aimed to develop an Advanced Thermal Demonstration Reactor (ATDR) in parallel with a Fast Breeder Prototype Reactor "MONJU", in order to secure some of its long-term energy for the future. ATDR had been developed based on the successful results of the prototype ATR "FUGEN" developed by semi-independent technology. However, the electric power companies abandoned the development plan of ATDR because it was disadvantageous economically. In August, 1995 the Atomic Energy Commission of Japan decided to abandon the development plan of ATDR. The Power Reactor and Nuclear Fuel Development Corporation (PNC) had carried out a design of a packaging to transport fresh mixed oxide (MOX) fuel assemblies for the ATDR, till the decision of abandoning of the development plan of ATDR. The packaging had been required to contain as many assemblies as possible to transport them efficiently, since about 600 assemblies had to be transported as an initial core for ATDR, and the mass of plutonium metal in a fuel assembly for ATDR was 5 kg (1.8 times higher than 2.8 kg of FUGEN). The packaging, having advanced materials for light-weight shock absorbing and high-performance neutron shielding, is designed as Type B(U) fissile package. The packaging has made it possible to contain a maximum of eight assemblies, and it is the largest fresh MOX fuel packaging developed in Japan. Demonstration tests were performed using two prototype packagings. As the results, the integrity of the packaging and the validity of the design technique were confirmed. This paper describes the summary of the packaging specifications and the demonstration tests.

2. GENERAL SPECIFICATIONS OF PACKAGING

This packaging is designed as a Type B(U) fissile package, and it meets national safety regulations which introduced IAEA Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990). As shown in Figure 1, the packaging is cylindrical in shape and mainly consists of eight fuel holders, a containment vessel and an overpack. The packaging is able to contain a maximum of eight assemblies and can be loaded on an 11-ton truck, which is commercially available for land transport. When the fuel assemblies are loaded or unloaded from the packaging, the packaging is stood up and retained in the vertical orientation. The summary of general specifications of this packaging is shown in Table 1.

2.1 Containment Vessel

The containment vessel forms a containment boundary of this packaging. The stainless steel body contains eight fuel assembly tubes welded to the flange. Each fuel assembly is fixed in a fuel holder inside its containing tube. The inner lid is fixed to the flange by bolts. The fluoro-elastomeric double O-ring is inserted between the inner lid and the flange. The inner lid is equipped with a leak test hole leading to the space between the O-rings and an alpha sampling port leads to the inside of containment vessel. The containment vessel has a helium gas leak-tightness of 1×10^{-4} atm.cm^3/sec or less.

2.2 Overpack

The overpack has an important function protecting the containment vessel in an accident such as a drop or a fire. It mainly consists of shock absorbing material, neutron shielding material and heat transfer fins, and is covered with an outer shell made of stainless steel. In the inner layer of the overpack, a resin neutron shielding material is located just outside of the containment vessel, and a polyurethane foam shock absorbing material resides just outside of the neutron shielding material. The heat transfers fins modeled in the shape of disks are inserted into the neutron shielding material and shock absorbing material at precise intervals in order to effectively transfer heat discharged from the fuel outwards. Balsa wood, having higher compression strength than that of polyurethane foam, is used in the ends of the packaging in order to suppress large deformation in the case of a slant impact. Fusible plugs are located in the outer shell to release combustion gas as generated from resin, polyurethane foam or balsa wood, if the packaging encounters a fire accident. Additionally, trunnions and base plates are located on the outer shell in order to lift and support the packaging.

3. CHARACTERISTICS OF PACKAGING

This packaging has adopted advanced technologies, such as high-performance neutron shielding material and light-weight shock absorbing material, compared with the traditional packagings for MOX fuel.

3.1 Use of High-performance Neutron Shielding Materials

It is necessary to effectively shield neutron radiation emitted from MOX fuel and to efficiently transfer heat discharged from MOX fuel outward, because the quantity of plutonium is about 1.8 times greater than 2.8 kg included in a fuel assembly for FUGEN.

Therefore, this packaging employs a resin which has already been used in the fresh MOX fuel packaging for MONJU. The resin adopted in these packagings is based on an epoxy resin, with a higher hydrogen content than general ones. Moreover, it has good fabricability and machinability in the process of manufacturing and has good heat resistance. The resin is formed in precise doughnut shapes and the disk-line heat transfer fins are sandwiched in between. Thus, use of the resin satisfies both the effective shielding of neutrons and the efficient heat transference of simultaneously.

3.2 Adoption of New Type Shock Absorbing Material

It had been required to contain as many fuel assemblies as possible and also to satisfy the loading limit of an 11-ton truck commercial truck. Accordingly, it was necessary to reduce the total weight of the package as much as possible. New developed polyurethane foam was then adopted as the shock absorbing material. It was improved to be incombustible, having the characteristics of low-density, high shock-absorbing capacity and homogeneous composition, in comparison with those of balsa wood which was used frequently in traditional packagings. Using polyurethane foam, the total weight of the packaging was reduced effectively, thereby making it possible to contain a maximum of eight assemblies and to be loaded on an 11-ton truck. If balsa wood had been adopted instead of polyurethane foam, the number of assemblies contained in the packaging would have been no more than seven assemblies.

4. SUMMARY OF DEMONSTRATION TESTS

A handling performance test, a land cruising test and a prototype packaging test were performed using two prototype packagings in order to confirm integrity of the packaging and validity of the design technique.

4.1 Handling Performance Test

This test was conducted to confirm a series of operations such as mounting the fuel assembly to the fuel holder, inserting the fuel holder in the containing tube, lifting the packaging, etc. It was verified that the packaging could be handled without inconvenience.

4.2 Land Cruising Test

An land cruising test with some measuring equipments was performed to confirm integrity of fuel assemblies and transportation system. It included a fully-loaded packaging, a fastening device and an 11-ton truck under the routine conditions of transport. A prototype packaging containing a dummy assembly was loaded onto an 11-ton commercially available truck. The 11-ton truck ran a test course on general and express ways whose total distance was about 1600 km. The results of the test showed that the average vibrational acceleration magnitude of the fuel assembly was approximately 1 G. The peak acceleration was 2.5 G when the truck passed over the joint of a road. After a visual inspection of a dummy assembly after the test, it was confirmed that no damage had occurred to the surface of the dummy assembly.

4.3 Prototype Packaging Test

The prototype packaging tests including drop, fire and immersion tests, were performed based on the national safety regulations which incorporated the IAEA Regulations for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990). The summary of results for the drop tests and the fire test using two prototype packages are shown in Tables 2 and 3. The first prototype packaging has been subjected to 9 m drop and 1 m puncture tests in a horizontal orientation. In the 9 m drop test, all of the impact energy was absorbed by the overpack. A part of the outer shell was penetrated during the 1 m puncture test conducted along the package's center of gravity, but the deformation did not reach the containment vessel. Leak tests conducted at the containment vessel O-ring conducted after each drop test verified that all of the leak rates were below the permissible leak rate: 1×10^{-4} atm.cm^3/sec.

Another series of tests was performed on a second prototype packaging including a 9 m drop and 1 m puncture test in a vertical orientation, a 9 m drop and 1 m puncture test in a horizontal orientation, a fire test of 800 ℃ for 30 minutes, an immersion test at a hydraulic pressure of 1.5 kgf/cm^2 during 8 hours, and finally an other immersion test at a hydraulic pressure of 20.0 kgf/cm^2 during 1 hour (which was introduced into the IAEA Regulations for the Safe Transport of Radioactive Material in the 1996 Edition). In the 9 m drop and 1 m puncture tests in vertical orientation, all energy was absorbed by the overpack, and there was no tearing of the surface of outer shell. In the fire test, some of the overpack materials for shock absorbing and neutron shielding burned up and disappeared. However, the maximum temperature measured at the O-ring was 58 ℃, sufficiently below the 280 ℃ maximum usable temperature of the O-ring. In the immersion tests, there was no deformation in containment vessel and leak tightness of the O-ring was maintained. Leak testing of two dummy assemblies inside each prototype packaging verified that the leak rate had been below the permissible leak rate.

5. CONCLUSION

This packaging did not go through the design approval application procedure in Japan and actual packaging fabrication because the development plan of ATDR was abandoned. However, PNC completed the design of the packaging for fresh MOX fuel assemblies which is able to contain many assemblies and to be loaded on an 11-ton truck, commercially available for land transport. PNC's experiences gained through the development of this packaging will be beneficial to the future development of packagings for MOX fuel assemblies.

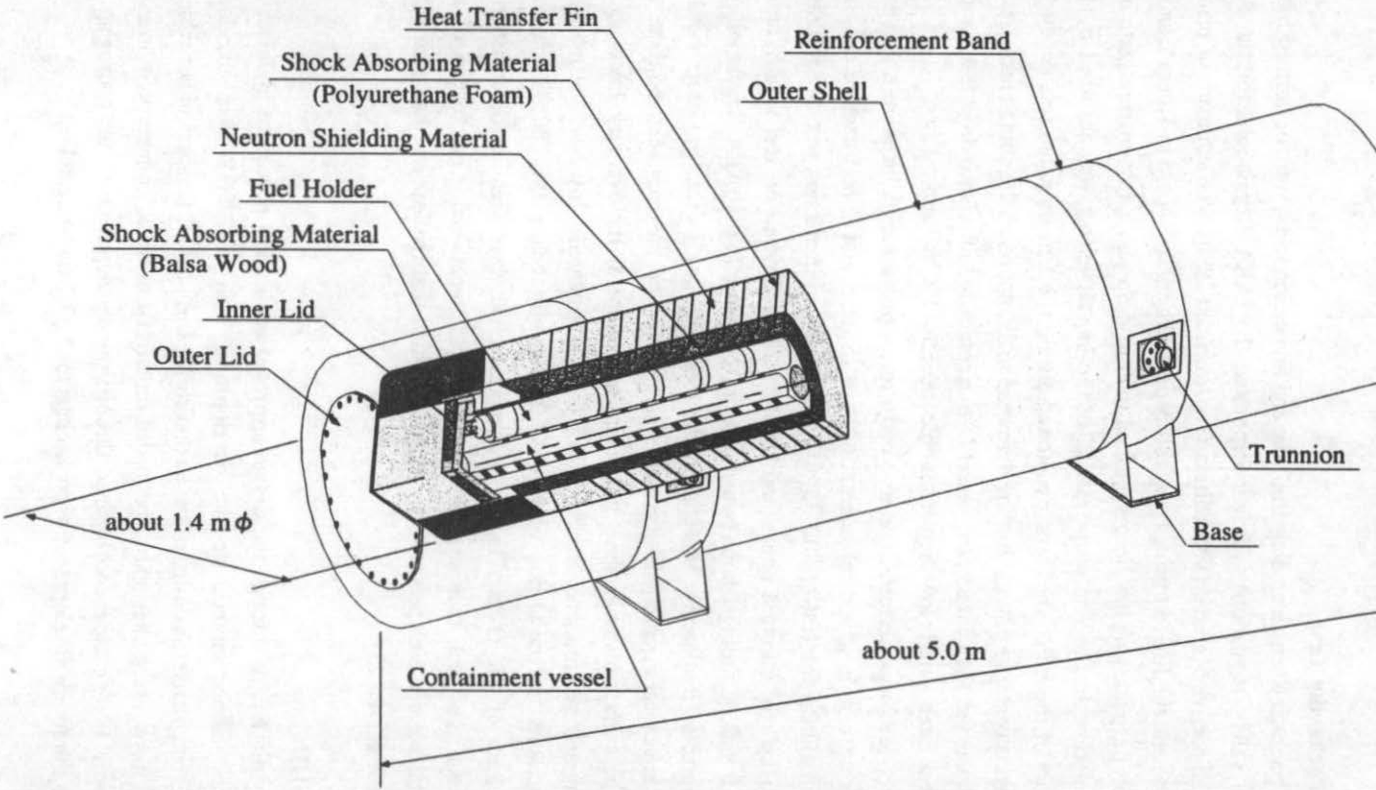

Figure 1. Perspective View of Package for ATDR

Table 1. General Specifications of ATDR Packaging

Type of Package	Type B(U) Fissile Package
Weight of Packaging	7.61 ton
Weight of Package	9.45 ton
Size of Packaging	
- Length	5.6 m
- Width	1.7 m
- Height	1.5 m
Materials of Packaging	
- Overpack	
- Outer Shell	Stainless Steel
- Shock Absorbing Material	Polyurethane Foam, Balsa Wood
- Neutron Shielding Material	Epoxy Resin
- Heat Release Fin	Copper
- Containment Vessel	Stainless Steel
- Fuel Holder	Stainless Steel, Rubber

Table 2. Summary of Drop Test Results

Name of Packaging	Item	Orientation	Deformation	Acceleration	Remark
Prototype Packaging A	9m Drop Test	Horizontal	Max. 48 mm	Max. 193 G	
	1m Puncture Test				
	- Around O-Ring	Horizontal	Max. 52 mm	Max. 76 G	
	- Center of Gravity	Horizontal	Max. 218 mm	Max. 19 G	Penetration
Prototype Packaging B	9m Drop Test	Vertical	Max. 78 mm	Max. 146 G	
	1m Puncture Test				
	- Center of Gravity	Vertical	Max. 95 mm	Max. 20 G	

Table 3. Summary of Fire Test Results

Name of Packaging	Position of Measurement	Temperature and Time from Beginning of Fire Test	Remark
Prototype Packaging B	Outer Shell	903 ℃ (0.5 hour)	
	Dummy Assembly		
	- Upper Side	72 ℃ (5.8 hour)	
	- Lower Side	46 ℃ (9.2 hour)	
	Inner Lid		Usable Temperature of
	- Double O-Rings	58 ℃ (4.4 hour)	O-Ring : 280 ℃
	- O-Ring of Sampling Valve	48 ℃ (10.8 hour)	280 ℃