DEVELOPMENT OF A SHIPPING CASK FOR CHOPPED FUEL PRODUCED BY POST-IRRADIATION EXAMINATION

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Abstract

DEVELOPMENT OF A SHIPPING CASK FOR CHOPPED FUEL PRODUCED BY POST-IRRADIATION EXAMINATION.

In Japan, post-irradiation examination (PIE) of nuclear fuels is being carried out quite frequently and the number of chopped fuel rods resulting from this has been increasing every year. The Power Reactor and Nuclear Fuel Development Corporation (PNC) has developed a shipping cask, P-3S(12T), to transport these chopped fuel rods from the PIE facilities to the PNC reprocessing plant at the Tokai Works. The cask consists of three independent vessels, the inner, intermediate and containment vessels. Intended to be handled at existing facilities, this cask has distinctive structural features that enable the fuel to be loaded vertically by using winches at PIE facilities. The fuel can be unloaded horizontally by using thrust rods at the reprocessing plant. Moreover, this cask is designed to prevent leakage of radioactive materials by maintaining the cask cavity at a negative pressure during transportation.

1. INTRODUCTION

Post-irradiation examinations (PIE) are carried out to determine the characteristics of fuel which has been irradiated in nuclear reactors. After PIE, fuel specimens are generally chopped into pieces a few centimetres long and the pellets are exposed to the air. There are two ways of transporting spent PIE specimens from 'hot' laboratories to the reprocessing plant. One is to enclose the chopped fuel specimens in new fuel cladding, to keep them intact, and then transport, them using a conventional spent fuel shipping cask. Another method is to ship them as they are, in a special shipping cask.

The Power Reactor and Nuclear Fuel Development Corporation (PNC) has developed a special spent fuel shipping cask, P-3S(12T), which will transport PIE specimens from hot laboratories to the PNC's reprocessing plant at the Tokai Works. The characteristics of the cask are as follows:

(1) It has its own lifting devices within the containment system, which simplifies handling at laboratories. The contents can be loaded or unloaded both from the top of hot laboratories, with the cask placed on them vertically, and also from the walls of laboratories, with the cask attached horizontally.
(2) The cask containment consists of three independent vessels, the containment, intermediate and inner vessels. The containment vessel is designed to keep inner pressure negative during transportation so that there is no release of radioactive materials. Various demonstration tests have been carried out under normal and accident conditions and the leaktightness and negative pressure of the cask have been confirmed.

2. OUTLINE OF THE P-3S(12T) CASK

Figure 1 shows a cutaway view of the cask, which consists of three vessels, lifting devices, side neutron shielding and impact limiters. The three vessels are all independent within the containment system. The sealing materials of the containment vessel are a graphite gasket for the shutter cover and fluoride rubber O-rings for other penetrations. A fluoride rubber lip seal is used for the intermediate vessel and a metal C-ring (Helico-flex) is used for the inner vessel. Loading and unloading of the intermediate vessel to and from the laboratories are done through the sluice door. Figure 2 shows the construction of the packaging.

The specifications of the cask and its contents are as follows:

(1) Type of package: B(U) fissile class 1
(2) Maximum weight of package: 15 t
(3) Materials:

Containment vessel:	Stainless steel
Intermediate vessel:	Stainless steel
Inner vessel:	Stainless steel
Neutron shielding:	Resin
Impact limiter:	Balsa wood covered with stainless steel

(4) Contents:

Quantity of fuel:	20 kg of UO_2 or mixed oxides (MOX)
Enrichment (max.):	5%
Average burnup (max.):	40 000 MW·d/t
Cooling time (min.):	730 d
Decay heat (max.):	130 W

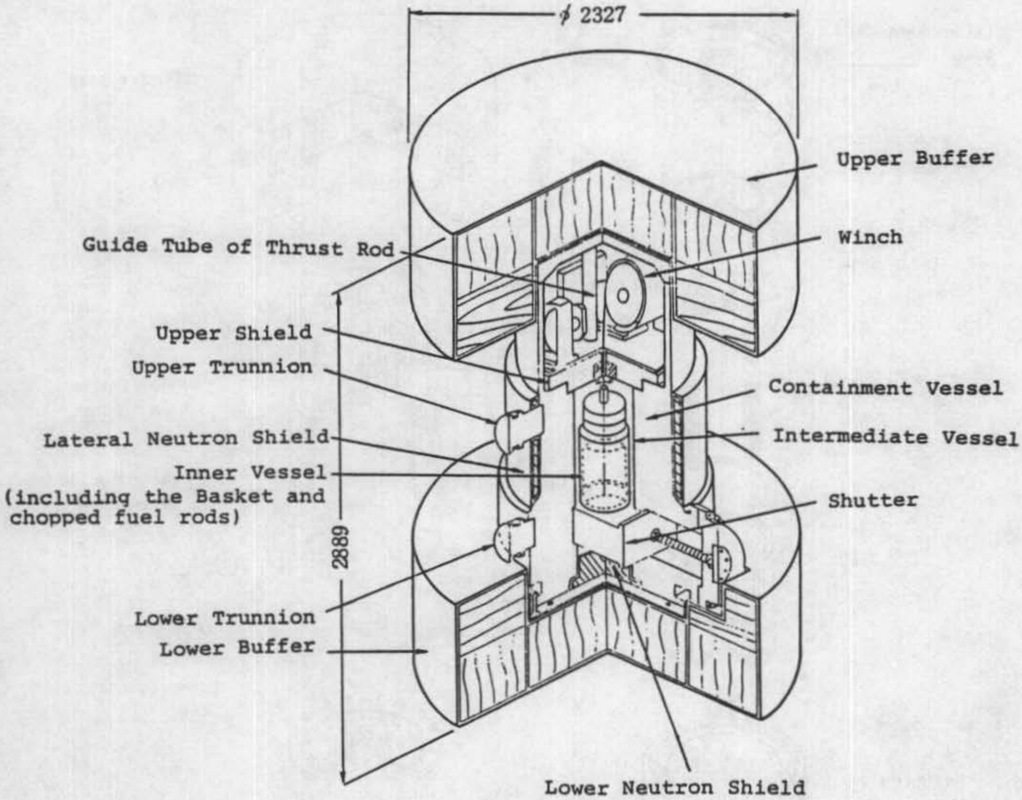

FIG. 1. Cutaway of the P-3S(12T) cask (dimensions in mm).

3. HANDLING OF THE CASK

The cask is designed to be handled at hot laboratories and at the PNC's reprocessing plant. It should be noted that the loading process at the reprocessing plant is quite different from the procedure for ordinary LWR spent fuel. The handling procedures at hot laboratories and at the reprocessing plant are as follows.

3.1. Handling at hot laboratories (Fig. 3)

First the cask is placed on the gamma gate of the cell ceiling, with the bottom lid off. Keeping the gamma gate and the sluice door open, the intermediate vessel is lowered into the hot cell by the lifting device of the cask. The PIE specimens are put in the sintered metal basket and then in the inner vessel in the hot cell before the intermediate vessel is placed in the cell. The lid of the intermediate

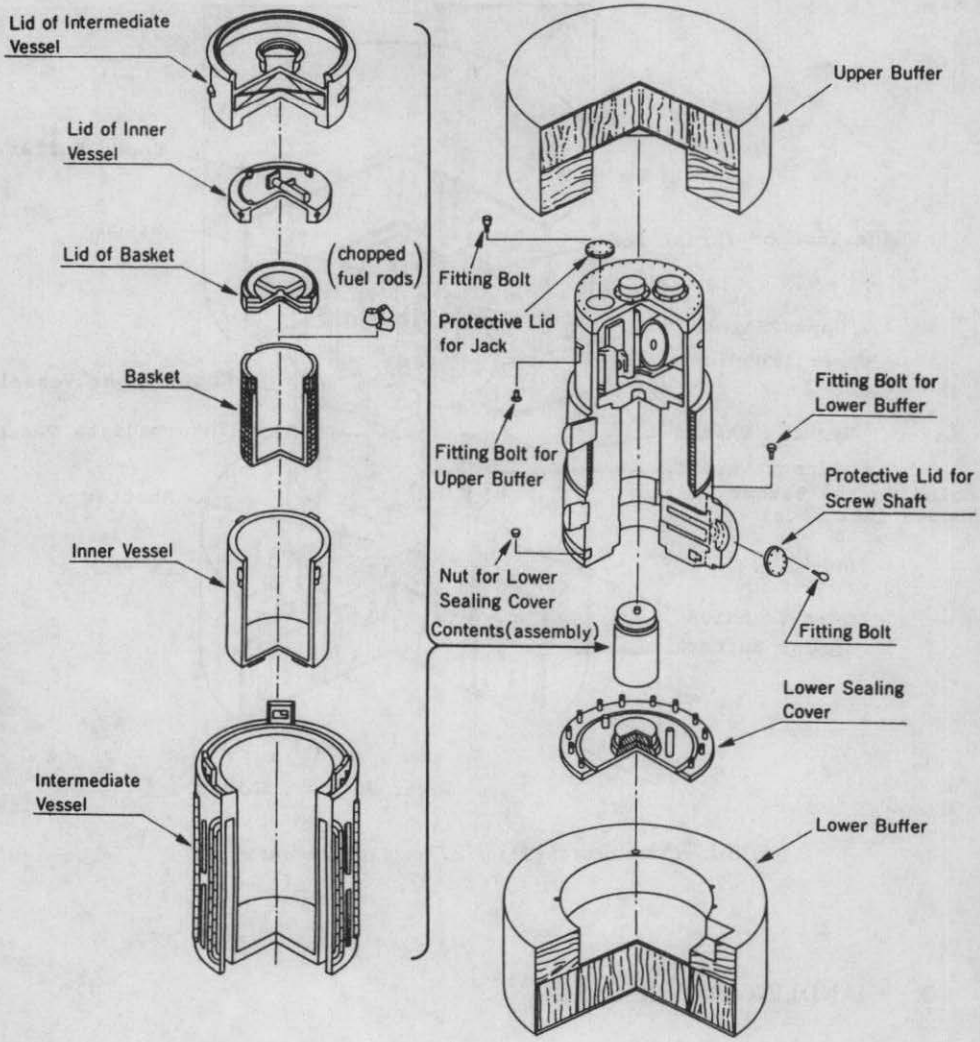

FIG. 2. Composition of the cask.

vessel is opened and the inner vessel, with the specimens in the basket, is loaded into the intermediate vessel. The leaktightness of the intermediate vessel is then checked in the cell using vacuum methods.

3.2. Handling at the reprocessing plant (Fig. 4)

The cask is mounted on a self-powered vehicle, which is specially designed for the cask and is fitted to the gamma port of the dissolver loading cell (DLC). The intermediate vessel is then unloaded into the DLC through the sluice door

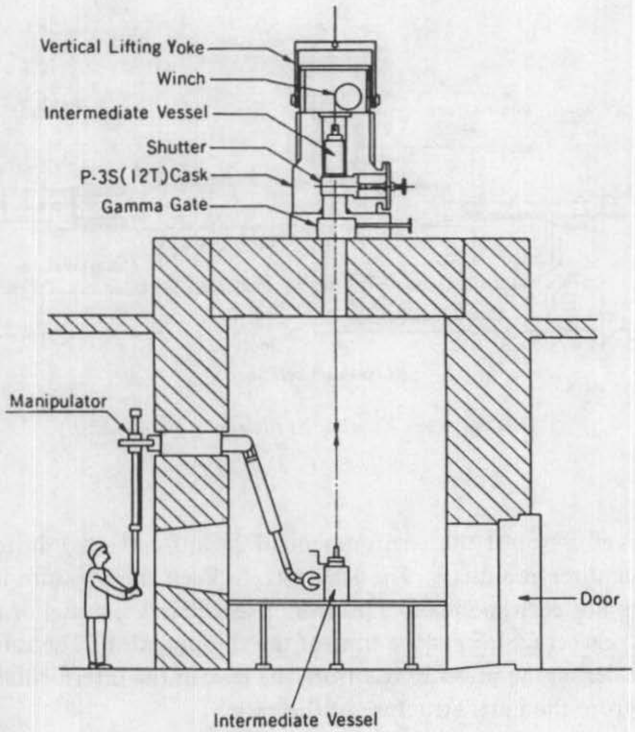

FIG. 3. Cask handling at the hot laboratory.

and gamma port by the thrust rod. The vessel has rollers to make the movement of the vessel smooth and it is fitted to the existing tilting device in the DLC, which is then turned upright. The inner vessel is taken out in the DLC and opened and the specimens in the metal basket are then thrown into the melting pond.

4. DESIGN PHILOSOPHY OF THE CONTAINMENT SYSTEM AND A DEMONSTRATION TEST

4.1. Design philosophy

The P-3S(12T) cask consists of three vessels, each having independent containment functions. In addition, the containment vessel is designed to keep negative pressure during transportation so that no release of radioactive materials to the environment will take place. The containment system is designed to keep its leaktightness under normal transportation and accident conditions. The containment vessel is evacuated to less than 1 mmHg before shipment and the vessel keeps

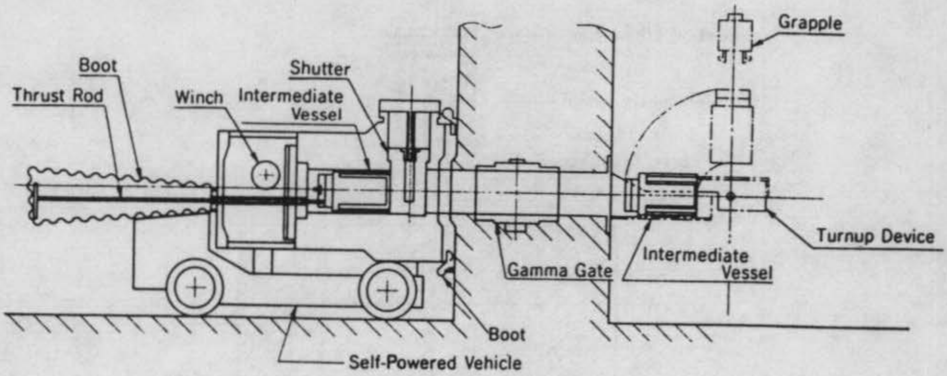

FIG. 4. Cask handling at the reprocessing plant.

negative pressure against the environment (0.25 kgf/cm^2 abs) during transportation for three months.[1] The leak rate to keep the pressure less than 0.25 kgf/cm^2 abs corresponds to a pressure rise rate in the vessel of 0.01 mmHg (1.36×10^{-6} kgf$\cdot$cm$^{-2}\cdot$h^{-1}) at the time of the shipping test. The value is determined also by considering the pressure rise from the leak in the intermediate vessel and 'de-gassing' from the inner structure of the cask.

4.2. Demonstration test

To demonstrate that the cask would keep its leaktightness and negative pressure under design conditions, the following tests were performed.

(1) Packaging performance test. A packaging performance test was carried out in order to prove that the four types of gasket (the fluoride rubber O-rings, the graphite gaskets, fluoride rubber lip-type gaskets and metal C-rings) used for the containment, the intermediate and the inner vessels, maintained their integrity under the design conditions.

(2) Measurement of the amount of de-gassing from 'inner' devices. The purpose of this test was to measure the amount of de-gassing from the inner parts of the containment, i.e. the metal surface, the lifting device (motor, oil, electric cable, winding-up wire, etc.) and the packaging under test temperatures and to obtain data to evaluate the influence of de-gassing on pressure increases.

(3) Mock-up test. The above-mentioned tests were carried out only on certain parts of the cask. Therefore, a demonstration test, with a mock-up model

[1] 1 kgf/cm^2 abs = 9.807×10^4 Pa.

simulating the actual cask's inner size, structure and materials, was performed to evaluate the scale-up error of the above tests and also to confirm that the cask was leaktight.

The tests showed that the maximum inner pressure of the cask was 0.18 kgf/cm^2 abs under design conditions and was less than the external pressure (0.25 kgf/cm^2 abs). It was also demonstrated that the cask had the required degree of leaktightness and that no leakage of radioactive materials would take place during transportation.

5. CONCLUSION

The P-3S(12T) cask facilitates the shipment of spent fuel specimens after PIE, hitherto considered difficult. No release of radioactive materials to the environment is anticipated from the use of this cask. The demonstration tests for the cask also provided a great deal of useful information, not only on the P-3S(12T) cask itself, but also on general cask design, on the leaktightness of gaskets and on de-gassing from the cask inner materials at elevated temperatures and under vacuum.