Design of High Performance Spent Fuel Shipping Cask

Ichizo KOKAJI[1], *Kenichi TANAKA*[2] *and Akio FUKAZAWA*[3]

[1]The Kansai Electric Power Co., Inc., Japan
[2]The Tokyo Electric Power Co., Inc., Japan
[3]Nuclear Fuel Transport Co., Ltd., Japan

INTRODUCTION

The construction plan for the Rokkasho reprocessing plant has been realized, and the preparation for the transportation of spent fuel to the plant is also being carried out aiming at the commencement of the plant operation.

On the other hand, a high burn-up plan for long cycle operation of power plants has been greatly progressed. The majority of the spent fuels transported to the Rokkasho plant are expected to be the high burn-up fuel.

To reduce the transport frequency by improving transport efficiency, the High Performance Spent Fuel Shipping Cask (HP-Cask) has been developed for optimum use of the cask-handling capacities of all power plants in Japan.

High burn-up of fuel will accompany higher enrichment, greater radiation intensity and greater decay heat, and therefore radiation shielding will necessarily become thicker and external fins higher than the existing casks, and the contents (number of fuel assemblies) tend to be fewer.

Consequently, the following policy for design of the HP-Cask was decided to increase the transport efficiency:

* to use neutron absorbing material in the basket lattice
* to extend the fuel cooling time as long as possible

It was found that the power plants in Japan could be appropriately classified into six groups with respect to their cask-handling capacity. Therefore, six types of HP-cask have been developed based on the same design concept. The present paper mainly describes the large type of HP-Casks.

GENERAL REQUIREMENTS

Design requirements were decided prior to the start of developments. Within the requirements, the HP-Cask was designed for maximum contents.

High burn-up fuel specifications

The specifications are shown in Table 1 for PWR and BWR fuel, respectively. The burn-up and enrichment were determined to take into account both present and future high burn-up plan of the fuel. Cooling time was determined based on the storage capacity of each power plant.

Limits for dimensions and weight

Based on the power plants and the reprocessing plant cask-handling capacities, the limits were classified into two cases for PWR and 4 cases for BWR as shown in Table 2.

Contents(number of fuel assemblies)

Among the existing casks for use in Japan, the TN-12 cask has the greatest capacity. It contains 12 PWR or 32 BWR fuel assemblies. Considering this fact, the target contents of large type HP-Casks were set as shown in Table 3.

BASIC SPECIFICATIONS FOR HP-CASK

Aiming at improving the transport efficiency including the increase of contents, the basic specifications were discussed and decided as described below.

Exclusive use of cask

Existing casks are designed for non-exclusive use of casks which can load either PWR or BWR fuel by exchanging the fuel basket. However, the HP-Casks were designed for an exclusive use of cask for the reasons described below.

(1) BWR fuel assembly is longer than the PWR and non-exclusive cask for PWR would have an excess void in the cask cavity.

(2) Even though the existing casks are designed for non-exclusive use of casks, the same cask is not actually used for both fuel types in Japan except PIE casks.

Wet type of cask

Comparison between the wet type cask, whose cavity is filled with water and dry type cask, whose cavity is dried up before transportation, was carried out from the viewpoint of transport efficiency.

It is concluded that the handling time of wet type is shorter than the dry type and the former is superior to the latter for domestic transportation in which turn-around time is rather short.

Cask materials
Cask materials were compared from the viewpoint of the contents : lead-steel-resin, steel-resin and lead-steel-water. For PWR, whose fuel cooling time is rather shorter, lead-steel-resin were superior to the others. For BWR, whose cooling time is rather longer, the lead-steel-resin and steel-resin are superior to the other.

Based on the results, lead-steel-resin was adopted as the constituent material for PWR casks. Steel-resin was adopted for BWR casks because the structure of steel-resin is simpler than that of lead-steel-resin.

DESIGN FEATURES

The HP-Casks were designed to comply with the IAEA transport regulations of the 1985 edition. Main features are described as follows.

Shielding thermal and criticality design
The effect of the high burn-up fuel on the cask design and the design considerations for the effect were summarized in Figure 1 as described below.

(1) Shielding
Increase of gamma ray intensity was controlled by extending the cooling time as much as possible. Increase of neutron intensity is important for high burn-up fuel and it cannot be reduced by cooling time extension. Therefore the neutron shield was increased to reduce the neutron dose equivalent to less than 20% of total dose equivalent, which makes it more flexible for future fuel. Epoxy-resin, which is one of the best neutron materials, was adopted for neutron shielding material.

(2) Thermal
Increase of decay heat of the fuel was reduced by extending the cooling time as much as possible. Decrease of radial heat conduction caused by low thermal conductivity of neutron shielding resin was compensated for by embedding the straight copper fins in the resin.

(3)Criticality

As the fuel enrichment of both PWR and BWR is higher, neutron-absorbing material was used to keep the system subcritical. High density lattice arrangement was adopted for BWR to maximize the contents. On the other hand, water gap was arranged around each lattice of PWR because its reactivity was higher than that of BWR.

Boronated stainless steel was selected for neutron absorbing material, and is also used as the structural material of the basket

Handling

As described above, the HP-Casks are exclusively used and their constituent materials depend on whether PWR or BWR; however, they were designed to be handled and maintained in the same manner and with the same equipment.

OUTLINE OF THE HP-CASK

The outline of the PWR large cask is illustrated in Figure 2.

The cask consists of cask body, fuel basket and impact limiters. The cask body incorporates a containment vessel and its components are a multi-layer shell body and forged lid. The basket keeps the fuels in the proper position in the cask cavity and the impact limiters are attached to both ends of the cask body for transportation .

Impact at the 9m drop is absorbed by both impact limiters and external fins. Decay heat is conducted from cavity water to cask body and dissipated from the external fins to the ambient air. Gamma ray shielding materials are structural steel and lead, and neutron shielding materials are cavity water and epoxy resin. Containment boundaries of the cask are lid seal and valves where leak test will be performed prior to shipment. Four trunnions are attached to the upper part of the cask body and are used for horizontal and vertical lifting, and two trunnions are attached to the lower part of the cask body and are used for horizontal lifting and tilting.

The dimension and the weight of the HP-Casks are summarized in Table 4. In addition to the PWR and BWR large type, the data of medium and small type casks are also shown in the table and were developed to comply with the power plants of smaller cask-handling capacities.

Table 1 Fuel Specification

	Enrichment(w%)	Average Burn-up(MWD/MT)	Cooling Time(month)
PWR	4.2	≤ 44000	21 (for large type) 15 (for small type)
BWR	3.6	≤ 40000	35 (for large type) 19 (for medium and small types)

Table 2 Limits for Dimensions and Weight

Case		Outer Dia. of Impact Limiter (m)	Outer Dia. of Cask Body (m)	Package Length (m)	Maximum Operating Weight (ton)
PWR	1	2.6	2.5	6.25	115
	2	2.6	2.1	6.25	80
BWR	1	2.6	2.6	6.5	125
	2	2.6	2.35	6.5	115
	3	2.6	2.1	6.5	100
	4	2.6	1.8	6.5	75

Table 3 Contents Requirement

	Required Number
PWR(large type)	more than 12
BWR(large type)	more than 32

Table 4 Main Particulars of HP-Casks

	Outer Dia. of Impact Limiter (m)	Outer Dia. of Cask Body (m)	Package Length (m)	Vertical Lifting Weight (ton)	Contents
PWR (Large type)	2.6	2.5	6.2	111	14
PWR (small type)	2.6	2.0	6.2	80	10
BWR (large type 1)	2.6	2.5	6.4	121	38
BWR (large type 2)	2.4	2.3	6.4	110	32
BWR (medium type)	2.6	2.1	6.3	96	22
BWR (small type)	2.3	1.8	6.4	69	12

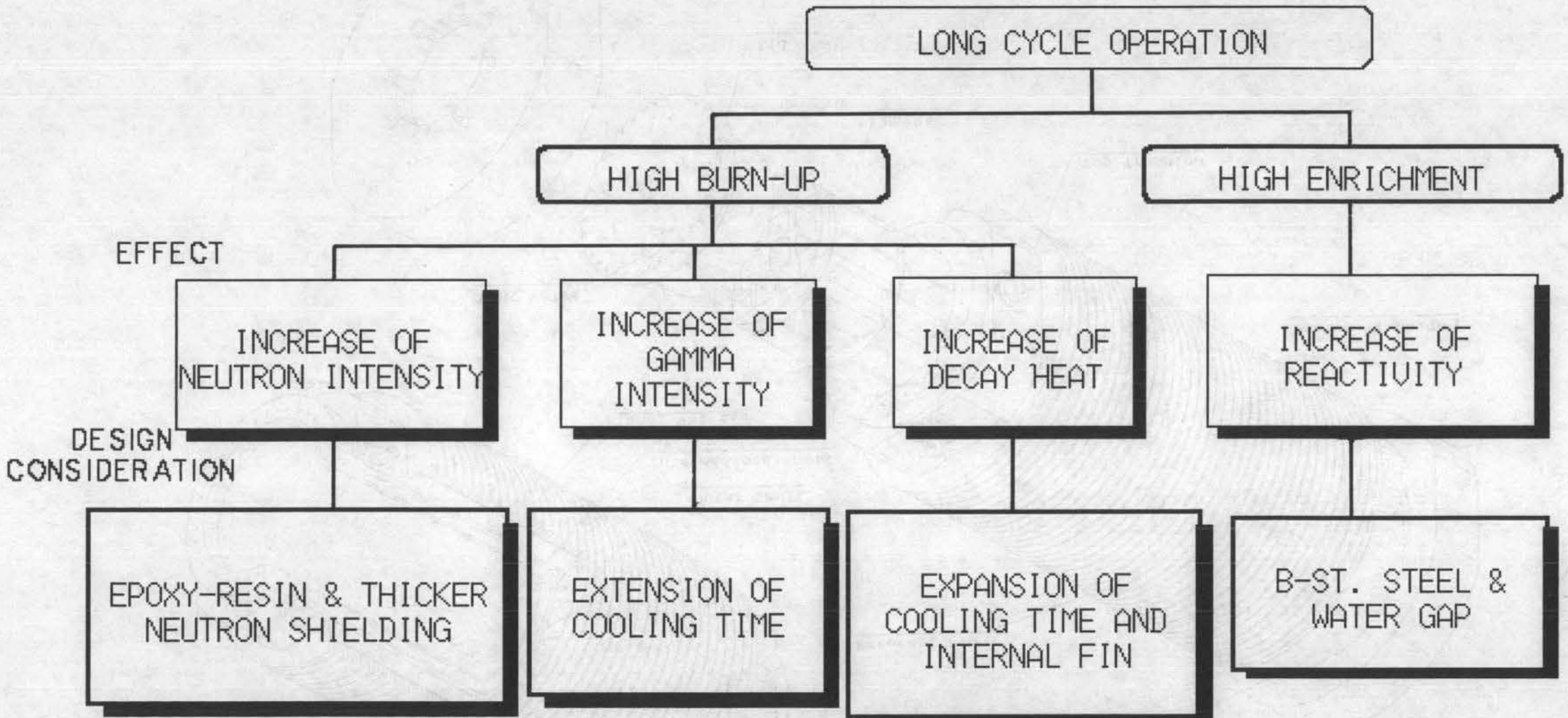

FIG.1 EFFECT OF LONG CYCLE OPERATION ON DESIGN

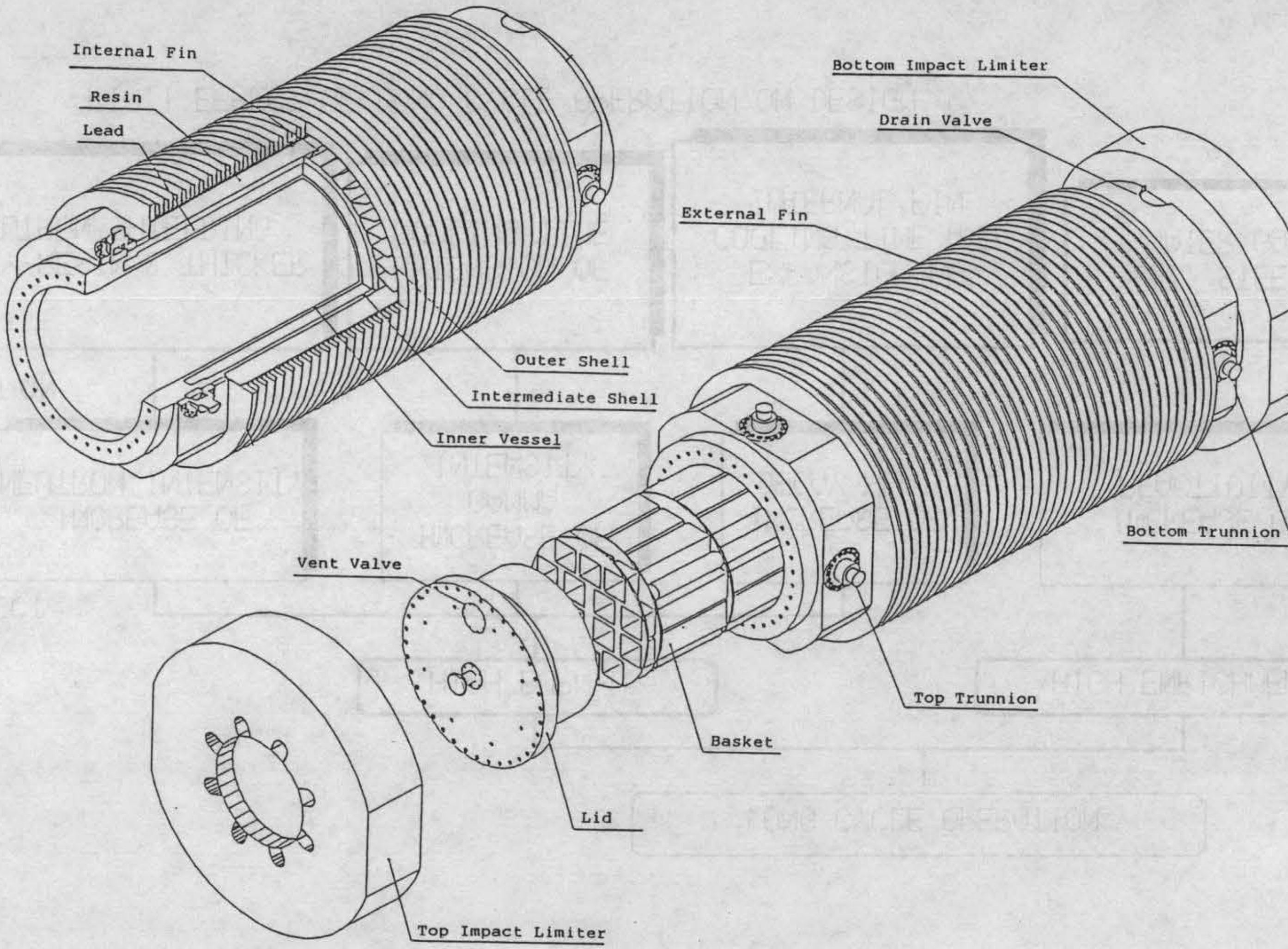

Figure 2 PWR Large Type HP-Cask