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DEVELOPMENT OF TK-26, NEW GENERATION TRANSPORT AND STORAGE CASK FOR PWR SPENT FUELS

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ABSTRACT

The design of TK type transport and storage cask for BWR spent fuels such as TK-69, TK-52 are completed and the safety analysis has been performed. Now, TK type for PWR spent fuels, named TK-26 transport and storage cask is under development using the experience on TN24 series.

The demand of higher safety of spent fuel dry storage from customers is being expected. Then, TK-26 has new structure with higher safety, maintaining large fuel capacity and higher economical advantage. One of the features of TK-26 structure is the introduction of the newly developed borated aluminum structure focused on PWR fuels. This structure enables us to design new basket having higher sub-criticality ability and higher structural strength with keeping enough heat transfer ability using very compact structure. Another is the countermeasure for the slap-down test and the impact of the delayed drop of contents at 9m vertical drop test. The effect of this countermeasure is confirmed by the drop test using a 1/3 scale model, and validity of structural safety analysis method is also confirmed.

As expand of the demand for storage casks is expected, study for standardization of the design of casks is being conducted to ensure flexibility of supply of several type of casks and stable supply. This paper explains the main feature and the effectiveness of TK-26 structure.

INTRODUCTION

Transport and storage cask need to satisfy both of transport and storage regulation, and demand of higher safety of the spent fuel dry storage is being expected in the world. In addition, the requirements against transport and storage cask in Japan are more severe than other countries. For example, 1) With respect to the dose rate limitation around a cask, the dose rate at 1m from cask surface is limited less than 100μSv/h in Japan, instead of the same dose rate at 2m by the IAEA transport regulation. 2) The allowable temperature of fuel cladding during storage is 300°C for BWR and 275°C for PWR in Japan. These temperature limitations are lower than that in Europe and the US. 3) As no equipments and no facility for opening the lid of casks are prepared in the interim storage facility for spent fuel casks in Japan, preparation of tertiary lid becomes necessary condition for transport and storage cask. This is because casks need to be transported with the tertiary lid if the leak tightness of the primary lid has any problem during storage period.

Considering these additional requirements, the design of TK type transport and storage casks for BWR spent fuels such as TK-69, TK-52 are completed and the safety analysis has been performed[1]. Now, TK type for PWR spent fuels, named TK-26 cask is under development.

1. BASIC DESIGN OF TK TYPE TRANSPORT AND STORAGE CASK

The origin of TK type transport and storage cask is the TN24[2], originally developed by TN International and Kobe Steel in 1985. After that, many TN24 series are designed and fabricated. Now, the series of TN24 is the most selling forged steel type transport and storage cask in the world, and the experience of fabrication, transport and storage confirms us the reliability of TN24. The basic structure of TK-26 is comes from TN24 design. This means that the main design feature except the material and modified structure explained in the following chapter is based on the experience of design and fabrication of TN24 series. The design of TK-26 is progressed as new generation cask by introducing newly developed materials, new licensing knowledge, and lesson learned from the fabrication and operational experiences.

2. NEW FEATURE ON TK-26 NEW GENERATION TRANSPORT AND STORAGE CASK

Table 1 shows the main feature of TK-26 cask, and Figure 1 shows the bird's-eye view of TK-26 under transport condition, and newly developed basket for TK-26. TK-26 has new structure to achieve higher safety, maintaining large fuel capacity and higher economical advantage. This cask satisfies all additional requirements in Japan as mentioned before.

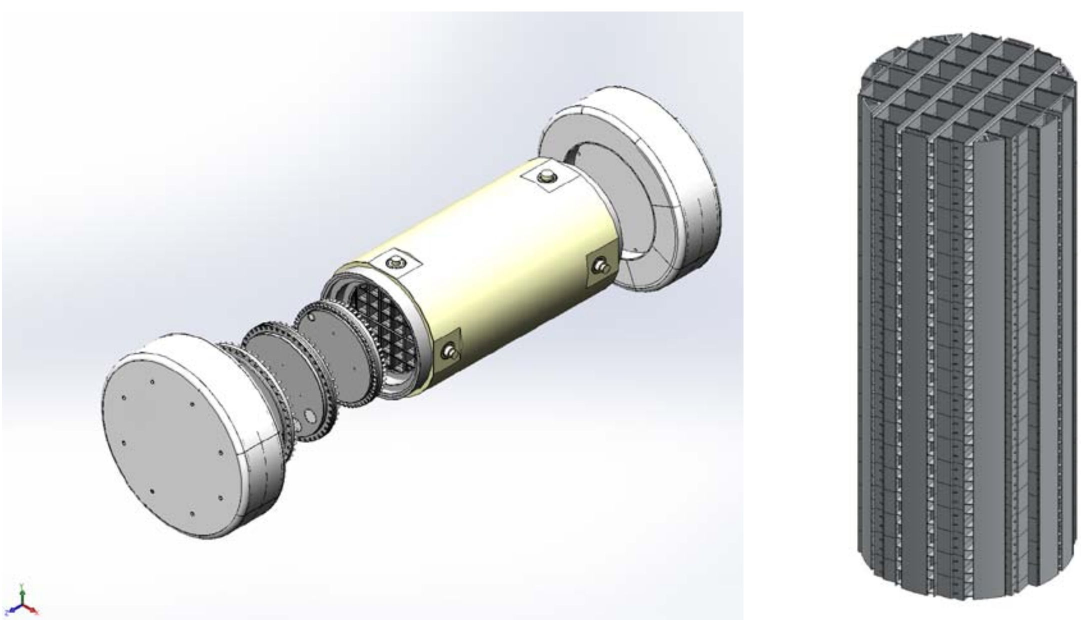
One of the features of TK-26 structure is introduction of the newly developed borated aluminum structure focused on PWR fuels. This structure enables us to design new basket having higher sub-criticality ability and higher structural strength with keeping enough heat transfer ability using very compact structure.

Another is the countermeasure for the slap-down test and the impact of the delayed drop of contents at 9m vertical drop test. The structure of lid and flange part including shock absorbing cover is modified.

As expand of the demand for storage casks is expected, study for standardization of the design of casks is being considered to ensure flexibility of supply of several type of casks and stable supply. This can be achieved by using two different types of neutron shielding materials.

Table 1. Feature of TK-26 transport and storage cask

Fuel specification	
Fuel type	17x17 and 15x15
Maximum burn up	48,000 MWd/tU
Minimum cooling time	15 years
Number of fuel loaded	26assemblies
Design thermal power	20kW/cask
Dimension	
Storage condition	
Total length	5.1m
Outer diameter	2.6m
Transport condition	
Total length	6.5m
Outer diameter	2.6m
Weight	
Under storage	120ton
Under transport	132ton
Temperature of fuel cladding	239°C(storage condition)
Dose rate at1m from cask	86μSv/h(2 dimensional SN calculation)
Keff+3σ	0.92(assumption : fresh fuel)



(a) Bird’s-eye view of TK-26 **(b) New basket for TK-26**

Figure 1. Feature of TK-26 transport and storage cask

2.1 New basket material and design

Our conversional borated aluminum alloy called "1%B-A6061-T651" [4] is registered to the code case of Rules on Transport and storage Packagings for Spent Nuclear Fuel, JSME S FA1-2007[3], (here after called "the JSME code") in 2009. This material is rolled plate. In 2013, newly developed extruded borated aluminum alloy called "1%B-A3004N-H112" [5] is also registered to the code case of the JSME code. This material is focused on PWR fuels and has higher strength in elevated temperature, and has advantage especially in designing basket with water gaps for PWR fuels because it can be manufactured with various cross-sectional shapes by extruding. This shape enables us to design new basket having higher sub-criticality ability and higher structural strength with keeping enough heat transfer ability using very compact structure as shown in Figure 2.

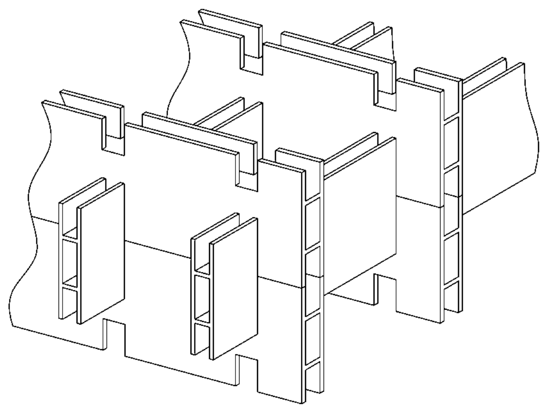


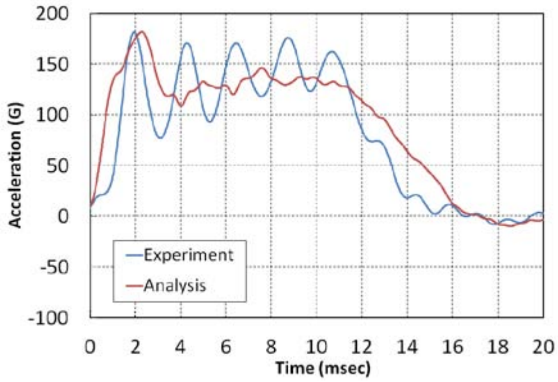
Figure 2 Conceptual view of basket structure with using 1%B-A3004N-H112

2.2 New feature against 9m drop test

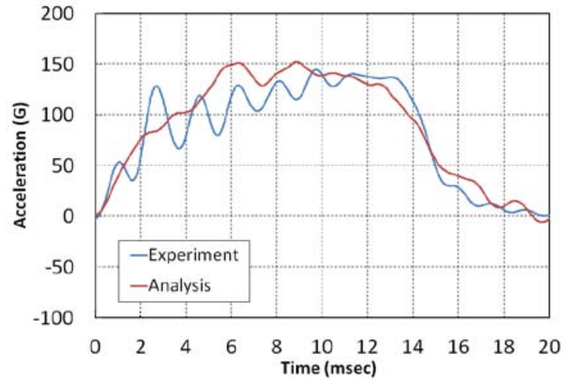
With respect to the leaktightness of lid, it becomes to be known as the acceleration by the slap-down test is sometimes higher than that of the horizontal drop test. Just before the 9m vertical drop test, the contents are touch on lid. But after starting free fall, the contents are not staying on lid, but moving in the cavity of the cask because of the force by spring back of lid just after starting free fall. This phenomenon creates delayed impact to the lid by the contents, and this impact is additional impact to the lid during vertical drop test [6]. The countermeasure for the slap-down test and the impact of the delayed drop of contents at 9m vertical drop test is considered in the design of TK-26. The structure of lids and flange part including shock absorbing covers is modified for this purpose.

The countermeasure for the slap-down test is already introduced for the design of TK-69, and the effect of this countermeasure is confirmed by the drop test using a 1/3 scale model [7]. Validity of structural safety analysis method for these drop tests is also confirmed [8]. Figure3 shows the comparison of measured and calculated acceleration during each drop test for some points. The good agreement is observed.

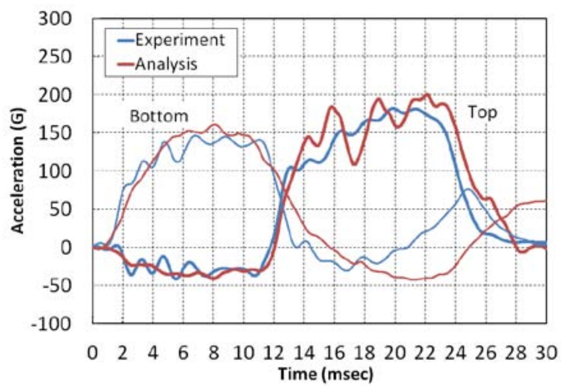
Of cause, countermeasure for the impact of the delayed drop of contents at 9m vertical drop test is already introduced for the design of TK-69, but the more effective design is plan to be introduced in TK-26. Additional drop test using a 1/3 scale model is performed recently. The results of these drop tests and comparison of measured data with analysis will be reported near future (maybe in the next PATRAM), but this new structure has been introduced in the design of TK-26.



(a) Vertical drop test (lid)



(b) Horizontal drop test (center of body)



(c) Slap down test (lid and bottom of body)

Figure 3. Comparison of acceleration during 9m drop test

2.3 Flexibility of fuel specifications loaded in cask

Two neutron shielding materials such as TN Vyal B™ (here after called “Vyal B”) and Kobesh EPR™ (here after called “EPR”) are planning to be used for TK-26. Vyal B is developed by TN International and EPR resin is developed by Kobe Steel. The necessary data of these materials to apply for the transport and storage cask in Japan has been already obtained [9].

1) Difference of Vyal B and EPR

These two neutron shielding materials have very different characteristics. Namely, Vyal B is composed of vinylester resin in a solution of stylene, aluminum hydroxide and zinc borate. Vyal B is pouring type. It means this material can be pouring directly into cask, or pouring into mold to make a certain shape of resin blocks. It has hard surface and the density is heavier (about 1.8g/cm^3).

On the other hand, EPR is Ethylene-Propylene-Rubber based resin. EPR is needed to be pre-shaped with heated press. It means this material can be used as only block type, but this is a kind of rubber, and it has very soft surface. This characteristic enables to make the gap between resin blocks, or between blocks and the fins penetrating the resin region, small enough to ignore the radiation streaming. The density is very light (about 1.2g/cm^3).

2) Shielding ability of Vyal B and EPR

a. In case of using same neutron shielding thickness

For example, the calculations of the dose rate at 1m from the surface of a cask at center of body assuming that the shielding thickness is the same for both materials, is performed and the results are shown in Table 2. The gamma dose rate by using EPR is around 50% higher than that of using Vyal B, but the neutron dose rate is around 40% lower than that. The total dose rate by Vyal B is a little smaller than EPR. This means that Vyal B has better total shielding ability than EPR, but EPR has better neutron shielding ability in this case.

b. In case of using different neutron shielding thickness to fit each neutron shielding material
When considering the light weight of EPR, if there is no severe limit for the outer diameter, thicker neutron shielding region can be acceptable up to having the same weight of the cask with Vyal B. For example, the comparison of dose rate at 1m from the surface of a cask at center of body when the total cask weight is the same, is shown in Table 3. The neutron dose rate when using EPR is extremely decreased.

Table 2. Dose rate at 1m from cask surface at center of body for Vyal B and EPR with same thickness condition

(unit : μSv/h)

	Vyal B	EPR
Neutron	31.3	23.0
Secondary gamma	12.1	17.9
FP gamma	21.3	33.6
Total	64.7	74.5

Table 3. Dose rate at 1m from cask surface at center of body for Vyal B and EPR with same weight condition

(unit : μSv/h)

	Vyal B	EPR
Neutron	31.3	6.2
Secondary gamma	12.1	14.2
FP gamma	21.3	25.1
Total	64.7	45.5

3) Effect to cask design
As known well, gamma dose rate is major in shorter cooling time, but later on, neutron dose rate becomes relatively larger, and neutron source intensity is very sensitive to burnup of spent fuel. Based on the calculation above, when the main structure is the same, the fuel specification that can be loaded in this cask is very different depend on the neutron shielding material chosen from these two materials. Namely, shorter cooling time is acceptable when Vyal B is used because this material has better gamma shielding ability. On the other hand, longer cooling time is necessary but higher burnup fuels are acceptable when EPR is used because this material has better neutron shielding ability.
In this case, if longer cooling time is set, higher burnup fuel specification is accepted when EPR is used. With respect to the safety analysis, when Vyal B is replaced by EPR, only the additional shielding analysis is necessary, but other safety analyses may be the same with using Vyal B. This work load is not so much.
Furthermore, when considering the light weight of EPR, thicker neutron shielding region can be acceptable. The outer diameter becomes larger, but the weight of the cask may be the same with

that using Vyal B. With respect to the safety analysis, additional thermal, structural, and shielding analysis is necessary, but the main design has no change. This means that minor modification makes it possible to prepare new cask design with higher burnup specification.

As shown here, the variety of fuel specification to be loaded in a cask can be obtained easily by only replacement of neutron shielding material. This means that this cask has flexibility to satisfy customer's demands.

CONCLUSIONS

The TK-26 transport and storage cask for PWR fuel assemblies is under development by using the experience of TN24 series which is the most selling forged steel type transport and storage cask in the world. The design of TK-26 becomes new generation cask by introducing newly developed materials, new licensing knowledge, and lesson learned. TK-26 has flexibility to satisfy customer's demands.

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