Fabrication of the Spent Fuel Casks for Tokai No. 2 Nuclear Power Station

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ABSTRACT

Storage of spent fuel in dry casks at Tokai No. 2 Nuclear Power Station commenced in September, 2001. The fabricated seven metal storage casks have a multi-wall type cask body, a double lid system and a 61 fuel lodgment basket. These casks are the first in Japan to be stored in the vertical position.This paper discusses the general plan for spent fuel storage, the design specification of the cask, and several issues during licensing and fabrication stages.

INTRODUCTION

Tokai-2 Nuclear Power Station (NPS) is 1,100MWe BWR completed in 1978 and operated by The Japan Atomic Power Company (JAPC). The capacity of the spent fuel storage pool at Tokai-2 NPS was increased from 1,740 assemblies (2.3 cores) to 2,250 assemblies (2.9 cores) by re-racking carried out from 1992 to 1994. In addition to that, high burn-up operation plan was introduced to reduce spent fuels.

It is noted in the "Long-Term Program for Development and Utilization of Nuclear Energy" issued by the Japanese Atomic Energy Commission that, in principle, spent fuel produced in domestic nuclear power stations should be reprocessed in Japan. In accordance with this policy, spent fuel assemblies discharged from Tokai-2 were shipped to Tokai and European reprocessing plants, and from the end of last year are being shipped to the storage facility at the Rokkasho reprocessing plant owned by Japan Nuclear Fuel Limited (JNFL). Rokkasho, still under construction, will be Japan's main reprocessing facility.

Even if these shipments, the completion of the facility construction, and subsequent consequent reprocessing were to stay on schedule, there would still be a gradual accumulation of spent fuel in Japan. Therefore, another spent fuel storage management scheme was established in 1995 and a Dry Cask Storage Facility was constructed at Tokai-2 NPS.

DRY CASK STORAGE FACILITY AT TOKAI-2

Taking into consideration both economical efficiency and cask handling capacity of Tokai-2 NPS, a storage cask with a capacity of 61 BWR assemblies was developed for the Dry Cask Storage Facility. The facility is one of the larger on-site spent fuel storage facilities in Japan, with a planned capacity of 24 casks. The facility consists of a storage building, an overhead crane and monitoring systems. After completion of the facility, the spent fuel storage capacity of Tokai-2 NPS is increased to 3,714 fuel assemblies (4.9 cores). A birds-eye view drawing and outside of the facility are shown in Figure 1.

The project to construct this Dry Cask Storage Facility was started in 1995, with a geological examination of the facility ground. The safety examination by Japanese competent authority was finished in March 1998, and the permission for construction of the facility was given in September 1999. Construction of the building and fabrication of the first 7 casks began in September 1999 and was completed in July 2001.

OUTLINE OF THE STORAGE CASK

The design policies of the cask are:

1. To maximize the number of spent fuel assemblies in the cask utilizing the existing capacity of the cask handling equipment at Tokai-2 NPS and considering the allowable cooling period of the spent fuel.
2. To conform to the safety standards for a dry storage cask established by the Japanese competent authority.

The cask is consists of a cask body with multi layers, a double lid system and a fuel basket. The cask body consists of three cylinders (inner, intermediate and outer shells), a bottom plate and a upper flange, which are made of Type 304 stainless steel as structural material. The major shielding of the cask is lead for gamma shielding and resin for neutron shielding. The primary lid and the secondary lid are fixed to the upper flange by bolts. The containment boundary is made of the inner shell, bottom plate, upper flange, primary lid and valve covers that are on the primary lid. Double metallic O-rings are used for sealing. The cask configuration and detail of the sealing are shown in Figure 2.

Fuel assemblies are inserted into the compartments of the fuel basket, which are made of Type 5052 aluminum alloy shaped by roll forming method. To keep sub-criticality of the cask, borated aluminum is used for neutron absorbing material, sheets of which are inserted between the fuel compartments of the basket. The outer periphery of the compartments is Type 5052 aluminum block.

The cask cavity is dried and filled with helium gas to remove decay heat. Also, negative pressure is maintained in the cavity to contain radioactive materials over a design storage period of 40 years. The pressure of the narrow cavity between the primary and secondary lids is monitored to confirm the performance of the sealing materials and structure. The cask is vertically held down with four bottom screwed trunnions during storage.

SAFETY FUNCTION OF THE STORAGE CASK

Safety functions required of the storage cask are heat dissipation, containment, radiation shielding and maintenance of sub-criticality. The storage building of the storage facility also enhances the function of both radiation shielding and heat dissipation. The safety functions of the facility are illustrated in Figure 3.

Heat Dissipation: The decay heat of the spent fuel in the storage cask is removed through the basket and cask body to maintain the integrity of the fuel, structural members, sealing and radiation shielding materials. The basket is made of aluminum material and the cask cavity is filled with helium gas to obtain high thermal conductivity. The heat dissipated from the cask is removed from the storage building to outside atmosphere by natural convection.

Containment: The containment design of this cask aims to maintain a negative pressure in the cask cavity for up to 40 years of designed storage period. The pressure of the cavity between the primary and secondary lids, which is set to positive pressure, is monitored to check the integrity of the double metallic O-rings. The positive pressure between the lids also serves as a pressure barrier against the cask cavity, which is set to negative pressure. If leakage occurs at either of the metallic O-rings, a decrease of the pressure of the cavity between the lids is detected by a pressure monitoring system. The double O-ring system of the two lids is shown in Figure 2 above.

The integrity of the double metallic O-rings during the storage period of 40 years was confirmed by experiments carried out by the Central Research Institute of Electric Power Industry (CRIEPI). The critical period for the metallic O-ring under circumferential temperature of 150°C is calculated to be 190 years, which verified that the integrity of the metallic O-rings could be maintained much longer than the designed storage period.

Radiation Shielding: In accordance with the Japanese regulations for on-site transportation, the dose rates are limited to be less than 2mSv/h at the cask surface and less than 100ìSv/h at one meter from the cask surface under normal transport conditions.

Sub-criticality: The cask must be prevented from reaching criticality in any condition that the cask may encounter. Specifically, it is necessary that the neutron multiplication factor does not exceed 0.95 including any calculation errors. For this purpose, borated aluminum alloy plates are inserted in the fuel basket.

The boron content and its uniformly distribution in the aluminum metal is inspected by three different methods, a chemical analysis, a neutron penetrate test and a neutron radiography. Each piece of borated aluminum plate inserted into each fuel compartment of the basket is cut out from a large plate so from a quality assurance point of view, the competent authority confirms the traceability of each smaller plate to the original large plate.

FABRICATION OF THE CASK

Seven casks were fabricated in Ariake Works of Hitachi Zosen Corporation and were delivered to Tokai-2 NPS at the end of June 2001. Several topical fabrication processes are explained below.

Welding Copper Heat Transfer Fins: Figure 4 shows the MIG welding process to join the copper internal fins to both intermediate and outer shells. This is an important weld to secure the heat transfer path through the neutron shielding. The welding is carried out in a narrow space between the two shells so it was necessary to conduct that pre-qualification tests to determine the weld conditions and ability to complete a satisfactory weld.

Pouring Both Gamma and Neutron Shielding Material: Lead is poured between the inner and intermediate shells as a gamma shielding material. Figure 5 shows a lead pouring equipment. The water pipes on the surface of the equipment are used for controlling temperature to solidify the lead in controlled manner from the bottom to the top.

Figure 6 shows the poured neutron shielding material, NS4-FR. The supply and pouring as by NAC International in accordance with a procedure, which is accepted both US and Japanese competent authorities.

Fabricating the Basket: The basket is designed to maximize the number of fuel compartment made in the cylindrical cask cavity so severe fabrication tolerances were specified. The process that would create the least amount of distortion of the square tubes was selected.. The square tubes were fabricated by a roll forming method. Figure 7 shows the process to insert both the assembled square tubes and neutron absorbing materials into the aluminum block.

The aluminum block surrounding the square tubes consists of 6 forged blocks welded together by a electron beam welding method to avoid distortion.

The completion of the basket is shown in Figure 8.

ON SITE TRANSPORTATION

After loading the spent fuel at the fifth floor of the reactor building, the cavity of the cask is dried up and filled with helium gas. The cask is then tilted down on a trailer and transferred to the storage facility. The cask is tilted up at the storage facility in to the vertical position for storage.

SUMMARY

The spent fuels will be loaded in Autumn 2001.This facility is the first and orthodox on site cask storage facility in Japan which stores casks in the vertical position. Additional 8 casks have already been ordered and are under fabrication, due for delivery in November 2002.

REFERENCE

O. Kato, C. Ito and T. Saegusa, "Development of an Evaluation Method for Long-term Seal Ability of the Spent Fuel Storage Cask", Journal of Japan Nuclear Society Vol. 38, No.6, 1996

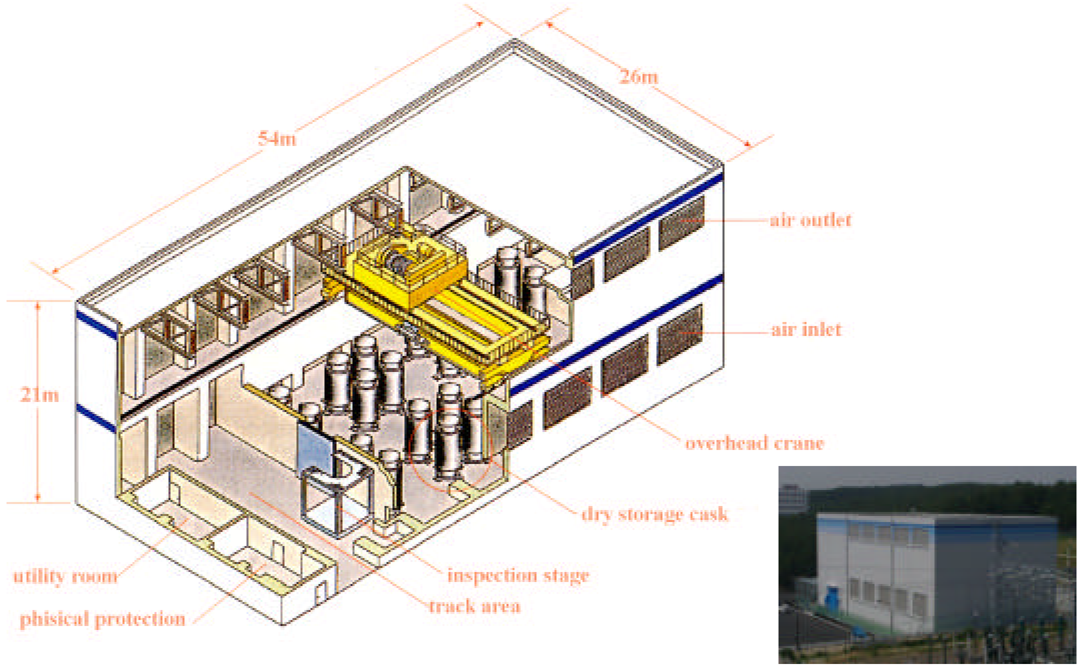

Figure 1, Tokai-2 Dry Cask Storage Facility

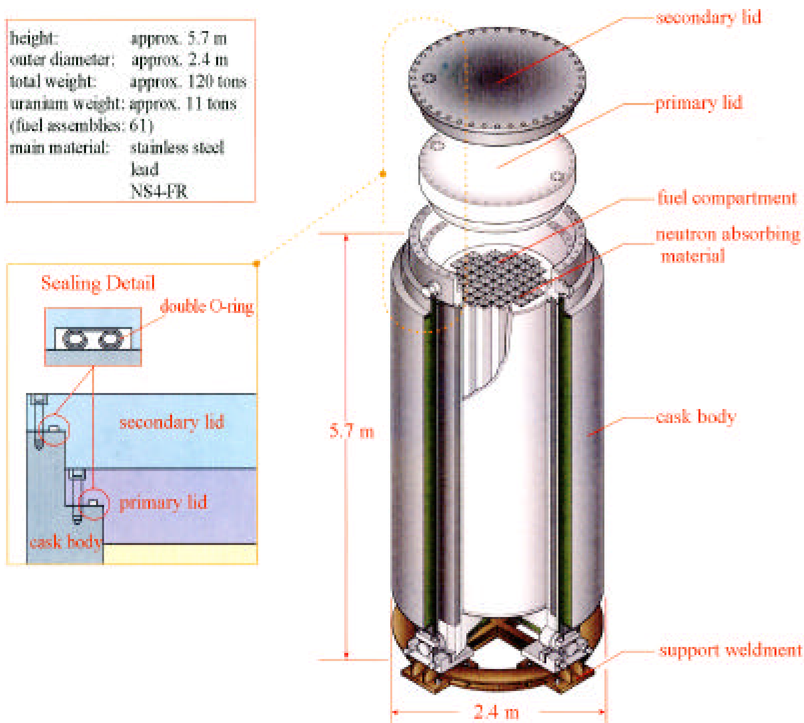

Figure2, Dry Storage Cask and Detail of Sealing

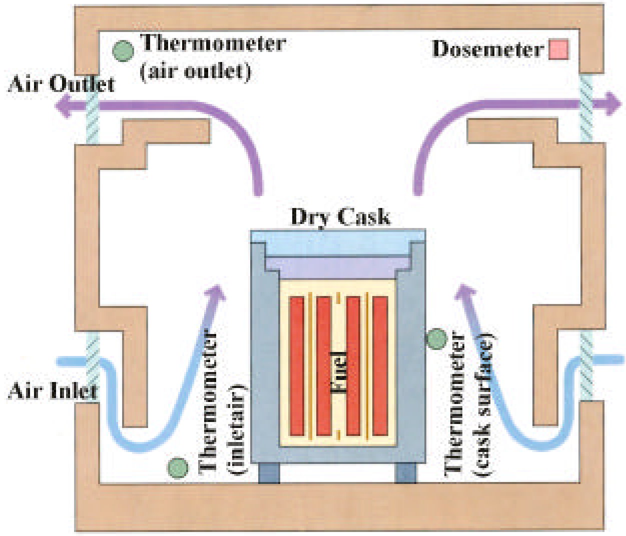

Figure3, Safety Functions of Storage Facility

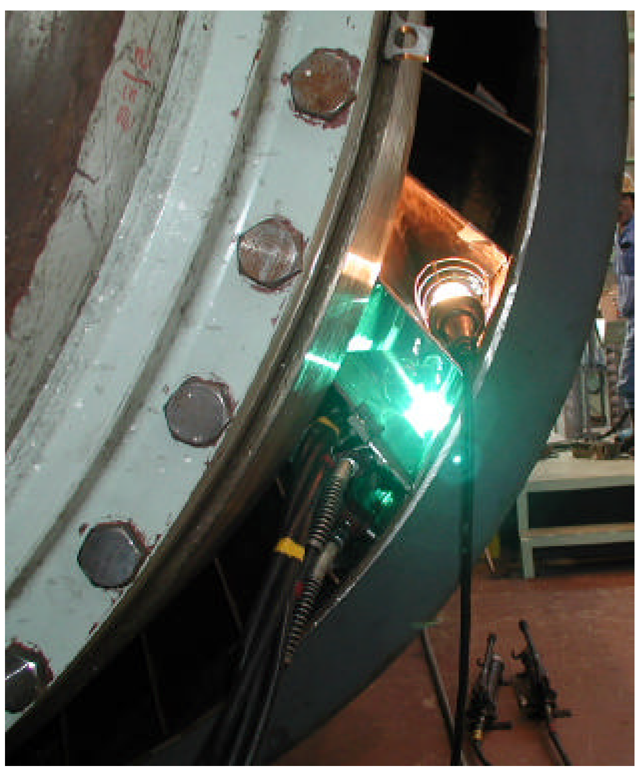

Figure4, Welding Copper Heat Transfer Fins

Figure5, Lead Pouring Equipment

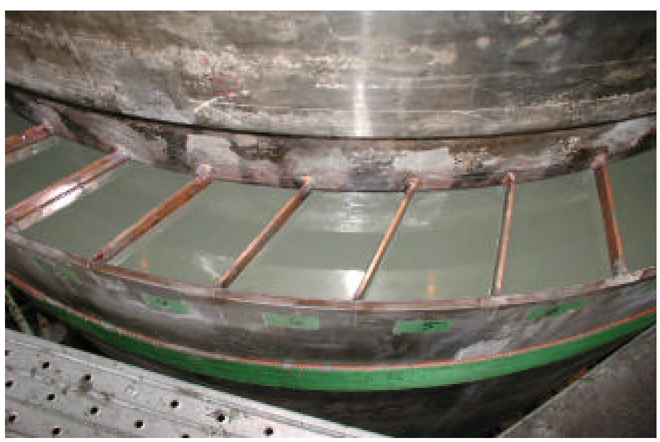

Figure6, Poured Neutron Shielding

Figure7, Assembling Square Tubes and Neutron Absorbing Materials in the Aluminum Block

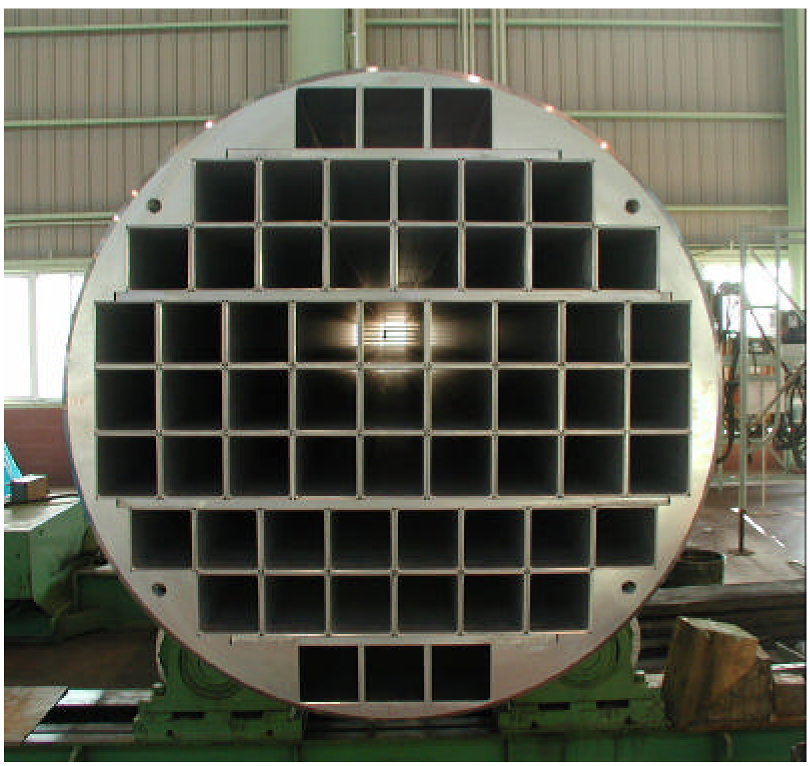

Figure8, Completed Fuel Basket