TN24 Mk II: A High Capacity Dry Cask for Storage and Transport of Long Cooled Fuel

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INTRODUCTION

Storage of spent fuel from Light Water Reactors is an important aspect of strategies currently developed or implemented world-wide by electric utilities for their spent fuel management. At present, contrary to what was anticipated when most of the nuclear power stations have been erected, only a small fraction of this spent fuel has been or will be reprocessed and large unexpected quantities shall be stored until a final solution can be available for their disposal. Until now, wet storage At Reactor in a spent fuel pool was the principal storage mode. However space shortage, even after re-racking, has now become an acute problem at the nuclear power plants of many countries and some of them are already involved in the construction of facilities to expand their storage capacity, particularly using dry storage concept and technology. As a matter of fact, dry storage in steel casks offers utilities a viable solution to circumvent this problem, especially considering the fact that the feasibility of dry storage has been demonstrated for all LWR fuel types <1>.

This paper describes a newly developed version of a high capacity dry cask for storage and transport of long cooled fuel named the "TN24 Mk II", which is now at the final development stage. This development has been undertaken within the framework of a joint development program between Transnucléaire and Kobe Steel Ltd. In order to achieve our goal, we gathered our respective know-how and expertise in the fields of design and fabrication.

DESCRIPTION OF THE TN24 Mk II CONCEPT

In the past, Transnucléaire offered a solution with the TN24 forged steel storage and transport cask <2>, the design of which was based on their experience with a fleet of more than 50 heavy shipping casks. A TN24 prototype cask manufactured by Kobe Steel Ltd has been subjected to several demonstration tests under a cooperative program sponsored by the US DOE, EPRI and Virginia Power Company, at INEL (Idhao, USA), and was thoroughly tested with two different payloads consisting of intact PWR <3> and then consolidated PWR <4> spent fuel. It was first loaded in December 1985 and, with the exception of a few short periods, it has been standing loaded on the INEL outdoor storage pad since March 1986. Then the TN24 cask design has been slightly revised to introduce some minor refinements that were detected during the tests at INEL, in particular concerning local improvements of shielding at extremities. The BWR version of the revised TN24 has received the transport licence in France, while the PWR version is expected to receive the storage licence in the USA shortly.

Starting from these achievements, we nevertheless decided to proceed with further investigation in order to satisfy the different requirements at a lower cost, to shorten the delivery time and to adapt the concept to specific licensing and fabrication conditions existing in various countries. From this research and development activity, an alternative design called TN24 Mk II came out, the major characteristic of which consists in splitting the gamma shielding and structural strength functions by the choice of a multiwall concept.

The main features of this alternative TN24 Mk II design are:

- containment vessel made of a high grade low alloy steel
- main gamma shielding constituted by a multilayered steel wall
- solid neutron shielding
- outer leaktight envelope made of a high grade low alloy steel
- passive heat transfer
- fuel in dry inert gas atmosphere
- highly reliable metallic gaskets
- smooth external surface easy to decontaminate
- compliance with various national regulations for storage
- compliance with transport regulations.

The TN24 Mk II casks are intended to be used for medium term storage of LWR spent fuels, but they also allow for their transportation, without repacking, in accordance with the IAEA regulations. As shown in Fig. 1, the TN24 Mk II concept consists of an assembly of the following components:

a) The containment vessel including a forged flange and formed plates for the inner shell, the inner bottom and the bolted lid. This vessel is designed with sufficient strength to withstand the most severe accident conditions and when necessary, it may also be qualified as a pressure vessel.

The selection of a low alloy steel grade for the plates has been particularly optimised to prevent brittle fracture, especially at the Lowest Service Temperature (-40°C) during transport. A Nil Ductility Transition temperature of -80°C or better is achieved, thus satisfying the requirements of NUREG/CR-1815 <5> for Category I corresponding to the largest margin of safety by requiring sufficient toughness to assure that there is no crack propagation. Such steel grade is available within construction Codes and Standards and offers relatively high mechanical properties with a good weldability. The lid has a single multipurpose penetration which allows smooth and easy operations when a connector, which engages into the cavity tube, is used. Highly reliable metallic O-ring gaskets equip all containment vessel closure components.

b) The main gamma shielding consisting of steel plates of an ordinary grade surrounds the containment vessel. Radially, they are tightly assembled, under the form of a layered shell, so as to minimise the temperature gradient through the body wall.

c) A radial layer of neutron absorbing resin surrounds, in turn, the main gamma shielding. Heat conductors are sunk into this resin to transfer the fuel decay heat to the external surface.

d) An outer structure which completely encloses the cask body, thus protecting the main neutron and gamma shieldings from degradation and the outer surface of the containment vessel from corrosion. This structure is made up of low alloy steel plates with good toughness properties at the Lowest Service Temperature so that it contributes, together with the containment vessel, to the mechanical strength of the cask. The external surface is totally smooth, it is covered using a paint easily decontaminable and having a high emissivity coefficient to optimize the release of heat load in the ambient air. This outer structure includes four integral trunnions made of a high strength stainless steel. They are used for lifting, supporting, tie-down and rotating the cask.

e) A fuel basket inserted inside the containment vessel cavity, consisting of a multitiered egg-crate assembly of interlocking profiles or flat plates which form square fuel compartments over the full cavity length. This structure retains its original geometry during a 9 m regulatory transport accident free drop.

f) One protective cover, used only during storage periods, which isolates the containment vessel closure components from the external environment, but which also provides additional neutron shielding at the top. Furthermore, it includes a tightness monitoring system.

g) Two protruding transport covers are fastened at both ends of the cask during transport operations. They are designed to provide protection during the most severe transport accidents specified by IAEA Regulations (i.e. drop from a height of 9 m and a fire of 800°C).

h) A secondary lid which may be installed additionally, when required.

i) Special attention has been given to surface conditions:

- all gasket seats are provided with stainless steel weld overlays
- the cavity and external surfaces are protected by metallization
- the external surfaces are also coated with a high-grade paint

Two main versions of TN24 Mk II casks are given in Table 1. The capacity has been optimized to limit the outer diameter of transport covers to 2.9 m, the maximum mass during transport to 112 tonnes and the maximum thermal power to 30 kW.

It shall be noted that the same cask can be used for routine transport when it is modified as follows to facilitate operations:

- a second orifice is added to a bottom side
- re-usable Viton gaskets are used instead of the metallic ones
- the cavity is entirely cladded with stainless steel (plates clad with stainless steel are used for the inner shell and inner bottom)

FABRICATION AND TESTING OF A PARTIAL SCALE 1 CASK

As indicated above, the main radial gamma shielding is constituted by a layered shell. This type of construction which is widely used for pressure vessels needed some experimental justification as concerns the heat transfer performances because it could not be satisfactorily justified based on existing experience or literature. The main item to be justified is the equivalent radial heat conductivity (γ_1) of the layered shell assembly. Because of the gaps between the different layers, it is only a fraction of that corresponding to solid steel (γ_s) : $\gamma_1 = \alpha \cdot \gamma_s$.

Therefore, we decided to fabricate a 2 m long slice of the cask body designed to accommodate 28 PWR assemblies. This test equipment is described at Fig 2. Full size diameters and the real thicknesses of the materials were considered. A heating system was placed inside the cavity to simulate the heat load of the spent fuel. Both extremities were carefully insulated to avoid heat leaks. A total of about 85 thermocouples were scattered around to continuously record the temperatures at appropriate locations. This model was tested at several heat power levels corresonding to a range of 15 to 35 kW for the complete cask. From the results, we derived the equivalent heat conductivity representative of the layered shell assembly (α is greater than 0.15).

Based on that test, we also calculated the temperatures at thermal equilibrium for the complete cask loaded with 28 kW, the results are summarized in Table 2.

In addition, the fabrication of the partial scale 1 cask also allowed to develop, test and qualify the appropriate fabrication processes and equipments.

CONCLUSION

The TN24 Mk II multiwall concept has been developed as an alternative to the former TN24 cask design based on forged steel, in particular for those countries where licensing or fabrication conditions could make it a more appropriate solution for a transport or storage cask.

REFERENCES

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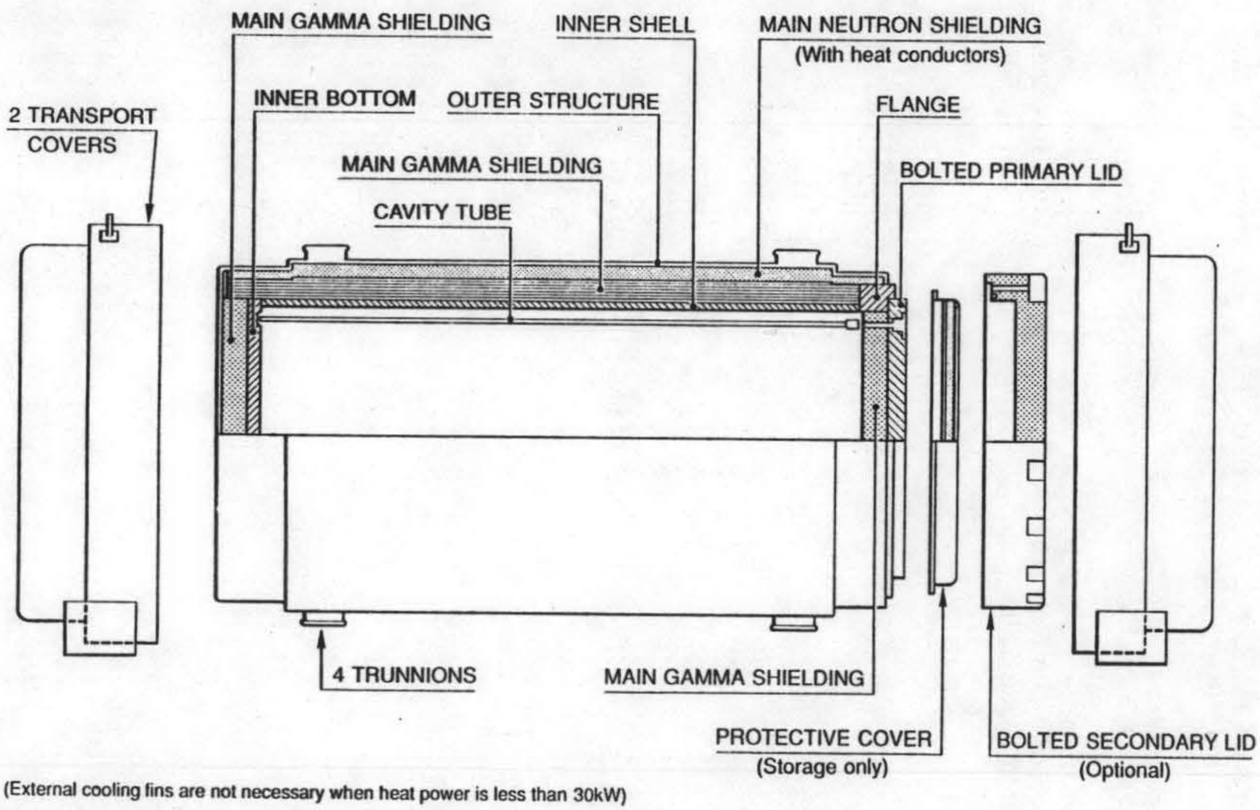
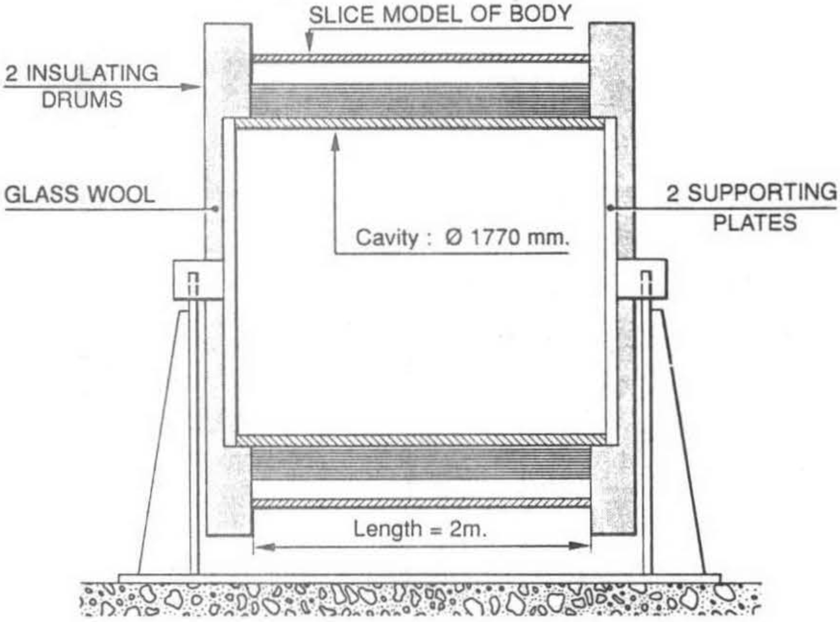


FIG. 1 - THE TN24 Mk II
HIGH CAPACITY STORAGE/TRANSPORT
CASK CONCEPT

FIG. 2 - DESCRIPTION OF THE 2 M LONG SLICE
OF THE TN24 Mk II CASK BODY

a) Longitudinal section



b) Transversal section

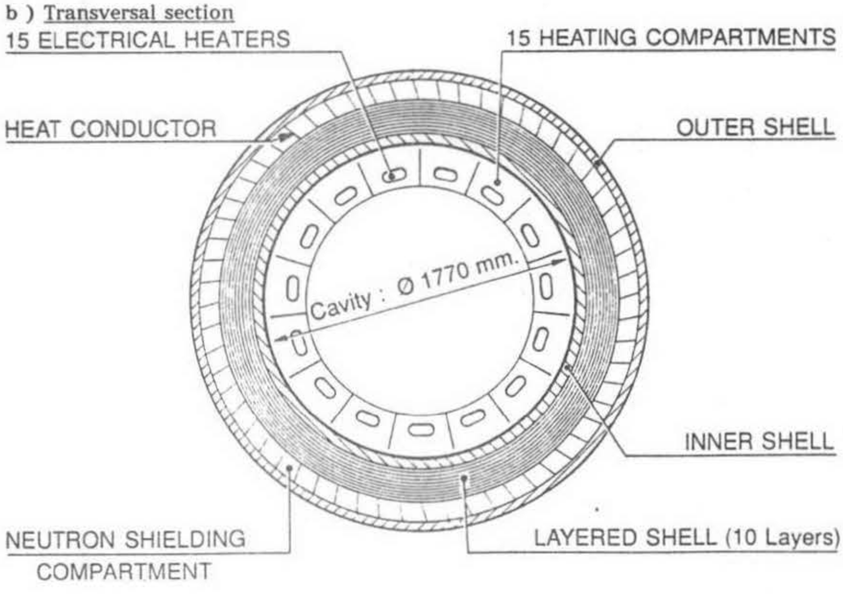


TABLE 1 : DESCRIPTION OF TN24 MkII HIGH CAPACITY CASKS

	PWR VERSION	BWR VERSION
CONTENTS		
. assembly (typical)	PWR 17x17	BWR 8x8
. number of assemblies	28	68
. mean burn up (MWd/tU)	35 000	35 000
. decay time (year)	5	5
. thermal power (W)	28 000	28 000
. U235 enrichment (%)	3.7	3.7
DIMENSIONS (mm)		
. cavity diameter	1770	1630
. cavity length	4140	4500
. fuel compartments section	220 x 220	142 x 142
. external diameter of body	2470	2330
. external diameter of transport cover	2900	2760
. length during transport	5800	6150
TOTAL MASSES (kg)		
. At crane hook during loading	110 000	110 000
. During transport	112 000	112 000
. During storage	107 000	106 000

TABLE 2 : SUMMARY OF THE MAXIMUM TEMPERATURES FOR THE COMPLETE TN24 Mk II CASK

LOCATION	TEMPERATURE (°C)
ambient	38
outer surface	120
neutron shielding	140
cavity	176
basket center	280
hottest fuel pin	320