An optimized cask technology for conditioning, transportation and long term interim storage of « End of Life » nuclear waste

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ABSTRACT

When preparing for the decommissioning of a nuclear facility, during its "end of life" management and while performing the actual dismantling operations, one has to consider a large diversity of nuclear waste in term of types, volumes and activities. Customers are frequently faced with the obligation to undertake multiple and costly waste management operations including handling, reconditioning or re-transferring from one package to another, for example when moving from on-site storage to transportation. To address this issue, a new - highly flexible - cask system named TN®MW is being developed. This cask has a total weight of 10T and is compliant with the 2012 AIEA regulations. It is developed on a flexible concept basis, adaptable to the various nuclear needs, including: from IP2 to B(U) / B(U)F ; on-site/ international transportation ; long term interim storage. Licensing and manufacturing of number of items of this TN® MW family is underway.

INTRODUCTION

The purpose of this paper is to present a new dual purpose cask system dedicated to waste packaging, transportation and long term interim storage.

When preparing for the decommissioning of a nuclear facility, during its "end of life" management and while performing the actual dismantling operations, one has to consider a large diversity of nuclear waste in term of types, volumes and activities. It ranges from High Level Waste to Low Level Waste with different natures such as: spent resins, sludge, activated fuel structures, control rods, thimble plugs, in-core instrumentation, contaminated equipment…

As of today, when waste is segmented and ready for conditioning, the operator faces the challenge to package, transport, and long term interim store. Solutions available today are often limited to one single waste type or to a single step of the overall management route.

Customers are frequently faced with the obligation to undertake multiple and costly handling, reconditioning or re-transferring operations from one package to another, for example when moving

from on-site storage to transportation or from transportation to storage. More than often, they also have no choice but to select different packaging solutions for each different type of waste type, or even more constraining: to develop a new packaging solution when waste characteristics are not compatible with the specifications of existing designs. This is also induced by the variety of regulatory requirements that can be very different from one waste type to another and from one country to another.

Following such observations and recent feedback from customers, AREVA launched the development of a new dual purpose cask – named TN® MW (MW for multi waste) - which main features are developed in the following sections.

CUSTOMER FEEDBACK

Customers are more and more expressing concerns about the complexity, cost and sub-optimization of their waste management strategies.

Too often, each waste type has its own processing route and packaging solution (and some of them don't even have any). This leads to a multiplicity of different packaging models, increasing volume to be stored and sub-optimized usage of the storage space. It can also lead to an additional multiplicity of operations to perform during the waste management life cycle. For example when a packaging model is adapted only to local storage of the waste and cannot be used for the next steps which are transportation and long term interim storage.

Most complex situation is encountered with HLW (High Level Waste) / ILLW (Intermediate Long Life Waste). Nuclear operators worldwide are looking for the best solution - technically and economically - to condition their HLW/ ILLW, keeping in mind that the waste generated today shall be conditioned for interim storage for a period of about 40 to 50 years nominally (or more if the final disposal is not available).

Following production of waste, operators could face a dilemma: either to define a strategy for the waste conditioning and packaging up to the long term interim storage period, or to containerize it temporarily, waiting for disposition conditions to be better defined before finalizing the waste management and packaging approaches. In some countries however, authorities allow only the first approach to be followed.

In the first case, one takes into account the available information and future trends relative to acceptability of the packages in order to define a robust solution. The benefit is to minimize costs for future package development and manufacturing, as well as to reduce the amount of multiple handling to transfer the waste package further down the road. Moreover it pushes for forward looking and standardization of packages as a far as possible, which is also another source of cost savings.

Pros and Cons of the second approach are inverted. It has the advantage of leaving the options opened, (and reducing the initial investments in solutions that would come to use in the future). However the main drawback is that it is exchanging uncertainties and unknowns related to future waste management criteria with uncertainties and unknowns related to the costs and risks of future retrieving and re-packaging operations. In addition, potential evolutions/degradations of the initial waste form in the meantime, would lead to extra costs and to the production of additional secondary waste.

It is however possible today to provide high integrity waste packaging solutions at a competitive price, such as the AREVA's TN® MW design. This system avoids multiple handling and reconditioning operations, while minimizing the risks of non-compliance with future WAC (Waste Acceptance Criteria).

FUNCTIONAL DEFINITION of the TN® MW dual purpose cask

The main drivers for the definition of the TN® MW dual purpose cask were the following:

Cask is built-up from a generic cask design, with well integrated options providing flexibility and adaptability to different configurations, such as:

- Standardized design of the key elements (with respect to licensing) including: the closure system, external dimensions of the package, penetrations, construction material, shock absorbers…
- Additional shielding options inside the shell
- Adaptable baskets to provide for waste retention

Weight

- Customers expressed the strong desire to handle casks with existing means available in their facilities (especially legacy plants under D&D). This avoids the need for extensive and costly refurbishment of existing devices or installing new and large equipment which usually have significant impact on the facility structure.
- 10 metric Tons was found to be the appropriate limit. This also allows using standard forklifts to move the package, which provides additional handling flexibility.

Dimensions

- The cask is to be used in cluttered environment such as those encountered in decommissioning projects. For example in reactors facilities or research labs there is limited available space to transfer casks and to stage them, before and after filling them with segmented waste. Sometimes waste packages have even to be interim stored in corridors because there are no other options.
- Consequently it is of utmost importance to limit the outer height and width of the package in order to fit with the majority of existing limitations.
- Our analysis of typical customers environment led to choose an overall volume limit of 1.5 m^3 with an outside diameter of 1080 mm (42,52 inches). The height is not critical but limited by the overall mass constraint. The standard height of 1475 mm (58,07 inches) was adopted, corresponding to a total mass of 10 metric Tons.

Design life objectives

- Customer targets for interim storage duration range between 40/50 up to 70/100 years. The limiting factors are: long term demonstration for the resistance to corrosion, and the cask closure tightness. TN® MW technology can easily meet the corrosion resistance criteria. Concerning closure tightness, one can hardly reach more than 50 years without replacement of the gaskets or perform periodic monitoring and confirmation of its tightness.
- Simplified maintenance
- Transportation by road, rail or boat, inside ISO 20’ container,
- Wet and dry loading / unloading

FIRST TN® MW TYPE B(U) MODEL

Description of the cask – design presentation

The first model considered - in the TN® MW family - is a Type B(U) package (according to 2012 IAEA regulation) to be licensed for transportation and interim storage for at least 50 years.

The TN® MW cask is designed to provide most cost effective solutions in terms of capital as well as operating costs, using common fabrication material and standard procedures. It is intended to be used for packaging, transportation and storage of HLW (High Level Waste), ILLW (Intermediate Long Life Waste) and ILW (Intermediate Level Waste).

The design basis includes the following requirements:

- Ensure containment of the radioactive contents in any conditions (normal conditions, transportation conditions, accidental and storage conditions)
- Ensure occupational exposure protection of workers and public, with the following transportation limits:
  - 2 mSv/h at any point of the surface of the cask in normal conditions,
  - 0.1 mSv/h at any point, 2 m from the external surface of the cask in normal conditions
  - 10 mSv/h at any point, 1 meter from the external surface of the cask in accident conditions

An overview of the TN®MW cask is provided in the following figures:

Fig. 1. TN® MW cask in storage configuration

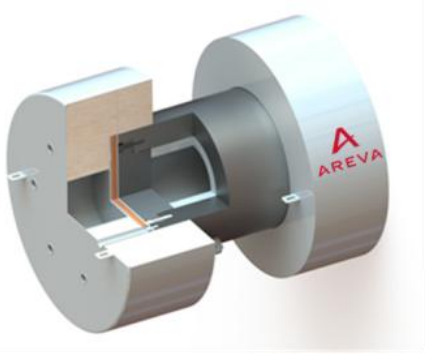

Fig. 2. TN® MW cask with shock absorbers for transportation configuration

Fig. 3. TN® MW cask in storage configuration positioned on its forklift frame

Fig. 4. Stripped down view of the TN® MW cask equipped with additional internal shielding

The waste types taken into account in the design basis include maintenance and operation waste as well as waste coming from dismantling operations. The TN® MW cask can be transported by road, rail or boat, inside an ISO 20' container with the following features:

- Underwater Loading / Unloading capabilities
- Dispositions to facilitate draining/drying of the package cavity
- On-site transfer and interim storage of the package without shock absorbers in vertical position
- Interim storage for up to 40/50 years on-site without maintenance (no gasket replacement nor leak-tightness monitoring required)

The TN® MW cask is composed of the following parts:

- A thick forged body with the following features
  - Bottom and top vents (on the lid) to perform draining / drying operations
  - 4 lifting lugs (welded or screwed on the container depending on client's preferences) or special gripping and handling interfaces
  - A closure system consisting of a lid secured by screws and two concentric gaskets (elastomer or metallic)
  - A test plug used for tightness monitoring
- Optional shielding shells
- Baskets to adapt the cavity and to maintain waste inside the cask
- Two shock absorbers (top and bottom) installed in transportation configuration.

Special characteristics

The cask design is based upon standard and proven models and technologies already developed and in use at AREVA's for other B(U) models. The body and lid are made of the same material and use same technology as used for other successful design packages, well approved by safety authorities. An important design constraint for the main structure is the brittle fracture at low temperatures. For this reason TN®MW is made of forged steel (instead of cast iron) which also provides for cost savings in the manufacturing process.

The shock absorbers are also derived from AREVA standard type B(U) existing design, well-known and accepted by safety authorities.

Metallic gaskets are used to ensure long term interim storage without maintenance for at least 50 years period, as already licensed for another series of AREVA casks.

Baskets characteristics

Different types of baskets can be used depending on the activity and shape of the waste.
The main requirements for the basket design are the following:

- they are made of non-corrosive material,
- the contents are mechanically wedged in the basket to fulfill to the transportation license requirements
- the baskets are drilled at their bottom if draining of the cavity is needed

TABLE I

	Dimensions (mm)	**Max Weight (including basket) (kg)**	**Max. Activity (TBq eq. Co-60)**
Basket Type 1 High volume / Intermediate activity	Diameter : 680 Height : 1000	2 000	2
Basket Type 2 Low volume / High activity	Diameter : 515 Height : 900	650	300

The TN® MW is designed to be leak-tight. For that purpose each penetration of the cask is designed to be able to maintain a total leak rate that does not exceed 1.10^{-8} $Pa.m^3.s^{-1}$ SLR.

The only penetrations of the TN®MW cask are:

- the primary lid,
- the draining and drying openings,

TN® MW Cask characteristics TABLE II

Overall diameter (without shock absorbers)	1080 mm
Overall height (without shock absorbers)	1475 mm
Mass with type 1 basket (without shock absorbers)	8.5 T
Mass with type 2 basket (without shock absorbers)	9.6 T
Mass with type 1 basket (with shock absorbers)	10.4 T
Mass with type 2 basket (with shock absorbers)	11.5 T

NB: given masses and dimensions are nominal values

To satisfy tightness specifications, each penetration is equipped with a metallic gasket and machined stainless steel contact surfaces. The metallic gaskets are designed for long-term stability and have high corrosion resistance over the entire storage period.

These high performance gaskets are composed of two metal linings formed around a helical spring. The sealing principle is based on plastically deforming the gasket outer linings. Permanent contact of the lining against the sealing surface is ensured by the outward force exerted by the helically-wound spring. Additionally, all metallic gasket seating areas are stainless steel overlaid for improved surface control.

This type of metallic gaskets is fully qualified for a lifetime of at least 50 years, and has high temperature resistance (at least 280°C in normal operation and 370°C in accident conditions). Therefore, the containment analysis is performed so as to demonstrate the compliance with IAEA TSR-1 regulatory criteria:

- 10^{-6} A_2 per hour in normal transport conditions,
- 1 A_2 per week for other radionuclide under accident conditions.

A specific containment analysis is performed for each type of waste contents taking into account its distinctive characteristics (source distribution, isotopes, mass…).

NEXT TN® MW MODELS

The next models currently in development to expand the TN® MW family are the following:

- a "dry" version with no penetrations and reduced package cost when only dry loading/unloading is required
- a "transportation only" version with elastomer gaskets to reduce costs when no storage is anticipated
- an "IP-2 version" for LSA or SCO material with no shock absorbers and elastomer gaskets
- an "on-site transfer" specific version adapted to 400L drums with or without shock absorbers
- a "large version" adapted to special waste or equipment (such as dismantling parts that cannot be segmented on site) with the objective to stay below 60 T
- a "fissile" version for the transportation of waste with fissile material contents (ex: research reactor targets)

CONCLUSIONS

Optimization of the "End of Life" waste streams management - from conditioning, up to long term interim storage - is a key factor to control and reduce life cycle dismantling costs. The comprehensive and forward looking approach brought by the TN® MW technology provide operators with reduction of equipment costs, types of different casks to procure, amount of operations to perform, and secondary wastes production.
The fabrication, licensing and delivery of the first TN® MW is scheduled to take place in 2017.

REFERENCES

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