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TN-MW® Cask Family

A New Packaging Focused on Waste Management from Operational Stage to End-of-Life of Nuclear Facilities

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ABSTRACT
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When preparing for the decommissioning of a nuclear facility, during its “end of life” management and while performing the actual dismantling operations, a large diversity of nuclear waste must be considered in terms 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, or from transportation to final disposal. To address this issue, a new – highly flexible – cask system, the TN®MW, is being developed as an “All in One Solution.” With a total weight of 10T, this cask is compliant with the 2012 IAEA regulations. It is developed on a flexible concept basis, adaptable to the various nuclear needs including: from IP-2 Type, Type A to B(U) / B(U)F; on-site/international transportation; long-term to final storage. Licensing and manufacturing of a number of this TN® MW family is now underway.

INTRODUCTION

The TN®MW is a new cask system developed as an “All in One Solution” dedicated to waste packaging, transportation, as well as long-term interim storage and up to final disposal.

When preparing for the decommissioning of a nuclear facility, during its “end of life” management and while performing the actual dismantling operations, a large diversity of nuclear waste must be considered in terms of types, volumes and activities ranging 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, activated metallic core components …

As of today, when waste is segmented and ready for conditioning, the operator are faced with the challenge of packaging, transport, long-term interim storage and final disposal (or preparation of final disposal if the repository is not yet available). Solutions available today are often limited to one single waste type or to a single step in the overall management route from the initial site -

where the waste was generated - to its final disposal.

Customers are frequently faced with the obligation of undertaking multiple and costly handling means, reconditioning or re-transferring operations from one package to another, for example when moving from on-site storage to transportation or from transportation to final disposal. More 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. The variety of regulatory requirements that can be very different from one waste type to another and from one country to another also contribute to the difficulties faced by designers and customers alike.

Following such observations and recent feedback from customers, AREVA TN has launched the development of a new cask system, the TN® MW, whose main features are developed in the following sections below.

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 do not even have any). This leads to a multiplicity of different packaging models, thereby increasing the volume to be stored by using an overpack for final storage and by sub-optimizing usage of the storage space. It can also lead to an additional multiplicity of operations during the waste management life cycle, for example when a packaging model is only adapted to local storage of the waste and cannot be used for the next step of transportation, then another transfer may finally take place when the waste arrives at the disposal site if the ways and means to transport it are not compatible with final disposal requirements.

The most complex situation is encountered with HLW (High Level Waste)/ILW (Intermediate Level Waste) and Fissile materials. Nuclear operators worldwide are looking for the best technical and economic solution to condition their HLW/ILW and Fissile materials, keeping in mind that the waste generated today will usually be:

- Put into interim storage for a period of 40 to 50 years at least
- Transported to the final repository at the end of this period
- Conditioned today, knowing that transportation regulations and final storage specifications to be applicable in 40-50 years have not yet been fully defined

Following production of waste, operators are faced with a dilemma: either to define a complete strategy for the waste conditioning and packaging up to its final disposal, or to put the waste into containers temporarily, waiting for final disposition conditions to be defined before finalizing the waste management and packaging approach. In some countries, authorities allow only the first approach to be followed.

In the former case, the available information and future trends relative to acceptability of the packages are taken into account to define a robust solution. The benefit is to minimize costs for

future package development and manufacturing as well as to reduce the number of multiple handlings needed to transfer the waste package further down the road, for example from an interim container to a final container (if more than one container needs to be considered). Moreover this approach pushes for a forward-looking vision and standardization of packages as far as possible, which is also another source of cost savings.

Advantages and disadvantages of the latter approach, putting the waste into temporary containers, are inverted. It has the advantage of leaving the options open, and of reducing the initial investments in solutions that would come into use in the future. However, the main drawback is that it balances 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 with potential evolutions/degradations of the initial waste form in the meantime while producing additional secondary waste.

Moreover, both the container and the waste form contribute to meeting the required performance of the waste packages. Thus, as the robustness is supported by the container, the required contribution of the form of the waste can be reduced.

Today it is possible to provide high-integrity waste packaging solutions at a competitive price such as AREVA's TN® MW design, "All in One Solution." 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 SYSTEM

The main drivers for the definition of the TN® MW system were the following:

One 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) such as: the closure system, external dimensions of the package, penetrations, construction material, shock absorbers…
- Adaptable additional shielding options to be inserted into the cask cavity
- Adaptable baskets to be provided 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 refurbishing of existing devices or the installation of new and large equipment which usually has significant impact on the facility structure.
- 10 metric Tons was found to be the appropriate limit. This can also make use of standard forklifts to move the package, which provides additional handling flexibility.

Dimensions

- The cask is to be used in cluttered environments such as those encountered in decommissioning projects. For example in reactor facilities or research labs there is limited available room and space to transfer casks and to store them, both before and after filling them with segmented waste. Sometimes waste packages even have to be put into interim storage in corridors because there are no other options.
- Consequently, it is of utmost importance to limit the outer height and width of the package to correspond to the majority of existing limitations.
- AREVA TN analysis of a typical customer environment led to the choice of an overall volume limit of 1.5 m^3 with an outside diameter of 1,060 mm (41.73 inches). The height is not critical but limited by the overall mass constraint. The standard height of 1,500 mm (59.05 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 70/150 years. The limiting factors are long-term demonstration of the resistance to corrosion and the cask closure tightness. TN® MW technology can easily meet the corrosion resistance criteria. Concerning closure tightness, a period of more than 50 years can hardly be reached without replacement of the gaskets or periodic monitoring of its tightness.

- For final disposition of Intermediate Level Waste – Short Life and Low Level Waste, the specifications are usually consistent with those of interim storage. The focus is on package integrity (ex: maintaining confinement including drop test conditions). Consequently the compatibility with final disposal is easily met.

- For final disposal of High Level Waste and/or Intermediate Level Waste – Long Life, the approach to ensure compatibility of the package is based on the following measures:
    - Integration of current best practices, future trends and recommendations provided by the authorities into the design: AREVA TN is already involved in the production of packages that are bound to geological disposal and is quite familiar with these considerations and interfacing with the authorities [1].
    - As the fundamental safety demonstration in the repository is provided by the geologic formation and not by the package itself (defense in depth), the very-long-term behavior is taken care of. The remaining question is then related to package behavior during the period of “reversibility.” It is, indeed, usually required that waste placed in a geological repository be retrievable for a period of about 100 to 150 years following initial placement. Hence, the integrity and confining functions of the packages need to be demonstrated for a period of about 150 years. To comply with this configuration, three main criteria are impacted: corrosion, fire resistance, and closure tightness.
    - In addition, in the event of additional requirements to “block” the inside contents, the system needs to be able to facilitate this operation.

- Easy maintenance

- Transportation by road, rail or boat, inside an ISO 20’ container

- Both wet and dry loading/unloading

TN® MW TYPE B(U) MODEL

Description of the cask – design presentation

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

The TN® MW cask is designed to provide the most cost-effective solutions in terms of both capital and operating costs, using common material and common standard procedures. It is intended to be used for packaging, transportation, and long-term storage and disposal of HLW (High Level Waste), ILW (Intermediate Level Waste) and LLW (Low Level Waste).

The design basis includes the following:

- Ensured containment of the radioactive contents under any conditions (normal, transportation conditions, accidental and storage conditions)
- Ensured occupational exposure protection of workers and public, with the following transportation limits:
  - 2 mSv/h at any point on 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 m 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

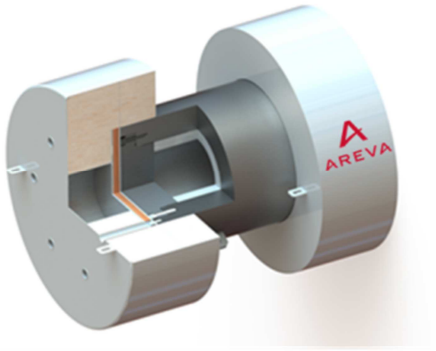

Fig. 2. TN® MW cask with shock absorbers for transportation configuration

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 TN® MW is compatible with waste such as legacy waste, orphan waste as well as waste produced during utility life (maintenance and operation) and during 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
- 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, possibility of leak-tightness monitoring if needed)
- Compatible with final disposal

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

- A thick stainless steel forged body with the following features:
    - A bottom part: an orifice is added at the bottom to perform draining/drying operations when loading operation is conducted in wet conditions
    - Lifting lugs: (welded or screwed on the container depending on client's preferences) or special gripping and handling interface
    - A closure system: composed of a lid closed by screws and two concentric gaskets (elastomer or metallic adapted to storage requirements). An orifice is located on the lid for draining/drying operations. The cask cavity is either pressurized or inert depending on the need.
    - A test plug: used for tightness monitoring if required

- 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 only

Special characteristics:

The cask design is based on standard and proven models and technologies already developed and in use by AREVA TN for other B(U) models. The body and lid are made of the same material and use same technology as other successful design packages approved by safety authorities. An important design constraint for the main structure is brittle fracture at low temperatures. For this reason the TN®MW system is made of forged stainless steel (instead of cast iron). The choice of forged stainless steel provides cost savings in the manufacturing process by avoiding coating/overlaying operations. It also allows AREVA to optimize the manufacturing schedule.

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

Metallic gaskets are used to ensure long-term interim storage without maintenance for a period of at least 50 years, as already licensed for other AREVA TN cask series.

Basket 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 into the basket to fulfill to the transportation license
- The baskets are drilled in their bottom if draining of the cavity is needed

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 which does not exceed 1.10^{-8} $Pa.m^3.s^{-1}$ SLR.

The only penetrations in the TN®MW cask are:

- The primary lid
- The draining and drying openings

TN® MW Cask Characteristics

TABLE 1 - TN® MW characteristics

(in mm)	Diameter	Height
External dimensions without shock absorber	1,060	1,500
Cavity dimensions - max	740	1,140
Cavity dimensions - min	515	900
Maximum weight when loaded without shock absorber	10 T	
Maximum weight when loaded with shock absorber	12 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.

This type of metallic gasket is fully qualified for a lifetime of at least 50 years and has high temperature resistance (at least 280°C under normal operation and 370°C under 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 content taking into account its distinctive characteristics (source distribution, isotopes, mass…).

Addressing Final Disposal

As discussed above, the main criteria for the cask to qualify for final disposal is to demonstrate its integrity and confining functions for a period of about 150 years. This essentially translates to corrosion resistance and long-term tightness of the closures.

Corrosion resistance is provided by the careful selection of the cask material and thickness of the shell in stainless steel (200 mm shell and 200 mm lids). To address the tightness requirement, the TN®MW cask is designed with provisions for permanent welding of the lid and caps instead of the use of gaskets when it is time to send it to final disposal.

Moreover, provisions are integrated in the design to facilitate the installation of additional options or to conduct additional operations prior to disposal in the event of additional requirements such as:

- A drying system to remove moisture (free liquid for storage or disposal must be removed to avoid any chemical reaction (free water radiolysis and corrosion of metallic waste for example)
- A system to fill the cask cavity with "blocking material" without having to reopen the lid (ex.: sand, glass beads, aluminum oxide, grout…)
- A semi-porous gas venting system (if needed, to evacuate radiolysis gases such as hydrogen while avoiding entry of humidity inside the cask)

NEXT TN® MW Models

The first TN MW version to be licensed will be a type B(U) version for fissile material.
The manufacturing, licensing and delivery of the first TN® MW cask for Type B(U) Fissile material will be in the first half of 2017.

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

- A Type B(U) "wet" version with no penetrations and reduced package cost when only wet loading/unloading is required (version describe here above)
- A Type B(U) "dry" version with no penetrations and reduced package cost when only dry loading/unloading is required (without any orifice on the bottom part)
- A Type B(U) "transportation only" version with elastomer gaskets to reduce costs when no storage is needed
- An "IP-2 version" for LSA or SCO material and "type A version" without shock absorbers and with elastomer gaskets
- An "on-site transfer" specific version adapted to 400L drums without shock absorbers
- A "CSD" version for the transport and the interim storage of residues issued from the Research Reactor Spent Fuel reprocessing plant which are under the form of CSD-V, CSD-B, CSD-U and CSD-C (Universal canisters containing vitrified or compacted residues)
- A Type B(U) "large version" adapted to special waste or equipment (such as dismantled parts that cannot be segmented on site) with the objective of staying below a mass of 60 T without shock absorbers

CONCLUSIONS

Optimization of the “End of Life” waste stream management - from conditioning and long interim storage to final disposal - is a key factor in controlling and reducing waste management costs of various waste forms such as legacy waste, orphan waste, operational and maintenance waste, dismantling waste…

The comprehensive and forward-looking approach brought by the TN® MW cask technology provides operators with reduction in equipment costs, types of different casks to be procured, the number of operations, and secondary waste production.

The manufacturing, licensing and delivery of the first TN® MW cask for Type B(U) Fissile material will be in the first half of 2017.

REFERENCES

[1] C. Lamouroux, A. Rodrigues, E. Bossé, F. Cochin, “Proceedings of Global 2015 Innovative solutions for waste management: Optimization of waste packages for the long term disposal,”