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The TN®MW, a new optimized cask for Research Reactors' waste management.

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ABSTRACT

Research Reactors activities and dismantling operations induce a large variety of waste to be managed by operators. These wastes significantly vary in terms of type, volume and activity, therefore multiplying packing and transportation solutions to be implemented.
To address this issue, NEW AREVA has been developing a new cask design named TN®MW to provide operators with an all-in-one solution, dedicated to waste conditioning, transportation, storage and disposal. This highly flexible cask aims to simplify legacy, operational and D&D waste management while optimizing associated costs. The TN®MW is particularly adapted to Research Reactors constraints through its reduced dimensions and weight that allow the management of small quantities of various wastes and easy handling operations.
Thanks to NEW AREVA's 50 years' experience as casks designer, the licensing and manufacturing of the first TN®MW casks started in 2015 were achieved in less than two years. Two casks were delivered and successfully loaded in September 2017.

1 Introduction

The TN®MW (MW for Multi Waste) is a new cask system developed as an "All in One Solution" dedicated not only to waste packaging and transportation but also to long-term interim storage and final disposal [1].

Research reactors activities and dismantling operations induce a diverse array of nuclear waste that must be considered in terms of types, volumes and activities ranging from High Level Waste (HLW) to Low Level Waste (LLW) with different compositions.

As of today, when waste is segmented and ready for conditioning, operators are faced with the challenge of packaging, transport, long-term interim storage and final disposal (or preparation for 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.

Research Reactors are frequently faced with the obligation of undertaking multiple and costly handling means, reconditioning or re-transferring operations from one package to another, as in the case 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. Regulatory requirements can be very different from one waste type to another and from one country to another which contributes to the difficulties faced by designers and customers alike.

Following such observations and recent feedback from customers, NEW AREVA has launched the development of a new cask system, the TN®MW, with its main features described in the sections below.

2 Customer feedback

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

Too often, each waste type has its own, unique processing route and packaging solution (with some waste types not having any solution). This leads to a wide variety of different packaging models, resulting in the need for larger, universal overpacks and less than optimized use of storage space. It may also lead to additional or duplication of operations during the waste management life cycle, as in the example when a packaging model is only suitable for local storage of the waste and cannot be used for transportation. Or consider the case where the waste is transported to the disposal site but must be transferred to a cask that is compatible with the final disposal requirements.

The most complex situation is encountered with HLW, Intermediate Level Waste (ILW), and fissile materials. Research Reactors operators worldwide are looking for the best technical and economical solution to condition their HLW/ILW and fissile materials, keeping in mind that the waste generated today shall most likely be:

- Put into interim storage for a minimum period of 40 to 50 years
- 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 avoid extra handling needed to transfer the waste package in the future (i.e. 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 much as possible, which is also another source of cost savings.

Advantages and disadvantages of the latter approach, putting the waste into temporary containers, are reversed. It has the advantage of leaving the options open, and of reducing the initial investments for future solutions. 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 retrieval and re-packaging with potential degradation of the initial waste form over time 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 NEW 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 Waste Acceptance Criteria (WAC).

3 Functional definition of the TN®MW cask 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 (containment) system, external dimensions of the package, penetrations, construction material, and shock absorbers
  - Adaptable shielding configurations inside the cask cavity
  - Adaptable baskets for optimized waste retention

- Weight
  - Research Reactors usually have limited on-site cask handling equipment, and extensive modifications of existing devices or the requirement to install new ones can be costly and have a significant impact on the facility structure.
  - 10 metric tons was determined to be the appropriate limit. This allows for the use of standard forklifts to move the package, which provides additional handling flexibility.

- Dimensions
  - The cask was designed for use in cluttered environments such as those encountered in decommissioning projects. Indeed, research reactor facilities or labs often have limited space to transfer casks and to store them. In some

instances, waste packages have even been put into interim storage in corridors because there are no other options.

- Consequently, it is of the utmost importance to limit the outer height and width of the package to correspond to the majority of existing limitations.
  - NEW AREVA analysis of a typical customer environment led to the selection of an overall volume limit of 1.5 m3 with an outside diameter of 1,060 mm (41.7 inches). The height is not critical but influenced by the overall mass constraint. The standard height of 1,500 mm (59.1 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 containment. TN®MW technology can easily meet the corrosion resistance criteria. With regards to containment, maintaining integrity for a period of more than 50 years can be challenging without the need for replacement of the gaskets or periodic monitoring.
  - For final disposition of ILW–Short Life and LLW, the specifications are usually consistent with those of interim storage. The focus is on package integrity (ex: maintaining containment including drop test conditions). Consequently the compatibility with final disposal is easily met.
  - For final disposal of HLW and/or ILW –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. NEW AREVA is already involved in the production of packages that are intended for geological disposal and is quite familiar with these considerations and interfacing with the authorities [2].
    - 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 100 to 150 years following initial placement. Hence, the integrity and containment functions of the packages need to be demonstrated for a period of up to 150 years. To comply with this configuration, three main criteria are impacted: corrosion, fire resistance, and containment.
    - 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

4 Addressing long term interim storage and final disposal

The waste container plays a key role in ensuring safety during several stages of a radioactive waste management system, from interim storage through transport to its final disposal. Waste containers are designed to provide radiation shielding and/or physical containment to restrict or prevent the spread of contamination.

Concerning Geological Facility Disposal (GFD), studies conducted for CIGEO in France, are attempting to demonstrate that integrity can be maintained during the phase of exploitation of the final disposal (100 to 150 years). The Research and Development (R&D) programs deal with:

- The corrosion performance and integrity of the container
- The flammable and corrosive gas production by radiolysis, corrosion or thermal degradation
- The dimensioning and demonstration of integrity of the ventilation system
- The chemical stability of the waste form

Corrosion resistance is provided by the careful selection of the cask material and thickness of the stainless steel shell and lid. To address the containment requirement, the TN®MW cask is designed with provisions for permanent welding of the lid and caps instead of the use of gaskets in preparation for final disposal.

Moreover, to better adapt to changing disposal requirements, provisions have been integrated into the design to allow for different configurations or to conduct additional operations prior to disposal:

- A drying system to remove moisture (free liquid for storage or disposal must be removed to avoid any chemical reaction)
- A system to fill the cask cavity with “blocking material” without having to reopen the lid
- A semi-porous gas venting system (if needed, to evacuate radiolysis gases while avoiding entry of humidity into the cask).

Corrosion

To provide containment of the waste form during all these steps, the container must retain its integrity for a number of decades. It could be that the disposal concept considers the specifics of the container to be a barrier after the closure of repository. In such case, a metallic container must achieve a required corrosion resistance. The waste package shall enable safe handling by way of its handing feature until the end of the GFD operational period. The waste container shall maintain containment for as long as is required by the GFD safety case. Integrity is defined as the ability of a waste container to provide containment of its content and of a waste package to be safely handled and stacked. The integrity is directly correlated to the ability to resist corrosion. For ILLW destined to go to GFD, evaluations must demonstrate that waste integrity is maintained for a minimum of 200 years to meet the requirements of interim storage and operational repository and early post-closure periods.

Industry’s response to this requirement has generally been to manufacture waste containers from stainless steel. The corrosion performance and mechanical properties of this material are regarded as optimum for the packaging of radioactive waste and this performance has been demonstrated by experience and industrial feedback. A variety of corrosion mechanisms can threaten the integrity of waste containers manufactured from stainless steel, the most significant of which are: (i) general atmospheric corrosion; (ii) pitting or crevice corrosion; and (iii) stress corrosion cracking. The rates of general atmospheric corrosion performance of stainless steel are widely reported and corrosion rates from < 0.2 µm/year to 3 µm/year have been observed in industrial, urban and marine environments. Initial measurements from long-term testing suggest corrosion rates of approximately 0.001 µm/year in a GFD environment that would suggest that such a mechanism is not a significant threat to integrity. Localized corrosion mechanisms such as pitting or crevice corrosion have also been extensively studied. Data extrapolated from tests have shown that the time for a pit to penetrate 1mm into stainless steel is many centuries. Localized corrosion is also dependent upon the presence of surface contaminants, in particular chlorides. Works and feedback are available to specify the requirements (references). Finally, intergranular corrosion can occur in austenitic steels that have been sensitized by the temperature.

Radiolysis

The radiolysis phenomenon is of great importance in the waste conditioning issue. Since 2006, CEA and NEW AREVA have carried out R&D with the aim of compiling a database of literature and data on experimental radiolytic yields values of a large number of materials (mainly polymers, salts). We then developed a calculation tool, called STORAGE (Simulation Tool of RAdiolysis Gas Emission) able to calculate and predict the gas production based on characterization of the content of the waste drums. The tool is currently undergoing qualification and validation testing with dedicated industrial instrumented drums. The evaluation of gas coming from radiolysis presents a number of advantages: (i) to predict and to help define the content of the waste container in order to avoid exceeding limits; (ii) to design the capacity of a suitable ventilation system. A specific module including thermolysis is currently under development

Ventilation system

A number of approaches can be adopted to reduce the consequences of gas generation by the contents of waste packages.

- Removing any chemical interaction between the waste form and the matrix by drying the waste and removing water
- Producing an inert waste form (i.e. vitrification)
- Equipping the waste container with a ventilation system. This approach is the approach recommended by the IAEA guidance on the requirements for waste containers containing ILW [3]. The presence of a ventilation system potentially conflicts with the requirements to ensure radionuclide and particle confinement and to avoid, or at least limit, the ingress of water during the interim storage and reversibility period in deep geological repositories.

This leads to the requirement for a filtered ventilation system. This requirement is usually achieved by the use of sintered filter or by using engineered filters, designed to ensure flammable gas evacuation and at the same time to limit water vapor ingress. This has been recently done for the development of a NEW AREVA waste package to condition dried sludge. The ventilation system is a part of the waste package, so it has to meet the same requirements of the waste container itself. In particular, the requirements of integrity, longevity and corrosion resistance must be met during interim storage and the GFD operational period.

Chemical stability of the waste form

The waste form refers to the waste in its physical and chemical form after treatment and conditioning resulting in a solid product prior to packaging. The primary safety requirements applied to the waste form is to confine and retain the radioactivity in the waste.

In response to this need, NEW AREVA developed this highly flexible cask with materials which guarantee its integrity for very long period of time. It incorporates the capabilities to evaluate the gas production, a ventilation system allowing the evacuation of gases if needed, and an integrated drying system.

5 TN®MW Type B(U) Model versions

Description of the cask – design presentation

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

The design basis includes the following:

- Ensured containment of the radioactive contents under any conditions (normal, transportation conditions, accident and storage conditions)
- Ensured occupational exposure protection of workers and public

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

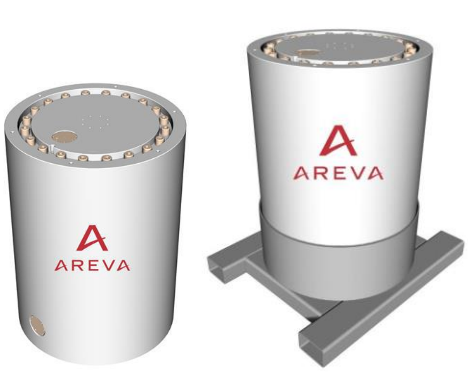

Fig. 1: TN®MW cask in storage configuration – in storage configuration positioned on its forklift frame – equipped with additional internal shielding

The TN®MW is compatible with a variety of waste types such as legacy waste, orphan waste, waste produced during the Research Reactor life (maintenance and operation), and during dismantling operations [4].

The TN®MW cask can be transported by road, rail or vessel, inside a standard 20' ISO container. A few of the major features of the TN®MW are provided below:

- Underwater Loading/Unloading
- Openings 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:
  - Draining mechanism: an orifice is located at the bottom of the cask to facilitate draining and drying operations when loading operations are performed in wet conditions

- Lifting lugs: (option of welded or screwed configuration on the cask depending on client's preferences) or special lifting and handling interface
- Closure system: composed of a lid closed by screws and two concentric gaskets (elastomer or metallic dependent upon storage requirements). An orifice is located on the lid for draining and drying operations. The cask cavity can be either pressurized or inerted
- Leak test plug: used for containment verification if required

▪ Optional shielding shells
▪ Baskets to adapt the cavity to a variety of loading configurations for optimized storage and restrain movement
▪ Two shock absorbers (top and bottom) required in the transportation configuration only.

Main characteristics

The cask design is based on standard and proven models and technologies already developed and in use by NEW AREVA 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 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 NEW AREVA to optimize the manufacturing schedule.

The shock absorbers are also derived from NEW AREVA 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 NEW AREVA cask series.

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

Table 1: TN®MW characteristics

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:

▪ Constructed of non-corrosive material
▪ Contents are mechanically retrained in the basket to satisfy transportation license requirements
▪ The baskets include bottom drain holes to support wet loading operations

Leak-tightness specification

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.m3.s-1 Standard Leak Rate (SLR).
The only penetrations in the TN®MW cask are the primary lid and the draining and drying openings and 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 provide high corrosion resistance over the entire storage period. These high-performance metallic gaskets are fully qualified for a lifetime of at least 50 years and have high temperature resistance (at least 280°C under normal operation and 370°C under accident conditions). Therefore, a specific containment analysis is performed for each type of waste content so as to demonstrate the compliance with IAEA SSR-6 regulatory criteria.

6 First TN® MW Type B(U) version

The first version of the TN® MW is a Type B(U) Fissile version with its dedicated basket for criticality. The loading and transport license has been successfully granted from the French and Belgium Safety Authorities in May 2017, after a one-year only process. Since then, the casks have been successfully delivered and loaded on client's site.

Fig. 2: TN®MW Type B(U) Fissile with its dedicated basket

7 Different TN® MW Models

NEW AREVA and AREVA TN are currently working to expend the TN MW cask family to better support research reactor's needs, through new models:

- A Type B(U) dual-purpose cask for transportation and interim storage of research reactors' spent fuels
- 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) "wet" version with penetrations when wet loading/unloading is required
- A Type B(U) "dry" version with no penetrations and reduced package cost when only dry loading/unloading is required (no drain orifice)
- A Type B(U) "transportation only" version with elastomer gaskets to reduce costs when no storage is needed
- An "IP-2 version" for Low Specific Activity (LSA) or Surface Contaminated Objects (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 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 MT (without shock absorbers).

8 Conclusions

With respect to the various waste generated during a Research Reactor’s life time, such as legacy waste, operational and maintenance waste, and dismantling waste with different forms, optimization of waste stream management is a key factor in controlling and reducing waste management costs.

Thus, the TN®MW package provides an “All in One Solution” as it offers a solution from conditioning up to final disposal over a diverse array of waste types. The comprehensive and forward-looking approach brought by the TN®MW cask technology provides operators with reductions in equipment costs, types of different casks to be procured, operation evolutions, and secondary waste production. The TN®MW, with its flexibility, answers the reversibility requirement from early conditioning for long term storage up to final disposal.

Its efficient design stems from the incorporation of NEW AREVA’s extensive experience in the development of different types of casks and also from its experience on ANDRA’s waste acceptance criteria. Such experience included the development of universal canisters to address different kinds of waste for long term disposal in a form that is stabilized and standardized.

9 References

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