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A NEW TYPE B(U) FISSILE, FLEXIBLE MULTI-SIZE CASK SOLUTION TO YOUR FUEL TRANSPORT REQUIREMENTS

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ABSTRACT

Background

INS, as an NDA subsidiary, has a long history of the design, licensing and subsequent transport operations (road, rail and sea) of RAM Transport Packages for a wide range of nuclear materials. Such materials include spent fuel, fresh fuel, MOX, vitrified high level waste, intermediate level waste, highly enriched uranium, plutonium and sealed sources that are generated for many medical and industrial purposes
ROBATEL Industries is a worldwide nuclear turnkey services provider, especially regarding bespoke radioactive material transportation casks. For decades ROBATEL has designed numerous package models, type B ones especially which require regulators approvals. Based on such a broad experience, the company acquired a comprehensive knowledge of the technical issues related to safety and to international regulations.

A new versatile fissile materials carrying type B cask

INS and Robatel are today looking to combine their strengths & experience to develop a cask as a flexible solution, in various sizes ranging from a small cask which can be handled manually through to a larger version for those utilities with greater lifting capacity and needs, in order to better serve the nuclear laboratories and research centers.

This new cask should be able to carry small quantities of PuO_2 powder, plutonium contaminated wastes, highly enriched uranium pellets and residues, MOX pellets and residues or compacted wastes…

The aim of this paper is to present this new type B Fissile package concept dedicated to the Research Reactor fuels transportation, describing in main design features on its specificities, mainly in terms of innovative implementation of materials to meet the latest SSR-6 requirements.

INTRODUCTION

ROBATEL Industries presentation

With its long nuclear history of more than 60 years and its strong experience in the design of radioactive material transport packages (with about 85 approved type casks designed over the years), ROBATEL Industries puts its technical knowledge to serve a cask family design that integrates not only the international regulatory requirements and the specific needs of INS but also the technical innovations able to meet the latest expectations of the Safety Authorities.

International Nuclear Services - INS

INS is a wholly-owned subsidiary of the Nuclear Decommissioning Authority (NDA) and has over 40 years experience of providing specialist nuclear transport, design and licensing services, and managing NDA's inherited fuel cycle contracts with UK and overseas customers.

International Nuclear Services and ROBATEL are looking to combine their strengths & experience to design a flexible B(U)F type cask to transport small quantities of PuO2 powder, plutonium contaminated waste, highly enriched uranium pellets and residues, MOX pellets and residues, or compacted wastes. The cask is intended to provide an up-to-date replacement for some of the ageing package designs used across the industry.

The cask will be designed as a flexible solution, in various sizes ranging from a small cask which can be handled manually through to a larger version for those utilities with greater lifting capacity.

DESCRIPTION OF CURRENT DESIGN

Background

The cask concept design started from an opportunity identified by INS on their customer based feedbacks and requests. The users, laboratories, research centers, radioisotope industry and research reactors, are looking for easy to use, light and versatile package solutions.
An initial concept was designed and called "INS 3578".
The INS3578 Transport Package had been designed to transport various types of radioactive materials (RAM) such as plutonium powder and exotic fuel sealed within several types of cans (i.e. Thorp finishing line PuO2 product cans, Magnox finishing line PuO2 product cans).

This project was stopped after several prototypes were built and partially tested, until technical issues on thermal HAC were detected.
This event had significant impact on material used for the neutron and thermal shielding and caused the project to be put on hold.
In 2018, INS decided to use ROBATEL Industries expertise in type B casks and in thermal and neutron shielding materials to review the container's design, and find solutions to complete its licensing process, while increasing its versatility.

Cask concept physical description

3578 Design principles:

- Initially driven by compatibility with existing plants, i.e. facility access, handling equipment and process methods at both UK (Sellafield) and French (MELOX) plants

- 2 x containment vessels of the package provide a multiple water barrier (MWB) system; increase in payload flexibility.

- Significantly reduced dose to operators for any given payload, due to the extensive use of a neutron shielding material deployed within the package structure.

The overall dimensions, weight and payload of the cask are described in the next table (Fig. 1)

Parameter	units	3578 design
Overall height	mm	1000
Overall Diameter	mm	450
Gross Mass	kg	300
Internal cavity height	mm	660
internal cavity diameter	mm	170
Loading capacity (x2)	kg	24
Max. Heat Load	W	170

Figure 1. Overall mass and dimensions

The cask body provides NCT and ACT impact protection, thermal insulation, neutron shielding, neutronic isolation (criticality) and constitute the outer containment vessel. The second

Containment boundary is composed of the removable inner containment vessel, its lid and inner O-ring seals. Each containment boundary has a testable seal arrangement. Figure 2 hereafter describes the design features of the package.

The contents, contained in primary containers (e.g. cans) are top loaded in the inner containment vessel, itself already placed into the cylindrical cavity of the cask body. The payload (maximum dimensions are approximately 170 mm in diameter and 660 mm high) is then retained and sealed by the inner containment vessel lid.
The ICV lid ring is installed, which will prevent movement of the inner containment vessel during transportation and the second containment enclosure is sealed by installing and bolting the outer lid.
For the transports, the package's body does not need additional impact limiter to limit the impacts in case of accident (especially for the regulatory 9 m drop tests on a rigid target) and also no additional thermal shield is required to ensure thermal protection in case of fire. The design, low weight and small size of the package allow for the cask body to fulfill these critical functions.
The overall design of the packaging is shown in Fig. 2: its overall dimensions are approximately 450mm m in diameter and 1.0 m high. The package is easily transported in the vertical position thanks to a specific and dedicated transport frame (as shown in Fig. 3) this isn't Fig 3?.

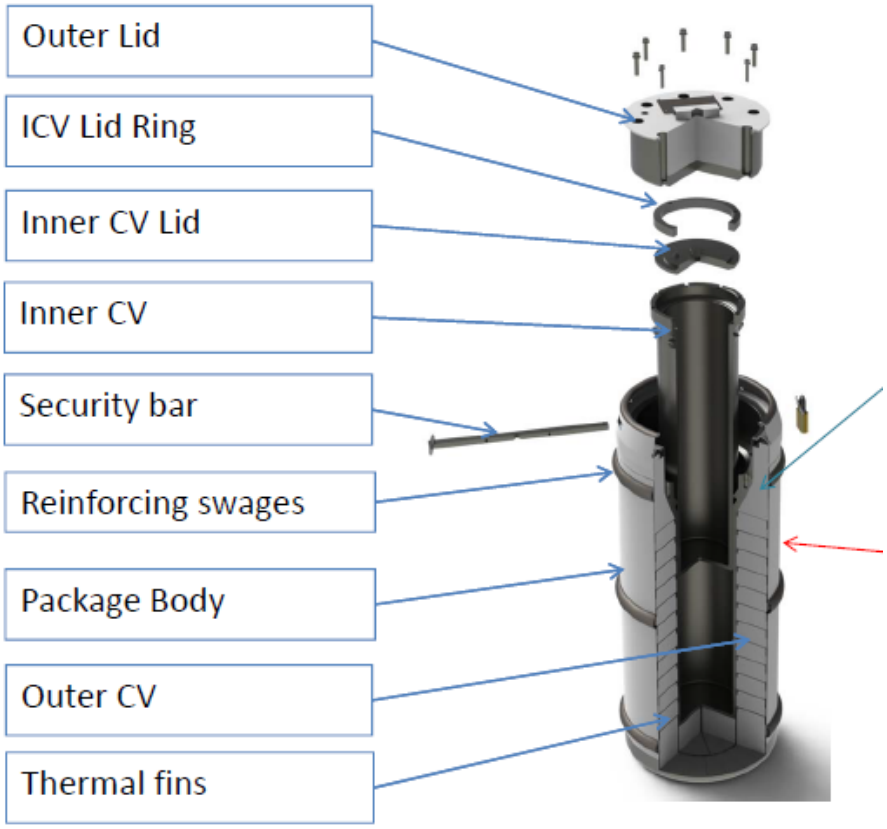

Figure 2. INS3578 main components

Transported Contents:

The 3578 was specifically designed for the following contents:

PuO2 powder transported within either one or two cans per package, surrounded by the appropriate internals and various other contents, referred to as "exotics" e.g.:
- Un-irradiated Plutonium,
- Un-irradiated Enriched Uranium,
- Irradiated Oxide, and
- Carbide (Un- irradiated and Irradiated).

NEW DESIGN AND SOLVED PROBLEMATICS

ROBATEL's neutron and shielding material solutions

The main issue the original design is facing is the performance of the neutron and thermal shielding material, especially during Accident Conditions of Transport (ACT). SSR-6 (Ref.1) requires the cask to undergo thermal test after HAC mechanical tests are complete. The thermal test requires:

"SSR-6 article 728 (a):
Exposure of a specimen for a period of 30 minutes to a thermal environment that provide a heat flux at least equivalent to that of a hydrocarbon fuel-air fire in sufficient quiescent ambient conditions to give minimum average flame emissivity coefficient of 0.9 and an average temperature of at least 800°C, fully engulfing the specimen, with a surface absorptivity coefficient of 0.8 or that value that the package may be demonstrated to possess if exposed to the fire specified. "

The original material selected for the shielding got exposed to fire after mechanical testing and during thermal tests which caused it to be consumed in a level that did not allow the temperature of the content and especially the containment seals to remain under specified limits.

On a neutron shielding perspective, the originally selected material has a high percentage of hydrogen, making of it a good performer. Additionally, the material's mechanical properties are also part of the model and contributing to 9m drop impact limiting feature. Therefore, in order to replace the initial material without impairing the cask to transport its expected fissile content, there are several aspects taken into account and being addressed.

ROBATEL Industries selected for this application a new compound family being the compound 23T^{M} and compound n°24^{TM}. These innovative neutron shielding materials are being presented in further details in this year's proceedings (abstract #1210 – presented by Dr. Constance ROBEYNS).

This polymer based materials differ by the first having high hydrogen and boron content, and the second being classified V0 (following standard UL 94), meaning it is fire resistant. The following figure describes the neutron absorption efficiency of ROBATEL's historical compounds and HDPE compared to the new Compound n°23™. The evaluation was performed under different moderators between the source and the shielding wall and using thermalized or fast neutrons. It shows the new compound 23™ matrix being much more efficient as former formulas and even more efficient than HDPE taken as a standard reference for comparison.

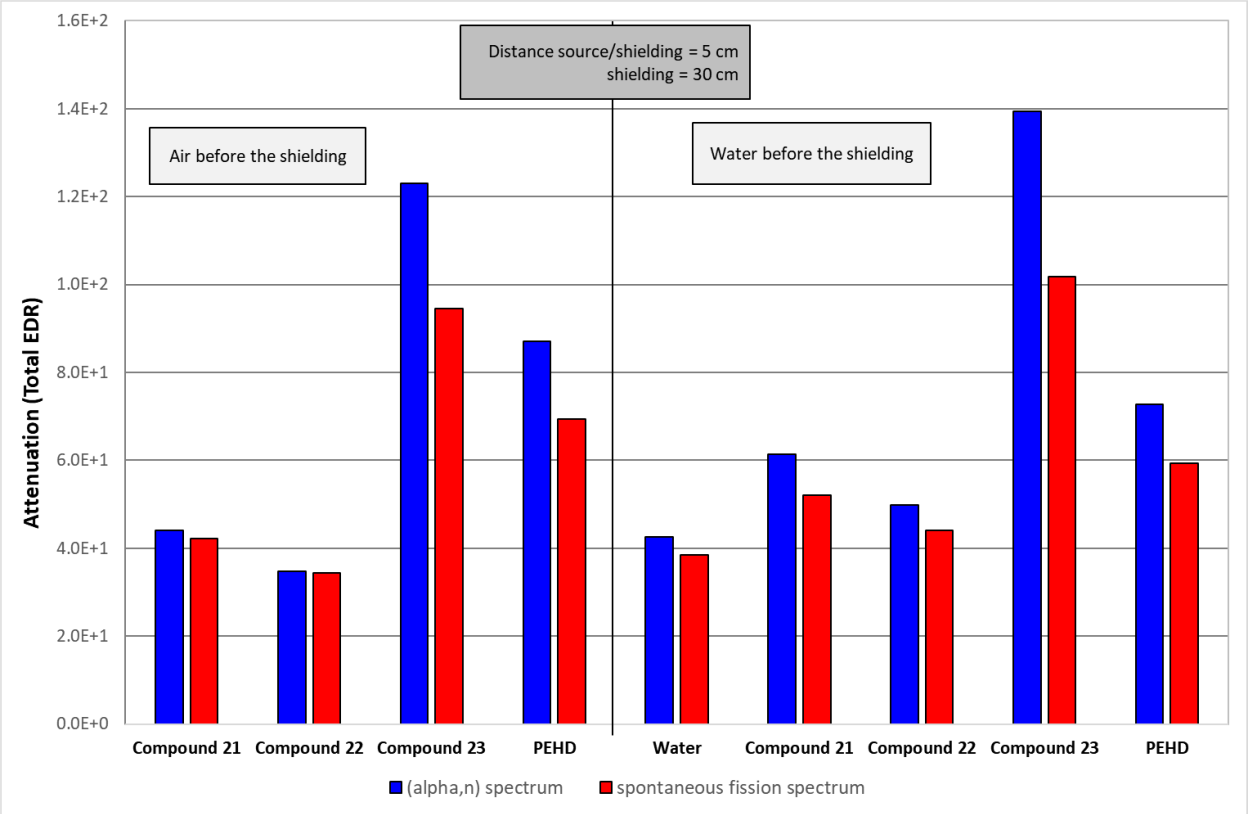

Figure 3. Compounds neutron shielding efficiency

The compound 23™ and 24™ also show great compatibility in terms of mechanical properties with Flexural stress reaching up to 35 N/mm² and compression stress reaching 50 N/mm², as is seen on figure 4. And figure 5.

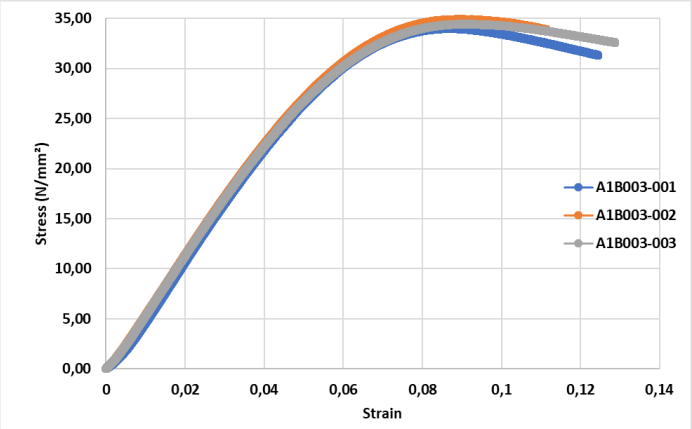

Figure 4. Mechanical characterization flexural stress - Compound 23^{TM}

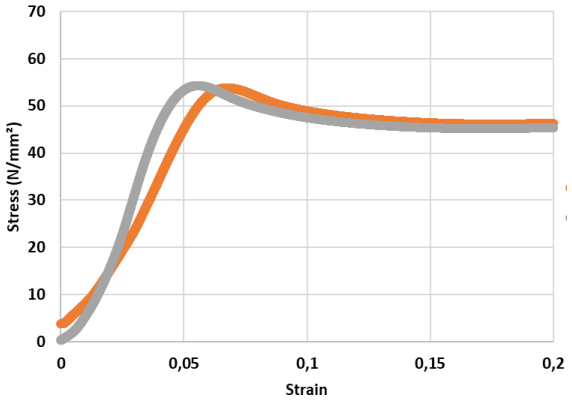

Figure 5. Mechanical characterization Compressive strength - Compound 23^{TM}

Based on its characteristics, we are able to implement our compound in the design of the new version of the 3578 cask. Its mechanical, thermal and neutron shielding properties allow the design to keep high quantities of fissile contents shipped, and its fabrication process being simpler than the former selected machined plate solution, we are able to simplify some aspects of manufacturing and offer different size of this new Type B(U) Fissile shipping cask.

Description of the proposed cask family solution

The new cask family will be designed as type B(U) fissile packages licensed per IAEA's latest regulations for the safe transport of radioactive material (Ref.1) for road, rail, sea and air transportation. There typical content will be similar as the original 3578 design being plutonium, enriched uranium, oxides and carbides and more generally samples, bulk isotopes in solid form. The design will offer high standard water barrier (double containment enclosure) and have the outer container will carry a releasable containment enclosure as per the principle of the presented package.

The dimensions of the payload will vary from small Ø75 mm x 200 mm approximately to larger sizes as presented here before and up to approximately Ø250mm x 950 mm. The maximum payload will be up to 40kg, the maximum permissible masses will be specified following content specifications addressed in the safety case in order to optimize the possible shipping load.

CONCLUSION

Since 2018, INS and Robatel are combining their strengths & experience to revive the 3578 development and to develop the cask as a flexible solution, in various sizes ranging from a small cask which can be handled manually through to a larger version for those utilities with greater lifting capacity.
We have been working on solving technical issues using innovative material solutions, thus securing overall features.
The different cask configurations presented here are still flexible and we are keen on to receive comments and suggestions from industry in order to tailor the design to the needs of the operators.

REFERENCES

Ref.1 – SSR-6 (Rev.1) Specific Safety Requirements – Regulations for the Safe Transport of Radioactive Material – 2018 Edition.

Ref.2 – PATRAM 2019 proceeding, #1210 - New Composite Materials for Neutron Radiation Shielding – Dr. Constance Robeyns, ROBATEL Industries, France