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Latest cask designs for international Use in Support of Medical and Research Reactors Stakeholders: TN®OGL , Flying Pig, TN®LC

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ABSTRACT

Research reactors and laboratories are centers of innovation and productivity for nuclear science and technology. Their work is essential for new developments in nuclear power, radioisotope production, nuclear medicine, material characterization and testing, and various other analyses. They are extremely valuable training and research tools. However, in terms of nuclear material transportation and package needs, they represent a small niche market with extremely specific requirements:

- There are 246 research reactors in 56 countries involving transportation between multiple countries with variations in regulatory practices.
- Materials for research purposes are typically with various characteristics (dimensions, material and isotopes) making package content standardization very challenging.
- New needs for transport packages emerge due to developments in the nuclear medical field and to new innovative therapies.

This paper presents three new cask designs being developed and licensed by the AREVA Logistics Unit in support of international needs for research reactors, laboratories and AREVA subsidiaries:

- The TN®OGL is a type A package for solid contents. By taking into account air transport regulations, the TN®OGL is able to transport isotopes with a short life duration worldwide. Its lightness (22 kg) and its compactness (diameter 40 cm and height 60 cm) make it very attractive relative to other Type A packages.
- The cask of the “Flying Pig” project is a B(U) package design to transport small quantities of irradiated material coming from various worldwide laboratories. With its

low weight (≅ 2.5 tons), small dimension (cavity diameter 150 mm, length 300 mm), and non-fissile material (<15g), the cask is able to travel easily throughout the world by air, sea or road. Furthermore, the transportable contents will be maximized due to its content definition (isotopes table).

- The TN®LC is a new type B(U)-F package for versatile contents that will accommodate full-length commercial 14-ft irradiated fuel assemblies or pins, or up to 180 research-reactor irradiated assemblies of different designs or other irradiated content. Its weight will be light enough to be used in the research reactor environment (25 tons) and to be transported by all modes. It will be available for US domestic and international shipments by end 2014.

INTRODUCTION

AREVA supplies solutions for carbon-free power generation. Its expertise and know-how in this field are setting the standard, and its responsible development is anchored in a process of continuous improvement. As the global nuclear industry leader, AREVA's unique integrated offer covers every stage of the fuel cycle, nuclear reactor design and construction, as well as related services.

Within AREVA, the Logistic Business Unit (BU-L) designs and manufactures packaging systems and organizes and carries out domestic and international shipments of radioactive materials, and also ensures tracking through its related services. For 50 years, the BU-L has provided high-performing, reliable and innovative solutions for the packaging and transportation of radioactive materials to its customers.

The BU-L has established a well-structured international network with unique capabilities to supervise transportation and manage risk, as well as an unfailing commitment to safety and security. The BU-L sets global standards with its internationally recognized know-how.

This paper presents three new cask designs, the TN®LC, the TN®OGL and the Flying Pig, being developed and licensed by the AREVA Logistics Business Unit to support the international needs for research reactors, laboratories and AREVA subsidiaries. They are the result of TN International in France and TN Inc. in the United States joint developments.

THE TN®OGL CASK, TYPE A

TN International has joined in the fight against cancer with its new TN®OGL cask developed for this specific project initiated by AREVA Med.

AREVA Med is an AREVA subsidiary specializing in the development of innovative therapies to **fight cancer**. AREVA Med has developed new processes for producing high purity **lead-212** (^{212}Pb), a rare radioactive isotope that is currently at the heart of promising nuclear medical research. To transport the radioisotopes from the production site to the test sites and optimize the flow as requested, TN International has developed a new cask, the TN®OGL (Oncology Globe Liaison).

Figure 1: TN®OGL package

The primary requirements in developing the cask were as follows:

- An increase in transport capacity
- Necessity to travel by air because of the short half-life of the radioisotopes
- Transportability on passenger flights
- A weight of less than 25 kg

Design of the cask

The TN®OGL is a type A cask, designed to transport solid materials. It consists of three distinct parts and weighs approximately 22 kg.

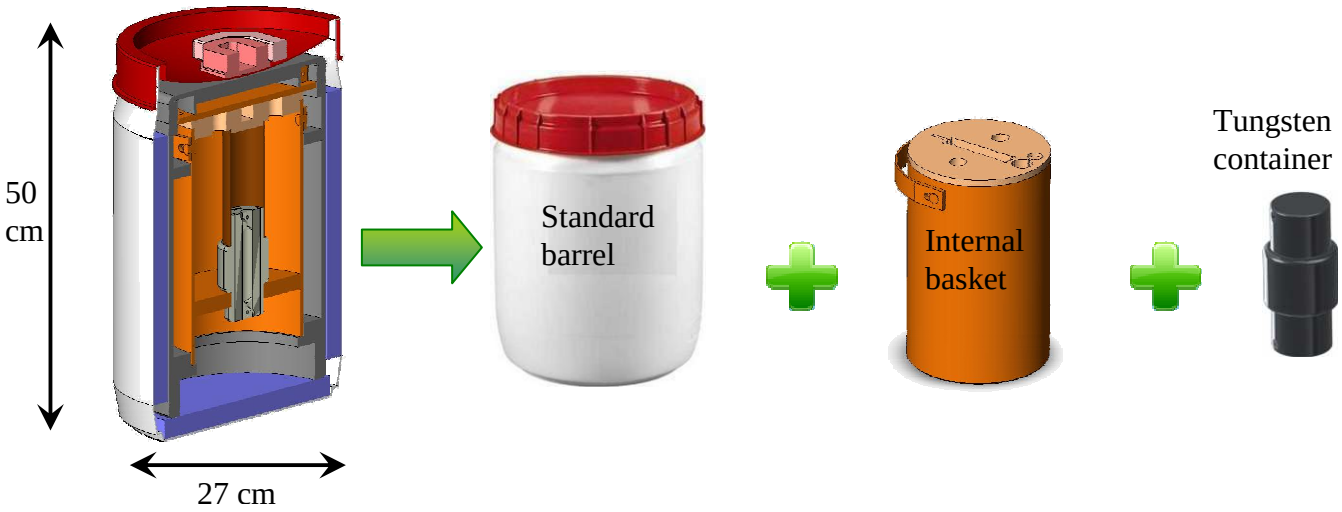

Figure 2: Exploded view of the TN®OGL cask

The size of the tungsten container, weighing 8 kg, was digitally calculated. The cavity was adjusted to the container of the transporter. The shielding is positioned very close to the source to optimize the weight of the cask and to make it as compact as possible.

This arrangement is adaptable relative to the content to be transported.

The basket has a double function: first to hold the tungsten container in place, second to facilitate the loading and unloading of the container during operations.

The dose of radioactivity when in contact with the cask is minimized by the optimization (digitally defined) of combining the geometric distance (via the internal basket) with the high density shielding (via the tungsten container).

A type A package

The certification of the cask was pronounced by TN International. The principle stages to define it are as follows:

- Identification of the applicable regulations relevant to the transport modes to be used and the countries in which the package will be transported
- Respect of the regulations, and of the AREVA Med radiological and mechanical specifications and size requirements

Radiological (Dose Equivalent Rate)

For the cask:

- Maximum Dose Equivalent Rate upon contact is **0.5 mSv/h** (regulation < 2 mSv/h)
- IT<3 (due to American air regulations for passenger flights)

For the internal compartment**:**

- Dose Equivalent Rate of 550 µSv/h upon contact with the interior compartment (operational requirement)

Mechanical (drop test)

- No loss or diffusion of material
- Increase of the dose rate < 20 %

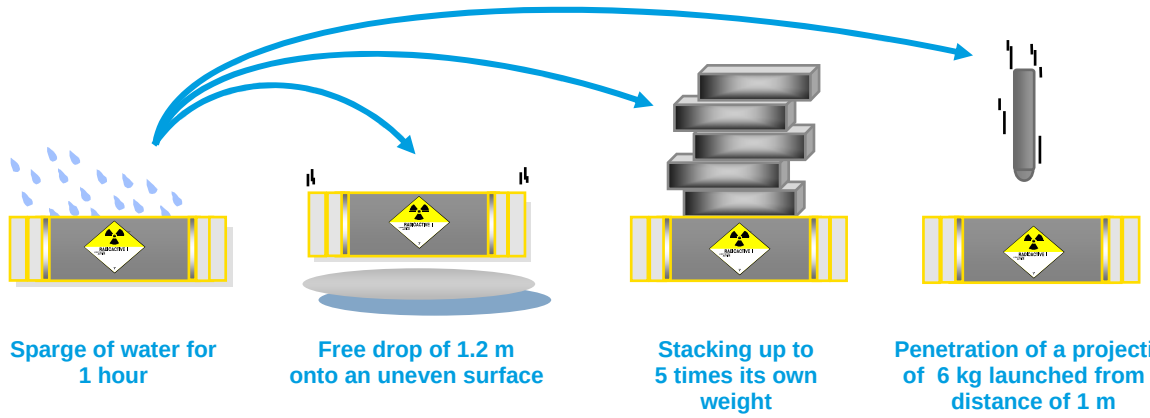

Figure 3: Tests for type A casks

- Validation of the design through a series of tests with positive results

The content

The content is composed of radioisotopes in solid form. The radioactivity is less than 1 A2 per year for a type A cask.

Diverse opportunities

The content may evolve according the need. This cask can be adapted to diverse contents using an identical design and demonstrations to those presented here.

The TN®OGL is able to transport isotopes with a short half-life worldwide while respecting air transport regulations.

Milestones

12 TN®OGL have been built and the first shipments are scheduled for mid 2013.

THE FLYING PIG TYPE B(U)

Over the past years, the demand for a **cost-effective** and **flexible solution** to transport small quantities of irradiated material for research purposes has been continuously increasing. However, there had been no small and low cost transport cask available on the market to carry out this task.

Hence, the Flying Pig project was initiated by some of the HOTLAB members: CEA (France), IFE (Norway), INL (USA), ITU (Germany), NNL (UK), NRG (the Netherlands), PSI (Switzerland), RIAR (Russia), SCK-CEN (Belgium), and Studsvik (Sweden). In this context, a specific Working Group was created in 2009 to investigate the transport issues and to develop specifications for a new transport cask. Taking into account prior experience and feedback of existing casks on the market, the Working Group was able to define the main principles of a new cask optimized for hot lab needs and to consequently issue a call for proposal for a cask following these principles.

The most important specifications for this B(U) cask are the transportability by air, a weight preferably below 4 tons, and the adherence to a fissile content limit of 15g (this value can increase as the regulations evolve). As no suitable cask could be identified, TN International was contacted at the beginning of 2011 for a first analysis. Taking into consideration the different kinds of contents, the thickness of shielding, and the release rate of fission gas, the mass of transportable irradiated material inside the cavity was determined for this new B(U) package. The goal was to reach a compromise between the package main dimensions and the transportable material masses (taking into account the results of shielding analysis and the loss of radioactive content analysis).

TN International's proposed solution maximizes the transportable content and takes advantage of an existing cask design, the TN®106. The objective is to keep the content definition as open and simple as possible in order to allow the greatest possible flexibility for clients.

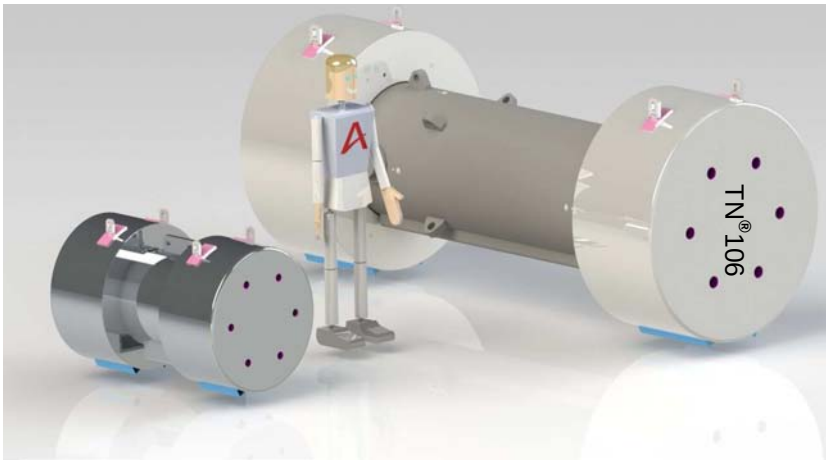

Figure 4: The Flying Pig and TN106 in Comparison

Main Design Principles of the Cask

As needed, the cask will be a "small cask" capable of shipping irradiated material by all modes of transport, including air, thus reducing the duration of transportation.
The new B(U) cask will have a French certificate with a US DOT validation, authorizing transportation in countries that have signed the ADR regulations and for international transportation to or from the United States.

The main characteristics of the cask are:

- a weight approximately 2.5 metric tons
- a cavity (cylinder) of:
  - ~ 300 mm in length
  - ~ Φ150 mm in diameter
- a gamma shielding equivalent to approximately 220 mm of steel

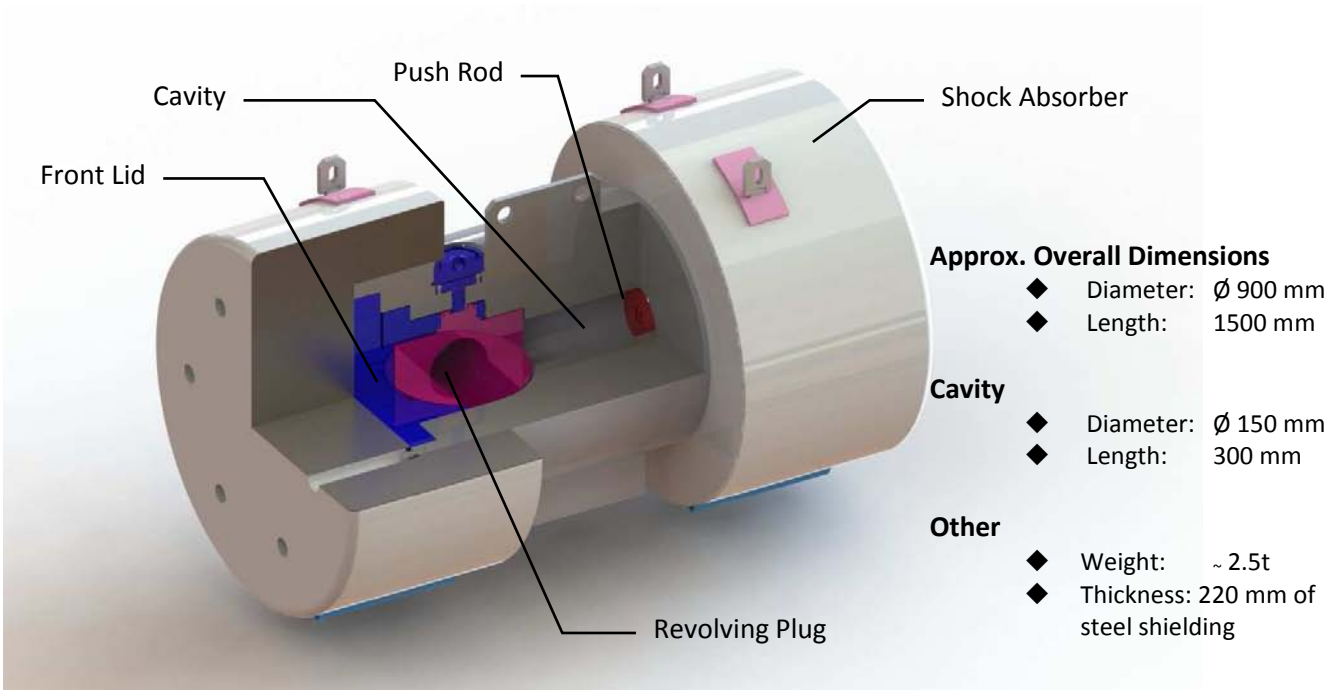

Figure 5: Flying Pig Design

In order to facilitate the modality of transportation, the cask will be a non-fissile cask (type B(U)). The quantity of fissile material will be less than 15g, in order to fall below the limit defined by the regulations (value which can increase with the regulations – 45g is the new value attempted in 2015).

Description and philosophy of content definition

In order to meet the main objectives (flexibility and cost efficiency), TN International opted to change the way of defining the content of the package for certificate of compliance. The content will be defined with a **"table of isotopes"** instead of a definition with **"physical parameters."**

The physical parameters defined the content of an irradiated pellet with its isotopic composition before irradiation, the type of irradiation, the burn-up fraction, the cooling time… This kind of definition is somewhat rigid. If the burn-up is higher than the maximum burn-up allowed by the certificate of compliance, a modification of the certificate will be needed which will reduce flexibility and increase costs. This is particularly detrimental for hot lab users whose needs are to transport very particular contents.

The definition using the **table of isotopes,** on the other hand, will detail each isotope present in the pellet and give the limits of all safety fields (release of activity, thermal evaluation…) for each isotope as shown in the list below. This way to define content **optimizes the capacity of the package** and **reduces the need to modify the certificate of compliance**. The safety studies use regulatory limits as a basis in order to optimize the capacity of the package. For users, this means that an optimized amount of material allowed under the regulations can be transported enabling them to quickly see which isotopes can be transported in what quantities.

Operability of the cask

The cask will be loaded and unloaded vertically as well as horizontally in connection to a hot cell (dry (un)loading) with its revolving plug and push rod, which are necessary to protect users.

The operability of the cask, broadly speaking, will resemble the TN®106, as the design of the cask is based on this existing TNI model. The use of the established design of the TN®106 guarantees good operability and reliability.

In fact, the TN®106 has an established track record of successful international shipments, having already completed more than 200 shipments since it was put into service in 2001. In addition, hot laboratories have already gained experience with this cask. It has, among others, a French FCA certificate, a DOT validation in the US, a BfS validation in Germany, as well as validations in Sweden and other countries.

THE TN®LC, A NEW TYPE B(U)F

In order to respond to new shipment needs and to support future USA domestic and international shipments, Transnuclear Inc. has developed a new transport package design named the TN®LC. The TN®LC package offers a specific and customized solution for research-reactor and laboratory shipments. In December 2012, the TN®LC package was licensed for transportation by the US NRC and is currently being manufactured. It will be available for US domestic and international shipments by the end of 2014.
The TN®LC ("Long Cask") is a new type of B(U)F package that features different basket designs that can fit into the TN®LC cavity, thus it can accommodate used fuel from research reactors (MTR, TRIGA, NRU/NRX, etc.), full length commercial irradiated fuel assemblies (PWR, BWR), irradiated pins (EPR™, MOX, PWR, BWR) to support Post Irradiation Examinations, or other irradiated content.
The TN®LC package can be used in commercial power plants as well as in research reactors and laboratories due to its operational flexibility.

About the TN®LC design

The innovative TN®LC package is a US NRC licensed transport package designed to safely handle U.S. domestic and international shipments of used commercial and research-reactor fuel assemblies and irradiated material. It has been designed to meet the most recent safety standards from the IAEA and of the different competent authorities of the countries where the TN®LC is intended to be transported. It is already licensed in the US (Certificate of Compliance USA/9358/B(U)F-96) and is planned to be licensed in many countries around the world.
Its design includes features that have already been developed and tested for other packages providing proven improvements in safety, increased transport capabilities and ease of operations.

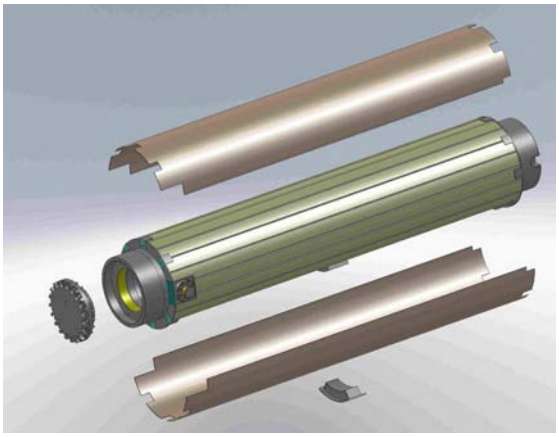

Figure 6 : TN®LC package design

The main dimensions and mass characteristics are the following:
Outer: length 197.5 inches (5,.017 mm); diameter 44.5 inches (1,130 mm)
Inner: length 182.5 inches (4,636 mm); diameter 18.0 inches (457 mm)
The TN®LC package can hold longer fuel assemblies with a total on-the-hook weight limited to 25 tons.

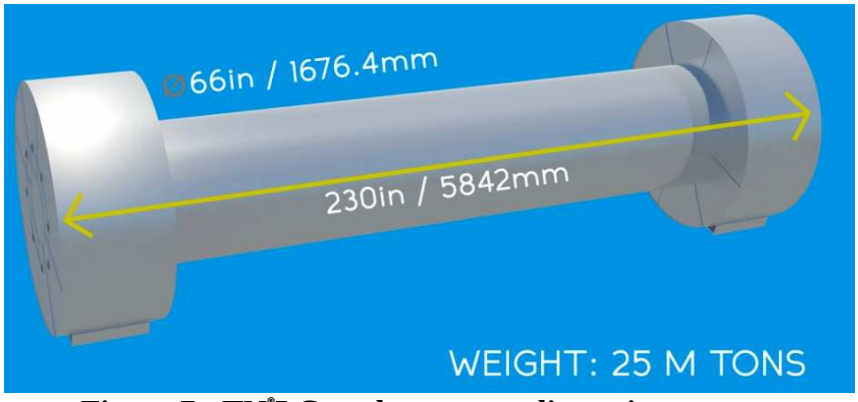

Figure 7 : TN®LC package outer dimensions

The TN®LC is the lighter and longer package with the higher capacity.

Versatile Package Designed for a Variety of Contents

The TN®LC package has been designed to transport various types of fuel pins from commercial and research reactors, including commercial fuel assemblies (BWR, PWR), rods or pins (EPR™, MOX, PWR, BWR), NRU/NRX, TRIGA elements, MTR fuel assemblies and more. For this purpose, four different internal arrangements, called baskets, have been designed to accommodate the different payloads in an optimal way:

- MTR basket: for the transfer of MTR assemblies (three by three arrays by bucket) using a dry transfer system
- TRIGA basket: for the transfer of nine TRIGA fuel assemblies at a time and the potential use of a dry transfer system
- NRU/NRX basket: for the transfer of thirteen intact or damaged NRU or NRX assemblies at a time with a dry transfer system
- 1FA basket: accommodates one intact full-length PWR or BWR fuel assembly, or pin cans that can accommodate up to twenty five intact PWR, BWR, EPR™ or MOX fuel rods
- Other baskets can also be designed to accommodate other contents as needed

The TN®LC capacity has been optimized. The TN®LC, with the longest and largest cavity on the market, can accommodate a larger payload resulting in more cost-effective transport. For each package, the maximum number of assemblies that can be shipped is:

- 1 PWR/BWR assembly
- 25 PWR/BWR/EPR™/MOX pins
- 26 NRU/NRX assemblies
- 54 MTR assemblies
- 180 TRIGA elements

The TN®LC for the Transportation of High Burnup Fuel.

The maximum burnup licensed by the US NRC is based on the type of fuel, on the enrichment and on the cooling time of the fuel. As there is a wide range of contents, a variety of combinations are authorized such as MTR fuel with a maximum enrichment of 94%wt. in U-235, the maximum burnup is 660 GWd/tU and minimum cooling time of 740 days for

example. It can also accommodate UO_2 fuel rods transported in the pin can with a maximum burnup of 90 GWd/tU.

Flexible Operational Capabilities

With its 25-ton weight, the TN®LC package complies with most commercial or research reactor site weight restrictions. An additional dry transfer system can be developed to support the dry transfer operation. The TN®LC package is designed to be loaded or unloaded in vertical or horizontal positions and can be operated in wet or dry conditions, in fuel pools or hot cells; allowing operation in sites with weight restrictions and shallow pools.

Schedule

The TN®LC package is under fabrication and will be available in 2014, simultaneously with the issuance of foreign validations.

CONCLUSION

New needs for shipping packages emerge due to developments in the nuclear medical field and in new innovative therapies. Material characteristics for research purposes typically vary widely (dimensions, material and isotopes) making package content standardization very challenging.

Three new casks have been presented: type A, type B(U) and type B(U)F at three development stages, designed to respond to new transport needs.

The first shipments using the TN®OGL will be executed this year. The content may evolve according the need. This cask can be adapted to diverse contents with a design and demonstrations identical to those presented here.

The "Flying Pig" design process is currently planned to be completed in 2014, the manufacturing of the cask one year later in parallel with French Competent Authority approval by the end 2015. Afterward, the "Pig" can fly in countries that signed the ADR regulations! For the US, the DOT validation will be issued approximately six months later.

The TN®LC package is a new generation transport package to be employed for the safe transport of used fuel. It has been designed to handle a large variety of contents for U.S. domestic and international shipments with flexible operational capabilities for use in commercial and research reactor sites. The main advantage of the new cask is its high capacity, the various types of content allowed, and its weight which is light enough to be used in the research reactor environment.

Notes

[1] A type B(U) package is a package which can transport various kinds of material with high activity. This kind of package can withstand a free drop of 9 meters and a fire of 30 minutes with limited impact on the environment.