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THE PACKAGING AND TRANSPORATION OF FUTURIX-FTA FUEL PINS

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ABSTRACT

The Futurix project is an international collaboration program between the United States Department of Energy (DOE) and the French Commissariat à l'Energie Atomique (CEA). The project deals with irradiation test of experimental fuels to be conducted in the Phenix Reactor located at the CEA-Marcoule site near Avignon, France. This paper describes the process for shipment of unirradiated plutonium based fuel pins from the Idaho National Laboratory to the Phenix Reactor utilizing a French licensed transport package; TN-BGC 1. This type of knowledge and experience is vital to the shipment of both fuel and radioactive waste material.

INTRODUCTION

The shipment of any radioactive type material includes the three basic elements of: the package, regulatory compliance, and transport logistics. The transport package must meet the physical requirements of the specified payload. Regulatory compliance ensures that all applicable governmental regulations are adhered to. Regulations concerning safety, material accountability, and liability are incumbent on the responsible party to understand and follow. The transport logistics dictates the actual mode of conveyance including air, land, and sea and the associated detailed planning of each transport route.

The shipment of the Futurix plutonium based fuel pins presented specific challenges in each of the three basic transport elements. The specified package, the TN-BGC 1, required an internal arrangement to contain the fuel pins to prevent damage during the transport and to record the temperature of the pins which could affect the sodium bonding of the metal fuel. Two TN-BGC 1 transports were utilized to streamline the regulatory process. The regulatory compliance issues

emanated from the United States, France, and various international regulations including the International Maritime Dangerous Goods Code (IMDG) [1]. In addition, international liability in the form of the Price Anderson Act (PAA) [2] and the Paris Convention Accords were applied appropriately throughout the transport. The logistics of the Futurix transport included ground arrangements in the United States and France, the ocean transport, and transfers at the ports of Savannah, Georgia and Cherbourg, France.

PAYLOAD

The Futurix payload consisted of four sodium bonded fast reactor fuel pins. INL fabricated the two metallic alloy fuel slugs and Los Alamos National Laboratory (LANL) fabricated two nitride fuel pellets. At INL, the four pins were clad in stainless steel tubes of 0.655 cm outer diameter and 50 cm in length. The pins make use of a metallic sodium bond in the fuel-clad gap. The metallic sodium will be solid during transportation. The projected elemental masses of the pins are delineated in Table 1.

The two metallic alloy fuel slugs fabricated at INL have design dimensions of: solid cylinders having a nominal diameter of 0.489 cm and a nominal height of 10.0 cm. The two metallic alloys have a nominal composition of Pu-12, Am-40Zr and U-29Pu-4Am-2Np-30Zr, where alloy constituents are given in weight-percents.

The nitride fuel pellets of two compositions were fabricated at LANL and shipped to INL for use in fabricating of two more experimental fuel pins. The fuel pellets as designed have outer diameters of 0.489 cm and the pellets are stacked in each of the two fuel pins to a nominal total fuel column height of 10.0 cm. The two nitride fuels will have nominal compositions of $(U_{0.50},Pu_{0.25},Am_{0.15},Np_{0.10})N$ and $(Pu_{0.50},Am_{0.50})N$-36wt%ZrN.

Table 1. Projected Elemental Masses of Metallic and Nitride Fuels in Shipment

	Fuel Elemental Masses (g)					
	Total	Total	Total	Total	Total	Total
Fuel Composition	Alloy	Np	U	Pu	Am	Zr
Pu-12Am-40Zr (1)	18.6	0.000	0.000	8.925	2.231	7.437
U-29Pu-4Am-2Np-30Zr (2)	21.4	0.428	7.493	6.209	0.856	6.423
(U0.50,Pu0.25,Am0.15,Np0.10)N(3)	21.8	2.057	10.262	5.145	3.088	0.000
(Pu0.50,Am0.50)N-36wt%ZrN (4)	19.5	0.000	0.000	5.904	5.907	6.094
TOTAL	81.3	2.485	17.776	26.183	12.083	19.954

TRANSPORT PACKAGE

The TN-BGC 1 transport package is utilized internationally for transport of low and high enriched materials up to 95% (powder, pellets, etc). Outer dimensions of the packaging are 1,800 mm × 600 mm × 600 mm (70.9 in × 23.6 in × 23.6 in). The maximum loaded weight is 400 kg (882 lbs). Figure 1 shows a cutaway view of this transport package.

The package is comprised of the following components:

1. An inner stainless steel shell defining a useful cavity of 178 mm (7.0 inches) in diameter, and 1,475 mm (58.1 inches) in length
2. A resin layer for neutron absorption for the criticality control and dose rate reduction.
3. An outer stainless steel shell protecting the resin.
4. A Closure Lid using a bayonet system device avoiding the use of bolts.
5. An impact limiter plug which protects the Closure Lid.
6. An aluminum frame surrounding the cask to facilitate the handling and tie down system.

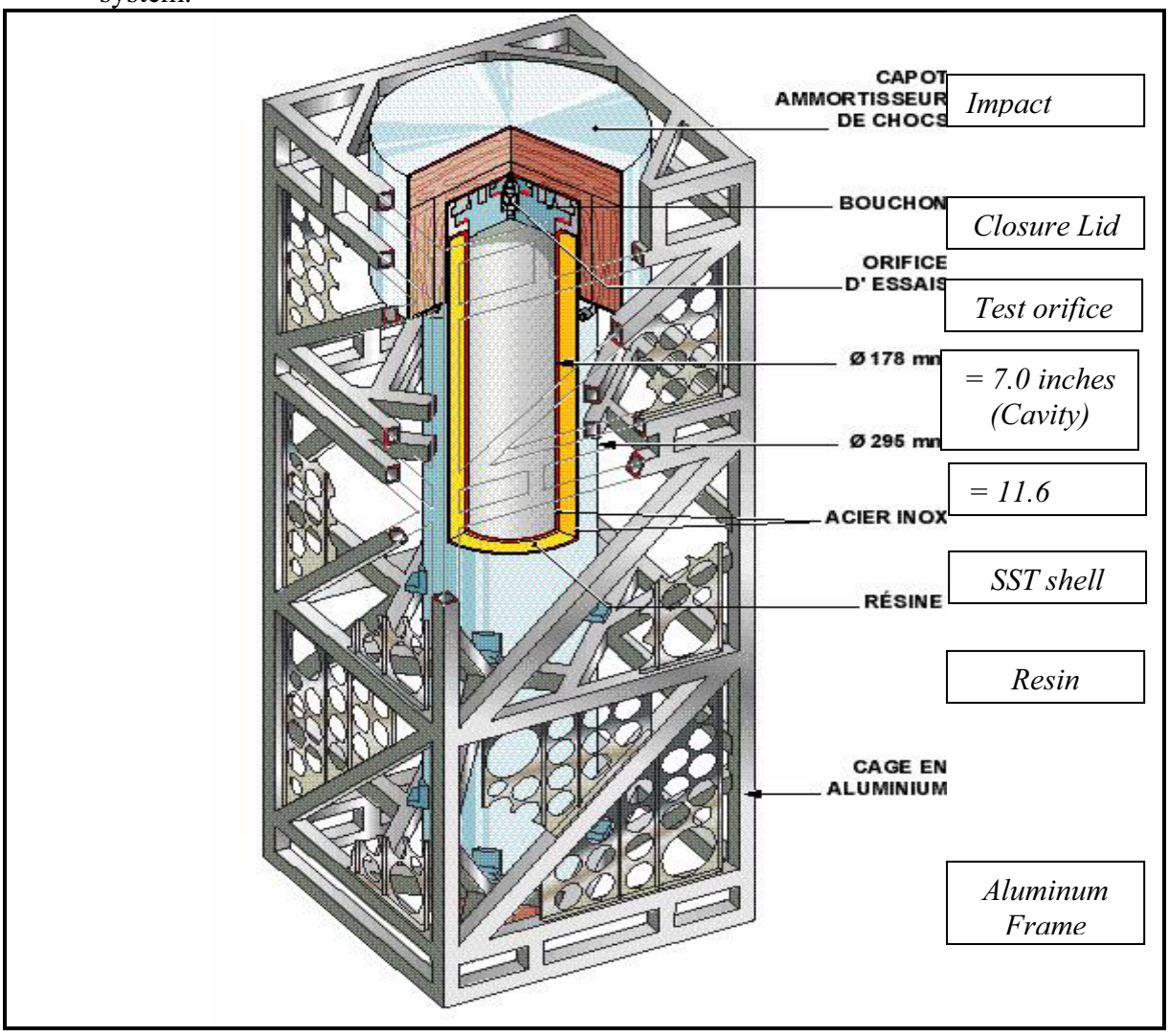

Figure 1. TN-BGC 1 Transport Package

Primary Arrangement

As the TNBGC-1 design accommodates various radioactive contents, a set of internal arrangements called Secondary Internal Arrangement and spacers are available and licensed accordingly for each payload. For the Futurix transport, the TN-90 Secondary Arrangement was utilized and a primary internal arrangement was designed specifically for this transport.

Temperature tape was required to document that the pins stayed below 80C to preclude the need for additional sodium bond settling upon arrival at Marcoule, France.

REGULATORY COMPLIANCE

International shipment involves the understanding of all the regulatory issues for each country that the package will travel through. In the case of the Futurix shipment, the French Safety Analysis Report (SAR) for the TN-BGC 1 was required to be amended by the CEA to add the Futurix payload to the French competent authority certification. Once this process was successfully completed, it was necessary to submit the revised French amendment, along with the payload configuration, for approval by the United States Department of Transportation (DOT) per 49CFR173 to allow for the import or export only of material meeting the Futurix payload profile. A United States export license issued by the Nuclear Regulatory Commission (NRC) was required. International liability was also a key issue to properly implement based on contractual agreements and legal regulations.

French TN-BGC 1 SAR Amendment Process

The TN BGC1 package design already had a French approval certificate. For the FUTURIX payload, a French extension of the approval certificate was necessary. CEA was required to revise the Safety Analysis report of the TN BGC1 package design in order to submit the FUTURIX payload. The application for the extension of the approval certificate was performed by CEA to the French Competent Authority (DGSNR) in February 2005. A type B(U)F package design was applied as it was initially foreseen to transport all the pins in only one cask. The French extension F/313/B(U)F-96 (Haf) for the FUTURIX content was issued in October 2005.

United States Revalidation Process

The utilization of foreign certified packages within the United States require the approval of the DOT in concert with the NRC as deemed necessary. It is important to stress that this revalidation of a foreign certificate of compliance is only valid for direct import or export activities.

According to 10CFR71.15, a content is exempt from classification as fissile material if the package contains 15 grams or less of fissile material. The benefit of the fissile exemption is that no criticality analysis is required. However, the package is still a Type B package, requiring certification from DOT. By shipping two pins per TN-BGC 1 it was possible to request the fissile exemption which reduced the supporting documentation to the DOT but necessitated the use of two packages.

Export License

An Export License is required for the export of special nuclear material such as plutonium. Because it is mandatory that the export license be approved prior to the initiation of the shipment, the effects of sea vessel timing can be heavily affected by this process. Approval of the Futurix Export License required 3 months due to the various governmental agencies completing the review both in the United States and France. Final contract negotiations with the sea vessel

were not completed until this document was received because of the possibility of costly port costs for maintaining a vessel on standby if the Export License was delayed.

International Liability

The Price Anderson Act (PAA) and the Paris Convention Accord were the two instruments utilized for liability during the Futurix shipment. It is important to understand where each of these instruments is applicable with respect to the actual shipment route. At a minimum, the PAA is typically invoked within the United States and territorial waters. However the entity that has title to the material plays a large role in the liability issue.

The nuclear liability protection afforded by the PAA with respect to the Futurix fuel pins arises from the DOE's "Nuclear Hazards Indemnity Agreement". DOE includes this agreement in contracts whose performance is deemed to pose a risk of a nuclear incident. This Indemnity Agreement is set forth in DOE's procurement rules per 48 CFR952.250-70. For these types of shipments it is vital that this DOE requirement is properly “flowed down” from the primary contractor to all subcontractors to indemnity all parties involved through the various purchase orders issued for the project.

The nuclear liability protection afforded by the Paris Convention and French law is based on the Third Party Liability of the Field of Nuclear Energy of July 29, 1960 and its protocols. The “Certificate of Financial Security” that is referenced in article 4(c) of the Paris Convention is the actual document required to be issued by the French operator (in this shipment; CEA) to the shipping contractor. The ” Certificate of Financial Security” documents specifically indicates the extent to which financial protection under the Paris Convention and French law implementing that Convention will be applicable. For the Futurix shipment, the details of the French Convention were stated in agreements between DOE and CEA.

TRANSPORT LOGISTICS

A time line for the major milestones of the Futurix shipment is presented in Table 2. This table gives a clear indication of the time and effort involved in planning and executing an international shipment of radioactive material.

One of the key requirements for a successful transport is the completion of at least one complete dry run of the entire process. Dry runs, utilizing qualified personnel, of the procedures with a simulated payload, the actual package, and supporting equipment such as the leak testing equipment and tie down systems are paramount to ensure the safety of the transport and compliance to regulatory requirements. In addition a thorough dry run of all transport paperwork minimizes issues from arising during the actual transport.

Table 2. Futurix Transportation Milestones

Milestone	Description	Activity Initiated	Activity Completed
Feasibility Study	A Packaging and Transport Scenario study written to describe all packaging services required to complete the Futurix Transport	7/2005	10/2005
French Amendment	Receipt of French Amendment for Futurix payload	2/2005	10/2005
DOT revalidation	Receipt of DOT approval of the French amendment for Futurix payload	2/2005	4/2006
Dry Run of loading	Verification of internal arrangements, leak testing, loading procedures	4/16/06	4/16/06
Fuel Fabrication	Fabrication of nitride pins at LANL, metal pins at INL, fuel jacket/sodium bonding at INL	5/2005	6/2006
Export License	Receipt of NRC Export License	4/2006	7/2006
US Ground Shipment	Load at INL for shipment via US public roads to Port of Savannah, GA	8/14/06	8/16/06
Atlantic Crossing	Transfer of cargo from truck to ship and shipment to Cherbourg, France	8/17/06	9/4/06
French Ground Transport	Unloading at Cherbourg, France and ground shipment to the Phenix Reactor	9/5/06	9/7/06
Final Acceptance	Radiograph of fuel pins to verify sodium bond and overall fuel pin integrity	9/17/06	9/17/06

Transport Documentation

A major aspect to any radiological shipment is the necessary paperwork to ensure safety and accountability of the material. The major documents required for the domestic transport segment of Futurix included: Inland Bill of Lading, Exclusive Use Instructions, and Radioactive Material Emergency Response Information.

The major documents required for the international segment of this transport included: Competent authority certification in USA, Competent authority certification in France, Pro-Forma Invoice, TNBGC1 Shipping Container Shipment Checklist, Dangerous Goods Declaration, NRC Export License, Shipper's Export Declaration, and Ocean Bill of Lading.

Tie Down Design

For US road transportation of generic materials, 49CFR393 specifies the loads to be considered for transporting material on public roads. However, these loads apply to any carried material and are not specific to dangerous goods and class 7 transportation. To utilize a more conservative standard, the draft American National Standards Institute(ANSI) N14.2 l, the International Code

for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships **(**INF) code, and the International Atomic Energy Agency (IAEA) were also reviewed. Table 3 shows the various load accelerations evaluated for the tie down design. The final values were a compilation of the reviewed data.

Table 3 – Load Acceleration per Transport Mode

Transport mode	**Longitudinal (+ forward / - rearward)**	**Transverse**	**Vertical (+ up / - down)**
US road transportation	+ 0.8 g - 0.5 g	± 0.5 g	-0.2 g
	± 1.5 g	± 1.5 g	± 1.5 g
Sea transport	± 1.5 g	± 1.5 g	+ 1.0 g - 2.0 g
Road Transport	±2.0 g	± 2.0 g	+ 2.0 g - 3.0 g
Bounding Load	**± 2.0 g**	± **2.0 g**	**+ 1.5 g - 4.0 g**

Based on the load analysis, the Futurix tie down system was designed of commercially available straps, lumber, and rigging bolts. The connection points within the ISO container were verified by the supplier to meet acceptable load limits for this transport.

United State Ground Transportation and Ocean Transport

The two TN-BGC 1 packages were shipped in an ISO container with the stated tie down system in place from the Materials and Fuels Complex on the INL to the Port of Savannah, GA. A team of two drivers meeting the appropriate DOT regulations for transporting radioactive material completed this transport segment.

The ISO container was loaded onto the Atlantic Osprey as shown in Figure 2. The Futurix Shipment and one other transport were the only cargo aboard ship. The Atlantic Osprey is an INF-2 vessel approved under the IMO code for the transport of irradiated nuclear fuel, high level waste and Plutonium with radionuclide activities of 2 x 10^6 TBq for the former two and 2 x 10^5 for Plutonium. The vessel is British Flagged and crewed by United Kingdom nationals. The Osprey is capable of both load/on/load off and roll/on/roll/off loading. The Osprey has accommodation for armed guards in addition to numerous shipboard security features. For this shipment none of these security features are required. The Atlantic Osprey calls into the US roughly twice a year with Foreign Research Reactor fuel being returned to the US DOE.

French Ground Transportation and Final Receipt

Upon arrival at the Cherbourg Port, the ISO container loaded with the TN BGC1 containing the FUTURIX pins was unloaded from the vessel onto a LMC vehicle. These vehicles comply with

the European Agreement concerning the International carriage of dangerous goods by road (ADR) and particularly for the transport of radioactive materials.

Figure 2. Cherbourg Unloading Preparations (Atlantic Osprey dock side)

After departing from the port, the Futurix transport traveled from Cherbourg to the CEA facility of Marcoule (2 days of transport). Due to the physical category of the transport, a stop over night in another nuclear facility of CEA (Saclay) was necessary. At the arrival at Marcoule, the TN BGC1 was transferred to CEA for unloading. Once unloaded, CEA completed radiography on the four FUTURIX pins at Marcoule and the condition of the fuel and bond sodium was confirmed to be consistent with the original fabrication data.

CONCLUSION

The Futurix Transport successfully demonstrated the international shipment of research plutonium based fuel pins by appropriately addressing the three basic elements of any shipment of radioactive material: package requirements based on payload properties, regulatory compliance of all nations involved including international liability, and transport logistics covering all conveyance modes.

The integration of these shipment elements requires detailed scope planning prior to execution of any actual shipment tasks. The ability to properly sequence issuance of regulatory approvals and notifications with the actual movements of the material is one of the major challenges of international shipment.

REFERENCES

1. International Maritime Dangerous Goods Code, International Maritime Organization, 2004 Edition.
2. Price-Anderson Nuclear Industries Indemnity Act, 1957, US Congress, amendment to the Atomic Energy Act of 1954.

