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KEY CHARACTERISTICS OF ROUTINE MOX FUEL TRANSPORT

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ABSTRACT

For more than 25 years, AREVA TN has been organizing worldwide transportation of MOX fuel assemblies. As MOX fuel assemblies are partially made of Plutonium, their transportation must comply with the International Physical Protection rules, in accordance with each national application thereof. AREVA TN implements more than 60 shipments per year of MOX fuel assemblies using the MX cask fleet. The first use of a MX cask was in 2002. The MX cask family is now the referenced cask family for the transportation of MOX fuel assemblies in Europe and in Japan.

The purpose of this paper is to present:

- The MX cask family characteristics for the transportation of MOX fuel assemblies
- The evolution of the different regulations for the transportation of MOX in the world
- How ARENA TN complies with these different regulations for international transportation with regards to the transport procedures, the different monitoring systems implemented during the shipments, the adaptation of the transport means, the conditions for the transportation of the empty casks after unloading of the MOX fuel assemblies
- The evolution of insurance policies covering loss and damage and their contractual consequences
- The management of the cleanliness of MOX transport casks vis-à-vis plant constraints

Application of the MX6 cask in the case of German and Japanese transport is also presented, proving that such transport is fully mastered and made simple for the customers.

INTRODUCTION

Mixed oxide fuel (MOX) is a blend of depleted uranium oxide powder and plutonium oxide powder. The physical appearance of a MOX fuel assembly is not different from that of UO2 fuel. However, there are important particularities which differentiate them: dose rate for radiation for MOX fuel is significantly higher; the thermal load is elevated; risk of contamination and criticality is higher. Furthermore, as MOX fuel assemblies are partially

made of Plutonium, specific transport means were developed to cope with the Physical Protection rules.

These specificities necessitate special packaging, transport means and organization conditions which have evolved in response to the changing environment over the last 25 years. The Competent Authorities have been continually preoccupied by safety and physical protection issues for the security of the public. In parallel, the nuclear industrial sector has amassed experience that has led to significant operational improvements. These regulatory changes and operational improvements have necessarily been incorporated into AREVA TN's design of transport means as well as our organizational services.

This paper is going to focus on the regulatory and industrial evolutions in the design of means and in organization in the last 10 years that have resulted in AREVA TN's state-of-the-art MOX offering.

1. MEANS

1.1. Casks

To better understand AREVA TN's current design, the MX6, an analysis of the evolution of the product is revealing.

1.1.1. FS69 to MX8

MX8 casks were developed by AREVA TN to transport fresh MOX fuel assemblies. They replaced the previous FS69 casks which were in service between 1995 and 2003.

1.1.1.1. Industrial input

The main characteristics stipulated by the utilities at the end of the 1990s were:

- Unloading under water in the NPP to limit dose rate
- The increase of the fuel burn up leading to an unfavorable Pu isotopic composition after reprocessing
- An equivalent payload which is therefore linked to the total transportation cost

<u>Fuel integrity</u>

To maintain fuel integrity, MOX fuel as well as UOx fuel is to be transported under very careful conditions. A wedging system is required to absorb the main mechanical stresses during the handling and the transportation phases. Due to relatively high dose rate (cumulated effect of the increased payload and Pu isotopic composition) the clamping system should be able to be tightened very quickly or should be remote controlled. The MX8 was designed with a sophisticated pneumatic remote command to remove the clamping system under water.

1.1.1.2. Regulatory input

Although the MX8 was developed in order to take into account the evolution of industrial needs, AREVA TN also took into account the new IAEA standard in its design:
IAEA 96 standard required a complete flooding of the cavity of the cask during the criticality demonstration whereas IAEA 85 had stipulated that the amount of water in the cavity had only to correspond to the leak-tight level of the package.

In addition, in the 1990s the French Authorities further required a demonstration of the integrity of the fuel assemblies which was verified through drop tests performed on casks with a mock-up of fuel assemblies to verify leaktightness of the cladding under accidental transport conditions. This unfortunately revealed a breech in the leaktightness of the fuel rods. As a result, AREVA TN improved the design of the shock absorbers, the basket, and the resin (as well as its implementation) of the MX8.

With the constraints of the IAEA 96, the demonstration of the criticality of the FS69 was no longer possible.

1.1.2. MX8 to MX6

1.1.2.1. Regulatory input

The same regulations were applied to both the MX6 design and the MX8 design. Meaning there was no regulatory change.

1.1.2.2. Industrial input

The MX6 cask was designed for dry conditions to simplify the loading and unloading process and to avoid contamination issues, leading to the optimization of operational costs:

- The operation for loading the fuel in the MX8, which is internally contaminated, is performed with a specific containment device in order to avoid the contamination in the loading room. As the MX6 cannot be internally contaminated, this device is no longer necessary.
- The duration of the unloading operation of an MX8 under wet conditions requires 12 shifts, where only 4 shifts for the unloading of the MX6 under dry conditions are necessary.
- Taking advantage of the reduced duration of the operations, the total dose the operators are exposed to dropped from 1 mSv for the wet unloading of the MX8 to 0.5 mSv for the dry unloading of the MX6.

Furthermore, the clamping system was simplified: The fuel assembly is simply clamped in position coupled with a V position in the basket lodgement. The advantages of this new clamping system are:

- Ease of the operations
- No more remote command equipment: Operating and maintenance cost reduction
- Flatness of the lodgement to facilitate cleanliness

Figure1. Clamping system in the MX6

Figure 2. V position during transport

1.1.3. MX Cask Family Characteristics

The MX casks consist of an outer body and internal basket. The outer body is a double shell cylinder described as follows:

- the inner steel shell which acts as containment
- the outer steel shell providing mechanical strength to the cask
- the area between the shells of a neutron shielding resin and copper fins for heat dissipation of the content
- an upper and lower flange welded to the inner shell
- a lid screwed onto the upper flange complete the containment
- wood covers (as shock absorbers) screwed onto the upper and lower ends to ensure the mechanical integrity of the cask

The internal basket consists of:

- 6, 8, 10 or 16 compartments to maintain the internal geometry of the cask in a criticality-safe configuration in accordance with transportation regulations
- an assembly clamping system to ensure fuel integrity during routine transportation operations

The fuel assemblies are transported in the horizontal position.

The MX6 cask (see Figure 3) is loaded either with 6 PWR fresh MOX fuel assemblies or with 10 or 16 BWR fresh MOX fuel assemblies. It has a total gross weight of less than 20 metric tons (MT), a total length of 5,980 mm, a body diameter of 1,340 mm and a shock absorber diameter of 2,130 mm.

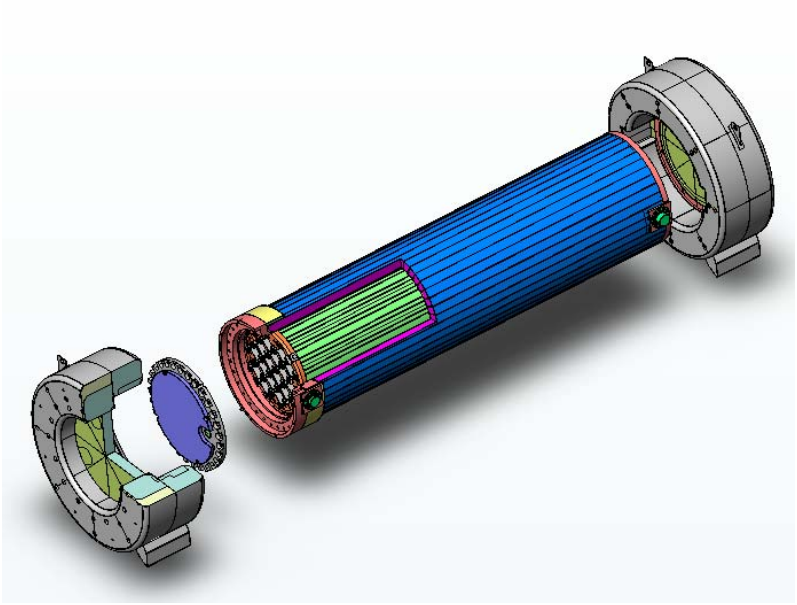

Figure 3. MX6 cask with BWR basket

The MX8 cask (see Figure 2) is loaded with 8 PWR MOX fuel assemblies. It has a total gross weight of around 22 MT, a total length of 5,183 mm, a body diameter of 1,379 mm and a shock absorber diameter of 2,282 mm.

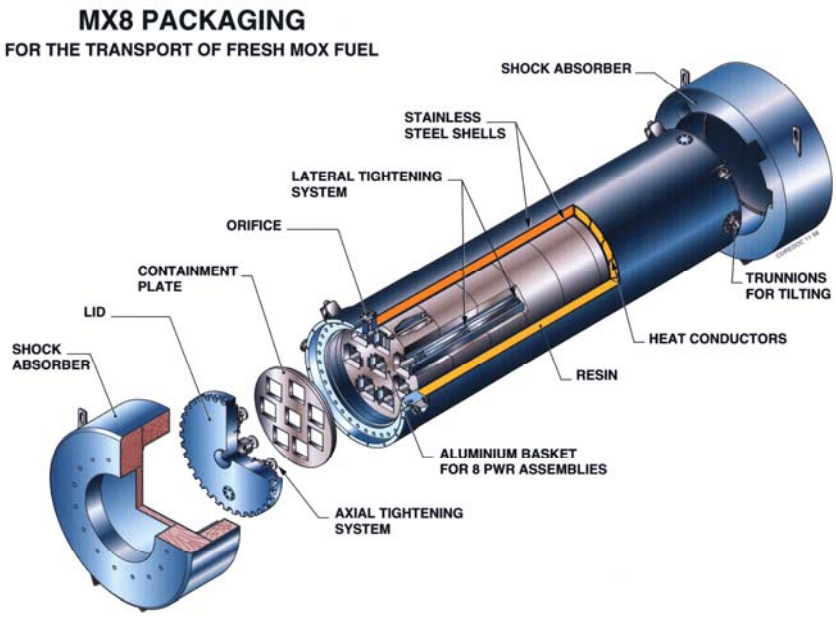

Figure 4. MX8 cask with PWR basket

The shielding is optimized to minimize the total dose absorbed by the operators and to meet the transport regulation.

The maximum characteristics of the 16x16, 18x18 or 15x15 (for the Netherlands) fuel assemblies to be transported in the MX6 cask are as follows: 15% total Pu, 6.5% to 8% fissile Pu, with a maximum heat capacity per fuel assembly of 1,100 W.

The maximum characteristics of the 10x10 fuel assemblies to be transported in the MX6 cask are as follows: 10.2% total Pu, 8% fissile Pu, with a maximum heat capacity per fuel assembly of 415 W.

The maximum characteristics of the 17x17 fuel assemblies to be transported in the MX8 cask are as follows: 10.2% total Pu, 8% fissile Pu, with a maximum heat capacity per fuel assembly of 1,100 W and a total maximum heat capacity per cask of 6,800 W.

The MX8 cask was first used to deliver fresh MOX fuel assemblies to the Tricastin nuclear power plant (NPP) in 2002; the MX6 cask was first used at the Gundremmingen NPP in Germany in 2004.

The MX casks are currently used in France, Germany and Switzerland. They will also be used in the near future to transport MOX fuel to the Netherlands. They are also used for Japanese needs, although only in France for the time being.

More than 300 shipments have been made since the casks entered in service, including both dry and wet unloading operations.

1.1.4. Management of cleanliness of the empty MOX transport cask

The operation of the casks in the nuclear power plants and in the manufacturing plants are performed under non contaminated conditions according to the regulations: less than 0.4 Bq/cm^2 for β,γ emitters and 0.04 Bq/cm^2 for α emitters. These requirements are in line with the ALARA rules.

To respond to the requirement of the plants, the design of the MX casks takes into the account the necessity to check and clean 100% of the external surface of the casks:

- External decontaminated paint
- No sharp areas
- Flat lodgment

Some dispositions are taken into account; main of them is the adaptation of a plastic envelope, for wet unloading to avoid contact between the contaminated water and the external surface of the package. Therefore, compliance of the cleanliness of the outer surface of the package in accordance with plant requirements is easier to meet.

After the offloading of all fuel assemblies, the casks which are unloaded under dry conditions are controlled 100 % internally and externally, whereas the casks which are unloaded under wet conditions are first dried internally and controlled 100% externally in order to meet plant criteria before being returned to the manufacturing plant. The latter are also controlled internally to meet transport regulations before returning. In that case, the empty package must comply with type A licensing. AREVA TN has extensive experience in dealing with this requirement. For both types of casks, the results are recorded in the transport file and sent to the plants so that the casks may be accepted.

The transport of the empty package is then carried out according to the UN2908 standard.

1.2. Vehicles

As an authorized transporter of Cat.1 materials in France, AREVA TN has developed secured conveyance means including: a secured truck, a secured trailer, a specialized secured container, and the loaded packages. Based on threats identified by the French Authorities, specific transport means for road transportation have been developed to comply with concerns of theft or destruction of the material.

To develop the transport means, AREVA TN has taken into account the specifications of the Technical Support of the French Authority (EOT): It has performed Research and Development studies and Physical Protection tests on representative samples, has issued manufacturing files, and has monitored manufacturing by authorized suppliers. Tests have been performed on the overall Physical Protection system including a representative mock-up of the package.

Throughout the development stages, the French Authority must give its approbation at each step. For instance, the list of manufacturers must be approved. The final step is the authorization for the use of the transport means.

Figure 5. High Security Vehicle for MX8 transportation

The High Security Vehicles (HSV) are stored in a safe and protected area and their maintenance is operated in specific units.

The maintenance procedures of the HSVs are validated by the French Authority during the last phase of the approval process. In order to verify the usability of the HSVs throughout their lifetime, the French Authority and its Technical Support regularly verify HSV compliance with the regulations. AREVA TN therefore regularly updates its fleet and the associated maintenance.

In order to perform similar transport in a foreign country, AREVA TN either develops specific transport means in collaboration with the authorized transporter in the countries crossed during the shipment or, in some cases, it validates its own HSV fleet in each of the countries crossed. The validation of the HSV in the foreign countries is led by the Authorities (both French and foreign) by exchanging information through a secured communication channel. In both cases, the relevant transport means must also comply with the international regulations for Physical Protection and their application in the respective countries.

For road transport in Germany, AREVA TN has developed, in collaboration with NCS Cargo GmbH, a specific HSV, the SIFA2/2, for the transport of the MX6. In order to perform the aforementioned shipments in Germany, which depart from Dessel, Belgium, the SIFA2/2 was also validated by the Belgium Authority.

In 2012, AREVA TN and its partners traveled more than 25,000 km by road, representing more than 60 deliveries of fresh MOX fuel assemblies.

1.3. Ships

For sea transportation of MOX fuel, AREVA TN uses PNTL vessels especially developed for Cat.1 material transportation. Two new ships were built in 2010 in compliance with the latest international Physical Protection rules. The ships also comply with the specific French Physical Protection rules:

- Escort to be implemented in a different ship from the transporter
- Packaging placed in a container tightened in the ship
- Use of an exclusive ship (No other type of material)
- Implementation of a specific real tracking system to follow the convoy

Therefore, for the transportation of light-weight packages such as the MX6, a specific maritime container was developed.

Figure 6. INF3 vessel for MOX transportation

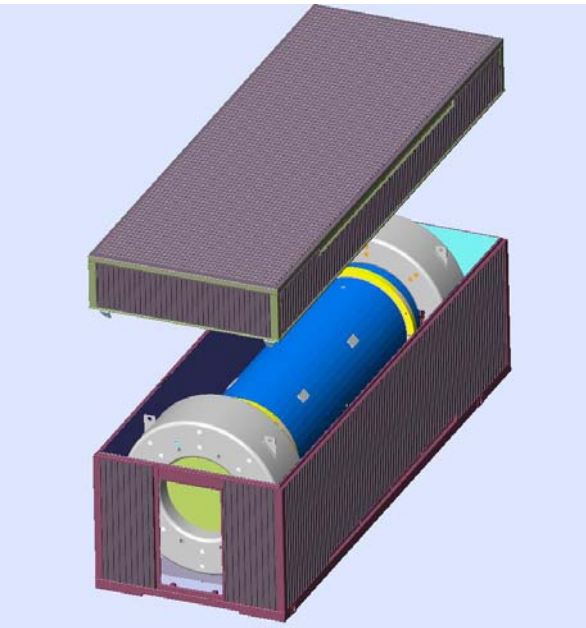

Figure 7. MX6 in its maritime security container

1.4. Frame

In order to comply with the fuel integrity requirements, specific frames were developed to minimize the acceleration of the fuel:

- Implementation of pads or springs
- Plastic absorbers between the body of the casks and the frames
- Plates for implementation of acceleration measurement devices, which have a sufficient autonomy for recording the acceleration on the packages during the transport

2. ORGANIZATION

2.1. Introduction

Organization and follow-up of the transport of MOX fuel also comply with the international rules for transportation and Physical Protection. Therefore, the documentation associated with such transport is updated as the regulations evolve.

The specific documentation for the preparation of such transportation is made with a transport plan including:

- the identification of the different stakeholders,
- the definition of responsibility regarding Physical Protection of material during transport,
- the definition of the responsibility during transfer,
- the description of the emergency response plan,
- the response plan where identification of threats and responses are described.

For shipments managed by AREVA TN, the overall transport plan is prepared by AREVA TN and submitted to the involved countries through the authorized carriers. However, each authorized carrier in each country develops AREVA TN's transport plan into a country-specific transport plan in order to describe the specificity related to each country.

Such information is exchanged through secured communication channels respecting a specific schedule.

However, improvement in the regulations and feedback on actual transport often lead to an adaptation of the schedule: Through its integrated transportation services, AREVA TN provides the necessary support to customers and assists in organizing the necessary arrangements.

For instance, the transport plan for maritime transportation, previously submitted 3 months in advance the transport, now must be submitted 5 months in advance. In France, the advanced shipment notification has increased from 15 to 30 days. AREVA TN customers require that it has the ability to keep abreast of these evolutions and to react to them in a timely manner for the smooth performance of these shipments.

In the same way, every aspect of the transport must comply with the regulations specific to each country concerned by the transport: organization of the escort, transfer of physical responsibility at the border, adaptation of the tracking system of the convoy during the transport as well as the transfer of responsibility. For instance, the tracking of the convoy falls under the jurisdiction of the French Authority in France whereas in Germany it is the responsibility of the transporter. Therefore, the monitoring systems of the transport means crossing both countries were adapted in order to comply with regulations in both countries. Before the execution of the shipment, the tracking system must be tested by the relevant organization and the test results must be transmitted through a secured communication channel.

Moreover, the organization of the transportation of such materials requires advanced preparation with all authorities involved. The specific rules for the tracking of these shipments may be different in each country.

With more than 60 such shipments per year, AREVA TN is continuously keeping abreast of the evolution of the International Physical Protection rules as well as their national application.

2.2. Quality plan

2.2.1. Content

AREVA TN takes into account the full transport process (From the licensing to the shipment approval requirements) in its documentation. The Quality Plan therefore includes:

- Description of the licensing requirements in terms of operation guidelines: Issuance of Transport documentation files
- Consignment approvals
- Specific risk analysis
- Emergency plan issued in compliance with the stakeholders
- Overall and detailed planning of the transport
- Description of the communication routes

2.2.2 Main improvements

- More accurate details of the physical protection response as required by the Authorities for the transport plan application
- At the end of each transport, feed back with the customers to respond to their needs with new services: Coordination with their own Authorities, for instance
- Study of the incident impact, such as a tsunami: An emergency response was issued describing how to react in the occurrence of a tsunami
- Improvement in the communication processes

2.3. Interface flexibility

- Being a worldwide company, AREVA TN has adapted its communication network to react in real time in case of an incident
- The close cooperation with the customer at each phase of the transport ensures quick up-to-date reactions and solutions in response to the customer's requirement
- Upon requests of the customers, proposals are made for on-site technical support on short notice

2.4. Public acceptance

- AREVA TN has developed a Public Acceptance cell to continuously manage the availability of the routes
- The P.A. cell keeps continuous information on the political changes in the involved countries and develops the appropriate message for route acceptance worldwide

2.5. How to manage a fresh MOX fuel transportation

In addition to the compliance of the casks to the IAEA standards, fresh MOX fuel transportation must comply with the different safety codes:

- European agreement concerning the international carriage transport of dangerous goods by road (ADR code)
- Regulations concerning the carriage of dangerous goods by rail (RID code)
- International maritime carriage of dangerous goods (IMDG code), International code for the safe carriage of packages for irradiated nuclear fuel, plutonium and high level radioactive waste on board ships (INF code)

Moreover, the transportation must meet requirements for Physical Protection of nuclear material.

The recommendations presented in the IAEA document, INFCIRC/225/Revision 5, reflect a broad consensus among Member States where the MOX fuel assemblies are delivered. In France, such recommendations have been stipulated in the "Code de la Défense" article 1333-1. Therefore, the French Authorities (Ministry of Ecology, Sustainable Development and Energy: MEDDE-HFDS) have specified their own Physical Protection measures: the last revision of such measures was defined in the decree dated August 18, 2010:

- Threat assessment considering the transport, the quantity and the form of the material
- The escort of the transport organized by the French Gendarmerie.
- The tracking of the convoy performed by the French Authorities (EOT)

Outside of France, the categorization of fresh MOX fuel is the same: Cat.1 for nuclear materials composed of more than 2 kg of un-irradiated Plutonium.

AREVA TN has therefore managed the transport of MOX fuel in accordance with both the international and French regulations and has developed partnerships with the specific authorized carriers for the transportation of Cat.1 materials in the foreign countries concerned with such transport as described in 2.1

3. INSURANCE

The carrier must be insured for loss and damage, and is also responsible in case of a nuclear incident during the transport. However, with the advent of the Fukushima accident in March 2011, insurance policies covering loss and damage have evolved significantly. Insurers now require more information about our transport system: the vehicles, the casks, the contents, the handling system at departure, the ship, the handling system at arrival, the dock conditions and, in the case of a possible earthquake, for instance with deliveries to Japan, the emergency measures taking into account the possible occurrence of a tsunami. Furthermore, a technical visit prior the departure is now performed by each of the insurers. AREVA TN has extensive expertise and quality processes in the handling of insurance matters that can be applied to the recent regulatory requirements. We can provide our customers with support throughout this laborious insurance process bringing confidence to insurers.

CONCLUSION

For 10 years, AREVA TN has organized and executed more than 350 shipments of fresh MOX fuel with the MX casks worldwide.

AREVA TN has made these shipments easy, safe, secure and clean for its customers through its knowledge of regulatory evolutions concerning the transportation of nuclear material and through its close contact with the Authorities.

The technologies developed by AREVA TN to transport fresh MOX fuel are anchored in a strong initiative for sustainable development and continuous improvement, which is a keystone of AREVA’s business strategy.