MX 8: THE NEXT GENERATION HIGH CAPACITY SYSTEM FOR THE TRANSPORT OF FRESH MOX FUEL

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SUMMARY

The choice of reprocessing policy was made a long time ago in France, leading to the development of an advanced Pu recycling industry. In 1987, Saint Laurent was the first French reactor to be loaded with fresh MOX fuel. Transnucléaire, then in charge of transport packaging development, created the FS 69 concept, derived from the classical RCC concept for the transport of UO2 fresh fuel. On the other hand, COGEMA, as the main actor in the field of fuel cycle and thus in transport matters, developed the associated security truck and security caisson in order to provide the transport system with the acceptable Physical Protection devices required by French Authorities. As a whole, the security truck and the FS 69 have now been used for more than ten years with a remarkable level of efficiency and safety. Indeed, more than 600 fresh MOX fuel elements have been delivered, without any incident, both regarding safety or fuel integrity requirements. But, as a matter of fact, the replacement of FS 69 transport system is now scheduled for several reasons. First of all, the burnups achieved with UO_2 fuel progressed together with its enrichment within the last ten years, and the MOX "equivalence" also implies that its Pu content be increased to enhance its reactor performances: from 5.25 % of Pu content today, the MOX fuel will reach 7 % tomorrow, and almost 10 % the day after tomorrow.

Lastly, the reprocessing/recycling policy has been confirmed and amplified, leading to an increasing number of "moxified" reactors: from 1 in 1986, today's figure is 16, and by the end of the century all 28 PWR 900 reactors operated by EDF may be licensed to use MOX fuel. The industrial era of MOX fuel is now a reality in France, and the matching transport system has to be developed.

As a consequence, the French utility (EDF), the fuel designer (Fragema, the joint venture between Framatome and COGEMA), the fuel manufacturer (COGEMA), and the transporter (Transnucléaire) joined in a specific working group devoted to the development of the MX 8, the next generation high capacity system for the land transport of MOX fuel.

MAIN REQUIREMENTS

The first aim of the working group was to settle the basic requirements of the transport system to be developed, and to search for the most attractive trade-offs between multiple and sometimes conflicting parameters affecting safety, security, performance and overall operational cost. An iterative process was chosen to optimize the transport system development. Frequent progress reports were organized to confirm the options previously taken, then discussed and validated within every partner's own framework. The main requirements were thus defined saving a precious time.

Regarding the interfaces of the MX 8 transport system, the packaging will be loaded at the Melox MOX fuel manufacturing facility, in a dry non-contaminated environment, while the assemblies will be unloaded in wet condition at EDF reactors.

The number one target was to create an integrated transport system allowing to ship 8 PWR 900 fuel assemblies at a time, meeting IAEA 1996 type B(U)F and national Physical Protection (PP) requirements, for an overall weight of 40 tons maximum, in order to remain within standard road transport limitations.

The second target was that provisional transport costs per assembly should remain in line with current conditions although the new fuel characteristics actually correspond to a three times harder radioactive source.

Indeed, EDF and Fragema provisions led to define the following envelope characteristics for the French-use MOX fuel of the day after tomorrow:

- % total Pu content : 9.75 %
- % fissile Pu content : 8.0 %
- heat power : 1,100 W per fuel assembly

TRANSPORT SYSTEM

The MX 8 transport system (see figure 1) is mainly composed of:

- the MX 8 packaging itself, featuring PP devices for trailor interfaces,
- a dedicated security truck, designed against the French PP requirements,
- a dedicated trailor, integrating the MX 8 support and tie-down system,
- a canopy designed to meet PP and heat dissipation requirements, assembled to the trailor.

Transnucléaire, acting as integrated transport system designer, was is in a position to develop an optimized system, thanks to its experience of both IAEA regulations and PP requirements. An integrated project team was set up, gathering design, fabrication, and testing engineers in the two specialties of packaging and transport means, allowing the efficient and quick development of the transport system.

Figure 1: The (dummy) MX 8 transport system

TRANSPORT MEANS DESIGN

Taking advantage of the twelve year experience gained in the operation and maintenance of the existing security transport system, an optimized equipment has been designed, that decreases the overall weight of the system, while keeping a comparable level of performance against PP requirements. Designing the packaging support as an integral part of the trailor allowed to obtain a lighter and more rigid overall system, which is favourable to maintain fuel assembly integrity during transport. This innovative approach also made possible direct interaction between packaging and trailor's physical protection devices. The acceptability of the complete transport system in EDF reactors has been demonstrated by a full scale operational test at one of the Tricastin reactors in August 1997.

PACKAGING DESIGN

(See figure 2)

MX 8 body and shock absorbing covers

The MX 8 body and shock absorbing covers have been designed according to IAEA 1996 requirements, and will constitute a reference in matters of safety for fuel assemblies transport. Indeed, the behaviour of the packaging was first studied on paper, then validated with a scale model on which actual effects such as those of slap-down could be measured to be integrated in the next step of packaging development.

The structural parts of the body, made of high grade stainless steel, are calculated to whistand the 9 m free drop test on an unyielding target including the low temperature effect. On another hand the external pressure resistance of the containment vessel corresponding to immersion under water is maximized with respect to the overall payload. Regarding the resistance of the packaging against the punch test, scale model testing allowed to optimize the thickness of the shells for a minimal packaging weight. Indeed, as far as MOX fuel packagings are concerned, the structural parts of the body are designed against this specific requirement and not to gamma shielding considerations, which are then quite negligible.

The internal shell, delimiting the containment vessel of the packaging, is made of high grade stainless steel. A proprietary polyester resin acting as an efficient neutron shielding is placed around the internal shell, crossed by copper blades welded on the internal shell, and made necessary for heat evacuation by conduction. The external shell, also made of high grade stainless steel, is welded on the bottom plate of the containment vessel (also welded on the internal shell), and bolted to the copper blades.

The packaging being unloaded in a wet pit in EDF reactors, the containment vessel has to be filled with water before the fuel assemblies are unloaded, and therefore qualified as a pressure vessel according to French regulations. The lower part of the body is equipped with a filling/draining orifice and the upper part with a vent orifice.

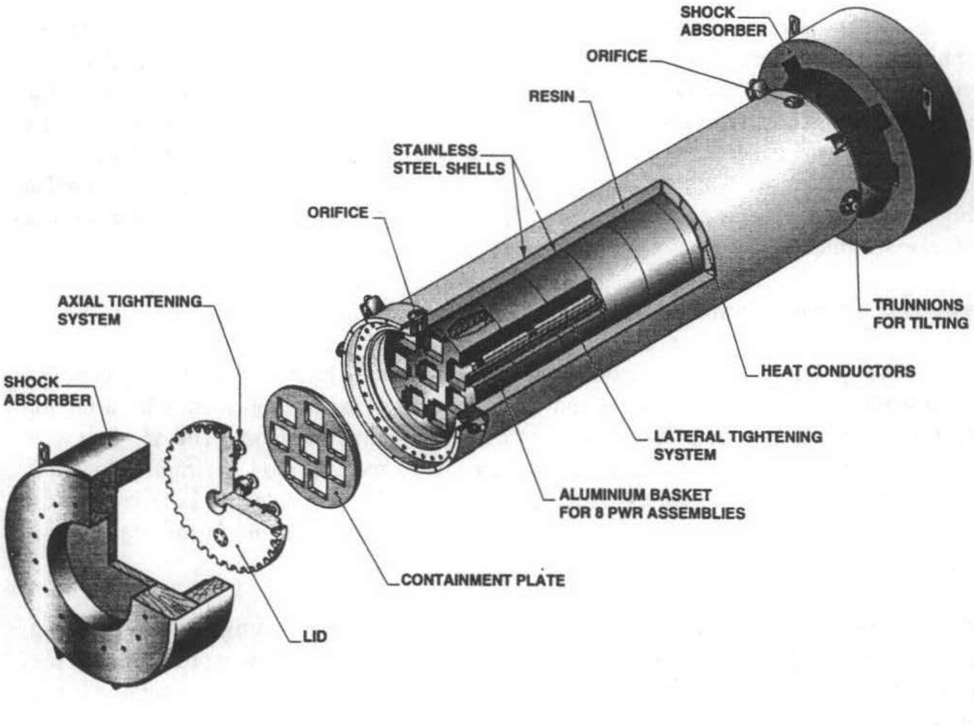

Figure 2: General view of the MX 8 packaging

As far as shock absorbing covers are concerned, stainless steel is used to make up the partitioning and the external envelope of the crushable material consisting of balsa wood whose behaviour within a large range of temperatures has previously been studied.

Closure system

The closure system is, in a quite classical manner, made of a thick high grade stainless steel plate, covered by neutron shielding material on its external face in order to reduce operators dose uptake at EDF sites once the shock absorber has been removed. The lid is equipped with two concentric elastomer "O" rings, allowing to guarantee that the transport regulations criteria for activity release are met, even under accident conditions.

As required by the operational constraints, provisions have been made to allow loading the assemblies in dry condition and unloading them under water at reactor, with no decontamination before reloading.

Lastly, the function of axial tightening of the fuel assemblies is also devoted to the closure system. Without any specific operation during loading, the eight MOX fuel assemblies will be axially tightened with controled effort levels taking into account the subsequent thermal expansion of the content, when closing the packaging.

Basket

The main functions of the basket are the following: first of all to place each of the eight fuel assemblies in lodgements, to tighten them in the transverse directions with respect to fuel integrity requirements, to conduct the heat power of the content (almost 9 kW altogether) to the cavity wall, and lastly to maintain the subcriticality of the content under the most severe regulatory accident conditions. For reaching such aims, and thanks to the feedback of an almost ten year experience in the design and manufacture of MOX baskets, Transnucléaire led a thorough study on the key point of this equipment, i.e. the transverse tightening system of the fuel assemblies.

Transverse tightening system

In such packaging design, using a cylindrical body fitted out with a tight closure system, the vertical loading of the fuel assemblies and the tightening of the assembly grids from the top part of the basket are required. Once again, our dual activities of transporter and designer were beneficial through a recognized knowledge of the shock and vibration environments within any types of transport. Indeed, the first requirement regarding fuel integrity is to provide the fuel assembly with such a tightening effort that any displacement during transport is prevented.

The additional requirement is to provide the fuel assembly with such a tightening effort that, whatever happening during normal transport, the total load that is supported by the fuel assembly (i.e. the tightening effort plus the dynamic effort) remains under acceptable limits. This was made possible thanks to a joint study between the basket designer, Transnucléaire, and the fuel designer, Fragema.

Other requirements, such as the ability of the system to undergo maintenance without removing the basket from the packaging, the ability of the tightening system to remain operational up to 200 °C (the maximum expected temperature of the basket), and the ability to operate under water, led to the development of three types of integrated tightening systems.

These "LRE"Ⓟ, "LRA"Ⓟ, and "R2P"Ⓟ devices have been qualified, prior to a demonstration transport test using a dummy scale one MX 8 packaging, which allowed to collect actual solicitations on the fuel rods from a dummy depleted uranium fuel assembly. The collected data have been used as input for benchmarking the dynamic calculation model performed by Fragema. The last step will be the determination of the allowable transport solicitations that will become the transport acceptance criteria for fuel delivery. For that purpose, the packaging will be equipped with an event recorder, in order to easily check after transport that the specified values, which are the output data of the transport system design, are respected.

This development has also provided the opportunity to test a new fuel assembly transport method, consisting in placing the fuel assembly section at a 45° "angular" position, without any further tightening. It has been checked that, thanks to the very good behaviour of the trailor suspension, the fuel assembly integrity could be maintained, even against rough events such as pitch plate tests, and hard brakings. Nevertheless, this innovation has not been incorporated in the final development because the models used to check fuel integrity after transport are all based on the conventional, "flat" and tightened disposition of the fuel assemblies.

Structural part

After completion of the advanced tightening system, which was the key point regarding basket architecture, the basket design could be finalized. The substantial heat power to be dissipated dictated the use of aluminium as structural material. The same material is also used to maintain subcriticality and thanks to close partnership with a specialized manufacturer, aluminium alloy can be supplied if necessary with a precisely adjusted and homogeneous content of boron. Here again, a very complete approach has been followed for the development of the basket regarding the subcriticality requirements. It can be considered that the main parameters which have an influence on the K effective, mainly in accident transport conditions, are:

- Basket geometry after drop: the loaded basket will be tested in the scale model, during the qualification drop test campaign, and its real geometry after drop will be taken into account in the criticality assessment,
- Fuel assembly geometry after drop: a parametric study has been performed during basket design on this issue, in order to analyze the impact of such parameter on the Keff of the package,
- Boron content of the basket partitions: a parametric study has been performed during basket design on this issue to analyze the impact of this parameter on the Keff of the package.

Thanks to such an approach, undertaken well in advance of the design completion, a solution has been reached offering an optimum trade-off between safety and cost considerations.

OPERATIONS

As previously explained, the packaging will be loaded in dry conditions at the Melox plant, in vertical position. In order to reduce operators dose uptake, a single centralized system has been designed to tighten simultaneously the 8 fuel assemblies in transverse direction. After this simple operation is performed, the packaging is equipped with its closure system, which ensures the axial tightening of the fuel assemblies. After tilting on the trailor of the packaging around its lower pair of trunnions, the interactive physical protection systems will be actuated, the transport canopy placed on the trailor, and the event recorder switched on. Upon arrival at reactor, the event recorder will be checked, the transport canopy removed thanks to an integrated equipment, and the transport system positioned in the reactor truck bay. The shock absorbing covers will then be removed, the packaging tilted to the vertical position (see figure 3), and lifted up to the pool level, using the same way as spent fuel shipping casks.

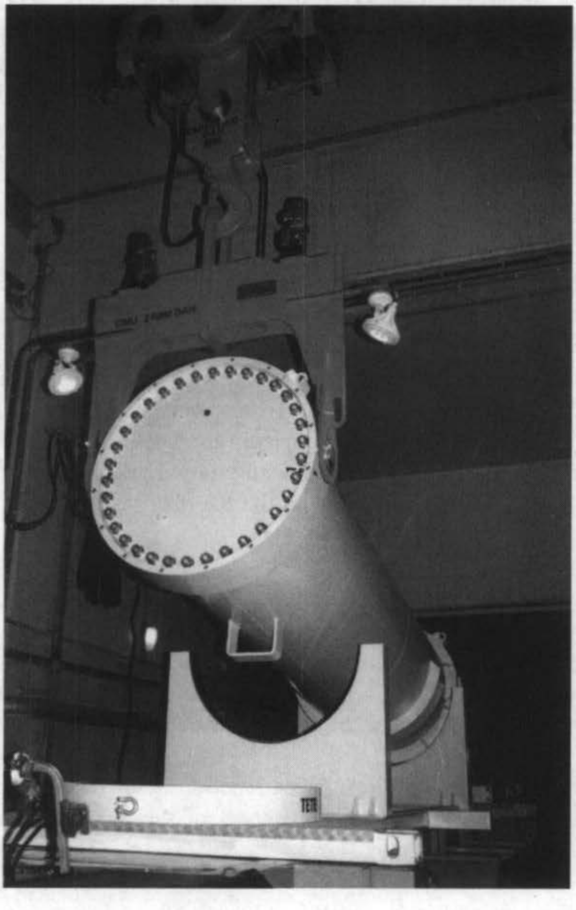

Figure 3: Tilting of the (dummy) MX 8 packaging on EDF site

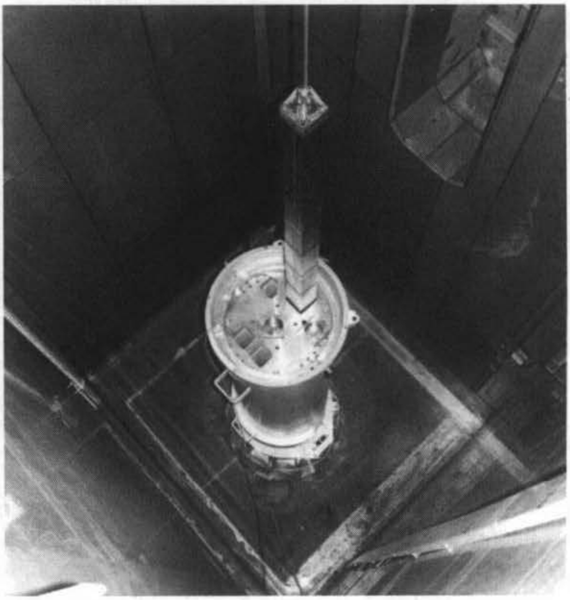

Figure 4: Unloading a fuel assembly from the (dummy) MX 8 packaging

After being placed in the preparation pit, the MX 8 will be filled up with clean water, using a specially designed pressure and temperature control module. The transport plug will then be replaced by a site plug, and the packaging transferred to the unloading pit. The 8 fuel assemblies will be remotely untightened simultaneously before the pit is filled up with water. The remaining operation is naturally to grip each of the 8 fuel assemblies with a specific tool to place them in the pool lift (see figure 4).

The major part of these operations was simulated during the August 1997 full scale demonstration test, which also enabled the designers to establish direct contact with the future operators of this next generation transport system, before its real implementation, since the MX 8 transport system is scheduled to be commissioned in the middle of year 2000.

This test enabled the designers to fully take into account the comments and suggestions made by the reactor's operational staff in the final design of the packaging and of its associated handling and ancillary equipment, with a special focus on the ALARA principle. Compared with current conditions, the new high capacity system will allow to reduce operators' integrated dose, while the radioactive source will be hardened by a factor three for keeping MOX equivalence to UO2 fuel. This is made possible thanks to the optimized shielding characteristics of this new packaging, and to the wet unloading condition.