M4/12 Package Project – Development of a Package for Transport of new MOX Fuel in Europe

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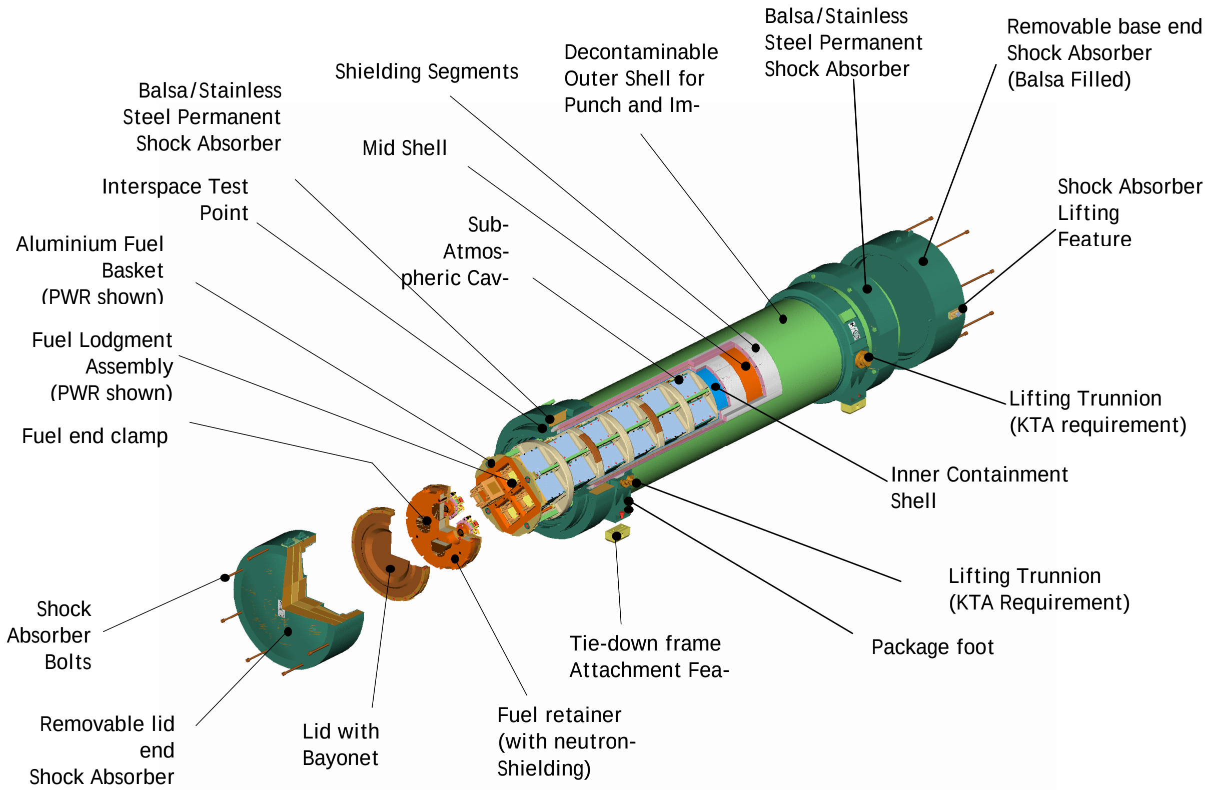

1. Introduction

BNFL has a requirement to deliver new MOX fuel from the Sellafield MOX Plant (SMP) to its customers in mainland Europe. To satisfy this requirement, a transport system has been developed which complies with national and international regulations and conventions relating to the transport of Category 1 materials.

Fundamental to this system is the transport package. BNFL has designed, developed, and is manufacturing a new transport package, the M4/12, This paper gives a brief overview of the overall transport system and then goes on to describe the development of the M4/12 package with particular emphasis on the novel features of the design.

2. Transport System

MOX fuel is classified, under the terms of the International Convention on the Physical Protection of Nuclear Materials (INFCIRC 225), as Category I material. This classification places certain obligations upon the shipper to protect the material in transit. MOX fuel is also a fissile material and, because of the quantity of material involved, a Type B package is required for the shipments. Transport of fuel between the UK and mainland Europe involves transport by both road and sea. The system developed must therefore take account of the security requirements as well as the regulatory requirements set out for the transport of MOX fuel.

For the road transport, it is necessary that the transport package (M4/12) be carried in a road vehicle that satisfies the requirements of the security authorities of the countries through which the vehicle will travel. Since the primary destination for fuel deliveries is Germany, it was decided to utilise the SIFA vehicle, designed and owned by Nuclear Cargo and Service, as the basis for the system. This vehicle is approved for operation in Germany and United Kingdom and satisfies the European road transport regulations. BNFL is procuring two vehicles, which will be designated as the European Secure Road Transport Vehicle (ESRTV). These will be available for service in February 2005. Each vehicle can accommodate one M4/12 package.

For sea transport, it is necessary for the ship to satisfy the requirements of the International Code for the Safe Carriage of Packaged Irradiated Fuel, Plutonium and High-Level Radioactive Wastes on board Ships (the INF Code). For total inventory of plutonium materials in excess of 4000 TBq, the vessel must satisfy the requirements set out in the INF Code for a Class 2 or Class 3 ship. For this primary purpose, BNFL has procured a vessel, MV Atlantic Osprey, which satisfies the INF 2 Code, thus enabling carriage of MOX fuel with a total inventory of up to 2×10^{5} TBq. The number of fuel assemblies this represents depends upon a number of factors but is typically about 8 PWR assemblies maximum. The Atlantic Osprey will be operated as a RO-RO vessel and is more than capable of transporting both ESRTV's, each loaded with one M4/12 package. The Atlantic Osprey as the additional capability for LO- LO

3. Package Design Criteria

For reasons of safeguards and security, the transport must be undertaken without the necessity for special permits. To comply with this criterion, it is necessary to limit the gross weight of the ESRTV to 40te. To accommodate this requirement the design target weight of the loaded package, including transport frame was limited.

For the purposes of fuel quality, it is necessary to restrict the fuel pin temperature to 200 deg C and also to minimise vibration and shock loads to the fuel during transport.

It was decided that the package should be licensed as a Type B (U) F, as defined in the TS-R-1 Regulations for the Safe transport of Radioactive Material 1996 edition (ST-1, Revised). The package must be easily decontaminable and contamination traps must be minimised.

During fuel transport deliveries the internal cavity of the package will be sub-atmospheric, limiting the possibilities of airborne contamination.

4. Design Features

The package body is in the form of a composite vessel, comprising three concentric cylindrical shells. These are manufactured from high strength Duplex Stainless Steel, the two annular spaces between the shells is fitted with neutron shielding. The shielding consists of Aluminium extruded trapezoidal hollow tubes, filled with low density, high temperature shielding, these are arranged longitudinally between the outer, intermediate, and inner shells. The aluminium extruded sections are multi - purpose in that they contain the neutron shielding whilst allowing for thermal expansion, provide some minimal contribution to the impact performance of the package, and transfer heat between the shells of the vessel. The internal heat transfer is primarily by radiated heat and by conduction through a pathway between shells. Surfaces of the aluminium extrusions are hard anodised to improve emissivity. This body construction combines lightness with excellent punch resistance whilst providing satisfactory heat transfer properties.

On the external diameter of the outer shell of the package body, are two trapezoidal hollow duplex stainless steel reinforcing rings, one towards the lid end and one towards the base end of the package. These are of a collapsible hollow construction to minimise package damage during an impact and make no direct connection to the inner containment boundary. Mounting pads on the reinforcing rings provide a transition fit location diameter for the trunnion spigot and tapped holes for the trunnion attachment bolts. Each of the mounting pads is fitted with a bolted stainless steel trunnion. The trunnions are also hollow to minimise inner shell damage in an impact. The package lifting features are designed in accordance with KTA Kerntechnischer Ausschuss (German Nuclear Technology Regulations).

The package is fitted with a fuel retainer that is engaged with the body lid flange, and secured in position with a bayonet assembly, this provides a substantial feature which restrains the fuel. During a lid end impact, these features transfer the loads directly to the body lid flange forging. The lid side of the fuel retainer has neutron shielding encapsulated within Stainless Steel cladding, to reduce operator dose uptake.

The package lid consists of a high strength duplex stainless steel seal carrier ring and a relatively thin Austenitic Stainless steel “deformable” centre section. The membrane centre section is designed to accommodate distortion of the fuel retainer and collapse of the shock absorber in a regulatory impact, without imparting excessive loads and distortion into the lid seal area. Under 200m immersion, the deflected centre section is supported by the fuel retainer. The lid also incorporates a pair of face type “O” ring seals and a bayonet type lid closure mechanism.

The PWR basket comprises four PWR lodgements and the BWR fuel basket comprises twelve BWR lodgements. The lodgements are longitudinally restrained within the basket construction to prevent movement under normal longitudinal accelerations/decelerations of the package. It is necessary for the fuel lodgements to be maintained with precise dimensional and geometric tolerances to ensure fuel product quality requirements are met. To achieve this, the lodgements are located in a series of accurately machined aluminium tubeplates arranged along the full length of the lodgement. The tubeplates are surface treated to enhance emissivity/absorptivity values.

The internal cavity of the package is a fabricated construction. In order to maintain the dimensional accuracy of the lodgements throughout the operational cycle of the package, the basket is designed with a positive location at the top and bottom end of the package cavity. The basket tubeplates are of a two piece construction comprising an inner and outer ring. The inner ring is rigidly attached to the lodgements and held together with longitudinal tie rods to maximise torsional stiffness and resistance to bending. The outer ring is expandable and floats radially on the inner ring. This allows the inner ring to expand into the internal cavity during assembly of the basket, taking up any dimensional irregularities. The tubeplates are then locked together using the longitudinal tie rods.

Fuel lodgements are manufactured from, a metal matrix material (MMC), which consists of Aluminium alloy and Boron Carbide. The manufacturing process results in the Boron Carbide being dispersed evenly throughout the composite, making it particularly suited for lodgement manufacture. The side panels are interlocked together to form the square lodgements which are secured in position within the basket tubeplates. The fuel assembly is protected from contact with the Aluminium Boron composite by inclusion of an austenitic stainless steel cladding. The lodgement plates provide neutron poisoning, thermal conductivity, precise geometric tolerances and structural performances. These plates are surface treated (anodised) to enhance emissivity/absorptivity values.

Each end of the package is fitted with a pair of balsa wood filled stainless steel clad shock absorbers. One part is permanently fixed to the outer vessel and the removable shock absorber is attached by retention bolts. These engage in threaded inserts in the permanent shock absorbers. The balsa wood energy absorption performance is enhanced, by accurate fitting inside the stainless steel cladding case and utilisation of the natural grain structure of the material. To present a thermal barrier in the fire accident situation, an engineered gap is provided between the inner face of the shock absorber and the package. In addition, an insulation layer is incorporated into the inner faces of the shock absorber adjacent to the package.

The tie-down of the package into the secure vehicles consists of two fabricated support structures, one at each end of the package. Each incorporates a set of eight anti-vibration mountings. Within the fabricated support structure, a mounting cradle provides the interface with the package with features that attach the package to the vehicle. The anti-vibration mountings are located between the mounting cradle and the lower support structure and isolate the package from the transport vibrations. Before removal of the package from the secure vehicle, the package is released from the transport frame. The transport frame remains attached to the secure vehicle as the package is lifted clear.

5. Testing

The transport system must comply with all relevant International and European regulations. The package design safety report must be supported by suitable design justifications, analysis and testing to enable all related licenses and approvals to be obtained from the competent authorities of the countries through which MOX fuel will be transported. The following is a summary of the testing that will be carried out during the design and development stages of the M4/12 package.

Fire testing of a full scale model of a balsa filled removable shock absorber has been successfully carried out. This has enabled comprehensive data to be collected to support analytical assessments for the regulatory fire testing requirements. Some similar investigative testing has also been successfully carried out on the neutron shielding material to demonstrate performance under simulated regulatory fire test conditions.

A series of scale model punch tests have been performed on segments that simulated the thin wall vessel construction. These have demonstrated exceptional performance both under, and in excess of, regulatory punch test conditions.

A comprehensive series of mechanical property tests have been carried out on materials of construction in order to verify specified requirements and / or provide validated data for use in analytical assessments of the mechanical performance of the M4/12 package. The materials tested include: Vitrite, Balsa wood, Boronated Aluminium, Duplex Stainless Steel, Aluminium alloys.

Material property testing has also included: Ageing, Emissivity, Decontaminability, Fracture toughness.

A series of regulatory drop testing sequences is imminently to be performed at AEA Winfrith on two full size models of the M4/12 package.

During commissioning and / or handling trials of the M4/12 package, thermal trials will be carried out to confirm analytical predictions and verify constructional conformity to the design intent.

6. Project Strategy

The M4/12 Project strategy, employed by BNFL Engineering, has been to operate in close partnership with both the detail design organisation and the main manufacturing contractor. This working arrangement has provided considerable benefits with development of innovative manufacturing techniques, and through these developments, improvements to the final design and reduced overall timescales.

7. Development

During the development stage, a set of full size drop test units (DTUs) have been manufactured. These units have only minor differences to the production packages in material specifications and constructional simplifications. For example, surface finishes such as anodising, pickling and passivation and bead blasting have been omitted from the DTU specification as having no bearing on drop test performance. The manufacture of these full size units has allowed the manufacturing partners to develop techniques and procedures that are to be fed into the package design and construction.

8. Conclusion

On completion of the drop testing sequences, the design safety report will be submitted to the UK competent authorities (Department for Transport) in order to obtain a type B (U) F, licence, this will be followed by submission to the German and Swedish Authorities for validation. The Production units are programmed to be completed and available for handling trials by the middle of 2005. Transportation of MOX fuel utilising the M4/12 is scheduled to commence in 2006.