Review of BNFL's Operational Experience of Wet Type Flasks

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1) Introduction

BNFL International Transport's operational experience includes shipping 6000te of spent fuel from Japan to Sellafield, through its dedicated terminal at Barrow, and to Cogema La Hague. This fuel was shipped under the PNTL (Pacific Nuclear Transport Ltd) banner for which BNFL is responsible. PNTL owned and operated a fleet of 5 ships for Japanese business and a fleet of 80 wet and 58 dry flasks, for the transport of Light Water Reactor (LWR) spent fuel, from both Pressurised Water Reactors (PWR) and Boiling Water Reactors (BWR). "Wet" or "dry" flask is the common terminology used to distinguish between spent fuel flasks transporting fuel where the fuel is immersed in water, or spent fuel flasks that have been drained of water and dried.
Also from European customers 1500te (total weight) of spent fuel has been shipped to Sellafield under the auspices of NTL (Nuclear Transport Ltd), and latterly BNFL itself. Early oxide shipments from mainland Europe utilised rail and commercial ferry, whilst latterly a dedicated BNFL ship, the European Shearwater, has transported the flasks from Dunkirk (through a dedicated BNFL Terminal run by BNFL Sa), to Barrow.
For transports of spent fuel to Sellafield, predominantly wet NTL / Excellox type flasks were utilised (apart from the NTL9, a TN type dry flask, which was used to transport fuel from Switzerland). For transports to La Hague, predominately dry TN type flasks were used, apart from some transports utilising the NTL11 flasks. (A wet Excellox type flask)
Another main difference in the transports was the use of Multi–Element Bottles (MEB's) for fuels transported to Sellafield, and open frames, used for transports to La Hague. The reason for this being the different pond storage philosophy adopted by BNFL and Cogema
In the UK the flasks were received at THORP receipt and storage facility (fig 1), a purpose built facility for receipt of wet flasks.

Fig1 THORP Receipt and Storage

2) Scope

This paper concentrates on the wet type of flask utilised to transport fuel to Sellafield, that is the Excellox type (including similar type NTL derivatives). It aims to provide a summary of operational experience during handling at power stations, shipment, unloading at reprocessors and from scheduled maintenance.

3) Description of Flasks.

The wet type of flasks, so called because it transports the fuel under water to provide neutron shielding from the fuel and heat transfer through the flask, fall into two basic types, those with and those without a lead liner. Both of these types of flask have circumferential steel fins.
Dry types of Flask, tend to be of a steel shell construction with neutron shielding in the form of resin applied to the outside. The cooling fins are usually copper “porcupine” type (Figs 2& 3 show pictures of a dry TN and a wet Excellox type flask).

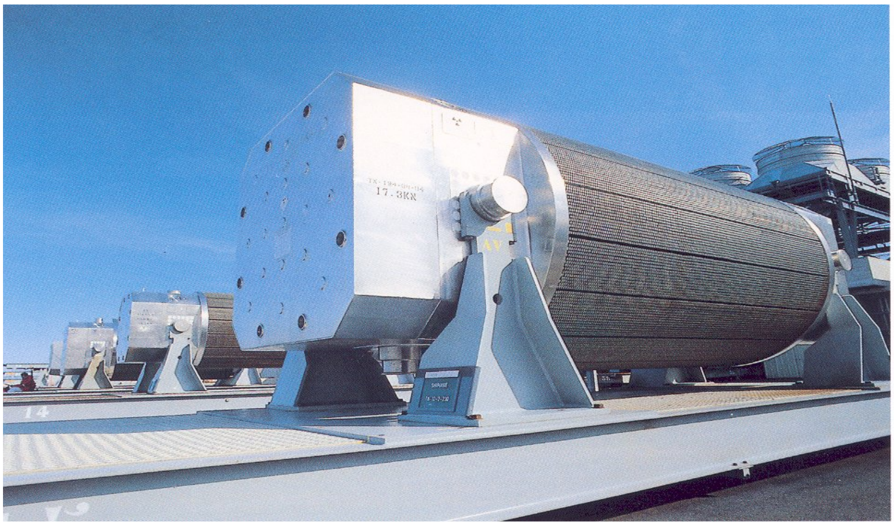


Fig 2 TN Flask parked at La Hague

Fig 3 Excellox 4 Flask in Storage at Sellafield

3.1) Wet Flask Types with Lead Liner.

The types with lead liner incorporate the EXL 3B and EXL4/2 type flasks, used from Japan and the NTL3 and NTL11 flasks used in Europe. (Fig 4 shows a typical lead liner arrangement.)
These flasks utilised a relatively thin walled shell – about 90mm thick usually of a rolled and seam welded carbon steel construction with a forged base of about 300mm thickness. Latterly, these flasks would be clad internally with stainless steel, whilst earlier flasks were painted. Corrosion protection and ease of decontamination, was provided by a specially developed paint. A stainless steel clad lead liner was utilised inside the shell to provide gamma shielding. A single piece lid, again of approximately 300mm thick forged steel, was attached by bolting, to the flask body.
Vent, water level and drain orifices were incorporated into flask body and lid. All body closures were sealed with a double "o" ring arrangement to enable leak tightness tests to be performed to ensure compliance with Transport Licences.

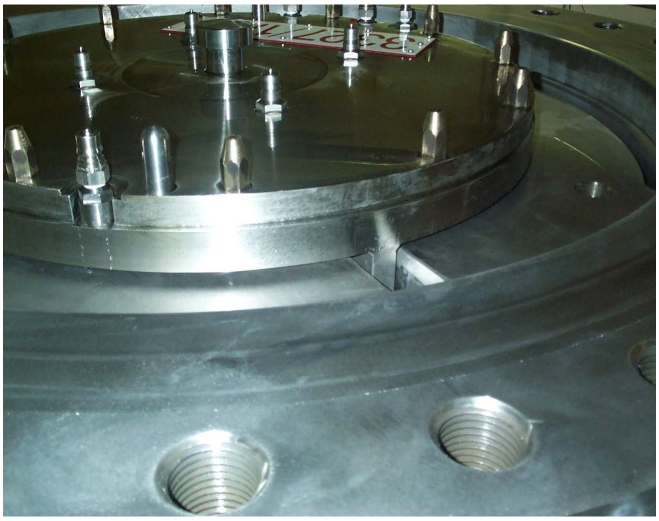


Fig 4 –NTL3MA and Lead liner

Fig 5 EXL 6 Flask with MEB fitted (no lead liner)

3.2) Wet Flask Types without Lead Liner

These are commonly called monolithic flasks, for example the EXL6 type, (figs 5), and are manufactured from a one - piece carbon steel body forging of approximately 300mm, clad with stainless steel. A one - piece forged lid is attached to the flask body by means of bolts.
Additional neutron shielding is provided by resin, underneath a carbon steel cladding.
External surface corrosion protection and ease of decontamination is provided by a specially developed paint.
Again, vent, water level and drain orifices were incorporated into the flask body and lid.
Operation of these orifice components is similar on both wet and dry TN type flasks.

4) Management Systems

BNFL International Transport operates under a fully approved Quality Assurance system that is approved by both customers and third party auditors. BNFL International transport is certificated to ISO9001/2000 for Quality Assurance and ISO 14001 for Environmental Aspects.
The Quality system ensures that the flasks and transports are controlled in compliance with all Approvals and Regulations.
The Q A system ensures that all activities from Design, Approvals and Operations co-ordinate and provide seamless compliance with the regulations.
The Management System is multi-layered from top tier Management Procedures, through Quality Plans, Specifications and Section Instructions to ensure that all aspects of the business are controlled.

This process starts with the Design Safety Report (DSR) for the flask, which is approved or validated as appropriate by the Competent Authority in the country of origin and by the countries in which the flask transits or is used.
Quality Plans are prepared to ensure that the flask is manufactured to the standard specified in the DSR. Quality Plans and Specifications are further specified to ensure that the flask is operated in the manner specified in the DSR. Maintenance is also controlled by Quality Plans and Specifications to ensure that standards set by the DSR are also complied with. The same rigorous levels of quality applied to manufacture of the flasks / packages are also applied to the manufacture of spare parts.

5) Operation Systems

Operations Specifications are specified in the DSR for the flask, and are therefore a condition of the Licence for the flask. To ensure compliance with the DSR during Operation of the flask, detailed Specifications and Instructions are prepared and issued to all parties to enable site specific instructions to be prepared. An extract from one of these documents is included as an example in Appendix 1, and would cover all operations from flask receipt, through preparation for loading, pond operations and preparation for despatch.

6) Maintenance Systems

As for Operational systems, maintenance systems are also fully specified in the DSR and as such are controlled in a similar manner.
Maintenance is usually carried out on three levels, turnround, and basic and major where: -

Turnround Maintenance - performed every cycle
Basic Maintenance - performed every three years or 15 cycles
Major maintenance - performed every six years or 60 cycles

These maintenance regimes are standard for spent fuel flasks and were jointly developed by the industry partners in the 1980's.
Typical activities performed under each level of maintenance are given in Appendix 2.

7) Operational Experience at Utilities

To enable flasks to be handled in accordance with the DSR, Specifications were provided to the utilities. In addition to this for all flask-handling operations, BNFL/ NTL engineers provided Technical Assistance.
Prior to the start of fuel transports from any reactor, feasibility studies and handling trials would be performed. These studies would determine the equipment required, the handling route for the flask and any constraints to operations. During "early" operations the level of technical involvement would also be very high, in order to enable the internal procedures and handling arrangements to be developed and optimised.
Some of the problems encountered during handling of the packages were: -
Lid Bolt seizure due to Nickel plating coming adrift –solved by bolt material changes
Leaking flat gaskets on MEB's – design change for later MEBs (gaskets changed to "o"rings)
Paintwork damage – care and attention during handling
Cosmetic damage – leaking trunnion sealant
Tightening of MEB lid bolts – awkward when operators are inexperienced. (Lock ring type MEB developed)
Removal of water from lid seal interspaces – either done using jacking bolts or blowing out water using more than one interspace. – Newer methods would employ vacuum drying.
Time for leak testing – early flask "o" ring grooves allowed for more potential movement of the lid seals in their grooves, which in turn would lead to increased soak time for the leak test.
Contamination issues – These issues have been fully dealt with at previous PATRAM's and are further discussed in this PATRAM.
Potentially one of the reasons for very few operational problems to surface at the Reactor sites is the application of the "Turnround Maintenance " approach, whereby each item that is operated is carefully inspected prior to each use.

8) Experience at Reprocessing Site (Sellafield)

Operations at Sellafield are similar to that at Reactor sites except that the MEB is removed from the flask as one component i.e. complete with the fuel inside it. All the items normally operated at Reactor sites are operated at the Reprocessing site. Again flasks / packages are subjected to “Turnround Maintenance” at this stage.
Very few problems with the flask were encountered during this stage as no bolting or leak testing operations were performed on MEB’s and the rebuild of the flask was performed dry. Each new MEB was also subjected to a Pre Service Inspection that confirmed its operation.
Most handling problems encountered were in fact due to the facility itself. The design of the facility was such that most operations were to be performed remotely, such as lid bolt removal, vent plug removal etc in order to minimise dose uptake, this resulted in some vent plugs being sheared due to excessive torque being applied.
Due to the paint system on the flask and the fact that all the fuel was stored in an MEB, there was very little problem in ensuring the flasks were fully decontaminated. In fact the only problems that were encountered with decontamination was with the actual decontaminant itself, which, due to a pigment contained in the product, stained the flasks yellow. Also of note was that due to the cleanliness of the ponds no cover or skirt was required to be used on the flask.
A design issue for wet transport and storage of the MEB’s however was radiolysis. To combat this, recombiners and getters were utilised within the design of the MEB, and to further negate this problem the MEBs were flooded whilst stored in the pond and connected to a vent system.

9) Maintenance Experience and Feedback

All the flasks involved in the Japanese Transports and latterly all the European flasks (apart from the NTL15 and NTL9), had their Basic and Major Maintenance performed in the Oxide Flask Maintenance Facility at Sellafield. (Fig 7). (NTL11 flasks were maintained for many years at the Cogema AMEC facility in La Hague).
This was a purpose designed and built maintenance facility for wet type flasks with painted finishes, and was equipped with decontamination areas, grit blast facilities, paint spray booths and rebuild areas.
The maintenance standards applied (specified in Appendix2), are very onerous and as explained in Section 4, tightly controlled.
As part of the Quality Assurance system and as required by the Regulators all “non conformances” were fully controlled. Any non-conformance found on the flask during maintenance was controlled by a “Concession” whereby a report would be submitted either from the “technician” or from an “Inspector”. This report would then be sent to the Design Authority and the Package Owner to be sentenced and arrangements made for the appropriate work to be performed.
It was during these maintenance activities that most of the problems associated with the flask, were uncovered.
Most of the defects detected could probably be traced back to original manufacture, i.e. correction of slight thread defects that were accepted during manufacture, or to operational damage such as scoring of trunnions.
However some more serious defects were discovered, fully investigated and remedial action taken.
These type of defects were mainly centred around bolt failures of some of the most high strength bolts, for example, the trunnion Securing Screws on the NTL11 and Exl 6 flasks. The trunnion screws were noted to have cracks beneath the heads. Investigation showed that this was due to stress corrosion cracking. To enable this situation to be thoroughly monitored, an “in situ” ultrasonic inspection method was developed by BNFL. This technique was capable of assessing the integrity of the as manufactured trunnion cap screws and was applied to the manufacturing process, and during each turnround, thereby giving a very high level of confidence in the integrity of the screws.
Application of this inspection technique to every screw on every trunnion allowed for continuous monitoring of the condition of the screws whilst approval was sought for reduction of the tightening torque values from TUV.
During all the maintenance work carried out approximately 500 concessions were raised.
These have been analysed and the results are presented in the following tables and pie charts.

Fig 6 Oxide Flask Maintenance Facility

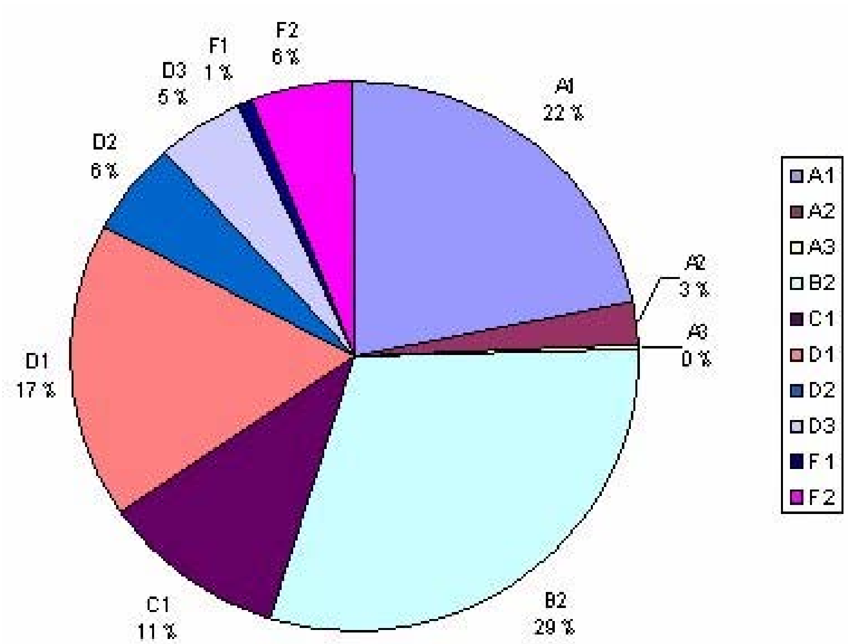
Detailed Analysis of Concessions from December 1983 to June 2004

Code	Typical Defects	General Cause	Qty
A1	Handling mechanisms, (damage to trunnions & pintle surfaces)	Operational Damage	109
A2	Handling mechanisms, (dimensional non conformances)	Original Design / Manufacture	13
A3	Handling Mechanisms (damage during maintenance)	Maintenance damage	1
B2	Receiver threads, spigots, c'bores, recesses, plugs	Original Design / Manufacture	150
C1	Receiver threads, spigots, c'bores, recesses, plugs	Operational damage	53
D1	Flask body/lid/fins/welds/major components	Operational damage	87
D2	Flask body/lid/fins/welds/major components	Original Design / Manufacture	28
D3	Flask body/lid/fins/welds/major components	Maintenance error/damage	25
F1	Flask to frame and other bolts/washers etc	Operational damage	4
F2	Flask to frame and other bolts/washers etc (dimensional non conformances)	Original Design / Manufacture	29

Note: Concessions not included covered the following items:

Castor flasks, Magnox flasks, MEBs, Transport frames, Labels, Label hole positions and General oxidation (except where welds affected)

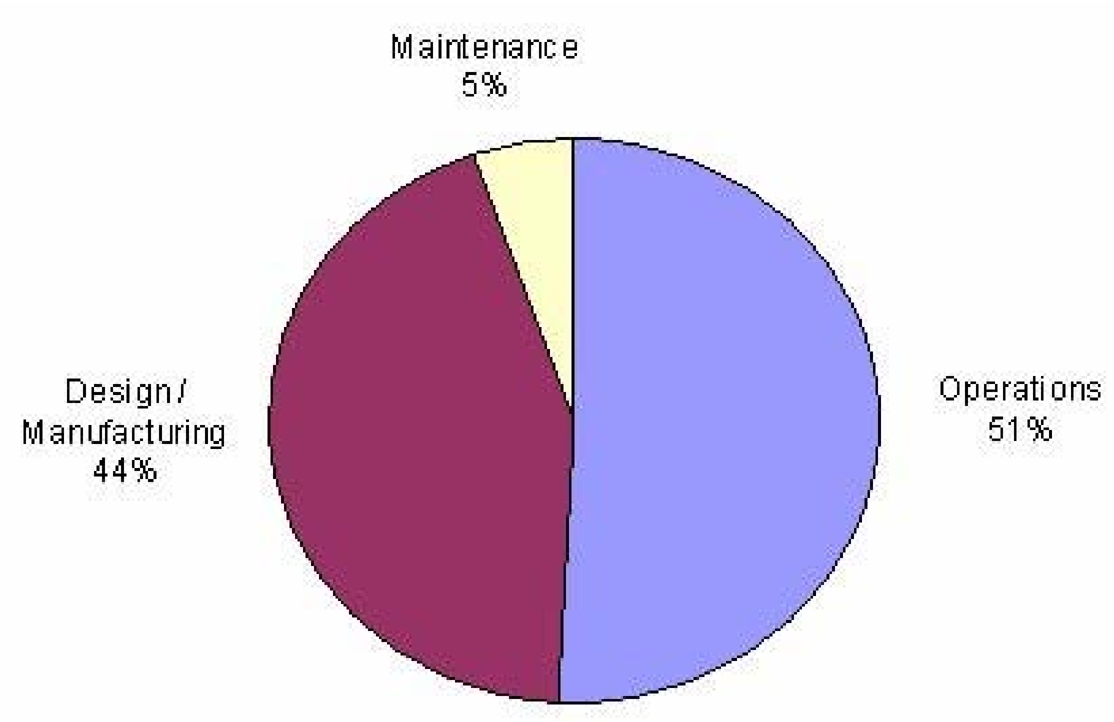
Pictorially this can be represented :-



Summary Analysis of Concessions from December 1983 to June 2004

Typical Defects	**General Cause**	**Qty**
• Handling mechanisms • Tapped holes • Orifice plugs • Location systems (dowels/spigots) • Flask body and major components • Fixing bolts	Operational Damage	253
• Handling mechanisms • Tapped holes • Orifice plugs • Location systems (dowels/spigots) • Flask body and major components • Fixing bolts	Original Design / Manufacturing non-conformances	220
Flask body and major components	Maintenance error or damage	26

Pictorially this can be represented: -



10) Summary

Throughout all the transports very few problems have been encountered, and none that stopped a shipment.
This success could be attributed to well-designed and constructed packages, that were operated in a professional manner. For example the flasks are designed to be simple to manufacture and build, operate and maintain, which in turn leads to simple, safe operations at all stages of operation.
The quality management system fully ensures that only approved operations are performed on the package at the appropriate time and in the appropriate place.
Further the operational system whereby the packages are subjected to turnround maintenance checks at both the reprocessor's and the reactor sites ensures that the likelihood of any failure of any component during operation is minimal.
Apart from the NTL11 / EXL6 trunnion screw problem most of the concessions / repairs could be described as of low significance and attributed to either design / manufacture or operational (i.e. handling) damage.
Therefore the design and operational systems for these packages have contributed to a safe, robust and effective transport system.

Appendix 1

Typical Operational Specification

BNFL

BNFL COMMERCIAL

TD/S	BNFL International Transport Specification
Issue : 7 Page : 3 of 1	**Specification for the Handling and Fuel Loading of the Excellox 6 Type Flask/3349 Type MEB**

1. **Introduction**

This Specification, in support of Management Procedure TD/M, is intended for BNFL reference only. The specification identifies the operational requirements associated with the receipt, preparation, fuel loading and dispatch activities of the Excellox 6 type flask/3349 MEB at a reactor site.

This Specification is flask specific and, subject to BNFL authorisation, may be used by the respective Utility as a guide for the development of independent site operating procedures for the Excellox 6 type flask when loading the 3349 type MEB.

2. **Package Data**

EXL 6 Flask Design Reference	3314
Reference Drawings	
EXL 6 Flask Functional Drawing	BE - XXXXXX & BE - XXXXX
3349 MEB Functional Drawing	0BE XXXXXX
3347 & 3348 Fuel Stools	BE XXXXXX
3350 MEB Stool	0BE XXXXXX
Associated Drawings	
Flask Body	BE XXXXXX & BE XXXXXX
Flask Lid	BE XXXXXX
Lid Shock Absorber	BE XXXXXX
Base Shock Absorber	BE XXXXXX
Rail Transport Frame	BE XXXXXX
Package Capacity	
Fuel Element Capacity	7 PWR Assemblies
Maximum Decay Heat Load	20 Kilowatts

Maximum Nominal Dimensions	Length	Diameter
Package - Shock Absorbers Fitted	6685 mm	2293 mm
Package - Shock Absorbers Removed	6130 mm	2150 mm
Flask Cavity	5235 mm	930 mm
Multi Element Bottle	4550 mm	914 mm (over pads)

Calculated Weights	
Flask Body	76,960 kg
Flask Lid	3,140 kg
Lid Shock Absorber	2,280 kg
Base Shock Absorber	1,760 kg
Removable Flask Components (i.e. lid bolts, etc.)	188 kg
Multi Element Bottle (MEB)	2,700 kg
Fuel Stools (Typical)	233 kg
MEB Stool	640 kg
Fuel Assemblies (Typical)	3,980 kg

Appendix 2

Turnround Maintenance Requirements

Examination of accessible body and lid areas
Examination of shock absorbers
Flushing of flask internals prior to discharge
Operation of all valves, examination of all seals, leak test of flask interspace
Examination of Transport Frames

Basic Maintenance Requirements

Physical examination of main areas (body and lid)
Examination, load testing and non-destructive testing of flask lifting points.
Examination of shock absorbers and load testing of lifting points
Pressure washing of upper surface and inner walls of flask liner
Dismantling and examination of valve components
Examination by gauging of all major screwed components and their receiver threads
Replacement of all seals and ‘O’ seals
Examination of Transport Frame
Repair of paint surfaces where required

Major Maintenance Requirements

Dismantling, examination, load testing and non-destructive testing of flask lifting points
Removal of paint from flask body and lid
Removal of flask liner
High-pressure washing of flask liner and flask cavity
Physical examination of main areas (body and lid)
Examination of shock absorbers, load testing and non-destructive testing of lifting points
Dismantling and examination of valve components
Examination by gauging of all major screwed components and their receiver threads
Cavity pressure testing
Re-painting
Replacement of all seals and ‘O’ seals
Removal of paint from Transport Frame, examination and re-painting