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TRANSPORTATION OF HIGH LEVEL WASTES

H.W. CURTIS*, A.J. SALMON**, I.J. HUNTER*,
L.G. JAMES*, D.R. KNOWLES**, W.G. MILNE**,
M. OLD**, A. WILLIS**

* Nuclear Transport Ltd,
Risley, Warrington, Cheshire

** British Nuclear Fuels plc,
Risley, Warrington, Cheshire

United Kingdom

Abstract

TRANSPORTATION OF HIGH LEVEL WASTES.

Fuel reprocessing generates wastes. One form is heat generating and is described as high level wastes (HLW). The British Nuclear Fuels reprocessing plant at Sellafield, in the United Kingdom generates HLW in a liquid form and special measures ensure the safe storage of this material. Additional facilities at Sellafield are being constructed to convert the high level liquid wastes into solid form using a vitrification process. The vitrified wastes will be encapsulated in special stainless steel containers and it is assumed that a proportion will be returned to the country of origin. The international transport of HLW presents a new challenge to the transporter and poses some interesting problems for the flask designer. Nuclear Transport Limited have been commissioned by British Nuclear Fuels to study the transportation of HLW and identify the most suitable flask design. Initial studies examined the utilization of existing LWR fuel flasks, but it was evident that poor payload and technical incompatibility made this option unattractive. It was decided to design a new flask for this purpose and the paper presents the outline design. The paper also highlights the special considerations in the flask design arising from the properties of the solid waste material. Transport modes and projected quantities are discussed.

The reprocessing of spent nuclear fuel by nitric acid dissolution and solvent extraction gives rise to a highly active liquid waste (HLW). This waste stream contains practically all the fission products, neptunium and trans-plutonium elements present in the irradiated fuel as well as traces of plutonium and uranium. HLW is stored in specially designed stainless steel tanks.

Tank storage is not the final solution for waste management and it is internationally recognised that conversion to a solid form would give advantages in safety, economy, handling convenience and stability for both transportation and long term storage. HLW will be solidified using a borosilicate glass formulation and a process known as vitrification. The vitrified waste will be encapsulated in special stainless steel containers and it is assumed that a proportion will be returned to the country of origin.

Development of the Vitrification Process

Development of the vitrification process began in the late 1950s. In Britain, the feasibility of the HARVEST method - a one step process - was demonstrated in an inactive pilot plant.

Meanwhile, the French CEA were developing a two-stage continuous vitrification process and by 1978 had constructed a full-scale active demonstration plant, Atelier de Vitrification de Marcoule (AVM). The plant demonstrated the process at industrial scale and it was decided that adoption of the French continuous process would enable vitrification on a production scale to be adopted at Sellafield several years earlier than would otherwise be the case. Consequently a contract was signed between BNFL and the designers of AVM, Societe Generale pour les Techniques Nouvelles (SGN), which involved SGN in the design of a production plant, the Windscale Vitrification Plant (WVP).

A series of trials has taken place at Marcoule where the process was shown to operate successfully with simulates of UK Highly Active Liquid Waste. A similar full-scale facility has been constructed at Sellafield to make the process as efficient as possible for UK wastes and on which operators are being trained. It will also be used for the development of handling techniques.

The vitrification product is formed in a calciner and poured into stainless steel containers which are seal welded and decontaminated prior to storage. The container is 1.3M long and 0.43M in diameter with profiled ends for nesting in vertical stacks. The approximate weight of the container is 500kg with a maximum radioactive content of 1 x 10^6 Ci.[1] The product is non-fissile but heat generating (up to 2.5KW per container).

The Sellafield production plant will have two separate lines, both of which will deal with the fuel from Britain's first generation of nuclear power stations - the Magnox reactors - and with oxide fuel from Advanced Gas-cooled and Light Water Reactors. Each line is expected to be able to handle, in a year, waste from 2,500 tonnes of Magnox fuel, or 800 tonnes of fuel from Advanced Gas-cooled Reactors or 500 tonnes of fuel from Light Water Reactors.

The Cogema plant at La Hague will have three separate lines to give an annual treatment capacity of 800 tonnes of irradiated fuel.

Transport Requirements

The vitrified product containers will be stored at the reprocessing plants in a purpose-designed storage building. Many of the reprocessing contracts include an option for the return of residues and it is anticipated that the vitrified waste will be returned to the country of origin.

In the case of Sellafield, it is estimated that during the period 1990 to 2000, up to 2000 containers may require transport to overseas destinations. Early studies showed that the maximum payload for a transport flask is 21 containers and hence up to 100 flask movements would be required during a 10-year period.

Approximately 60% of transports will be to Japan, the remainder being to European destinations. Transport modes will be sea or, where possible, by rail in purpose-designed transport flasks. A small fleet of transport flasks will be required.

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[1] 1 Ci = 3.70×10^{10} Bq.

Use of existing transport flask designs

A study has been made of the international transport of HLW to evaluate the effectiveness of existing irradiated fuel transport flask designs for the transport of HLW.

There are two main types of flask currently used to transport irradiated fuel from reactors to commercial reprocessors; the Excellox type operates with a water-filled cavity and the family includes the EXL 3B, EXL 4, NTL 11 and NTL 14 Flasks. The TN type operate with a dry cavity and this family includes the TN 17/2, TN 12/1, TN 12/2, TN 13/1, TN 13/2 and NTL 10 flasks. All of these flasks are Type B packagings with radiation shielding, containment systems and heat dissipating surfaces designed specifically for the safe transportation of light water reactor fuel.

Initial studies established the number of vitrified waste containers which could be carried by each flask.

The EXL 3B flask has a cavity diameter of 860 mm and could carry 3 containers in a single stack. If the cavity was modified by fitting a revised design of liner, the capacity would be doubled to 6 containers (2 stacks of 3).

The EXL 4 flask has a cavity diameter of 914 mm and could carry six containers in two stacks. A revised liner design could increase the capacity to nine (3 stacks of 3).

The NTL 11 and 14 flask types have cavity diameters similar to the EXL 4 and the payload potential in both the standard and modified form is equal to the EXL 4.

The TN 12, TN 13 and NTL 10 flasks have a cavity diameter of 1200 mm which would accommodate 12 containers (4 stacks of 3). The monolithic construction of these flasks rules out simple modifications to increase payload. (The EXL type all contain removable liners).

A new flask design with a cavity diameter of 1440 mm could carry 21 containers (7 stacks of 3).

The initial studies were restricted to physical constraints and further data emerged during heat transfer and radiation shielding analysis.

The source strength of irradiated fuel has a known axial variation and flask shielding has been designed to cope with this.

The vitrified waste containers will contain a homogeneous glass product which alters the shielding requirements for a transport flask. In particular neutron shielding is required at both the lid and base ends. None of the existing irradiated fuel flasks has neutron shielding at the ends.

The Excellox flasks dissipate fuel decay heat by conduction and convection within the water-filled cavity. The cavity water also gives neutron shielding. In some cases, an additional neutron shield is fitted in the form of an external cover. As the waste containers would be loaded into the flask at a dry storage facility, it is logical to exclude the option of water-filled cavities. Excellox-type flasks could be operated dry for moderate decay heat loads but additional neutron shielding would be required.

The TN type flasks transport irradiated fuel with a dry cavity system. Decay heat is transmitted by radiation to a support structure in the cavity. Neutron shielding is fitted to the outside of the flask. These flasks have been designed for total heat loads of up to 120 KW. This is equivalent to a full load of 48 vitrified waste containers and hence the external heat transfer systems are adequate.

The study concluded that existing designs would give a poor payload of high level waste. In some cases there was technical incompatibility as the flasks were designed to operate with a wet cavity for compliance with pool handling constraints at reactors and the reprocessing plants. The high level waste containers will be stored in a dry condition and it is therefore logical to consider dry transport systems only. It was concluded that a purpose designed transport flask would be required to provide an economic transport system.

A purpose-designed transport flask

Engineering studies of packaging requirements have generated a new flask design.

The vitrified waste flask together with its high level waste contents forms a Type B(U) Package with a capacity of 21 waste containers. The overall envelope size is approximately 2.4 metres diameter by 5.5 metres long and the all up weight is 107 tonnes.

The flask consists principally of a one-piece cylindrical body and base and a bolted on lid. The flask body has external cooling fins which encapsulate neutron shielding material.

Protection of the flask against severe impact damage during handling and transport is provided by lid and base shock absorbers, the latter being integral with the flask body. For handling and transport operations the flask has two pairs of trunnions and two pedestals attached to the body. The cavity is protected with a non-corrodable finish accurately machined to allow close contact with the inner support structure. Externally the flask is treated with a high quality paint system specially developed to give a hardwearing and readily decontaminable surface.

The waste containers are carried in an internal support structure which forms 7 longitudinal channels, each having a capacity for 3 stacked containers. The support structure, which is built up from a number of individual aluminium segments has a number of advantages over the more conventional monolithic type of structure. Each segment is firmly fixed to the wall of the flask cavity, the flow of heat from the contents into the flask wall is thus maximised. The assembly clearances between each segment minimise differential thermal expansion effects and the relatively small size of the segments simplifies manufacturing and handling processes. The whole support system can be remotely assembled and dismantled.

Transport Methods

The Vitrified Waste flask will be located in a transport frame for all off site handling and transport operations. The flask/transport frame unit is compatible with the ship and rail transport systems currently used for irradiated fuel movements. Thus new purpose-built ships and port facilities are not required and it is intended to utilise existing facilities where possible.

For shipments from Sellafield to Japan, HLW would be transported by special ships also carrying empty irradiated fuel flasks. If the port has no railway the flasks could be carried on a suitably adapted road vehicle.

There are two options for European Shipments from Sellafield. Flasks could be transported from a suitable port by special ship or alternatively the commercial rail ferry could be used for crossing the Channel. Transport within Europe will be by rail on special rail vehicles. The chosen route will depend upon the location of the HLW receipt facilities.

Comparison with Irradiated Fuel Transports

Considerable experience has been gained during nealy 20 years of irradiated fuel transports and the knowledge gained can be used to draw comparisons with the future requirement to transport high level waste.

Irradiated fuel could be described as a by-product of electricity generation with physical characteristics closely related to reactor design criteria. Consequently, there are many variations in fuel element shapes, sizes and contents which gives rise to numerous designs of transport packaging. The vitrified waste in its purpose-designed stainless steel container is a direct product of a waste management system with controlled physical characteristics. Hence the design of packaging and its operation is less complicated in certain areas. For example, the stainless steel containers are surface decontaminated prior to storage giving an essentially "clean" packaging operation whereas irradiated fuel requires more careful consideration due to the possibility of surface crud on fuel pins.

Criticality safety is an important area of irradiated fuel transport and special attention is paid to the design of internal structures and detailed analysis to ensure safe operation. The vitrified waste product is non-fissile which eliminates any specific requirements for criticality control.

Irradiated fuel transports in most cases involve pool handling at both the reactor and reprocessing sites. Special equipment and operating procedures have been developed for this. Flasks are often fitted with protective skirts during pond operations to simplify decontamination operations. Some flasks are transported with a partially water filled cavity and others operate with a 'dry' cavity requiring purpose designed equipment at the reactor following pool handling. No pool handling is envisaged during the despatch or receipt of high level waste flasks which simplifies both the operating procedures and contamination controls.

It is concluded that existing technology developed from irradiated fuel transports is more than adequate to cope with the future requirement to transport high level waste.