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THE EVOLUTION OF WASTE MANAGEMENT PROCESSES AND TECHNOLOGIES IN BNFL

R W Asquith and G A Fairhall
British Nuclear Fuels plc
Research and Technology, Sellafield, Seascale, Cumbria, CA20 1PG, UK

ABSTRACT

The treatment of wastes arising from BNFL's nuclear fuel cycle operations can be traced through a number of phases. The first was the development of vitrification and cementation for fresh arisings and plants are now in operation. To handle the mixed, heterogeneous intermediate level wastes, retrieval, segregation and robust treatment processes are at an advanced stage of development, with all plants to be operational from 2002. BNFL is focusing attention on reducing waste management lifetime costs including reducing waste volumes of source. Technologies aimed at significant reductions are now being developed. The final phase, now in progress, recognises the need for an integrated approach to advanced fuel cycle processes which incorporates BNFL holistic concept.

I. INTRODUCTION

Operations at British Nuclear Fuels Plc's Sellafield Site have been ongoing for approaching half a century. Over this period a wide range of radioactive waste streams have been generated from the various operations. Sellafield has produced the majority of radioactive wastes in the UK for each of the different categories.

The arisings are classified into the following categories:

- High level wastes (HLW) are those in which the temperature may rise significantly as a result of their radioactivity. HLW refers to the concentrated waste product from the first extraction stage of a fuel reprocessing plant.

- Low level wastes (LLW) contain radioactive materials not exceeding 4 GBq/te alpha or 12 GBq/te beta/gamma.
- Intermediate level wastes (ILW) are those that lie between HLW and LLW categories and include streams defined as TRU.

Waste has arisen primarily from reprocessing of spent nuclear fuel but also from fuel fabrication, reactor operations and more recently from the decommissioning of some of the earlier nuclear facilities. Over the past decades the approach to waste management has changed. This paper traces the development and evolution of waste management within BNFL at Sellafield. It also defines current practices and novel processes and technologies that will continue to support radioactive waste management in the future.

II. EARLY WASTE MANAGEMENT AT SELLAFIELD

Radioactive wastes generated from early operations of the nuclear industry at Sellafield were stored on site in purpose built stores, silos, tanks and ponds. Up until the end of the 1970's wastes were produced and remained in an unconditioned state. For a large volume of wastes this resulted in streams being stored in mixtures, in many cases diverse streams were stored together.

From the late 1950s the Drigg LLW repository became operational and now accepts waste from nuclear sites across the UK as well as hospitals, Universities and research organisations. It is planned that this facility will continue to operate well into the next century.

During the 1950 - 1970s little emphasis was placed upon waste minimisation or the need to ultimately treat and dispose of ILW. As a result over 35,000m^3 of Intermediate Level Waste has been generated and stored at Sellafield in an unconditioned form.

III. BNFL WASTE MANAGEMENT STRATEGY

From the early 1980s BNFL has developed and implemented a comprehensive waste management strategy which includes all the ILW generated in the past and projected arisings for the future. The key drivers for this were to:-

- maximise safety
- minimise life time waste management costs
- minimise effluents
- meet regulatory requirements
- minimise waste volumes
- condition waste to meet storage and transport requirements and to fulfil anticipated disposal requirements.

A systematic approach has been adopted which has involved identifying and evaluating a range of treatment options against a number of criteria. A key component in the strategy is the immobilisation of both HLW and ILW into appropriate wasteforms.

Since 1990 HLW has been vitrified at Sellafield in the Waste Vitrification Plant (WVP) (1). The vitrification process at Sellafield involves two steps, those of calcination of high active (HA) liquor and vitrification. The HA liquor is a suspension of metal nitrates which are introduced into a rotating hot tube enabling the evaporation and partial denitration of the material to form a reactive and friable calcine.

The calcine is then fed into the vitrification melter along with glass frit. The aim is produce a product having a waste loading of around 25%. This process was developed for the treatment of liquors arising from Magnox and THORP reprocessing and was underpinned by an extensive development programme, including full scale test facilities. The glass products that have been generated are in engineered storage pending ultimate disposal in the UK or return to customers overseas.

For the ILW strategy cementation was selected as the best option for the encapsulation of all ILW.

The choice for cementation was made following an exclusive R&D programme covering a range of encapsulation options and a systematic evaluation of these options against a number of criteria (2,3,4). BNFL work closely with Nirex to establish criteria that covered disposal of waste.

A major programme has been undertaken by BNFL over the past decade to implement the ILW strategy for waste cementation. This has involved R&D work relating to the encapsulated product and the conditioning processes. The product evaluation programme was structured in a number of phases and covered over 30 ILW types. In excess of 30 properties have been evaluated at small and full scale using non active simulants. Where appropriate active small scale trials have been undertaken. More details of the individual properties are described elsewhere (5).

To guarantee successful encapsulation in cement it is esstntial to understand product stability. A number of key parameters have been established as very important by BNFL to meet waste strategy disposal requirements:-

- behaviour and properties of the cement raw materials
- how the waste interacts with the cements
- effects of scale up
- design and control of the encapsulation process

Over the past 18 years BNFL has developed two basic processes for encapsulating ILW, although other options have been evaluated. These are grouting for solid wastes and in-drum mixing using a lost paddle for slurries and sludges. Solid wastes are encapsulated by infilling the voidage between the waste with a fluid grout. The solid waste will range from discrete pieces such as fuel cladding to massive items including supercompacted waste.

Five cementation plants have been planned for the encapsulation of ILW at Sellafield. The first four plants were designed and built bu BNFL Engineering Ltd, BNFL's engineerings subsidiary and are in active operation with the final plant due to be commissioned over the next 5 years. These facilities encapsulate all current arisings of ILW generated from Magnox and THORP reprocessing. In addition since 1993 historic wastes have also been retrieved from silos and encapsulated. Over 14,000 fully active products have been produced and are stored in engineered facilities prior to ultimate disposal.

IV. TREATMENT OF HETEROGENOUS AND HISTORIC WASTES

Many ILW streams, particularly mixtures of historic wastes, would require significant preconditioning to enable cementation to produce homogeneous products. The pursuit of technological solutions to satisfy the preconditioning requirements could involve unacceptably complex and expensive processes. As part of the optimisation of the ILW strategy alternative processes have been evaluated and are now being pursued. Two examples described below:-

A. Sellafield Drypac Plant (SDP)

Until the advent of the Magnox Encapsulation Plant (for on-line encapsulation of fresh Magnox arisings) decanned Magnox cladding was consigned to underwater storage in silo compartments. Here the metal corroded steadily to an extent dependent on temperature and water availability, leaving a heterogeneous magnesium hydroxide sludge/metal mixture. These silos also provided a storage facility for operational solid waste items.

The wastes currently in storage represent a range of diverse characteristics, physically and chemically and in addition the sludge component changes behaviour when processed particularly when water is added. These mixtures of waste would have necessitated complex processes using existing technologies to separate and condition the sludges and solids for cementation using grouting and in drum mixing. In particular to ensure appropriate pre conditioning of sludges significant addition of process water would be required resulting in an unacceptable increase in the waste volume.

The response to the challenge was to develop the Sellafield Drypac Plant (SDP). The concept of the facility is to minimise the segregation of waste thereby reducing process complexity and to remove the original water from the sludge waste thereby reducing waste volume.

The key stages of the process are:-

- initial separation of large items from the retrieved waste using mechanical screening.
- transfer of the undersize material (sludge, small solid items) to sacrificial cans.
- drying of the undersize material using an oven system.
- supercompaction of the dried undersize waste in the sacrificial cans to produce waste pucks.
- grouting of the pucks in 500 L drums to produce packages for engineered storage prior to disposal.

The process has been developed by BNFL, engineering by BNFL Engineering Ltd and will become operational in 2002. The plant will utilise novel technology not employed for ILW streams of these characteristics before. This includes in can drying and supercompaction of high alpha/gamma active waste. A major R&D programme has been undertaken to underpin the plant design and to ensure product quality of the packages. Process development has been undertaken at full scale to demonstrate the technical feasibility of the initial waste separation, drying and supercompaction. The work has demonstrated that a robust, yet relatively simple process can treat the wide range of ILW streams in the silos.

The product from this process is fundamentally different to the encapsulated waste generated from the cementation of wastes from ongoing reprocessing operations. A major R&D programme focused on the characteristics of the package and in particular its behaviour during storage and disposal. The drying and supercompaction of the sludge produces a solid waste product which provides containment for the radionuclides. By utilising an enhanced drum and a high quality in filling grout it has been possible to demonstrate the suitability of this product to UK regulators and Nirex, the company responsible for ILW disposal in the UK.

The adoption of this process by BNFL will have a major advantage for the treatment of these wastes. Significant waste volumes reduction will be achieved and major life time cost savings will result from the simplicity of the plant when compared to alternative conventional technologies.

B. Waste Treatment Complex

Plutonium Contaminated Material (PCM or TRU) represents about 25% of the total volume of ILW at Sellafield. The waste consists of mixtures of organics such as paper, plastic, rubber and metallic items. Practices in the past have involved the double bagging of these waste in PVC and storage in drums. Larger items have been stored in sealed crates.

A large R&D programme has been undertaken in the past to investigate a range of technologies for the treatment of TRU wastes. These include:-

- sorting
- size reduction
- decontamination
- incineration
- Pu recovery from soft (organic), hard wastes and incinerator ashes
- supercompaction
- encapsulation

The technologies utilised active wastes and many were developed at pilot plant scale, for example a Pu incinerator R&D facility was operated at Sellafield for about 10 years. This processed over 30 te of TRU waste with a Pu content of about 30 kg.

BNFL utilised this technology and designed and constructed a facility which waste segregate, size reduce and package wastes for sea disposal. The facility planned to include Pu recovery from high Pu content wastes.

The facility was mothballed in the 1980's due to the cessation of sea disposal. Further evaluation of treatment options identified the optimised solution to be a process which included assay of waste, supercompaction and cementation of the waste pucks. This option represented a simpler process route in which no Pu recovery was included and generated significant volume reduction compared with the stored raw waste volume. A key part of the TRU management is to minimise the Pu content of the waste and source thereby removing the need to undertake complex and uneconomic Pu recovery processing downstream.

The original processing plant was modified in the 1990's to accommodate this new optimised process. The plant, the Waste Treatment Complex started active operation in 1997.

As for the SDP product quality of these packages involved a large programme of R&D which successfully proved their suitability for storage and disposal.

V. CURRENT DEVELOPING TECHNOLOGIES

Waste reduction in particular reduced life cycle costs is an aim which continues the overall theme. A key area within waste reduction is waste volume minimisation. Specific BNFL technology developments contributing to waste minimisation in this area are being undertaken aimed and improving established waste management operations. These include:-

- Selective compaction of hulls waste
- Improved encapsulation matrices
- Engineered transfer systems for handling alpha active materials
- Dewatering, drying and compaction of slurries
- Improved sorting and categorisation of wastes
- Metal melting
- Incineration

Comprehensive reviews of BNFL's waste and decommissioning strategies and associated liabilities have provided the basis for targeting development effort.

Development initiatives include waste reductions and elimination at source, minimisation of secondary arisings (e.g. operational materials, decontamination reagents), and enhancement of first generation waste treatment processes. Increased loading of waste in cement-encapsulated, products could be achieved by:-

i. increasing drum volume utilisation,

ii. improving in-drum mixing techniques to allow higher waste sludge incorporation,
iii. pre-treating metallic wastes, to increase the packing density prior to grout additions.

Enhancements with regard to vitrification processes are under similar investigations with objectives of increasing the HLW incorporation beyond 25%.

Free release of materials is a key objective, either for re-use or non-nuclear disposal, with the objective of reducing the volume for LLW disposal. A major success has already been achieved in respect of free release, for re-use, of large quantities of aluminium from decommissioned uranium enrichment plant. Decontamination and monitoring technologies are being developed for arisings from reprocessing plant and equipment. Building structures, potentially forming a major volume of waste, are the subject of bio-decontamination investigations and development of both in-situ and post demolition's monitoring techniques.

VI. FUTURE WASTE TREATMENT OPTIONS

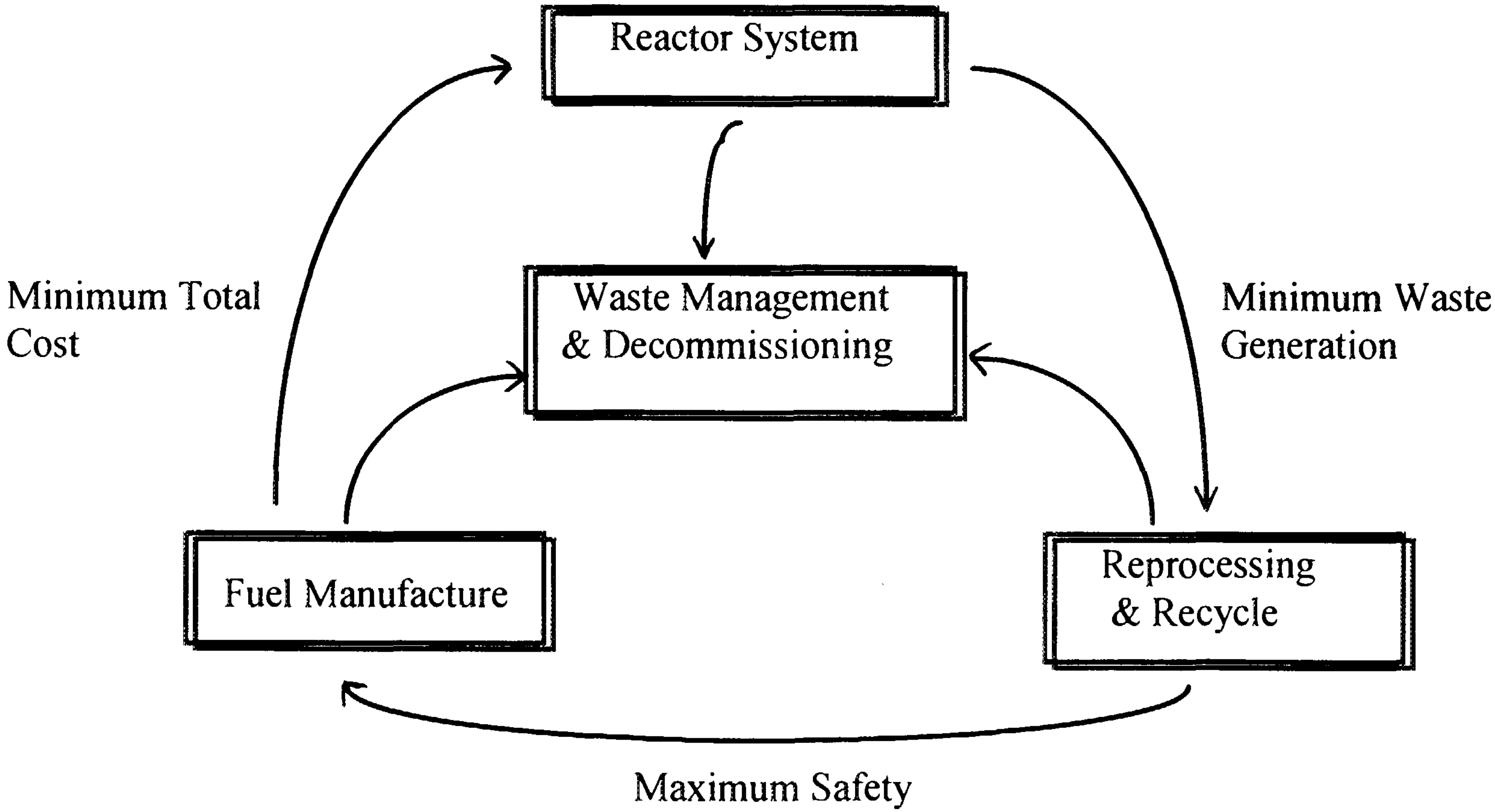
The holistic approach, is a concept (see Figure 1) that integrates the various options in fuel manufacture, reactors, reprocessing, waste management and decommissioning to simplify and optimise the whole fuel cycle within the requirements of the total nuclear system. This is done with due regard to : maximising safety, minimising waste generation, minimising total cost, satisfying the requirements of security and safeguards and therefore maximising public acceptability.

A Waste Management & Decommissioning

The holistic view shows that waste management is a central part of the concept. BNFL is active in many of the areas, in particular, we are developing an integrated waste programme which is considering the various waste scenarios posed by advanced reprocessing. This includes work in :

- Solid waste disposal - international collaboration on novel waste matrices

Figure 1 - Holistic Fuel Cycle



based on ceramics.

- Waste immobilisation - includes pre-treatment and advanced wasteform technology development.
- Effluent treatment - minimisation of effluent arisings and cost effective treatment of those which are unavoidable. Novel technologies include biotreatment and

advanced membrane processes.

- Retrieval and decommissioning - advanced robotic developments giving greater intelligence, mobility and flexibility and so enabling work in hazardous environments.
- Destruction and treatment - intensive and selective processing / separation using laser and plasma technology.

Waste minimisation provides the underlying philosophy for all the work being carried out.

VII. CONCLUSION

The paper thus follows the evolution of waste technology in BNFL through four distinct phases, illustrating a broad, in-depth experience and the capability to develop fit-for-purpose cost-effect solutions to waste treatment problems. The waste technology will continue to evolve to support future operations and underpin BNFL's vision for a Holistic Nuclear Fuel Cycle.

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