INTERMEDIATE LEVEL WASTE ENCAPSULATION

G G Howarth, W Heafield, A Elsden
British Nuclear Fuels plc
Risley, Warrington, Cheshire
England

ABSTRACT

Intermediate level wastes (ILW) arise from fuel fabrication and reprocessing operations at the Sellafield site of British Nuclear Fuels plc (BNFL). At present the waste is stored in bulk without pretreatment. BNFL is planning to encapsulate and package such wastes, and all future arisings, in a cement-based matrix. The encapsulated wastes will be stored in an easily retrieved manner, and will be in a form suitable for public sector transport and for eventual disposal. A wide variety of intermediate level waste streams have been identified as being suitable for encapsulation; mainly fuel cladding debris from Magnox and oxide fuel reprocessing, slurries, flocs, and ion exchange material from effluent treatment and miscellaneous solid waste (sometimes termed 'technological waste'). The scope of the encapsulation facilities, the programme and cost for their provisioning, together with a brief description of the process are presented. The development programme in support of the project, the choice of container and the product quality assurance requirements are also discussed.

INTRODUCTION

Reprocessing of irradiated nuclear fuel has been undertaken at Sellafield since 1952 when the first reprocessing plant was commissioned. A second facility was brought on-stream in 1964, primarily to reprocess the irradiated uranium metal resulting from the UK civil Magnox reactor programme. To date, in excess of 25,000 tonnes of Magnox fuel arising from both UK and overseas nuclear power stations have been processed in the plant and it is expected that it will continue to operate until around the turn of the century.

Additional facilities are being built at Sellafield to reprocess irradiated oxide fuels from advanced gas-cooled reactors (AGRs) and light water reators (LWRs). THORP (Thermal Oxide Reprocessing Plant) is due to start up in 1990 with a committed throughput of 6,000 tonnes, of which about two-thirds will come from overseas.

The generation of nuclear energy, like all complex industrial activities, results in the formation of waste materials. In discussing the treatment of wastes it is convenient to categorize the various types. The following classification is used in the UK:

1. High level heat generating wastes (HLW) which are those wastes in which the *temperature may rise* significantly as a result of their radioactivity. This factor has to be taken into account in designing storage or disposal facilities.
2. Low level wastes (LLW), which are wastes containing radioactive materials other than those acceptable for dustbin disposal (very low level), but not exceeding 4 G Bq/t alpha or 12 G Bq/t beta/gamma.
3. Intermediate level wastes (ILW) which are wastes, with radioactivity exceeding the boundaries for low level waste, but which do not require heat generation to be taken into account in the design of storage or disposal facilities.

In practice the high level waste category is applied to the concentrated waste product from the first extraction stage of a reprocessing plant. Thus to be consistent this classification is adopted by BNFL in grouping its waste arisings although BNFL's intermediate level wastes include certain streams in which heat generation cannot be ignored in store and repository design. However, the heat generation rates in these wastes are very much less than for HLW.

Reprocessing operations give rise to a variety of ILW streams. These may be summarized as:

1. Fuel element cladding (Magnox swarf) mechanically removed from Magnox fuel elements prior to dissolution.
2. Fuel element hulls and assembly fittings remaining after the dissolution of oxide fuel.
3. Slurries and flocs resulting directly from reprocessing operations and the treatment of effluents.
4. Technological waste, which refers to a wide variety of waste produced from plant operations and maintenance (typically filters and scrap engineering components).
5. Plutonium Contaminated Material (PCM) which is a generic term covering materials which range from soft shreddable items, such as PVC bags, gloves, through to large non-combustible items such as redundant glove boxes; all having varying degrees of plutonium contamination. It should be noted that PCM treatment is not considered in this paper.

About 30,000m^3 of ILW (including 6,000m^3 of PCM) have arisen from operations at Sellafield over the last thirty years. The wastes are currently stored, unconditioned, on the site. BNFL's plans for the future management of these wastes and also for fresh arisings are well advanced. The strategy is to encapsulate, in a cement based matrix, all such wastes with the resulting solidified wastes being held on site in engineered retrievable stores until such time as a suitable disposal route is available.

The implementation of this strategy requires the provision of an encapsulation facility with sufficient capacity to treat fresh waste as it arises and also retrieved waste from existing stores. Thus the MASWEP (Medium Active Solid Waste Encapsulation Plant) Project has been initiated by BNFL.

Existing storage capacity for Magnox swarf will be fully utilised in 1989/90 which determines the date by which encapsulation facilities must be available. Facilities for encapsulating ILW from THORP will be required in 1990/1. The timescale for the retrieval of existing stored (unconditioned) wastes for encapsulation will be determined by a number of factors including:

- the capacity available for encapsulation;
- the physical state of existing storage facilities;
- the availability of an appropriate disposal route.

SCOPE OF ENCAPSULATION FACILITIES

The MASWEP project will be completed in three phases:

Phase I: (to be operational in 1989/90)	The first encapsulation plant (EP1) which will encapsulate Magnox swarf; the first product store (EPS1) and a Services Building.
Phase II: (to be operational in 1990/91)	The second encapsulation plant (EP2) which will encapsulate THORP ILW and flocs from an effluent treatment plant.
Phase III: (to be operational in 1993/94)	The third encapsulation plant (EP3) which will encapsulate other stored waste (mainly sludges); additional product store modules.

EP1 will be a single line plant designed to be capable of processing up to 6m^3/day of Magnox swarf. The exact scope of EP2 and EP3 has still to be finalized. All the plants will generate encapsulated products contained in stainless steel drums of nominal capacity 0.5m^3.

EPS1, the first product store module will have a storage capacity for about 12,000 drums. It is estimated that if a permanent disposal route is not available by the end of the century, up to six storage modules could be required to store the encapsulated products generated by this date.

The total volume of wastes arising from reprocessing operations up to the year 2000 which will eventually be treated by the encapsulation plants described in this paper amounts to about 50,000m^3. A total in excess of 100,000 drums of encapsulated waste will be produced.

The Services Building will provide such facilities as changerooms, inactive services (steam, water, compressed air, electricity) to meet plant requirements, and will house such facilities as plant data recording, model rooms, offices, etc.

PROJECT COSTS

Phase I of the MASWEP project is anticipated to cost about £130M (January 1986 Money Values).

The total project including Phases II and III and recovery of the wastes from the existing stores has a budget cost of about £700M (January 1986 Money Values).

PROCESS DESCRIPTION

For the encapsulation of Magnox swarf, Zircaloy/stainless steel hulls and other bulk solid wastes, an in-drum grouting process is employed, which involves the addition of a pre-mixed cement grout to a container of waste. The method is termed vibrogrouting. A Blast Furnace Slag/Ordinary Portland Cement (BFS/OPC) mix has been selected as the preferred encapsulant. The grout is sufficiently fluid to be easily pumped to the grouting station.

The principle stages in the vibrogrouting process are:

Drum filling	- The drum is filled with the waste to be encapsulated.
Waste Dewatering	- Any water associated with the waste is removed.
Grouting	- The grout is added whilst the drum is vibrated to remove air.
24 hour curing	- The grout is allowed to gain sufficient strength for movement.
Capping	- A self levelling grout is added to trap any loose activity on the product surface.
24 hour curing	- The capping grout is allowed to gain sufficient strength for movement.
Lidding	- A lid is fitted.
Decontamination	- The drum is washed to remove surface contamination.
Monitoring	- The drum is monitored for residual contamination.

The in-drum mixing process is similar except that there is no dewatering stage; dry cement powder is added to the slurry/floc.

When the drum has been monitored it is placed in a stillage capable of holding four drums. The stillage is then transported to the product store for storage in an array of 14 x 14 x 16 high.

THE CONTAINER SIZE

A fundamental requirement of an encapsulation strategy which is to proceed in advance of a suitable disposal site, is the use of an appropriate container. The purpose of a container is to provide secondary protection of the waste (after the matrix) to minimise the risk of any spread of active material during on-site handling and storage operations, and, subsequently, during off-site transport and disposal.

After a careful evaluation of container sizes ranging from 200 liters to 2,000 liters it was decided to standardize on a nominal 500 liter drum. This decision was based on a number of factors including:

1. Magnox swarf is already transferred for (unconditioned) storage in a flasked container of about 450 liter capacity; metering and dispensing of such a material poses significant problems;
2. the need to guarantee uniform mixing, within the container, of cement powders into a range of slurries/flocs/ion exchange materials;
3. the need to restrict wasteform centerline temperature increases resulting from activity content and the setting exotherm and thus to avoid impairing 'product' quality;
4. a reasonable shape and weight to allow reliable handling and transfer operations during encapsulation and afterwards (the overall weight of a filled 500 liter drum is up to about 1,500 kg);
5. acceptance by UK Nirex Ltd of such a container as a standard package;
6. overall cost including drum fabrication, storage, transport and disposal.

DEVELOPMENT

Development work in support of the MASWEP project has been divided into four main categories:

Feed Characterisation and Simulation
Process Development
Product Evaluation
Safety Studies

The feed characterisation program includes the extraction of samples from the existing plants for detailed physical examination and chemical analysis. Based on the information obtained suitable simulants are recommended for subsequent development work.

The process development programme includes inactive investigation of all the process stages including storage to provide data for design and to confirm the performance of prototype equipment.

The product evaluation programme was instigated in 1982 with joint BNFL/Department of Environment funding to investigate the properties of a variety of matrix/waste formulations to enable the most suitable to be specified.

One of the main problems in development work in the nuclear field is that it is rarely possible to carry out full scale active work. Hence other experimental arrangements have to be made such that reliable extrapolation can be made. Thus the Product Evaluation programme was sub-divided into

1. small scale non-active;
2. full scale non-active;
3. small scale active.

With the large number of different types of wastes to be examined, it was decided that each waste form would be studied in three phases:

Phase 1

1. Defining the waste form.
2. Indication of special characteristics.
3. Identification of possible treatments and encapsulation matrices.
4. Waste characterisation.
5. Simulation of active waste.

Phase 2

1. Practical investigation of potential encapsulation matrices identified in Phase 1. Typically these have included:

    inorganic cements;

    polymers;

    polymer modified cements.
2. Comparison of the most promising matrices. Limited product evaluation tests including thermal stability, leach testing, mechanical strength and radiation stability are performed on small scale samples in order to identify the preferred formulation(s) for Phase 3 studies.
3. An indication of waste pre-treatments that may be required.

Phase 3

A systematic evaluation of the product properties of the selected process(es) from Phase 2 studies. A detailed data base of information on the preferred option will be used for its justification and safety arguments for storage, transport and disposal.

Phase 2 studies have been carried out for the major ILW streams and the BFS/OPC has been selected as the preferred encapsulant for ILW. Important benefits associated with the use of cement when compared to alternate matrices include:

1. The processing plant is relatively simple.
2. Cement is suitable for encapsulating wastes ranging in composition from dry solids to wet sludges.
3. Cement is composed of thermodynamically stable hydrated salts with well documented physical and chemical properties.

4. Cement has excellent thermal stability due to the low thermal conductivity and non-flammable nature of the material.

5. Because of its pH and sorptive capacity cement has excellent properties for actinide retention.

Phase 3 studies for Magnox swarf are confirming the suitability of BFS/OPC as an encapsulating medium.

ENCAPSULATED PRODUCT QUALITY ASSURANCE

The approach to this important aspect of plant design and operating philosophy has been constrained by the obvious difficulty in making physical checks on the finished product, ie the encapsulated waste package. There are two main areas of concern:

Activity Content

There is no existing equipment capable of providing, with any worthwhile accuracy, the nuclide inventory of drums of cemented wastes of the type described in this paper, although such measurements may be possible in the future.

Assessments of activity content of the encapsulated waste will therefore be based on measurements taken on the wastes before encapsulation. For example the measurements taken by the High Resolution Gamma Spectrometry (HRGS) equipment to assess fuel residue at the Magnox fuel decanning caves can be used to provide an accurate assessment of the activity associated with a given identified batch of Magnox swarf.

Product Quality

Similarly it has not been possible to identify other than a few very basic measurements which could be practically made on the product. It is possible however to envisage how product quality can be assessed and assured based on various in-process measurements coupled with a quality control plan and an adequate data base derived from both small scale active and full scale inactive encapsulation.

BNFL is negotiating with its overseas customers, the Nuclear Installations Inspectorate and the UK Authorising Departments to establish the detailed QA requirements.