RADIOACTIVE WASTE CONDITIONING AND DISPOSAL IN THE UNITED KINGDOM

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ABSTRACT

This paper outlines the strategies for radioactive waste management which have been developed in the light of UK Government policy and against a background of statutory legislation and increasing public awareness. The paper also describes the treatment and conditioning which is undertaken within BNFL to immobilize activity and package the three categories of waste for storage and for disposal.

High Level Wastes are being vitrified in the recently completed Windscale Vitrification Plant and held in engineered storage pending final disposal.

Low Level Wastes (LLW) are containerized and placed in engineered vaults. This is an interim measure prior to the installation of a new compaction facility to upgrade the waste form and reduce disposal volumes.

Intermediate Level Wastes (ILW) arising from the reprocessing of Magnox and Oxide fuels (THORP) are being routed through dedicated conditioning and storage plants. The first encapsulation plant - for Magnox cladding wastes - was actively commissioned in 1990; encapsulation plants for THORP wastes and for flocs arising from liquid effluent treatment are due for completion in 1992.

It is intended that conditioned ILW and LLW will be disposed of in a deep underground repository planned to be in operation by 2005. Geological investigation of potential sites at Sellafield and Dounreay is in progress and final proposals will be supported by extensive design and development programs currently underway. These programs include particular emphasis on the evaluation of waste form performance and on the subsequent migration of nuclides through the repository structure and the surrounding geology.

INTRODUCTION

The UK nuclear power program has developed steadily over the past forty years and during this period there has been a corresponding development in the management of wastes arising from power plant and associated reprocessing operations. The success of this program has required an understanding of waste composition and conditioning which has continued to develop against a background of statutory legislation and increasing public awareness.

In the UK overall responsibility for the development of a national policy for radioactive waste management rests with the Government. Within what is now a well-established framework the nuclear industry has developed strategies which are being implemented by waste producers and by UK Nirex Limited which has specific responsibility for the future disposal of low and intermediate level wastes.

The various categories of waste generated by the waste producers and the procedures adopted to condition these wastes are described in this paper. The development of plans and proposals for a deep repository for disposal of the majority of this waste by Nirex is also described.

The paper provides an overview of the UK national policy for radioactive waste management and the strategy of the waste producers (concentrating particularly on BNFL as the major waste producer) for conditioning and storage of wastes.

NATIONAL STRATEGY AND LEGISLATIVE ARRANGEMENTS

It is Government policy that wastes should be disposed of under strict supervision to high standards of safety and the periods of storage should be the minimum compatible with safe disposal. For heat-generating wastes this means storing the wastes for at least 50 years to allow them to cool. For low and intermediate level wastes it is desirable to dispose of them as soon as possible, and to avoid the creation of additional accumulations and the provision of costly and extensive storage capacity. The principal objectives include:

- ensuring that the creation of waste is minimized;
- ensuring that the handling and treatment of wastes are carried out with due regard to environmental considerations;
- securing the programmed disposal of waste (already) accumulated at waste producers' sites.

The basic radiological protection principles on which the strategy is based are derived from the work of the International Commission on Radiological Protection and are embodied in the various legislative instruments. They include the following:

- all practices giving rise to radioactive wastes must be justified, i.e. the need for the practice must be established in terms of its overall benefit;

- radiation exposure of individuals and the collective dose to the population arising from radioactive wastes shall be reduced to levels which are as low as reasonably achievable (ALARA), economic and social factors being taken into account;
- the average effective dose equivalent from all sources, excluding natural background radiation and medical procedures, to representative of members of a critical group should not exceed 1 mSv per year;
- for a single repository, the appropriate target at any time, is that the risk to an individual member of the public should not exceed the value equivalent to that associated with a dose of 0.1 mSv; about 1 chance in a million.

As part of its own standards BNFL has adopted a design limit of 15 mSv per year as the maximum individual operator dose for new plant with a design target averaging 5 mSv for the plant workforce as a whole. Both of these are subject to ALARP not requiring further dose reduction.

DEFINITIONS OF WASTE CATEGORIES

Although there is no unified categorization of radioactive wastes at the international level, there are similarities among the various national classifications. In the UK it is common practice to allocate radioactive wastes into one of three categories:

High Level Wastes (HLW), or heat generating wastes, are defined as those in which the temperature may rise significantly as a result of their radioactivity. The design of storage or disposal facilities for HLW must therefore take this factor into account.

Low Level Wastes (LLW) contain radioactive materials not acceptable for disposal as ordinary non-radioactive trash, but not exceeding 4 GBq/te alpha or 12 GBq/te beta/gamma.

Intermediate Level Wastes (ILW) are those containing radioactivity above the levels set for low level waste, but which do not experience a significant temperature rise as a result of their radioactivity.

In practice the HLW category is applied exclusively to the concentrated waste product from the primary separation stage of fuel reprocessing. Consequently in adopting this classification certain wastes are categorized as ILW, although they may generate a modest amount of heat.

WASTE DISPOSAL AND UK NIRED LIMITED

In 1982 NIREX, the Nuclear Industry Waste Executive, was set up to implement the strategy for disposal of solid intermediate and low level waste produced by the UK nuclear industry. In 1985 it was reconstituted as a company, UK Nirex Limited, known as Nirex. The shareholders are British Nuclear Fuels plc, Nuclear Electric, Scottish Nuclear and AEA Technology, with one special share being held by the Secretary of State for Energy on behalf of the Government.

The Company's earlier work on shallow waste disposal facilities was abandoned in May 1987. Nirex is now carrying out the research, development and design work necessary for the aim of developing a deep underground commercial disposal site for ILW and LLW. This is programmed to be available in the year 2005.

The planned deep disposal facility will adopt the multi-barrier approach to ensure that radioactive materials are initially contained and their eventual dispersion and return to the biosphere minimized. Thus the waste will be packaged into containers which will be sealed into vaults using a cement-based grout. The vaults will form part of the cement-based structure of the repository which will be located in a geological formation with low hydraulic conductivity. Thus the waste will remain isolated from man through a combination of chemical and physical barriers for many thousands of years.

In a comparative assessment of design and safety aspects of difference repository concepts it was shown that the concept of excavating large cross section vaults (up to 35m high x 25m wide) in competent hard basement rock, at a depth of approximately 500m, performed particularly well. Two potential sites have been identified for a repository based on this concept, one at Dounreay in Scotland and the other at Sellafield in North West England.

Geological investigations are being carried out at both sites with the aims of confirming the 3D regional geological structure, providing characteristic values for important geological properties, and assessing the constructability of the repository. These investigations are to include the drilling of fully cored deep exploratory boreholes and the geophysical logging and hydrogeological testing of these boreholes. The results from the boreholes will be used to calibrate in particular the regional seismic survey which is being carried out in parallel.

Since both sites are on the margins of marine basins geophysical surveys are being carried out offshore as well as on land. Other regional surveys, including gravity and aeromagnetic, are similarly being conducted both on land and offshore.

Another important aspect of the detailed characterization of the two sites is the study of the ecology, amenity value, planning and socio-economic aspects of the site locations. This provides important information to enable the preparation of an environmental impact assessment of the proposed repository development, in line with requirements under the relevant selection of a preferred site next year, following which Nirex intends to seek planning permission. This application, programmed for late 1992, will inevitably result in a Public Inquiry which is likely to commence in 1993.

The continuing programs of geological investigations are being conducted in parallel with research into engineered barriers, near field chemistry, groundwater transport modelling, gas evolution and migration and the evolution of the biosphere. The results from these studies are drawn together to enable assessment of the radiological safety of the repository after its closure and over geological timescales. The aim of this assessment is to demonstrate that the dose to the most exposed member of the public will not exceed the regulatory target of 0.1 mSv per year.

Nirex is also developing package standards and specifications, and associated transport systems. A standardized approach to waste container design and to the transport of conditioned ILW and LLW from the waste producing sites to the repository is being developed. Nirex will also produce detailed waste package specifications for waste to be disposed of at the deep repository. Prior to disposal waste producers will have to demonstrate that their conditioned waste products satisfy these formal Nirex specifications.

Outline designs for both the surface and underground facilities of the repository have been developed for both sites. Studies of the performance of the standardized waste packages under normal operating conditions and accident conditions have been carried out in the context of the repository designs. This work is conducted to demonstrate that radiation exposure and dose uptake for both classified works and members of the public are within the limits set by the relevant regulatory and radiological protection policy framework. Similar assessments are carried out to validate the safety of the transport of wastes to the repository.

UK NUCLEAR INDUSTRY

Radioactive wastes are produced by many organizations throughout the UK. Major producers include:

- British Nuclear Fuels plc (BNFL) which provides a complete range of nuclear fuel cycle services (fuel fabrication, enrichment and reprocessing) as well as operating Magnox reactors;
- Nuclear Electric (formerly part of CEGB) which is the nuclear electricity utility in England and Wales;
- Scottish Nuclear (formerly part of SSEB) which is the nuclear electricity utility in Scotland.
- AEA Technology which is responsible for nuclear research and development establishments.

In addition, Amersham International (radiochemicals for medicine, industry and research), Ministry of Defence (research and production), hospitals and university research establishments also produce radioactive waste.

HLW MANAGEMENT

Highly active liquor (HAL) arising from the first separation cycle in spent fuel reprocessing normally contains 97-99% of the fission product activity. Historically this liquor has been concentrated by evaporation and stored in high integrity, shielded and cooled tanks. While liquid storage has been demonstrated to be safe and reliable with more than thirty years operational experience, storage in a solid form significantly reduces the potential for release of radioactivity and the waste in this form can be suitable for eventual disposal.

The vitrification of HAL at Sellafield in the Windscale Vitrification Plant (WVP) commenced in mid 1990 and in accordance with Government policy the canisters of glass produced are being stored in a natural ventilation air-cooled store where they will remain for at least 50 years prior to disposal.

The vitrification process consists of four basic steps:

1. Metering the radioactive liquors into a heated rotary calciner where water and acid are evaporated to leave a dry powder in which the waste product nitrates are converted to oxides.
2. Mixing these oxides with measured quantities of glass frit in an induction-heated melter which converts the mixture into molten glass.
3. Casting the glass into 150l (about 400 Kg) stainless steel containers.
4. Welding on the container lid, decontaminating and placing the container in the adjacent store.

A recent detailed assessment by the independent UK Advisory Committee on Safety of Nuclear Installations (ACSNI) concluded that the design adopted by BNFL is the only one with a tried and proven record of performance.

LLW MANAGEMENT

Solid LLW generated in the UK has been disposed of at the Drigg site which is owned by BNFL and has operated since 1959. Originally solid LLW was placed in sealed bags, tipped into open-cut, carefully prepared trenches which were then covered with clay and earth. However several important improvements in the management of this waste have been introduced in recent years, including volume reduction, waste containerization and the implementation of a rigorous quality assurance and checking regime. The most significant improvement has probably been the move to engineered concrete-lined vaults rather than trenches. These vaults, which incorporate surface, perimeter and under-slab drainage systems, have been in use for the past two years. When full, the vaults will be capped with clay and grassed over. It is estimated that the site will have the capacity to accommodate LLW until well into the next century.

LLW arising at the nuclear utilities are normally packaged in 200l drums and whereas only certain utilities have used incineration of combustible wastes and in-drum compaction to reduce volumes prior to disposal, a major program is now underway to provide volume reduction facilities at all utility sites and to provide improved packaging and in-drum monitoring facilities. The design and construction of a new compaction plant is underway for Sellafield LLW with the compacts being grouted into steel containers prior at disposal to Drigg.

ILW MANAGEMENT

A wide range of waste types fall into this category. ILW containing mainly short-lived activity arise mainly from nuclear power stations and research institutions. Examples are ion exchange resins and sludges from treating effluent streams and cooling pond water, fuel assembly debris and miscellaneous contaminated items.

Long-lived ILW from fuel reprocessing operations contain significant quantities of isotopes having half-lives of 30 years or more. Although a large number of ILW streams are generated at BNFL's Sellafield site, they may be grouped according to their origins or properties as follows:

- Fuel Element Cladding Wastes: comprising essentially solid wastes such as leached cladding and end assembly fittings from oxide fuel (known as hulls) and Magnox fuel element cladding (swarf).
- Miscellaneous Beta-Gamma Wastes: any waste which although contaminated has very little alpha emitting activity associated with it. This might typically be maintenance scrap and certain spent fuel storage equipment.
- Slurries: a broad range including ion exchange materials, flocs from liquid effluent treatment and sludges from the corrosion of Magnox swarf in water.
- Plutonium Contaminated Material (PCM): drummed packages (usually 200l) of small scale wastes and large items of equipment such as redundant gloveboxes.

Historically ILW has been stored at BNFL's Sellafield site in its raw, unconditioned form. Approximately 30,000 m^3 of ILW have arisen from nuclear fuel handling and reprocessing operations at the site over the past 35 years (the total UK ILW inventory is currently 50,000 m^3). As many of the storage facilities currently available for ILW do not have the capacity to accommodate future arisings, BNFL has been faced with the choice of building further storage facilities for unconditioned wastes or conditioning (immobilizing) the waste in anticipation of eventual disposal. While storage generally meets current safety regulations, detailed technical assessments have shown that storage in an encapsulated form would be preferable.

BNFL has therefore developed a strategy based on the direct encapsulation of future ILW arisings and no further raw waste storage facilities will be constructed. In addition, existing wastes will be retrieved and conditioned on a timescale determined by the condition of their respective stores, encapsulation plant capacity and the availability of the repository. This strategy not only improves overall safety but is also less costly than the alternative of raw waste storage followed by retrieval and conditioning at a later date, as it:

- reduces the mobility of activity, thereby reducing the consequences of a major event such as fire or aircraft impact;
- reduces the requirements for monitoring and surveillance of waste;
- reduces operator dose uptake by reducing the number of handling operations;
- minimizes store contamination and thus reduces decommissioning costs.

DISPOSAL CRITERIA

In the UK there are no statutory acceptance criteria for radioactive waste packages and, given that waste disposal is dependent on the multi-barrier concept, it may be inappropriate to lay down over-prescriptive requirements for any one of the barriers such as the waste package.

Nevertheless Nirex is in the process of developing specifications which will address all aspects of the waste package and will take into account specific information from the site investigation and repository design programs. Against this background and because of the long lead times for the design and construction of encapsulation plants, BNFL has had to formulate its own package specifications and has developed waste encapsulation processes and equipment to meet these specifications.

To achieve this BNFL has carried out an extensive Product Evaluation program which incorporates a formal approach to the choice of waste treatment and packaging methods including:

- definition of the essential and desirable requirements which waste packages must satisfy;
- a systematic review of all potential encapsulation matrices and selection of the optimum;
- the determination of the characteristics of the chosen matrix;
- establishing what range of process conditions are required for a practical plant; and

- designing a plant which can be controlled and monitored so that product characteristics always lie within a defined range.

Nirex has been supportive of BNFL's strategy and after detailed evaluation of the justification documents produced for specific waste packages has endorsed BNFL's approaches to the regulatory bodies for permission to construct and operate the relevant plants.

The first encapsulation plant (EP1 for the cementation of Magnox swarf) started active operation in 1990; EP2, which will encapsulate hulls and slurries from Oxide fuel reprocessing and WPEP, which will encapsulate flocs, are both scheduled to be operational in 1992.

CONCLUSIONS

In the absence of prescriptive statutory waste acceptance criteria and in advance of the formal issue of package specifications from Nirex, BNFL has developed its own waste product specifications which have enabled a waste management strategy based on early encapsulation of wastes to be implemented.

Thus a vitrification plant is currently operating to immobilize highly active liquid wastes in borosilicate glass. Also, with the support of Nirex, BNFL has been able to begin operating a plant to encapsulate intermediate level wastes in cement, and to design and construct further ILW encapsulation plants for operation in 1992.

Improvements to low level waste management at the national near- surface disposal site at Drigg will provide capacity for its continued operation well into the next century.

A deep underground repository for low and intermediate level waste is planned to be operational by 2005.