WM'00 Conference, February 27 – March2, 2000, Tucson, AZ

TREATMENT AND STORAGE OF WASTE FROM THE DECOMMISSIONING OF THE WINDSCALE PILE REACTOR

D H Norton, Project Manager
British Nuclear Fuels plc

W Botzem
Nukem Nuklear

A Dale
Rolls Royce Nuclear Engineering Services Ltd

ABSTRACT

The Windscale Pile Reactors were constructed in the late 1940's as part of the British nuclear weapons programme. Pile 1 was the first of two Windscale Piles to go critical and operated from 1950 until 1957 when a core fire rendered the plant inoperable.

Work has now started to dismantle and decommission the graphite moderated, air-cooled reactor. Part of this process is to construct and operate a waste processing and storage facility to treat the 2000te + of waste (mainly graphite blocks) for long term storage.

This paper describes how the design of the Waste Processing Facility has dealt with many problems and difficulties associated with such a cocktail of mixed waste. These include irradiated damaged and undamaged fuel, isotope cartridges, Wigner energy in the graphite and pyrophoric material.

Some of the processing and sorting will have to be carried out under an Argon blanket to prevent problems such as oxidisation of the graphite. New processing techniques have been developed to demonstrate that the facility will produce a waste product which is acceptable for long term disposal.

The design of the facility is almost complete and is programmed to be operational by 2002 with an operating life of 3 years.

This paper will be of interest to those companies involved in the processing and storage of radioactive waste arising from D&D operations.

Demonstrating the ability to deal with the complex waste arising from the decommissioning of the Windscale Pile is seen as a major achievement in the treatment of hazardous waste.

INTRODUCTION

The United Kingdom Atomic Energy Authority (UKAEA) owns and operates the Windscale site in North West England. This site, and the adjacent Sellafield site operated by British Nuclear Fuels plc (BNFL) were formed in the late 1940's to support the military and civil nuclear programme. UKAEA is charged with decommissioning the redundant nuclear facilities on the Windscale site which include the Windscale Pile 1 Reactor.

Pile 1 was the scene of the UK's worst nuclear disaster in October 1957 when a fire took place in the core during an operation to release Wigner Energy. The task to safely decommission this reactor offers a unique challenge in the history of nuclear decommissioning.

The Pile 1 Reactor Building and associated chimney is shown in the photograph below.

BACKGROUND

The two Windscale Pile Reactors were constructed between 1946 and 1950 and operated until 1957 when Pile 1 was shut down following the core fire. A contract to undertake the decommissioning of this reactor was placed by UKAEA in August 1997 to the Consortium BNFL plc, NUKEM Nuklear GmbH and Rolls-Royce Nuclear Engineering Services (RRNESL).

Windscale Pile 1 is a graphite moderated, air-cooled reactor which was fuelled with uranium metal rods clad in aluminium with longitudinal fins to improve heat transfer. The moderator is essentially a cylinder of diameter 15m and length 7.5m, laid on its horizontal axis. The core is surrounded by a 2.6m thick biological shield constructed of reinforced concrete. The thermal power rating of the Reactor was 180 mw with a mean core temperature of 395° C.

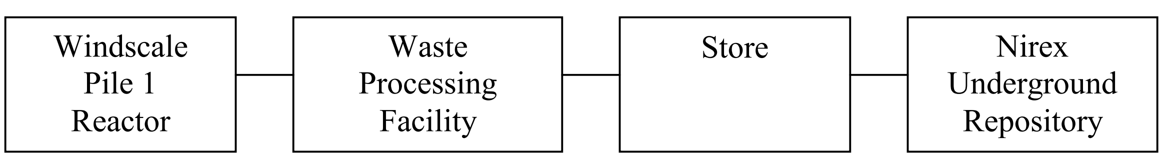
During the fire, temperatures in excess of 1200°C were measured resulting in severe damage to approximately 20% of the graphite core. Water was used as part of the process to extinguish the fire. As a result, the decommissioning team are faced with the problems associated with a cocktail of materials which include:

- Fuel – both damaged and undamaged (Iste)
- Isotope Cartridges – (1.7te)
- Graphite – 48000 blocks some with lead contamination
- Pyrophoric material
- Radioactive dust (several m^3)

The goal of the contract is to take Pile 1 from its current state to an end state in which the core has been fully dismantled and all fuel and isotopic material as well as graphite have been processed and packaged for medium and long term storage. The Pile 1 bio-shield will be sealed and the core filled with an inert gas during dismantling.

Remote controlled equipment will be installed within the bioshield to carefully dismantle the 200,000 or so reactor components and transfer to a new Waste Processing Facility (WPF).

Figure 1 Overall Process



The (WPF) will be constructed and operated during the realisation of the project. Intermediate level waste (ILW) will be processed to a form acceptable for both interim storage and final disposal through United Kingdom Nirex Limited (Nirex). Nirex is responsible for providing and managing facilities for the safe long term disposal of radioactive wastes. A new waste store suitable for at least 100 years will be erected.

DESCRIPTION OF THE WASTE PROCESSING FACILITY AND PROCESSES

The WPF acts to link the Pile 1 core and the new ILW store and incorporates all the facilities needed to condition the waste arisings before export for storage. Waste arisings from the core will principally arise in three forms, fuel elements, isotope cartridges and graphite. Waste present within Pile 1 includes up to a maximum of 15te of uranium fuel elements and up to 1700 isotope cartridges together with approximately 2000te activated graphite. Dependant upon the level of damage to the fuel elements, level of contamination and the residual Wigner energy associated with the graphite, separate treatment routes are planned, see Figure 2.

Dismantling of the main core of the Pile 1 reactor will be carried out under an inert gas blanket. To maintain the waste arisings in this atmosphere prior to conditioning of the fuel elements both the buffer store connecting to the Pile 1 core and waste sort areas of the WPF are to be inerted. Air locks are consequently provided to link to non-inerted plant areas. The inert gas is supplied to the WPF via two separate distribution systems.
Graphite recovered from the core which contains significant levels of Wigner energy will be subjected to an annealing process to remove some of the stored energy and to raise the temperature at which further energy release could commence. This process will be operated under an inert atmosphere to avoid oxidisation of the graphite.

Undamaged fuel was originally considered not to be an acceptable feed stream to Nirex. However, a study for fuel management has concluded that either the storage of all fuel elements recovered from the Pile 1 core in a grouted form or the storage of damaged fuel in a grouted form with the export of those capable of being reprocessed to the existing facilities on the Sellafield site constitutes the best practical means of managing the recovered fuel.
As far as the safety case is concerned, fuel recovered from Pile 1 will be considered to be damaged if:

- It is mechanically damaged such that it is unsuitable for reprocessing. Clearly melted fuel will come into this category. Fuel elements which are badly distorted are also expected to be in this category. Minor damage to the aluminium cladding e.g. partially crushed fins would not be expected to cause an element to be considered as damaged. Designation of a damaged element will be made by the operators remotely handling fuel in the sort area on a *visual identification* basis.
- A fuel element which is not mechanically damaged shows indication of the presence of hydride or other pyrophoric material such that there is a *detectable temperature* rise when subject to testing in the test chamber.

Damaged fuel will be subjected to a surface passivation process which will oxidise hydride and other pyrophoric material. Fuel elements will subsequently be placed into steel canisters prior to grouting to minimise potential disruption and handling requirements affecting the oxide surface. Undamaged fuel will be tested to confirm that there is no significant hydride present and then placed into steel canisters providing containment of the element.

Two types of boxes are to be utilised for the storage of wastes, a $3m^3$ and 4m box. The fissile inventory limit for the 4m box is restricted such that in this application it will only be suitable for storing graphite.

After the completion of the stabilisation processes i.e. fuel passivation and graphite annealing, waste will be prepared for long term storage, this will comprise:

- Placing mixed debris, isotope cartridges, damaged fuel and damaged graphite within $3m^3$ boxes and then grouting these wastes with a cementation grout.
- Placing undamaged fuel within canisters into $3m^3$ (NB depending on the preferred final disposal route undamaged fuel may be exported directly from the WPF to BNFL facilities for reprocessing or grouted within the $3m^3$ box).
- Loading undamaged graphite into 4m boxes – with the option to grout at a later stage.

A waste tracking and assay system is provided in the WPF and ILW store which will allow the contents of each $3m^3$ and 4m box to be recorded and maintained.

The processes used within the WPF have been designed to satisfy the conditions of acceptance set by NIREX. An extensive research and development programme is underway to support this design. Quality of the stored product will be demonstrated through a strict sampling regime.

All operations within the WPF associated with the handling of fuel elements and isotope cartridges will be carried out remotely. The WPF is consequently equipped with Master Slave Manipulators and Power Manipulators to carry out remote operations. Skips of waste and other waste movements are performed utilising either in cell cranes or roller conveyor systems. Filled waste boxes are remotely traversed to locations accessible by an Electric Overhead Travelling crane which serves the store.

The WPF is expected to have an operational life matched to the core dismantling operations and will then be placed into a Post Operation Clean Out regime. The design of both the WPF and ILW store have considered requirements for decommissioning.
An inactive grout preparation and delivery area abuts to the WPF and grout will be supplied and routed from this facility to separate areas for $3m^3$ and 4m box grouting.

DESCRIPTION OF THE STORE

A purpose built Intermediate Level Waste Store will be constructed as an integral part of the Waste Processing Facility.

The boxes will be stored within a shielded storage vault within the ILW store. The 4m boxes can be stacked up to 6 high and the $3m^3$ boxes up to 9 high. The 4m boxes are self shielded incorporating concrete shielding within the design but the $3m^3$ boxes require additional shielding plates above the top layer of boxes. Operations within the vault will be controlled remotely.

The number of boxes required will vary dependant on the mix of materials from the core dismantling. The store is designed to hold 315 off $3m^3$ and 180 off 4m boxes. The external surfaces of the boxes will be radioactively clean.

The store will be serviced by an electric overhead crane controlled by an electronic crane co-ordination system to ensure accurate placement and retrieval of boxes.

The store has a nominal design life of 100 years, with an environment which will be controlled to ensure that boxes are stored in dry conditions. Inspection of the external faces of the boxes will be possible during the storage period.

On completion of the quiescent storage period it is intended that the entire contents of the ILW store will be exported to the long term repository or in the case of undamaged fuel to the BNFL reprocessing facility. The design of the store includes the required export facilities.

CONCLUSION

The decommissioning of the Windscale Pile is considered to be a very difficult, complex, unique and challenging project. The waste forms resulting from the dismantling of the core can only be defined with a high level of uncertainty and risk. Therefore, the design of the Waste Processing Facility and Store requires a large contingency to deal with variations in the waste forms produced. Also the throughput and operational times for the facility must match the core dismantling operations to ensure the total project costs are minimised.

Demonstrating the ability to design and ultimately to operate successfully a versatile Waste Processing Facility and Store to deal with such a complex mixed waste form is seen as a major achievement in the treatment of hazardous waste.

ACKNOWLEDGEMENT

This project is funded by the UK Ministry of Defence and the UK Department of Trade and Industry via a contract managed by UKAEA.

Figure 2. Waste Treatment Routes