Decommissioning Sellafield's First Fuel Storage Pond - 11125

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ABSTRACT

The Pile Fuel Storage Pond (PFSP) at Sellafield was built in 1949/50 to receive and coolstore fuel and isotopes from the Windscale Piles, as well as the decanning of the fuel elements prior to reprocessing. Following closure of the Windscale Piles in 1957 and commissioning of First Magnox Fuel Storage Pond, plant operations were scaled down until fuel processing eventually ceased in 1962. Since the cessation of its main operations the facility has been used to store miscellaneous orphan wastes from the UK nuclear programme.

Due to the long and varied operating history of the pond, the inventory contained within it is varied and complex, ranging from highly mobile organic sludge to reactor furniture and experimental fuels. Both the variety of waste forms (almost 1000 have been identified on the plant inventory) and the limited information available for many of the wastes present different challenges. They each have to be dealt with as part of the remediation programme, which must also work within the time constraints set by the site programme and the external regulators, as well as the physical and process constraints associated with the pond itself.

INTRODUCTION

The Pile Fuel Storage Pond (PFSP) at Sellafield was built and commissioned between the late 1940s and early 1950s as a storage and cooling facility for irradiated fuel and isotopes from the two Windscale reactors. The pond was linked via submerged water ducts to each reactor, where fuel and isotopes were discharged into skips for transfer along the duct to the pond. In the pond the fuel was cooled then decanned underwater prior to export for reprocessing.

The plant operated successfully until it was taken out of operation in 1962 when the First Magnox Fuel Storage Pond took over fuel storage and decanning operations on the site. The pond was then used for storage of miscellaneous Intermediate Level Waste (ILW) and fuel from the UK's Nuclear Programme for which no defined disposal route was available. By the mid 1970s the import of waste ceased and the plant, with its inventory, were placed into a passive care and maintenance regime.

By the mid 1990s, driven by the age of the facility and concern over the potential scale of the programme to dispose of the various wastes and fuels being stored, the plant operator initiated a programme of work to remediate the facility. This programme has to balance a number of competing drivers to deliver the optimum solution for the plant, these include:

- The pond being situated on a very congested part of the Sellafield site; and being surrounded on all sides by buildings which originate back to the earliest history of nuclear operations on the site. This limits the opportunity for new infrastructure, heavy lifting and temporary facilities.
- The pond is outside and is very close to occupied areas of the site. This limits the opportunity for high energy retrieval systems that could result in uncontrolled disturbance of activity or low shielding solutions.

- The Pile Fuel Storage Pond is one of a number of legacy plants on the site, The waste streams from the pond are more varied but much lower volume than many of the other plants. This requires the programme to take a responsive and opportunistic approach to movements within the overall site programme.
- The various waste forms within the pond present different challenges and hazards. In striving for the earliest hazard reduction these need to be considered against each other and a sequence of operations selected which not only gives early hazard reduction but minimises the risk overall.
- The pond infrastructure needs to be maintained and improved, balancing time and money spend improving infrastructure against hazard reduction is a key part of the programme.

The programme developed and implemented consists of the following seven interdependent phases of work which link together towards the overall goal, each of the phases being delivered by a number of projects the combined delivery of which will achieve the desired outcome.

Pond Preparation

Before any remediation work could start the condition of the pond had to be transformed from a passive store to a plant capable of complex retrieval operations. This work included plant and equipment upgrades, removal of redundant structures and the provision of a effluent treatment plant for removing particulate and dissolved activity from the pond water.

Canned Fuel Retrieval

Canned fuel, including oxide and carbide fuels, represent the largest inventory in the pond and is therefore the highest priority within the programme. The project associated with this stream has provided handling and export equipment required to remove the canned fuel from the pond. It has also developed treatment routes utilising existing site facilities to allow the fuel to be reprocessed or conditioned for long term storage.

Sludge Retrieval

In excess of 300 m^3 of sludge has accumulated in the pond over many years and is made up of debris arising from fuel and metallic corrosion, wind blown debris and bio-organic materials.

The Sludge Retrieval Project has provided the equipment necessary to retrieve the sludge, including skip washer and tipper machines for clearing sludge from the pond skips, equipment for clearing sludge from the pond floor and bays, along with an ‘in pond’ corral for interim storage of retrieved sludge.

Two further projects are providing new plants, which will initially store and eventually passivate the sludge.

Metal Fuel Retrieval

Metal Fuel from various sources is stored within the pond; the fuel varies considerably in both form and condition. The Metal Fuel Retrieval Project will provide fuel handling, conditioning, sentencing and export equipment required to remove the metal fuel from the pond for export to on site facilities for interim storage and disposal.

Solid Waste Retrieval

A final retrieval project will provide methods for handling, retrieval, packaging and export of the remaining solid Intermediate Level Waste within the pond. This includes residual metal fuel pieces, fuel cladding (Magnox, aluminium and zircaloy), isotope cartridges, reactor furniture, and miscellaneous activated and contaminated items. Each of the waste streams requires conditioning to allow it to be and disposed of via one of the site treatment plants.

Pond Dewatering and Dismantling

Delivery of the above projects will allow operations to progressively remove the radiological inventory, thereby reducing the hazard/risk posed by the plant. This will then allow subsequent dewatering of the pond and dismantling of the structure. Strategies for this phase of work are currently being developed.

A graphical illustration the programme structure is shown in figure 1.

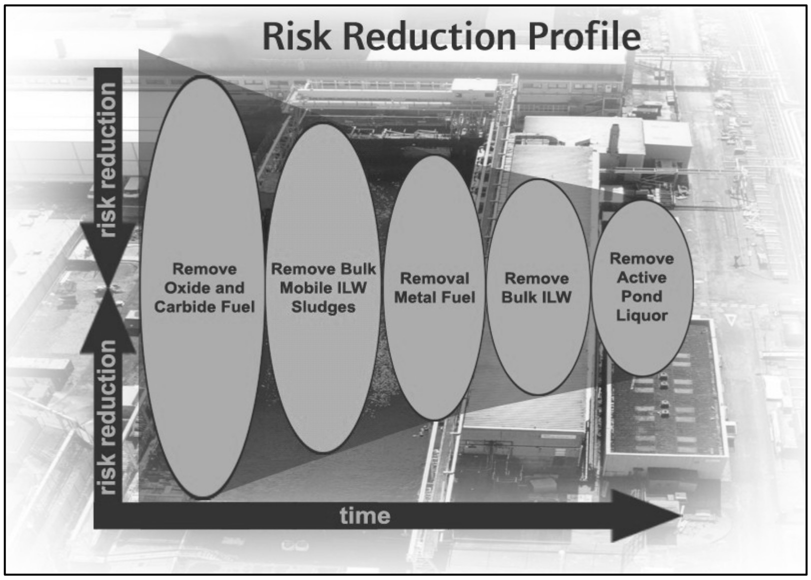

Fig. 1. Graphical Representation of PFSP Remediation Strategy

POND PREPARATION

The Pile Fuel Storage Pond is situated on a very congested part of the Sellafield site; it is surrounded on all sides by buildings which originate back to the earliest history of nuclear operations on the site. The operating areas are generally small and the building infrastructure reflects the smaller scale of the early nuclear operations. Much of this infrastructure had reached the end of its design life. It was recognised early in the programme that, if efficient retrieval operations were to be established, improvements to the building infrastructure and working environment would be required.

General Refurbishment

A series of building refurbishment projects were initiated, with the first priority being the replacement of the skip handler, which had not operated since 1972. The skip handler is essential to operations, as it not only enables skips to be moved in the pond, but provides general lifting capability above the pond and provides the only operator access over the pond. The first project completed replaced the original skip handler with a modern system capable not only of moving skips but also providing a general lifting capacity of up to 20t over the pond, this was essential to enable future works. In addition to this work hydraulic isolation barriers were installed to separate the pond from the ducts through which fuel was originally transferred under water from the Windscale Piles. Installation of these barriers considerably simplified interactions within the pond as it enabled the pond to be considered as an independent water retaining structure.

Fig. 2 Pile Fuel Storage Pond Skip Handler before and after replacement

Other building refurbishment work included the provision of a new radiological protection system, a new ventilation system, improved piped services, upgrade of main electrical supplies, improved lighting, replacement decanner and withdrawal bay cranes. This refurbishment work was accompanied by a general clean up of the facility to remove historically contaminated areas. With these improvements complete work then commenced on removing some of the items stored in and around the pond to reduce congestion. In these campaigns 21m^3 of zircalloy hulls were retrieved and exported and 25 redundant fuel flasks stored in and around the pond were sent for disposal.

To allow space for working and for construction of new facilities, a number of redundant structures were demolished. This included the demolition of the winch house shown in figure 3 which was used to pull skips of fuel from on of the Windscale Pile into the pond. The area where the winch house used to stand has been transformed into a general purpose work and decontamination area where items removed from the pond can be worked on. To the North of the pond a redundant change room and office building were demolished, opening up access for the project work and freeing space for construction of new facilities.

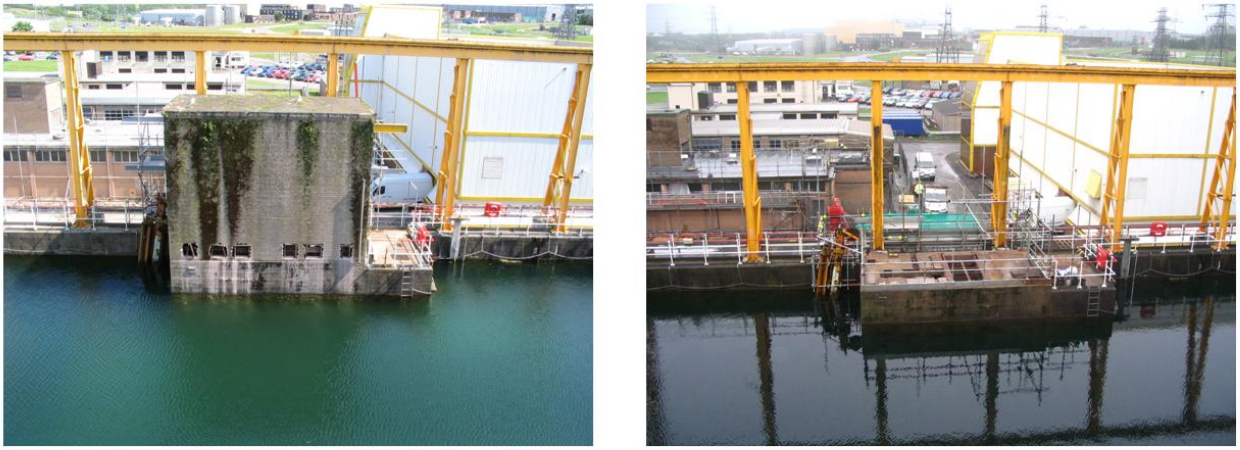

Fig. 3 East Winch House before and after demolition

Local Effluent Treatment Plant

The provision of a Local Effluent Treatment Plant (LETP) for the pond was an essential pre-requisite for the programme. The levels of activity in the pond water have been gradually increasing over the years due to the corrosion of fuel held within the pond. These rising activity levels pose difficulties as they increase the dose to operators working around the pond and increase the activity in the pond overflow, which is discharged down the site's low active drain to the Segregated Effluent Treatment Plant (SETP) prior to discharge to sea. It is expected that the retrievals processes will cause further increase in the activity burden in the pond. It was therefore considered essential that a means of controlling the pond discharge was available to ensure that future retrieval techniques were not limited by environmental discharge constraints.

The principles of the LETP are to reduce the potential for any solids to discharge to drain by introducing a sand bed filter designed to capture solids down to a few microns in size, and to reduce the activity of the pond liquor discharge using an ion exchange process extracting extract caesium and strontium. These nuclides together contribute over 99% of the soluble activity within the pond liquor. The LETP unit designed can process up to 125m^3 per of pond water day, of which typically 100m^3 is returned to the pond, with the remainder discharged to the low active drain.

The sand bed filter and ion exchange system along with the associated pumping equipment and pipework are all mounted on a single skid unit which has been installed into the pond, see figure 4. Auxiliary control and services systems were provided on skids located to the side of the pond structure. The plant was designed in this way to allow all of the key processing equipment to be assembled and tested off site, with minimal dismantling prior to installation. This minimised the work required over the pond and the risk of installation errors affecting the plant. Clearing the site to the North of the pond offered the opportunity to lift the LETP module, weighing in excess of 20t, in a single lift using a mobile crane. Due to the weight of the module and the reach required to lift the LETP over the Pile Fuel Storage Pond crane gantry, the lift required one of the largest mobile cranes in Europe, with a capacity of 800 t and use of a 60m long boom.

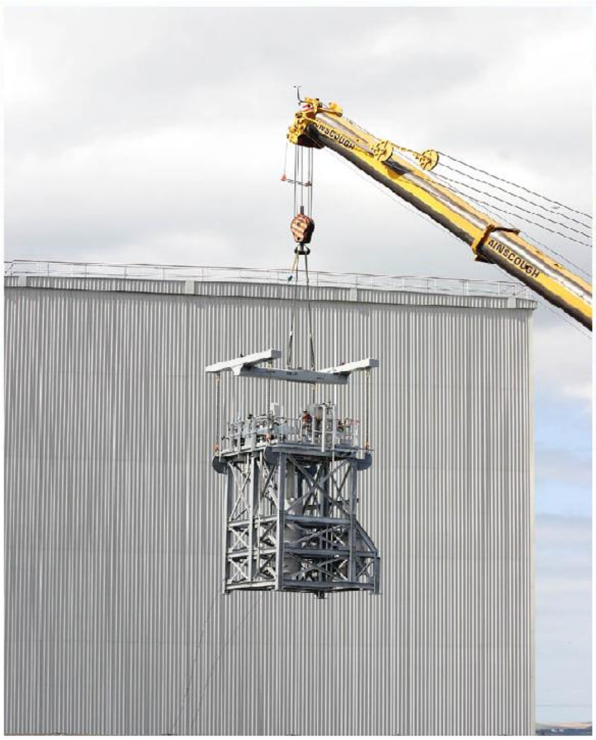

Fig. 4. LETP Module undergoing works testing and installation

Preparation for the lift required 4 fuel skips to be removed from the pond and the pond floor under the module to be cleaned, this not only created space for the LETP but provided valuable data for the future programme of skip recovery and sludge retrieval. The ground under the mobile crane also had to be prepared, to take the large imposed loads from the lift. With these preparatory works complete, the lift was undertaken and the module placed into the pond within a few millimetres of its designed location.

The LETP has been successfully brought into service and has reduced the activity in the pond liquor discharges by a factor of 100. This has not only enabled further retrievals activities to be undertaken but has also led to a significant reduction in the Sellafield Site discharges.

Survey, Sampling and Characterisation

In addition to these works to improve the building itself extensive survey, sampling and characterisation work has been completed to understand both the inventory of the pond and the physical condition of the pond structure itself. These studies provide the all of the underpinning data for the programme, not only for the projects to retrieve the waste, but also to justify the extended life of the facility while retrievals are undertaken.

The completion of these extensive preparatory works has significantly improved the working environment and capability of the Pile Fuel Storage Pond and enables the retrievals elements of the programme to be effectively deployed.

CANNED FUEL RETRIEVAL

The Pile Fuel Storage Pond contains oxide and carbide fuels from a number of sources including, research reactors, the Windscale Advanced Cooled Gas Reactor and the Winfrith Steam Generating Heavy Water Reactor, these are collectively known as canned fuels. The first priority for the programme was to establish inventory data for these fuels and to determine whether any of the fuel was suitable for reprocessing. Extensive research of industry records established sufficient evidence to confirm that the oxide fuel could be treated within the site Thermal Oxide Reprocessing Plant (THORP) and the carbide fuel was suitable for storage with other orphan fuels within the inlet pond to that facility. Unfortunately the cans the fuel was built into could not be handled in that facility and no infrastructure existed to export or re-can the fuel

The Canned Fuel Project was initiated to establish a waste route for the fuel. This project has provided retrievals and export equipment, figure 5, within the pond to allow the fuel to be retrieved from the pond skips and placed into a new fuel flask. Using the new fuel flask the fuel can be transferred to an existing fuel handling facility which has been modified by the project to re-can the fuel in packages suitable for handling at THORP. All of the infrastructure required to export the fuel is now in place and inactively commissioned. The programme is waiting a suitable operational window in the downstream plant to export the fuel.

Fig.5. Canned fuel as stored in the pond and retrieval tool during works test

SLUDGE RETRIEVAL

Operation of the pond, which is open to the environment, has led to the gradual accumulation of in excess of 300 m^3 of sludge in the bottom of the pond. The sludge generally consists of debris from fuel and metal corrosion, wind blown debris, and bio-organic materials such as algae and bird guano.

The pond floor is covered with a blanket of the sludge, which has been observed to be piling up in the pond corners. Quantities of sludge have also accumulated in fuel skips and within the bays originally used for decanning and withdrawing fuel. To complicate matters further, in addition to the sludge there is a large quantity of pond floor debris, which includes pieces of concrete, graphite, wire, cladding, spent fuel and other metals present as oxides. Removal of the accumulated sludge is a top priority for cleaning up the Pile Fuel Storage Pond as it is one of the most mobile waste forms, increasing the hazards associated with loss of containment. The sludge also prevents effective characterisation and retrieval of the other waste forms.

To enable the sludge to be removed three interconnected projects have been undertaken; these provide the sludge retrieval equipment (Sludge Retrievals Project), provide interim safe storage for the retrieved sludge (Local Sludge Treatment Plant Storage Project) and a plant for passivation and packaging of the sludge for long term storage (Local Sludge Treatment Plant Export Project).

Sludge Retrieval Project

The general principle of the Sludge Retrieval Project is to retrieve sludge from all the pond areas and collect it in an in pond corral. The concept of the in pond corral is to disconnect the time consuming and labour intensive process of sludge retrieval from the construction of the sludge storage plant. This parallel working will save several years on the overall retrieval programme.

The sludge in the pond has collected in three distinct areas, within the decanning bays and within the pond skips, where there is a higher concentration of corrosion product and on the pond floor, where the sludge is generally organic material and wind blown debris. Retrieval of sludge from each of these areas required different retrieval technology to be developed and implemented.

Bay Desludging

The plant has twelve wet bays, in which fuel was decanned and exported for reprocessing; the bays are generally very congested with redundant machinery from these operations. The bays contain various quantities of sludge, which is relatively rich in corrosion products from the debris left behind from decanning operations.

A process has been deployed, which takes advantage of the hydraulic linking of these bays in pairs, and creates a current within each pair of bays that will mobilise and transfer the sludge to the main pond, from where it can be retrieved with other pond floor sludge to the corral. This is achieved by placing a pump (figure 6) at the entrance to one of the bays and drawing water from the pond through the U-shaped pair of bays and forcing it back into the pond. Once the through current is established the sludge bed is disturbed using water lances forcing the sludge into the flow and out of the bay.

Fig. 6. Bay desludging operations

The bay desludging equipment has now been deployed on eight of the twelve wet bays and has effectively removed the bulk sludge from these bays. Once the bays are desludged blanking plates are fitted on the bay doors which prevent migration of sludge pack from the pond.

Pond Skip Desludging

The pond now contains 160 fuel skips, which are arranged in a matrix on the pond floor. The skips contain a variety of miscellaneous ILW and fuel. Sludge has accumulated in the skips by a combination of corrosion of the skip contents and through organic material and wind blown debris falling into the skips. Sludge has to be removed from the pond skips for two reasons, firstly the skips contain a significant proportion of the sludge inventory and this must be captured, secondly desludging of the nominally empty fuel skips allows these to be cleaned and exported from the plant. Exporting these skips creates space on the pond floor, enabling the sludge to be retrieved from there more easily.

To enable skip desludging a skip washing machine and a skip tipping machine have been developed and installed into the pond (figure 7). Each of the empty skips, measuring 1.8m by 2.1m by 1.5m is transported to the to the skip washing machine. Sludge is then washed from the internals of the skip and transferred to the corral using a hydraulic resuspension technique where recirculating pond water is jetted onto the sludge bed within the skip gradually entraining the sludge. The washed skip is then transferred to the skip tipping machine where any solid debris is removed and consolidated into a single skip. The externals of the skip are then washed and the skip exported. The active commissioning of the skip desludging equipment, which includes the export a number of fuel skips from the pond is complete, with a number of fuel skips having been exported as low level waste from the pond.

As the pond floor desludging progresses each of the pond skips will need to be moved to create the empty floor areas required. As part of that movement each skip is transferred to the skip washing machine to remove the sludge. The project is also looking to take the opportunity afforded by washing each skip to inspect and where possible consolidate skip contents to underpin future ILW and fuel retrievals work.

Pond Floor Desludging

Pond floor desludging is again achieved mainly using a hydraulic resuspension technique. A large desludging hood is deployed in the area of the pond cleared of pond skips and recovers the sludge by a similar method to that used by the skip washer. The desludging hood is transported around the pond by the skip handler machine and transfers sludge to the corral via a tensioned umbilical system which prevents the skip handler becoming entangled with the sludge transfer lines.

While the pond floor desludging hood is ideal for clearing large open areas of pond a number of other devices have been provided to collect sludge from more inaccessible areas, these include a remote operated vehicle with a plough and eductor to retrieve the sludge. Lances, pumps and eductors, which can be used from the skip handler machine mast or from the pond wall, have been provided to move sludge into areas where it can be collected by the sludge hood.

Operation of the Corral

The sludge that has accumulated on the pond floor has generally settled in situ to a density of around 10% wt solids. The hydraulic retrieval techniques employed to collect the sludge from the pond have the effect of reducing the sludge concentration by at least an order of magnitude.

Transferring retrieved sludge to an in pond corral provides two benefits. It divorces the sludge retrieval programme from the provision of the storage plant, the corral also has a function in reducing the size and complexity of that plant by concentrating sludge, allowing transfer at a higher average solids content.

Fig 7 Corral installation

The sludge retrieved from the pond is discharged into the in-pond corral from the skip washing machine, the pond floor hood or the remote operated vehicle in a very dilute form. The solids in the sludge settle in the corral as the retrieved liquor slowly passes through before overflowing back into the pond via a weir. The corral is over 17m long which gives sufficient residence time for most of the sludge solids to settle out. The aim is to settle sludge in the corral to provide a bed with 10% wt solids. The target is to transfer this to the Local Sludge Treatment Plant (at an average of 5% wt solids. This initial thickening massively reduces the volumes of liquor that need to be handled by the storage plant and therefore dramatically reduce its size. The corral itself has a capacity of nearly $100m^3$ which allows a significant volume of sludge to be collected from the pond before transfers to the storage plant begin.

Local Sludge Treatment Plant Storage Project

The Pile Fuel Storage Pond Local Sludge Treatment Plant (LSTP) provides the facilities to store, and eventually passivate the sludge by encapsulation. The plant is being delivered in two phases; the first phase provides the modern stainless steel storage tanks for containment of the sludge retrieved from the pond, the second will provide capability to passivate and export the sludge for long term storage. The development of two separate projects has enabled work to progress on the facilities to store sludge from the pond earlier than would have been possible for a combined project due to site constraints, hence accelerating hazard reduction.

The storage plant is built to the North of the pond, figure 8, on the area cleared earlier in the programme and contains settling and storage tanks along with facilities to enable future export to the encapsulation facility.

Sludge will be transferred to LSTP from the in pond corral, via a dedicated pipebridge to a settling vessel where the sludge is concentrated from an average of 5% wt solids to 10% wt solids. Gravity settling has been selected as the means of doing this concentration as it proved more effective than active thickening processes in trials and generally leads to a simpler plant design. A batch of concentrated sludge accumulates in the settler before it is transferred to one of three Bulk Storage Tanks each with a capacity of over $100m^3$; the stored sludge is circulated every few days to prevent build up of flammable gases and to ensure the sludge remains mobile. The plant is also fitted with a sentencing vessel and sampling system which allows the stored sludge to be sampled and eventually exported to the passivation plant.

The storage project provides the infrastructure including ventilation and piped services for the future export facility.

METAL FUEL RETRIEVAL

Metal fuel in the form of rods, flat bars, pennies and bits is present throughout the pond and originates from many areas of the UK national nuclear programme. An extensive study of industry records and plant surveys have been undertaken which has confirmed that where fuel cladding is present it is either aluminium or magnox clad and that very little of the fuel is suitable for reprocessing in existing site facilities.

The inventory of fuel in PFSP is not significant in comparison to the overall site inventory and will not drive the overall solution to this waste problem. Therefore, the objective for the PSFP programme is to ensure that sufficient infrastructure exists to retrieve the fuel and export it to the site Fuel Handling Plant which is to be used as interim storage pending the development of the storage programme. To enable this, the Metal Fuel Retrieval Project has been initiated which will develop sorting, segregation and export facilities in the pond similar to those used for the canned fuel. The project will also develop the export route via the fuel inspection facility where aluminium cladding will be removed as this is not compatible with the downstream interim storage pond.

SOLID WASTE RETRIEVAL

Over 700t of activated and contaminated intermediate level waste are present in the pond and will be dealt with as part of the final retrievals phase of the programme. Good records of skip contents were maintained when the pond was undergoing early operations, however these were not maintained as thoroughly when plant operations ramped down. This leads to difficulties in defining the inventory to be dealt with by this project. This is further complicated by the size of the skips and presence of closed boxes and tins which limits the value of simple visual inspection for inventory determination

Despite the limitations in records and surveys has been undertaken and identified around 1000 separate waste types to be dealt with by this project, these include but are not limited to:

- Fuel cladding (Magnox, aluminium and zircaloy),
- Isotope cartridges, irradiated within the piles and Magnox reactors,
- Reactor furniture, from Calder Hall, Chapelcross and the piles,

- Residual items of sludge, larger than the sludge recovered during sludge retrieval operations.
- Original process equipment, such as fuel skips, flasks, decanners, guide rails and trolleys,
- Debris which has fallen into the pond,
- Scrap items which have been stored in the pond as no other waste route was available at the time.
- Ion exchange media

Fig.08. Video survey of a fuel cladding and isotope skip

The baseline strategy for dealing with this waste is to export it to a new purpose build ponds solids treatment plant, which is to be built on the site, where it will be encapsulated in cement along with waste from other Site facilities.

The principle challenge for the PFSP programme is the export capacity required to empty the ILW out of the pond in reasonable time duration. The limited load bearing capacity and restricted operating environment within the plant limit the currently available export capability to around $^{1}/_{3}$ tonne per week giving a clearly excessive operational window for the plant. The project is therefore developing options for higher payload low weight flasking options and in pond size reduction sort and segregation opportunities to limit the duration of this programme.

POND DEWATERING & DISMANTLING

Pond dewatering will be the final stage of the retrievals programme; this will require the removal of all non fixed plant and equipment before operations to fix or remove activity from surfaces and remove the pond water. As these activities remain sometime in the future and technology is being developed in similar facilities worldwide no firm plans for achieving this step are being developed. However it is critically important for the success of the programme that infrastructure provided for earlier phases will support this work, for example the local effluent treatment plant provided at the beginning of the programme has been designed to allow modification to empty the pond if required.

CONCLUSIONS

The programme developed for remediation of the Pile Fuel Storage Pond has proved to be effective with significant inroads having been made in the improvement in infrastructure, provision of retrieval equipment and commencement of retrieval. The programme has also proven to be very robust having seen limited change to the technical or logical baseline despite some of the biggest changes in the history in the UK nuclear industry environment.

Excellent progress has been made in transforming the facility and commencing retrievals operations, however significant progress is still required to remediate the facility. The unknown nature of the remaining inventory and the interactions with the wider Sellafield Site remediation programme are likely to remain the biggest challenges. However the robust work completed to date has ensured that both the facility and the projects to support its remediation have sufficient flexibility to handle these changes.

GLOSSARY

ILW	Intermediate Level Waste
LETP	Effluent Treatment Plant
LLW	Low Level Waste
LSTP(E)	Local Sludge Treatment Project (Export)
LSTP(S)	Local Sludge Treatment Plant (Storage)
PFSP	Pile Fuel Storage Pond
SETP	Segregated Effluent Treatment Plant
THORP	Thermal Oxide Reprocessing Plant