

## **SELLAFIELD DECOMMISSIONING PROGRAMME - UPDATE AND LESSONS LEARNED**

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### **ABSTRACT**

The Sellafield site in North West England has over 240 active facilities covering the full nuclear cycle from fuel manufacture through generation, reprocessing and waste treatment. The Sellafield decommissioning programme was formally initiated in the mid 1980s though several plants had been decommissioned prior to this primarily to create space for other plants. Since the initiation of the programme 7 plants have been completely decommissioned, significant progress has been made in a further 16 and a total of 56 major project phases have been completed. This programme update will explain the decommissioning arrangements and strategies and illustrate the progress made on a number of the plants including the Windscale Pile Chimneys, the first reprocessing plant and plutonium plants. These present a range of different challenges and requiring approaches from fully hands on to fully remote. Some of the key lessons learned will be highlighted.

### **INTRODUCTION**

Following the announcement by the Secretary of State for Trade and Industry, Patricia Hewitt, in November 2001 of the formation of the Liabilities Management Authority (LMA) the strategic direction and organisation on the Sellafield site has been transformed. Although site licence responsibility will initially remain with BNFL, all capital assets will transfer to the LMA when it is formed under UK statute presently envisaged within the next 2 years. Responding to this change the management of the various business groups at Sellafield have been restructured into a single, integrated management team, titled Sellafield Management and Operations Services. The prime focus for this new organisation is the delivery of safe operations and the acceleration of remediation activities on the Sellafield site. (See the associated presentation; The changing face of Sellafield).

The Sellafield decommissioning programme has been underway since the early 1980s and has demonstrated BNFL's ongoing commitment to reducing the historic liability burden for over 20 years. When the current reprocessing programmes are complete the Sellafield site alone will have over 120 radioactive plants which will require decommissioning. The recent announcement of the early closure of the Calder Hall reactors will add to the decommissioning work programme substantially in the near term. In order to achieve this massive workload there is an increasing emphasis on the acceleration of remediation work programmes across the site both in radioactive and non-active facilities to reduce both the hazard posed by the site and the overall "mortgage" costs in running the site. A new group has been formed to focus on remediation strategies and prepare a baseline remediation programme for the Sellafield site.

This paper provides an update on progress in delivering the Sellafield decommissioning programme.

## **BACKGROUND TO THE SELLAFIELD SITE**

Initial work at Sellafield in the late 1940s involved the construction of the two Windscale Pile reactors and the associated plants to cool, decan and reprocess the fuel together with the plutonium and uranium finishing lines and the associated waste and effluent treatment facilities. In the mid 1950s the first of the Magnox reactors came on line and it was apparent that the proposed expansion of the civil Magnox programme could not be supported by the existing reprocessing plants. This led to the construction of the Magnox reprocessing plant which came on stream in the mid 1960s together with additional pond storage and decanning facilities, many of the existing waste and effluent plants however continued to be utilised with some capacity enhancements. This philosophy of maximising the utilisation of capital investment has continued. The Thermal Oxide Reprocessing Plant (THORP) plant for the reprocessing of oxide fuels, commissioned in the mid 1990s, utilises some supporting plants from both the original defence and Magnox programmes. Reprocessing of Magnox and oxide fuel is currently anticipated to continue until 2012. Additionally there is a legacy of highly active liquors and medium active wastes (mainly fuel cladding) which needs to be recovered and conditioned ready for ultimate disposal. The site interactions are therefore extremely complex and the decommissioning programme both for the plants already shut down and operating plants must be integrated with the operational needs of the site.

## **DECOMMISSIONING ARRANGEMENTS**

UK legislation requires that the site licence holder prepare suitable decommissioning arrangements for each nuclear site. Since 1999, in consultation with the regulator the Nuclear Installations Inspectorate (NII), these arrangements have been revised at corporate and site level for BNFL sites. These arrangements comprise; a corporate level policy document covering all of BNFL's UK sites with individual sites preparing a site level decommissioning strategy; a schedule of plant decommissioning to ensure a systematic and progressive reduction in hazard on the site; and individual plant decommissioning plans and programmes.

For Sellafield, the largest and most complex of the BNFL sites, the responsibility for drawing together the integrated site operating and decommissioning strategy and the preparation of the site decommissioning schedule lies with the sites Long Term Planning team. The Head of Remediation is accountable for developing a new baseline programme for the accelerated remediation of the Sellafield site. The Waste Retrieval and Decommissioning operating group are responsible for the delivery of decommissioning projects on the Sellafield site and for the preparation of the individual plant's decommissioning plans and programmes. These plans and programmes may be required to be submitted to the regulator, depending on the assessed level of risk and safety classification of the project, for the issue of a licence instrument prior to commencement of operations.

## **OVERALL STRATEGIES**

The present historic liability decommissioning programme at Sellafield encompasses a broad selection of nuclear facilities in terms of radionuclide type, radiation and contamination environment, size of plant and waste infrastructure requirements. The majority of this current decommissioning programme is due to be complete by 2008 (excluding demolition phases).

In terms of the total site decommissioning programme the present programme accounts for approximately 14% of the undiscounted total cost. It is therefore essential to understand the interrelationships between current and future projects so that lessons learned and improvements made to current operations can be incorporated into the technical and financial strategy for dealing with decommissioning.

To this end a variety of development programmes have been in place for over a decade which concentrate on both generic and project specific issues covering topics such as waste management, decontamination, radiometrics, remote engineering, cost modelling, data collection and benchmarking. These programmes allow a greater confidence to be gained that the future risks (e.g. increased political and regulator pressure on reducing discharges) can be anticipated and managed albeit at a likely higher cost. The emphasis is to reduce the full impact of a risk with some financial detriment rather than allowing the full cost of the risk to materialise. It would be imprudent to suggest that all risk can be removed given the increasingly demanding environment in which decommissioning is taking place.

BNFL has identified extensive potential benefits from adopting a range of procurement strategies to optimise the involvement of the supply chain. These range from adopting a Partnering approach, working with suppliers and contractors as a team at both corporate and strategic level on major, complex projects to direct engagement of the supply chain at the implementation stages for smaller or lower complexity projects. The range of strategies enables significant cost and programme savings to be achieved along with enhanced delivery of project quality and safety.

## **SELLAFIELD DECOMMISSIONING PROGRAMME PROGRESS**

Decommissioning operations have been undertaken at Sellafield since the mid 1950s. This was originally undertaken to create space for new facilities or to refurbish and reuse plant and equipment. The current decommissioning programme commenced in the early 1980s to reduce the hazard posed by the nuclear inventory of the redundant historic legacy plants. Real progress has been made in reducing the hazard from contaminated plant and equipment with complete decommissioning of 7 plants and significant progress in a further 16 plants. Overall 56 major project phases have been completed to date at a combined total of 90% of the sanctioned cost. The restructuring of the BNFL management team at Sellafield into Sellafield Operations and Management Services has resulted in remediation operations being accelerated across the range of site facilities. This acceleration will continue with the formation of the Liabilities management Authority.

The following brief summaries describe the decommissioning challenges and progress from some of the current major project areas:

### **Windscale Pile Chimneys**

Built in the early 1950s to support the UK military programme the two Windscale piles each comprise a pile building housing the graphite moderated reactor and a 125m high ventilation chimney. The piles lie on the Windscale nuclear site and are the responsibility of the UKAEA whilst the chimneys lie on the Sellafield nuclear site and are the responsibility of BNFL. Both piles were shut down following the 1957 fire in Pile 1. The chimneys consist of a 98m high main shaft surmounted by a filter assembly comprising diffuser section, filter section, concentrator section and upper section. The shafts were lined with thermal insulation

material that has had to be removed remotely to reduce dose to operators. This was undertaken utilising a remotely operated vehicle mounted on a hoist platform that could be raised or lowered via four winches installed on the top of the chimney.

Pile 2 chimney, being less contaminated, was progressed ahead of Pile 1 chimney to pilot decommissioning and demolition techniques. The demolition of Pile 2 chimney was completed in January 2001, making a significant change to the Sellafield site skyline. The original intent was to demolish the chimney to the 95m level where it would achieve seismic stability equivalent to current design standards. However, a modified demolition process enabled the chimney to be quickly and cost effectively demolished and capped at the level of the main reactor building (to ensure the structural integrity of the pile building) reducing overall ongoing maintenance costs and maximising free release opportunities for the constituent materials. During the Pile 2 chimney demolition programme 3000te of concrete and 600te of mild steel were processed to free release levels and recycled.

Pile 1 decommissioning has progressed in parallel with Pile 2 demolition work. The removal of the highly contaminated insulation material from the main shaft and the diffuser section of Pile 1 has been completed and access platforms are currently being constructed to enable demolition of the filter gallery to commence in early 2003.

Initial remote phases of the project utilised a specially designed and built system which, whilst achieving the result, was complex and difficult to maintain. The later phases have utilised commercially available robust electro/hydraulic machines adopted for remote operations which have been very reliable and effective. The special design is constrained to the deployed tooling.



**Fig. 1. Pile Chimney decommissioning remote operations**

### **First Separation and Head End Plant**

Built for the dissolution and chemical separation of the Windscale Pile fuel, including separation of the Plutonium, Uranium, medium active and highly active waste streams, the plant is 61m high with eleven floor levels and consisting of four highly active and two medium active cells. The plant continued in operation for the reprocessing of Magnox fuel until 1965 when it was replaced by the Magnox reprocessing plant. The north half was then washed out and permanently shut down but the south side underwent extensive alterations including the removal of metal fuel dissolvers, installation of shearing, dissolver, accountancy and maintenance cells to allow head end operations on oxide fuel utilising part of the existing solvent extraction plant. Decommissioning of the plant poses a particular challenge due to the height of the cells, absence of in-cell crange, no designed access routes for equipment, varying radiological conditions, limited radiological data and absence of accurate as built drawings. Typically, as with many older plants, the cell ventilation was inadequate by modern standards and a new fully filtered system has been installed to support all decommissioning operations. A waste handling facility has been constructed adjacent to the medium active north cell and incorporates automatic commercial remote robotic size reduction, mainly using plasma arc, linked to an integrated control system and 3D modelling. This facility will handle the waste from all the cells.

Decommissioning operations are progressing in a number of plant areas in parallel:

- The main focus within the Primary Separation plant is the remediation work on the highly active north cell (HANO), where structural support members have been found to be corroded following the exposure to acidic ventilation stream in the early 1970s. This leads to the potential for process vessels to be displaced.
- A full cell survey has been completed and a vessel movement detection system installed. Option studies for the stabilisation of the cell process vessels are being undertaken.
- Dismantling operations have been completed on 4 of the 8 levels in the MAN cell; however, this work has now been suspended whilst the structural problems in the adjacent HANO cell are resolved.
- Stainless steel hulls arising from the oxide reprocessing programme stored in a purpose built intermediate level waste silo in the base of the medium active south cell have been removed to the beta gamma waste facility. Decontamination operations within the silo are currently underway.
- Decontamination and preparation work for entry into the medium active south cell has been completed.
- Extensive clearance of redundant out-cell services has been undertaken and a major asset care programme initiated.

As with the Pile Chimney early remote operations utilised specialised robotic equipment which proved fragile. Later phases will utilise robust equipment. The size reduction facility utilising commercial robots but specialist control systems has been very successful.

### **Solvent Regeneration Plant**

Built for regeneration of the Butex solvent utilised in the original reprocessing plant the plant and consists of six cells each 11.25m x 8.25m x 23.5m high. Two of which were fitted out for the solvent regeneration process, two were held in reserve, one was prepared for shielded research and development work, eventually being used for the THORP pilot plant, and the remaining cell for post irradiation examination (PIE) of irradiated fuel. The solvent

regeneration process performed better than expected and the two spare cells were released for additional development work including a highly active instrument test facility.

The solvent regeneration cells were contaminated to low level waste levels with moderate background radiation levels allowing manual decommissioning techniques after access floors had been installed. Dismantling was carried out utilising manual cold cutting techniques, due to the hazard posed by the possible presence of residual flammable solvent, size reducing waste in a purpose built roof mounted size reduction facility. The roof top facility provided access to the cells through the original construction hatches and contains independent filtered ventilation equipment and plasma arc size reduction facilities. The facility is mounted on rails and can be moved along the roof to provide access to pairs of adjacent cells at a time.

Decommissioning of both of the solvent regeneration cells, the instrument test facility and the PIE facility has been safely completed. The decommissioning of the THORP development facility is in progress, all of the out-cell gloveboxes and the loose in-cell equipment has been stripped out. Research and Development operations in the remaining cell were completed in August of this year and post operational clean out is underway. The plant now has only a minor residual nuclear hazard with all remaining dismantling operations within the plant scheduled for completion by 2005.

### **Plutonium Purification Plant**

Built to purify the plutonium stream from the first generation reprocessing plant, the plant is large alpha facility, comprising two mirror image cells, four storeys high with a brick wall as the secondary containment, the vessels and pipework being the primary containment. The in-cell plant and equipment is very highly contaminated from the plutonium bearing process streams with localised radiation sources in excess of 15mSv/hr. Intrusive surveys of the cell vessels have been completed to assess the amount of residual liquor. Dismantling is undertaken manually, moving components to a waste handling facility, constructed on the South side of the plant, for size reduction using plasma arc and cold cutting techniques, and packaging. All external control, sampling and fuel cabinets have been removed. As with many plutonium facilities there is the potential risk of criticality and extensive in situ inventory monitoring has been undertaken prior to the movement of vessels to the size reduction facility. Work in this facility was delayed by technical problems with the plutonium inventory monitoring equipment, these have now been resolved and work has recommenced. Removal of vessels and pipework in the south cell is 85% complete and 20% complete in the North cell. In-cell dismantling work scheduled for completion in 2005.

### **Fast Reactor Fuel Facilities**

The Co-precipitation and Dry Recovery plants associated with the conversion of recovered plutonium and uranium for the Prototype Fast Reactor (PFR) programme have already been totally decommissioned. These plants formed the basis for the development of many of the techniques and equipment needed for plutonium plant decommissioning including in situ inventory assay, containment, decontamination, size reduction, and recirculating suit showers with water treatment. The current operations centre on the PFR Fuel Fabrication Facility and the associated Dry Granule Production Plant (DGPP) which provided the mixed oxide fuel granules. The PFR plant converted the granules into pellets, which were then loaded into fuel pins and assembled into fuel assemblies for shipment to Dounreay. Decommissioning of the final assembly area, pin filling line pellet load and vibro-compaction areas and low dose fuel

line cubicles was completed utilising manual techniques. The final assembly area has been converted into a PCM storage area for decommissioning waste. The final phase of the project, the remaining fuel line cubicles where the pellets were prepared, is the most heavily contaminated with a high residual mixed oxide content and high radiation fields which require remote dismantling. Since the last update all the remote equipment has been installed, the decommissioning safety case submitted to the regulator for approval and all the contaminated cell and glovebox ventilation ducting removed. Decommissioning operations are scheduled for completion by 2005 and the building will continue in operation as a PCM store for the next decade.

DGPP was originally a small-scale pilot facility operated by the Research and Development Department, which was subsequently refurbished for full-scale production operations within the existing plant boundary walls. The result has been a significant decommissioning challenge in terms of residual inventory and dose rates combined with very restricted access. In addition to the techniques used on other projects it has been necessary to develop a manipulator system to allow remote dismantling of the main part of the plant. Following extensive off site development and training, utilising full-scale mock-ups, the machine was deployed on the DGPP plant. DGPP plant decommissioning has been completed, returning the plant to free breathing conditions and available for re-use. The manipulator system has been moved to the PFR plant for remote fuel line decommissioning.

The Fast Reactor Fuel Plant produced mixed oxide fuel for the Dounreay PFR. The plant underwent several modifications to trial alternative fuel manufacture methods and consisted of both hands on glove box operations and operations through shielded walls. The dismantling similarly utilises hands on and remote techniques. The majority of the hands on phases have been completed and remote operations utilising experience gained on the Pile Chimneys and DGPP are underway.

Early plutonium plant decommissioning operations were all based on cold cutting techniques but progressively hot plasma arc cutting has been deployed. Whilst hot cutting produces a fine airborne particulate waste this can be easily contained and filtered out using high velocity cyclone filter ventilation systems. Trials have shown that often cold cutting generates a greater airborne hazard than plasma and plasma offers the great benefit of much faster production reducing dose uptake which is a significant problem in these plants which operated with commercial reactor plutonium.

### **Caesium Extraction Plant**

The Caesium Extraction Plant (CEP) was constructed in a building void above some high active liquor storage tanks. The facility was used to produce Cs137 isotopes for use as medical radiotherapy sources and was operated between 1955 and 1958. The facility was shut down following operational problems in one of 4 process cells in 1958, and has been left shut down until decommissioning commenced. The facility is highly contaminated with highly mobile Cs 137 with radiation levels exceeding 1Sv/hr thus precluding man entry.

In-cell radiation levels require decommissioning to be undertaken remotely, however, access to the rooftop facility is very limited due to space constraints imposed by adjacent plants, and has to be co-ordinated with the ongoing operations on the storage tanks situated below the CEP which support current reprocessing. An 800te free standing mobile module has been constructed adjacent to the CEP which houses a remote access manipulator and intermediate

level waste flasking facility. The remote manipulator has a remote tool change system to exchange the 20 tools, that have been adapted from proprietary equipment, identified as being required for dismantling tasks.

The remote dismantling of the first cell commenced in 2001 and was completed in September 2002. Radiation levels within the cell now permit man access for decontamination operations prior to the module being moved to commence decommissioning of cell 2. This work has been highly successful, careful maintenance and decontamination has enabled continued access to the remote manipulator throughout the period without dose detriment to the operations team. Decommissioning operations are scheduled to be completed in 2008.

Development and trials of the remote machines were extensive and fully replicated the 'real' job. Although the high technology robotic equipment may not be our choice today the thorough testing programme has resulted in highly reliable operations.



**Fig. 2. B212 Caesium Plant Dismantling Machine**

### **Uranium Purification Plant**

The Uranium Purification Plant was constructed to process uranyl nitrate arising from the primary separation plant. The main structure is a three storey asbestos cement clad building containing a central rectangular core of four shielded process cells, each cell being 23m x 15m x 11m high. The cells contain stainless steel process pipework and vessels contaminated to a level requiring man entry in pressurised suits. On completion of plant operations in 1964 the plant was utilised for a variety of minor processing duties and also housed the pulsed column and centrifuge active test rigs for the THORP process equipment development.

Decommissioning of the four process cells was undertaken manually utilising plasma cutting size reduction. All the cells and test rigs have now been completely dismantled and the building structure is about to be demolished. The method of construction of the main

structure and the close proximity to other operating plants and service pipebridges and trenches preclude the use of heavy machinery for demolition. This work is scheduled for completion in 2004 and the approach adopted will endeavour to maximise the free release of demolition materials.

## **CONCLUSIONS**

The decommissioning of the Sellafield site presents an ongoing challenge requiring an integrated and co-ordinated programme. The successful completion of a number of projects and the large number of projects currently undergoing practical decommissioning demonstrate that fuel cycle facility decommissioning can be safely and cost effectively accomplished.

Processes and initiatives are in place to enable BNFL to learn from experience and constantly strive for the reduction of historic liabilities:

- The discharge of the Sellafield decommissioning programme has already delivered a tangible reduction in the hazard posed by the historic legacy facilities.
- The decommissioning programme has been delivered with no major radiological incidents.
- Site remediation has the highest priority at Sellafield and remediation activities are accelerating across the whole of the Sellafield site.
- Learning from experience processes enable the decommissioning, waste management and corporate risk reviews to be carried out and kept up to date based on practical experience.
- Ideally remote equipment should be robust and based on commercially available systems. Where specialist design is required there must be thorough and extended trials.
- Plant operations and risk reviews result in development programmes being targeted, to enable the Company to develop new technologies, so that it can cost effectively deliver its current and future decommissioning plans and proactively manage major risk areas.
- Effective involvement of the supply chain provides additional opportunities for the reduction of the cost of delivering the capital and decommissioning programmes on the Sellafield site.