

## **Remote Decommissioning Experiences at Sellafield**

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### **ABSTRACT**

British Nuclear Group has demonstrated through delivery of significant decommissioning projects the ability to effectively deploy innovative remote decommissioning technologies and deliver cost effective solutions. This has been achieved through deployment and development of off-the-shelf technologies and design of bespoke equipment. For example, the worlds first fully remotely operated Brokk was successfully deployed to enable fully remote dismantling, packaging and export of waste during the decommissioning of a pilot reprocessing facility. British Nuclear Group has also successfully implemented remote decommissioning systems to enable the decommissioning of significant challenges, including dismantling of a Caesium Extraction Facility, Windscale Pile Chimney and retrieval of Plutonium Contaminated Material (PCM) from storage cells. The challenge for the future is to continue to innovate through utilization of the supply chain and deploy off-the-shelf technologies which have been demonstrated in other industry sectors, thus reducing implementation schedules, cost and maintenance.

### **INTRODUCTION**

British Nuclear Group has demonstrated a proven capability to deploy innovative decommissioning technologies to deliver complex and challenging remote decommissioning projects safely, effectively, on time and economically.

### **REMOTELY DECOMMISSIONING THE MAGNOX REPROCESSING PILOT PLANT**

The Magnox Reprocessing Pilot Plant at Sellafield supported the design and early operation of the commercially scaled Magnox Reprocessing Plant at Sellafield. The Pilot Plant was shut down in the late 1960s with limited POCO (Post Operational Clean Out) undertaken. Significant quantities of process equipment, irradiated fuel and various other items remained in four shielded cell areas consisting of a Dissolver Facility, Metal Cutting Cell, Primary Separation Cell and High Active Cell.

Specific issues supporting the business driver include: a significant uranium inventory, the presence of uranium fuel in the facility presented concerns over the initiation of a uranium hydride fire. Historic leakages have led to High Active Liquor or liquor residues in the facility

resulting in significant contamination. The deterioration of the cell structure, and its ability to maintain containment posed a potential risk to ongoing operations within the building.

### **Program**

A program of work was undertaken to decommission the pilot plant, consisting of four phases:

Phase 1: Completion of capital works and decommissioning of New Dissolver Facility and Metal Cutting Cell - Complete

Phase 2: Decommissioning of High Active Cell - Complete

Phase 3: Decommission Primary Separation Cells and demolish cell plinths - Ongoing

Phase 4: Decontamination and clean out of the laboratory

### **Methodology and Tool Development**

The decommissioning methodology has been to decommission manually where possible, however, remote decommissioning has been deployed where radiation exceeded working levels. An integrated Intermediate-level Waste (ILW) export route has been installed to enable a fully remote operation to be undertaken, including waste packaging and export.

To enable delivery of Phases 1 and 2, remotely operated vehicles were deployed namely, a schilling manipulator and a Brokk Mini Cut (Fig. 1.). This deployment of a remotely operated Brokk system was the first in the nuclear industry. By deploying off-the-shelf technology from the construction industry we were able to identify a flexible yet proven technique to effectively dismantle the facility, whilst minimizing development costs. A control system was manufactured to effectively deploy a fully remote system. The control desk comprised of a camera system, monitors and control desk. The Brokk Mini Cut, along with the schilling manipulator had the capability to remove and dismantle plant equipment and irradiated fuel from the cell area.



Fig. 1. Brokk Mini Cut

The project has developed a range of tools to meet the needs of the decommissioning project. Tool development was performed by the project team, who developed simple but successful solutions to address decommissioning problems. A key tool development included the deployment of the hydraulic cutting shear that provided the opportunity to grab, spread and shear – thus offering a multi-purpose tool where previously at least two separate tools would be required. A reciprocating saw was also developed and deployed.

Other examples include a specially adapted household vacuum cleaner, which was deployed to remove contamination, lead shot and fuel pennies. The vacuum cleaner was modified to pick up uranium fuel pennies that had proved very onerous with conventional manipulator jaws. A nozzle with a diameter less than that of the pennies was attached to the vacuum cleaner and the suction was used to pick up the pennies quickly and efficiently.

The possibility of initiating a hydride fire was highlighted as a risk and a mitigation activity was to develop simple plastic scoops that were deployed remotely by the Brokk to clear debris from the cell. The use of plastic tools instead of metal tools reduced the risk of igniting uranium fuel present in the facility.

In-cell equipment removed using the Brokk Mini Cut included the dissolver vessel, the primary separation contactor, raffinate storage vessels and pipe-work, irradiated spent fuel, and high active pipe-work. Finally, the decommissioning of the Primary Separation cell (Phase 3) will be manual unless radiation levels dictate otherwise.

The methodology for demolishing the cell plinths is to deploy a Brokk 180. A hydraulic shear, successfully deployed on the Brokk Mini Cut, has been developed and will be deployed. The Brokk 180 also allows remote tool changes to progress utilizing a quick hitch system to prevent human entries.

All phases have successfully delivered to budget and a cost effective, flexible solution has been delivered by utilizing the supply chain, using off-the-shelf technologies and deployment of a multi-skilled team. The table below highlights the waste volumes recovered to date:

Table I. Waste Removed During Decommissioning at the Magnox Reprocessing Pilot Plant

<b>Waste Type</b>	<b>Volume</b>
Irradiated fuel	Significant, from whole rods to fuel pennies
PCM	12 m <sup>3</sup>
ILW	28 m <sup>3</sup>
LLW	30 m <sup>3</sup>
Lead	8 m <sup>3</sup>

## **REMOTELY DECOMMISSIONING THE CAESIUM EXTRACTION PLANT**

### **Plant History**

This plant produced kilocurie caesium sources for medical purposes, using the High Active Raffinate (HAR) stored in the tanks below as feedstock for the process. The plant extracted caesium from the HAR and carried out a process of refinement, concentration and finally encapsulation into a platinum capsule.

The Caesium Extraction Plant (CEP) was constructed in a building void above the Sellafield high active liquor buffer storage tanks in the early 1950s. The facility was used to produce Cs-137 isotopes for use as medical radiotherapy sources and was operated between 1955 and 1958. During operations the plant suffered from a number of malfunctions, resulting in leaks and spillages, eventually leading to closure in 1958.

Following closure the plant was maintained on a limited care and maintenance basis until the early 1980s, when a refurbishment program was carried out. The extent of POCO at the end of production is unknown but visual inspection and health physics surveys indicate that significant chemical residues remain in many of the process vessels, and that measured radiation levels of up to 370 rem/hr in the cells and 7 rem/hr in the voids exist, prohibiting human entry. The facility was fully isolated from other plants and is now largely unventilated.

### **Business Drivers**

The key project driver has been to remove the plant equipment and waste to mitigate the requirement for long term care and maintenance. The decommissioning of the plant is in line with British Nuclear Group policy to carry out decommissioning of redundant facilities, to reduce radiological and conventional safety hazards, and reduce customer liabilities. The key business drivers being:

- High radiation: Radiation levels of 370 rem/hr in the cells and 7 rem/hr in the voids have been measured.
- The facility is highly contaminated with highly mobile Cs-137
- The plant had limited ventilation.
- There is a risk of further deterioration
- There is the potential for loss of containment.

### **Plant Structure**

The facility comprises of four cells each of which require decommissioning. The plant comprises four cells: Cells 1, 2 and 3 (all are 3 m long, 1.5 m deep and 3 m high) and a Feed and Effluent (F&E) Cell. Cell 1 contains fourteen stainless steel process and transfer vessels mounted on RSJ supports. Cell 2 contains six stainless steel and glass process vessels with plastic interconnecting pipe-work. These glass vessels are similar to those that would be encountered on a laboratory bench and are held in position to a steel frame by bosses and clamps. Cell 3 contains forty-four spherical glass vessels similarly mounted to those in Cell 2. Several furnaces are also contained in this cell, and were used for final encapsulation of the caesium source; remote handling equipment and export facilities are also included. The F&E cell consisted of four stainless steel tanks enclosed within brick shield walls. All four cells were equipped with stainless steel sump

trays to guard against spillage of liquors onto the floor of the voids, the contents of which could be ejected to the HAR storage tanks below.

### **Methodology**

Engineering option studies were carried out to address the potential methods for gaining access to the plant and for the facilities required to remove and process the decommissioning waste. These studies identified that the integrity of the remaining building would dictate that no significant loadings could be placed on the roof or floor in the CEP. It was concluded that the only viable option was to gain access to the plant through openings formed on the outside wall. Initially this was to be by a fixed building but this was modified to become a Mobile Decommissioning Module that would dock onto each opening, allowing the decommissioning equipment to be deployed into the CEP. Processing of the waste would subsequently be undertaken at separate facilities already existing on the Sellafield Site.

### **Program**

The project is split up into seven phases as detailed below:

- Phase 1 - Feasibility Study
- Phase 2 - Front End Design
- Phase 3 - Front End Design of Revised Scheme
- Phase 4 - Design and Manufacture of Decommissioning Machine
- Phase 5 - Design and Build of Decommissioning Module
- Phase 6 - Cell Operations
- Phase 7 - Decommissioning and Site Clearance

Phases 1 to 5 are now complete. British Nuclear Group are currently progressing Phase 6 Cell Operations and have completed Cell 1 decommissioning and are progressing Cell 2, with Cell 3 and the F&E cell still to complete.

### **Decommissioning Module**

An 800-ton free standing Mobile Decommissioning Module has been designed and constructed adjacent to the CEP which houses a remote access manipulator (Fig. 2.) and ILW flask export facility.



Fig. 2. Mobile Decommissioning Module

The Mobile Decommissioning Module consists of a shielded structure, 15 m high, 15 m wide and extending 12 m from the face of the building. The module is mounted on nine rail bogies, running on three parallel rails secured to a new reinforced concrete raft foundation. The module docks on to the front of each of four lobbies through which access is gained to the CEP. There are three main floor levels from which operations are undertaken:

Level 1 – An empty shielded waste flask is transferred from road transport to the transfer bogie. The flask bogie is advanced through the shield door to the lid removal machine. The lid is removed before the flask further advances to the skip hoist-well station. The flask contains a liner which is raised through a shielded hoist-well to Level 3. From here the Decommissioning Machine (DCM) transfers the liner to the lobby.

Level 2 - contains the electrical services for the module and the Decommissioning Machine.

Level 3 - the upper module houses the DCM, a manipulator tool carrousel and a decontamination booth.

### **Decommissioning Machine**

The role of the DCM is the most important within the project. Operational throughput is dependent upon it providing a reliable means of removing waste from the CEP. It was recognized from the initial option studies that the DCM would need to undergo extensive inactive trials and development work to determine the methods for removing the CEP waste. The DCM design and manufacture was therefore programmed to occur before completion of the module design.

The DCM consists of two principal features, the Boom Carriage Unit and the Deployment Machine. The Boom Carriage Unit consists of a six wheel electrically driven bogie and cantilevered boom, which provides longitudinal traverse for the Deployment Machine. The first stage of the Deployment Machine consists of a slewing ring, which provides rotational motion. Motive power for rotation is provided for by two electric motors, one for normal speed and the other for slow. Each motor is driven by its own dedicated electrically operated clutch. The slewing ring is also equipped with an electrically operated brake. Attached to the slewing ring is the telescopic boom formed by a Hunger two-stage, non-rotating hydraulic cylinder. This is raised and lowered by two luffing hydraulic cylinders. The tilt table is attached to the telescopic boom. It has a hydraulically powered rotational motion with proportional speed control. A self-leveling system is also incorporated. The top face of the tilt table is fitted with two Remote Tool Change (RTC) stations. These enable remote connection of a range of manipulators and tool packages.

The DCM can be controlled from two locations. The normal mode of operation is from a remote console with the aid of closed circuit television (CCTV) in the central control room. The CCTV system consists of up to thirty cameras located around the DCM with five monitors in the control room.

The DCM can also be controlled locally from a portable control panel within the upper module, the operator being clad in protective clothing, which enables control of all machine axes and hoist functions. This facility is only utilized to aid commissioning and maintenance operations.

The remote manipulator has a remote tool change system to exchange the twenty tools that have been adapted from proprietary equipment, identified as being required for dismantling tasks. The tools that have been used to undertake the various tasks in the CEP can be remotely detached from either the manipulator or from the DCM tilt table. These tools are then loaded into a decontamination booth, which uses a combination of high-pressure water and decontamination agents to clean away any contamination from the tools.

The DCM itself is too large to place in a dedicated decontamination facility. However, the increased distance between the workforce and the DCM is expected to result in lower levels of contamination which will be removed during human entries to the upper module shielded area. This strict regime of housekeeping will allow continued man entry into the upper module area for maintenance of the DCM and other equipment.

### **Waste**

Waste liners are monitored by gamma monitors prior to export to the determined waste route which can be either ILW or LLW. ILW waste is exported for storage in the Miscellaneous Beta Gamma Waste Store on Sellafield Site. LLW is exported to the Low-level Waste Repository. Additional identified waste forms, like liquors or mercury, are dealt with on a case by case basis to ensure operations and disposal methods are within the bounds of the safety case.

### **Progress to Date**

The remote dismantling of Cell 1 commenced in 2001 and was completed in September 2002. Radiation levels within the cell were reduced to permit human access for decontamination operations prior to the module being moved to commence decommissioning of Cell 2. Cell 2 is currently being progressed. The project has been highly successful; careful maintenance and decontamination has enabled continued access to the remote manipulator throughout the period without dose detriment to the operators.

## **REMOTELY DECOMMISSIONING THE WINDSCALE PILE CHIMNEYS**

Built in the early 1950s to support the UK military nuclear program, the two Windscale Pile Reactors each comprise a pile building housing the graphite moderated reactor and a 125 m high ventilation chimney. Both piles were shut down following the 1957 fire in Pile 1. The chimneys consist of a 98 m high main shaft surmounted by a filter assembly. The shafts were lined with thermal insulation material that has had to be removed remotely to reduce dose to operators. This was undertaken utilizing 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 the decommissioning and demolition techniques. The demolition of Pile 2 chimney was completed in January 2001, making a significant change to the Sellafield skyline. During the Pile 2 chimney demolition program 3,000-tons of concrete and 600-tons of mild steel were processed to free release levels and recycled.

## **REMOTELY DECOMMISSIONING AN INTERIM BETA-GAMMA WASTE STORE**

The Interim Beta Gamma Waste store was constructed in the early 1950s to house sand bed filters for the low active liquid effluent system. However, the sand bed filters were never used and the shielded concrete structures were subsequently used for the interim storage of miscellaneous beta-gamma waste arising from Sellafield Magnox Reprocessing operations. The store comprises eight concrete shielded cells (Fig. 3.), six of which were covered by a steel clad overbuilding in the late 1990s.





Fig. 3. Waste storage in one of the cells prior to construction of the overbuilding

The waste stored within the shielded cells was consigned from the early 1970s and as a result of the management procedures in place at that time, is not fully defined as per current storage requirements. The waste has a significant radiation hazard with some items being measured at levels  $> 100$  rem/hr. The waste types vary greatly in form and size ranging from small wrapped soft waste items to a redundant 42-ton transport flask. The significant dose rates indicate that much of the in-cell waste will be removed by remote means.

Decommissioning of the cells is very important to the cleanup of the Sellafield Site and is working towards a regulatory specification that requires the accumulated waste to be retrieved and stored in an approved place by 1 August, 2010.

The target for the first phase of the project involved removal, assay and export of all interspaced waste to an appropriate storage location and removal of redundant decommissioning plant. To do this there was a requirement to decant the waste drums to ensure they contained no free liquor and complied with LLW and ILW Conditions for Acceptance. Out of a total of seventy-six drums, sixty-nine were exported as LLW via the Waste Monitoring and Compaction plant (WAMAC); the other seven drums were exported as ILW to the Miscellaneous Beta-gamma Waste Store. Ten filter box units were also moved to storage and will be returned for processing during the second phase of the project.

The waste retrieval solution (Fig. 4.) needs to cover remote retrieval systems, size reduction and packaging capabilities and appropriate ventilation and containment systems. The methodology for removal of the in-cell waste is currently being developed and will require remote operations to be implemented.

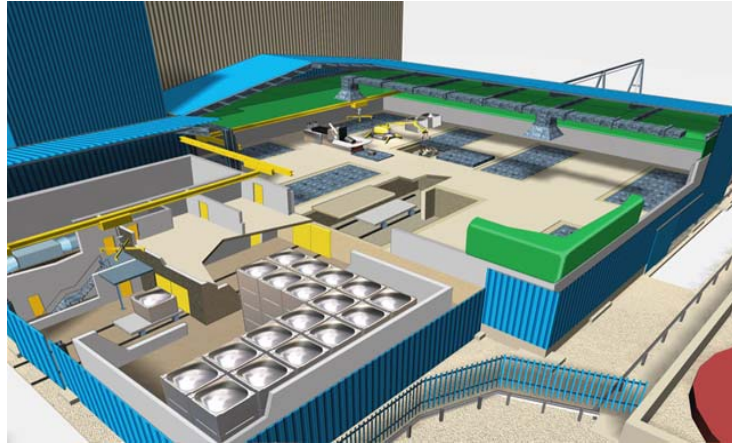


Fig. 4. Retrieval scheme for interim beta-gamma waste store

## REMOTELY DECOMMISSIONING THE NORTH GROUP COMPOUND

The North Group Compound (NGC) was originally constructed in the early 1950s as a small compound area to support operation of the Windscale Pile Reactors and other areas of the UK's early nuclear program. It has developed over time with additional storage facilities and waste handling areas being introduced and now consists of the following active facilities:

- A PCM waste storage facility.
- A newly constructed waste retrieval, storage/export facility to support PCM retrieval operations.
- A control rod mortuary, storage chambers and burst slug store (predominantly below ground).
- Two waste mortuaries, one located above ground the other below.

The four waste storage facilities are at different stages of decommissioning which primarily involves the retrieval of the radioactive inventory. Active waste retrieval from the four quadrants of the PCM waste storage facility commenced in July 2002 and is now complete. A total of 3,700 drums of PCM have been exported from the facility, representing 400-tons of retrieved waste, at a rate of twenty-six drums (2.5-tons) per day. Semi-remote retrieval equipment (BROKK) was installed and utilized to support waste removal in the more challenging areas of the facility where radiation levels prohibited permanent human entry.

## REMOTE DECOMMISSIONING AT THE WORLDS FIRST MOX FUEL FABRICATION FACILITY

A number of facilities were introduced during the development of the Prototype Fast Reactor (PFR) mixed-oxide fuel manufacturing program. They 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 re-circulating suit showers with water treatment.

The current operations centre on the PFR Fuel Fabrication Facility. The PFR plant converted a mixture of plutonium oxide and uranium oxide granules into pellets which were then loaded into fuel pins and assembled into fuel assemblies for shipment to the Dounreay Site in northern Scotland. Decommissioning of the fuel stringer assembly area, fuel pin filling line, pellet load /vibro-compaction areas, and low dose fuel line cubicles was completed using manual techniques. 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 a mix of controlled manual entry in pressurized suits and fully remote dismantling. The remote equipment has been installed and the decommissioning safety case has been submitted to, and accepted by, the Nuclear Installations Inspectorate (NII). Operations on the final phase have commenced. To date all of the contaminated cell and glove-box ventilation ducting has been removed and four of the remaining twenty-one glove-boxes have been manually dismantled. Remote operations are scheduled to commence later in the year on the final glove-boxes.

## **LESSON LEARNT**

The projects illustrated within this paper have developed a range of tools to meet the needs of a variety of different decommissioning tasks. The developments in remote tooling have been applied to other decommissioning projects employing remote techniques

The remote decommissioning experience gained will allow better estimates for durations of decommissioning tasks for future decommissioning projects.

In some cases the decommissioning has been delivered within an existing operational facility that continues to support ongoing Sellafield operations. The interface between decommissioning and the building management has been of paramount importance with respect to coordinating the respective operations and provision of services from the building owners.

Increased understanding of the plants and their inventories has aided the effective planning of each project. However, detailed plant surveys are not always feasible, due to access reasons or radiological conditions and may not be As Low As Reasonably Practicable (ALARP). Appropriate assumptions should be made which are recognized in the risk assessment, and projects should be phased appropriately to make best use of the information available.

The Phase 3 Brokk control system, deployed for dismantling the Magnox Pilot Reprocessing Plant, has been fully commissioned inactively by erecting a full scale mockup of plant, thus aiding operator development, mitigating technical problems to ensure smooth handover to plant, and ensuring stakeholder confidence in the scheme. It is recommended to implement inactive demonstration where appropriate.

Remote operations have been delivered safely, which reflect the primary priority of these projects, but also demonstrates the benefit of employing remote techniques.

Experience has demonstrated the benefit of employing a multi-disciplinary team for decommissioning work. The operators of the remotely operated vehicles were also trained to maintain the equipment and the plant. With respect to the schilling manipulator, understanding the limitations of the equipment helped to minimize breakdowns. The inclusion of maintenance personnel and health physics expertise within the decommissioning team avoided delays due to the unavailability of personnel sourced from outside the project.

Use the supply chain! The supply chain has been effectively engaged to deliver fit-for-purpose decommissioning solutions. The supply chain has been engaged for all phases of these decommissioning projects, for example:

- Procurement of off-the-shelf and bespoke decommissioning equipment.
- Construction contracts to enable deployment of resources to deliver operations.
- Design and manufacture of control systems
- Design and manufacture of ventilation systems
- Preparation of safety case documentation

## **FUTURE DECOMMISSIONING AND TECHNOLOGY CHALLENGES**

The future holds significant decommissioning challenges at Sellafield. In particular the legacy storage ponds and silos pose significant challenges in retrieving the waste and decommissioning the facilities. The retrieval strategies for the Legacy Ponds and Silos have challenged remote handling requirements and the proposed design and construction of new support plants will present new requirements. Therefore, there is an ideal opportunity to reconsider remote handling strategies and the use of industrial robots.

British Nuclear Group has typically followed a traditional route of designing special purpose machines together with in-cave hoists, power manipulators and Master Slave Manipulators (MSM) to meet production, production support and maintenance requirements. The design, manufacture and setting to work of one-off special purpose machines is very time consuming and very expensive, and such machines will not have the reliability of machines developed over many years and many thousands of units for very demanding customers e.g. the automotive industry. Utilizing off-the-shelf technologies reduces cost and improves the opportunity for reutilization by other projects

Industrial robots are adaptable and have the proven capability to do a wide variety of production line operations from heavy-duty to delicate. A single machine could perform a range of tasks within its reach. Where new plants are to be built, designing for the incorporation of robots should not be a major challenge.

The use of industrial robots in existing plants presents a greater challenge (but has been successfully achieved by POCO and decommissioning projects). The main challenges facing the use of robots are: the acceptance of a different approach to plant design, and the development of deployment and mounting arrangements.

## **CONCLUSIONS**

British Nuclear Group has demonstrated through delivery of significant decommissioning projects the ability to effectively deploy remote decommissioning technologies and deliver cost effective solutions. This has been achieved through deployment and development of off-the-shelf technologies and design of bespoke equipment. Nuclear decommissioning is a relatively new industry when compared to other sectors and British Nuclear Group will continue to develop and implement cost effective solutions to meet future cleanup and decommissioning challenges.