

Decommissioning of the Plutonium Purification and Residues Recovery Plant

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ABSTRACT

British Nuclear Group is continuing to build on BNFL's successful record of decommissioning redundant nuclear facilities. Challenging radiological conditions and complex technical problems have been overcome to reduce the hazard associated with the UK's nuclear legacy.

The former Plutonium Purification and Residues Recovery Plant at Sellafield operated from 1954 through to 1987. This is the only plant to have experienced an uncontrolled criticality incident in the UK, in August 1970 during operations.

The plant comprised of two mirror image cells approximately 6.5 m x 13.5 m x 16 m, constructed of bare brick. The cell structure provided secondary containment, the process vessels and pipes within the cell providing primary containment. The plant utilized a solvent-extraction process to purify the plutonium stream. Surrounding the two process cells to the north, east and south is an annulus area that housed the operational control panels, feed and sample glove-boxes, and ancillary equipment. The building was ventilated by an unfiltered extract on the process cells and a filtered extract from the vessels and glove-boxes.

During the long operational lifetime of the plant, the primary containment deteriorated to such an extent that the process cells eventually became the main containment, with levels of radioactive contamination in excess of 14,256 pCi alpha. This led to significant aerial effluent discharges towards the end of the plant's operational life and onerous working conditions during decommissioning.

Implementation of a phased decommissioning strategy from 1991 has led to:

- A reduction of approximately 60% in the Sellafield site's aerial alpha discharges following installation of a new ventilation system,
- Removal of 12 plutonium contaminated glove-boxes and sample cabinets from the building,
- Disposal of the approximately 500 m² of asbestos building cladding,
- Removal of over 90% of the active pipes and vessels from the highly contaminated process cells, despite challenging criticality and radiological hazards.

With Phase 2 decommissioning nearing completion, work has commenced on Phase 3 to define and deliver the final phases of work that will lead to the complete remediation of this highly

contaminated building. This work will include the development of fit for purpose engineering solutions linked to reliable and innovative safety cases to enable accelerated:

- Removal of the highly contaminated redundant ventilation system,
- Removal of the process cell structure which consists of contaminated brick, concrete and steel,
- Remediation of the Low Active drain trench,
- Demolition or recovery of the building structure

INTRODUCTION

Significant challenges faced in this project, that tend to be characteristic of redundant plutonium plants include:

- High levels of radioactive alpha contamination, requiring containment systems and protection against inhalation and ingestion;
- Rising levels of low-energy gamma radiation, as a result of the radioactive decay of Pu-239 to Am-241;
- A risk of criticality due to accumulation of material;
- Plant and equipment that was not designed with decommissioning in mind, often presenting access difficulties with limited space for installation of decommissioning facilities;
- Constraints and interactions associated with other facilities within an operational site.

The former Plutonium Purification and Residues Recovery Plant at Sellafield operated from 1954 through to 1987. Uniquely in the UK, this plant experienced an uncontrolled criticality incident in August 1970.

The plant comprised of two large mirror image cells approximately 6.5 m x 13.5 m, four storeys high, as shown in Fig. 1. The bare brick cell structure provided secondary containment, with the vessels and pipe-work being the primary containment for radioactive materials. The plant utilised a solvent-extraction process to purify the plutonium stream. Surrounding the two process cells to the north, east and south is an annulus corridor that housed the operational control panels, feed and sample glove-boxes, and ancillary equipment. The building was ventilated by an unfiltered extract on the process cell and a filtered extract from the vessels and glove-boxes.

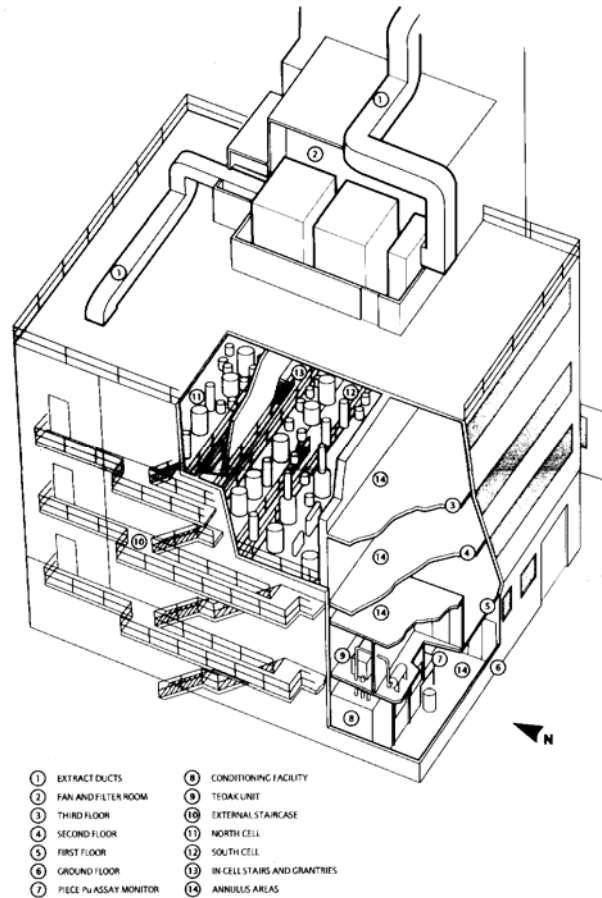


Fig. 1. Isometric view of the plant

During the long operational lifetime of the plant, the primary containment deteriorated to such an extent that the process cells eventually became the main containment, with levels of radioactive contamination in excess of 14,256 pCi alpha. This led to significant aerial effluent discharges towards the end of the plant's operational life and onerous working conditions during decommissioning.

COMMERCIAL DRIVERS

The two key project drivers were to reduce the safety hazard associated with a deteriorating plutonium processing facility and to mitigate long term care and maintenance costs.

The phased decommissioning strategy applied to this project progressively reduces the hazard and discharges the customer's liability.

DECOMMISSIONING STRATEGY

The decommissioning project objective was to remove all inventory, plant and equipment from the building and consign it to appropriate long-term storage. The project was broken down into the following three key phases, dictated primarily by the condition of the ventilation system and the deteriorating standard of containment of the process cells.

Phase One consisted of the installation of a new filtered ventilation system to facilitate decommissioning. This phase of work was completed in 1993.

Phase Two consists of the removal of operational equipment and glove-boxes from the annulus area and removal of the process vessels and pipe-work from the cell. This phase of work is ongoing and is approximately 85% complete.

Phase Three consists of the removal of the highly contaminated redundant ventilation system, the highly contaminated process cells and the Low Active Drain connections. The engineering of this phase of work has now commenced.

Safe and cost effective decommissioning is being delivered through the selection of fit for purpose technological solutions, taking account of the radiological conditions and physical layout of the plant.

PHASE 1 – SECURING THE ENVIRONMENT

Due to the high levels of aerial alpha discharges from the plant, it was considered essential that a new ventilation system was operational prior to undertaking any significant intervention work such as removal of plant and equipment from the process cells.

As a precursor to the installation of the new ventilation system, two highly contaminated glove-boxes and associated services were removed from the 4th floor to make room for ventilation plant and equipment.

A modern ventilation system was designed to replace the largely unfiltered extract system which had served the plant for its operational lifetime. The system was designed to maintain containment of the process cells and the redundant ventilation ducting at all times, through a combination of depressions and minimum airflows across barriers. The new ventilation plant was designed in 1991 to modern standards, providing High Efficiency Particulate in Air (HEPA) filtration via three banks of primary and secondary filters (50% redundancy) and a dual fan system with an auto-change function (100% redundancy).

This phase of work was an outstanding success and was a step-change in hazard reduction for this plant. When the system was brought on line in 1993, emissions from the plant fell by approximately 99.8% leading to a reduction of approximately 60% in the Sellafield Site aerial alpha discharges.

Isolation of the redundant ventilation ducting from the base of the main discharge stack, which also serves several other operational plants on the Sellafield Site, was not undertaken at this stage and forms part of the scope of work for Phase 3.

PHASE 2 – REMOVING THE PROCESS PLANT

The second phase of decommissioning progressively reduces the hazard associated with the process plant, including over 220 vessels, weighing up to 500 kg each, more than 7,500m of stainless steel pipe, over 50 redundant glove-box panels and a large quantity of miscellaneous wastes that had built up over more than 30 years of operations.

CHALLENGES TO OVERCOME

The level of radioactive contamination within the cells is in excess of 14,256 pCi alpha, in excess of the measuring capability of the existing instrumentation, requiring decommissioning operators to wear pressurised air-fed suits. Background radiation readings are generally 5 mrem/hr gamma although some areas as high as 1.5 rem/hr gamma have been identified and shielded enabling manual work to be carried out.

The process equipment was suspended over 4 storeys from a network of steel beams, with little provision for human access. The vertical layout presented a challenge for operators working in pressurized air-fed suits. The project team worked closely with PPE manufacturers to develop modern replacements for the Windscale Suit including a version compatible with fall-arrest harnesses for work at height.

Following plant shutdown in 1987, a campaign of Post Operational Clean Out (POCO) was completed to reduce the residual fissile inventory and levels of radiation. However, this was hindered by physical interruptions to the process line and poor human access to most vessels. Furthermore, evidence gathered following the criticality incident in 1970 showed that a build-up of material within vessels was possible. Since it was not possible to determine the fissile inventory within the vessels and pipes via physical assay, a robust criticality safety case was developed for decommissioning, underpinned by the requirement to employ an assay technique for the dismantled plant.

Also as a result of the limited POCO, significant quantities of liquor have been encountered within vessels and pipes throughout this stage of decommissioning.

INTEGRATED TECHNOLOGY

A Waste Conditioning and Access Facility was designed to interface with the cell, incorporating operator access facilities, mechanical lifting systems, a cutting enclosure, plutonium assay equipment and a waste disposal route. A schematic of the facility is shown in Fig. 2.

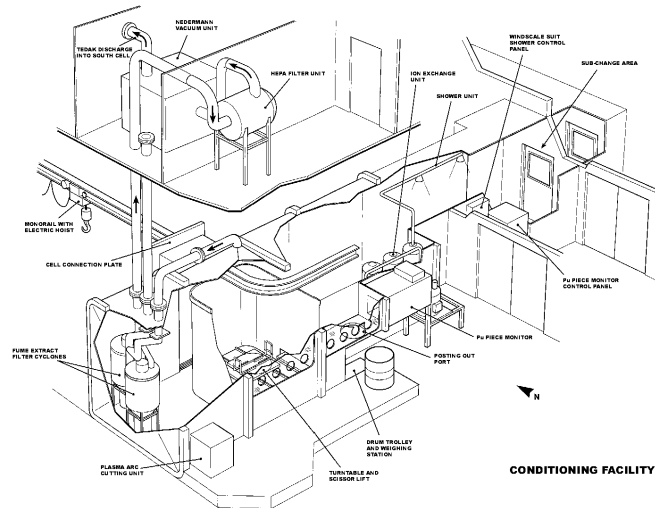


Fig. 2. Waste conditioning and access facility

Prior to installation of the facility in the ground floor south annulus, the area was cleared of redundant control panels and ancillary equipment.

Operators access the vessels and pipes via purpose built scaffold, inspect for liquor and bulk fissile inventory and lower vessels individually to the ground floor of the cell. Vessels are then transported to the Waste Conditioning Facility where they are cut to fit into a 200 L drum with a plasma-arc torch, assayed for fissile content and disposed of as Plutonium Contaminated Material (PCM) waste. Drums are packed within the constraints of total mass, fissile mass and volume.

The cutting enclosure is ventilated by a three-stage filtration system that yields a fume Decontamination Factor of 10^6 . The system comprises of:

- A dual-cyclone separator that segregates fume and heavy particles,
- A sock-filtration system,
- High Efficiency Particulate in Air (HEPA) filtration.

This innovative integration of burning technology into the nuclear industry by British Nuclear Fuels in the early 1990s signified a step-change in decommissioning technology.

Airborne activity is minimised during egress from the facility by the use of an air-fed suit decontamination shower. Liquid effluent discharges were minimised by the re-circulation of shower water through an ion-exchange filtration system. Notably, operator safety is maximized by the deployment of the plasma torch from the C3 area via glove-ports. Major safety benefits are segregation of the operator from the molten metal and from the highly contaminated fume.

PROGRESS TO DATE

To maximize productivity project tasks were scheduled in parallel. Concurrent with the design and construction of the Waste Conditioning Facility, out-cell decommissioning tasks were undertaken. This included:

- The removal of 12 plutonium contaminated glove-boxes and sample cabinets from the annulus areas,
- The strip out of process control systems on four floors,
- The removal of over 500m² of asbestos cladding sheets and the re-cladding of the building to modern standards.

Decommissioning of the process cells has progressed significantly. To date, over 1'800 drums of PCM waste have been removed and the following items have been disposed of:

- The redundant glove-box panels stored in the cell;
- Over 20m³ of historic miscellaneous wastes;
- 206 vessels and over 90% of the pipes within the cells.

Figure 3 shows the congested layout of the north cell, the south cell being a mirror image. This image was taken during commissioning in the 1950s and does not reflect the poor condition of the cells following over 30 years of operation.

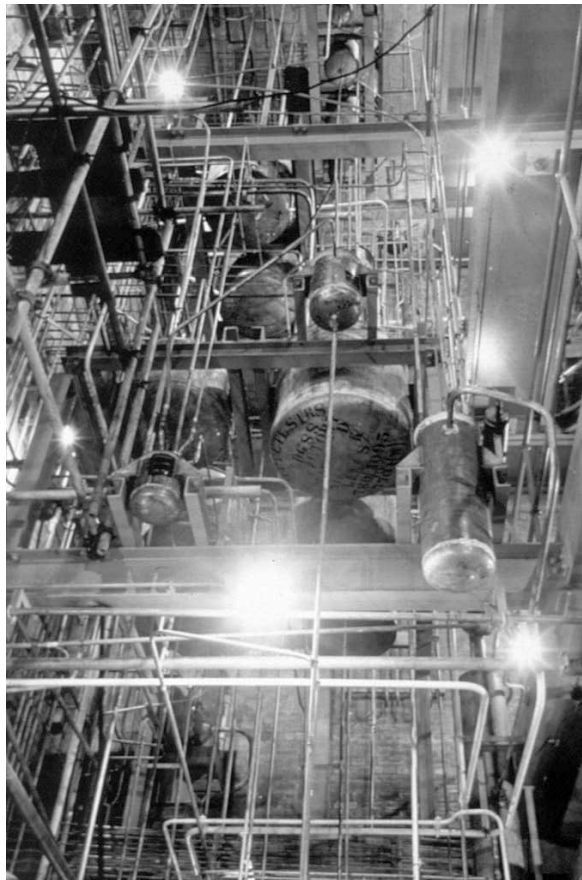


Fig. 3. Process vessels and pipes prior to operations

Figure 4 shows the significant progress in the north cell by mid-2005. The photograph is taken from the 1st floor level looking to the cell roof. The remaining vessels and pipes visible in this photograph have now been removed, although scaffold floors currently prevent a clear view. Over 110 process vessels and approximately 3,500m of stainless steel pipes were removed from the north cell.



Fig. 4. Progress in the north cell mid-2005

Phase 2 of the project will now be completed ahead of schedule in October 2006 and will result in the removal of all process plant and equipment from both cells. The remediation of the highly contaminated cell structure is within the scope of the third project phase.

PHASE 3 – LARGE CONTAMINATED STRUCTURES

The third and final phase of decommissioning for this plant deals with large-scale highly contaminated structures and services, namely:

- The process cells,
- The ventilation systems (operational and redundant)
- The Low Active Drain system

This phase will be followed by demolition of the building or reutilization if deemed appropriate at a later stage.

CHALLENGES TO OVERCOME

Commercially, this phase presents a significant opportunity to minimize the long-term costs associated with waste disposal. As previously stated, contamination within the brick-built cell is widespread. Initial surveys and core samples taken from the brick cell structure have shown a variety of contamination depth profiles, ranging from superficial to 100%.

The total volume of the cell structure is approximately 376 m³, consisting of:

320 m³ brickwork
44 m³ concrete
12 m³ mild and stainless steel

Given these large volumes of contaminated material, development of the strategy for waste minimization will play a key role in the success of this phase. During the demolition phase, it is expected that the majority of the building fabric and superstructure, will generate significant volumes of free release material.

The dismantling methodology for this phase will incorporate the extensive experience gained during the first two project phases. British Nuclear Group's expertise in containment of radioactive materials will be fundamental to the safe delivery of this phase. In particular, the removal of the unfiltered redundant ventilation system and the dismantling of the process cells may pose significant radiological safety challenges.

Conventional safety issues, including working at height, will continue to play a major role in Phase 3 as in the previous phase. For example, the ventilation ducting runs from the 4th floor of the plant up to the 10th floor of an adjacent building prior to entering the discharge stack.

PROGRESS TO DATE

An options study was carried out in 1998 to develop a preferred strategy for the remaining scope of work. This identified that Phase 3 should be subdivided into the following key work packages, to be undertaken consecutively:

- Removal of the redundant ventilation system, followed by a period of long-term care and maintenance;
- Removal of the process cell structure, followed by a period of long-term care and maintenance;
- Removal of the Low Active drain and demolition of the building.

Important changes in the nuclear industry, namely the delay in availability of a long-term waste repository and the formation of the Nuclear Decommissioning Authority (NDA), have resulted in the need to re-assess the timescales of the strategy.

Thus, detailed design and engineering of the first work package commenced in April 2005. In parallel, a review of the original strategy is being carried out to determine the safest and most cost effective approach to the remaining scope of decommissioning for the plant.

Investigative work to determine the levels of contamination within the redundant ventilation ducting have been carried out along with assessment of the structural integrity of the system. This data will be used to refine decommissioning options and enable option selection for detailed design.

CONCLUSION

Decommissioning of the former Plutonium Purification and Residues Recovery Plant at Sellafield has led to progressive reduction of the hazard. Very significant reductions in aerial effluent discharges have been achieved. Recovery of plutonium contaminated materials into passive safe storage is also reducing the radiological hazard.

The integration of non-nuclear industrial technologies to nuclear environments has proven to be cost effective and highly efficient, as demonstrated by the use of plasma arc cutting and fume decontamination.

British Nuclear Group is building on the successes achieved in Phases 1 and 2 with the development of the third and final phase of decommissioning.