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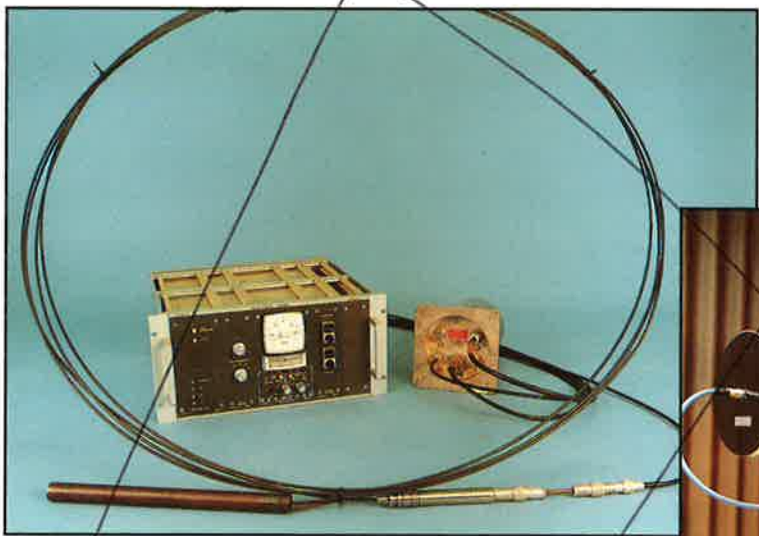

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Building	
Height	27m
Width	50m
Length	115m
Enclosed volume	44,600m^3
Total floor area	10,351m^2
Laboratory and office floor area	4030m^2
Building fabric	
Asbestos cladding	3500m^2
Amount of concrete	4000m^3
Amount of brickwork	900m^3
Basemat depth	2.1m
Amount of structural steel	1200 tonnes
Length of lagged pipework	2500m
Length of ductwork	4200m
Area of chequer plate flooring	1700m^2
Area of floor covering	3600m^2

Major building parameters.

Power reactors are not the only structures in the nuclear industry that require careful decommissioning. Much can be learnt from the dismantling of the rigs and pilot plants used to develop reactor and fuel cycle technology. Building 351 at the Harwell Laboratories of AEA Technology was originally constructed 40 years ago to support the development of separation techniques for nuclear fuel materials. Since then it has been used to house many experimental rigs and pilot plants covering all aspects of the fuel cycle. As the requirements of the nuclear industry have moved away from the experimental verification of different processes, so has the need for a general purpose adaptable facility receded. Building 351 is undergoing the initial stages of clearance and decommissioning so that a Stage 3 status (effectively a cleared site) can be achieved within five years. Because of the diversity of use, the challenge for cost-effective decommissioning differs from that faced in dedicated single-use facilities.

Dismantling a chemical engineering building

Ed Abel and Clive Hamblin

For one large building at least, a steady programme of decommissioning followed by demolition is substantially cheaper than delayed decommissioning after different regimes of care and maintenance.

From the beginning of its operational life the emphasis in Building 351 was on liquid/liquid extraction and purification, uranium recovery, solvent recovery and dissolution. Although plans for full scale recovery and purification of plutonium produced in slugs in the Harwell Pile appear to have been dropped, the building housed pilot plant and production rigs for most stages of the processing and reprocessing of nuclear fuels.

Original concepts for the building were dominated by shielding requirements for plutonium separation. Final designs featured a large open process area (40m by 25m by 25m high), galleried on four levels at one side, with an active extract housed on a sixth floor. To one side was a two level analytical laboratory with its own active extract system, and to the opposite side a large pit area was used for fuel dissolution, and active effluent delay tanks. The open area allowed a range of shielded cells to be built as required, with flasking facilities to solvent extraction columns running from the ground to the fourth floor. A two storey extension was added to the west end of the building and was fitted with large ventilated cubicles. Many internal and external alterations have been made to the building in 40 years, including the addition of flooring at the second level, over the open process area, to provide more experimental space. The 'Pit' has housed many experiments and still contains the building active delay tanks.

In the early 1950s, the solvent extraction of natural uranium and thorium was investigated. This was followed by the operation of a Solvent Extraction Pilot Plant, built in 1955, to process irradiated thorium blanket rods from the Windscale Piles. The rods were decanned and chopped in a plant submerged in two 12,000 gallon water-filled tanks housed in the Pit. The 233U product extracted from the Pilot Plant was used to produce light and heavy water solutions for the criticality investigations known as the Zero Energy Thermal Reactors ZETR I and II. ZETR II was

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reconfigured and became the reactor known as HAZEL (Homogeneous Aqueous Zero Energy Liquor). The 233U was finally recovered from heavy water in the building and transported to other sites for further investigations into those types of reactors.

From 1960 to 1964 a plant known as FINGAL (Fixation in Glass of Active Liquors) was operated in the Pit area. This programme established the scientific and engineering feasibility of batch vitrification of highly active liquid wastes. At the end of the programme, active liquors from Windscale were put through FINGAL, culminating in the production of a 500TBq cylinder of glass. This unique source is in store on the Harwell site and has been used to calibrate instrumentation that can be used on full sized vitrification plant.

During the 1960s, blending and vacuum packing of uranium dioxide and thorium oxide powders was carried out on the third floor in large ventilated cubicles. The work was in support of the fuel preparation programme for Advanced Gas Cooled Reactors (AGRs). In the first few years of the decade, thoria slurries were routinely handled in a variety of rigs from the ground to the third floor. Powder transfers between rigs were frequent, and the operators used full face masks or air hoods.

From 1967-83, the Mark I Sol-Gel Plant operated, producing uranium/thorium mixed oxide and 20% enriched 233U oxide spheres for conversion to nuclear fuel for PFR research. Using the design data from this plant, a Mark II Sol-Gel Plant was built in a suite of cubicles and operated as a production unit. In the mid-1980s the plant was largely dismantled, releasing some of the cubicles for non-nuclear chemical engineering rigs.

From 1976-85 the FINGAL Project was re-established on a much larger scale under the title HARVEST. The plant, built adjacent to the abandoned FINGAL Cell in the Pit, continued the study of vitrification using a fission product simulant which was formed in 600mm diameter vessels. A very low level (0.04%) of natural uranium was present in the fuel to make it chemically representative of the highly active fission product liquid waste from a fuel reprocessing plant.

The new Solvent Extraction Pilot Plant (SEPP) was commissioned in 1982 to allow the study of solvent extraction of simulated spent fuel. SEPP is contained in interlinked cubicles stretching from the ground to the fourth floors. The extraction columns, banks of centrifugal contactors and other vessels are protected by an extensive automatic fire extinguishing system. Since 1982, a glass evaporator has been used to concentrate the aqueous products from the mixer settlers. It is situated in the Pit, alongside stainless steel bulk feed and product liquor tanks, and is some distance from the solvent extraction equipment. In 1987 four extra mixer settlers were added to SEPP to allow recovery of product liquors from the columns and centrifugal contactors. The extra equipment is housed in a new cubicle in the SEPP plant room on the first floor, and is also protected by the same fire extinguishing system. Aqueous feed to SEPP contains nitric and sulphuric acids with 300gU/litre as depleted uranium. The organic phase is a solution 20% by volume of tri-n-butyl phosphate in odourless kerosene. All parts of SEPP are connected to the building active ventilation system.

Several dissolver rigs have been built during the building's lifetime. More recently, in 1985, the Dissolver Optimisation Pilot Plants (DOP) were built to investigate the dissolution of fuel simulant in nitric acid. Each dissolver is linked to a reflux condenser, and to the acid and caustic off-gas scrubber. The DOP are designed to handle up to 100kg batches of depleted uranium oxide pellets.

In 40 years of continued operation, Building 351 has hosted many hundreds of rigs, plant and experimental equipment. At its peak, over 200 staff populated the building. Now, although substantial new rigs have been added over the last five years, AEA Businesses have tended to relocate their operations away from the building. Even so, redundant equipment from earlier years remains throughout, and fixed contamination in the building floors and walls marks out the locations of original rigs and plant.

This cleared laboratory used to house the Mark I Sol-Gel rig for processing natural uranium and thorium into a liquid, which then reacted with ammonia to form a gel. The floor covering is currently being removed with vibration reduced long pole pneumatic hammers which have a shroud at their end connected to a vacuum cleaner which incorporates high efficiency filters.

Delayed decommissioning more expensive

AEA Decommissioning and Radwaste took safety responsibility for Building 351 in 1990. Decommissioning planning began in 1991 as part of the

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then Department of Energy (now Department of Trade and Industry) DRAWMOPS programme.

Initial analysis of a strategy for the building demolition included a thorough analysis of remnant rigs and equipment, and the calculation of the cost of decommissioning. Alternative uses for the building were considered. Although substantial inventory remained in a few rigs and storage areas, there was no immediate safety-related need to carry out extensive decommissioning. However, for a variety of scenarios, it was established that a steady programme of decommissioning followed by building demolition was substantially cheaper than delayed decommissioning after different regimes of care and maintenance. The cost benefit of early decommissioning is derived because of the high care and maintenance costs of the building, which is asbestos-panel clad and is not energy efficient.

The mothballing of old contaminated rigs requires extensive work before safe storage can be achieved. Often the cost of mothballing a rig in this building is similar to its decommissioning cost. At present, only about 20% of the building is occupied by working experimental rigs, mainly in the technical areas of dissolution, separation and air filtration. Decommissioning of rigs and equipment has proceeded over the last two years as the building occupants have moved out. Continuing the process of steady decommissioning, current planning suggests that the building shell will be totally cleared of rigs and contaminated materials by 1996, allowing near-conventional demolition to take place in 1997.

Laboratory clearance

Initially there were over a hundred radiologically designated areas (RDAs) in the building. As members of staff have left, equipment and rigs have been isolated from building services and, where appropriate, decontaminated or decommissioned. Once the areas have been cleared of radiological and chemical hazards then decategorisation of the RDA is possible. Over the last two years the number of RDAs has been roughly halved.

Many of the laboratories and rigs contained unknown or unidentified materials and chemicals. Over the last two years more than 4t of bulk chemicals and over 2000 chemical containers have been radiologically and chemically identified for disposal through appropriate routes. General housekeeping around old rigs helps minimise uncertainties for future decommissioning.

The building has been resurveyed throughout to ensure that baseline information is available against which decommissioning operations can be planned. Moreover, any spread of contamination from clearance activities would be noted

Clearance of contaminated items from cubicles and gloveboxes. General housekeeping around old rigs helps minimise uncertainties for future decommissioning.

immediately under the current routine monitoring regime. In some cases, fixed contamination is removed and analysed to establish its historical origin and potential for changing the cost of building fabric clearance.

Fume cupboards and ventilation systems in Building 351 have similar safety implications. A common approach is taken in both safety documentation and working instructions for decommissioning. The advantage of this approach is that project preparation is simplified as only specific information relating to the item that is to be decommissioned is necessary. The specific information is added to the generic documentation to form a robust decommissioning safety case.

The Mark I Sol-Gel Rig

The Mark I Sol-Gel Rig had been built in a separate laboratory area on the second floor of Building 351. Three interlinked cabinets were connected to the building extract system, and housed the plant which processed natural uranium and thorium into a liquid. This liquid (as a nitrate) then reacted with ammonia to form a gel. Several washing stages were incorporated, followed by product drying. The cabinets stood 4m high and had an approximate floor area of 12m^2. An electrical cabinet and control cubicle, chiller unit and effluent tanks made up the balance of equipment that remained in the Sol-Gel Laboratory.

System doorway. The Mobile Filtration Unit was cheaper to install, has reserves of capacity, including redundancy in design, and uses much shorter duct lengths. The Mobile Filtration Unit can also be used in other parts of the building as extract ducting is decommissioned or becomes unavailable.

Lighting and electrical power feeds remained in place within the cell. The first decommissioning entry concentrated on the disconnection of all service feeds to cell items, so that decommissioning could proceed safely. The Method Statement defined a sequence of events including replacement of all old ductwork by flexible ducting connected to the Mobile Filtration Unit. The ovens and other large items would be lifted using 3/4t folding cranes, which collapse to 500mm by 500mm cross-section and can be easily installed in the Modular Containment System or cell. The lead cell is 3m high (the main cell roof height is 3.43m) and is made up of over 800 lead bricks, with a total weight of about 40t. The bulk of the wall is fabricated in the old 'System 10' bricks which each weigh 150kg. Handling such large items at height presents particular problems for operators, so an electrically driven pedestrian stacker truck has been specially modified for use in the cell, to help with dismantling the wall and dismantling the furnace sections. The 1t capacity stacker has been modified so that it can be broken into smaller parts and re-assembled in the cell. The access corridor width limitation means that the stacker must be broken into three parts. Remote charging of the batteries has also been accomplished.

The Mobile Filtratioh Unit and Modular Containment System used in the decommissioning of the FINGAL cell.

New electrical services for the cell have been provided from a temporary distribution board placed inside the Modular Containment System. A CCTV and audio communication system allows operational staff to communicate directly with supervisors outside the System. Key aspects of the work have been video recorded to help with task planning and to keep a record of work progress.

The cell will be partially cleaned when all equipment is removed, to get its background levels of contamination to a similar status as the rest of the Pit Area. The Modular Containment System panels and Mobile Filtration Unit will be used elsewhere in the building to provide similar levels of safeguards to operators, building staff and the environment.

First FINGAL decommissioning entry.

Finding cost-effective solutions

Decommissioning an old building presents special difficulties. For 40 years, Building 351 has contained a multiplicity of rigs, plant and equipment, operated under a variety of management controls. The consequent problems for decommissioning planning and operations are complex, but experience gained in the last two years shows that cost-effective solutions can be found that are both safe and efficient. In particular, the methodology has been to:

- Use operational or maintenance procedures as a source of data for safety case documentation.
- Build up plant knowledge through interviews with the original operators, health physics staff and by searching archives.
- Establish Health Physics data (historical and current) early on.
- Review past incidents or accidents.
- Use appropriate levels of technology to solve specific problems, such as handling loads, which did not arise during operations or maintenance.
- Specify decommissioning equipment (such as cutting tools, Mobile Filtration Unit or Modular Containment System) that can be used on more than one rig or plant.
- Employ decontamination or size reduction techniques to reduce the overall costs of waste disposal.
- Develop generic safety documentation and procedures that can be applied (perhaps with some slight specific additions) to many similar tasks such as glovebox and fume cupboard removal, active ducting decommissioning, decontamination, etc.

Acknowledgement
The decommissioning of Building 351 is funded under the DRAWMOPS Programme by the Department of Trade and Industry.

The main detected radioactive inventory consisted of uranyl nitrate, uranium dioxide, thorium nitrate and thorium oxide. Most of this material in the cabinets was in the form of loose yellow or black powder, with a total inventory of 53MBq. A further 5MBq of fixed contamination was estimated in active items in an adjacent mixing room and on and under floor coverings. Ammonia and nitric acid hazards were not present during decommissioning, but quantities of hexanol were discovered as the plant components were disconnected.

Decommissioning the Sol-Gel plant was successful. Removal of extract ducting revealed an asbestos-clad pipe which needed special attention as the cladding had aged badly. Work was temporarily halted whilst this pipework was removed. The floor covering is currently being removed. All loose radioactive material found during this operation will be processed as low level waste. Vibration-reduced long pole pneumatic hammers are being used to lift the floor covering. They have a shroud at their end which is connected to a vacuum cleaner which incorporates high efficiency filters to prevent aerosol releases.

The Mild Steel Loop

The Mild Steel Loop was installed on the second floor of the building. It was used to simulate extended water corrosion effects, more recently for the fast reactor programme, and operated at the high temperatures and pressures—eg 350°C and 18MPa—found in power station steam generators. The water side could be carefully analysed and doped with additives, and the sodium side conditions could also be controlled. Analysis of water chemistry, including gas evolution and corrosion formation, was carried out in the building's analytical laboratories.

The Loop was not used for radioactive experiments. Its complexity and location provided the justification for its early removal. The Loop operators had been dispersed to different businesses, and the Loop itself was closed in mid-1989. Parts of it were still electrically connected and the water circuit was isolated from the building cooling water (10,000 litres) and demineralised water (10,000 litres) header tanks by only single manual valves. Below the Loop was the Sodium Laboratory, which could be flooded if a pipe or coupling broke.

Electrical disconnection of the Loop took six man-weeks. As the Loop grew to meet different requirements, additional service feeds had been added. Argon, compressed air and cooling water supplies were disconnected and the system was drained without incident. The cladding around the Loop pipework was removed and dismantling proceeded easily. The Loop provided an ideal opportunity to test under inactive conditions the performance of hydraulic shears and cutters that were to be used on FINGAL decommissioning. All the Loop was removed by May 1992, and minor patches of fixed contamination were found under the Loop drip tray. They probably originated from earlier work in the area such as processing, counting, and analysis of the micron-sized sol-gel product and its feed materials.

Inspection of the FINGAL ('Fixation in Glass of Active Liquor') ovens and furnace with a colour camera and βγ probe.

FINGAL

The major recent decommissioning task is the FINGAL Cell. The 'Fixation in Glass of Active Liquor' process was conceived in the early 1960s to demonstrate an alternative to storing highly active and long-lived fission products in glass. The pilot plant cost £80,000 to build, and ran from 1962 to 1964; its final runs produced glass cylinders containing highly active fission product ➢

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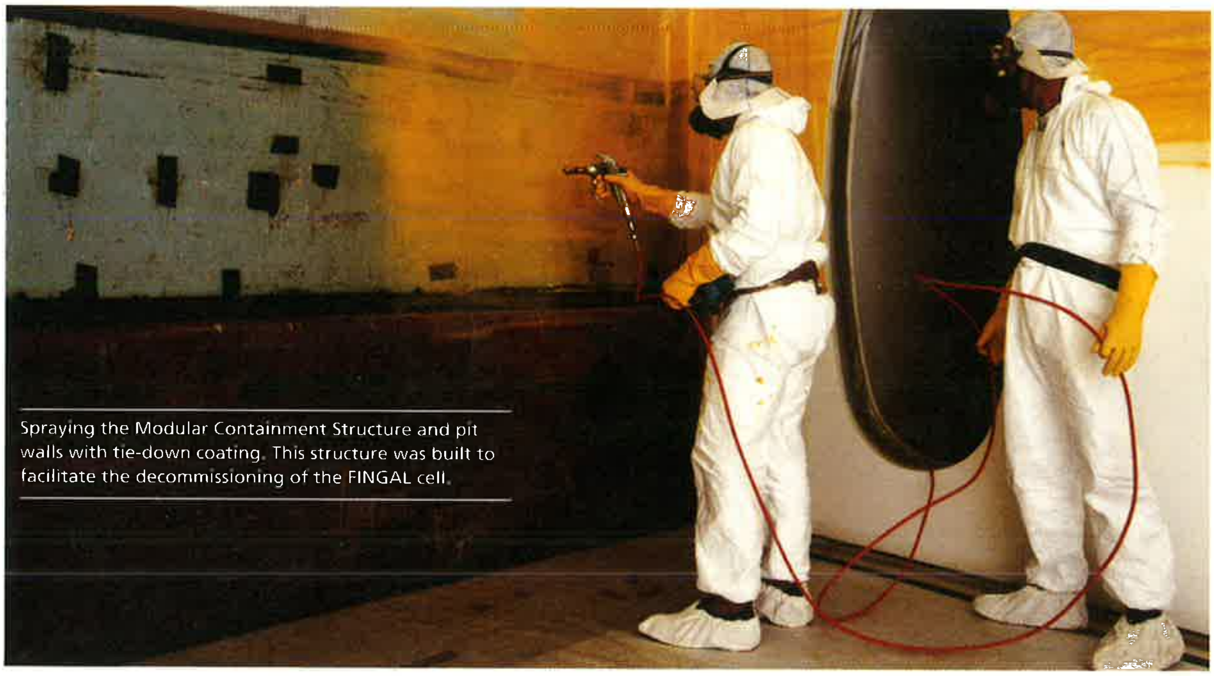

Spraying the Modular Containment Structure and pit walls with tie-down coating. This structure was built to facilitate the decommissioning of the FINGAL cell.

waste from Windscale Magnox fuel reprocessing operations.

All the remaining equipment is in a concrete cell in the Building 351 Pit. A spill of active liquor on the roof of the cell resulted in an additional sealing layer of concrete being laid which prevents access to the cell by lifting off the concrete roof shielding blocks. Failures of automatically-made pipe connections in the cell has led to contamination problems within the cell itself, and the project team had decontaminated major items to reduce cell dose to operators. The cell contained two ovens, a furnace and a lead cell housing the mixing and process vessels. All these items were placed in position by the 50t crane. Although the process vessels in the lead cell were thoroughly flushed before the cell was abandoned in the mid-1960s, it was not assumed that all pipework would be radiologically or chemically clean.

A safety case was developed using a HAZOP I analysis of decommissioning tasks that were detailed in a 'Method Statement'. The risk to operators and the potential for radioactive discharge to the environment were deemed to be acceptably low, and well within guidelines for site operations.

The remaining inventory in the cell was calculated as 550MBq, with 90Sr and 137Cs in the ratio of 3:1 as the major constituents. As the last operation was nearly 30 years ago, shorter lived isotopes, such as ruthenium, have decayed to undetectable levels. The inventory calculation was based on the known throughput of FINGAL, and is consistent with health physics data from cell entries where smears and samples were taken and dosimetry was left in specific locations. The bores of the two ovens and the furnace have been intrusively inspected, working from the roof, using a telescopic $\beta\gamma$ probe and a miniature colour CCD camera. The inspection confirmed that there were no significant radiation hot spots in these structures, and that their physical condition was good despite their age and past operations at high temperatures.

Access to the cell is through one small doorway and along a shielded corridor. Space inside the cell for dismantling is limited, and so the 'Method Statement' called for another area to be available for waste processing and preliminary storage. A Modular Containment System was built in the Pit and sealed to the cell doorway. Internal surfaces were sprayed with a tie-down coating to reduce contamination of the pit walls, and also to allow re-use of the Modular Containment System after the project.

The Modular Containment System and the cell are ventilated by a Mobile Filtration Unit. The choice of a dedicated ventilation system over the use of the existing building active extract system was based on installation cost and potential reliability. Using the building system would have required extensive use of flexible ducting and would only just have provided adequate flow through the Modular Containment

This 1t electrically-driven pedestrian stacker has been modified for use in the FINGAL lead cell to help with dismantling the wall and furnace. The modified stacker can be broken into three parts and re-assembled in the cell.

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