DIDO Operators Meeting, 16-17 April 2008, Roskilde, Denmark

Overview of activities since the final shutdown of the DIDO and PLUTO MTRs

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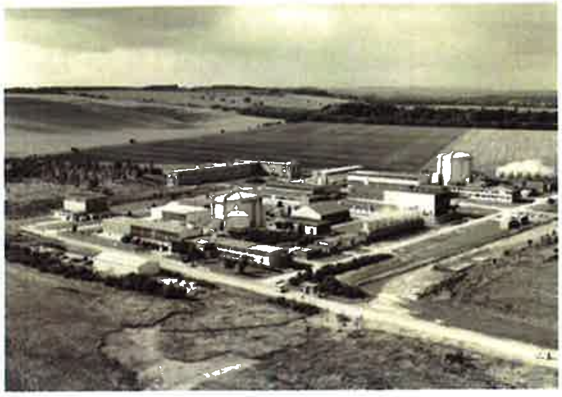

UKAEA Research Reactors Division, 1967

Harwell Projects Department, MTRs, Stage 2: Phase 1 decommissioning complete, 1998

Introduction

Decommissioning Harwell's two 26MW(th) Materials Test Reactors (MTRs) was started as soon as operations ceased and both were shut down on 31st March 1990. Stages 1 and 2: phase 1, decommissioning included defuelling, removal of all fissile and rigs' sample materials, draining of the heavy water and its transfer to Winfrith, removal of the balance of plant and demolition of most of the surrounding buildings and facilities. That programme of work was completed by 1998. At this point, the reactors were expected to stay in continuous Care and Surveillance until approximately 2037 – 2040, by which time radioactive decay would have reached a point that further delay would not show significant benefits in waste management cost saving nor in ease of decommissioning. By then a National ILW Repository was expected to be available.

Several different dismantling plans for Stage 3 (decommissioning to green field) were proposed in the period between 1990 – 2002; some examined options for early decommissioning but the best option was always to defer. However, in 2003 – 2004, an accelerated programme was proposed for decommissioning UKAEA facilities. For Harwell, the MTRs would be decommissioned by 2025 and the whole Harwell Site would be delicensed. Subsequent years' programmes were improved such that both of the MTRs could be decommissioned by December 2016, provided the Front End Decommissioning Engineering and Regulatory engagement could be started in 2007.

The challenge for accelerated decommissioning was to produce safe and cost-effective strategies using predominantly commercial off the shelf (COTS) equipment. However, the decommissioning techniques proposed in the pre-2004 plans were not suited to such a rapid programme and the original techniques were unduly complicated and expensive. Year-on-year improvements to the plans have produced more efficient and cheaper methodologies that would make early decommissioning possible, provided the funding and technical skills resource were available.

By 2008, national funding priorities for the Nuclear Decommissioning Authority have meant that the UKAEA accelerated programmes have been re-assessed; the Harwell MTRs will remain in Care and Surveillance until at least 2021, assuming funding levels are not further reduced. Nevertheless, the improved approach to decommissioning will continue to be the baseline.

Previous DIDO Operators' Meetings, in particular the 1997 Julich Meeting, have had presentations from Harwell about the status of decommissioning work. This paper will give a description of the organisational changes that have happened, a brief pictorial overview of the DIDO and PLUTO early decommissioning milestone events since shutdown, provide a few more details of the DIDO HAHC decommissioning and describe the philosophy behind accelerated decommissioning plans.

Management Changes that have affected MTR decommissioning

UKAEA had begun to reorganise in the late 1980s into commercially-focused groups under the banner AEA Technology (AEAT) and the MTRs decommissioning was managed within the Decommissioning Group of Engineering Services. In October 1990, all UKAEA Sites were brought under the Nuclear Installations Inspectorate's licensing regime, which represented a step change in safety management. A UKAEA Programme Management Group (the Corporate DRAWMOPS Directorate, or CDD) authorised the budgets and the internal contracts with the decommissioning projects. This structure stayed much the same until 1994 when AEA Technology was established as the Commercial Division of UKAEA and CDD became part of UKAEA's Government Division (GD); Decommissioning Project Managers were part of AEAT but seconded into GD, and were required to operate behind a "Chinese Wall" in commercial operations with AEAT. In 1996, AEAT was established as a separate company but the secondees remained in UKAEA to ensure that safety responsibilities and Regulatory compliance was maintained. At Harwell, the Decommissioning Project Managers and Programme Managers were formed into one UKAEA unit, the Harwell Projects Department (HPD). AEAT retained pre-existing UKAEA Intellectual Property and key functional units such as nuclear engineering, decommissioning and radiological protection stayed in AEAT.

Progress with MTRs decommissioning was initially rapid, with visible changes to the reactor infrastructure. By 1995, the workforce had been reduced as most of the radiation work had been completed. The remaining reactor-focused staff took responsibilities for the other Harwell Reactors, GLEEP and BEPO and the three remaining Hangers.

The next significant management change was the establishment of the Nuclear Decommissioning Authority (NDA) as defined in the 2004 Energy Act. NDA are now the owners of the old UKAEA sites and UKAEA are Contractors to NDA, carrying out agreed programmes of work. Harwell and Winfrith operate under an integrated management team and will soon become Research Sites Restoration Ltd (RSRL), a UKAEA Group. NDA will compete the management of RSRL in the near future.

Early decommissioning – the successful reduction of hazard

The shutdown of DIDO and PLUTO after approximately 34 years of operation was sudden. Decommissioning planning had not been prominent in the minds of the reactor staff and managers. Just six years before the closure announcements, the top shield plug had been replaced on PLUTO. This improvement was in anticipation of much more than a decade of commercial and experimental programmes, supporting industry and the new commercial reactor programmes that were expected to replace the MAGNOX and some coal-fired stations that would come to the end of their economic life in the next 20 years. Irradiation of materials such as silicon, production of isotopes and neutron radiography were thriving, but essentially subsidised activities. Plans had even been laid to build DIDO-2, a 50MW research reactor that would eventually take over from the original MTRs, providing a more versatile and higher neutron flux resource.

However, the operational teams turned to decommissioning efficiently, despite the clear knowledge that they were working themselves out of a job. The management structure stayed virtually the same, initially, and early work such as defuelling, removal of samples from rigs and minor decommissioning required the same skills set and operations that were needed in reactor operation. Specific tasks such as the decommissioning of the DIDO High Active Handling Cell were different and required new equipment, which fortuitously had been developed in Harwell's Remote Handling & Robotics Department. The significance of this work is that it introduced a radically new technology to solve difficult decommissioning problems.

The decommissioning plans followed the IAEA model of three stages, but Stage 1 was split into three phases and Stage 2 was split into two phases.

The definitions for the MTR decommissioning phases were:

Stage 1	Phase 1	• Defuel & remove D_2O • Remove samples, except cobalt, from rigs • Obtain approval for Safety Justification for Phase 2
	Phase 2	• Remove less hazardous secondary systems external to block • Obtain approval for Safety Justification for Phase 3
	Phase 3	• Remove remaining Secondary System • Unload cobalt from rigs • Obtain approval for Safety Justification for Stage 2, Phase 1
Stage 2	Phase 1	• Complete Interim decommissioning & decontamination • Decommissioning old ventilation systems and install new ones • Obtain approval for Safety Justification for Stage 2, Phase 2 • Modify Safety Case, reduce category to Safety Category 3
	Phase 2	• Extended Surveillance & Maintenance
Stage 3		• Reduction of reactors' legacy to a delicensed (no harm) state

The key events up to and including Stage 2, Phase1 were:

EVENT	DATE ACHIEVED	
	DIDO	PLUTO
Decision to shut down	February 1990	October 1989
Reactor shut down	31 March 1990	31 March 1990
Decommissioning Plan issued	August 1990	January 1990
Decommissioning Plan approved	September 1990	April 1990
Fuel unloaded	April 1990	April 1990
Fuel transferred to B466	June 1990	June 1990
D2O drained into drums	May 1990	
Shift work ceased	August 1990	August 1990
Completion of fuel dispatch for reprocessing	Sep 1990	Sep 1990
D2O dispatched to Winfrith	July 1991	
DIDO and PLUTO projects combined	November 1991	
Stage 1 Phase 2 Safety Justification issued	September 1990	September 1990
DIDO/PLUTO Stage 1 Phase 3 Safety Justification issued	March 1992	
Stage 1 Phase 1 complete	June 1990	June 1990
Stage 1 Phase 2 complete	October 1991	February 1995
Stage I Phase 3 complete *	January 1993	
DIDO/PLUTO Stage 2 Phase 1 Safety Justification issued	December 1994	
Stage 2 Phase 1 complete	June 1995	June 1995
Rigs in final storage positions	January 1993	February 1994
Rig disposal programme complete	July 1994	
Cobalt pencils disposal programme complete	NA	February 1995
New ventilation system installed	March 1995	March 1995
Category 3 status achieved **		
HAHC demolished	31 August 1994	NA
Cranes and VALs disabled	November 1994	September 1995

Achievement of significant industrial and nuclear hazard-reduction milestones are shown in the following images:

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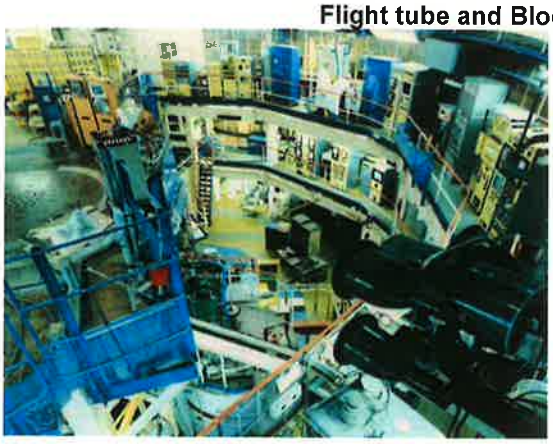
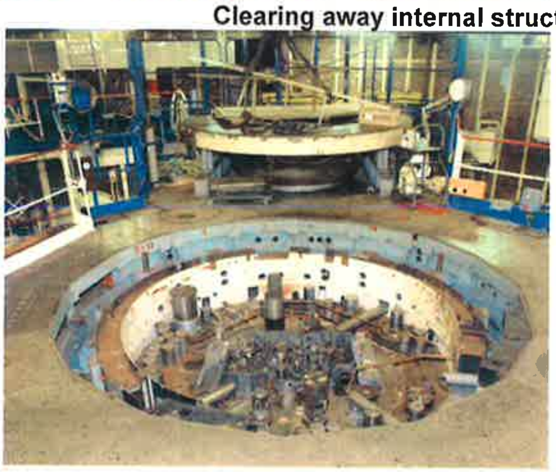
Removing the Cooling Towers


Flight tube and Block House demolished



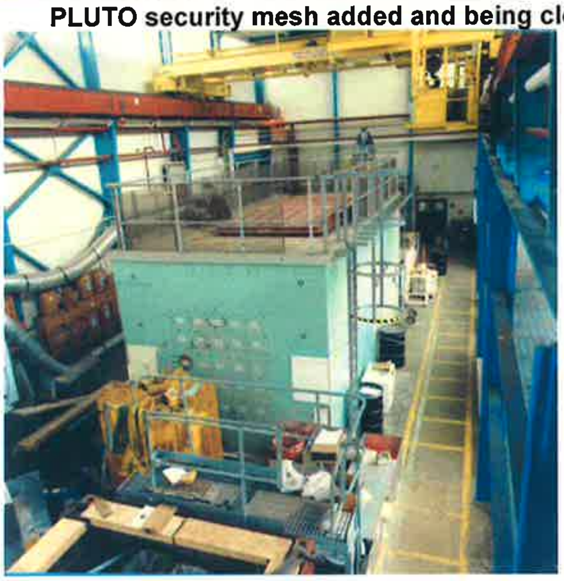

Clearing away internal structures, services and equipment




DIDO security mesh added


Removing an air heaters from PLUTO **Scaffolding for clearance & monitoring shell**


PLUTO security mesh added and being closed for Surveillance & Maintenance Phase




The External Storage Block

Cutting out the VAL

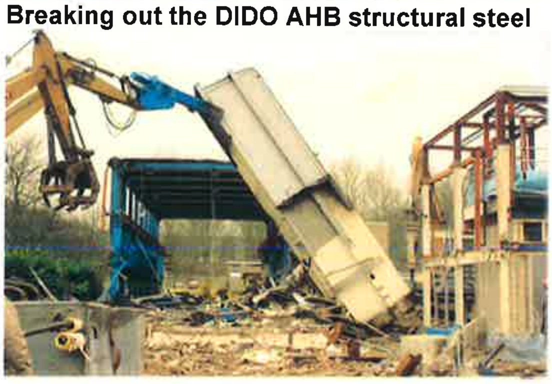
DIDO Office Block demolished

Clearing the DIDO AHB

Removing the DIDO AHB crane gantry

Breaking out the DIDO AHB structural steel

Last sections of the DIDO AHB



Demolishing the VAL

Cladding the new DIDO lobby

The DIDO High Activity Handling Cell

Initial decommissioning had already begun on the DIDO High Activity Handling Cell (HAHC) before the closure of the MTRs. The HAHC had been used to support DIDO operations and latterly, process ^{60}Co. It had been closed since 1984 and placed in care and maintenance. Concerns over its safety resulted in the start of refurbishment work in January 1989 as a precursor to full decommissioning. During the initial attempt to remove the overhead power manipulator, in June 1991, one of its hydraulic hoses split, releasing an unknown quantity of oil into the cell. All operations were stopped. Although attempts were made to clean up the cell, uncertainty about the amount and distribution of oil and flammable debris within the cell prevented the use of plasma-arc cutting techniques, the preferred method of gross size reduction of cell furniture and components.

The DIDO High Activity Handling Cell

The Harwell Remote Handling and Robotics Department (RHRD) had already developed a radiation-tolerant industrial robot, NEATER, that could be controlled remotely. As part of a systems engineering approach to modern remote handling, RHRD had also developed radiation tolerant 3-D television systems, TV^3. Both ranges of equipment had a designed and tested radiation tolerance of beyond 1 MGy, but used commercial-off-the-shelf (COTS) components; they were commercially available through AEA Technology. The first application of NEATERs was at Sellafield for swabbing the outside of vitrified high level waste containers, and was delivered within six months from receipt of BNFL's order. The alternative from the Vitrification Plant's original designers was more expensive, was a unique and unproven design and was less flexible in programmability and ease of control.

Another application for NEATER, at much lower activity levels, was at Harwell's Chemistry Division for size reduction of over 180 alpha-contaminated gloveboxes. A saving of £35k in reduced waste disposal cost for each glovebox was seen and reduced the continuous need for costly and hazardous pressurised suit operations.

Both applications demonstrated the versatility of the systems in nuclear applications and the very significant savings that could be made, compared to the normal nuclear industry practice of the time. As the development of NEATER and the supporting systems such as TV^3 were funded through the same Department of Energy Programmes as the DIDO HAHC decommissioning, it made sense to apply NEATER to solve the problem at the Reactor site. Because of the novel application, and the experience gained through the TELEMAN programme, the Commission of the European Communities (CEC) were asked if they would agree that the project was suitable for matched CEC funding as a decommissioning task. In 1992, they agreed to support the use of NEATER in decommissioning the DIDO HAHC, and the telerobot and ancillary equipment were installed in July – August 1993. This was the first decommissioning application of a radiation tolerant telerobotic device, made from standard industrial robot components.

Reactor Decommissioning staff were trained by RHRD in the use of the new remote handling equipment. The size-reduction of the in-cell facilities and furniture was completed quickly. NEATER's last job was to foam-clean all surfaces to bring background levels down to < 500μSv $^{h-1}$ (from >1 Sv $^{h-1}$, contact, in some hotspots). In early March 1994 the telerobot was extracted and the contamination control designs (labyrinth seals, strippable coatings and customised gaitering) were found to have worked effectively so it could be cleared for transport and re-use.

Conservative estimates put the application of the robot as saving >80 mSv, £1.1M and reduced the programme time by 2 years. However, it would have been a very difficult task to make an ALARP justification for man-entry in such a dangerous and cluttered radioactive environment.

NEATER: size-reducing cell furniture

NEATER: foam decontamination, post strip out

Once the cell was clean, conventional demolition techniques were used to reduce down the hulk of the cell. One unusual characteristic of the HAHC was that it was a steel plated framework structure with shielding volumes formed that were filled with sand. The HAHC had zinc bromide windows and the Maintenance Bay area had shield doors fabricated in steel plate and filled with lead shot. About 30 tonnes out of the 180 tonnes of sand was contaminated and had to be disposed of as LLW, as did the cell roof plates and outer walls.

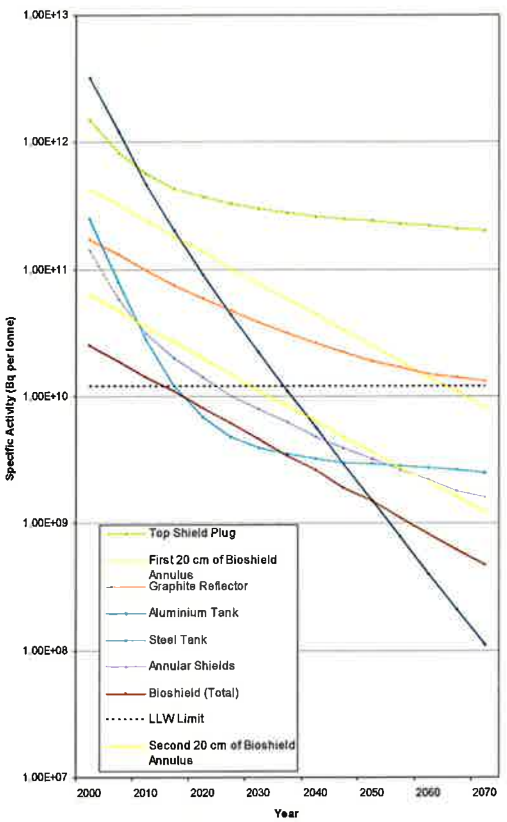
The process of dismantling and clearing the HAHC was completed by August 1994.

Drilling the drain hole to removing the sand

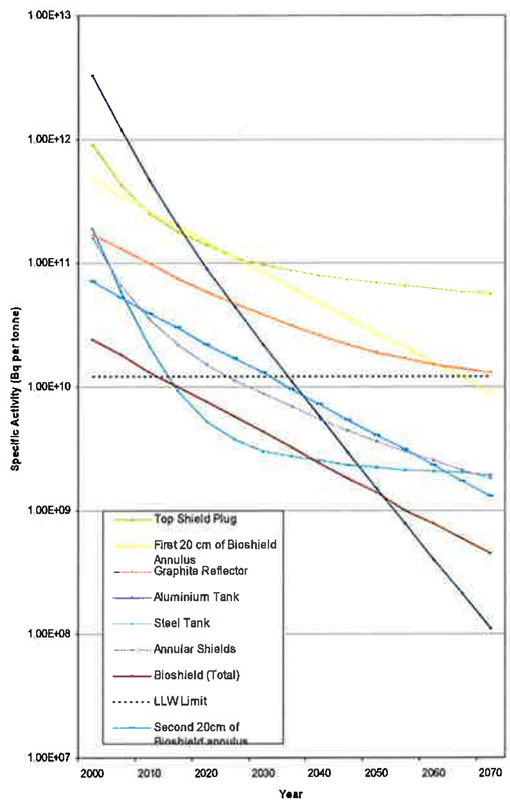
The HAHC part-dismantled

Accelerated Decommissioning
In 2004, UKAEA's accelerated plans for decommissioning the Harwell Site by 2025 posed severe challenges for decommissioning managers. For the MTRs, the assumption was always that radioactive decay was worth the wait: by about 2040, the bulk of the activity in components would have started to level off and the decommissioning would be relatively straightforward, with only a few components requiring special arrangements. The bulk of the reactors would also have decayed down below the 12G Bq t^{-1}, which is the threshold between Intermediate and Low Level Waste.

DECAY OF MAJOR COMPONENTS - DIDO



DECAY OF MAJOR COMPONENTS - PLUTO



If the MTRs were to be decommissioned early, then the dismantling techniques would have to deal with high activity components and would need to be performed remotely. Previous decommissioning plans had not been refined in any detail and because the outcome of optimization was to delay until 2030+, there had never been any serious technical review of the techniques suggested.

Virtually all the schemes relied on un-defined, thin mast-mounted manipulators passing through existing reactor top penetrations, deploying tools within the RAT. This followed the practice at power reactor sites such as Niederaichbach, Fort St Vrain and WAGR. However all these reactors had much larger internal diameters than the MTRs' RATs. In the 1980's, RHRD assisted the Research Reactors Division with RAT NDT inspection, using an extended reach Walischmiller master-slave-manipulator, borrowed from Lucas Heights. The deployment of cameras, the NDT tooling and lighting was complicated by the restricted degrees of freedom available in such a confined volume. If a decommission approach was to use a similar manipulative strategy, then it would be likely to fail as there was virtually no means to provide adequate space for aggressive, force-generating tools.

RAT NDT Inspection, using extended reach equipment

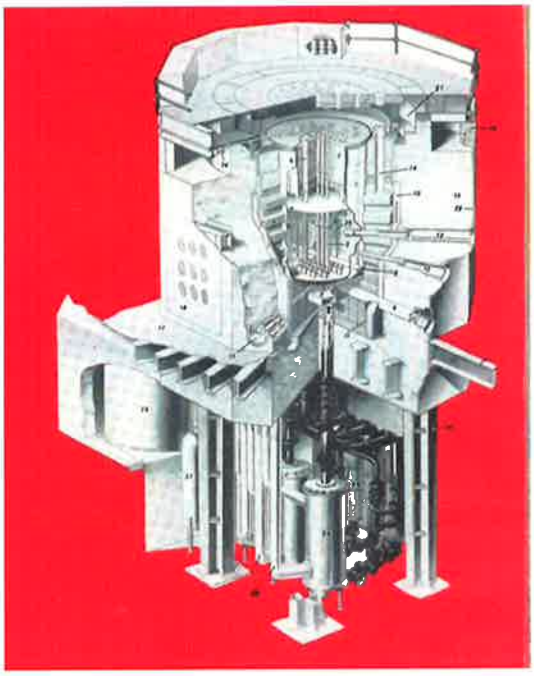
A review of techniques that might achieve early decommissioning considered what could be done to improve on the plan. Experience of non-reactor decommissioning projects at Harwell such as the Variable Energy Cyclotron, the Chemical Engineering Building facilities, the plan for sudden JET decommissioning, all confirmed that the optimum decommissioning technique was to consider how the decommissioning and waste management could be made most efficient, rather than starting from operational or physical constraints fixed by the facilities topography. For the MTRs at Harwell, the existence of the rigs and the lack of craneage and flasking that met Modern Standards was a setback. The obvious access route to the reactor internals is by removing the top shield plug but because of the high activity levels, additional structures would be needed to deal with the most radioactive components, first.

Examination of research reactor decommissioning projects worldwide showed that tank reactors and TRIGA reactors were being decommissioned using the same sorts of tools and remote vehicles that had been developed and used by RHRD over several decades. BNFL had decommissioned two small reactors in the UK, the Scottish Universities' Argonaut reactor at East Kilbride, and ICI's TRIGA reactor at Billingham. Brokks were used at these locations.

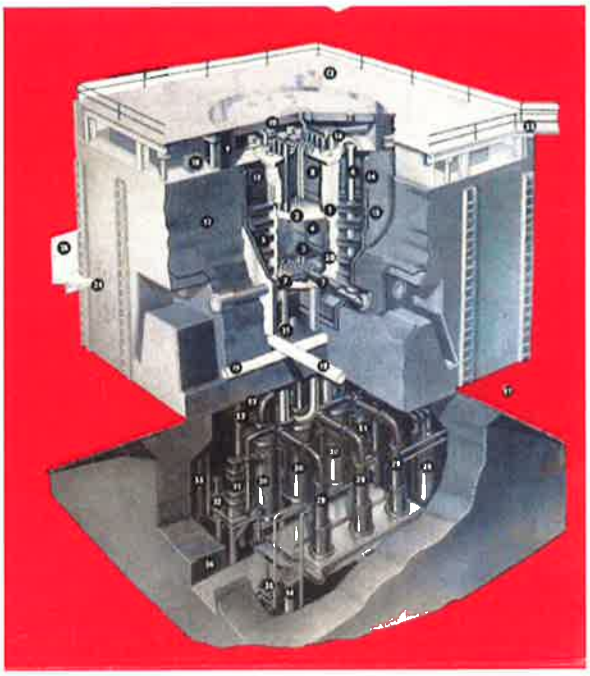
In America, a US DOE Large Scale Demonstrator Project had occurred at ANL's CP-5 reactor, using advanced equipment from other US DOE labs and specialist suppliers. CP-5 was the inspiration for DIDO but only ran at 5 MW, over 25 years. The activity levels did not warrant the use of advanced remote handling but the research work that was published is a useful source for decommissioning projects. Most of the techniques had already been examined and tried in Europe in National Labs or through the CEC's decommissioning or TELEMAN programmes.

CP-5 used Brokk mobile manipulators to demolish the reactor's concrete pedestal, clear away the biological shielding and remove underground embedded steelwork. Brokks have been used in Europe in the nuclear industry since 1970, when the Swedish Royal Institute of Technology used one to decommission their underground R1 reactor in Stockholm. There are now over 3000 Brokks in use in conventional demolition as well as hazardous environment work. There is a nuclear hardened version.

The new approach for Harwell's MTRs is to take advantage of the natural physical weakness of the structure and use a Brokk to excavate the reactor internals from a horizontal pathway. The cut away sections of the reactors show that there are easy access points associated with the horizontal tubes and, for DIDO, the horizontal thermal column. An initial structural assessment indicates that openings can be made through to the Reactor Steel Tank up to 2 m x 2 m without compromising the strength of the remaining biological shielding. The vertical rigs would be withdrawn first, but as some of the horizontal rigs are known to be stuck, they would be removed when exposed, by the Brokk. The base of the plug would be ripped away by the Brokk from below.



DIDO thermal column and H tubes as access routes



PLUTO easily broken-out shielding by H tubes

A set of Decommissioning Principles was generated for the new approach:

- retain the PLUTO AHB for training, mock-up tests and storage;
- build an auxiliary building with craneage, joined to the reactor shell;
- recondition the polar crane;
- recondition the one remaining vertical flask;
- build a shielded separation, segregation and packing station that interfaces with the flask – a new, enhanced View Cell;
- use the flask to remove all vertical rigs;
- coarse-segregate rig components, attempting to separate out long-lived ILW;
- install additional, reusable shielding and containment to extend the reactor biological shielding boundary;
- use Mobile Filtration Units to provide local exhaust ventilation;
- use Modular Containment Systems to supplement containment envelopes;
- use COTS remotely-controlled mobile machines as the major manipulative equipment for decommissioning;
- use COTS cutting equipment for size-reduction and segregation;
- minimise the need for tooling development programmes;
- always trial an operation and train staff before active working, in a proof of principle test area;
- penetrate the bulk biological shielding from the side and directly access the reactor components, possibly using the horizontal beam holes as breakthrough points;
- extract horizontal rigs as they become accessible during reactor dismantling;
- size reduce in situ and remove the structural materials in the reactor and the reactor aluminium tank, possibly including the above-RAT plugs and plates;
- remove inner annular layers of Barytes biological shielding that are ILW and LLW;
- use 2 m shielded boxes and perhaps shielded third height ISO containers for dense and heavy ILW, rather than 4 m boxes;
- ship ILW and LLW containers ungrouted.

The plan submitted to the NDA has been refined, year–on-year. An additional push to quicken the programme in 2006 required MTR decommissioning to be complete by December 2016. This was possible provided Front End Decommissioning Engineering, optioneering and Regulatory engagement started in April 2007. Revised Site funding limits have resulted in delays to this programme. The current programme now shows MTR decommissioning starting some 14 years later.

Brokk applications at CP-5

Nuclear version of the Brokk Mobile Machine

Long Term Care and Surveillance

The Harwell MTRs are in the phase of Surveillance and Maintenance (S&M). They are in a safe and secure state where the radioactive material is managed and the containment envelopes are maintained to ensure that there is no degradation. This does not mean that there is no change, from year to year. The ventilation system that was installed in 1995 keeps humidity and temperature conditions inside the Containment Shells at levels where corrosion within the reactor and rigs will not occur. This system also continually purges the reactors of any evolved tritium which is measured and discharged through a registered point, meeting our Environmental Discharge Authorisation conditions.

The ventilation controllers are several years beyond support from the supplier and will be replaced this year with functionally similar PLCs. Other S&M activities include replacing old refrigerants, carrying out structural surveys within the biological shielding and to the fabric of the Shells. Progressive reduction of loose contamination, removal of asbestos and replacement of VIR-insulated wiring continue. Documentation, plant and decommissioning records are being reviewed so that an integrated, consistent approach to nuclear knowledge management for the Harwell Reactors is achieved, that will last the decades before future decommissioning teams re-form.

Replacement of ozone depleting refrigerant

Structural inspection in the D_2O Plant Room

Structural inspection and maintenance of the Shell

Overview of activities since the final shutdown of the DIDO & PLUTO MTRs

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Dr Ed Abel

Harwell Engineering & Reactors Manager

March 2008

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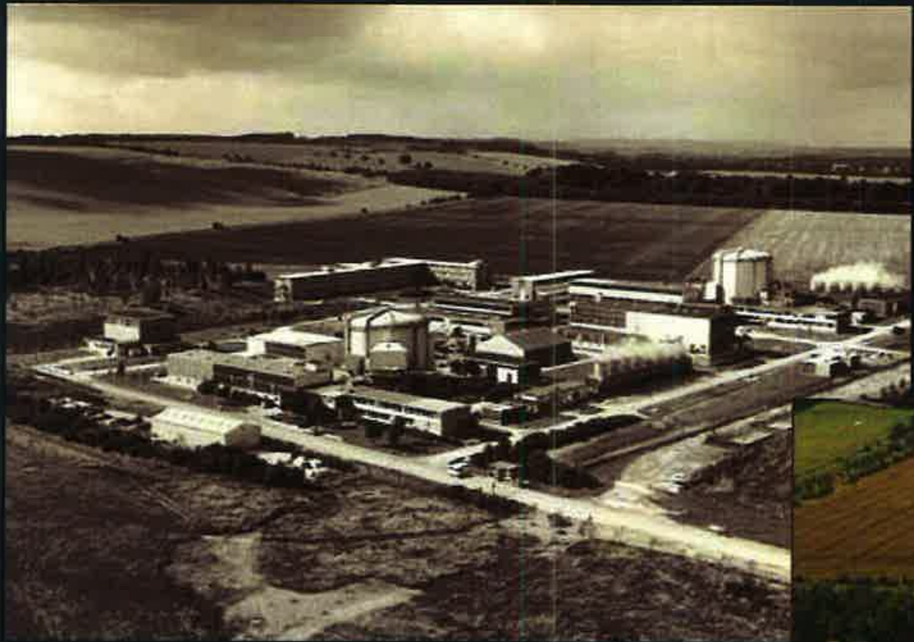
The MTRs in 1967 and 1998



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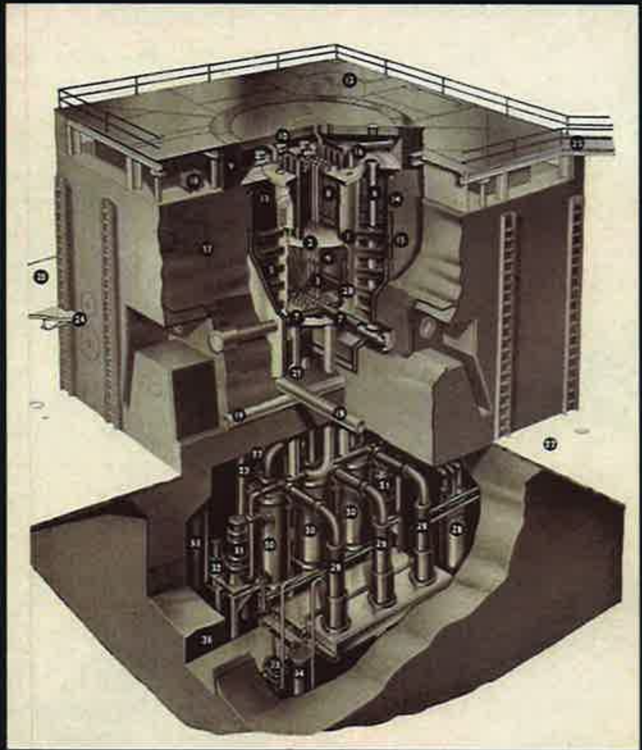
PLUTO



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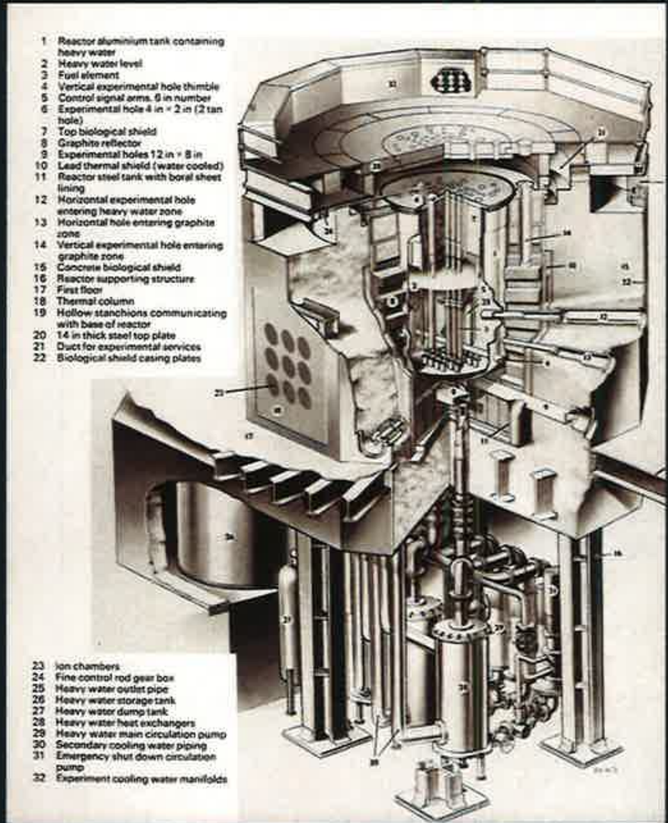
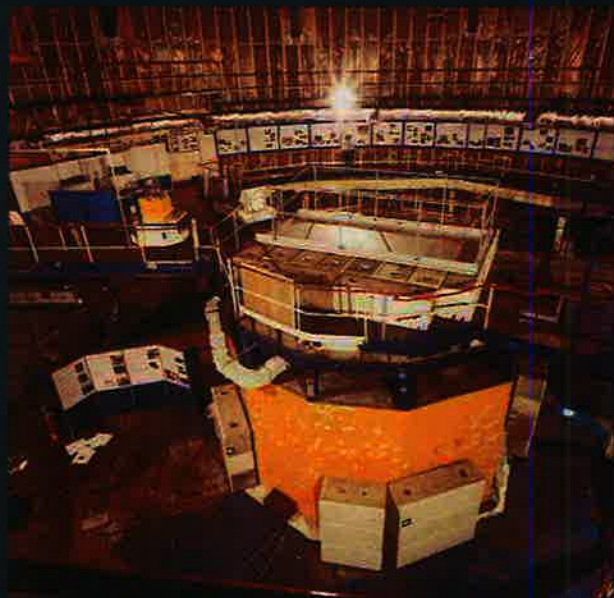
DIDO



1 Reactor aluminium tank containing heavy water
2 Heavy water level
3 Fuel element
4 Vertical experimental hole thimble
5 Control signal arms, 6 in number
6 Experimental hole 4 in × 2 in (2 tan hole)
7 Top biological shield
8 Graphite reflector
9 Experimental holes 12 in × 8 in
10 Lead thermal shield (water cooled)
11 Reactor steel tank with boral sheet lining
12 Horizontal experimental hole entering heavy water zone
13 Horizontal hole entering graphite zone
14 Vertical experimental hole entering graphite zone
15 Concrete biological shield
16 Reactor supporting structure
17 First floor
18 Thermal column
19 Hollow stanchions communicating with base of reactor
20 14 in thick steel top plate
21 Duct for experimental services
22 Biological shield casing plates
23 Ion chambers
24 Fine control rod gear box
25 Heavy water outlet pipe
26 Heavy water storage tank
27 Heavy water dump tank
28 Heavy water heat exchangers
29 Heavy water main circulation pump
30 Secondary cooling water piping
31 Emergency shut down circulation pump
32 Experiment cooling water manifolds



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The three Stages of decommissioning (& sub-phases…)

Stage 1	Phase 1	• Defuel & remove D_2O
		• Remove samples, except cobalt, from rigs
		• Obtain approval for Safety Justification for Phase 2
	Phase 2	• Remove less hazardous secondary systems external to block
		• Obtain approval for Safety Justification for Phase 3
	Phase 3	• Remove remaining Secondary System
		• Unload cobalt from rigs
		• Obtain approval for Safety Justification for Stage 2, Phase 1
Stage 2	Phase 1	• Complete Interim decommissioning & decontamination
		• Decommissioning old ventilation systems and install new ones
		• Obtain approval for Safety Justification for Stage 2, Phase 2
		• Modify Safety Case, reduce category to Safety Category 3
	Phase 2	• Extended Surveillance & Maintenance
Stage 3		• Reduction of reactors' legacy to a delicensed (no harm) state

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Key events in initial decommissioning

EVENT	DATE ACHIEVED	
	DIDO	PLUTO
Decision to shut down	February 1990	October 1989
Reactor shut down	31 March 1990	
Fuel unloaded	April 1990	
Fuel transferred to B466	June 1990	
D2O drained into drums	May 1990	
Completion of fuel dispatch for reprocessing	Sep 1990	
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Rigs in final storage positions	January 1993	February 1994
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Cobalt pencils disposal programme complete	NA	February 1995
New ventilation system installed	March 1995	
HAHC demolished	31 August 1994	N/A
Cranes and VALs disabled	November 1994	September 1995

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Removing the Cooling Towers

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Demolishing the Flight Tube & Block House

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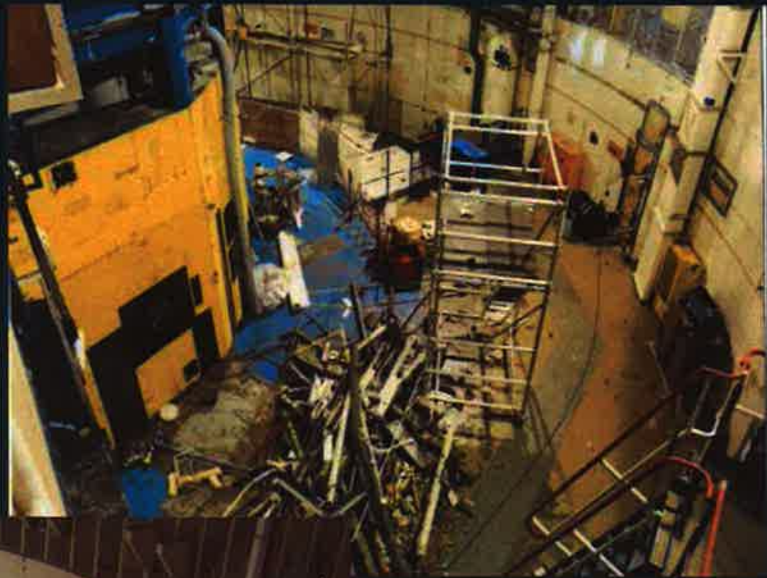
Clearing away internal structures, services & equipment



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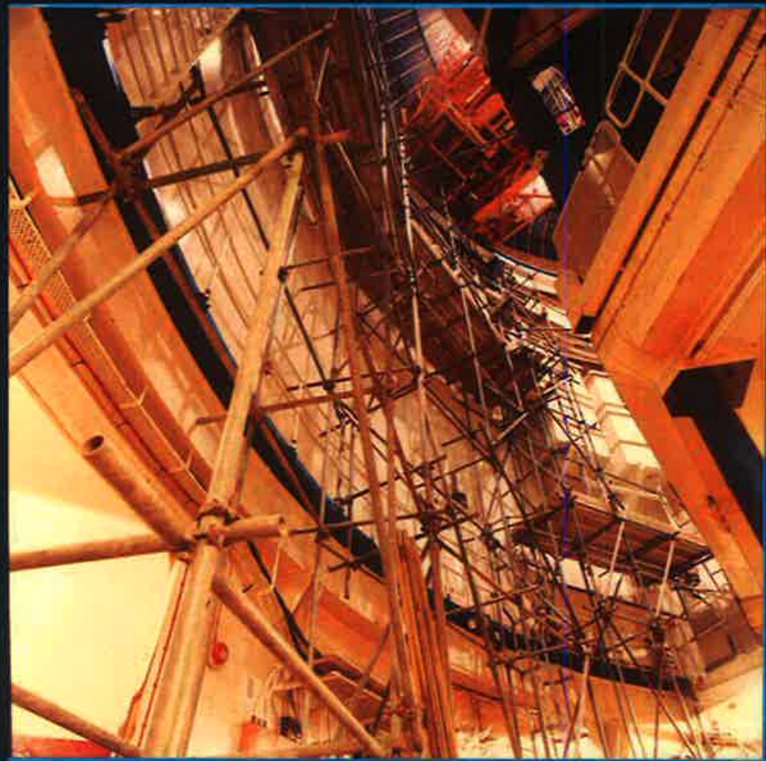
Air Heater removal and clearance & monitoring



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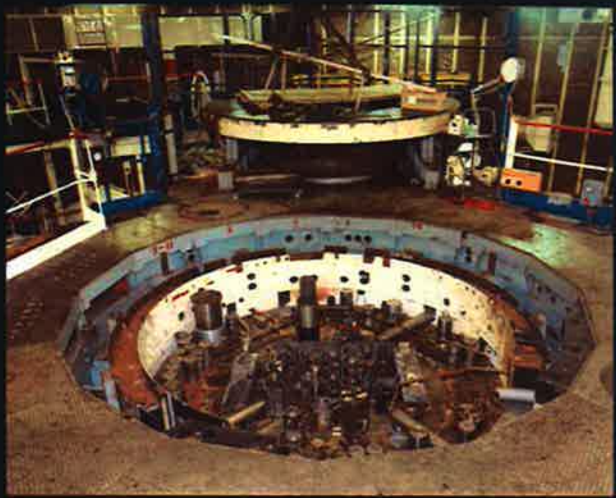
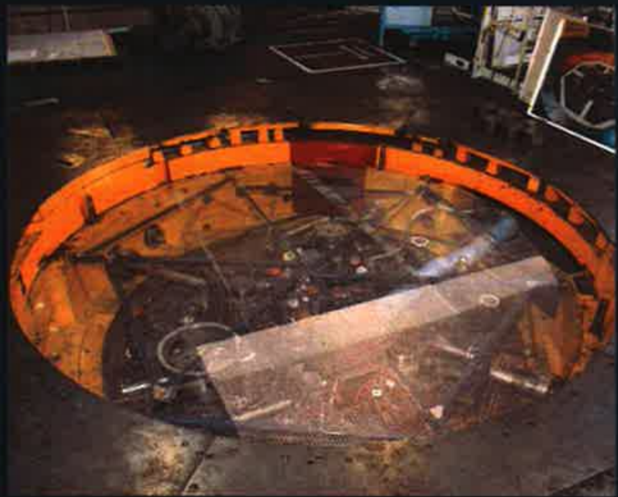
Closing up the reactor tops





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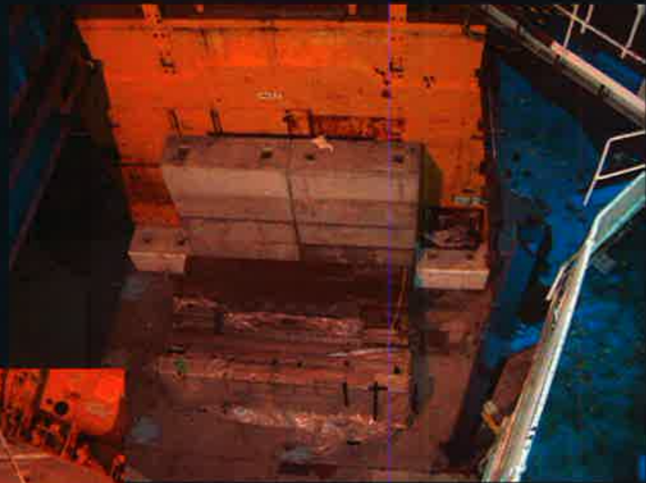
External Storage Block – bits are still with us



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Demolishing the DIDO AHB

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Demolishing the DIDO Office Block

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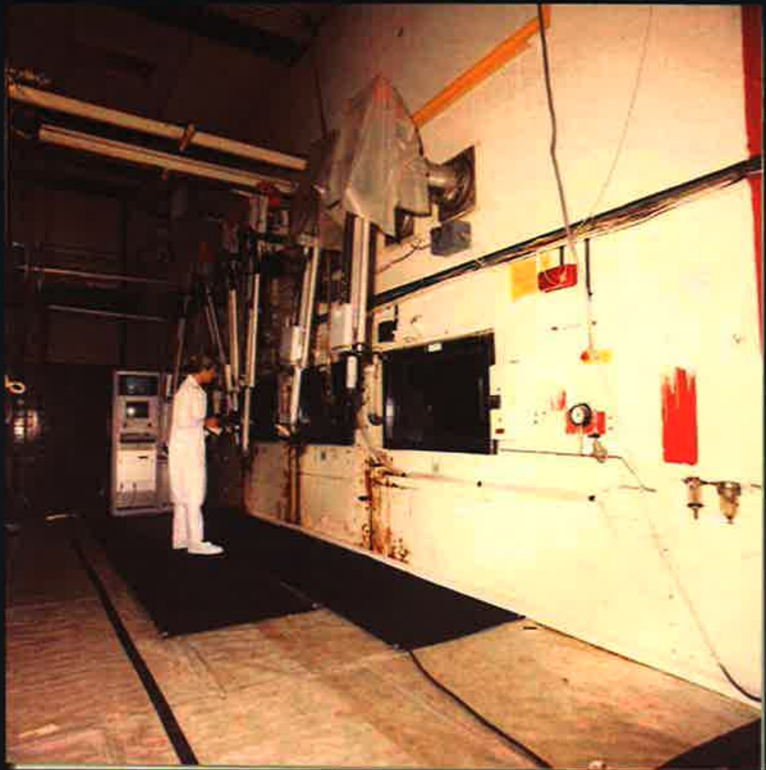
The DIDO High Activity Handling Cell (HAHC)



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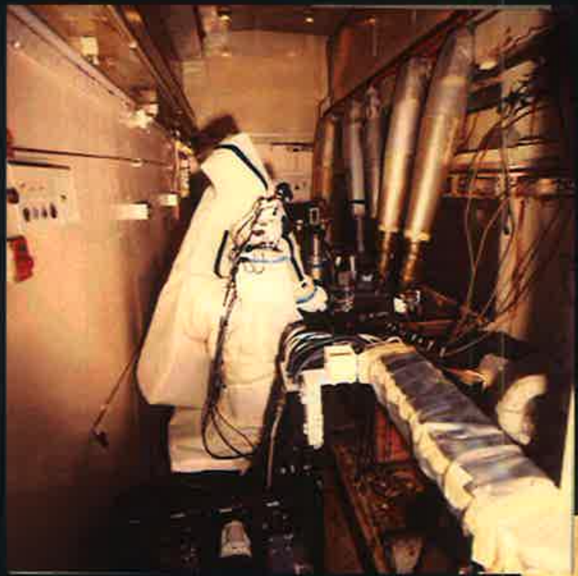
NEATER size-reduces in-cell furniture



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NEATER cleans up

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HAHC demolition – sand and flame cutting

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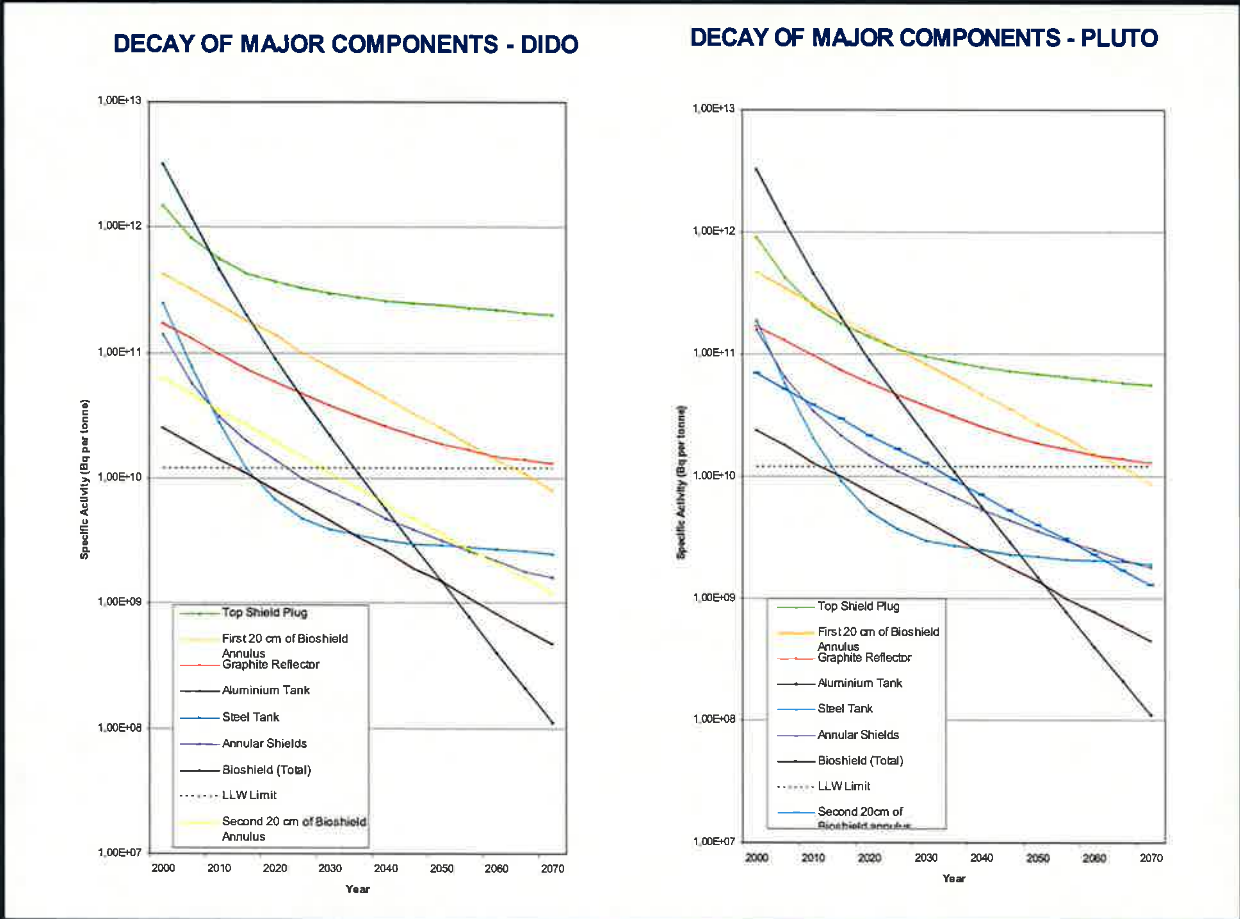
Accelerated Decommissioning vs half life?



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No space to move in a 2 m RAT

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BNFL uses Brokks for small reactor decommissioning

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ANL's Chicago Pile – 5, the idea behind DIDO

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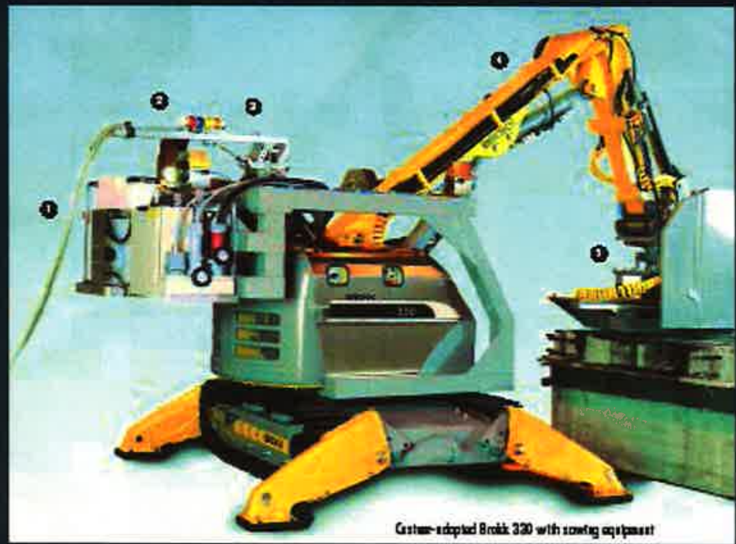
Brokks at ANL, CP-5, & radiation tolerant version



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Tracked Brokk & multi-tool dispensing!

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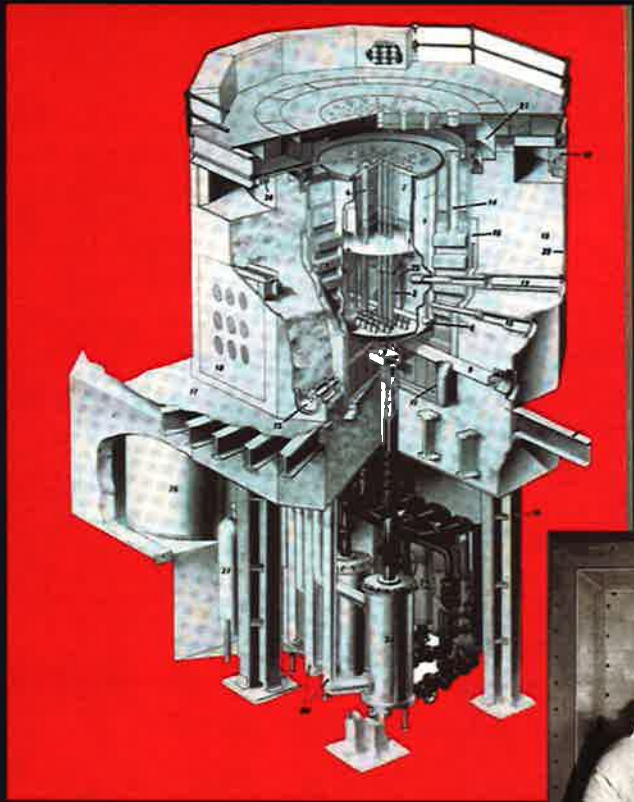
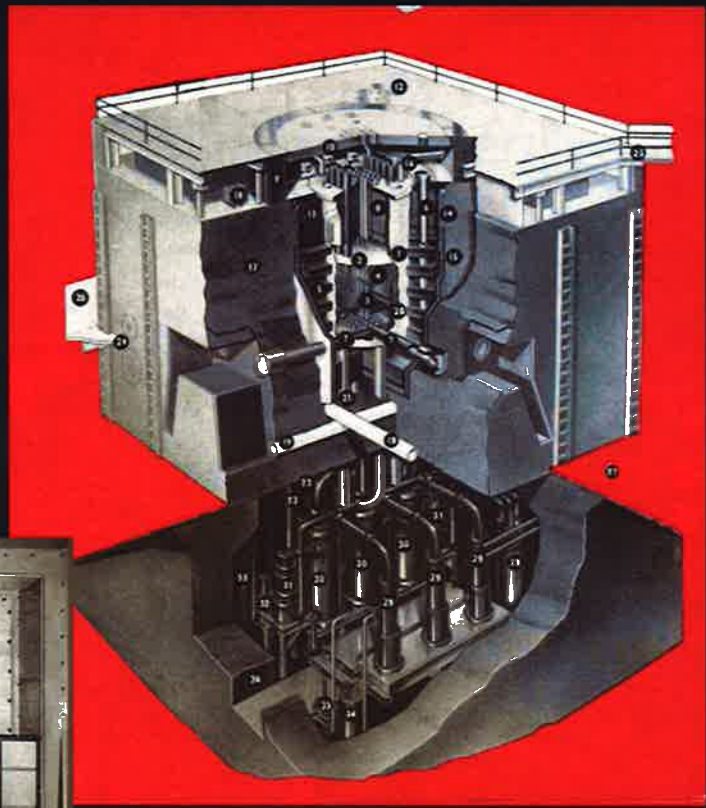
Horizontal access for decommissioning





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Surveillance & Maintenance

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DIDO today

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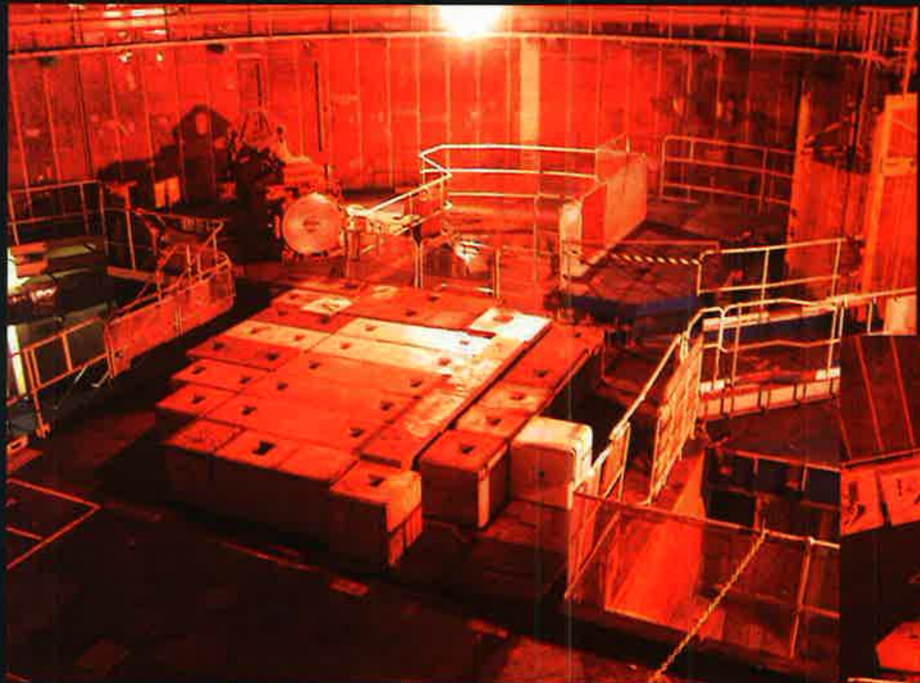
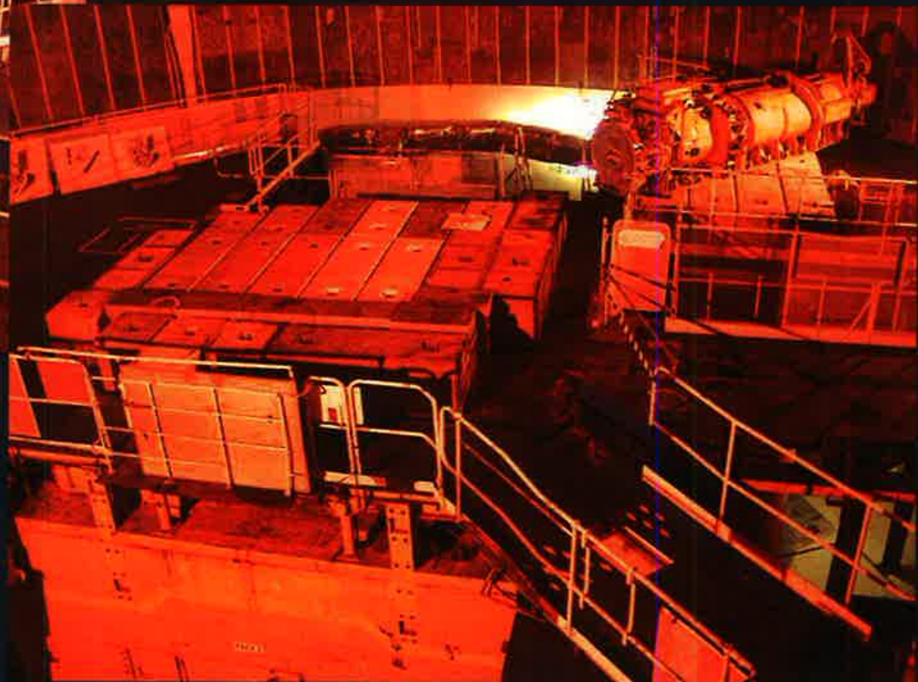
PLUTO today





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