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Operational experience of decommissioning techniques for research reactors in the United Kingdom

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Abstract. In previous co-ordinated research projects (CRP) conducted by the IAEA no distinction was made between decommissioning activities carried out at nuclear power plants, research reactors or nuclear fuel cycle facilities. As experience was gained and technology advanced it became clear that decommissioning of research reactors had certain specific characteristics which needed a dedicated approach. It was within this context that a CRP on Decommissioning Techniques for Research Reactors was launched and conducted by the IAEA from 1997 to 2001. This paper considers the experience gained from the decommissioning of two research reactors during the course of the CRP namely: (a) the ICI Triga Mk I reactor at Billingham UK which was largely complete by the end of the research project and (b) the Argonaut 100 reactor at the Scottish Universities Research and Reactor centre at East Kilbride in Scotland which is currently is the early stages of dismantling/site operations. It is the intention of this paper with reference to the two case studies outlined above to compare the actual implementation of these works against the original proposals and identify areas that were found to be problematical and/or identify any lessons learnt.

Introduction

In total there were 36 Research reactors constructed in the UK over an approximate 30 year period, ranging from the late 1940's to the early 1970's. These reactors covered a diverse range of types and sizes as well as a number of different operators. The majority of these reactors have reached the end of their useful life and have been progressively shutdown over the past 20 years leaving only a small number that are operational today.

As with most countries attention has more recently turned to the decommissioning of these historical facilities although within the UK a range of approaches is being considered as a direct consequence of the differing technical complexities, commercial considerations and individual operator strategy. A number of facilities have opted for prompt decommissioning including the Windscale AGR, the Universities Research reactor (URR) and the Jason Reactor at Greenwich. In the case of the URR the project was successfully complete in 1996 with the delicensing of the site and the subsequent sale of the land for commercial, non-nuclear redevelopment. Alternatively certain facilities, albeit generally larger, have opted for a longer term care and maintenance approach similar to that proposed for the Magnox nuclear power plants.

Considering the range of research reactors within the UK and consequently the varied approach to decommissioning strategy BNFL were delighted to participate in the IAEA CRP on Decommissioning Techniques for Research reactors and help facilitate the exchange of practical experience gained by Member States in this field to date.

Objective

As previously highlighted the emphasis of the CRP was to concentrate on the practical experience gained by the Member States from the real-scale application of decommissioning techniques on a diverse range of facilities. Throughout the course of the CRP programme (1997 to 2001) BNFL were engaged on fixed price contracts to decommission two research reactors within the UK namely the ICI TRIGA Reactor at ICI Billingham and the Argonaut 100 Reactor at the Scottish Universities Research Centre at East Kilbride.

Fortunately the respective contracts were at different stages of execution within the window of the CRP and allowed all aspects of the project life cycle to be captured, from initial concept design through safety justification to actual implementation works including defuelling, core dismantling and removal of all activated material in preparation for delicensing. It is the objective of this paper , with reference to the two case studies outlined above, to compare the actual implementation of these works against the original proposals and identify areas that were found to be problematical and/or identify any lessons learnt.

Case Study 1 - Decommissioning ICI Triga Mk I Reactor

1. Introduction

The ICI Triga reactor was located at Billingham, Cleveland and was used as a source of neutrons predominately for activation analysis and the commercial production of radioactive tracers.

The Mk 1 Triga was a pool reactor which operated at powers up to 250kW, using a Zirconium Hydride moderated fuel containing 8.5wt% uranium at 20% enrichment. It was commissioned in 1971 and operated until 1996. BNFL were initially awarded a contract to de-fuel the reactor and remove the activated components and ancillary equipment, leaving the reactor vessel and concrete containment intact. Subsequent to the completion of these works the contract with BNFL was extended to remove the remaining tank and concrete foundations. With the ultimate aim being to de-license the site ICI have decided to let a further third contract to BNFL to totally demolish the remaining reactor building and associated laboratories/offices.

2. Scope of work

BNFL were awarded the contract to de-fuel the reactor and remove all the activated components in February 1996. Together with the subsequent contracts the total scope of works included: -

- Development of the optimum decommissioning methodology, associated detailed design and all supporting technical justification/calculations.
- Provision of the Pre-Decommissioning Safety Reports (PDSR) and all associated safety documentation, assessments, method statements etc.
- Licensing of the fuel transfer flask
- Procurement, fabrication or provision of all the necessary equipment to support the decommissioning
- Execution of all necessary commissioning and training.
- Assistance in seeking authorization from the necessary Regulatory Authorities
- De-fuelling of the reactor

- Removal of reactor Intermediate Level Waste components
- Removal of reactor Low Level Waste components and free release waste
- Removal of the Reactor Tank and foundation concrete.
- Demolition of the reactor building, associated laboratories and offices
- Radioactive waste disposal on a fixed price basis
- Final radiological survey

3. Development of the optimum decommissioning strategy

A number of decommissioning schemes were assessed at each stage in order to determine the optimum methodology for decommissioning the ICI Triga Reactor. Design concepts were developed in parallel with the production of radiological, criticality and industrial safety assessments.

A number of factors influenced the eventual choice of preferred decommissioning methodology and this decision making process was assisted by a series of detailed HAZOP[1] Studies. These studies were undertaken with a broad representation of personnel including individuals from both BNFL and ICI to ensure that decommissioning as well as facility/operation perspectives would be applied to each problem. The main issues affecting the preferred reactor decommissioning methodology were:

- The final fuel destination was undecided at the time. A methodology was required which retained sufficient flexibility to be compatible with both UKAEA Dounreay or the USA.
- The estimated categorization of the various wastes that would be produced during the course of the decommissioning operations and their necessary condition on acceptance e.g. no free liquids.
- The physical size of the Reactor Hall was very restrictive. The limited number of viable mechanisms for the movement of transport flasks (of gross weights up to 20 tonnes) proved central to the eventual methodology. It should be noted that due to the loads involved extensive assessment of the reactor hall floor structural capability was undertaken with subsequent remedial/strengthening operations conducted in anticipation of the flasks being brought onto site.
- The Licensed Site boundary was located at a distance of only seven metres from the reactor tank. All operations needed to be conducted in a manner that minimized the dose rate to employees and the public (UK limit of 7.5S μSv/hr at a nuclear site boundary was mandatory).
- The Licensed Site was also located within only a short distance from local schools and shops. This imposed further restrictions in terms of the permissible potential accident scenarios. The potential for an off site occurrence, as a result of any of the decommissioning operations, had to be 'engineered out'.

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[1] A Hazard and Operability study (HAZOP) involves suitably qualified and experienced people in a systematic process that is aimed at identifying both safety and operability hazards associated with the design, construction or decommissioning of any plant or process. It is a process of examination that is prompted by the use of selected guidewords and can be applied to almost any situation or set of circumstances.

- With a view to minimising the off site implications, together with the lack of suitable facilities on the site BNFL endeavoured to keep any size reduction operations to the absolute minimum.
- Considering the relatively low radiological hazard from the reactor tank and concrete foundations removal the industrial safety hazards of the proposed methodology was the primary concern. The client was very keen to minimize (or totally prevent if possible) man entry into the reactor tank and avoid all the potential hazards of confined space working.
- Also critical to the removal of the reactor tank and foundation concrete was the structural stability of the bio-shield, both during and after completion of the works. The inherent stability of the structure throughout the operation was critical to the whole concept of activated concrete removal, and therefore a detailed structural analysis needed to be performed on each potential option.

The schemes which best satisfied the above criteria, together with all the other issues resulting from the HAZOP Studies, were developed further into an engineered solution. The detailed design was co-ordinated via a dedicated design engineer who acted as a single point of contact for all such issues to ensure each interface was well defined. Having reviewed this developed scope of work, and in order to facilitate the regulatory approval process, BNFL proposed to divide the decommissioning programme into a number of discrete stages of work (see below).

4. Safety documentation

The principle document justifying the overall decommissioning approach at each stage was the Pre-Decommissioning Safety Report (PDSR). The safety case strategy was agreed as early as possible through a series of meetings conducted at ICI and importantly was developed in parallel with the preferred design solutions that resulted from the above. As with the design it was considered essential to form an integrated team comprising personnel from both BNFL and ICI. A dedicated BNFL Safety Advisor was appointed to co-ordinate the many parallel activities and provided assistance to the Project Team. Every safety case author was encouraged to attend all the HAZOP studies to ensure a thorough understanding of the project and subsequent to these meetings regular contact was maintained with the Project Team. It was insisted that draft sections of the document were issued throughout production to ensure that the correct operational information was included within the safety case as well as allowing the Project Team to brief the ICI Site Management on overall and specific issues. This document was ultimately submitted to the ICI Nuclear Safety Committee and subsequently the Nuclear Installations Inspectorate for approval.

The other supporting documentation including Method Statements, Risk Assessments and Manual Handling Assessments were produced by personnel directly involved with the proposed work on site. The Project Manager considered that this was the only manner in which a full appreciation of the activities could be gained as well as ensuring that the project personnel became fully familiar with the scope of work and decommissioning strategy.

5. Stage 1 – preparatory works

5.1. Decommissioning authorizations

Regulatory approval proved to be one of the more time consuming exercizes. The major regulatory bodies involved in the decommissioning process were:

- the Nuclear Installations Inspectorate (NII), - involved with all aspects of the decommissioning programme. Agreement was required before any works could proceed
- the Environment Agency (EA), - involved with all activities involving the transportation and disposal/discharge of solid, liquid or gaseous wastes
- the Department for the Environment, Transport and Regions (DETR), - involved with issuing flask licences to allow transportation of the fuel and intermediate level waste.

The latter two issues led to a number of problems in achieving the project timescales (see Programme and Performance).

5.2. Commissioning and training

To fully test all equipment complete in-active simulation of the proposed decommissioning operations was undertaken off the ICI site utilising a flooded pit to recreate the reactor tank. This enabled load and functional testing of all manufactured equipment prior to transportation to ICI. All significant operations were trialled under the supervision of both BNFL and ICI to ensure functionality and ascertain compatibility with the reactor site. Although a minor number of changes were implemented at this stage which could have caused significant delays if encountered later on the ICI site.

Following off-site commissioning the equipment was installed within the ICI reactor hall. To facilitate this second stage of commissioning the fuel flask and necessary cranes were also delivered to the site. Full inactive commissioning was satisfactorily completed using a 'dummy' fuel element. These operations were also utilized as a training exercize and consequently all personnel identified to undertake actual operations were involved throughout commissioning to ensure a complete understanding and familiarity of the equipment and processes involved. During the course of the commissioning a number of minor improvements were implemented which simplified the eventual operations as well as contributing to significant radiological dose uptake reductions. Formal approval of the on-site commissioning was required by the NII before de-fuelling operations could commence.

6. Stage 2 – reactor de-fuelling

The reactor was defuelled utilising a cylindrical transport flask (Modular Flask) positioned directly above the reactor tank. A support frame was manufactured to provide secondary support to this flask (to ensure integrity in the event of a dropped load) in addition to a Lift and Carry Mobile Crane. This support frame also provided shielding in the form of steel and lead collimators which extended into the reactor tank water. The fuel was loaded into a purpose built fuel basket (to cater for either fuel elements and/or longer fuel followed control rods), positioned within the reactor tank next to the reactor core. When full the fuel basket was hoisted directly into the transport flask for onward shipment within a dedicated 'overpack'. The reactor had an inventory of 86 fuel elements and three control rods - hence seven transport shipments in total were required. This stage was successfully completed by December 1998 within the site programme and well below the predicted dose uptake.

A formal report of the initial shipment, comparing planned with actual operations, was required by the NII before authorization was granted to continue with the defuelling programme.

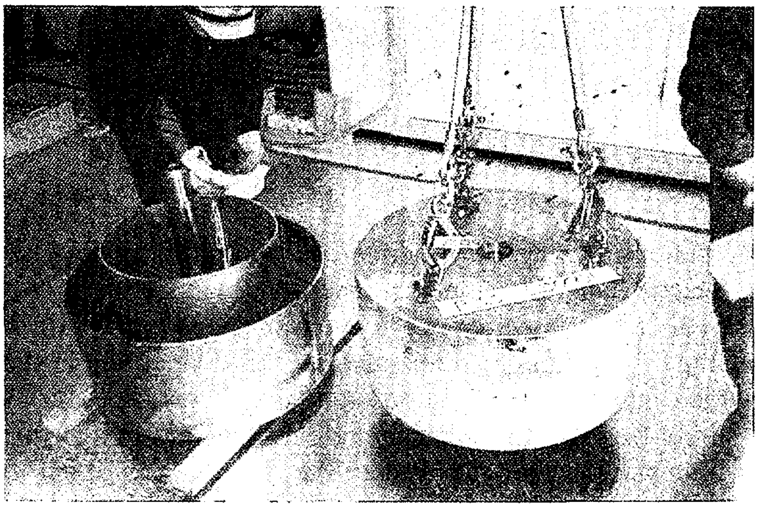
7. Stage 3 – intermediate level waste (ILW) removal

This stage constituted removal of all the ILW components of the reactor namely all the stainless steel items positioned close to the reactor core. These consisted primarily of research equipment such as the Rotary Specimen Rack (RSR) and Argon activation vessels.

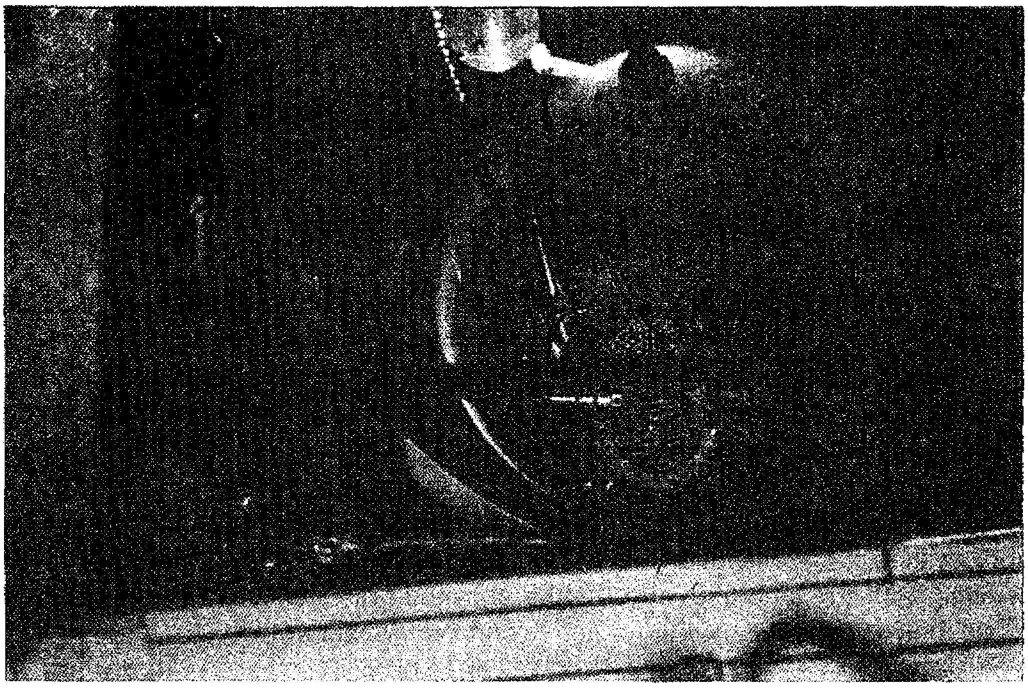
A purpose built shielded container was designed and built specifically for the removal and disposal of this waste. The steel container incorporating lead shielding top and bottom included two concentric areas for waste and was positioned on the in-tank frame located next to the reactor core.

The principle issue to be considered with the eventual disposal of these items was to comply with the requirement of the waste plant operator to ensure that all consignments were devoid of any free liquid. This created a significant problem with the disconnection of the air filled RSR under water. A number of sealing methods were tested at the design phase although in order to guarantee that no liquid was present it was decided to grout the RSR in situ.

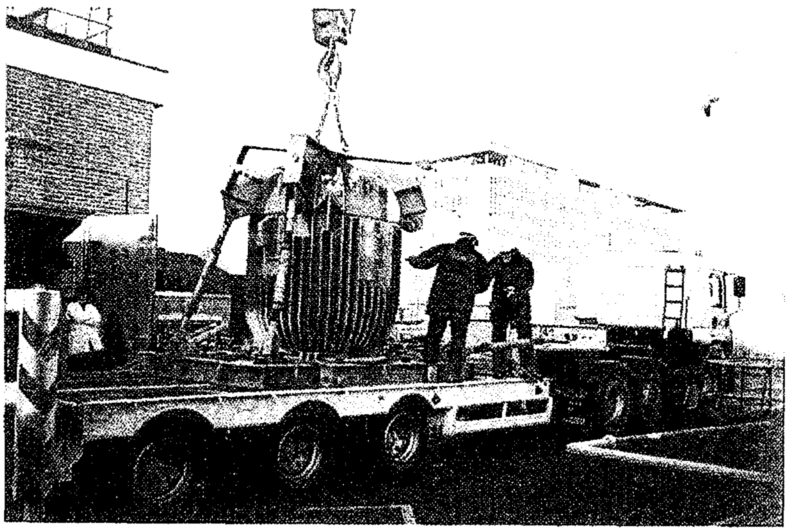
Once grouted the RSR was then allowed to cure/harden before the two connections were sheared with a hydraulic cropper. Following hydraulic cropping of the RSR connections the inner section of the container was loaded with the remaining identified components following remote size reduction with hydraulic croppers where necessary.



COMMISSIONING OF ILW CONTAINER



CROPPING OF ILW ITEMS INTO ILW CONTAINER



UNIFETCH FLASK LOADED ONTO TRANSPORTER

The support frame positioned above the reactor tank was complemented by the addition of a transfer shield. The shielded container was then removed from the reactor tank using a mobile crane. During removal, the container mated with the transfer shield to allow safe movement of the package to a Unifetch transport flask. On 27 January 1999 the waste was successfully transferred to Sellafield for interim storage pending ultimate disposal.

8. Stage 4 – removal of low level reactor waste

The remaining waste consisted primarily of the aluminium clad graphite reflector, primary and secondary cooling systems and experimental facilities such as rabbit systems etc. These items were dismantled and placed directly into a $10m^3$ ISO skip for grouting and disposal at the Drigg Low Level Waste (LLW) Repository.

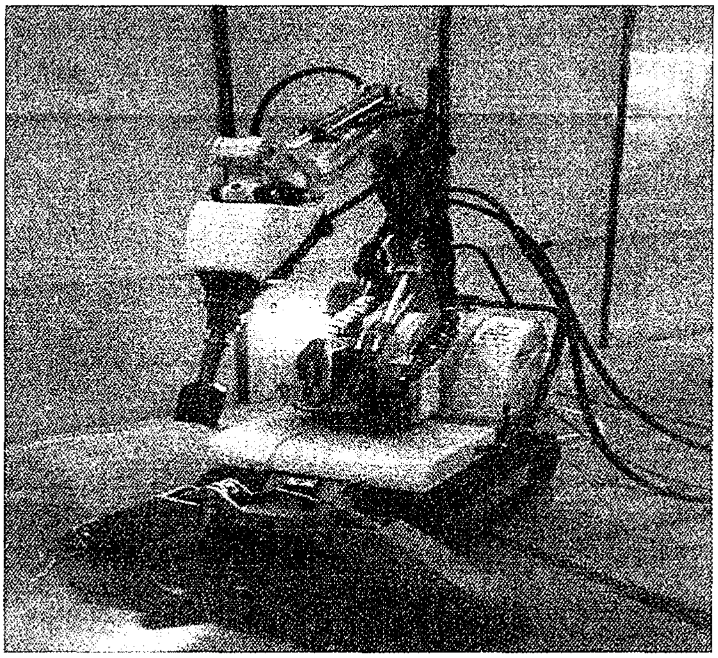
This task was successfully completed with receipt of the waste consignment at Drigg on 17 February 1999.

9. Stage 5 – removal of reactor tank and foundation concrete

As previously mentioned the client was very keen to avoid entry into the tank because of the potential risks of confined space working and therefore strongly favoured the remote solution offered by using a Brokk Minicut. This mini-excavator could be operated, via the use of cameras, from outside the tank and could undertake all the necessary tasks involved i.e. concrete breaking, cutting metal components and waste removal

In preparation for the task a modular containment, modified lifting equipment and a dedicated ventilation system was installed over the drained reactor tank. Once this had been commissioned both the tank and surrounding concrete was subjected to extensive sampling and analysis to determine the profile for active concrete breakout.

The first operation to be performed was the removal of the aluminium tank walls up to 2m from the tank base. Specially selected cutting discs were acquired and adapted to be compatible with the Brokk Minicut. When all of the tank wall aluminium was successfully removed concrete breakout commenced. – see below. The depth of breakout was routinely checked using a standard laser distance-measuring device.

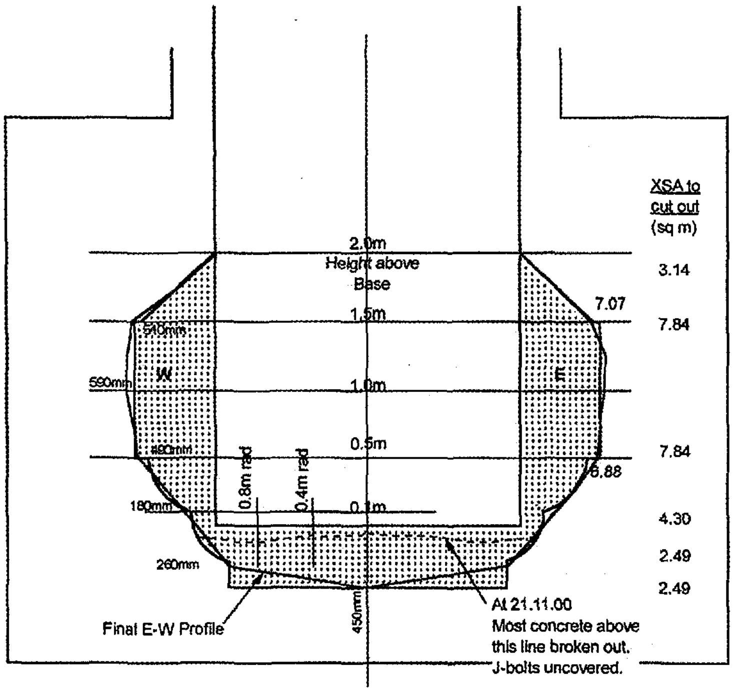


BROKK MINICUT WITH CONCRETE BREAKER

9.1. Base removal

When it was deemed that sufficient concrete had been removed from the walls, the aluminium base was removed with the grinding attachment. Once the tank base was removed the concrete was broken out as before.

The profile of the broken out concrete is shown on the drawing below. The final profile matches the original proposed breakout profile, except at the outer extremities of the base.



FINAL CONCRETE BREAKOUT PROFILE AGAINST PROPOSED PROFILE

10. Programme and performance

An interesting feature of the programme shows that the original timescales allocated for the application/granting of the necessary regulatory approvals were consistently underestimated. This was particularly evident in the case flask licensing which needed to be completed by the owners of the fuel flask. Not only was this task started late due to the prolonged decision making process on the final destination of the fuel and consequently which flask to use, the duration of licensing itself exceeded the original estimate by over 50%.

Apart from the above the two primary issues were the unforeseen requirement for reinforcement of the reactor hall floor and ICI's major uncertainty with the ultimate fuel destination. There were two final possible destinations available (Dounreay and the USA) and in order to retain flexibility ICI wished the development of a scheme compatible with both. This necessitated the review of the proposed scheme, required additional design effort/time and the nomination of a new fuel flask to ensure that this compatibility was maintained. When the decision to dispatch to the US was made BNFL agreed to arrange interim storage of the fuel as an extension to contract pending the eventual onward transfer. This change of scope further delayed the original project programme whilst an application for regulatory approval was submitted to support this new requirement for interim fuel storage.

Once the above issues had been resolved which significantly lengthened the preparatory works programme the actual site works were completed in a shorter timescale than originally anticipated i.e. 20 weeks as opposed to 26 weeks. This trouble free implementation is deemed to be a direct consequence of the considerable time and effort that was dedicated during the design development, safety case preparation and commissioning.

With respect to the removal of the aluminium tank and concrete the initial works proceeded as programmed although there were a few minor difficulties with the aluminium tank. The major issue was that actual concrete breakout rate was considerably lower than rate derived from the inactive trials. On investigation this was attributed to the specific nature of the reactor concrete.

11. Safety

11.1. Radiological dose uptake & health physics data

As can be seen from below there was a significant difference between the predicted and actual total project dose uptakes of 19.98 mSv and 1.57 mSv respectively. One explanation is that defuelling was considerably delayed hence the fuel had experienced far greater cooling. Other factors included over estimating working times and using worst case activation levels. However this dose uptake still compares very favourably with all previous decommissioning projects of this complexity and emphasizes the importance of developing the design in parallel with the safety cases, rigorous training/commissioning and strict supervision. With respect to the tank and foundation concrete dose measurements taken after removal of the reactor demonstrated that there was no significant radiological hazard. This was confirmed by actual dose measurement during operations.

11.2. Potential accident scenarios

Following the extensive HAZOP studies three potential accident scenarios could not be discounted and needed to be further addressed in order to justify the safety of the project as a whole.

ACTUAL VS PREDICTED RADIOLOGICAL DOSE UPTAKE

TASK	ACTUAL DOSE /mSv	PREDICTED DOSE [2] /mSv
Stage 1		
Site Preparation and Inactive Commissioning	0.054	1.15
Stage 2		
Active Commissioning and Reactor Defuelling	0.239	5.65
Stage 3		
ILW Removal Operations	0.058	6.21
Stage 4		
LLW Removal Operations	1.219	6.97
Total Dose Uptake	**1.570**	**19.98**

[2] Predicted Dose based on Pre-Decommissioning Safety Report - Dose Assessment - April 1997 - Based on decommissioning operations commencing March 1998

These comprized:

- Possible dropping and damage to the ILW container shielding on transfer to the Unifetch Flask.
- Possible damage to the graphite reflector leading to the possibility of Carbon 14 contamination
- Accidental damage to the core by a falling fuel flask (weight c. 10 Te).

These scenarios each required extensive modelling and assessment to justify the ultimate safety of the proposed decommissioning approach. Each assessment resulted in key amendments to the detailed to ensure that all the necessary criteria were met.

11.3. Conventional safety

The main conventional safety hazards were identified as water hazards, electrocution, moving machinery, work at height, possible confined spaces and lifting and handling operations. In conjunction with ICI, BNFL ensured that all individuals involved with the project were suitably qualified and experienced for each specific task. In addition for each task detailed method statements, incorporating risk assessments were generated by the individuals involved and submitted to ICI for approval before commencement of any works.

11.4. Safety performance

No injuries or accidents occurred to any member of the decommissioning team including BNFL, ICI and contract personnel. This was directly attributable to the planning which took place, particularly during the design and commissioning of the equipment, combined with the training regimes all employees underwent.

12. Project management & resourcing

The development of an integrated project management team was considered to be one of the most important contributing factors to the overall success of the project. The core project team was very small (3 BNFL and only 1 full time ICI) and hence all support from both organizations was very focused and well co-ordinated., It was considered imperative that the same team was maintained throughout the life of the project, from design through to implementation, and that each individual was involved with every aspect of the project development. The small, dedicated, team also promoted an in depth understanding of the project strategy from conception, provided an appreciation of how/why the proposed decommissioning methodology had been developed and a detailed knowledge of the proposed implementation. In addition, because the team incorporated both BNFL and ICI personnel, with specialist support resources where necessary every task was considered from a range of perspectives and hence ensured that each task could be successfully implemented on the ICI site.

A close working relationship was developed within the integrated management team as both parties had the fundamental priority of completing the project safely. This helped move BNFL/ICI away from a contractually based approach and allowed a greater flexibility with respect to the deliverables and accountabilities of both organizations. This working relationship built on trust and honesty was mutually beneficial and promoted the single commitment towards safe and effective project delivery. Such a relationship was considered essential to the success of this project.

13. Current status and further work

The ultimate aim of ICI, the client, is to de-license the site. During discussions with the NII, it was decided that the only sensible way to satisfy all the necessary criteria would be to totally demolish the facility. Consequently a third contract has recently been awarded to BNFL to demolish the reactor building, associated laboratories and offices.

The current indicative programme is as follows:

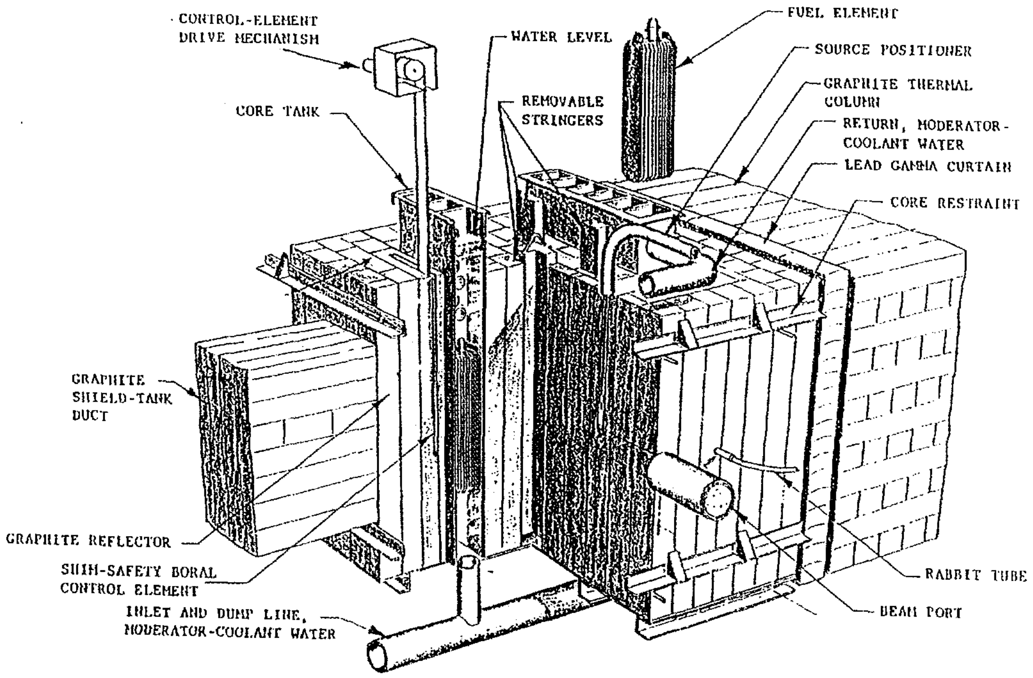
Preparation of safety documentation — June–October 2001
Soft strip building — January 2002–June2002
Demolish building August 2002
Final surveys application to de-license March 2003

Case Study 2 - Decommissioning of the Scottish Universities Research Reactor (SURR)

1. Introduction

The Scottish Universities Research Reactor (SURR) is owned by the universities of Glasgow, Edinburgh and Strathclyde and is situated at East Kilbride, Glasgow. The UTR Type Reactor first went critical in 1963 with a maximum power of 100KW although it was up-rated to 300KW in the early 1970s. In the early 1990s a decision was made to decommission the reactor and demolish the reactor hall with the ultimate objective of de-licensing the site. The reactor was defuelled in January 1996 and a large Co-60 irradiation source was removed in early 1999 (by BNFL under a previous contract). SURR conducted a competitive tender evaluation to complete the remaining decommissioning and awarded a contract to BNFL to undertake these works in May 1999.

The reactor core consists of a carbon stack in which are embedded two parallel core tanks, which previously contained the fuel around which water circulated (see diagram below). The water was returned to a dump tank adjacent to the reactor. The whole reactor is contained within a reinforced concrete bio-shield.



SECTION THROUGH THE REACTOR CORE

2. Scope of work and proposed methodology

Principally the required scope of the project and the proposed methodology can be defined in following main areas of work:

- Safety justifications and supporting documentation/evidence
- Preparatory work including installation of flexible containment system suspended from roof structure of reactor hall with dedicated ventilation/filtration system.
- Remove free release concrete from outer faces of reactor monolith using Brokk 330 (to minimize the risk of cross contamination from later LLW removal).
- Remove shield blocks and graphite using Brokk and gantry crane.
- Remove ILW using Brokk, Mini Cut and specially designed cutting tool.
- Break out remaining LLW concrete and foundations.
- Strip out active ventilation and drain lines.
- Demolish, undertake comprehensive radiological survey and de-licence

3. Development of the optimum decommissioning strategy

From the radiological data supplied by the client tender stage one of the initial tasks of the project was to undertake extensive sampling and analysis to characterize all resulting wastes. One of the more significant requirements was to identify the boundary between free release waste (FRW) concrete and low level waste (LLW) within the concrete monolith. The method utilized was to remove/analyse a series concrete cores from the outside face of the bio-shield. Extrapolation of these results was further supported by a number of physical samples obtained from the inside faces. Based on these estimates, the waste was split into three categories: -

(a) Free release waste, estimated to be the outer 1-1.5m of the concrete bio-shield.

(b) Low level waste (LLW), the remainder of the concrete bio-shield, the graphite from the core and thermal columns, and miscellaneous aluminium pipe-work within the concrete.

(c) Intermediate level waste (ILW), principally all the steel components with in the reactor core.

The methodology was based around a remotely operated vehicle, in this case a Brokk 330, with various tools used to remove the reactor components. The strategy adopted was to remove the FRW before activated material to avoid cross contamination. A primary containment was required to prevent spread of contamination during active operations.

4. Safety documentation

The Pre Decommissioning Safety Report was again the principal safety document and was supported by the necessary design justification reports. In the particular case of the ventilation design the design engineer attended the HAZOP meetings and provided the safety case writer with relevant technical information.

To ensure continuity of work a separate sub- safety case was produced to justify erection of the containment structure in advance of the main PDSR.

The project team also produced a series of method statements and risk assessments to support all the installation activities and commissioning documents were produced to control testing of the installed plant and equipment. All of this documentation was presented to the SURRC Nuclear Safety Committee and subsequently the NII for approval.

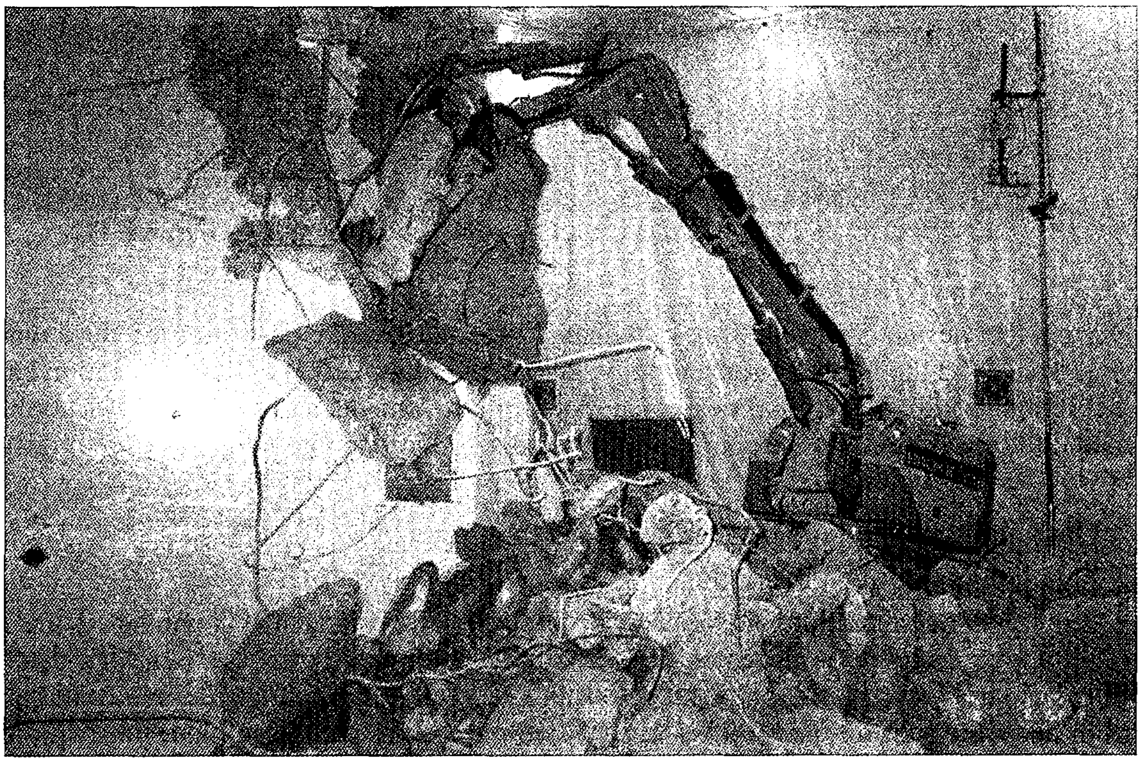
5. REGULATORY AUTHORIZATIONS

As explained in Case Study 1 the principle UK Regulators were the NII. The necessary NII approvals to proceed were obtained as required although this is largely attributed to early and regular contact between the NII and the client. The client again included BNFL staff in all Regulatory discussions which ensured an essential level of mutual understanding.

Because of the geographic location waste authorizations were undertaken by the Scottish Environmental Protection Agency (SEPA). Unfortunately these became a critical programme issue with their expected granting to take in excess of twice the programmed duration of 15 months. Another aspect of the waste authorization was the requirement to measure aerial releases of tritium, even though the Radiological Risk Assessment predicted the worst case scenario to be within acceptable limits. An additional tritium measuring system needed to be developed to sample from the building ventilation system. As Free Release Waste (FRW) is exempted from authorization this phase of the work was able to proceed – see below.

6. Decommissioning work to date

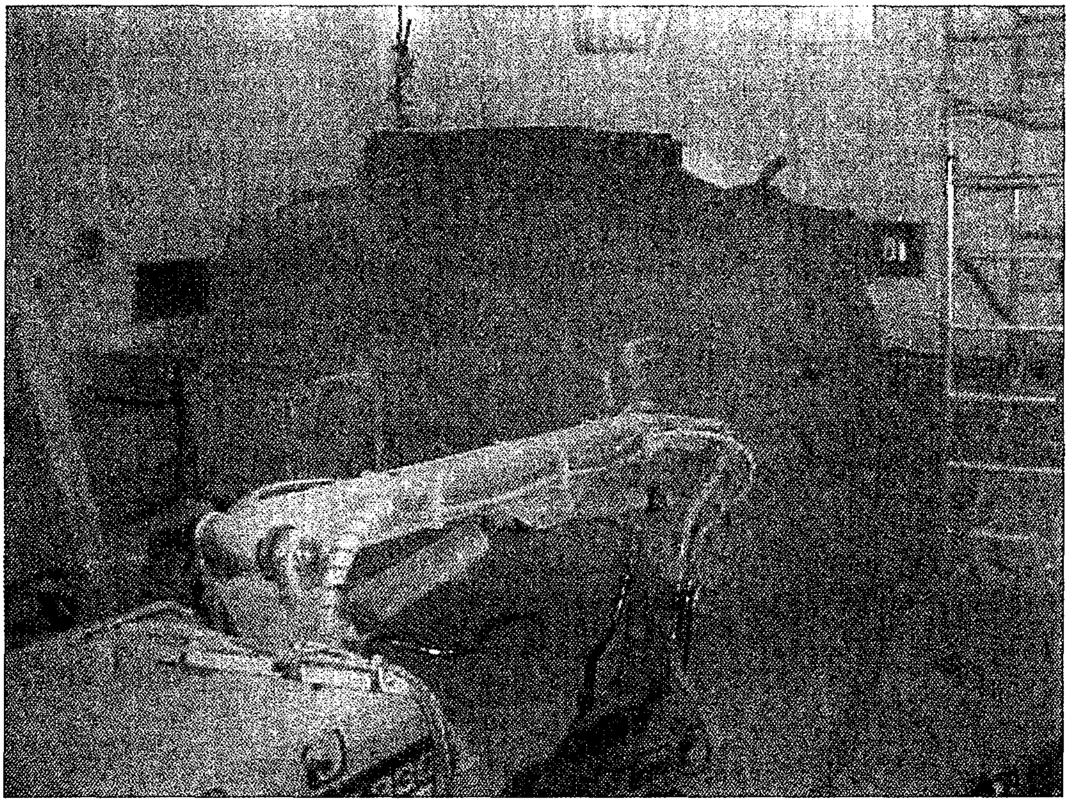
All of the Free Release Concrete has now been removed from the reactor bio-shield, using the Brokk with concrete breaker and clamshell bucket for waste removal (see below)



BROKK BREAKING OUT FREE RELEASE CONCRETE

When sufficient concrete was broken out, samples were taken both from the broken concrete and the remaining concrete on the reactor. Once confirmed as FRW the concrete was loaded into a hopper, which was wheeled out of the containment and tipped into a FRW skip located outside the reactor building.

The original core sampling provided the basis for the detailed approach of each removal campaign. Concrete was generally removed to a depth of 0.5m in the first pass before the bio-shield was again subjected to confirmatory sampling/analysis. Work proceeded on that basis until all free release concrete had been removed.



REACTOR AFTER REMOVAL OF FREE RELEASE CONCRETE

During the design stages it was anticipated that substantial quantities of dust would be generated from the removal methodology. Although minimization of dust generation had been incorporated into the original design continual improvements and minor modification of the methodology throughout the operation delivered a 70% reduction in the quantity of dust.

7. Outstanding/completion issues

When waste authorizations are issued the project will resume with removal of the reactor core, active concrete and removal of ancillary equipment prior to building demolition. Currently trials of the ILW size reduction machine are progressing. The machine has again been adapted to fit on the Brokk and will size reduce the core base plate for disposal in an existing and approved ILW liner.

A separate safety case has been prepared for the building demolition and is currently being reviewed by the client.

8. Lessons learnt

The principle lessons learnt can largely be attributed to either of the two case studies and hence are presented below as an independent section:

- A clear and concise understanding of the overall decommissioning problem and definition of the exact deliverables is necessary before any development of a strategy is undertaken.
- Review all the parameters that have the ability to affect the optimum design scheme e.g. requirements of waste plant operators, specific site restrictions due to location, physical access, etc.
- Generally research reactors were designed to be operated and not to be decommissioned. Consequently unexpected demands may be made on the reactor and surrounding areas e.g. the excessive loadings which necessitated reinforcement of the ICI reactor hall floor.
- Wherever possible physically confirm all information taken from existing drawings of the facility. Never assume that drawings accurately reflect the actual status of plant.
- Develop safety documentation in parallel to the engineering solution as they are inherently linked.
- Endeavour to provide flexibility within the detailed design to overcome perceived uncertainties.
- Undertake extensive risk assessments from a hazard and operability view point to assist the design process. Involve representatives from a broad cross section of disciplines, including existing operational reactor staff.
- The initial stages of the project are key to the eventual success. Ensure sufficient time is allocated for the development of the optimum strategy and the detailed design. Incorrect decisions at this critical stage of project development could have a very onerous effect on both safety and costs at a later date.
- Allow adequate time within the programme for tasks outside the direct control of the project team e.g. the submission of applications for regulatory approval.
- Appoint a dedicated and integrated core management team comprising individuals from both a decommissioning and operational background. Ensure continuity of the team is maintained from project conception, through design and implementation, to completion.
- The integrated management team need to co-ordinate all aspects of the project to gain a complete knowledge base of the project. Although specialist support resources may be required, tasks (particularly the development of the necessary site documentation) should be undertaken directly by this team wherever possible providing that they are suitably qualified and experienced.
- Undertake comprehensive commissioning and training. Where possible utilize inactive mock-ups, away from the nuclear site to demonstrate and improve the operation of the equipment. Once delivered to site it is recommended that inactive trials of all equipment are then conducted to confirm compatibility/functionality before undertaking active operations. This also allows personnel to familiarize themselves with the proposed tasks as well as provide the opportunity to include any identified improvements within the methodology.

- Continual improvements should be sought throughout the decommissioning operations, particularly those of longer duration e.g. dust management at the SURRC. Consider combining methodologies to get the best elements of both i.e. for ICI concrete removal a number of schemes were considered at the design stage however experience suggests that a combination of techniques may have been more effective.
- Activated concrete contains substantial quantities of tritium. If potential for aerial release exists the regulator may require this release to be quantified and methods of measurement will be required.
- A variety of standard tools can easily be adapted to suit a variety of decommissioning and remote tasks saving expensive development of specialized tools and equipment.