

RESEARCH REACTOR DECOMMISSIONING – POTENTIAL BACK END OPTIONS

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ABSTRACT

As with all nuclear facilities, research reactors will, at some stage, reach the end of their useful life, in fact over half of the research reactors throughout the world have already been permanently shutdown. The majority of these facilities have not been designed and operated to facilitate the eventual decommissioning process and, given the different nature of the research works that were undertaken, do not always have the necessary infrastructure readily available to meet these demands.

As a minimum all site operators have the responsibility to ensure that facilities removed from operational service are put in a safe condition to protect the workforce, the public and the environment. This paper endeavours to outline the various back end options available to operating organisations, following the shut down of their facilities, to ensure a smooth, safe and cost effective transition between operational and D&D phases.

INTRODUCTION

To date, well over 650 research reactors have been built or are in the construction or planning phase throughout the World. Of these, over 350 have already been shut down and decommissioned to different stages. Most of these research reactors have not been designed and operated to facilitate the decommissioning process. However, experience has shown research reactors may be safely decommissioned soon after shutdown, that the technology is available and the cost to the operator of decommissioning and waste disposal is offset by costs that would be incurred in care, maintenance and regulatory involvement. In addition, if the eventual objective is to return the site to unrestricted use the capital assets associated with land ownership may be recovered by the sale and subsequent re-development.

Despite the wishes of the specific site operators it is inevitable that all research reactors will, at some time, reach the end of their useful life. This may arise for a number of reasons including commercial viability, regulatory/environmental pressure, technical alternatives and fuel issues but will result in the same fundamental question - what next ?

SCOPE OF PAPER

There are numerous factors that need to be considered before making a final decision, with one of the main issues being management of the spent fuel. This together with remaining activities on the site, disposal of waste arisings, care and maintenance costs etc. all give rise to a very involved and complicated decision making process. Even if the path of decommissioning is opted for this still gives rise to the question - to what stage ?

Whatever the decommissioning objective it is imperative, from operational experience, that this process is clearly outlined and subjected to detailed planning at an early stage. This will facilitate the execution of the project and ensure that it is undertaken safely, cost effectively and to programme. It is the intention of this paper to outline the potential options available to research reactor operators, two of which are further developed in case studies for the decommissioning of the URR and the ICI Triga Reactor (work that has been undertaken by BNFL). It will endeavour to highlight the particular areas of importance and indicate a number of lessons learnt from actual decommissioning projects.

INITIAL DECOMMISSIONING OBJECTIVES AND CRITERIA

Once the decision has been made to decommission a reactor the initial requirement is to determine to what stage. In deciding how far a nuclear reactor could or should be decommissioned it is customary to recognise three generic stages. The three stages (as outlined in Ref 1) are:

Storage with surveillance

The reactor is defuelled and the fuel transported away from the reactor.

The plant is kept under continuous on-site surveillance, and the equipment necessary for monitoring radiation both inside the plant and in the surrounding area is kept operable. Ventilation and service systems are kept operational. Surveillance is maintained in accordance with applicable regulatory requirements. Periodic measurements and visual checks are carried out to ensure that contamination control systems, i.e. ventilation systems and permanently sealed contamination barriers, continue to function properly.

Restricted site release

The reactor is completely defuelled and the fuel transported away from the site.

All readily removable contaminated materials, and some highly contaminated materials are removed to reduce the physical size of the reactor to a minimum. In some cases this may well include the heat transfer systems and all peripheral services to the reactor (with the exception of the necessary monitoring equipment to ensure containment of remaining activity).

Contaminated areas are decontaminated to the extent appropriate, and remaining areas with unacceptable residual radioactivity levels are sealed to prevent unauthorised access. Some parts of the plant or site could be converted to new uses or released, with certain constraints in accordance with appropriate radiological protection measurements.

Surveillance around the restricted areas is required in accordance with regulatory conditions.

Unrestricted site use

The reactor is completely defuelled and the fuel is transported away from the site. All materials, equipment and structures in which radioactivity levels exist above prescribed limits are removed to an approved storage or disposal site.

In all remaining plant areas the radioactivity levels will be reduced to those that permit unrestricted use allowing possible sale and/or redevelopment of the site.

The extent of the decommissioning should take into account the final use of the facility or site in question. If the facility or site is to continue with radioactive operations then it is unlikely that complete unrestricted use will be required. When no further use of radioactive material is envisaged, then release of the site for unrestricted use should be seriously considered. It should be stressed that there is no formal requirement to define the decommissioning objective in terms of stages (these are used as guidelines only) or that it does not necessarily require the adoption of all three stages in chronological order.

There are obviously many factors and parameters, in addition to the future use of the site, that will affect the decommissioning requirement and all these should be considered when determining and setting the final objective/goals. A large percentage of these parameters will be set by the infrastructure of the specific site/facility and the services available to it. In addition regulatory requirements, waste storage and disposal options, geographical location and national legislation should all be considered before finalising the framework within which the decommissioning will be undertaken.

It is customary to inform the appropriate regulatory authorities as soon as the decision has been made to decommission the reactor. In practice this may be well in advance of the proposed reactor shut down date although it is prudent to commence discussions with the regulators as soon as possible to ensure a smooth transition between the operational and decommissioning phases hence avoiding potential lengthy negotiations which may impact on the decommissioning programme.

BNFL has accumulated considerable experience in providing solutions to various operating organisations following the end of the operational life of their reactors. This work has included the production of feasibility and optioneering studies, the design/manufacture of specialist equipment, safety justification, liaison with regulatory authorities and execution of eventual on site decommissioning operations.

REFERENCES

1. IAEA Technical Reports Series No. 373, Decommissioning Techniques for Research Reactors, Vienna, 1994.

CASE STUDY 1 – DECOMMISSIONING OF THE UNIVERSITIES RESEARCH REACTOR

The Universities Research Reactor (URR), see Fig 1, was located on a site owned by the Universities of Manchester and Liverpool at Risley, Cheshire and was used for post-graduate training and research into various fields including nuclear engineering, radio-chemistry and neutron and solid state physics. The Argonaut type water moderated water cooled reactor, originally designed for continuous aspiration at 100kw, was commissioned in July 1964 with the operating power increased to 300kw in 1966. The reactor was shut down in 1991 and BNFL were contracted to decommission the reactor and dispose of all waste, hence returning the site to a “green field” status with the eventual revocation of the nuclear site licence.



Fig. 1. An Aerial View of the Universities Research Reactor

STAGE 1 – DEFUELLING

As part of the final reactor operations the fuel was removed from the core and placed in the on site dry storage pit. The only suitable transport flask available was designed for operation underwater and, as no fuel pond was available, special equipment was required to enable the fuel to be loaded safely. It was decided to utilise a temporary extendible pond arrangement to provide primary shielding, particularly during replacement of the flask lid, and combine this with a shielded transfer machine.

The fuel transfer was successfully completed with the fuel leaving site in December 1992. During the transfer operations no measurable radiation doses were received by the workforce, nor was there any measurable contamination on any of the equipment used.

DECOMMISSIONING PLAN

The Pre Decommissioning Safety Report (PDSR) examined the proposed decommissioning operations (designated as Stage 2) and described the plant and operational programme with emphasis on the safety management aspects.

The programme was split into 4 phases consisting of 41 discrete tasks. The PDSR was presented to the University Nuclear Safety Committee and the appropriate regulatory authority for approval, following which the use of hold points between the four stages to allow a review of work completed, before proceeding to the next stage, was requested.

The detail dose assessment included within this report predicted that with strict planning and control, the individual limit of 10mSv/year would not be exceeded within the predicted collective dose uptake of 79.6mSv.

STAGE 2 – DECOMMISSIONING

Stage 2A&B - Preparatory and Preliminary Work

The main reactor shielding material was barytes concrete blocks with supplementary lead shielding located at various positions around the core. The four corners of the bio-shield were formed by cast barytes concrete monoliths with removable concrete blocks providing access to the core. The 32 peripheral shield blocks which had been identified as Free Release Material (FRM) were removed from the reactor hence increasing the working area.

A Reusable Modular containment (RMC) had been designed to encompass the reactor and process pit which incorporated a changeroom for controlled man-entry and an air lock for the transfer of goods and materials. The RMC was fitted with a dedicated ventilation system incorporating double pass HEPA filters. A proportional sampler installed downstream of the filters estimated the aerial discharge during decommissioning operations.

In order to ensure that the project team were all suitably trained to commence reactor dismantling, a comprehensive series of training courses was arranged by BNFL Training Department. Training remained an important element of the safety management system with the continuous use of “mock-ups” before tackling potentially complex engineering problems with high radiation levels.

Stage 2C - Reactor Dismantling

It was anticipated that removal of the control blade mounting frames would be the most dose intensive operation of the decommissioning programme and in order to size reduce and minimise handling problems associated with the highly active steelwork

(approaching 200mSv at contact), a milling machine was designed, developed and tested. The swarf produced was transferred by way of a four component conveyor system, directly into a standard ILW flask liner avoiding unnecessary handling and hence dose uptake.

Removal of the Primary Thermal Column (PTC) required the design and casting of additional concrete shielding. Subsequent removal of the reactor core graphite blocks was hindered by the interlinking fuel boxes and 'rabbit tubes'. It was decided to retain the shielding used for PTC and to develop a method of remotely pulling the blocks out of the core thus removing them from the high radiation areas present in the centre of the reactor.

The fuel boxes were mounted on a steel frame cast into the concrete foundations which constituted a major radiation source. It was considered beneficial to remove this frame as soon as possible utilising a hydraulic bursting tool, thus allowing it to be lifted to a shielded area for waste categorisation.

Three beta in air monitors were in constant use during all the decommissioning work within the RMC. Although respiratory protection was routinely worn where it was deemed possible that airborne contamination might be generated, this did not in fact constitute a problem and the monitors never reached their airborne setting.

Stage 2D - Completion Tasks

The reinforced concrete monoliths were progressively broken up using a diamond drilling/hydraulic bursting technique. With extensive radiological analysis of core samples accurate assessments were made of the free release boundary. Considerable efforts were made to segregate the active and non-active wastes thus minimising the waste disposal costs. The monoliths were removed down to floor level. All activated service pipes and concrete associated with the reactor foundations were progressively removed with the strategic use of temporary shielding. The potentially contaminated peripheral equipment associated with the reactor (e.g. fume cupboards, hot cell, reactor ventilation system, pneumatic rabbit system etc.) was removed prior to decontamination and subsequent removal of the RMC.

Although the initial contract to complete the decommissioning was now complete, the University made the decision to demolish and remove all the buildings from the site.

STAGE 3 – DEMOLITION OF THE BUILDINGS AND CLEARANCE OF THE SITE

Initial negotiations with the regulatory authorities suggested two independent radiological surveys would be required, one for the buildings and services to justify demolition, the other for monitoring the cleared site to support ending the operating organisations period of responsibility (known as a Nuclear Site Licence in the UK).

Prior to demolition the building was subjected to a comprehensive independent survey to ensure that there was no remaining measurable radiological material which might cause problems during the work itself and/or subsequent disposal of waste. The radiological survey gave confidence that there would not be any significant radiological hazard during demolition which was demonstrated in the Pre-Demolition Safety Case (PDmSC). The demolition commenced in August 1996, following authorisation, and was completed two

months later. Despite the demonstration of safety within the PDmSC arrangements were made to monitor each load of demolition waste prior to removal from the site.

As the final stage of the overall programme, after all materials used in the construction of the reactor (outbuildings, drainage system, adjacent roads, hardstandings, foundation material etc.) were removed from the site, a final radiological survey was undertaken. This included radiation field measurements and analysis of samples of surface and subsoil with emphasis on areas immediately below the reactor foundations. These measurements provided the final verification that, beyond any reasonable doubt, there was no residual radiological hazard associated with the site due to the operation of the Universities Research Reactor which should restrict the site's suitability for development.

REGULATORY AUTHORITY ISSUES

The major regulatory bodies involved were HM Nuclear Installations Inspectorate (NII) and the Environmental Agency (EA). The NII were involved in all aspects of the decommissioning programme, their agreement was necessary before any major stages could proceed. EA authorisation was required for all activities involving the transporting and disposal of waste and discharge of both gaseous and liquid effluents.

CONCLUSIONS

The final radiological survey was submitted to the Universities Nuclear Safety Committee and subsequently to the NII, together with a request for revocation of the site licence in April 1996. Following confirmatory radiological surveys conducted by the NII notification ending the Universities period of responsibility was received on 26 July 1996. Following receipt of this notification the Universities finalised the sale of the land to a private developer who has now constructed a distribution warehouse for a large computer company.



Fig. 2. The URR 'Greenfield' Site Following Delicensing

CASE STUDY 2 – DECOMMISSIONING ICI TRIGA MK I REACTOR

INTRODUCTION

The ICI Triga reactor is located at Billingham, Cleveland and was used as a source of neutrons for experiment and irradiations for activation analysis. It was also used commercially for the production of radioactive tracers.

The Mk 1 Triga is a pool reactor which operated at powers up to 250kW, using a Zirconium Hydride ceramic fuel containing 8.5wt% uranium at 20% enrichment. It was commissioned in 1971 and operated until 1996. BNFL were awarded a contract to defuel the reactor and remove the activated components and ancillary equipment, leaving the reactor vessel and concrete containment intact. The reactor building will continue to be used for radiochemical operations so there is no requirement to delicense the site.

The proposed strategy was divided into four discrete stages of work as described below:

STAGE 1 – PREPARATORY WORKS

A number of decommissioning schemes were assessed 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 PDSR was prepared to encompass all operational aspects of the reactor decommissioning. This was submitted to the ICI Nuclear Safety Committee and subsequently the NII for approval.

A number of factors influenced the optimum design scheme. The formal route of arriving at this scheme arose from a series of detailed HAZOP Studies relating to the proposed

methodologies. The resulting actions from these studies served to identify to the preferred approach. The main issues concerning the decommissioning methodology were:

- The estimated categorisation of the various wastes that would be produced throughout the decommissioning operations. This dictated which waste disposal sites would be utilised, indicative volumes and the subsequent consignment requirements/transport medium.
- The physical size of the Reactor Hall was very limiting. In order to provide mechanisms for the movement of transport flasks of up to 20 tonnes considerable optioneering was carried out. This resulted in the selection of a Franna Lift and Carry Mobile Crane (see Fig 3) for fuel flask operations and an airlift platform for ILW flask movements. Due to the loads involved extensive assessment of the reactor hall floor structural capability was undertaken with subsequent remedial/strengthening modifications required.

- 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 minimised the dose rate to employees and the public, the limit being the need to restrict the radiation dose rate at the site boundary to less than $7.5\mu\text{Sv/hr}$. This requirement particularly influenced the design and safety of the defuelling and Intermediate Level Waste (ILW) removal operations.



Fig. 3. Inactive Commissioning Trials of the Specialist Crane

- 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 safety of operations was continually assessed throughout the period of scheme design until safeguards, included in the methodology, would ensure that the worst case accident scenario would result in no off site occurrence during any of the decommissioning operations.
- With a view to minimising the off site implications, together with the lack of suitable facilities on their site, ICI stipulated that one of the requirements of the preferred BNFL solution would be to ensure that any size reduction operations were kept to the absolute minimum.

A scheme which satisfied the above criteria along with any others issues resulting from the HAZOP Studies was developed further into the engineered solution. The cumulative dose assessment predictions for all decommissioning operations was 19.6 man mSv.

STAGE 1 – PREPARATORY WORKS

The required preparatory works included civil improvements to the existing facilities, including transport flask laydown plinths and reinforced mobile crane loading areas. Extended monitoring and changeroom facilities were provided to accommodate the increased workforce. This decommissioning equipment was designed, fabricated and in-actively commissioned during this stage of the project.

STAGE 2 – REACTOR DEFUELLING

The reactor was defuelled utilising a cylindrical transport flask (Modular Flask, see Fig 4) positioned directly above the reactor tank. A support frame was manufactured to provide secondary support to this flask (also capable of maintaining integrity in the event of a dropped load) in addition to the Lift and Carry Mobile Crane. This support frame also provided shielding in the form of steel and lead collimators which extended one meter into the reactor tank water. The fuel was loaded into a purpose built fuel transport basket, positioned on an in-tank aluminium frame located next to the reactor core. The universal basket, containing 13 positions for either the fuel elements and/or the significantly longer fuel followed control rods, was hoisted directly into the transport flask for shipment to Sellafield for interim storage. The reactor had an inventory of 86 fuel elements and three control rods - hence seven transport shipments were required with the final shipment arriving at the interim store 21 December 1998.

The total dose uptake for all seven defuelling operations was 0.82 man mSv against a budget of 5.65 man mSv. This discrepancy was attributed to the pessimistic shielding requirements introduced as part of the anticipated worst case radiation levels at the detailed design stage.



Fig. 4. - Delivery of the Modular Flask to the ICI Site

STAGE 3 – INTERMEDIATE LEVEL WASTE (ILW) REMOVAL

The components of the reactor which constituted ILW were the stainless steel items positioned close 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 for the purpose of removal and disposal of this waste. The container, consisting of steel and lead shielding, was positioned on the in-tank frame located next to the reactor core. ILW was loaded into this container following remote size reduction by hydraulic croppers. One problem encountered was with respect to the RSR which was air filled. It was necessary to disconnect this underwater and prevent free liquid, which would not drain on removal from the tank due to physical construction, being consigned to the Sellafield storage plant (which would breach conditions of acceptance). To overcome this issue the RSR was grout filled utilising technology developed for use in the Sellafield waste storage plants prior to shearing of the grout filled access pipes following curing.

The support frame positioned above the reactor tank was complemented by the addition of a transfer shield. Once full the ILW container was removed from the reactor tank using a mobile crane. During removal, the container was designed to mate with the transfer shield to allow safe movement of the package to a transport flask (Unifetch Flask). This waste was transferred to Sellafield on 27 January 1999, for interim storage pending ultimate disposal.

STAGE 4 – REMOVAL OF LOW LEVEL WASTE (LLW)

The remaining waste consists mainly of the aluminium clad graphite reflector, primary and secondary cooling systems and experimental facilities such as rabbit systems etc. These will be dismantled and placed directly into a 10m³ ISO skip for grouting and disposal to the Drigg Low Level Waste Repository. These tasks are programmed for February 1999.

The benefits of removing the activated aluminium reactor tank and lower concrete foundations at the end of Stage 4 is currently being assessed by ICI as part of their negotiations with the NII with respect to the necessary requirements of the proposed care and maintenance regime. It may be cost effective to undertake this work immediately reducing the site activity inventory and in turn simplifying the care and maintenance regime, rather than imposing a significant delay.

The decommissioning operations (to whatever point it is decided to take them at this stage) will conclude with a detailed radiological survey of the reactor tank, containment and building. The results of this survey will determine the need for further work, although it is anticipated that the water will be disposed of via the existing active drain followed by a permanent cover being installed above the reactor tank. It is anticipated that some form of removable in fill material will be placed into the reactor tank to ensure long structural stability. A care and maintenance regime will then be operated pending the clients decision to delicense the reactor site.

CONCLUSIONS

Both Defuelling and Removal of ILW has now been successfully completed well within the anticipated radiological dose uptake. It is hoped that the remaining Stage 4 operations should be complete before the end of February 1999 although further work associated with the potential removal of the aluminium reactor tank and concrete foundations may require the programme to extend beyond this date. The impact of these further operations is currently being assessed to ensure that overall, ICI are left with the optimum longer term option with respect to care and maintenance.