DECOMMISSIONING CONSORT – CONTROL ROD REMOVAL

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ABSTRACT

The CONSORT Low Power Research Reactor is currently undergoing decommissioning following final shutdown in 2012. At the time of construction (1963), little thought was given as to the means by which the reactor would be decommissioned. The reactor's four control rods presented an interesting decommissioning challenge. This included size reduction of the control rods in the reactor vessel, posting operations to bring the active sections of the rods into a transfer flask, and further size reduction of the control rod blades in a shielded cropping cell prior to loading them into a type A package for transport. The Control Rods were successfully decommissioned in June 2016.

A range of solutions were considered, which had the aims of minimising dose to operators and where possible using simple off the shelf equipment or reusing existing equipment. Options were limited by the range of available type A packages licensed for use in the UK, which required cutting of the active control rod blades, necessitating the construction of a shielded cropping cell.

The control rods consisted of a blade section (98cm) which was connected to an actuator rod (248cm). The blade section was highly activated requiring the use of shielding throughout the decommissioning process, which was divided into two phases

1. Preparing the control rod to fit in the transfer flask. This required size reducing the control rod, by cutting to remove low active sections of the actuator bar and fitting a lifting attachment for the posting rod, whilst keeping the active blade section below water level.
2. Lifting the control rod blade out of the reactor tank and transferring it to the shielded cell for cropping and loading into the transport container. This required docking the shielded transfer flask with the reactor tank, posting the control rod blade into the flask and transferring the flask to dock with the shielded cropping cell. Then posting the control rod blade into the cropping cell, where the blade was cut into three sections which dropped directly into the transport container.

1. Introduction

The CONSORT Reactor was a 100kW, light water cooled and moderated research reactor which operated at Imperial College's Silwood Park Campus from first criticality in April 1965 to final shutdown in December 2012.

The reactor was defueled in June 2014 under a modification to the operational safety case. Decommissioning started in November 2015 following regulatory approval of the decommissioning safety case. Decommissioning was divided into a number of phases, the first of which was removal of the reactor start-up source. This paper discusses the second phase of decommissioning which was removal of the reactor's four control rods.
Removal of the Control Rods presented a number of challenges.

The Control Rods were ILW and due to the dose rate, would need to be transferred in a shielded container from the reactor tank to a transport container. This would require

- Identification of a suitable transfer flask with sufficient shielding and an internal cavity that would fit the active section of a control rod
- A method for size reducing the control rod in the reactor tank as the combined length of blade and actuator bar was 3.46m. The upper section of the actuator bar was low activity so would need segregating into a different waste route form the blade and additionally, there was insufficient height in the Reactor Building to accommodate a transfer flask that could take the full length.
- A means of docking and aligning the transfer flask with the reactor top to allow use of a posting rod system to lift the control rod into the flask.
- A means of remotely connecting the posting rod to the size reduced section of the control rod.

A suitable transport container was required, with sufficient shielding, a large enough internal cavity to take the four ILW blade sections and licensed for use on the UK roads. Such a transport container was not immediately available, this left two choices

- License a suitable transport container, a process which was estimated to take 18 months and which would result in significant delay to the decommissioning programme
- Use a smaller licensed container and further size reduce the blade sections of the control rods to fit. This was the chosen option.

This necessitated the design and build a shielded cell, which had to be able to

- dock with the transfer container
- cut the control rod blade into sections
- load the cut sections into the transport container

2. The CONSORT Control Rods

The CONSORT Reactor had four control rods. These were all blade (98cm) type control rods attached to a longer actuator bar (248cm). The Safety Rod (S), and two course rod (A & B) blades were cadmium clad with steel. The fine control rod (F) blade was steel. The actuator bars were aluminium, sheathed in steel on the bottom 91cm. The control rod actuator bars (rods A, B & F) were connected to tapes which were raised and lowered by the control rod drive motors. In order to detect a sticking control rod, the tapes ran through a slack tape sensor mechanism. The Safety Rod had a different diverse mechanism, which used an electromagnet rather than a tape, to raise the control rod.

The blades moved up and down in the lower guides. The Cruciform was mounted on the top of the Reactor tank and supported the upper control rod guides, which prevented the control rods being pulled out of the tank, the control rod tape mechanisms and their slack tape sensors and the electromagnet and motor for the safety rod. It also supported the floor plates which were used to cover the reactor tank and provide a working platform.

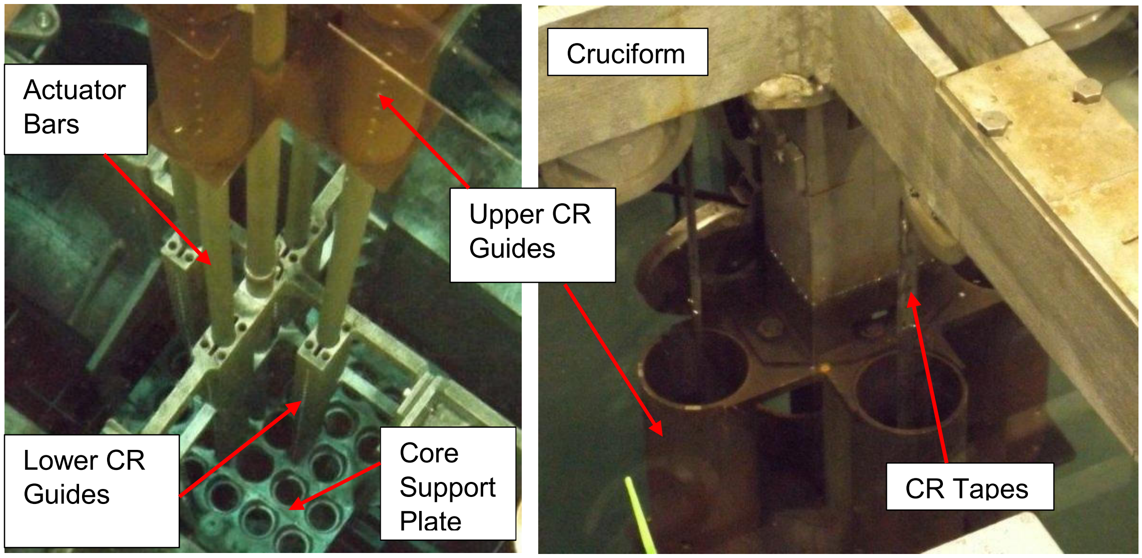

Figure 1: CONSORT Control Rods

3. In tank Dose Rate Measurements

The design of the transfer flask and shielded cropper cell were largely dictated by the shielding requirements, so a series of dose rate measurements were carried out in the Reactor Tank to measure the dose rate from the control rods.

Measurements were made using a Sonde STHF probe specifically designed for the measurement of high flux gamma fields in an underwater environment. The probe was held at a distance of 5cm from the control rod guides. The highest dose measured was from the bottom end of the Fine (F) Control Rod. This was to be expected as this was the steel control rod. Some of the dose rate measured was from the core support plate, which though made from aluminium contained some steel components and was located at the bottom of the control rod guides. The mid line of the core, the location of the highest neutron flux, was located 40 cm above the core support plate.

The measurements showed that the dose rate drops off to a few micro Sieverts per hour at the top of the blade section. Confirming that size reduction of the control rods by cutting the actuator bar was feasible allowing the selection of a transfer container that only needed to hold the blade section of the rod.

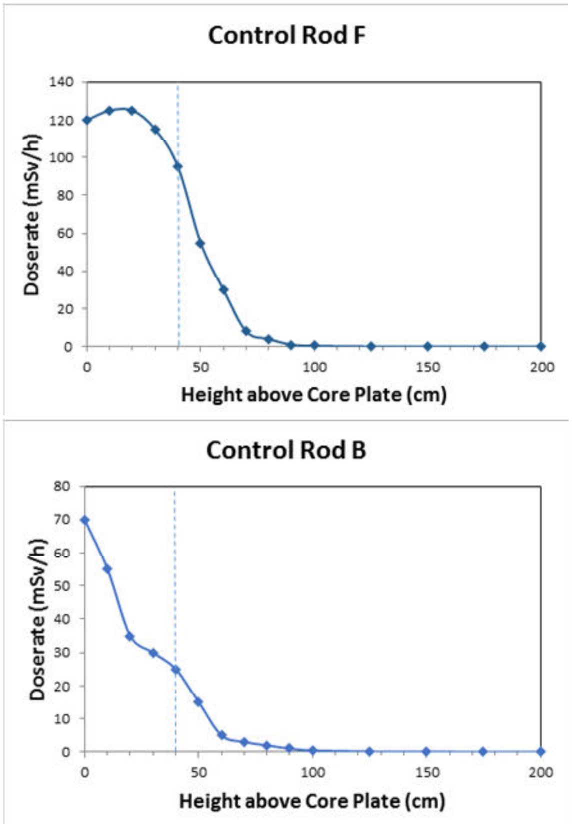

Figure 2: Dose rate measurements of control rods in-situ in the reactor tank.

Throughout the planning and design of the control rod removal equipment there was an emphasis on keeping doses ALARP. This was achieved through a combination of shielding, use of long handled tools and minimising time taken to complete tasks by optimising the process and practicing on non-active mock ups.

4. Making use of available equipment

The preferred option for removing the control rods was to reuse as much of the equipment installed for defueling as possible.

The defuel equipment consisted of a flaskway structure with a rail system, which allowed a bogie carrying a shielded transfer flask to dock with the reactor top. From there posting rods were lowered through the transfer flask to connect to the fuel element and raise it into the transfer flask. The bogie was then manually moved along the rails to dock with the transport container interface plate where the fuel was lowered, using the posting rods, into the fuel transport container.

A careful check of the reactor drawings demonstrated that it should be possible to reuse the transfer flask (figure 4) and posting rod system that were designed for the fuel. This would require cutting the actuator bar just above the blade leaving a short length to which could be attached a lifting adaptor, to allow the posting rods to be connected to the control rod.

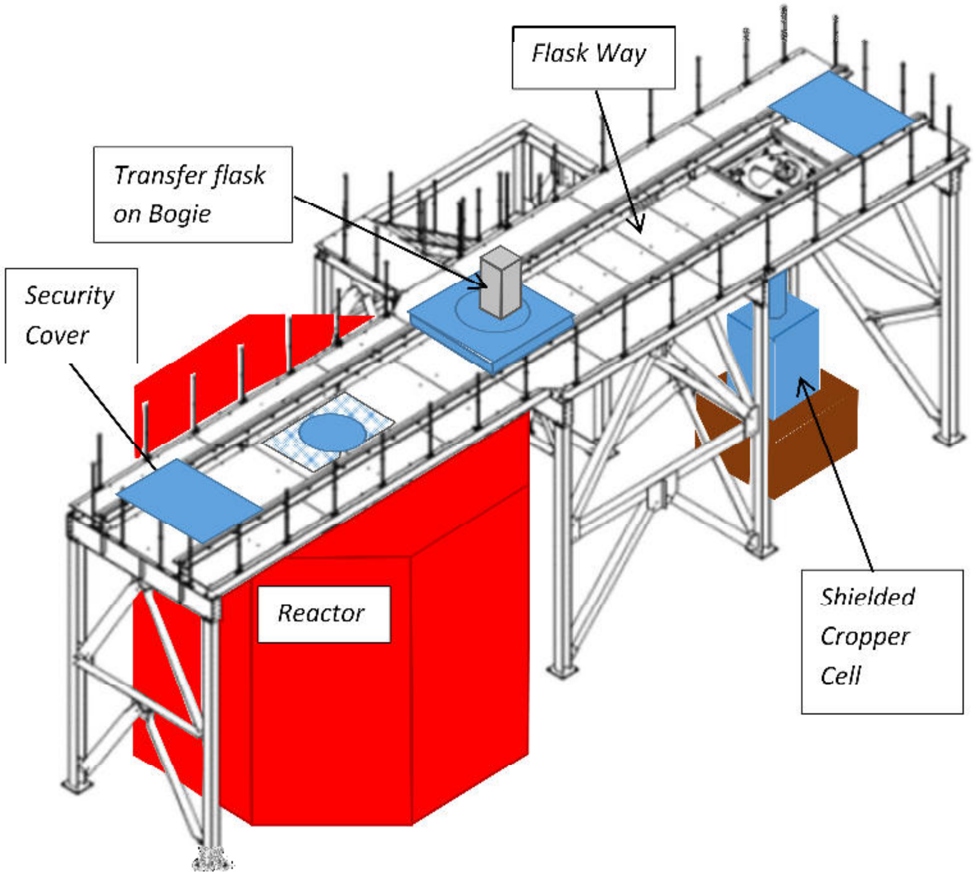

Figure 3: Flask way and rail system for transfer of control rods from reactor tank to shielded cropper cell. Reusing equipment from defuel.

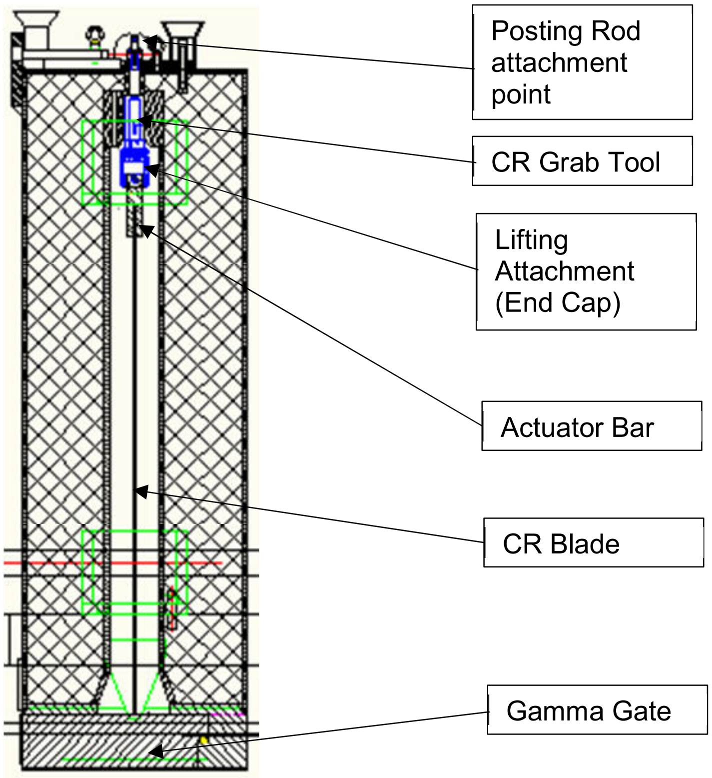

Figure 4: Cross section of control rod in transfer flask.

5. Size reduction of the Control Rod Actuator Bar

The sequence for getting the control rods out of the tank was complex as the cruciform and upper guide tubes prevented the blades from being pulled out of the tank and got in the way of using the posting rods and transfer flask. The following sequence was identified

- Cut the control rod tape (rods A, B and F)
- Dismantle the slack tape mechanism or magnet/drive mechanism in the case of the Safety Rod.
- Pull the actuator bar up 1 metre
- First Cut: Cut the actuator bar, then drill and tap a hole in the top of the actuator bar, to fit a lifting tool
- Lower the control rod back down fully into the lower guides using the lifting tool. Disconnect the tool.
- Repeat for all four rods.
- Lift out the reactor cruciform and upper control rod guides from the reactor tank.
- Attach the lifting tool and raise the control rod
- Second Cut: Cut the actuator bar (just above the blade section).
- Fit the lifting attachment to the bar (end cap)
- Attach grab tool to end cap and lower back into lower guide
- Repeat for all four rods.

6. Equipment and Tooling for Cutting the Control Rod Actuator Bar

A number of considerations went into the design of the tooling for size reducing the control rods.

The first was to design an Interface Plate to provide a safe working platform on the Reactor Top which would give access to the control rods in the reactor tank and allow for the mounting of the various tools required. This replaced the original reactor tank covers.

The Interface Plate could be rotated by steps of 90 degrees to index with the four control rods. A tool plate fitted in the largest access port on the interface plate with mounting positions for the tools.

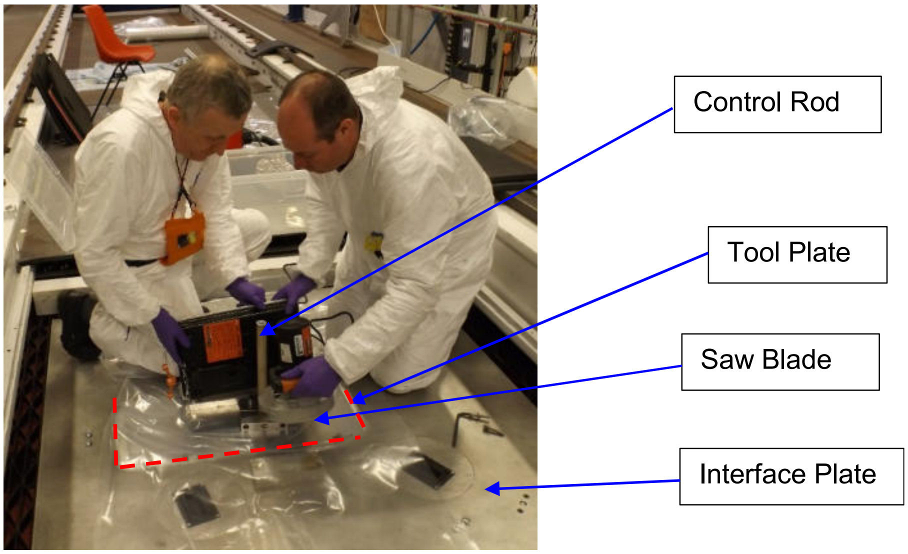

Figure 5: Mounting the cutting tool (rotary saw) on the Reactor Top Interface Plate. The control rod is partially raised and clamped in place to prevent it falling back into the tank.

It was decided to use simple off the shelf tooling where possible and modify the tools as required to mount them to the tool plate. The tools were set up on a testing rig and trialled to demonstrate that they operated satisfactorily as part of the commissioning.

A rotary saw was used to cut through the actuator bar.

The first cut was made through the non-active section of the actuator bar (1m from the top). Swarf from the cutting operations was contained by operating the saw inside a small containment tent made from plastic sheeting. On completion of the cut the swarf was vacuumed up using a HEPA filter vacuum system when the containment was opened.

The location of the second cut through the actuator bar was critical as there was only five mm clearance for the control rod in the transfer flask. The mount held the saw blade at the correct height above the tool plate and a recess in the bottom of the tool plate ensured that the top of the blade section was in the correct position and also, as a safety measure, could not be withdrawn any further from the tank.

Dose rates were measured at cut position 2. The dose rate for the steel control rod (F) was 200μSv/h. The three Cd-Steel Rods were 5 to 10 μSv/h. The actuator bar was assumed to be activated at this location requiring careful control of swarf. The maximum dose received by an operator for second cut was 11 μSv.

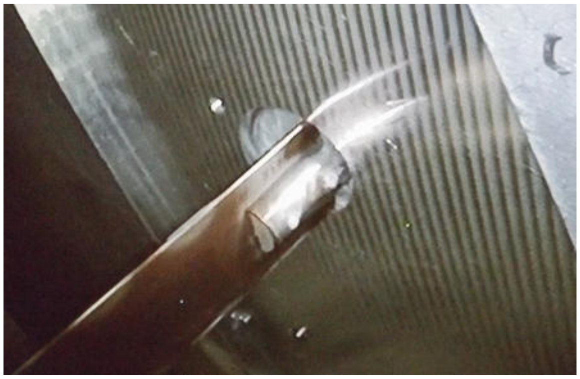

Figure 6: CCTV image from below the Interface Plate confirming CR blade located in recess to ensure correct cut position.

Following the first cut, the cutting tool was replaced with an electric drill mounted on the tool plate, which was used to drill a hole into the top of the rod. Tapping a thread into the hole was then done by hand. The control rod was then lowered back down into the tank using a pole which screwed into the rod.

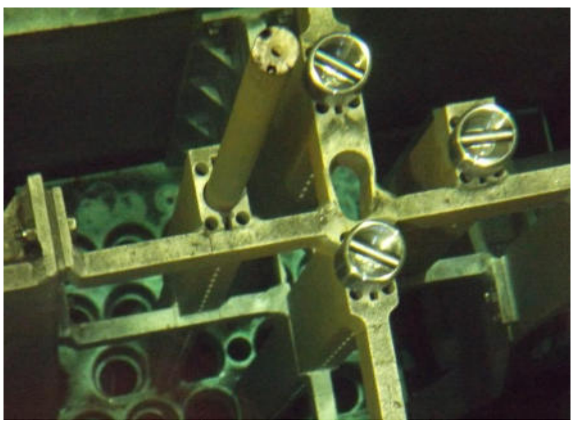

Figure 7: Three Control Rods have been fully size reduced and fitted with their 'end cap' lifting attachment. Final rod is awaiting second cut. (Depth in tank 4m)

7. Removal of Cruciform Structure

The arms of the cruciform structure which supported the upper control rod guide tubes were too narrow for the 'end cap' lifting attachments to pass through. Hence, it was necessary following the first cuts of the four control rods to remove this structure from the tank. This was a straight forward lift with the Reactor Crane, although it was essential to confirm that the structure had been fully disconnected from the tank and was free to lift. On completion the Interface Plate was repositioned over the tank.

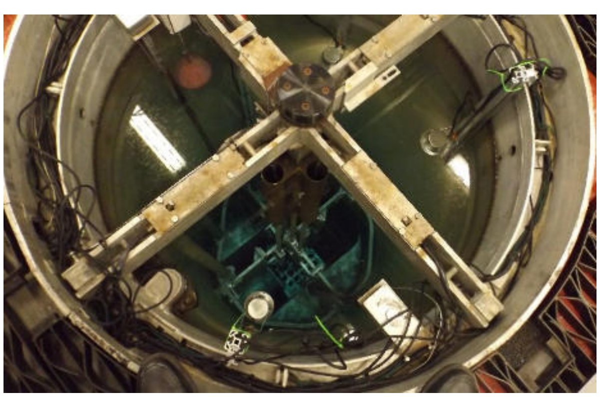

Figure 8: Cruciform structure

8. Posting and Cropping Operations

The next stage was the transfer of the control rods, one at a time, from the tank to the transport container.

8.1 Posting control Rods out of the Tank

This required the transfer flask, on its bogie, to align accurately above the control rods and above the shield column over the Shielded Cropper Cell. The alignments were established in advance using line of sight and plumb bobs. Index marks were placed on the bogie turntable and rail system to allow the alignment to be replicated. Only two of the control rod positions were accessible from the bogie, necessitating moving the second two control rods between lower guide tubes in the tank.

The transfer flask was aligned over the control rod position in the tank. The grab tool was lowered into the tank using posting rods and connected to the ‘end cap’ lifting attachment using an underwater CCTV camera to relay the image to the operators. The Control Rod was raised into the flask, allowed to drip dry and then the gamma gate on the flask was closed.

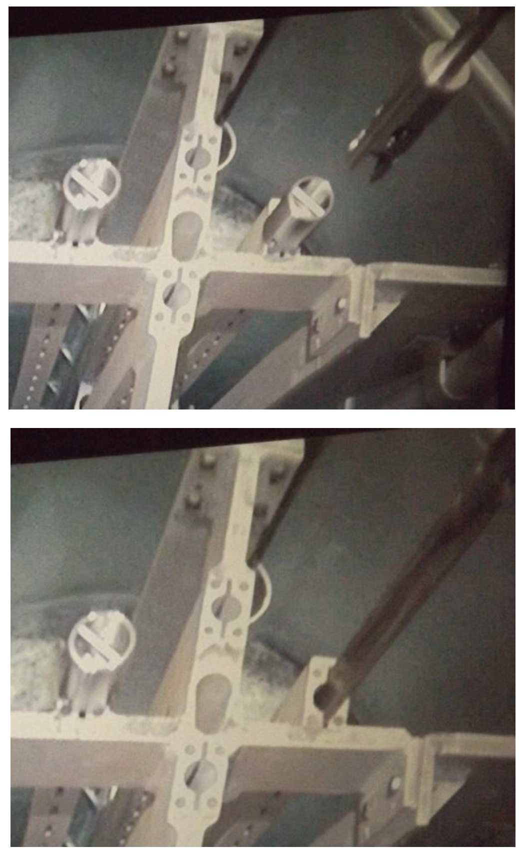

Figure 9a: Operators using posting rods

Figure 9b: Grab tool about to be connected to the ‘end cap’ lifting attachment and
control rod blade being lifted out of the lower guide

8.2 The Cropping Cell

The cropper shielded cell was designed to sit on the buggy and rail system originally built to bring the fuel transport container into the reactor building. It was designed, built and tested at the manufacturer's premises before being installed on site.

The Cropping Cell was tested using mock ups of the control rods, to ensure all the equipment worked as required and to train the operators in use of the cell.

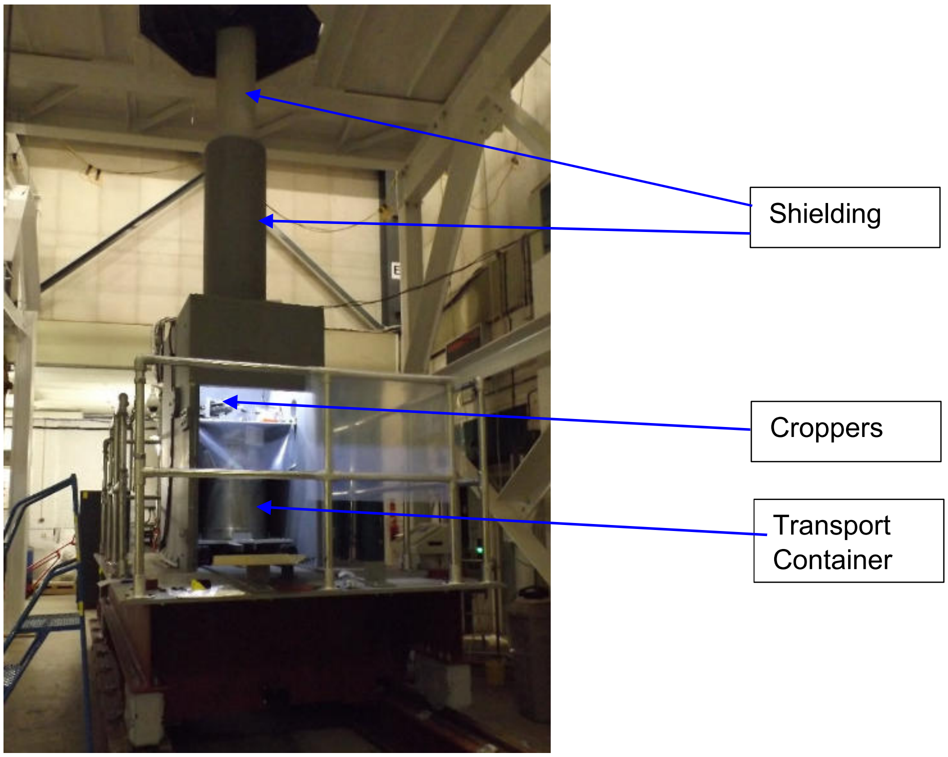

Figure 10: Cropper Shielded Cell aligned under flask way. The access door for transport container is open. The transport container is moved in and out of the cell on a trolley.

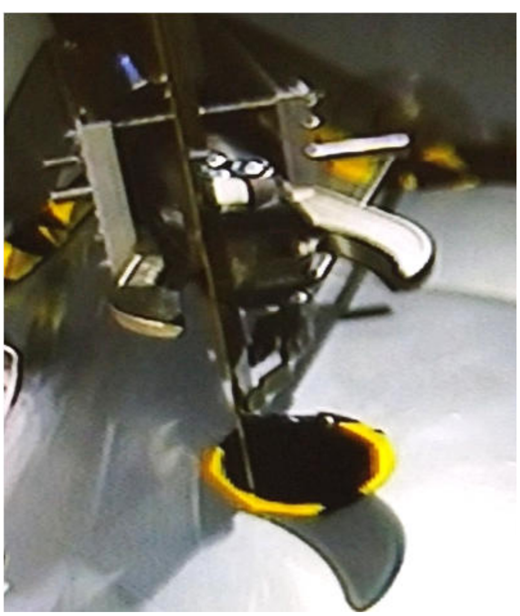

Figure 11: Control Rod between cropper blades and cropper cell operators.

In order to fit the control rod blade section into the transport container it was necessary to crop the blade into three pieces. The transfer flask was aligned over the top of the shielded cropper cell. From there, the control rod blade was lowered out of the transfer flask, down through the shielded column and into the cell. Lowering was stopped at a pre-set mark on the posting rods, which positioned the blade for the first crop. The blade was held steady with tongs whilst the cropper blades were closed using a manually pumped hydraulic system.

The transport container was located directly below the hole in the cropper table. A small mobile bullet camera, held with a second tong, was used to look down through the hole allowing the section of blade to be aligned and dropped into transport container.

This was repeated for the second crop.

Finally the grab tool was disconnected from the top third of the control rod blade, which dropped into the transport container along with its 'end cap' lifting adapter.

Once the cropping of all four control rods was complete, the shield door was removed from the cell and the transport container moved out of the cell on its bogie, to where the lid could be lifted back on ready for transport.

9. Conclusion

Decommissioning unique facilities like the CONSORT Reactor requires innovative solutions to the decommissioning challenges. These solutions need to find the right balance between safety, cost and time scales.

This was achieved through the reuse of existing equipment and off the shelf tooling to keep costs down and gain the benefit of previous experience from defuel.

The lack of a suitable in-license transport container was a significant issue, resulting in a choice between extra costs for building the shielded cropper cell or a lengthy, possibly more costly, delay to the programme whilst a suitable transport container was licensed.

The control rod removal was carried out by the reactor operational team, which allowed good use to be made of their experience from operating and maintaining the reactor.