

Decommissioning of the Dragon High Temperature Reactor (HTR) Located at the Former United Kingdom Atomic Energy Authority (UKAEA) Research Site at Winfrith – 13180

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ABSTRACT

The Dragon Reactor was constructed at the United Kingdom Atomic Energy Research Establishment at Winfrith in Dorset through the late 1950s and into the early 1960s. It was a High Temperature Gas Cooled Reactor (HTR) with helium gas coolant and graphite moderation. It operated as a fuel testing and demonstration reactor at up to 20 MW (Thermal) from 1964 until 1975, when international funding for this project was terminated. The fuel was removed from the core in 1976 and the reactor was put into Safestore.

To meet the UK's Nuclear Decommissioning Authority (NDA) objective to “drive hazard reduction” [1] it is necessary to decommission and remediate all the Research Sites Restoration Ltd (RSRL) facilities. This includes the Dragon Reactor where the activated core, pressure vessel and control rods and the contaminated primary circuit (including a ⁹⁰Sr source) still remain. It is essential to remove these hazards at the appropriate time and return the area occupied by the reactor to a safe condition.

INTRODUCTION

Decommissioning commenced in 2005; the first phase was de-planting and decontamination of the outer and then inner (primary) containment of the reactor. This work was terminated prematurely in 2007 when the Winfrith programme was reduced and the facility was put back into Safestore.

At the time of recommencement of the project the reactor structure still contains the activated core and pressure vessel, activated control rods, the contaminated primary circuit, and a ⁹⁰Sr source housed in a circulator. The inner containment needed to be de-planted and decontaminated to allow access for decommissioning the remainder of the reactor during phase 2.

The existing Decommissioning Safety Case (DSC) [2] for the Dragon Reactor expires in 2014, at which time Dragon will revert to a position of Safestore until full decommissioning of the reactor is sanctioned. A new DSC would then be required for this phase of work. There is an opportunity at this time to complete the Phase 1 work under the existing DSC and eliminate the cost of producing a DSC for the Phase 1 work at a future time. When the Phase 1 work is complete the Category of the facility will change from Category 3 to Category 4 and the ongoing cost of Safestore of the facility will reduce. In addition, when decommissioning resumes, the Phase 2 work will commence about 2 years earlier than would be the case if the Phase 1 works were deferred.

BACKGROUND

RSRL is the site license company responsible for the closure programme at Winfrith; Winfrith was a major centre for groundbreaking reactor development from the late 1950's to the 1990's.

RSRL, formerly the United Kingdom Atomic Energy Authority, has been successfully decommissioning nuclear reactors and their associated facilities since the early 1980's. The NDA was formed as a result of the Energy Act 2005 with responsibility to manage the UK's nuclear liability. RSRL operates under contract to the NDA and conducts its business to the highest financial, ethical and legal business standards.

There were a number of experimental reactors constructed at Winfrith; these were mostly material test reactors and simple by design although the site was home to more significant projects.

It was identified early on by the company that there would most likely be a loss of knowledge of the reactor and its operation; this is true of any complex feature left for extended periods of time. Whilst there remained a number of good records these were often incomplete or difficult to locate. The general approach to the decommissioning process was that of reverse engineering where possible; much of the Dragon reactor [Fig 1] had been designed to be readily maintained and as required replacement of significant plant and equipment.

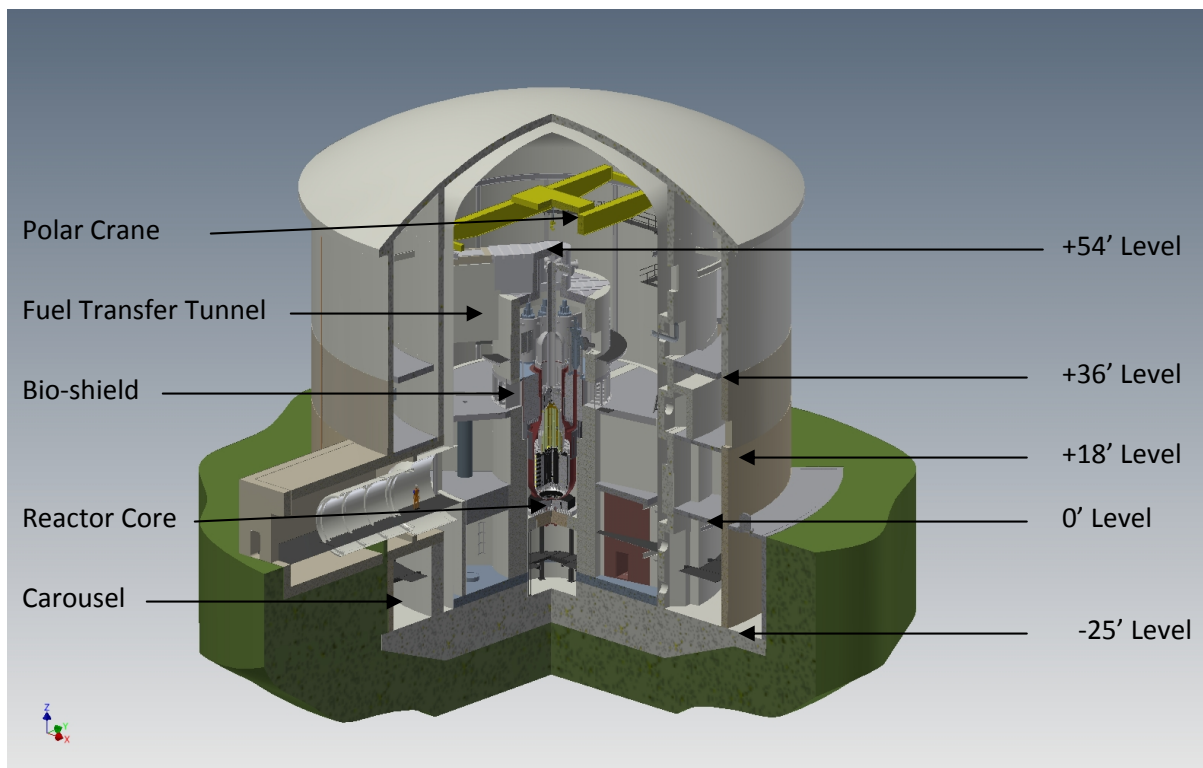


Fig 1. General Layout of the Dragon Reactor.

DESCRIPTION

The work to be carried out consists of:

- Removal of the carousel [Fig 3], the carousel is the fuel element storage facility that consists of 42 positions arranged in a radial direction to carry the Dragon fuel elements when being exported from the reactor. It is of bolted construction so should be able to be readily dismantled. It is sealed behind a lead wall, made up of 5 tonnes of lead blocks in front of another 1 tonne of concrete blocks. The carousel is surrounded by a cooling coil that is suspended from the cell roof on four hanger bars that was surrounded on the outer diameter by aluminium sheeting. It was also believed that two emergency filters were installed located on the floor of the cell.
- Removal of the helium clean-up plant, known as the Hot and Cold Plant which is located under the +18' level shielding floor within the inner containment. This plant removed H² and CO impurities from the primary cooling circuit when the reactor was operational. The plant is contained under 5' thick shielding floor beams and has not been accessible since 1965.
- Removal of the transfer tunnel [Fig 2] – a shielded facility and its associated plant where fuel was transferred from the loading and unloading area into and out of the reactor pressure vessel.
- Removal of all plant in the refueling machine area [Fig 2] – i.e. all the plant above the main shield plug and within the confines of the bio-shield from the charge machine down, including the charge machine, the top of the reactor pressure vessel, primary circulators (X6), primary heat exchangers (X6), canning facility and fuel chutes.
- Demolition of the reactor bio-shield [Fig 4] from the +43' level down to the +23'6" level, 400 tonnes of reinforced concrete with some barites.

This phase of decommissioning is intended to clear all reactor plant, equipment and support facilities in preparation of the next phase. The next phase will begin with a new build, constructing a head end cell over the reactor core, assay facilities and ILW/LLW packing and processing facilities.

Proposed Removal Methodology:

Carousel – the lead wall was to be progressively opened to enlarge the access to the cell with partial removal of the aluminium thermal shield and cooling coil. Then the removal of the fuel element carriers with the upper restraint components and lead shield and the lower support segments from the main shaft. Afterwards the complete removal of the upper coupling shaft, the main shaft, support pedestal and the emergency filter units.

Helium Clean Up Plant (HCUP) – consisting of 3 hot plants each covered with asbestos insulating material, 3 cold plants constructed of stainless steel and hermetically sealed, 3 nitrogen dump tanks, 4 leak detection vessels and a myriad of stainless steel pipe work that was contained in a 20x20x40 ft area. Firstly the floor beams are to be removed, which will involve the removal of lead and steel shots used as shielding. The hot plants will be the first to be removed followed by the cold plants then the nitrogen dump tanks and leak detection vessels are removed last. It is intended to remove the floor beams intact

and replace them to their original location after the area has been surveyed thus creating a value saving on a replacement floor.

Lower Viewing Facility – a periscope like piece of equipment with a camera that allowed the reactor operators to see inside the reactor pressure vessel during shut down. It is mounted in a branch pipe on the reactor pressure vessel at a height of +15 feet, which is approximately 10 feet above the core face. The main optical system, illuminating lamp, focusing, scanning and change of magnification mechanisms are fitted within a pressure tight housing of approximate dimensions of 15'-6" long and 4.5 inches OD. The viewing and illumination of the object is through the pressure windows located at the inner reactor end. The extreme inner end of this housing over a distance of 18 inches is open to reactor full load conditions and houses a combined radiation and thermal shield. A pressure bulkhead is provided between this portion and the rest of the housing. The pressure tight housing is located within an open sleeve which is inserted into the reactor branch pipe to form a guide liner, the outer end of which is flanged and bolted to the branch pipe to form a gas tight seal.

Sr-90 Source – located inside the circulator end plates, its objective was to discharge static electric build up on the rotor in operation. It was mounted in the area of the rear thrust bearing to locally ionise the gas and provide a discharge path to ground. Once removed and packaged the end of the circulator would be sealed.

Primary Circulators – six in total each attached to the six primary heat exchangers located within the reactor bio-shield. Their role was to compress the coolant gas after it had been cooled passing through the primary heat exchangers. They were routinely removed for servicing or replacement during shut down, using a specially constructed two piece trolley and frame, some of which still remains in the facility. The rotor of the circulator ran on gas bearings within the helium atmosphere of the reactor.

Moveable Bio-shield blocks – located atop the reactor bio-shield, these blocks totaling 100t need to be removed in order to gain access to the rest of the plant within the bio-shield.

Fuel Transfer Flask - the Transfer Flask was motor driven and is mounted on steel rails within the transfer tunnel. The machine also connected with the Fuel Canning Facility to enable irradiated assemblies to be sealed inside steel liners for storage in the carousel located below. The Transfer Flask operated within the Transfer Tunnel and was used to transfer fuel elements to and from the RPV. A new fuel element was collected by the Transfer Flask via the Entry Fuel Chute from the Fuel Element Loading/Unloading Area at ground level.

Charge Machine - comprises of a series of apparatus that was used to manipulate fuel and other items. The cage comprises a long tube fitted with a radial bearing at the top and guided with a row of recirculating ball castors at the bottom. A winch was fitted at the top of the cage to which the column was suspended by two stainless steel cables and guided by two rails mounted in the cage. A counter-weight was provided to balance the column. Other items include radial arms, universal joints and grapple heads.

Canning Facility - irradiated fuel was canned in this facility adjacent to the Main entry Valve (MEV) before being dispatched by the Transfer Flask to the Fuel Element Storage Carousel. It had a carousel arrangement in its base which was used to reposition a fuel can during fuel element movements. On

arrival in the facility, the lid was lifted from the can, the can then rotated on the carousel and the lid parked on a second position. The can would then be rotated back into position to receive the fuel element, then the lid replaced.

Fuel Transfer Tunnel – this housed the fuel transfer flask, the internal rails, drive shafts, gearboxes and interlocks etc. The work will include detaching many of the mechanisms from the flask and stripping out cabling and control systems.

Primary Heat Exchangers - the primary circuit comprised of six coolant loops, where each circuit comprised a primary heat exchanger and a circulator. The heat exchangers are approximately 13 ft long and 4 ft in diameter weighing 4te each. A connection flange is located on the side onto which the circulator is connected.

In-Cast Bio-Shield and Transfer Tunnel Removal - concrete shielding blocks are found on the +18ft and +54 ft levels and the transfer tunnel. The upper sections of the plant are surrounded by 300te of 3' thick concrete reinforced with steel bar and some in situ poured barites concrete, used for basic shielding purposes. An assessment of techniques concluded that the best available technique for the removal of the structure was by use of Diamond Wire Cutting Equipment.

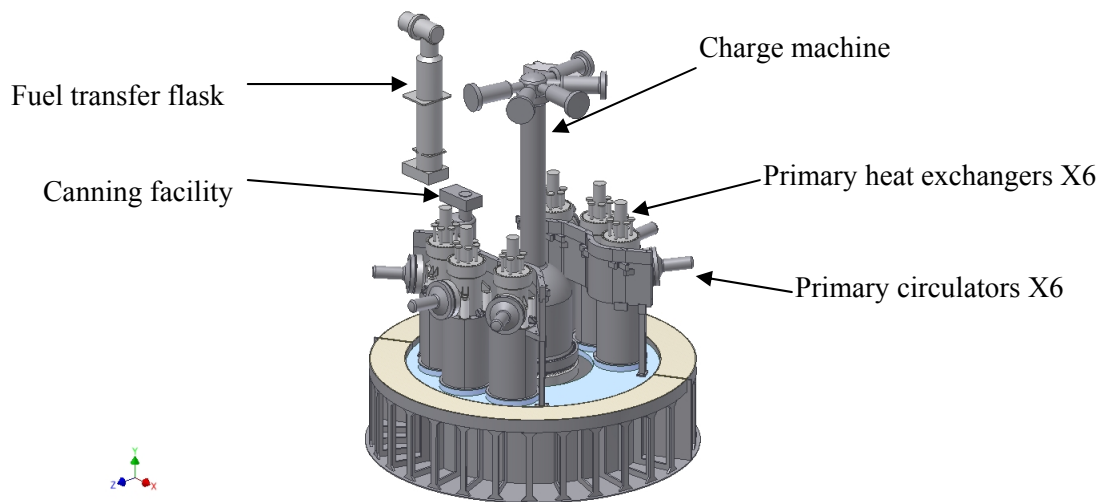


Fig 2. Layout within the bio-shield

DECOMMISSIONING EXPERIENCE

Carousel - The challenge was to reverse engineer the carousel and pass the components through an opening only 4 ft by 4 ft. This was achieved using a specially constructed runway beam and trolley [Fig 5, 6 and 7] that raised and transferred components out of the chamber for further size reduction and processing by the Dragon waste team. The information available about the carousel was very good; as a result an extremely comprehensive methodology could be constructed to assist the decommissioning

team. A total of 20 tonnes of metal was removed from the carousel area and released as free release waste to be recycled.

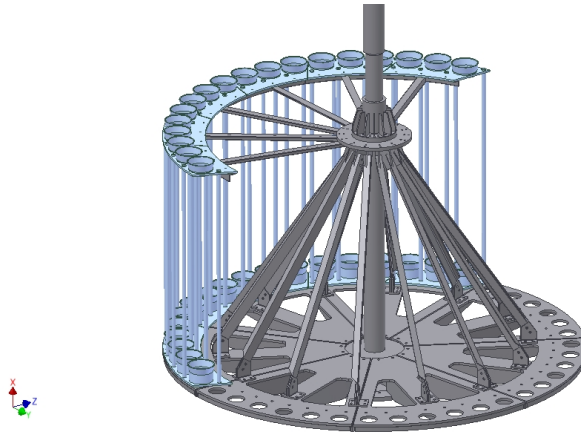


Fig 3. Carousel (Fuel storage) assembly

Helium Clean Up Plant (HCUP)-In order to preserve the shielded floor beams for refitting later, a great deal of care was taken to remove the steel shot, lead shot and grout from between the beams. This work was labor intensive and time consuming; some 15 tonnes of lead and steel shot was removed using a combination of powerful vacuum units and hand held scoops.

Asbestos was present on the three hot plants as it was used as insulation and an asbestos removal enclosure 20' high was constructed to allow specialist contractors to remove the asbestos insulation. This took two weeks and created 883ft³ of asbestos waste that was disposed of as free release.

The most challenging task was the removal of the 3 cold plants; these were expected to be in the region of 15 tonnes in weight and 36 ft tall. They were destined to stand inside a birdcage scaffold construction to allow systematic deconstruction from the top down. During construction of the facility the cold plant were brought into the facility in two pieces and joined whilst suspended within the void. It was not possible to reverse this process which created a difficulty due to the height to which the crane hook could be raised, as a result the rigging of the vessel needed to be no more than three feet to the crane hook. This was achieved and allowed the cold plant to be raised and moved to an adjacent void with a pre-constructed bird cage scaffold. The remaining two cold plant units were removed in the same method.

The cold plants were insulated with perlite which is a natural material comprising mainly a mixture of silicon dioxide and aluminium oxide. When handled, this powdery material increased in volume as it was handled and was removed using vacuum systems, this created 4944 ft³ of insulation waste that was released as free release.

It was expected that the plants would become highly radioactive and for this reason they were installed inside a concrete shielded cell. However, work on similar plant items from the primary circuit has shown low contamination levels, so contamination levels were expected to be low.

The principal concern with this strategy was the unknown construction of the frames into which the cold plant is built. No drawings have been found upon which any assessment can be made of the strength of the frames or any lifting attachments, assuming any of the latter were provided. As a result a systematic top-down approach was utilised, the top six feet being removed by diamond wire cutting. This was deemed necessary due to the mass of small bore pipe work and valve pots present in this area of the cold plant. The remainder of the plant was size reduced using hand and power tools with the majority (80%) being monitored free release.

Lower Viewing Facility - In operational use, the end of the periscope was extended into the RPV during periods of reactor shutdown. Though internal contamination could not be excluded, contamination of the periscope through contact with the gas flow inside the RPV is a possibility, likely to be greatest on the outside of the periscope, but may not be limited to external surfaces.

Activation is likely to be greatest at the end of the periscope which projected furthest into the reactor and therefore had the least shielding from the reactor neutron flux.

The method of removal was by gradually withdrawing, monitoring, decontaminating and cutting the periscope into manageable sections after removing all ancillary equipment. The majority of the lower viewing facility was able to be decontaminated to a point where it could be released as out of scope.

⁹⁰Sr Source - The removal of the source presented a direct radiation and inhalation dose hazard due to the potential for an operator error during removal by dropping, resulting in potential to the source and steel container and exposure to beta radiation from the source. The unmitigated dose for 30 minute exposure duration at 3' was calculated as 29 μ Sv.

The method of removal was by cutting a 3 inch diameter hole in the area of the source carrier, using long handled tools to release the source from its carrier into a pre-prepared transport package.

Primary Circulators - The preferred method of removal employed was to use the same system as the operations team utilised when exchanging/removing the circulators. Some items of the specially constructed two piece trolley remained on site; the frame had been disposed of at some stage earlier. Drawings were available of the original equipment which was readily reproduced. The decommissioning team followed the original methodology for the safe removal of the circulators; the ring of bolts required the use of flogging spanners. Once removed the circulators were placed in a shielded area to wait onward processing.

The average contamination/radiation levels on the circulators were 36500 cps beta/gamma with a contact dose of 1.5m/Svhr.

Moveable Bio-Shield Blocks – Removal of these blocks allowed the operating teams during reactor shut down to remove items of plant in the event they require replacement or repair. The project used this foresight to decommission the plant within the bio-shield and allow access by the crane to the; primary heat exchangers, cast shielding, thermal shields, fuel transfer flask and charge machine.

The moveable blocks each contained in-cast lifting points; an asbestos blanket was laid between each block to prevent stiction. After testing each lift point for suitability the blocks were removed, monitored and removed from the facility as free release, a total of 100 tonnes of reinforced concrete was removed.

Fuel Transfer Flask - The predicted maximum individual dose was 1.78mSv for 1236 hours of operation and a collective dose of 7.04mSv for a total work duration of 4936 man hours. For the external areas of the flask a survey reported contact dose rates of 0.1 – 0.2 μ Sv/h.

However, the thickness of lead shielding affected the ability to measure contamination from within the flask. The interior of the flask was assumed to be contaminated due its function of moving fuel elements. Survey of the interior surfaces (probe and smear surveys) was used to determine contamination levels.

The fuel transfer flask was a substantial vessel so the facility crane was positioned above the flask (bio-shield block removal made this possible) to support the weight. Whilst supported the drive shafts, gearboxes, cabling and interlocks were disconnected. The flask was lifted from the supporting rails and access provided by block removal allowed the flask to be transferred out and over the bio-shield. At ground level the flask was turned to the horizontal and placed on a trolley for removal from the inner containment.

Charge Machine - The charge machine was technically challenging due to its complexity and was located inside the upper removable section of the reactor pressure vessel. It was comprised of a pantograph which was controlled from a separate control room and the majority of its items had been in contact with the Helium coolant and were likely to be contaminated.

The five gearboxes that operated the pantograph were removed prior to the removal of the moveable blocks when access was still available. The removals of the gearboxes allowed for a balanced lift as the gearboxes each weighed 700kg and were off-set. The TV facility was disconnected as was the main entry valve; these items would have caused the machine to be held or be unbalanced during lifting. The charge machine was secured to the reactor pressure vessel by 80 heat stretched fasteners; calculations determined that it was possible to cut these bolts diametrically opposed with a slitting disc without concern of movement or instability. This done the charge machine was lifted from the top of the reactor pressure vessel to an area of the facility earmarked for the potential maintenance of the charge machine, this maintenance facility was never utilised during the operation of the reactor.

It was estimated that the dose rate would be between 2-3 μ Sv/h with a maximum of 15 μ Sv/h in one localised spot, directly below the main entry valve, with another survey conducted to show a dose rate of < 1 μ Sv/h β/γ on the underside of the charge machine; on the outside of the transport bag when being removed. This is with an estimated maximum collective dose of 10 μ Sv and the highest individual dose of <5 μ Sv/h.

Canning Facility - Health physics surveys performed in 2004 at the refuelling machine level involved surveys of the canning cell. No dose rates exceeded 1µSv/hr. Smears collected from the area were found to be as background suggesting there is no loose contamination on exterior surfaces; additionally survey data from the canning cell collected in November 2006 supported this result. Analysis of smears revealed low levels of Am 241 (<0.5 to 0.4Bq) whilst maximum values for ⁶⁰Co and ¹³⁷Cs were 34 and 55Bq respectively.

The estimated maximum dose rate was 30µSv/h with an average of 10-20µSv/h with a collective dose of 50µSv/h; mainly from the primary heat exchangers.

The canning facility was a unit bolted to the floor plates adjacent to the charge machine, driven by dual motors located in an area below. The canning facility was isolated from the drives and the driveshaft cut, any linking pipe work was removed. The gamma gate on top of the facility was disconnected from the main body and removed. The remainder of the canning facility was released from the floor plates and lifted clear of the bio-shield, turned to the horizontal and moved to a trolley for transfer from the inner containment.

Fuel Transfer Tunnel - This involved the removal of items of plant and equipment in the area in order to continue with the rest of the decontamination. It was not expected to be any significant radiation or contamination in the area as surveys undertaken in this area revealed contact dose rates of 0.3 – 0.5µSv/hr for the transfer tunnel.

The inside of the transfer tunnel was further accessed by scaffold to facilitate the removal of redundant plant and equipment at the higher levels.

Primary Heat Exchangers (PHE) - The asbestos surrounding the six PHE units was removed by a specialist contractor and the doses anticipated to be experienced during this process were incorporated in the overall dose assessment for the project. The asbestos contractors used the inside of the bio-shield to form the majority of the asbestos enclosure. It was noted that two of the six PHE units had low radiological burdens as the internal tube bundles had been exchanged for refurbished units shortly before final reactor shut-down in 1975.

It was thought originally that the worst expected dose would be 5µSv/h (based on local area surveys) but in fact it was found from further survey after the thermal shield had been lifted that it was 800µSv/h β/γ and 650µSv/h γ contact and 350µSv/h at 3.2 ft away. This resulted in the decommissioning of the heat exchanger to stall whilst there was a review as the doses were much higher than anticipated. If work continued it would have been outside of scope of the modification to the DSC.

An Option Study, ALARP Review and Method Study were completed before the removals of the heat exchangers were attempted. Micro-shield Assessment was then completed for the PHE 'C', this being the only one accessed at that point.

It was decided that the original proposal to remove the heat exchanger tube bundle and then the main body was not ALARP in light of the new data. It was concluded that the best method was to remove the PHE complete, this would maintain a level of shielding, and to dispose of them as a package. The confirmed method involved the removal of a section of the thermal shielding, to support the PHE on the

facility crane whilst the clamshell cutter was used to cut the main coolant duct. The main coolant duct material was nimonic steel and as such was thought to be particularly difficult to cut. In reality the clamshell cutting tool severed the duct with ease. The principal advantage of the clamshell cutter was that once fitted correctly to the duct the operation was controlled remotely. Once the coolant duct was cut the PHE was free to be bagged and lifted to a shielded area where it could be turned to the horizontal ready for packing and transport.

PHE removal was the most dose intensive part of the operation comprising the cutting, bagging and removal of the PHE; landing and re-slinging in the Cathedral area before lifting and set down on the 10 te trailer. The period in which the highest dose rates and the greatest dose uptake was experienced when the PHE had been lifted and was fully exposed.

In terms of contamination, the highest detected loose contamination was ~ 20000 cps beta on the internals of the PHE. There was minimal spread of contamination; 200 cps was detected on clamshell cutter blades and 500 cps on bolt croppers. There was also 50 cps beta detected on the lip of the PHE just above the cut. The clamshell cutter and bolt cropper contamination was reduced by swabbing to 40 and 100 cps respectively and the ends of the bolt croppers were bagged. The contamination on the lip was covered in PVC during the bagging process.

The PHE was lowered onto a bunded area within the shielded area and as expected there was a small amount of water which leaked as the PHE was laid on its side. This water was monitored and there was no detectable contamination from swabs. Samples were taken and sent for tritium analysis which proved negative.

In-cast Bio-Shield and Transfer Tunnel Removal - Surveys undertaken in this area revealed contact dose rates of 0.3 – 0.5 μ Sv/h for the transfer tunnel and bio-shield concrete. [Fig 4]

The bio-shield had the potential to be contaminated in discreet areas and required health physics surveys, however for tritium concentrations cores were collected in order to determine general activity levels. A cutting plan was developed by RSRL and provided to a contractor which dictated the sequence of removal. It was concluded by assessment that the most effective method of removal was by diamond wire cutting. This was decided because of the amount of control the project could exert over the demolition, the control of liquid arising and the control over block weight, each block will by necessity vary in weight although the expected weight of each block will average 6 tonnes, circa 50 blocks. Scaffold was constructed along side the transfer tunnel and within the bio-shield to allow access for coring and cutting. The blocks were pre-slung on the crane, once cut they were moved to a shielded area for free release monitoring and decontamination if required.

The diamond wire contractor recovered all cooling water used during the process for reuse/recycle; slurry cakes were passed to RSRL for disposal.

The removal of the in-cast concrete bio-shield realized the conclusion of the phase 1 decommissioning by removing and monitoring as out of scope more than 300 tonnes of concrete. This removal leaves the upper support ring which contains 24 absorber rod control mechanisms and the remainder of the reactor pressure vessel containing the reactor core.

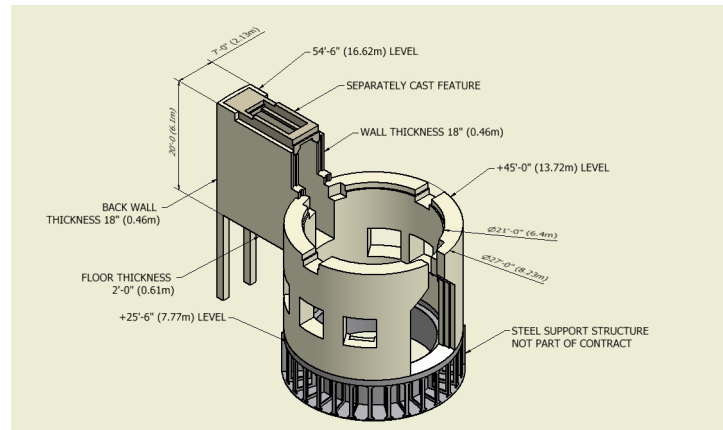


Fig 4. In-cast bio-shield and transfer tunnel

RESULTS and CONCLUSIONS

The reverse engineering approach proved to be an effective measure for the majority of the project, other decommissioning methods needed to be employed at various times. There were a number of novel cutting methods used to solve particular problems as they were encountered. The use of diamond wire cutting techniques was routinely used to cut both concrete and metal including the top of the reactor pressure vessel; cold plant and in-cast concrete bio-shield. A clamshell cutter normally utilised within the oil and gas industry was used to cut the six primary heat exchanger coolant ducts due to high levels of plated contamination within.

As the project progressed it became increasingly apparent that to successfully reverse engineer the reactor access to the original equipment used to service and maintain the reactor was crucial. In the case of Dragon reactor the extended period of Safestore resulted in much of this equipment being disposed of as waste. This premature disposal was due in the main to lack of knowledge of the function of these items, more than 35 years of shutdown caused a succession of guardians to consider the equipment redundant and candidates for disposal. Fortunately for the project suitable drawings remained to enable reproduction; this did however contribute to additional expense and delays.

Techniques

For the majority of the decommissioning and waste processing activities conventional techniques were utilised including use of:

- Hand and power tools
- Cold cutting – reciprocating saws, circular saw etc
- Hot cutting – Oxy-propane, grinding, plasma etc
- Chemical cleaning
- Concrete scabbling

Some significant pieces of work were completed using less conventional techniques; these are used within the nuclear environment but do not normally feature in every project managers tool bag, these include;

- **Diamond Wire Cutting** - Diamond wire cutting is the process of using wire of various diameters and lengths, impregnated with diamond dust of various sizes to cut through materials. Because of the hardness of diamonds, this cutting technique can cut through almost any material that is softer than the diamond abrasive. The Dragon project utilised this technology to remove the stainless steel top sections of each of the cold plants and the size reduction of the charge machine into manageable sections.
- **Clamshell Cutter** – These are compact, split frame clamshells that provide for ease of set-up and spark free cutting. This tool is available in a number of sizes plus they offer the capability of using interchangeable tooling and machine parts. The clamshell cutters mount directly onto the outer diameter of the pipe, requiring minimal radial and axial clearance (just 4.5" from the back of the machine to the cut line). This tool was used very successfully to cut the six coolant ducts that provided primary circuit to and from the primary heat exchangers. This tool allowed the project to cut the duct remotely, with little waste arisings and no airborne contamination.

Learning from the Decommissioning Experience

The reverse engineering principal utilised throughout phase 1 of the Dragon decommissioning project proved to be an extremely viable option; providing a number criteria were achieved. Specialist equipment provided during operations, for maintenance and plant replacement must be retained after reactor shut-down and post operational clean out. They should be maintained in good order and the instructions in their use retained; this knowledge management is essential given the long durations afforded nuclear facilities once they reach the end of their useful life. Drawing records, in particular as built drawings and modifications to plant should be in a format that can be easily accessed. Facilities such as Dragon that had in international collaboration produce documents and drawings in a number of languages, metrics and styles; it is beneficial to have some commonality throughout all records. Operational records, plant logs, daily diaries etc can also prove beneficial to the decommissioning teams, any deviations from the normal or proposed operation of the reactor may be of relevance to a project even 40 years after reactor shut-down.

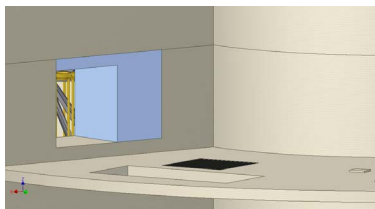


Fig 5. Carousel construction opening

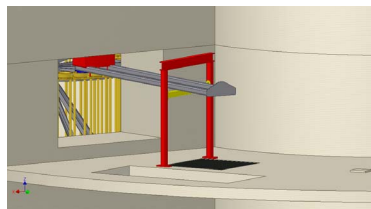


Fig 6. Carousel gamma gate removal gantry



Fig 7. Carousel plant removal gantry

Access to reactor components should be considered a challenge to the D&D teams; during the construction of the facility designers ensured that plant regardless of its size and complexity could be located where it was required. This would have been facilitated with the construction of openings and temporary works which are not recorded or known by today's D&D project managers or planners. This lack of knowledge presents opportunities to think "outside the box" in order to overcome particular problems; an example of this is the opening of a construction opening and use of bespoke lifting equipment shown in Figures 5, 6 and 7.

It should also be a consideration that work practices in the 1950's to 1970's would not be permitted today, changes in health, safety, welfare and radiological protection requirements will reduce the number of decommissioning options available.

Where water is used within the process it should always be expected by the D&D team that water will remain in the system in varying quantities regardless of the assurances that a system has been drained. When used in a circuit such as primary or secondary heat exchange the water in itself is not an issue. The problems arise when it spills in an area of high loose contamination, the water acts as a carrier of the contamination, thus creating decontamination issues away from the area of work.

Accurate radiation dose levels are easy to record given the sophisticated instrumentation available to today's D&D teams. Care should be taken with the interpretation of the results however, failure to consider the results and the impact the decommissioning works will have on those results will force the project to reconsider or rework the programme. Table 1 shows in line 1 the estimated dose uptake for the removal of the primary heat exchangers, the radiation measurements were taken in the area of the heat exchangers with thermal shielding in place. Line 2 shows the actual radiation measurements taken when the thermal shielding was removed; this difference caused the project to stall for a period of time whilst an ALARP review was undertaken prior to continuing.

TABLE 1. Primary heat exchanger dose uptake [3]

Task Description		No. of Pers	Pers Type	Task Duration (hrs)	Total Hours	Measured Dose Rate ($\mu\text{Sv/h}$)	Collective Dose (μSv)	Max Ind Dose (μSv)
1	Removal of Primary	3	Ops	72	216	5	1080	360
	Heat Exchangers X 6	1	HPS	36	36	5	180	180
2	Removal of Primary	3	Ops	3	9	255	2297	1100
	Heat Exchangers X 6	1	HPS	1	1	250	250	45

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