Use of Nuclear Divers in Decommissioning of Spent Fuel Pools/Ponds in the United Kingdom-17431

Allen R. Neiling*,
*Fluor Corporation

ABSTRACT

Magnox Ltd. (Operated by the Cavendish Fluor Partnership) has initiated decommissioning of spent fuel pools/ponds utilizing divers. This decommissioning technique is being employed to disassemble and size reduce underwater equipment and furniture, as well as the collection of sludge and debris prior to draining of the pool. This technique has proven to be highly effective at reducing the radiological exposure to the workforce over previously implemented methods and is expected to significantly reduce overall decommissioning durations and costs.

The decommissioning of the UK Nuclear Decommissioning Authority's (NDA) Dungeness A power station spent fuel ponds was initiated in 2015 to eliminate the mobile hazards and prepare the facilities for entry into a Care and Maintenance period. This dual reactor site has two spent fuel ponds each containing 1000 m3 of water, with the fuel removed since April 2012, which will utilize divers to remove solid wastes from the ponds prior to drain down.

This technique has overcome many challenges to implementation including regulatory approval and high airborne contamination. The use of divers for decommissioning was a new technique for the Magnox Sites and required early engagement with the UK Office for Nuclear Regulation (ONR) and the Health and Safety Executive (HSE). The use of plasma arc cutting underwater required the pond area to be classified as an airborne contamination area. The implementation of local ventilation has controlled this hazard.

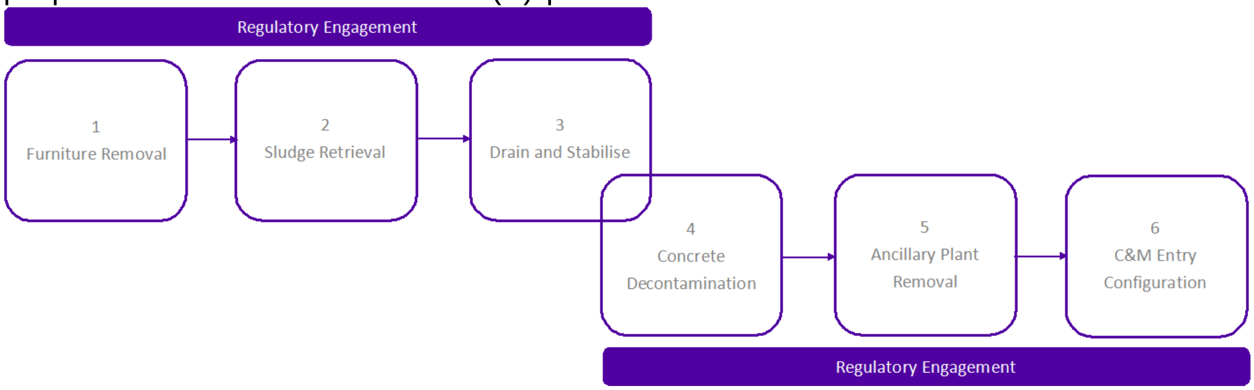
The initial demonstration dives at Dungeness A were completed in April 2016 and the decommissioning dives are expected to be completed in March 2017. This is a substantial improvement to the project schedule and will allow the project completion 5 ½ years ahead of the Licence Condition milestone. This technique is planned to be implemented at two further NDA Magnox power stations over the next three years. This paper provides the accomplishments and lessons learned to date.

INTRODUCTION

Scope of work description:

Magnox Ltd. is contracted by the United Kingdom (UK) Nuclear Decommissioning Authority (NDA) to complete decommissioning of 12 nuclear facilities over a nearly 14 year period. This decommissioning is being implemented through a series of programs that each implements scopes of work across these 12 sites.

The Magnox Ltd. Ponds Program is tasked with preparing the spent fuel cooling ponds/pools at 7 of the 12 Magnox Ltd. nuclear reactor sites for entry into a Care and Maintenance (Safestore) period (estimated to be 50-80 years). These preparations are divided into six (6) phases.



Phase 1: Furniture Removal

Plant and equipment stored in the ponds is removed and packaged for disposition. Typically, this will involve the removal of redundant fuel skips, caesium management equipment, pipework and other fixed items within the pond.

Phase 2. Sludge and Debris Retrieval

Removal of any legacy sludge from the pond and segregation and packaging of debris from the pond.

Phase 3. Drain and Stabilise

The pond is drained of active liquor (contaminated water) via an appropriate water treatment system. The empty pond may then be cleaned and, if it is deemed necessary, surfaces may be stabilised through the application of a fixative to prevent the production of airborne contamination.

Prior to pond draining, assessment of the pond wall/floor radiological and chemical characteristics takes place and this enables determination of whether an aggressive clean is required during drain down in order to control likely dose and contamination levels.

Phase 4. Concrete Decontamination

Core samples are taken from the pond walls and floor to enable characterisation. This characterisation enables determination of how decontamination is necessary from surfaces and joints to establish an appropriate Care and Maintenance Entry Condition. Concrete decontamination may be achieved through a variety of techniques including hydro-lasing, dry scabbling, high pressure water wash or chemical elution (ion exchange leaching out of the concrete back into solution. The method is dependent on level of contamination in the embedded in the concrete and the levels allowed to remain as defined by the care and maintenance entry safety case..

Phase 5. Ancillary Plant Removal

The remaining pond complex plant is evaluated for civil/structural integrity and fire safety. A minimized deplanting strategy is implemented using the output from the civil and fire evaluations. Plant items that are deemed unsuitable for long term storage during the C&M period are removed.

Phase 6. C&M Entry Configuration

During this stage, the physical configuration of the pond required by the C&M Safety Case will be established. This may involve such activities as full removal of the pond structure, installation of an overbuilding or capping of voids. It is notable that the degree of demolition prior to Care and Maintenance varies from site to site depending on the C&M entry criteria and the site access arrangements for inspection and maintenance during the Care and Maintenance phase.

DESCRIPTION

The use of divers to perform this decommissioning was selected as the preferred method through a methods evaluation process called “Optioneering”, where safety (radiological and conventional), technical, costs, and schedule factors are all taken into account and scored to select a preferred approach (reference 1, “Ponds Diving Optioneering”). The diving decommissioning method was compared to the approach previously utilized at three other Magnox Ltd. Reactor facilities (Hunterston A, Bradwell A, and Hinkley Point A) that had completed similar scopes of work. This evaluation showed diving to provide a significant benefit when applied across multiple sites. The cost and schedule savings at the first site were estimated to be less than the follow on sites due to enabling activities, familiarisation and equipment costs, but were still sufficient to warrant selection as the preferred option. The lessons learned in set up and operations as well as reuse of equipment increases the cost and schedule benefits at follow-on sites.

The use of divers during phases one through three (1-3), described above, is planned to be implemented at three sites (Dungeness A, Sizewell A, Oldbury A). The relative size of these pond/pool facilities is given in Table I. The dive team is used to accelerate the removal, size reduction, and packaging of waste materials (Table II) under water. Additionally, the divers implement sludge and debris removal and packaging.

The execution of the diving decommissioning project at Dungeness A was executed by the Ponds project team. The project team prepared the engineering documentation, and both the nuclear safety case, and radiological and conventional safety documentation. This team also installed and tested the field enabling equipment to allow for diving execution. In additional, this team executed the project management for this work scope including contracting with a diving company (Underwater Construction Corporation, UCC). UCC is a United States based company selected for its experience in nuclear diving at nuclear reactor facilities throughout the world. The project team also contracted with Falmouth Divers of the United Kingdom to serve as the company “Intelligent Customer” or technical oversight for the work. This roll is defined as the “Client Representative” under UK regulations. This additional technical support was needed due to the limited diving expertise within Magnox Ltd. and to provide direct field technical oversight of UCC to ensure the UK diving regulations were met. This oversight contractor proved to be invaluable in preparing the dive, to certify the equipment and divers and execute the work. The dive team consisted of 6 divers (1-2 in the water, 1-2 standby/rescue, 1 umbilical tender, 1 equipment tender), 1 dive supervisor, 4 Radiological control technicians, 2 support operators, 1 operations supervisor. UCC was contracted to provide a full service scope, including providing all of the diving equipment and much of the decommissioning underwater tooling. UCC nuclear diving experience has proven key to the success of the work to date. Their knowledge of how to execute the work along with their experience working in radioactively contaminated water (see Table III, Isotopic levels), gave them the ability to work with the project team to plan and set-up the work area, train and practice dressing, decontamination and rescue drills.

Diving Tasks – the dive team is required to:

- Size reduce former fuel skips (steel fuel containers) into flat plates and package into steel baskets, for removal and placement into the waste container for disposition as Intermediate Level Waste (ILW[a]). The skips are a rectangular, painted, reinforced box (no lid) approximately 4 feet by 3 feet by 3 feet constructed of 3/8 inch carbon steel plate, weighing ½ ton each. The size reduction is accomplished manually with plasma arc cutting under water on a stand and each plate rigged into a submerged steel basket. Approximately 2 skips are packaged into each basket for further dry packaging into the final waste container.

- Remove Low Level Waste (LLW[b]) fixed furniture and size reduce it as necessary. Fixed furniture is defined as steel structures (pipes, equipment, guides, wall attachments, bay gates etc.) submerged under the water surface required to be removed to meet the Care and Maintenance entry criteria. The size reduction is also carried out by plasma arc cutting. The size reduced pieces are loaded with excess LLW skips for disposition.

Footnotes:

[a] Intermediate-level waste (ILW) has radioactivity levels that are higher than low-level waste (see below) but which do not generate enough heat to require special storage or disposal facilities. However, like other radioactive waste it still needs to be contained to protect workers from the radiation. ILW arises mainly from the reprocessing of spent fuel and from general operations and maintenance at nuclear sites, and can include metal items such as fuel cladding and reactor components, graphite from reactor cores, and sludges from the treatment of radioactive liquid effluents.

[b] Low-level waste (LLW) is defined in Government Policy as “radioactive waste having a radioactive content not exceeding 4 gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity”. See Reference 2.

- Collect sludge and debris from the floor of the pond/pool by pumping the sludge into a collection tank and segregating and packaging the debris into waste containers for further packing outside the pond/pool. The debris includes Miscellaneous Activated Components (MAC) which measure of as high as 1-2 Sv. The debris are small items, typically less than three inches in all dimensions accumulated in the pond/pool over the 40 plus years of power generation. The sludge, once consolidated in the pond/pool is then pumped to a collection tank in the waste water treatment facility, where it joins other sludge generated over the power station's life.

TABLE I – Facility Details

Size	**Dungeness A**	**Sizewell A**	**Oldbury A**	**Total**
Number of Ponds/Pools	2	1	1	4
Approximate Total Water Volume (m^3)	2000	4000	2500	8500
Approximate inner surface area (m^2)	1800	2400	1600	5800

TABLE II – Waste Types

Waste type/Estimated Quantities	**Dungeness A (R1 &R2)**	**Sizewell A**	**Oldbury A**	**Total**
Total skips (Number)	117	148	136	401
ILW skips (Number)	53	45	28	126
LLW Furniture Removal (Tons)	20	375	30	425
Sludge (m^3)	2.5	4.1	3	9.6
Debris (MAC/Other Debris) (m^3)	1	3	2	6

TABLE III – Water Isotopic Levels

Isotope	**Concentration (Mbq/m^3)**
Cs-137	10
Sr-90/Y-90	3
H-3	70
Am-241	10^{-2}

DISCUSSION

- **Set up and challenges**

The area set up required the installation of many physical modifications to the pond building. Electrical modifications were required to ensure diver safety while in the water. An entry/egress platform over the pond surface was required to be designed, fabricated and installed due to the limited existing access to the pond. A floating ventilation hood was designed, fabricated, installed and commissioned to collect airborne contamination during hot cutting from the contaminated water. Finally, a temporary ventilation barrier was constructed to separate the dive control station from the diver entry platform and the pond itself. This ventilation barrier allows for the control station to be in a non-contaminated area, but also enclosed the diving entry platform to form a separate ventilation area on the platform from the pond itself. The separate ventilation area on the entry platform was necessary to allow the diver to be decontaminated and enable removal of the dive helmet and suit in a suitable radiologically controlled area, separate from the airborne area of the pond and the clean area of the dive control station. The separate area is required due to the calculated airborne concentrations created by the diver exhaust bubbles and the water disturbance from the underwater plasma cutting. These calculations were proven correct in the dive trials stage, when the pond area airborne contamination exceeded respiratory protection thresholds (C3 conditions in the UK) on the first dive. This was further confirmed in the full scale execution work when the airborne concentrations exceed high airborne contamination levels (C4 conditions in the UK) during plasma cutting operations. See reference 3 for definitions of C3 and C4 conditions.

These physical modifications proved to be the critical path schedule to commencing the field work. This is a testament to success of the early engagement with the regulators to gain permissioning for implementation of this decommissioning technique.

- **Regulatory Engagement**

The approach to regulatory permissioning for use of diving decommissioning was implemented with a very open approach. The regulatory agencies, Office of Nuclear Regulation (ONR), and the Health and Safety Executive (HSE) were engaged in the earliest stages of planning. Two months after project kick off the regulators were briefed on the general approach and the expected activities to be achieved. After the initial optioneering, the regulators were brought back in to review the selection of the diving option. The ONR were then briefed upon completion of the Nuclear Safety Case and a round of detailed questions and answers were held. Clean water cutting trials were also performed and to select the optimum cutting method. Videos of these clean trials were also presented to the regulators to increase their knowledge of the process. The ONR and HSE were given a field walk down of the diving area prior to preparation beginning and the modification for radiological control described. These series of interface meeting and discussions allowed the ONR and HSE to gain a level of understanding of the technique and how it was to be implemented. The increased level of understanding by the ONR and HSE lead to a level of confidence that the diving could be completed safely within the limits of the safety case, and in compliance with the safety documentation and regulations. The regulatory engagement process was completed over a nine month period of sharing information and answering questions.

The ONR and HSE have each visited Dungeness to witness and carried out formal inspections of the diving decommissioning and have been satisfied with its implementation.

- **Benefits of diving decommissioning**

Decommissioning of nuclear fuel storage ponds/pools utilizing underwater diving has proven to have many benefits. The Magnox Ltd. work has shown three (3) main benefits to utilizing underwater diving. First, the removal and size reduction of redundant equipment and materials can be accomplished much more quickly than removal with long reach tooling. Second, the work is also accomplished with a lower cumulative work radiation exposure than with conventional use of long reach tooling for equipment removal and in air size reduction of wastes. Table IV below shows a comparison of the radiological exposure calculated for traditional methods of decommissioning verses diving decommissioning and the indicative dose received to date by the divers during the first 25 dive evolutions verses the pre-dive calculations. Third, acceleration of schedule provides shorter overall project duration and therefore lower overhead costs.

The schedule advantages at the Dungeness A facility accounted for a reduction 5 1/2 year ahead of the regulatory completion milestone. The traditional technical solution in Magnox for removal of highly active equipment and structures has been to use long handled tooling to remove the components, followed by a separate campaign to size reduce and package the waste for disposition. The diving decommissioning approach allows for the removal, size reduction and initial packaging to be completed as one activity. The final packaging is completed after waste is removed from the water and placed in the disposal/disposition container.

The radiological exposure advantages utilize the shielding properties of the pond/pool water itself. The divers maintained a small distance from the high activity waste, which has the shielding benefit to keep exposure rates ALARP/ALARA This was even the case on the initial dives where the divers utilized small stands installed at the bottom of the pond/pool to maintain a 2 foot clearance above the floor surface. While on the stands, the divers cleared highly active sludge and debris from the floor beneath the stands and in the general area, allowing them to reduce the contact dose rate at the pond floor surface.

Diving decommissioning is expected to produce cost savings for the Dungeness A facility of £3.5M and over £16M across the three sites combined. This is mainly attributed to the reduction in the overall site closure duration. Completing the pond decommissioning in an accelerated manor removed this project from site critical path schedule and will allow the overall site closure to be completed 2 years earlier than previously planned.

TABLE IV

Task	Calculated Dose for traditional Method	Calculated Dose for Diving Method	Actual Exposure for the first 25 dives (man uSv)
Furniture removal, Size reduction and packaging	180	80	47
Sludge and debris collection	545	186	7
ILW skip size reduction and packaging	2200	100	154
Dive support team	16519	2650	2211

CONCLUSIONS

The implementation of diving decommissioning at the Dungeness A Reactor 2 pond facility has been a great success. The completion of the diving trial and initiation of full scale implementation has been completed safely with no radiological contamination or conventional events. The diving has been witness by the UK regulatory agencies and has met all compliance requirements and passed all audits. The planned scope to date has been completed within budget but is slightly behind schedule due to longer durations to complete preparatory works including breakdowns of the 50 plus year old plant. The UK NDA are pleased with the progress to date and the development of a new technique for decommissioning nuclear facilities under their liability in the UK. This decommissioning method is now being planned to be implemented at the Sizewell A Magnox Ltd. facility in the summer of 2017 and will be evaluated for implementation at the Oldbury A Magnox Ltd. facility in 2018.

REFERENCES

1. M.G. TILSLEY, “Programme Level Options Assessment – Decommissioning of the Dungeness, Sizewell and Oldbury Ponds “, DNA/PONDS/23376/RPT/2953
2. Magnox Ltd. Standard, S-036, Integrated Decommissioning and Waste Management Strategy
3. Ionising Radiations Regulations 1999 (UK - IR99)

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