PLANNING FOR DECOMMISSIONING IN UK NUCLEAR NEW BUILD

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Abstract

When submitting designs for regulatory approval in the United Kingdom, reactor vendors are required to ensure that the whole plant lifecycle has been considered; not just build and operation. A specific requirement relates to decommissioning and in particular demonstrating that such activities can be performed safely, many decades in the future.

As experience demonstrates, there are significant technical challenges relating to decommissioning of commercial reactors. Furthermore, the UK regulatory regime presents additional challenges in terms of the demonstration that risks from decommissioning are reduced So Far As Is Reasonably Practicable (SFAIRP).

In addition, potential operators of these proposed reactors are required to have sufficient financial arrangements in place to fund decommissioning, waste management and various other costs relating to end of reactor life. This is demonstrated through the submission of a Funded Decommissioning Programme (FDP), before commencement of construction.

Such challenges must be met by any organisation looking to build and/or operate reactors within the UK. An important 'tool' in meeting such challenges is the use of previous experience of decommissioning in the UK. For example, what is deemed to be good practice in one country may not necessarily be considered good practice in another. Such experience is invaluable in supporting reactor vendors and utilities who may lack such an awareness and understanding of UK regulation and good practice.

This paper highlights some of those key challenges and how they can be overcome. Vital experience from both a design for decommissioning and a programme management point of view has already been gained from projects in the UK and this paper describes how some very novel problems have been solved.

1. Introduction

This paper presents an overview of decommissioning in the UK, taking a forward look at decommissioning arrangements for new nuclear build.An overview of the main nuclear sites in the UK is presented, along with a discussion on how decommissioning is funded for these sites, whether they be legacy, existing generation or new build facilities.The UK regulatory regime is described in relation to decommissioning, which leads to a discussion on some key lessons learned internationally from decommissioning of facilities performed to date.A number of example decommissioning projects in the UK are then presented; highlighting some of the key challenges, which may hopefully be avoided when decommissioning future facilities by taking into account the relevant lessons learned.

2. Background

As the UK nuclear industry began to expand during the post-war years a large number of facilities were constructed.In order to develop and support the nuclear weapons programme at that time, these facilities were constructed and commissioned at great pace. Decommissioning was rarely considered.A significant consequence of this approach means that today, the UK is faced with a large number of legacy facilities requiring decommissioning under challenging circumstances.One organisation in particular, the Nuclear Decommissioning Authority (NDA),alone is responsible for 17 sites itself across the UK, dating back to the 1940s [1].

These facilities were constructed with little, if any, planning for decommissioning. The focus was on bringing the technology in to service quickly.Indeed, the fledgling nuclear industry had very little experience to draw upon for such activities at the time and there may also have been the expectation that future technological developments would allow for safe decommissioning. To the present day, as decommissioning of legacy facilities forms a large part of the nuclear industry, significant technical challenges are being overcome through the application of sound, but sometimes novel, engineered solutions; as well as some simpler, but perhaps less obvious solutions.

Figure1, published by the Office for Nuclear Regulation (ONR) [2], shows the range of sites that they regulate in the UK.It is clear to see from this Figure that a number of nuclear sites have already commenced decommissioning.

3. Decommissioningfinancing arrangements

Financing for the decommissioning of facilities in the UK is dependent on the type of facility in question:for legacy sites (e.g. Magnox sites, Dounreay etc.), the NDA manages funding; decommissioning of existing generation sites (e.g. EDF Energy's fleet of Advanced Gas Reactors (AGRs) and Pressurised Water Reactor (PWR)) will be funded via the Nuclear Liabilities Fund; operators of new build stations are required to manage the costs themselves, as stated in theirFunded Decommissioning Programmes(FDPs).

3.1. The Nuclear Decommissioning Authority (NDA)

The NDA is the UK public body which owns 17 of the legacy nuclear sites across the UK.The role of the NDA is strategic, setting the overall approach and budgets for the decommissioning of these sites. The NDA cite their responsibilities as follows [3]:

- decommissioning and cleaning up these nuclear facilities
- ensuring that all waste products, both radioactive and non-radioactive, are safely managed
- implementing policy on the long-term management of nuclear waste
- developing UK-wide strategy and plans for nuclear Low Level Waste (LLW)
- scrutinising the decommissioning plans of EDF Energy, who own the operating fleet of AGR nuclear power stations

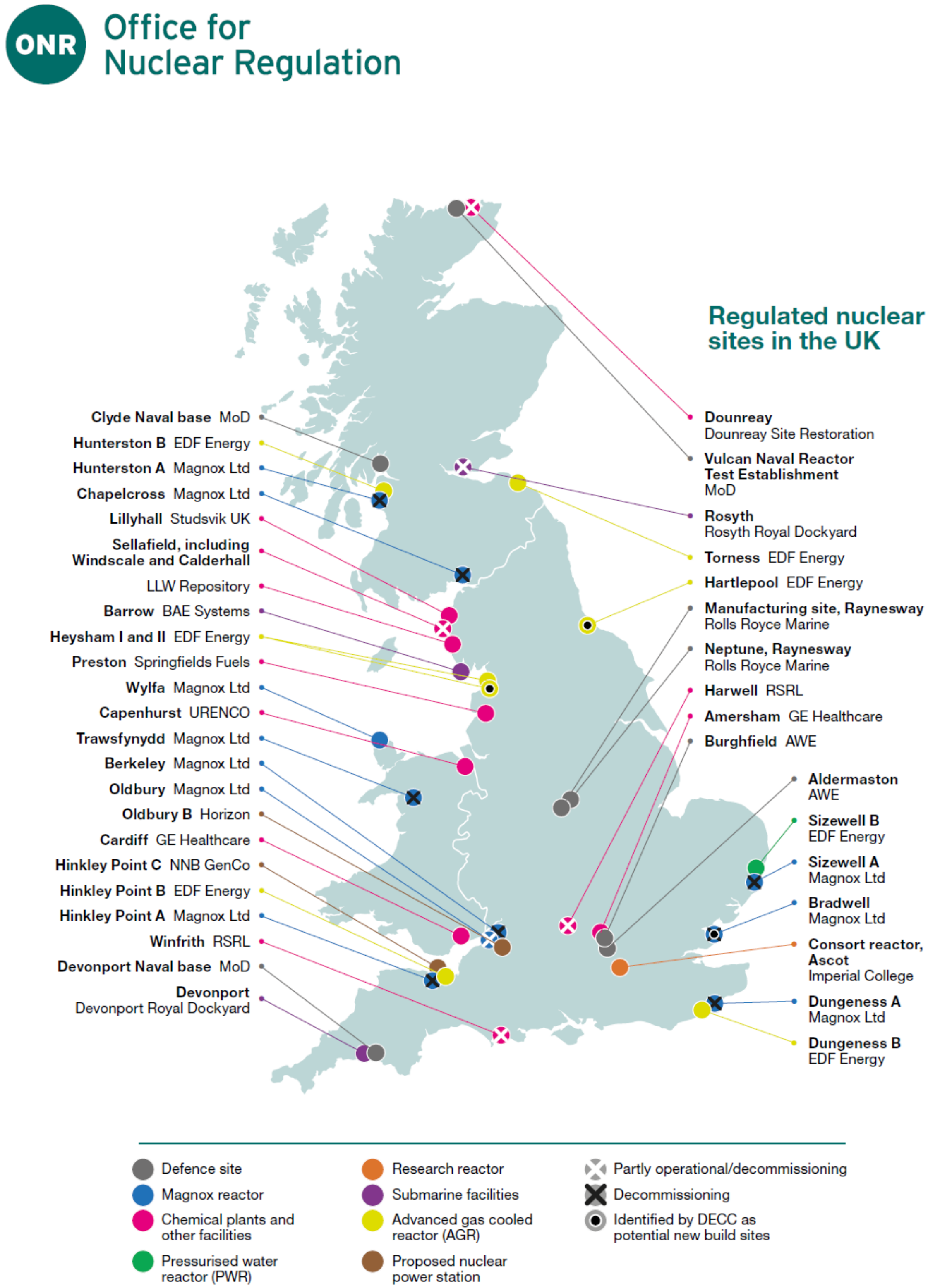

Figure 1 - Regulated nuclear sites in the UK [2]

3.2. Existing Generation

Funding for EDF Energy's fleet of seven AGRsites and one PWR is managed by the Nuclear Liabilities Fund [4]. This was formerly the Nuclear Generation Decommissioning Fund and is a UK Government fund aimed at financing long term costs associated with the decommissioning of these reactors.The UK Government is responsible for funding any shortfall in the fund in relation to the costs of decommissioning.

3.3. New Nuclear build

In terms of new nuclear build in the UK, funding requirements are enshrined in law by the Energy Act 2008 and various pieces of secondary legislation such as the Nuclear Decommissioning and Waste Handling (Designated Technical Matters) Order 2010 (SI 2010/2850), the Nuclear Decommissioning and Waste Handling (Finance and Fees) Regulations 2011 (SI 2011/134) and the Nuclear Decommissioning and Waste Handling (Finance and Fees) Regulations 2013 (SI 2013/126).

The Act ensures that secure financial arrangements are made by operators to cover the full costs of decommissioning. This includes costs related to waste management.These arrangements are contained within the operators FDP, which contains detailed, costed plans for decommissioning as well as waste management and disposal.The FDP needs to be submitted by the operator to the Secretary of State for approval before construction commences.Operators will then put aside funding throughout the operational lifetime of the plant.Ownership of wastes will be passed on to the Government.

4. Regulatory requirements for newbuild pertinent to decommissioning

Regulation of nuclear activities, and therefore decommissioning, in the UK is primarily the responsibility of the ONR in terms of nuclear safety.For environmental aspects such as disposals and discharges of radioactive waste, the Environment Agency, Scottish Environmental Protection Agency and Natural Resource Wales hold regulatory responsibility for England, Scotland and Wales respectively.This section summarises some of the key regulatory requirements relating to decommissioning in the UK.

In terms of UK law, the key pieces of legislation are the Health and Safety at Work etc. Act 1974 and the Nuclear Installations Act 1965.

- The Health and Safety at Work etc. Act introduces the requirement for the risk from work based activities to be As Low As Reasonably Practicable (ALARP). This is a principle which runs deep within the UK nuclear industry.
- The Nuclear Installations Act sets the requirement for nuclear site licences. These are required in order to build and operate most nuclear facilities, including reactor sites.

4.1. Site Licence Conditions

There are 36 conditions [5] attached to a site licence and these provide the main basis for ONR regulation.Whilst the 36 site licence conditions have applicability for the whole plant lifecycle,Licence Condition 35 specifically relates to decommissioning. There are two elements of Licence Condition 35 that are of particular relevance in the context of this paper:

35(1) The licensee shall make and implement adequate arrangements for the decommissioning of any plant or process which may affect safety.

35(2) The licensee shall make arrangements for the production and implementation of decommissioning programmes for each plant.

The first part of Site Licence Condition 35 is intended to ensure that decommissioning is planned and taken into consideration during all parts of the plant's lifecycle. The second part to ensure an appropriate, resourced, decommissioning plan is in place for all relevant parts of the facility.

4.2. Safety Assessment Principles

The ONR Safety Assessment Principles (SAPs) [6]provide a framework by which ONR regulators can make consistent judgements on the safety cases concerning nuclear activities. The requirement for safety cases derives from a number of separate Site Licence Conditions.There is a specific section within the SAPs that relates to decommissioning. In terms of design and new build, one of the key principles, taken directly from the SAPs, is as follows:

DC.1 Facilities should be designed and operated so that they can be safely decommissioned.

Para 828. Decommissioning and waste retrieval should be taken into account during the planning, design, construction and operational stages of a new facility or modifications of an existing facility, including: (a) design measures to minimise activation and contamination etc; (b) physical and procedural controls to prevent the spread of contamination; (c) control of activation; (d) design features to facilitate decommissioning and to reduce future dose uptake by decommissioning workers; (e) consideration of the implications for decommissioning when modifications to and experiments on the facility are proposed; (f) identification of reasonably practicable changes to the facility to facilitate or accelerate decommissioning; and (g) minimising the generation of radioactive waste.

Further information of the assessment of Decommissioning is covered in the ONR Technical Assessment Guide for Decommissioning [7]. This document serves as an additional guide to ONR assessors.

5. Decommissioning Experience and Lessons Learned

5.1. Decommissioning Experience in the UK

The 11 Magnox sites in the UK have all been retired from operation and are at varying stages of decommissioning. In addition, a number of other research/prototype reactors (such as Prototype Fast Reactor (PFR) at Dounreay and Windscale AGR (WAGR) at Sellafield) are undergoing decommissioning.

Berkeley was the first Magnox station to be shut down during the late 1980s. It entered the 'Safestore' period in 2010, the first site to do so.Figure2 taken from [1] shows the current status of decommissioning for each of the Magnox sites in the UK as well as other sites owned by the NDA.

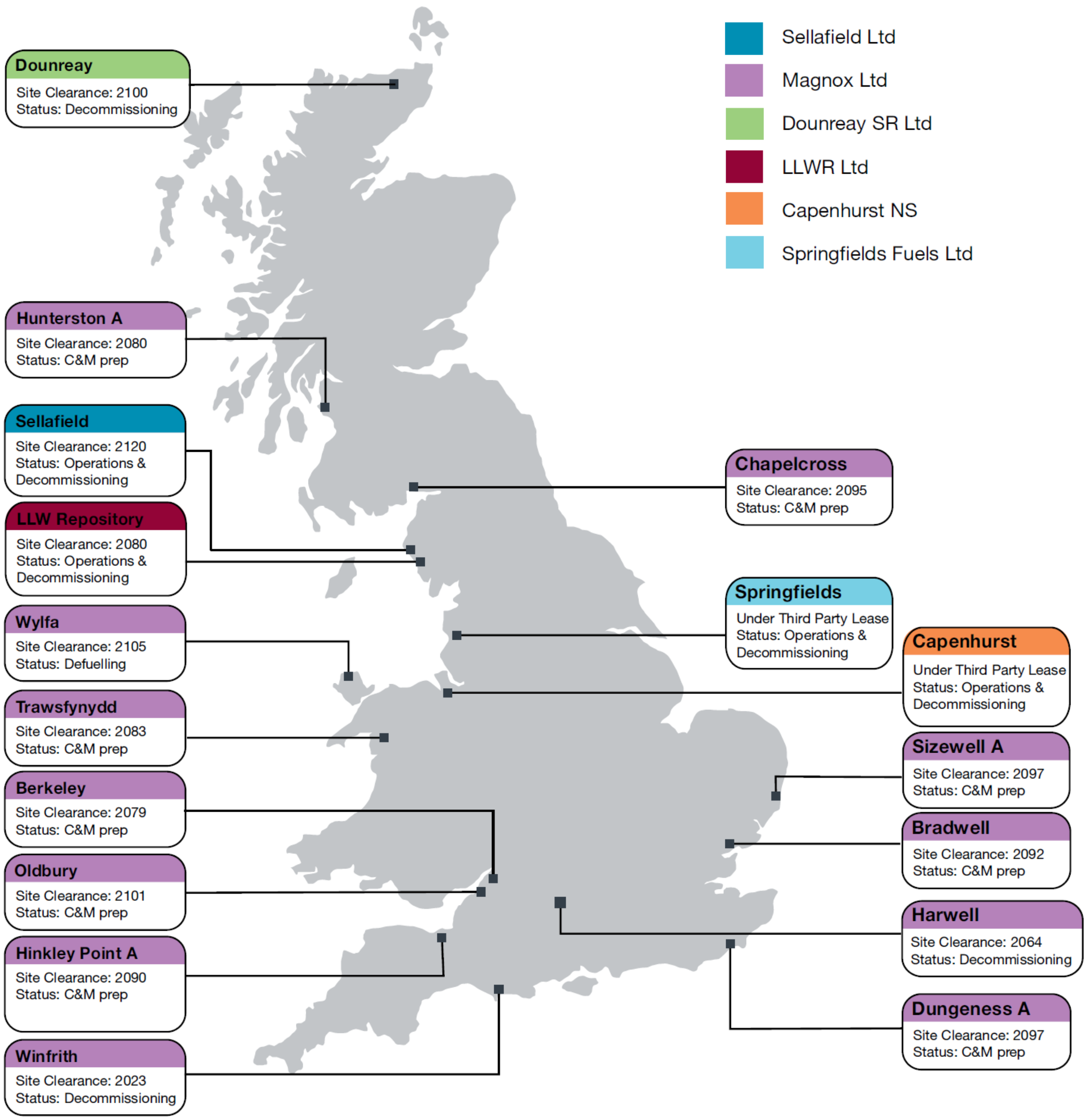

Figure 2 - NDA Estate [1]

5.2. Decommissioning experience globally

According to data published by the World Nuclear Association (WNA) [8], around 90 commercial power reactors, 45 experimental or prototype power reactors, as well as over 250 research reactors and a number of fuel cycle facilities have reached the end of their operational lifetime.

A significant amount of experience has therefore been built up already and some key lessons learned have been published by the International Atomic Energy Agency (IAEA) [9].The IAEA performed a detailed literature review of the available lessons learned from decommissioning and presented the results in a report.There were found to be many similarities and common areas between projects and the IAEA were able to group lessons learned in to five specific sections:Policy and Strategy, Licensing and Safety, Radiation Protection and Optimization of Shielding, Project Design and Management, and Waste Management and Decontamination.The IAEA report [9] also identifies a set of design features to be considered as part of the design for decommissioning process as follows:

- Minimization of Activated Products
- Rigorous Contamination Control and Provision of Decontamination Facilities
- Easy Access and Adequate Space for Dismantling Radioactive Items
- Modular Designing for Easy Removal
- Segregation of Contaminated Items
- Providing the Ability to Segment Large Items In-situ
- Design of Ducts and Piping Systems
- Limiting the Provision of Underground Services and Equipment
- Designing for Thorough Post-operation Clean Out
- Designing for the Minimization of both Operational and Decommissioning Waste
- Providing Adequate Waste and Spent Fuel Storage Facilities
- Management of Records for Decommissioning

6. Project Examples

These section presents a summary of a number of decommissioning projects previously performed in the UK along with some of the key lessons learned. With decommissioning of a whole facility being such a significant task, the examples provided relate to specific activities and are as follows:

- Decommissioning of tanks at Trawsfynydd– a project to remove a tank in an area with both load and access constraints.
- Steam Generating Heavy Water Reactor (SGHWR) Decommissioning – an overview of a major decommissioning project.
- Winfrith External Active Sludge Tanks (EAST) Treatment Plant (WETP) – a project highlighting the type of difficulties arising as a result of poor record keeping and unknown inventories.

6.1. Decommissioning of the Trawsfynydd RB Tank

6.1.1. Introduction

Nuvia delivered the contract to decommission the problematic sludge filtering and drying vessel at Trawsfynydd Magnox station which was constructed in the 1970s and named the RB Tank after the late Trawsfynydd engineer, Robert Byron Jones. The tank, which was a legacy of the site's electricity generation era, had the highest level of alpha contamination ever encountered on site and the safe conclusion of the project marked a major hazard reduction milestone for Magnox.

6.1.2. Challenges

A challenging working environment was presented by the presence of non-load bearing floor areas and restricted access around the existing enclosure of the tank. This led to the development of an innovative approach to the installation of the modular containment. A sectional rail system was designed to enable the steel support frame to be constructed in a low radiation area at one end of the Active Workshop. The rail system spanned the non-load bearing areas of the workshop floor and allowed the steel frame and partially constructed modular containment (ModuCon®) to be pushed into position over the tank. Once in its final position, the containment end wall was installed and the entry/exit and waste posting facilities constructed, the entire unit was then sealed. A new, upgraded ventilation system was connected to the containment.

6.1.3. Lessons Learned

The use of the rail system enabled construction away from the tank minimising dose uptake during the installation phase and the risk of damage to the existing tent enclosure already in place. This methodology consequently minimised the risk of contamination of the environment.

For new build facilities, consideration of access (including space and loading requirements) for decommissioning activities is required. This would hopefully minimize the occurrence of such challenges, reducing duration, cost and most importantly, dose to workers, during such activities.

6.2. Steam Generating Heavy Water Reactor (SGHWR) Decommissioning

6.2.1. Introduction

The SGHWR at Winfrith operated from 1967 until 1990, closing 18 months earlier than expected for economic reasons. It was a 100MW(e) boiling water-cooled heavy water moderated reactor built as a prototype for the UK's third generation of nuclear power stations.

6.2.2. Scope

The project objectives included preparing the reactor for long term storage with minimum care and maintenance. This was to be achieved whilst minimising radioactive waste and radiation dose. The project was arranged in six work areas within which 120 individual sub-projects were identified. The decommissioning operational programmes were:

- Nuclear Fuel Repackaging and Dispatch - At shutdown the fuel pond and active cave lines contained many non-standard, damaged and partially dismantled fuel elements produced during operations and development work. The work programme included repackaging fuel, and design, development and operation of novel handling equipment.
- Fuel Ponds - The fuel and associated ponds were cleared of equipment, drained and decontaminated to allow access as a Supervised Area.
- Primary Circuits - Detailed care and maintenance strategies were developed for individual circuits including the primary cooling circuit, moderator plant, shutdown system and neutron shields. Work included structural assessments and the design and operation of novel inspection equipment to establish base line data and monitor corrosion.
- Secondary Circuits - Again, strategies were developed for each individual plant taking into account structural integrity, radiation and chemical hazard reduction and long term cost effectiveness. When left in-situ plant was disconnected from other services and clearly labelled.
- Containments - A containment strategy encompassing individual enclosures and a revised safety justification was put in place allowing ventilation and emergency generation systems to be decommissioned. Detailed structural assessments were used to identify remedial work and justify long term care and maintenance. As part of the work in this area an asbestos register was collated and, where justified on cost and ALARP grounds, the asbestos hazard was removed by approved contractors.
- Buildings and Electrical Supplies - Where it was justified by studies, external buildings and peripheral plant structures were decommissioned and demolished to reduce the station footprint. Wherever justifiable on cost and ALARP grounds equipment was decontaminated and sold off for recycling to offset decommissioning costs. Electrical supply systems were rationalised for long term care and maintenance.

6.2.3. Lessons Learned

SGHWR stage 1 decommissioning produced a number of unique problems that were managed safely and efficiently. Such a large decommissioning project enabled a large amount of experience to be gained in general. This was especially so given a lot of the work was novel.Lessons learned were captured and recorded at closeout for use on future projects.

6.3. Winfrith EAST Treatment Plant (WETP)

6.3.1. Introduction

At the former United Kingdom Atomic Energy Authority (UKAEA) research site at Winfrith in Dorset England, Nuvia Limited was contracted to design, build, commission and operate a waste treatment plant to stabilize 300 m^3 of radioactive sludge stored in four concrete storage tanks - the External Active Sludge Tanks (EAST). The sludge was generated during the operational lifetime of the SGHWR, which was shut down in 1990.

6.3.2. Challenges

During the latter stages of the retrieval of the ‘bulk heel’ from Tanks 1 and 4, it was discovered that there was a quantity of what appeared to be a gravelly material >2mm in size, together with some bolts and other extraneous items on the base. The origin of the gravelly material is unknown but may have entered the tanks during construction of the roof or the later addition of extra concrete shielding. The significance of materials >2mm in size is that the 500 litre drums were not permitted to contain any materials above this diameter in order to ensure required conditions for the stabilization process.

Various methods were used to recover the metallic items from the tank using magnets on cords and other ad-hoc processes but recovery of the gravelly materials was more problematic. Larger chunks were recovered using a ‘dustpan’ unit with long poles to push the items into it and then lift away to the roof. In order to assist with the recovery of the remainder and to concentrate the residues of sludge and water into Tank 2, a ‘Big-Brute’ industrial vacuum pumping system was purchased and used to transfer these materials between the various tanks. This powerful vacuum system was required owing to the ~4.5m height that the heavy debris had to be lifted from the tank base to enable it to be transferred between tanks.

Tests showed that the equipment was ideally suited for this process and it was extremely successful in operation. After fitting a recessed 2mm filter screen into the Tank 2 roof port, the ‘Big-Brute’ was used to transfer small batches of sludge and associated debris from Tank 3 into Tank 2 such that the oversize materials could be intercepted, rinsed and removed with the ‘Big-Brute’. This ensured that the resulting sludge contained only solids <2mm in size in accordance with the terms of the Letter of Compliance required for the resulting 500 litre drums.

Around 1700kg of gravelly materials were recovered from the tanks and placed in ~25kg batches into 68 prepared 200 litre LLW drums. The ‘Big-Brute’ recovered ~25kg batches of the oversize materials from the >2mm filter located over Tank 2 into the prepared can located outside the tanks at ground level.The ~60 m^3 of ‘bulk heel’ in Tank 2 were then processed as before down to the last 400mm depth when the stirrers became ineffective.During these operations leading up to handing of the ‘final heel’ in Tank 2, when these last ~ 20 m^3 of consolidated sludge were to be processed, a further problem was encountered with the discovery of a quantity of sandy residues in the bottom of the tanks. These finely divided materials had clearly passed through the 2mm sieve and tests showed that they contained high levels of silica.

The radioactivity of this debris was significant but not much different to that for the main sludge batches with a dose rate of ~250µSv/h from a 100 cm^3 sample. At this point the final phase of the recovery and processing was instigated with the introduction of the Separation and Filtration Vessel (SFV) via an enlarged opening in the roof port of Tank 1. The port had previously been stitch-drilled and sufficient concrete removed to permit the introduction of a 1.5m diameter tank.

The requirement for another vessel to hold the ‘Final Heel’ had been planned much earlier since a means had to be found to ensure that this material met the target specification. Thus a 1.5m diameter steel vessel was constructed with a 4.7m height and support legs to hold batches of about 6 m^3 of sludge and supernate. The base was domed to accommodate a stirring system and an outlet pipe for the contents when ready for stabilization.

The ‘Big Brute’ was then used to move the ‘final heel’ into the SFV, although a quantity of the sandy materials remained at the Tank 2 base for later attention. This ‘final heel’ was then stirred to homogenize it and, after sampling, excess water was removed to allow these final batches of sludge to be pumped to the WETP facility and the last 500 litre drums of encapsulated sludge produced. This process did not go as smoothly as had been hoped, since during pumping of sludge to WETP the pipe-work became blocked with sandy materials. After due assessment of the situation it was decided to introduce a new suction pipe from the top of the vessel down to a point above the base to minimise sucking up the sandy materials collected at the domed base. After some local adjustment this worked well and provided the flexibility the system needed to overcome this problem.

We have already noted that the disposal of the oversize gravelly materials was undertaken ahead of handing the ‘Final Heel’ to clear these materials from the work areas. The completion of the encapsulation of the SGHWR sludge in the ‘final heel’ then allowed attention to be focused upon the handling for disposal of the ~3 m^3 of sandy materials. In both cases a similar approach was adopted using a disposal container located centrally inside a standard 200 litre LLW drum. The bulk of this drum held crushed concrete to surround the can used to hold the two types of debris. The ‘Big-Brute’ at all times remained at the roof level and away from operatives to minimise dose uptake and local shielding was also used to assist in the achievement of this objective.

The final stage of this process concerned the recovery of the sandy materials from Tank 2 and the SFV. In this case the system included an initially open inner can to allow the sandy debris to be introduced by the ‘Big-Brute’, and then cement and water added and the whole contents stirred remotely with a small machine to homogenize them and allow them to stabilize when the mixture cured.In this situation, dose rates were measured dynamically on the outside of the LLW drum to ensure that the 1mSv/h acceptance level for LLW disposal was not exceeded. Trial and error showed that between 15 and 20kg of sandy material could be added before challenging this dose rate. The drum was then covered and moved to a shielded location to cure; then it was capped off with more crushed concrete and the lid attached. Again, astonishingly, a total of 186 of these drums were produced during this process which stabilized about 3 m^3 or about 2.75Te of this debris.

6.3.3. Lessons Learned

The project methods were developed on the basis of available historical information including details of the tank contents. A clear lesson is to be more circumspect about old records and take steps to verify information where possible. In this instance, through discussions with the client, it may have been possible to sample the tank bases for signs of other materials as one tank only held about 5 m^3 of sludge.

During this project there was considerable attention to operator dose minimisation but the presence of the oversize materials and latterly the sandy debris significantly added to this burden. Thus the collective doses during the recovery and stabilization of these two sets of debris were 5.3mSv and 7.5mSv respectively. Despite these exposures within a team of about 8 operatives, no Dose Restraint Objectives (DROs) for the EAST /WETP plants were ever exceeded.

Crucially, the presence of gravelly and sandy debris at the bottom of each tank was seriously challenging to the timescale, and thus the costs, of the project. It has been estimated that the task of recovery, stabilization and disposal of these materials added about 18 months to the project duration. It also produced 254 additional LLW drums for disposal. The problems noted above demonstrate the difficulties often experienced with projects of this nature on old plant and facilities where unexpected problems nearly always emerge in the course of the work. As described above, good recorded keeping is clearly an important tool in reducing such unexpected issues.

7. Conclusion

This paper presents an overview of decommissioning in the UK, with a specific focus on new nuclear build.An overview of the main nuclear sites in the UK is presented, along with a discussion on how decommissioning is funded for legacy, existing generation and new build facilities.

The UK regulatory regime is also described in relation to decommissioning, which leads to a discussion on design for decommissioning and lessons learned from decommissioning of facilities performed to date. These two facets together highlight the strong focus placed on decommissioning even before a new reactor can be built in the UK.

A number of examples of decommissioning projects in the UK have also presented, highlighting some of the key challenges, which may hopefully be avoided with future facilities.

8. Acknowledgements

This paper contains public sector information published by the Health and Safety Executive and licensed under the Open Government Licence.

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