STABILISATION OF SGHWR SLUDGE AND THORIUM METAL IN A COMMERCIAL PLANT IN THE UNITED KINGDOM

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ABSTRACT

Nuvia Limited is contracted to design, build, commission and operate a waste treatment plant to stabilise the active sludge stored in the External Active Storage Tanks (EAST) at the former United Kingdom Atomic Energy Authority (UKAEA) research site at Winfrith, UK. The sludge was generated during the operational lifetime of the Steam Generating Heavy Water Reactor (SGHWR), which is now in the early stages of decommissioning. This is in support of UKAEA's mission, which is to carry out environmental restoration of its nuclear sites and to put them to alternative uses wherever possible. Recently UKAEA has been reorganized and responsibility for the site now lies with Research Sites Restoration Limited (RSRL) with funding provided by the Nuclear Decommissioning Authority (NDA).

The process of stabilisation of the SGHWR sludge from the EAST tanks within 500 litre stainless steel drums in the Winfrith EAST Treatment Plant (WETP) is now almost complete with 1033 drums stabilised to date and only a few more anticipated. At this point it was originally planned to decommission and demolish the WETP facilities but RSRL have contracted Nuvia to undertake in the plant another stabilisation project involving 11Te of thorium metal waste. As a result the plant is in the process of being revised to provide facilities for encapsulation of the thorium metal within modified 500 litre drums together with a number of changes to the plant control system.

The concrete-shielded WETP facility consists of five cells separated by shield doors and is designed to maintain strict contamination control. There is a wet cell where the drums are filled with the sludge and powder, a cell with stations for curing and grouting the drums, a cell for lidding, bolting and QA inspection, a maintenance and gamma monitoring cell and a buffer store to hold the completed drums. After completion, drums are moved in a shielded overpack to the Treated Radwaste Store located on a different part of the Winfrith site.

The process of recovery and homogenization of the residual sludge in the bottom of each tank to the required specification has been described earlier to include use of a tall steel filtration/separation vessel within one concrete tank to hold the final batches such that they can be homogenised as required. The final stages of this process will be given particular attention in the paper.

In the revised cell line configuration to deal with the thorium waste, the wet cell will be isolated and not used. The 500 litre drums are to be introduced as before but taken to the original rework cell located to one side halfway along its length. The modification to this cell to make it suitable for handling the thorium waste within a drum loading enclosure will be described together with changes to the drum to centralize the bars under revised grouting arrangements using Ordinary Portland Cement and Pulverised Fly Ash.

The final aspects of the paper will briefly describe the approach to be adopted for the final decontamination and demolition of both the EAST facility and WETP plant.

INTRODUCTION

The External Active Storage Tanks (EAST) is a set of four concrete storage tanks located in the south-west corner of the UKAEA (now RSRL) Winfrith site (Figure 1). It was constructed at the same time as the experimental Steam Generating Heavy Water Reactor (SGHWR) to accept the radioactive effluent and ion exchange resin that arose from the operation of various sections of the reactor plant. A number of campaigns of reactor circuit cleaning were involved throughout the operating period aimed principally at the removal of iron and other metallic contaminants. Although of relatively low specific activity the sludge is unacceptable for disposal at the Low Level Waste Repository (LLWR) site due mainly to its high C^{14} content and is therefore treated as Low Level Waste unacceptable for the UKs LLWR waste depository. The concrete tanks are each 7.3m x 7.3m x 4.3m high and were fitted with a set of four submersible stirrers mounted from the roof structure to provide a means of suspending and homogenising the sludge.

Figure 1:   Exterior view of the WETP facility with the
EAST Tanks Building in the background

Most of the details about the processes concerned with recovery and treatment of the sludge in the four tanks has already been reported, (Reference 1). One of the key features is the requirement for the sludge to be homogenised by stirring within the tanks and sampling to demonstrate that it contains the required solid to liquid ratio necessary for stabilisation in the 500 litre drums. The means by which this ratio is adjusted to the required level has also been described before but in essence allows for the removal after stirring of calculated quantities of supernatant water after a short period of settlement followed by transfer to a holding tank at the WETP plant.

The emptying of the four tanks has almost been completed with three now completely empty and the last currently concentrating upon recovery of a quantity of sludge residues and sandy fines found at the bottom. The discovery and means of recovery for disposal of these latter materials will be discussed later. The latter stages of the sludge stabilisation concerned the transfer of the final residues and debris from Tanks 1 and 4 into Tank 2 and the introduction of a tall steel filtration vessel (SFV) into Tank 1 to hold and then homogenise the 'final heel' sludge from all other tanks. The reasons for this are based upon the large floor area of the tanks and the need to be able to homogenise and concentrate the sludge from the final tank to meet the delivery specification ahead of the stabilisation.

This paper will set out the means by which the tanks have finally been emptied and also the plans that are in place to allow the receipt and encapsulation tanks in WETP to be emptied of sludge residues ahead of the proposed decommissioning and demolition of the plant. The modification of the WETP plant to provide for the stabilisation of metallic thorium residues released from the Winfrith site will also be described in outline. Some details about the plans for decommissioning and demolition of the EAST tanks are included which may be of interest to others working in a similar environment.

OVERVIEW OF STABILISATION PROCESS

The process of homogenization of the SGHWR sludge, its recovery to the WETP plant and stabilisation into 500 litre drums for intermediate storage on the Winfrith Site has already been described, (Reference 1). Briefly, the sludge is homogenised and then pumped across from the EAST facility to the WETP plant where it is held and kept stirred to supply ~350 litre batches of sludge to the individual drums. A mixture of Ordinary Portland Cement (OPC) and Blast Furnace Slag (BFS) is then added to the drum which has a 'lost paddle' to provide for full mixing of the contents for a specified period. After standing for 24 hours the drums are then cap-grouted with a mixture of OPC and Pulverised Fly Ash (PFA) to complete the sealing of the contents. After a further time for curing, the drums are lidded and swabbed to ensure the external surfaces are clean and ready for transfer to the on-site Treated Radwaste Store, (TRS). Two drums are recovered into a transfer stillage and then moved using a large fork-lift truck to the store where an automated crane is used to load them into vertical storage tubes, where the materials will remain for a period of years ahead of other disposal options being considered.

The WETP plant was constructed by Nuvia for the purpose of stabilising the sludge and once all materials have been treated will then be used to stabilise a small quantity of Thorium metal into similar 500 litre drums for location in TRS. Full details about the design of this plant and how it operates are given in Reference 1. Unless further stabilisation work is identified for this plant, other than the ~11te of thorium metal already mentioned, the final stage of the project will be to decommission both the EAST tanks and the WETP facilities and then carry out demolition.

TANK EMPTYING PROGRESS

The tank emptying process comprised three phases starting with removal of bulk sludge from each tank down to around 400mm from the base. The electric stirrers, which were introduced through four roof openings into each tank, were then removed and recovery of what is termed the 'bulk heel' (the materials from ~400mm to the base) undertaken using a small submersible pump. Once the sludge reached a level of around 25mm from the base of the tank, it ceased to flow to a single retrieval point so a high pressure water jet was then used to move the sludge toward the submersible pump for removal. Although this process was successful, this method introduced significant additional quantities of water into the tank and dose uptake by operatives during this activity was higher than planned.

During the latter stages of retrieval of sludge from each tank, it was discovered that each contained a quantity of what appeared to be a gravelly material >2mm in size together with some bolts, lengths of wire and other extraneous items that must have fallen into the tank over the many years of operations. The origin of the material >2mm is unknown but may have come about during the pouring of the tank roof during construction or later work on the tanks when additional concrete shielding was applied to the original roof. Various methods were used to recover the mainly metallic items from the tank but the gravelly materials were more problematic. In order to assist with their recovery and to help to concentrate the residues of sludge and water into one tank, a commercial vacuum pumping system was purchased and used to transfer these materials from Tanks 1 and 4 into Tank 2. This produced a greater quantity of sludge, water and gravelly material in Tank 2, allowing Tanks 1 & 4 to then be rinsed and further emptied to complete this stage of the decommissioning. The rinsing was undertaken using a commercial irrigation head introduced in turn through each of the four tank roof ports. The head provides a powerful water jet that can be articulated by the water flow such that it covers almost a 360° arc to rinse all surfaces within about 5m of its nozzle. This process was extremely successful as was confirmed by subsequent monitoring of the tank internals where low levels of residual activity down to a few tens of microsieverts/hour were recorded.

During subsequent operations the opportunity was taken to consolidate all the sludge and debris into Tank 3 using the vacuum system and then to gradually remove the oversize debris with a 2mm filter assembly located within a roof port during final transfer of all the contents back into Tank 2. This ensured that the resulting sludge contained only solids <2mm in size in compliance with the terms of the Letter of Compliance required for the resulting drums. Since this tank had been emptied earlier, it allowed the operation to take place within an acceptably low dose-rate background. After rinsing the debris in the filter within Tank 2 to wash off any remaining sludge, these materials were recovered using the vacuum system and placed into specially equipped 200 litre drums for disposal. This operation was completed by the end of 2008 as has been described earlier (Reference 1).

INTRODUCTION OF THE SLUDGE FILTRATION VESSEL

It was recognised that for recovery of the final vestiges of sludge it would assist if the materials could be retrieved into a tall, slim steel vessel located within one of the empty tanks. The sludge filtration vessel (SFV) was designed to hold about $6m^3$ of sludge and supernate within which it could be homogenised, excess supernate removed and the remaining sludge sent to WETP for stabilisation. This recognised the difficulty in recovery of the sludge tailings from each tank and the need to remove the gravelly, oversize debris ahead of its stabilisation. These operations and the introduction of the steel vessel into Tank 1 via an enlarged roof port have already been described elsewhere, (Reference 1).

PROGRESS WITH STABILISATION OF SLUDGE IN WETP

Over the past two years the bulk of the SGHWR sludge from all four tanks has been homogenised and transferred to WETP for stabilisation. The WETP plant has continued to receive and stabilise the sludge since the earlier report (Reference 1) and to date 1033 drums have been produced, virtually without incident. On the basis of current estimates, less than another 30 drums will be produced from the materials remaining in Tanks 2 & the SFV to complete this task. The plant performance has generally remained good but in these final stages of recovery of the sludge some finer, sandy materials have been found at the bottom of Tank 2. Whilst this material can be picked up by the commercial vacuum system for placing into the SFV its characteristics make it more difficult to keep suspended particularly during transfer to the WETP and within the receipt and encapsulation tanks inside that plant. As a result there have been difficulties with the plant operation and in a few cases blockage of the suction dip pipes in the tanks, which has hindered the transfer of the material in EAST and WETP. A number of techniques were introduced to safely remove the blockages and changes have been made to the stirrer units and their speed of rotation to increase the suspension of these finely divided materials so that further drums can be filled with sludge batches for stabilisation and disposal. Shortened dip pipes were also introduced to 'decant' the lower density and smaller particle size material.

Once the WETP plant has completed the stabilisation of the sludge inventory it will enter a pipework/tank flushing regime to recover any residues left in the system. A specific procedure for undertaking this non-standard routine has been prepared and it is possible that as a result a small number of non-specification drums may result owing to the difficulty of meeting the solid/liquid ratio required in the main stabilisation programme. The issues surrounding this possible outcome are currently being investigated. This will avoid having to deal with small amounts of residual sludge at the end of the next project which concerns the stabilisation of a batch of Thorium metal bars, fragments and fines within the 500 litre drums.

THORIUM STABILISATION PROJECT

A quantity of ~11te of thorium metal bars, broken fragments and fines is to be stabilised in modified 500 litre drums following completion of the sludge stabilisation programme. These materials have been retained at the Winfrith Site for many years and no further value or use could be identified for them. A plan for their stabilisation inside modified 500 litre drums used for the sludge has been agreed with the NDA with interim storage in the Treated Radwaste Store on the Winfrith Site.

The WETP rework cell has been modified and provided with a drum loading enclosure (DLE) where the thorium will be recovered from steel boxes and placed into metal trays, (Figure 2) using manipulators. The cell is provided with a water filled viewing window since the thorium metal has a very low specific activity. The trays can be loaded centrally into drums such that they can be grouted with a cement/PFA mixture that will stabilise them for long term storage. The drums are introduced through the route originally intended for defective sludge drums from the main cell line. These drums will contain the sets of metal trays within which the thorium bars and other sections will be loaded. Facilities are provided in the DLE to lift these trays out of the drum for loading and subsequent replacement.

There are concerns about the risk of fire during unpacking and loading of the drums from thorium fines such that great care has been taken to eliminate any combustible materials from the DLE. The facility is also provided with temperature monitoring equipment to check that the thorium is not getting hot and there are a number of fire sensors present to alarm if any fires start in the facility. Graphex extinguishing powder is being provided to assist with fire suppression should any occur

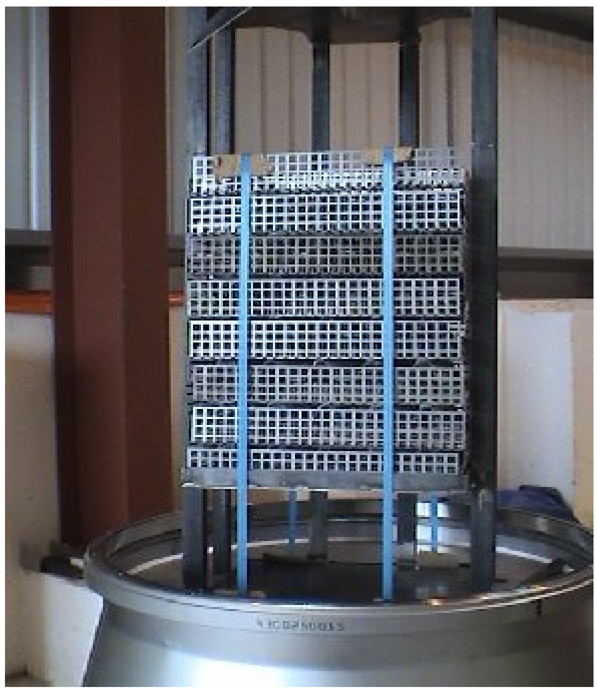

Figure 2: Test 500 litre drum with thorium holding trays

Thorium fines associated with the bars are to be stabilised inside small steel dishes which will hold a quantity of cement/PFA to which the fines will be slowly added and stirred to minimise any concerns about a thorium/water reaction. Larger fragments will be treated in the reverse manner, with grout being added to small dishes holding them.

Work is now well advanced with all the mechanical installations complete and the electrical control system installed. The setting-to-work and integrated testing phase is currently in progress leading to inactive commissioning in the near future.

OPERATIONAL EXPERIENCE & LESSONS LEARNT

In an earlier paper (Reference 1), the original problems associated with setting to work the WETP plant and creating 500 litre drums of stabilised sludge have been described. Several important lessons were learnt during this period and over the past year a different range of problems have emerged to be solved associated with the production phase and dealing with the unexpected.

The presence of extraneous items and gravelly debris at the bottom of each tank has been challenging to the project. The mixture of these materials along with the sludge greatly complicated the latter stages of recovery into the required solid to liquid ratio for subsequent stabilisation. Whilst the recovery of the mainly metallic items was relatively simple, the coarser gravelly debris was more difficult. The solution here was to purchase a commercial vacuum pumping system to recover all but the largest sections of concrete from the tank base into a >2mm mesh filter box at the tank roof. However, its separation from the adherent sludge by spraying with water would have been much better undertaken at the tank base position rather than the tank roof since operatives' radiation exposure levels were greater than predicted. This shows the importance of better knowledge of the tank contents such that solutions can be found ahead of need rather than devised to solve an immediate problem.

Recently another problem has emerged due to the detection of what appears to be coarser sandy materials within the final layers of sludge at the base of Tank 2 and in the SFV. However revisions to the speed of rotation of the stirrers within WETP tanks has assisted as has the changes to some sections of pipework to minimise the drawing of sandy materials into the final delivery of batches of sludge to the encapsulation vessel.

The problems noted above demonstrate the difficulties often experienced with projects of this nature where debris has to be recovered for disposal purposes from old plant and facilities and unexpected problems emerge in the course of the work. The key issues are to identify the nature of the unexpected materials and to find a means of dealing with them such that the process can be completed with minimal impact upon progress. In this case the success with this latter objective can only be described as patchy and there have been some delays experienced whilst effective solutions were found.

EAST TANKS & WETP DECOMMISSIONING PLAN

A comprehensive decommissioning plan has been prepared to cover both the EAST and WETP facilities based upon previous experience with projects of this nature, (Reference 2). The project falls into two reasonably distinct phases since at the end of the sludge recovery process the EAST tanks will be available for post operative clean-out (POCO) and decommissioning well ahead of the WETP plant. This is because the latter plant will, after flushing to recover residual sludge, be reprogrammed to undertake a short programme of stabilisation of a quantity of Thorium metal for RSRL using similar 500 litre drums. Later, the second phase concerning the POCO and decommissioning of the WETP facility will be undertaken. Here the plant was designed and constructed with ultimate decommissioning in mind so that the process is expected to be achieved more readily than will be the case for the EAST facilities constructed mainly in the 1960's.

The EAST tanks are enclosed within a portal framed building constructed in the mid 1990s to provide weatherproofing for the facilities. They comprise a concrete structure with 0.6m thick walls standing 4.6m high and occupying a floor area roughly 16.4m x 18.0m. The four tanks have internal dimensions of 7.3m x 7.3m x 4.27m high and all surfaces except the roof structure are coated with an epoxy/phenolic paint to minimise contamination from the sludge. Recent sampling of concrete from the outer shield walls and roof has revealed that the whole structure is contaminated with tritium (H^3) whilst the roof structure also contains measurable levels of fission products Cs^{137} and Co^{60}. This is probably due to the absence of any paint on the roof inner surface, a notable omission during its construction. These contaminants put the latter materials into a LLW category unless some decontamination can be undertaken. The general absence of significant penetration of fission product contamination into the external walls, and by implication the interior walls too, suggests that this may yet be possible. The ultimate fate of only tritium-contaminated sections of concrete has yet to be agreed between RSRL and the Environment Agency with a VLLW route distinctly possible.

The decommissioning plan provides for the cutting of openings into the walls of each tank by diamond sawing to provide man and machine access from ground level. The interior of each tank will be monitored and then cleared of residual items and debris such that man entries become possible. The interior will be decontaminated manually by swabbing and other non-invasive techniques. The walls and floor can then be scabbled as necessary to remove the painted layer plus up to 10mm depth of the underlying concrete. The concrete roof will be supported with steel props and then cut away by diamond sawing for disposal followed by large sections of the shield walls using diamond wire techniques due to their thickness. Gas-powered fork-lift trucks with ~8Te capacity will be used to handle the concrete sections, moving them out of the building for temporary storage ahead of any required further decontamination and size reduction. The plan is to clear most of the tank structure to create space within the building and then to bring the sections back for scabbling in a horizontal plane using mechanical equipment. The building will be provided with HEPA-filtered local extract units to support these operations to minimise the risk of escape of contaminants to the environment.

Work on decommissioning of the WETP facilities will follow later but in parallel with parts of the programme for the EAST tanks. Here the levels of internal contamination from sludge are known to be low and being of modern construction much more thought has been given to its ultimate decommissioning and demolition. As a result the vast bulk of materials from the process cell are expected to be disposed of as exempt waste with a significant amount of recyclable material from the steel structures.

CONCLUSIONS

Over the past year the recovery and stabilisation of sludge left over from the operation of the SGHWR plant at Winfrith into 500 litre drums has continued within a new WETP facility constructed by Nuvia Limited and a total of more than 1000 drums have been produced.

Early decommissioning problems were overcome by harnessing the skills of the engineers and work force to develop practical solutions and the plant throughput has been reasonably high over the past year. As the tanks reached an empty state two unexpected problems emerged associated with the viscous nature of the sludge at the base and the discovery of gravelly and sandy debris at the tank base. Solutions to these problems have now been developed and it is anticipated that up to about 30 more drums will be produced to complete the project.

Plans are well advanced concerning the modification of the WETP facilities to undertake the stabilisation of 11te of thorium metal once the sludge operations have been concluded.

A comprehensive decommissioning plan for the EAST facilities and WETP plant has been produced and it is anticipated that this will commence during the last quarter of 2009.

ACKNOWLEDGMENTS

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REFERENCES

1. Hall C, Hagan M, Cornell R M and Staples A, 2008,
   Operational Experience with a Sludge Handling & Stabilisation Plant at UKAEA Winfrith.
   Proceedings of Int. Conf. on Waste Management, WM'08 Conference, Phoenix Arizona, USA**.**

2. Cornell R M and Adlem L, 2008,
   EAST and WETP Decommissioning Plan
   Nuvia Document TR/045710/226 Issue 5.