

OPERATIONAL CHALLENGES AND SUCCESS IN THE STORAGE, MOBILISATION AND SOLIDIFICATION OF LEGACY FLOCCULANT SLUDGES AT AWE

M. J. Beresford
Atomic Weapons Establishment
Aldermaston, Berkshire, UK, RG7 4PR

ABSTRACT

The atomic weapons establishment (AWE) has provided and maintained the United Kingdoms Nuclear deterrent since the 1950's. A by-product of its effluent treatment process is a Ferric Flocculant Sludge. Traditional methods of cementation and disposal by sea dumping was discontinued in the 1980's. The sludge continued to be generated and was stored in ageing tanks, awaiting the commissioning of a new sludge treatment facility. The new treatment plant was not commissioned and the legacy problem of stored sludges had grown considerably. Following a Best Practical environmental option (BPEO) study vitrification was chosen as the long-term solution for dealing with these sludges.

The continued deterioration of the tanks led to a major review of the stored sludge problem and accelerated the urgency for dealing it. The opportunity to use and evaluate an industry proven portable cementation rig to cement and dispose of the contents of two of these tanks of sludge led to the adoption of cementation as the long term solution for immobilisation and disposal of the stored sludges.

INTRODUCTION

The treatment of stored legacy sludges at AWE presented both large engineering and operational challenges. The major engineering challenge was to install a modern, fully operational mobilisation and transfer system in and around existing ageing plant whilst maintaining a respect for the condition and unique problems of the plant. The installation was carried out over two years and is currently commissioned and dealing with the legacy sludge holdings. One of the major operational challenges was to change the mind-set of the past which had led to a negativity and avoidance of this legacy waste problem. The adoption and encouragement of the correct people, who ignored this pessimism and recognised that the challenge could be tackled successfully has resulted in a cohesive and dedicated project team which is currently on track to achieve all objectives to the required timescale.

Generation of Wasteform

Active Liquid Effluent treatment at Aldermaston has been via a flocculent settling process since the early 1960's. Active effluent is batched in large tanks of up to 75m³ where it is mixed with a seed sludge and dosed with chemicals. This treatment initiates the settling process. The liquid is then pumped to a clarifier, receiving further chemical dosing on the way and then separated from the sludge via a weir system and pumped to a treated effluent holding tank. The effluent is then

pumped via a large sand filter to pre-discharge tanks where it is sampled and if found to be below discharge limits, subsequently discharged to the River Thames via a 16km underground pipeline.

Active and inactive heavy metal particles are retained in the flocculent sludge at the clarifier stage of the plant. The sludge is maintained in storage cones where it is regularly sampled and continues its use as an initiator until its content exceeds specified levels of activity and/or heavy metals. It may then be pumped from the storage cones to sludge storage tanks.

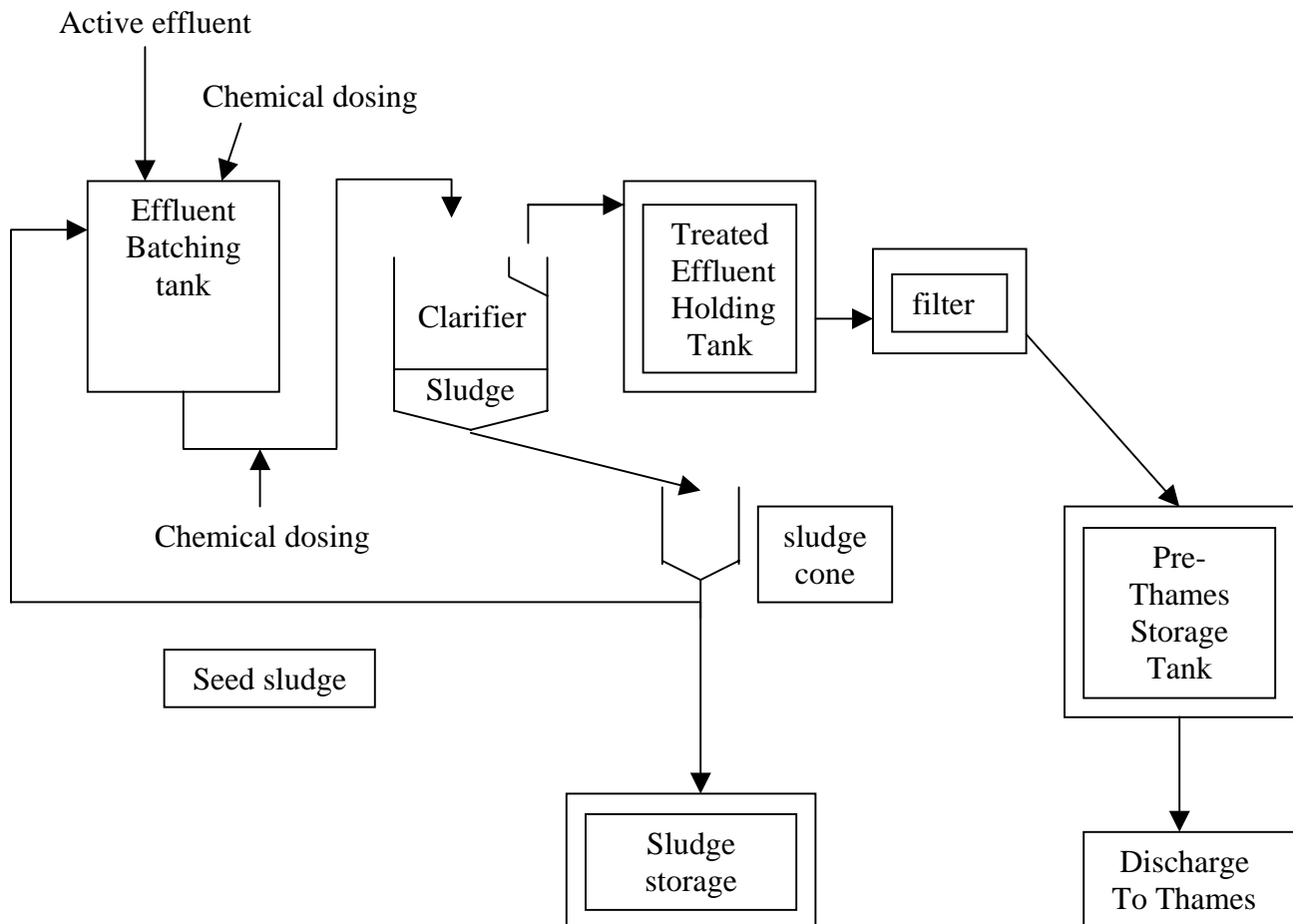


Fig. 1. Schematic of water treatment process

Until the early 1980's the sludge was taken from these storage tanks and treated and solidified in an adjacent facility. The final waste form was sea-disposal drums which were then disposed of at specified locations in the North Atlantic Ocean.

Following the International treaty which led to the Cessation of Sea dumping in the early 1980's the sludge continued to be generated and when it had exceeded its limits for use in the plant

continued to be transferred and stored a total of twenty identical 30yr old 50m³ Open air bunded storage tanks.

This storage was deemed to be temporary whilst the building and commissioning of a new Cementation plant was undertaken. The proposal was to transfer and then cement the sludges into Stainless Steel NIREX approved containers for long-term storage. This would be initially on site at AWE and eventually at the UK's forthcoming underground long-term repository.

Inventory/Properties of Wasteform

The raw process sludge which was received into the storage tanks had a very low solids content. It was discovered that the settling process continued within the storage tanks and that the tanks could be regularly de-watered. During the period of generation in the tanks a regular programme of re-visiting the tanks and removing the clear 'supernate' was implemented.

The clear supernate, which had a low activity, when compared to the remaining sludge could be treated and disposed of via the Liquid effluent treatment plant. The reasons for this were twofold. The Main reason was to reduce the volume of holdings in the tanks but it was also to maintain reserve capacity in the tanks for the introduction of further sludges if required.

In July 2000 an incident occurred which questioned the integrity of these holding tanks and led to the cessation of further storage of new arisings within these tanks.

At this point it was estimated that the holdings in the tanks were in the order of 800m³.

Table 1. Estimated Active Inventory of Storage Tanks

Pu	1.5 – 100g
Heu	30 – 300g
Utotal	3000 – 15000g

The incident in question was the discovery of a pinhole leak on the underside of one of the tanks and a small quantity of Supernate leaking into the bund. The leak was dealt with effectively but the urgency for dealing with the stored sludges was accelerated.

It was anticipated that due to the fast settling nature of the sludge it was unlikely that, with the exception of a major tank failure a large leak of sludge would occur. The hydrostatic pressure on the tanks due to the supernate above the sludge was deemed to be a hazard which could help contribute to a major tank failure and the volume of supernate could represent a substantial release if it were to leak. An immediate programme to reduce the volume of supernate above the sludges in these tanks brought the total holdings down from approximately 800m³ to 300m³ (approx 60%).

Objectives

The main regulatory body for the British Nuclear industry the Nuclear Installations Inspectorate (NII) imposed a time framework upon AWE for dealing with the problem. This was that that AWE fully immobilise the contents of one tank by April 2001 and that the contents of all the tanks be Immobilised by April 2008.

Effect on Operation of Water treatment facility

It was fortunate that at this time there were allied projects at AWE which included the reduction of liquid discharges from active waste streams and the de-commissioning and refurbishment of various effluent facilities. This was to coincide with the ultimate goal of closing the Thames discharge pipeline in April 2005 and the replacement of the water treatment plant with an Evaporator. These projects were already having a significant effect on the volumes of effluent being treated. There was therefore less generation of activity within the sludges held in the water treatment plant and it was possible to operate the plant for three years until new reception facilities were available, without the need to change this sludge and without exceeding process activity limits.

Following the installation of new receipt facilities for the final processing of the waste 42m³ of raw process sludged from the treatment plant has been dewatered to 17m³. This figure of approximately 60% is consistent with the volume reduction of the bulk holdings.

One of the projects aimed at reducing liquid waste arisings included the refurbishment of the bunds and the covering of the tank farms with lightweight tent structures. Although not directly linked with the treatment of the stored sludges this benefited the project in the following ways:

- Ensuring the integrity of the bunds below the tanks.
- Offering a degree of containment in case of major release.
- Comfort factor for operatives working on the project, independant of weather conditions.
- Deceleration of tank corrosion with reduced exposure to the elements.

Assessment of tank condition and emergency arrangements

Assessing the condition of the tanks and the likelihood of further leaks was now essential to establish the urgency of dealing with the stored sludges. It was also important to tighten up existing and implement new emergency procedures should a situation arise. It was important that the extent of tank corrosion be established and it was anticipated that the areas of greatest thinning would be where the tanks were in contact with their supporting saddles. Two empty tanks which were of the same vintage but had not been used for sludge storage were chosen and were raised from their existing saddles. Extensive ultrasonic testing work was carried out on these two tanks. It was discovered that the saddle areas and the general condition of the tanks

was reasonable and the saddles areas were cleaned and refurbished. The tanks were lowered back onto their existing saddles and designated as emergency receipt tanks for future use. The rest of the tanks were subjected to ultrasonic testing to confirm the corrosion rates and wall thickness. It was discovered that for these two tanks there was quite widespread thinning of the walls in the region of 20 – 40% and with several areas of localized thinning to > 60%. This was prevalent at both the bottom curvature of the tanks and the tank ends. An example of tank end scan results is shown in Figure 2.

Additional emergency equipment (pumps, hoses, liquid metal repair kits) was purchased and ready use stores were set up to assist in recovery should another incident occur. Sufficient and Relevant staff received necessary training to initiate a response both during the working day and silent hours.

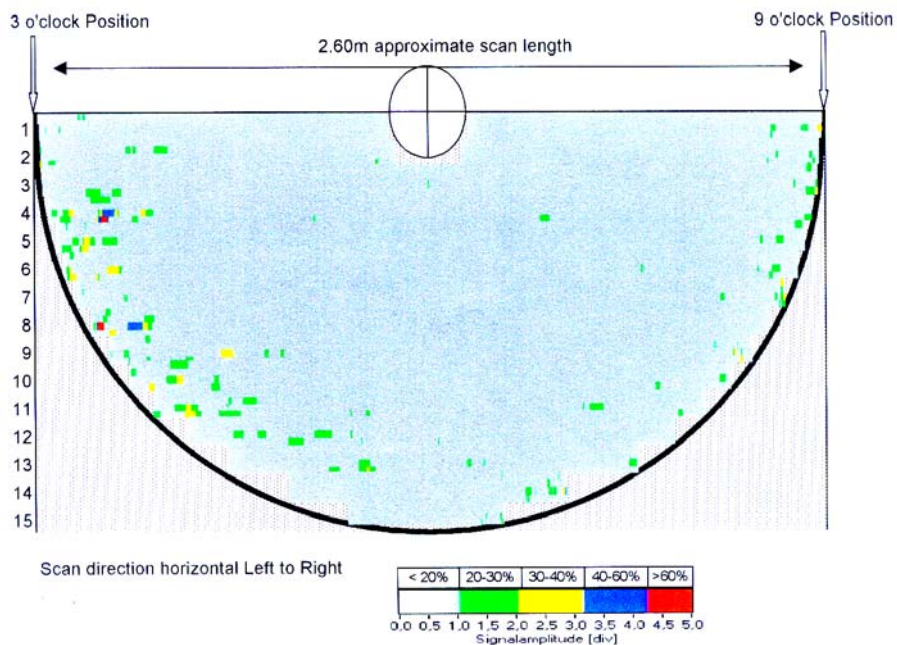


Fig. 2. Example of wall end thickness results
(percentages represent percentage thinning)

Option Study

During the course of events leading to and including the storage tank leak option study by the company had been continuing. Use of Best Practical Environmental Option (BPEO) studies and Business Practice Management (BPM) studies had resulted in Vitrification being chosen as the solution to processing and disposing of the stored sludges. A project team was set-up, with their specific aim being to use vitrification as the long-term solution.

Opportunity and Change of Direction

In the autumn of 2000 the opportunity for AWE to explore an alternative to Vitrification became available. The process was initially seen as an option to complete the first NII objective and cement the contents of one tank while still pursuing vitrification as the long-term solution for the sludges.

A portable cementation rig which was designed, built and operated by a joint consortium of BNFL (British Nuclear Fuels Limited) and NSG (Nuclear Services Group) became available for a limited time. This opportunity was taken and the successful cementation and disposal of the contents of two bulk storage tanks followed in the period October 2000 to March 2001. The process rig was installed in a facility remote to the tanks and transfer of the sludge was via road tankers.

The first tank was not a flocculent sludge and was not typical of the majority of the sludge inventory. The sludge was an organic sludge which had accumulated from many years of washing down external sumps and bunds. Due to the nature of its generation the major problem encountered when dealing with this sludge was the presence of large items of debris (stones, wood, etc). These items were problematic in both the process filters and the road tanker valves.

Notwithstanding these problems the project successfully disposed of the contents of this tank and carried on further to dispose of the contents of the first flocculent sludge tank.

The success of this project led to a re-thinking of the strategy for dealing with the stored sludges. Despite substantial investment in both time and money towards vitrification such was the confidence in the success of cementation that AWE abandoned the Vitrification project and concentrated on Cementation as the long term solution for the disposal of the stored sludges.

Formulation

A practical evaluation of the finished product when the sludge was added to cement was required to collect data which would allow AWE to choose the best formulation with variations in sludge properties. Encapsulation trials were carried out by chemists from NSG (Nuclear Services Group) using scaled down quantities of sludge and cement for sludges from the first two sludge tanks to be emptied. This gave rise to the following graph.

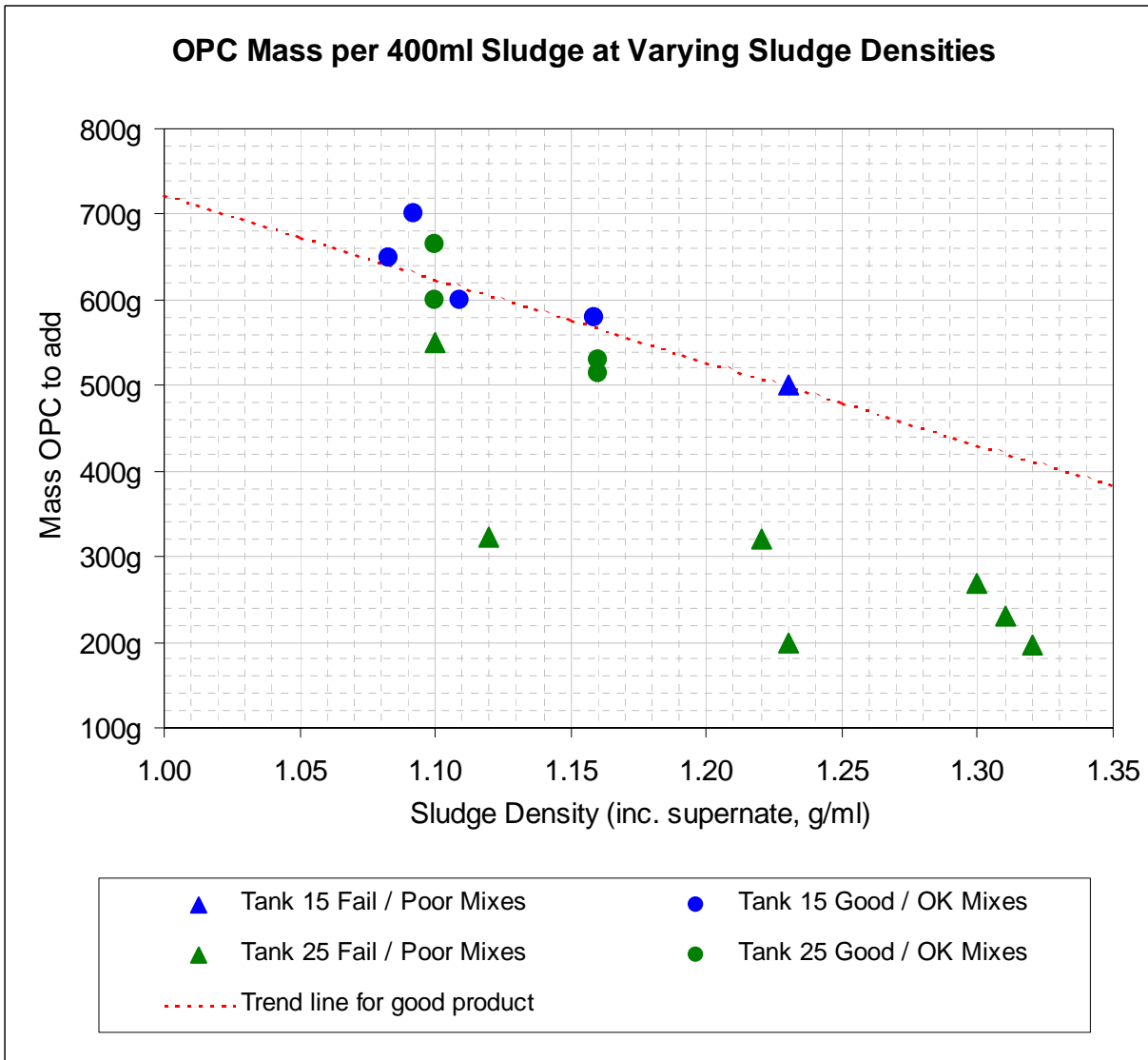


Fig. 3. (Courtesy of NSG): Graph showing tank 15 and 25 mix results

The trend line has proved consistent for sludge from further tanks which have been processed.

Development to Existing Project

Between 2001 and 2003 AWE took the experience and lessons from the first two tanks and set up an integrated project team to design and develop a plant and process to successfully process the remaining sludges. The following important lessons were realised from the completion of the first two tanks:

- Road tankers were used to transport the sludge in the first phase. A fully engineered and versatile sludge transfer system was required.

- Bespoke receipt facilities for the receiving and conditioning of sludge prior to cementation was required.
- Greater importance needed to be attached to the pre and post operational tasks of the project such as de-watering, sampling and tank washing. Where possible they were to be integrated into the engineered solution.

The location of the new process was ideally to be as close to the Sludge as possible. It was decided to position the cementation rig in the existing building which sits between the two rows of sludge tanks. This was the same building which had been in use up until the early 1980's for production of sea-dump drums. The layout of the building also allowed for all of the curing, handling and loading of the cemented drums into Half Height Iso (HHISO) containers to be carried out within the building.

The lost paddle technique for cementation of wastes is a well-known technique which has been used successfully throughout the British Nuclear industry for many years. A new encapsulation rig, based largely upon the design which had been already used for the contents of the first two tanks was commissioned and built for the project. The major challenge to this project lay in successful and complete mobilization and transfer of the settled sludges.

To ensure a continuous and suitable supply of sludge to the rig a large receipt and processing station was required. This represented a very large engineering project in itself. The mobilization, emptying and removal of three existing tanks and the fabrication and installation of three brand new tanks was required. The mobilization was made more difficult by the apparent quantity of debris lying with the sludge in the tanks including nuts, bolts and wire. One of the tanks which was to be removed was the tank which had developed the pinhole leak and hastened the project. It was therefore an ideal opportunity to remove this problem tank at the same time.

A peristaltic pump fixed installation was put in place for transfer of the sludge from the three tanks to the two new receipt tanks. This installation would later serve as the recirculation pump for the final delivery of sludge to the encapsulation rig.

Mobilization of the tanks could now take place.

Choice of Mixers

During the 2000 phase of mobilization the tanks chosen had large vertically installed mixers which were used as the primary stirrers. However smaller horizontal jet ring stirrers had been used successfully in the final stages for attacking of stubborn banks and in the lower areas of the tanks when the fixed stirrers became ineffective. The three tanks to be moved had fixed stirrers but these were obsolete and beyond economical repair. It was decided to use four of these new stirrers in each of the three tanks to achieve mobilization. This was later increased to six when it was established that there were blind spots between stirrers in the tank which led to the development of 'dams' across the tank. The result of this is the interruption of the flow of sludge to the low point suction end of the tanks in the final stages of emptying. In the first tank there

was a lot of jamming of the stirrers with surprising debris such as bolts, plastic and stones. The narrow clearance between blade and jet ring meant that it only took tiny debris to jam the stirrer.

For the next tank the stirrers were modified with sheet metal mesh strainers to try and stop this debris reaching the jet ring. However following the emptying of the tank it was discovered that the force of the sludge upon these guards during mobilization had lead to collapse and even destruction of the guards

A heftier Weld mesh guard was used for the stirrers on the third tank. These withstood the forces but upon retrieval from the tank it was discovered that the guards were blinded with fibrous material.

It was discovered that reversing the motors for a few seconds would dislodge all but the worst Jams and the guard idea has been abandoned in favor of reversing the motors. To achieve simplicity of this operation the project no longer hard-wires the stirrers to the electrical supply but uses plugs and sockets. To reverse the stirrer an operator simply has to insert a small lead with reverse phase wiring and run the stirrer as normal. This is cheaper than installing reversing starter boxes and faster than calling out an electrician when a problem arises.

One of the three tanks had a novel problem. The rubber liner between the sludge and the tank shell had detached, bulged and collapsed for a significant length of the tank.

After painstaking option study, including some extremely far-out suggestions it was decided that the solution lay not in re-positioning the liner but preventing further collapse and that if further collapse happened as long as it was checked from falling into the sludge it should present no further problem. Therefore a simple lightweight framework of scaffold poles with rubber grips to the side of the tank was installed to catch the liner if it sagged any further. It did sag upon emptying of the sludge from under it and the frame did prevent it becoming a further hazard. It was also discovered that the liner had been breached and that there was sludge between the liner and the tank. The timescales were extremely tight at this time so the liner was quickly sliced open and the sludge dropped into the bottom of the tank. Had this not been discovered then a serious problem may have presented itself had a failure occurred during lifting and the implications of this being accidentally discovered during later size reduction of the tank would have been extremely serious.

Following emptying of the sludge the tanks were refilled with water and the stirrers run to rinse out the tank. The project made the discovery that a process effluent transfer line ran close to the tanks with a valved Tee less than twenty feet from all three tanks. This allowed us to refill the tanks for washing by using existing process effluent in a couple of hours, saving weeks of time consuming tanker operations and without generating any new waste. The washings could then be transferred using the same transfer system as the sludge, except this time diverted to the effluent process tanks.

Initially it looked as if washing had been unsuccessful with a significant amount of sludge remaining in the base of the tanks. After a visual inspection which included 'prodding' the residue, it was described as being like the sand on a beach after the tide has gone out. A simple

question to the effluent process foreman established that there was a large backwash sandfilter included as part of the effluent treatment and that upon emptying of the treatment vats there was often a significant amount of sand in the base. This discovery came as a relief to the project and it was decided that this could be allowed to remain until decommissioning of the tanks. A simple desiccant of cement powder was added to the tanks to absorb remaining moisture in the tanks.

The tanks could now be wrapped, craned onto lowloaders and transported to an area where they were offloaded and positioned awaiting size reduction and disposal.

The bund was refurbished and the new process tanks, complete with stirrers and walkways were installed.

Alongside this the installation of a complete intertank transfer system with two further Peristaltic pumps was being carried out. During the Autumn and winter months of 2003 with the encapsulation rig in place, but the transfer system not completed, the decision was taken to pump the contents of one of the lower activity tanks to the rig for processing. This was to be carried out by use of a metered peristaltic pump delivering a measured amount of sludge straight to each drum. The metering was based upon running time of the pump. This was a complete success with another tank of sludge removed from the inventory. The production rate of this smaller project exceeded expectations by about 50% which served as valuable information when predicting timescales for the rest of the project.

The significant problem of 'dams' of sludge remaining in the tanks in the final stages of tank mobilization and emptying has been solved by angling the stirrers 30° downwards from the horizontal. This has the effect of being able to erode these dams by forcing mobilized sludge at them. The sum of all the experience gained from emptying tanks has led to the adoption of the following sequence for mobilizing and emptying a tank.

1. Immerse flygt stirrers below surface of sludge and mobilise surface banks until surface of contents is level and liquid.
2. Regularly adjust stirrers direction ninety degrees at a time to 'sweep' contents of tank.
3. Commence pumping sludge to reception tanks and stop when banks of sludge become visible in the tank.
4. Repeat step 1 and adjust direction of flygt stirrers to 'attack' these banks of sludge.
5. Repeat steps 2 and 3.
6. When level in tank is just above the limit of effectiveness of the flygt stirrers (this is normally with approximately 5m³ remaining in the tank) adjust their direction to clear the centreline of tank and maintain route for sludge to flow to low-end suction point.
7. A decision needs to be made to 'go for broke' since once pumping re-commences the level will drop quickly and the stirrers will become ineffective.
8. Continue pumping until suction is lost.

There always remains the option of adding liquid to dilute remaining sludge and a quantity of the removed supernatant liquid is retained for this to avoid generating new wastes. The option of a movable suction leg which can be positioned at a point along the length of the tank is also available. Up until now these contingency options have not been needed.

Current Status

AWE now has a completely engineered transfer, blending and cementation plant based upon the technology used and lessons learnt from the mobilization and transfer of the three old tanks. This is currently allowing us to mobilize, transfer, blend and cement up the entire sludge inventory held in our tanks.

It consists of two large peristaltic pumps which are protected against debris in the tanks by simple basket strainers. There are two of these strainers, a duty and standby. This allows rapid changing of filters without interrupting transfer operations. Each pump is dedicated to a row of tanks on either side of the process building. The pumps allow transfer of both sludges to the receipt tanks and rinsings from the tanks to the process effluent treatment plant. A third peristaltic pump recirculates sludge from the receipt tanks. A remotely operated valve then allows the recirculating sludge to be diverted to the rig where it 'drops' into the lost paddle drums. A manually operated diverter valve in this recirculation loop serves as a sampling point. This aids greatly when obtaining a sample for quick evaluation of the sludge and via small-scale formulation trials sets the mixing ratios used in the cementation process.

Opportunities to reduce hazard, where practicable have also been incorporated into the new system and the system is completely self-draining for maintenance.

Consequently the completion date of the complete mobilization and cementation of the entire sludge inventory is within reach of both our internal and NII targets.

CONCLUSION

The legacy problem of these stored flocculent sludges presented a unique challenge for AWE. The project team had to tackle an unquantified problem. There was the need to develop new skills in characterization and practical, efficient problem solving. Tolerance of ideas and an open policy of encouraging experimentation, without crushing the enthusiasm of the project team has greatly contributed to the solution of this problem. AWE are not alone in having volumes of stored radioactive sludges and there have been ongoing positive exchanges between AWE and other similar waste producers.

FOOTNOTES

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