TREATMENT AND DISPOSAL OF LEGACY WASTE AT THE ATOMIC WEAPONS ESTABLISHMENT (AWE)

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185 -The disposal of legacy wastes is becoming more and more of a concern within the nuclear industry with constraints imposed by both external and internal forces becoming increasingly restrictive. The Atomic Weapons Establishment (AWE) is currently facing one such problem where Intermediate Level Waste (ILW), a legacy of years of waste effluent treatment, must be converted to a safe passive form in a relatively short period of time. As a result of years of treatment of liquid effluent generated from various processes on the AWE site, a number of tanks of waste have been accumulated. This waste is in the form of a sludge with a range of 10 to 40 % solids content with supernate. The sludge is a ferric floc with calcium chlorides, sulphates and various heavy metals from the treatment process. The quantity of fissile material varies from tank to tank, however the majority has been classified as ILW waste due to its alpha activity. The sludge has settled and stratified over the years. The tanks are constructed of mild steel and have been operational for thirty years. A recent survey indicated that they are coming to the end of their useful life due to the advent of corrosion. Further studies are being conducted to attain as accurately as possible the remaining lifetime of these tanks. Therein lies the main driver for this project, in conjunction with Company policy which requires AWE to maintain its facilities in a safe condition meeting regulatory and ALARP (As Low As Reasonably Practicable) principles. Whilst the prime driver for this project is to remove the possibility of an accidental release to the environment by failure or fracture of a storage tank, the lack of potential storage capacity and its inherent cost, provided a secondary initiative. At present a national repository for ILW waste is not operational, meaning on site storage would be required for a considerable time. Therefore, to achieve a final waste product in a passively safe form in conjunction with a large volume reduction is a consideration of high importance. This approach is now being employed in Europe and the USA, as regulatory concerns are, in general terms, similar to those in the UK. Delays to national repositories have had the same effect, in essence driving waste generators to achieve substantial volume reduction. Existing technologies, particularly within the UK have focused heavily on cementation processes. The waste product does meet the criteria for a passive form but greatly increases the volume to be stored on Licensed Sites. The project has been considered in stages; retrieval, treatment to volume reduce and encapsulation for long term storage in a safe and passive state. Various options were considered in great detail, taking into account the constraints imposed and the risks involved. These options included cementation, drying and vitrification for the treatment process and were considered against five generic criteria; safety, environmental impact, ALARP, proven technology and cost. It was concluded that the preferential option meeting the criteria and fulfilling the constraints was (i) to homogenise and remove the sludge from the storage tanks using a pumping mechanism which would not effect the integrity of the tanks, (ii) volume reduce the waste by a drying process and (iii) high force compact the product in sacrificial drums which would be transferred to a designated storage container. The choice of this option breaks through new ground for AWE and the nuclear industry in the UK. While drying technology is in use in Europe and the USA, it is relatively new

to the UK. In support, extensive research has been undertaken by AWE to demonstrate that this option will meet all the Company safety and regulatory requirements.

INTRODUCTION

The Atomic Weapons Establishment (AWE) based at Aldermaston in the UK is currently facing the challenge of dealing with a legacy waste problem with significant safety concerns. A number of storage tanks exist on the site containing the waste product, a radioactive sludge, from the site Liquid Effluent Treatment Plant. The tanks have been operational for over thirty years and are now coming to the end of their useful life. They are constructed of mild steel and are known to be corroding, therefore disposal of the waste is required to eliminate the hazards associated with continued storage, predominantly loss of containment leading to a release to the environment.

Therefore, a project has been instigated to investigate, determine and carry out a process of retrieval and processing of this waste to produce a final waste form which is acceptable for storage and disposal. This means that the method and technology chosen must produce a waste form which meets all identified criteria and is in a safe and passive form acceptable for storage and to the appropriate disposal Facility.

Based on historical data records and analysis studies undertaken it has been ascertained that the majority of the waste does not meet the conditions of acceptance for disposal as Low Level Waste (LLW) and therefore has been classified as Intermediate Level Waste (ILW). This has placed one of the significant secondary constraints on the project, essentially the need for volume reduction due to storage restrictions on the AWE site required due to the lack of a National Repository at present for ILW.

BACKGROUND

The Liquid Effluent Treatment Plant collects, stores and treats potentially radioactive contaminated water from AWE Facilities to a level at which it can be safely discharged to the environment. The treatment process is essentially chemical with the addition of acid and alkali to control pH, sodium hypochlorite for oxidisation and precipitation purposes and polyelectrolyte to promote coagulation. The result is a precipitated ferric floc containing heavy metals forming a sludge which is separated off for storage.

There are eighteen tanks situated in rows in a single uncovered open location. Each tank is cylindrical in shape and 10m long by 2.6m diameter supported horizontally on five saddles. A central access hole 2.1m long by 1.5m wide is situated on the top of each tank. These openings have sliding doors for access but are not water tight and so rain water is likely to have entered over time. The tanks are mostly grouped in a three to a bund arrangement with each bund capable of holding 110% of the contents of one tank. The tanks were originally rubber lined which may have perished over time.

The tanks and saddle supports are constructed of mild steel and have remained uncovered and exposed to the environment for the whole of their operational life. The tanks have relaxed on their supports and distorted, therefore some tanks are no longer in contact with the saddles. Any contact is direct as no weld or protective layer was introduced during construction. This has allowed rainwater to seep down between the seal/tank interface, resulting in the electrolytic corrosion of the tanks. Consequently, many of the tanks exhibit significant amounts of rust in these contact regions. However, where there is no contact, little or no corrosion has been observed. A study utilising Finite Element Analysis to determine the life expectancy of these tanks has been carried out at AWE (1). This was based upon the minimum safe operating thickness of the tank walls before they rupture. Wall thickness measurements were calculated using computational and ultrasound methods, the results of which varied considerably across the tank/saddle interface. This resulted in difficulties in determining a definitive lifetime but confidence was provided that the tanks could be emptied safely within a technically feasible time frame.

Due to the length of time some of the sludge has been stored and the fact that stirrers, installed at construction, no longer function, the heavier particulate has settled out to the bottom of the tanks leaving an essentially clear supernate layer at the surface. The tanks contain a total of approximately 800m^3 of sludge due to a regular dewatering process by plant operations. Volume and fissile content is not uniform across the tanks. Some tanks have a high fissile content but are not physically full by volume while others are full but contain a relatively small percentage of fissile material. Analysis of samples taken from certain tanks showed that the waste could be easily dispersed and homogenised but quickly re-settled upon cessation of agitation.

Sampling and analysis has been undertaken of some of the tanks to determine the characteristics of the sludge. This is particularly important in determining the method for retrieval, possible treatment and disposal of the waste. Samples were taken at various depths along the length of the tanks but due to access restrictions difficulties were encountered in obtaining an ideal representation of each tank. In taking the samples no difficulty was encountered in inserting the sampling tube and little resistance was encountered during penetration of the layer even down to the lowest position. Overall, the samples were presented as thin sludges with a high water content. The solid fraction was very finely divided with the majority settling out within approximately twelve hours but was readily dispersed by vigorous agitation. Trends across and down each tank were not observed. Calcium and Iron were identified as the main metallic species along with fairly significant levels of chloride and sulphate. Organics were found to be present at approximately 1wt%.

The radioactive inventory of the tanks, based on historical data and various surveys, including gamma spectrometry, revealed alpha activity potentially due to Am^{241} , Pu^{241} and U isotopes and the presence of other fission and activation products which are suggested to be pure beta, possibly Ni^{63}, Fe^{55} and Sr^{90}. The actual level of activity per tonne of sludge, in the liquid form as stored, ranges from approximately 0.05 GBq to 5.7 GBq. In determining the classification of this waste the figures for each tank were compared against the conditions of acceptance for the UK LLW repository; BNFL Drigg. It was determined that only three of the tanks could potentially be accepted. The main restrictions for this type of waste are associated with Plutonium isotopes. This is currently being discussed with representatives of BNFL Drigg. Therefore, the only other option at present for disposal of this waste is as ILW to the proposed ILW repository. However, this is not expected to be operational for a minimum of fifty years which means that continued storage on site is required for this waste in a safe and passive form, i.e. a stable form which can be safely controlled. Herein lies the justification for a processing method incorporating volume reduction due to storage restrictions on site.

Project Constraints

The primary driver for this project is the elimination of the hazard associated with continued storage of the sludge waste, predominantly a significant release to the environment. Within this lies one significant safety constraint; the removal of the waste from unstable structures.

The need for on site storage of ILW has already been identified as a project constraint driving the method for processing towards volume reduction. This presents another constraint in that currently in the UK the majority of techniques to process "liquid" waste into a safe and passive form for long term storage and disposal involves cementation techniques which actually increase the volume. The technology and feasibility is therefore not well represented. Due to the nature of the hazard and the condition of the tanks, time is not a luxury. The regulator has placed specifications on the project which are driving its completion due to their concerns regarding the integrity of the tanks. Hence, the lifetime study of the tanks was carried out to provide confidence that the tanks could be emptied in line with these constraints and more importantly before a significant incident occurred. This confidence has been provided.

OPTION STUDY

Independent option and feasibility studies were carried out by Companies actively associated with the nuclear industry. These included participation from AWE representatives to ensure ownership of the project, input of relevant knowledge and involvement from the beginning in the logical decision making process.

Initially a set of criteria were determined against which all identified options would be assessed. These included:

- Safety;
- Waste Classification;
- Current Industrial practice;
- Technical feasibility;
- Economic and Financial considerations;
- Space requirements for siting purposes;
- Time scale and plant throughput;
- Tank condition;
- Secondary waste generation;
- Retrieval and transport;
- Storage;
- Environmental impact and public relations;
- Regulatory considerations.

An initial generic options assessment was undertaken, resulting in the list of options below, which would be further broken down for more detailed consideration.

1. Do nothing;
2. Life extension of the tanks;
3. Retrieval/immobilisation of the sludge followed by storage elsewhere;
4. Retrieval and storage of sludge in new tanks in a new Facility;
5. Dry bulk storage of sludge in a new Facility;
6. Sludge reprocessing and reclamation;
7. Sludge dilution and discharge;
8. Off-site processing;
9. Removal of tanks complete with sludge.

Review of these against the criteria resulted in options 3, 4, 6 and 8 being considered further as viable options. Options such as do nothing and extending the life of the tanks either did not address the hazard or prolonged the eventual removal and treatment process; considered unacceptable. Dilution is against the conditions of acceptance for national repositories and therefore could not be considered further and removing the tanks themselves was considered to create a significant unacceptable hazard beyond that already present.

In support of this process visits to various Companies, both in Europe and the USA, were undertaken by AWE project representatives to assess the technologies available for feasibility, ascertain operating experience and check for compliance with regulatory requirements in the UK. These visits provided invaluable information and evidence of alternative options available to aid in determining the optimum process for this project.

It was considered practical at this point to assess the project as general stages of retrieval, treatment (conditioning/processing), handling and transport, and disposal, due to the inherent differences with each.

Retrieval

In assessing the best method for retrieving the sludge, tank integrity is the foremost consideration. Any movement, such as vibration, and load on the tanks themselves needs to be minimised to prevent any loss of containment. In this respect many mechanical devices were considered unsuitable. Other factors to take into account were whether homogenisation of the sludge was required and could be achieved if considered necessary for retrieval and the environmental impact of various techniques.

Methods brainstormed varied greatly from using mechanical techniques such as pumps and suction techniques to dissolution methods and from digging the waste out to cementation of the waste in situ. It was assessed that the chosen option would need the addition of a minimum quantity of water to aid in re-suspension and pumping out of the resultant sludge mixture and that the majority of the sludge would need to be removed with a final wash out if necessary to reduce contamination to as low as reasonably practical. It has been acknowledged that further characterisation may be required to determine the rheology of the sludge to optimise pumping conditions.

All mechanical aided techniques were screened out immediately as placing too much undue stress on the integrity of the tanks. Dissolution results in a large volume increase and could potentially damage the tanks due to uncontrolled reactions and the need to use hot concentrated acid, which is an unacceptable chemical hazard in itself. Methods to dig the sludge out either in solid or liquid form were rejected on the basis of maintaining containment and the difficulty in fully emptying the tanks.

The option preferred was that of power fluidics which met all specified criteria to the greatest extent. This process works by sucking the waste into a piston under vacuum and subsequently releasing it back into the tank thereby creating turbulence which will enhance mixing of the sludge. Please refer to figure 1 below. The minimisation of moving parts will reduce the risk of loss of containment due to vibration. To mitigate against any potential releases during retrieval it is proposed that temporary containment is provided over the tanks being emptied at the time.

Sludge Tank Emptying

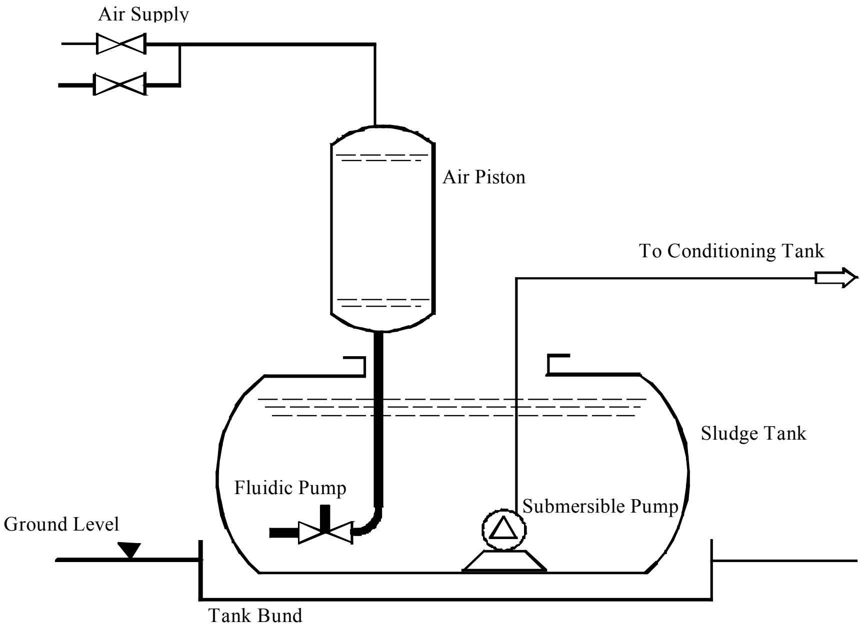

Figure 1 Diagram demonstrating the proposed sludge retrieval process

Conditioning

During investigations it was determined that in order to categorically classify the waste and monitor its content, transfer to a conditioning tank prior to processing would be required. This tank will need a capacity greater than one single tank to allow for an increase in volume due to homogenisation with the addition of water at the retrieval stage. Samples could then be obtained for fissile material control purposes and to obtain information required by the national repository prior to final acceptance. The waste will be continuously agitated to prevent settling.

Processing

A number of options, classified as either dewatering or wet sludge techniques, were considered for this process stage, including evaporation, incineration and solvent extraction. Criteria, in addition to the safety considerations, against which these were assessed were primarily driven by the need for volume reduction, due to the limited on site storage space available, its associated cost and the final waste form to be stored. Regarding cost implications not only would storage need to be taken into account but also the potential need for a new Facility to house the process equipment.

Evaporation was not considered to be a total process due to limitations on actual water content removed and also proved to be a relatively high capital cost operation. Solvent extraction also proved to incur high capital costs and presented a criticality risk and significant production of secondary waste products. Other methods which essentially remove the water content such as incineration, freeze drying, and reverse osmosis were considered to be less effective than evaporation with its disadvantages.

Cementation, the most common technique currently used in the UK, rated very highly in a number of areas, particularly proven technology, minimisation of environmental releases and production of a recognised, safe final waste form. However, due to the very nature of the process, a large increase in volume will be produced which will incur significant storage costs.

Other processes which also rated highly and were considered to be the option most appropriate for this project included methods based on drying techniques producing either a powder or pellitised product. Please refer to figure 2. These scored highly regarding volume reduction and following visits to various Companies evidence of successful operational experience was provided meaning that technical feasibility was very comparable with the cementation technique. The hazard of environmental release during the drying process has been investigated and based on operational evidence is considered not to be a significant safety issue. Technologies employed at present in other countries utilise containment with necessary filtration in conjunction with remote operating to control this hazard and will similarly be employed at AWE. More specifically it is considered that in drum drying will be most beneficial to AWE.

Sludge Drying Process

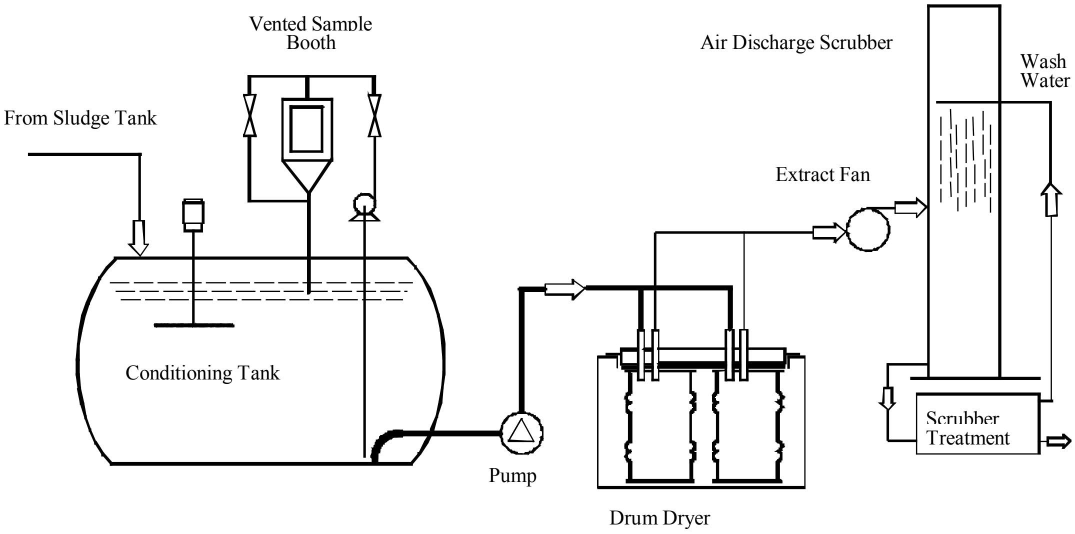

Figure 2 Diagram representing the sludge drying process

The figure shows that the extract from the dryers, expected to be mainly water vapour based on operational experience, will be passed through a scrubber to remove contaminants prior to venting to atmosphere via HEPA filtration. Water vapour which will condense in the scrubber will be diverted to an on site liquid effluent treatment plant for further treatment prior to discharge.

This option needs to be taken further in ensuring production of a safe and passive waste form which is stable and controllable for a significant time period. Whilst the drying process will result in a product in the form of a "cake" a further process is required to stabilise this waste in the drum. Methods considered included vitrification, calcination and high force compaction. Vitrification proved very costly and calcination does not produce a final "end state" waste form, a further encapsulation process such as cementation would be required for disposal. High force compaction was assessed to be the best option on advice from regulators.

Handling and Transport

At various stages of the process the waste, in whatever form at the time, will require to be moved from one area to another. As the process has been developed these areas are essentially from the storage tank to the conditioning tank which will potentially be in a separate Facility and in its final waste form from the processing Facility to the storage Facility. Options for carrying out these moves included pipeline for wet sludge, tanker, closed skip in a contained Facility and transfer as dry powder, i.e. blow as for cement powder. The preferred options are that as part of the retrieval process the wet sludge will be pumped to the conditioning tank via pipeline which it is proposed will be housed in the same Facility as the drying and high force compaction equipment. Due to the fact that the whole process will be contained in one building the final move to a storage Facility on site awaiting final disposal will be by designated transport appropriate to the waste container ensuring control and monitoring of fissile material in accordance with existing AWE requirements.

Disposal

Finally the storage conditions required assessment. The possible options identified, taking into consideration the need for long term interim storage, were

- Store as waste ready for disposal to the forthcoming ILW repository, i.e. in standard 500 litre drums accepted by the repository;
- Dry and store as waste in a form which would require treatment prior to disposal to the repository;
- Wet storage of the sludge in a new Facility awaiting disposal at some stage in the future.

From discussions already laid out and the constraints placed on the project the only feasible conclusion is the first option.

Preferred Process

Extensive investigation and discussion including advice from Companies with experience in similar fields both in the UK, Europe and the USA brought AWE to the conclusion that the process most compatible with the criteria set should follow a staged process as follows:

- Homogenisation of the sludge by fluidic pumping;
- Transfer of the sludge to a conditioning tank for sampling and characterisation;
- Drying of the sludge;
- High force compaction of the final waste material in sacrificial drums;
- Packaging of the compacted drum "pucks" into appropriate storage containers (i.e. 500 litre approved containers).

It is believed that a process of this type will produce the required results of a safe and passive waste form acceptable to the regulators and appropriate waste repository. It will also achieve a volume reduction of the original waste and most importantly the hazard associated with continued storage will be eliminated in the timescales necessary.

As part of the process in coming to this conclusion all of the hazards associated with the above process also required preliminary assessment to determine that it could be carried out safely.

PROCESS HAZARDS

The following section outlines those hazards considered significant to the safety of this project and are specific to the scope of retrieval and processing, i.e. those stages considered to be novel to normal working practices at AWE.

Loss of Containment

In addition to the possibility of a loss of tank containment either due to natural causes or the action of the retrieval system, a release from the pipework whilst transferring the sludge from the tanks to the conditioning tank is possible. This may be due to pipe failure, leaks, corrosion blockages or freezing. It is possible that the rubber lining which existed within the tanks has perished and may cause blockages, however the sludge is relatively free of any other similar materials. Safeguards and mitigating features which could be put in place include pipework to be double skinned with engineered welds and the use of a foot strainer on the end of the pump line. As expected Contingency procedures already exist on site to deal with a major sludge spillage.

Regarding the processing stage; from conditioning tank to drums, there are a number of steps with the potential to release radioactive material if accident conditions arose. These include a number of transfers from one stage to another either by pipework or possibly lifting equipment for drums. There is also the drying process itself; overheating of the dryer could result in failure of the dryer unit integrity. However, the unit will need to incorporate a trip function in the event of elevated temperatures which will shut the unit down. The unit itself will also need to be in a dedicated ventilated enclosure. Also, the high force compaction process will bring its own hazards. With the waste now being in powder form, although "cake -like", there is the potential for a release of material if the containment on the system failed. This and the drying unit will require significant scrutiny prior to installation to ensure all of these hazards are adequately controlled.

Although many hazards were identified and assessed with regard to radiological release it was considered that, from discussion with experienced operators and AWE assessment, that they could be controlled by engineering design resulting in risks considered to be As Low As Reasonably Practical (ALARP). The above discussion only enforces the rigorous process and investigation undertaken to determine and provide justified confidence that this process can be applied safely and efficiently compared with a technique such as cementation which although is tried and tested in the UK and proven to be a relatively low risk process cannot comply with all the necessary criteria required for the project.

Criticality

The storage of the sludge in the tanks is not considered to present a significant criticality hazard due to the robust and stringent systems on site to control the movement of fissile material. However, a number of steps in the process to treat and dispose of the sludge have been identified as possible hazards without appropriate control. These areas follow and will require full assessment prior to operations.

During homogenisation and pumping of the sludge within the storage tanks all of the fissile material could potentially become a single mass. This is considered unlikely as it has been demonstrated by sampling and Non Destructive Assay techniques that the fissile material is evenly spread through out the tanks and mixing will not be sufficiently turbulent to allow the required movement.

In the conditioning tank there is also the potential for fissile material accumulation, therefore control measures will need to be identified. However, accumulation is likely to be small due to design and the incorporation of a washdown procedure in the process. In addition, accumulation will be estimated prior to processing.

Fissile material content of the storage/transport drums will be derived by destructive chemical analysis or radiometric non-destructive assay to ensure compliance with a safe working limit.

CONCLUSION

AWE are facing the problem of dealing with a legacy waste issue, predominantly classified as ILW. This paper presents the nature of the problem and the investigative process which has been undertaken to come to a proposed resolution for dealing with this waste in line with project constraints and required criteria. The conclusion made proposes a process which will meet the requirements for the project; produce a safe and passive waste form acceptable to the regulators and appropriate waste repository, achieve a volume reduction of the original waste and most importantly eliminate the hazard associated with continued storage in the timescales necessary.

The process proposed incorporates a drying process, a technology rarely used in the UK, but evidence has been gathered of operational experience both in Europe and the USA to provide confidence that this technique can be applied, both safely and effectively, to this particular project. Preliminary assessments of the hazards associated with the process collaborate this conclusion.

This technique has been compared rigorously with the usual working practice of cementation which is a relatively simple technique, proven in the UK, i.e. the argument of if it works why change it? However, with the constraints on this project as a result of the classification of the majority of the waste as ILW driving the need for volume reduction, in conjunction with timescales and operational experience demonstrating the relatively quick processing times compared to cementation, it is concluded that cementation is considerably undesirable to the success of this project.

Extensive involvement with the regulators and national repositories has ensured that the final chosen option will be acceptable to them all in terms of risks associated with the actual process and the waste form produced.

It should be emphasised that while this is the preferred option as determined by AWE, the tendering phase only began in the last quarter of 1999 and AWE are open to any proposals that fully meet the required criteria. However, AWE are confident that due to the extensive research carried out the final process will not significantly differ from that proposed here.

REFERENCES

1. MOD(PE) report; M G BERRILL , "Finite Element Analysis of Bulk Storage Tanks," AWE/DWE11/99/B20002 (1999)