The Retrieval and Processing of Historic Mobile Flocs into a Safe and Passive Waste-form Suitable for Long Term Storage - 9569

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ABSTRACT

In the earliest days of reprocessing operations on the Sellafield site, the Sludge Storage Tanks formed a key part of the systems for cleaning up the site's liquid effluents. The legacy of these operations was that until recently the 50 year old tanks held over 4500m^3 (approx 1.1m US Gallons) of actinide rich sludge containing some 2000TBq (approx 55000 Ci) which required retrieval and treatment for long term safe storage. To enable this retrieval and treatment a significant programme of work, costing in excess of £120m, has been delivered to bring the plant as far as possible to a modern nuclear standard and provide the capability to recover and treat the sludge. To date, this programme of work has resulted in over 1500m^3 of sludge being recovered, emptying the oldest tank within the complex. Over 1000m^3 of this sludge containing some 760TBq alpha activity has been encapsulated in cement generating a long-term stable wasteform, thereby immobilising over one third of the plants nuclear inventory.

This paper describes the project work undertaken and the operating experience gained in retrieving and treating the waste.

INTRODUCTION

Sellafield site is a compact and complex nuclear licensed site which since the 1940s has been home to a range of facilities associated with the UK production and reprocessing of nuclear material. Nuclear fuel reprocessing continues on site however, waste management and decommissioning activities are of increasing importance.

The old Sludge Storage Tanks and newly associated Floc Retrieval Plant (FRP) is one such plant area on the Sellafield site where significant world-class waste management activities have started, making a significant contribution towards Sellafield Site risk reduction and towards meeting the requirements of License Instrument 326 a): *"At least 80% of the total volume of all Intermediate Level Waste sludges originating from operations prior to 2000 and which have been accumulated as radioactive waste shall be stored in a safe passive form"* – Compliance to be achieved by 1 August 2020.

The Sludge Storage Tanks / FRP is a complex of ten 1700m^3 tanks with the original tanks dating back to the early 1950s and with the most recent tank being added in the mid 1980s. These tanks supported site reprocessing operations from the 1950s until the late 1980s.

Whilst operational, the process was a relatively simple one with the high level unit operations consisting of storage, settling and sea discharge. The plant received active metal-hydroxide precipitates commonly known as floc feeds from the upstream effluent treatment plant into one of the Primary Sludge tanks (PS1-6). The floc precipitate was allowed to settle thus allowing solid floc / liquor separation. When separated, the lower-active clarified liquor known as supernate liquor was decanted off using a floating boom system (note original design was for bottom dewatering through filter bed but this quickly blocked and was never used) and transferred into one of the Sea Tanks (ST1-3) to allow sampling prior to onward discharge to the Irish Sea. The 10th tank, PS7, was never used. The active floc remained within the storage tank as a settled sludge

The legacy remaining in the early 90s was an ageing and degrading tank complex with visibly leaking tanks open to the atmosphere, no aerial or liquid secondary containment and no route out for the tanks stored contents. The tanks were not considered suitable for indefinite storage. The inventory of the complex stood at approximately 7500m^3 volume containing some 2000TBq total alpha and 90TBq total beta activity. The activity was principally contained in approximately 4500m^3 of activity-rich, settled and compacted flocs stored in PS tanks 1-6, with PS1 containing some 50% of the total activity.

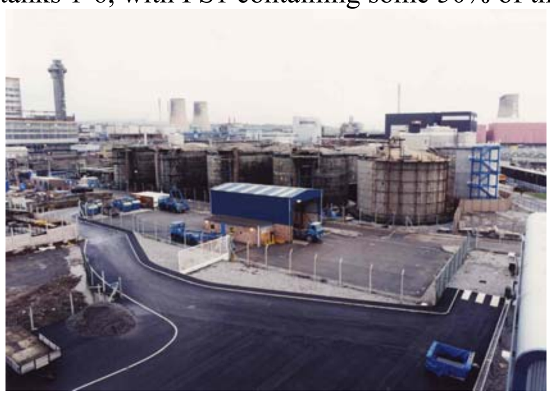

Figure 1 – Floc Storage Tanks in the early 1990s

An extensive programme of interrelated projects have been completed between the years of 1986 and 2005 transforming the historic 1950s tank complex into a modern nuclear complex, which has the capability of retrieving and treating in excess of 95% of both the active and volumetric inventory from the six storage tanks This work at a cost in excess of £120m culminated in the successful active commissioning and operation of the Sellafield Floc Retrieval Plant in 2005. In addition, a further 3 years of retrieval operations have been completed.

This paper describes these early interrelated projects, commissioning of the facility in 2005 and routine operations between 2005 and 2008. The principal focus o the paper is lessons learned particularly during the years 2005 to 2008.

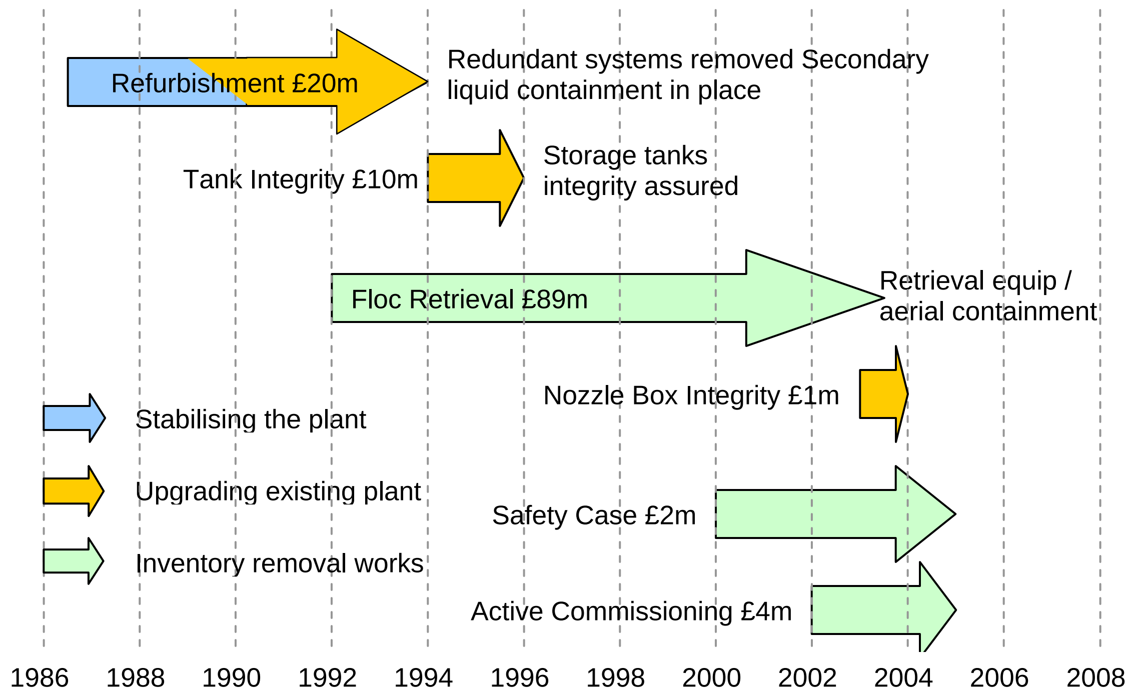

Figure 2 - Overview of Sludge Storage Tanks Programme

Stabilisation and Upgrading of the Plant

These projects together cost upwards of £30m spread over almost 10 years principally ensuring the continued safe passive storage of the floc inventory.

A large proportion of the work involved general improvement of the radiological conditions including significant hands-on decontamination and decommissioning resulting in the removal of in excess of 400te of waste and equipment. Included in this work was the removal of leak points associated with the inlet and outlet pipework systems and the removal of the floating boom systems.

The next phase moved on to the provision of improved secondary containment resulting in the construction of a seismically-qualified secondary containment bund capable of holding the entire contents of all the tanks which completed in 1993 and also the full wrapping of all the ageing tanks in fully welded steel jackets to give addition structural rigidity to prevent tank failure. [Figure 3]

Figure 3 – Tank Improvement - Welded steel jackets

Developing the Understanding of the Inventory

The first step in developing the retrievals process was to understand the inventory in the tanks. When the project began approximately 4500 m^3 of settled floc material with approx 3000 m^3 of attendant supernate liquors were stored within the tank complex. Although, various sampling campaigns had been completed during the lifetime of the plant, common with other facilities the exact inventory and its properties was not accurately known.

A project was undertaken to sample and determine the inventory of the tank contents. The process for sampling was not a simple one. There were no installed sample points or sample systems. The floc to be sampled had in some instances been settling for 30-40 years. The material took on different rheological properties depending on tank depth ranging from gel or thick ketchup consistency through to a thick mud or clay like material. Core samples were extracted form the actinide-rich (mainly ^{241}americium) floc at differing cross-sections and heights within each of the tanks to obtain the necessary representative samples required to develop the process flowsheets to aid development of the process.

Upon completion of the sampling and analysis, a comprehensive floc-database detailing the chemical, physical and radionuclide properties of the floc contained in each of the PS tanks was generated and used as the basis for the design flowsheets used to produce floc-simulants for research and development work and process development.

Developing the Retrievals Process

Once the inventory was understood then the process for retrieving and treating the waste could be developed and after significant optioneering work a patented hydraulic jet mixing and transfer system was developed. The retrieval equipment comprised of a submersible sludge pump, three ‘spillback’ pipes with diametrically opposed nozzles lowered into the sludge bed which could be rotated. The pump would then pump mobile liquor from the top of the tank, at design flowrates of approximately 400 m^3/hr, to each of the spillbacks in turn to discharging it into the sludge bed. The discharge of mobile liquor from the spillback would cause localised resuspension of the sludge, which by alternating the spillback in use, would gradually mobilise the entire bed.

The downside to this retrieval process was its potential impact on the tank structures. The additional static head of liquor necessary to have enough mobile material, the jetting forces required to resuspend the bed and the additional heat generated by recirculation of liquor all increases the stress on the ageing tank structure (tank structures already degraded by ammonium nitrate attack on the reinforced (wire wound) concrete). It was therefore recommended that the resuspension process should take no longer than three weeks, after which the mobile contents of the tank would have to be removed to a buffer storage facility. The retrieval process for each tank therefore became a 'one shot' process with no opportunity to practice before hand.

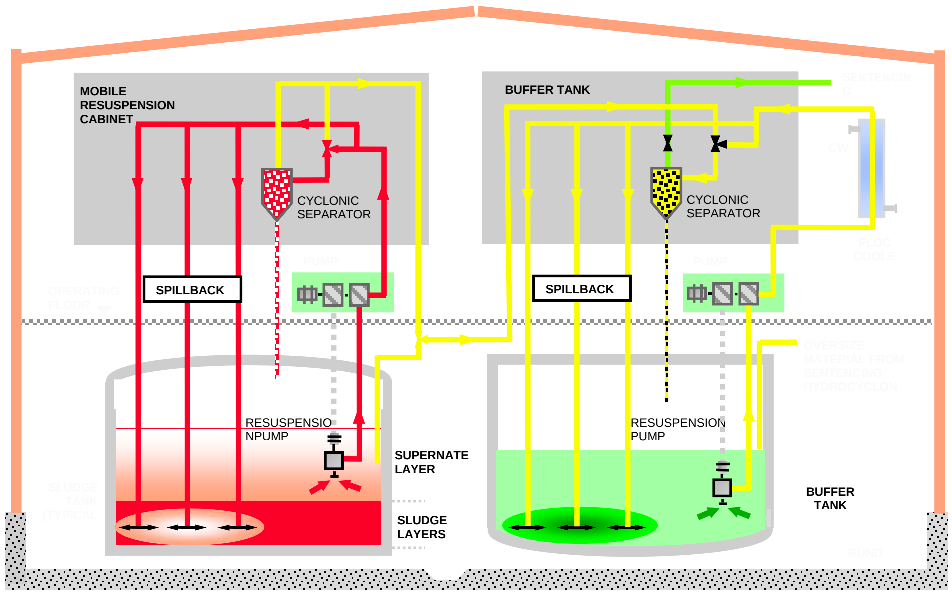

Figure 4 – Schematic of the resuspension process

Following initial resuspension and transfer of a PS tank to the Buffer Tank, the batch processes are somewhat more routine and carry less risk and unknowns. The FRP process involves a further short-duration resuspension in the Buffer Tank followed by onward batch transfer of nominally 30m^3 to the Sentencing Tank where it is diluted with water. The dilute floc batch is continuously re-circulated through a hydrocyclone system for up to 24hrs designed to remove grit and larger particles not suitable for downstream processing in EARP. Following this the floc is sampled prior to onward transfer to EARP. The process is then repeated as necessary to reduce the volume in the Buffer Tank to create enough ullage for the receipt of the next PS tank.

The treatment process developed took advantage of existing floc treatment and encapsulation facilities (EARP and WPEP).

The original design intent was for a typical floc batch receipt of 75m^3 made up of 30m^3 from the Buffer Tank diluted with 45m^3 of water. This is fed forward to the ultrafilters for dewatering and then saltswashed prior to further dewatering to produce 15m^3 of concentrated floc at a concentration of 45g/l for export to WPEP where it is encapsulated. Following a chemical clean of the ultrafilter, the batch process is repeated for another 75m^3 batch until all PS tanks in the FRP were emptied.

The floc in encapsulated in 500litre stainless steel drums in WPEP. The WPEP process is essentially that of a production line with a number of discrete operations as follows: floc addition to drum, calcium hydroxide powder addition + mix, conditioning, cement powder addition + mix, cement curing, addition of wet grout cap mix to seal the drum contents and allow lid fixing and finally transfer to interim store. The encapsulated drums are the final ILW waste-form suitable for long-term safe storage.

Building the Floc Retrieval Plant

With the process developed, the building to house the floc retrieval equipment could be designed and constructed. There were many competing requirements and restrictions on the structure to be considered. The building of the plant involved the provision of an over-building including an operating floor positioned above the tank tops. The most difficult aspect of the building work was the fact the over-building could not be installed traditionally as the Safety Case would not allow for loads suspended above the tank tops due to their potential inability to withstand dropped load impacts

To meet these requirements the project developed an overbuilding design based on a portal frame design, with a suspended operating floor above the tanks from which the equipment required for the retrieval of the contents could be deployed. The building would be 100 m long by 45 m wide by 21m high. Construction of the building was undertaken in sections at the south end of the complex and the building was incrementally slid into place, avoiding the need for lifting above the tanks. On the final slide the building weighed approximately 2800 tonnes.

Housed within the overbuilding is all of the equipment required to retrieve the floc from the tanks.

Figure 5 – Original uncovered tanks mid 80s → Overbuilding being slid into position late 90s → Completed overbuilding in 2000

Operating the Retrievals Process

Final active commissioning of the plant and process culminated with the actual resuspension of Primary Sludge Tank PS1 starting early March 2005 with the transfer to the Buffer tank completing on 19th March 2005. Processing in the FRP, EARP and WPEP progressed shortly afterwards and continues today.

The focus of this paper is principally on the Improvements made and lessons learned since 2005 through operation of the FRP retrievals process, downstream processing in EARP and immobilisation by encapsulation in WPEP

DISCUSSION – LESSONS LEARNED

Resuspension and Transfer to the Buffer Tank

This method of retrieval, although used in other industry was a first for Sellafield site and a first for consolidated clay-like active floc contained in ageing and fragile 50+ year old tanks. The technology and process delivered as expected with manageable levels of process intervention proving the capability in re-suspending, homogenising and transferring. PS1 floc was resuspended and transferred to the Buffer Tank early 2005 exceeding the 95% mobile floc recovery target with 98.4% of PS1 contents eventually transferred to the Buffer Tank. In so doing, transferring 50% of the total building mobile radiological inventory and hence risk to a higher standard of containment.

In addition to exceeding the target retrieval rate and proving the technology, operations in the active PS1 environment have yielded a number of other valuable lessons and observations

Resuspension
The end result surpassed expectations; however process intervention was required at the start of the resuspension. This was due to blinding of the pump inlet with clumps of clay-like floc. This required a lot of intervention, requiring the pump to be frequently stopped and raised out of the floc/supernate and then re-lowered and restarted, until the floc had been broken down sufficiently to allow uninterrupted, continuous mixing.

Tank Structural Integrity
The 50+ year old tank structural integrity (albeit with additional steel coat) remained intact and suffered no significant damage from the energy intensive resuspension process. This gives confidence that the process is suitable for the remaining PS tanks.

Hydrogen Safety Case
No discernable hydrogen was detected during the resuspension and transfer. This coupled with the fact that PS1 having the greatest radiological inventory, and as such being the most likely tank for the generation of radiolytic hydrogen gives confidence that the remaining PS tanks will also have little hydrogen content. This has paved the way for a review and relaxation of the hydrogen Safety Case allowing acceleration of the retrieval programme.

Floc Processing Improvement Group
From an early point in FRP retrievals, an improvement group was established to look at the floc processing Value Stream in order to identify and action improvement activities in support of the key LAEMG strategic aim – *Acceleration* of FRP remediation programme at *Reduced Cost*. The Improvement group oversaw the whole value stream from FRP, through EARP and WPEP.

The multi-discipline group incorporating Lean Manufacturing Practitioners, technical specialists, plant operators and engineers using basic but powerful improvement tools and techniques across the whole value stream were able to develop a focussed improvement plan tackling both quick and easy wins but also more importantly the bottleneck constraining part of the process. The tools and techniques successfully deployed have included Value Stream Mapping, Process Mapping, data collection and analysis techniques, Six-sigma and Failure Modes and Effects Analysis (FMEA). All improvements have been linked to the strategic aim and take the form of cycle-time improvements, cost reduction improvements or in most cases both together.

Cost Reduction
The major means of cost reduction was identified prior to starting retrievals as it was based on similar experiences from the processing of other flocs. The saving arises from improved floc incorporation i.e. increasing the floc concentration factor in EARP such that the final volume for discharge to WPEP and encapsulation is reduced. This reduces the number of ILW drums produced and the associated cost of materials (drums + powders), interim drum storage and final disposal costs.

To this end a major area of development to assess and set the upper limit of concentration suitable for encapsulation was undertaken and completed. This effectively concluded a theoretical upper limit of 102g/l, more than twice that assumed in the design flowsheets suggesting it possible to more than half the number of the ILW drums produced. This in itself, if fully realised, has the potential to generate in excess of £14 million savings in material costs alone over the plants' lifetime.

In reality it was accepted that the theoretical upper limit may not be re-producible in real-life as elements of the development work were not replicated as the full-scale plant actually operates e.g. the concentration trials were carried out using centrifuging rather than ultrafiltration hence it may not actually be possible to dewater and concentrate within the ultrafilters in EARP.

Improvements in floc incorporation have been made between 2005 and the present time. Early flocs were produced at approximately 40g/l with the most concentrated recent floc being in the region of 70g/l. An average of 62g/l has been established over the past 2 years. Should this average be sustained over the remained of the life-time then savings of approximately £7 million will be realised through materials costs alone.

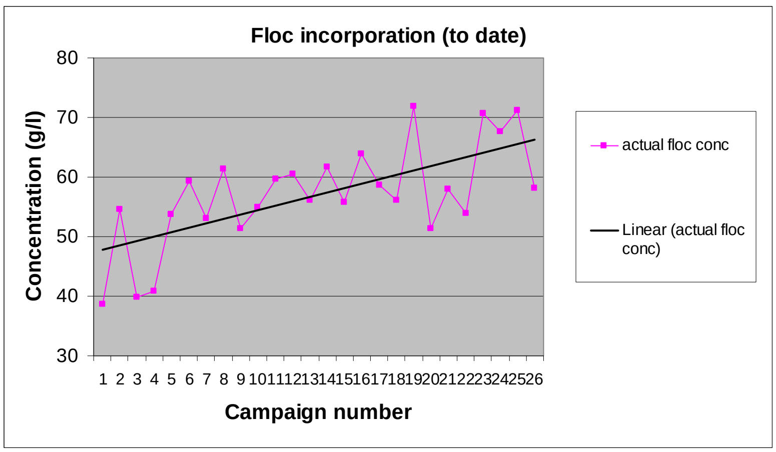

Figure 6 – Floc incorporation improvement since 2005

Cycle Time Analysis

Early commissioning and operating experience confirmed the initial expectation that WPEP would be the rate determining step constraining the overall batch cycle time. Process Mapping and associated cycle-time data collection and analysis have essentially verified this. Notwithstanding this, a number of incremental improvements have been identified for all three plants to tackle local bottleneck issues, which although not necessarily impacting directly on the overall cycle time did cause localised blocking/starving issues.

Floc Processing within FRP

48 batches have been recovered from the Buffer Tank since 2005. This has resulted in the transfer of some 760TBq total alpha out of the FRP facility to EARP and WPEP where it has been processed and encapsulated. This, a reduction of 37%, translates into a significant risk reduction for Sellafield site. During this time a number of observations have been made and more importantly a number of local improvements have been identified and implemented in support of the Strategic aim.

Sampling and Analysis

The initial floc sampling and analysis results gave good correlation with the floc-database. This confirmed validity of the core sampling methodology employed in the mid 1990s and gives confidence that the inventory in the remaining PS tanks will also give a good correlation. The results confirmed the process flowsheet and underpin the assumptions going forward with future tanks giving confidence in our ability to fulfil the FRP Life Time Plan. In addition, the confidence gained has helped in the argument for relaxation of the sampling and analysis requirements saving both analysis costs and also reducing the batch cycle time by at least 3 days per batch. This cycle time improvement tackles an interplant starvation issue between FRP and EARP.

Wash Volumes

An integral part of the FRP process is the washout of floc lines to protect against the risk of blockage. This is a normal part of the process however, the floc contaminated wash water being directed back to the Buffer Tank, has the undesirable effect of diluting the Buffer Tank contents and generating re-work and extending the retrieval programme. The impact of this was never fully assessed and understood. This has been reviewed and operations modified in 2 ways to reduce the impact: -

1. The volume of these washes has been reduced by at least 25% following re-assessment.
2. Implementation of a routine whereby the floc is settled periodically and larger supernate-only batches are recovered and processed separately.

Both these improvements have reduced the processing life-time of the plant by several months and reduce the volumes eventually discharged to sea by as much as $1000m^3$.

FRP Engineering Maintenance

The FRP process is a once-through batch process with no in-built redundancy, in terms of stand-by equipment, to accommodate plant failures. This was the original design intent and operating philosophy devised during the development phases of the project. The philosophy was such that floc processing would simply stop as a result of plant failure whether the failure could be rectified in days or months. There have been two significant extended outages to date, one associated with spillback operation and the other with the main pump seal flush system, both resulting in several months downtime. This original philosophy no longer fits with Sellafield Limited (SL) and Nuclear Decommissioning Authority (NDA) drive for accelerated remediation driven by short-term throughput target setting. That aside, in order to better align the drive for acceleration with the original design of the plant, Failure Modes and Effects Analysis (FMEA) has been successfully deployed on the plant and utilised to drive engineering reliability and maintainability going forward.

Floc Processing in EARP

Discharges to sea

Radionuclide ultrafilter permeate discharges were in line with predications thus underpinning the design flowsheets. Heavy metal discharges, particularly chromium however, were elevated. Although chromium discharges were predicted, the levels being observed were higher such that they were challenging the Sellafield Site IPC Discharge Authorisation. Investigation and assessment confirmed correct plant operation and concluded that indeed our predictions for chromium were simply too low. This was resolved following assessment and application to the Environment Agency for a variation to the Authorisation. A less restrictive limitation is now in force with the recent implementation of PPC permit to replace IPC. This has a more flexible compliance arrangement than was the case under IPC. However the Environment Agency have also indicated a shared aspiration that FRP processing rates should not be negatively impacted by metals concentration limits during normal operations and so have enabled an improvement opportunity under PPC to further review these and make a case for revision or removal of constraining metals limits. It is intended to pursue this opportunity in the coming year.

Batch Process Optimisation

The original design intent was for a 1:1 batch relationship through the Value Stream i.e. 1 batch recovered from FRP results in 1 batch exported to WPEP. This has since been optimised in order to reduce the EARP cycle time and to reduce volumetric discharges to sea. Normal operations are now considered to be 2 batches recovered from FRP resulting in 1 batch exported to WPEP. Cycle time and discharge savings are illustrated in Figure 7. This shows only one saltswash and chemical clean per two floc batches processed and although the batch 2 processing time and saltswash time are of increased duration, the overall cycle time is reduced. In addition there is a reduction of three Sea Tank discharges per two batches processed. This will not only reduce sea discharges by up to 15000m^3 but will also reduce analysis costs by up to £150k over the lifetime. It should be noted that the progression to three batches has been considered but is not possible at this time due to the size of the batch produced for discharge to WPEP.

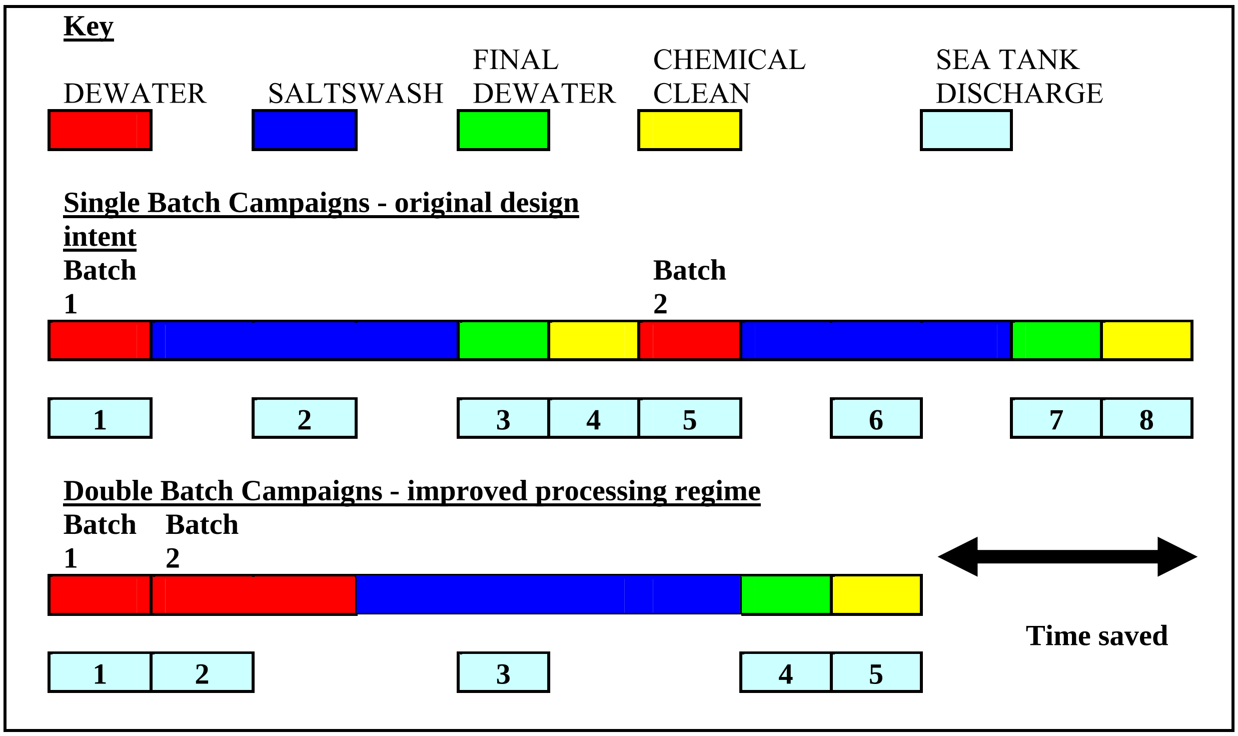

Figure 6 – Benefit of double batch campaigns vs. single batch campaigns

Ultrafilter Replacement Strategy

EARP processing rates were not anticipated to present a bottleneck in comparison to downstream throughputs in WPEP. This was initially the case in early operation. However the ultrafilters that have been in service since the commencement of FRP processing have suffered significant performance deterioration over time due to irreversible blinding of the ultrafilter pores and hence are nearing the end of their effective life. However early commitment of spares to replace these ultrafilters has been avoided to date to defer unnecessary costs, avoid disposal difficulties associated with contaminated wastes and to allow time for development and purchase of the next generation of ultrafilter with improved performance. Consequently EARP has recently replaced WPEP in becoming the principal rate determining step affecting retrieval rates. In developing a future ultrafilter replacement strategy in EARP concentrates, to recover long term performance and shorten campaign cycle times, it will be necessary to balance the potential performance improvements with the significant investment costs in ultrafilter spares. Downtime for filter replacement as well as the significant waste disposal issues associated with FRP floc contaminated waste filters would also have to be considered. It will be appropriate therefore to review the ultrafilter replacement strategy once the new generation of ultrafilters have had a sufficient testing period in-service. This is likely to be approximately 1 year after installation dependant on performance deterioration and available run time.

Saltswashing
As discussed above, there has been increased focus on optimising incorporation rates for FRP floc to reduce ILW drum numbers in order to reduce lifetime costs. The consequence of this is that EARP has to work harder in processing a FRP floc batch which inevitably increases the cycle time irrespective of long term deterioration in ultrafilter performance. Whilst replacing the filters will help in due course, other opportunities for cycle time improvement in EARP have been explored. One such opportunity will be to reduce the amount of saltswashing of the FRP floc. This will be pursued in the coming year.

Line clean optimisation
FRP has been pursuing opportunities to optimise line cleaning operations to minimise water usage. This has provided significant benefits in EARP in reducing the total volumes to be processed and increasing the inventory of floc in each campaign. This will make a further positive contribution to EARP cycle time reduction in future. Both this and the reduced saltswashing improvement also provide significant secondary environmental benefit in terms of reduced discharges and water usage.

Floc Processing in WPEP
Early commissioning and operating experience confirmed the initial expectation that WPEP would be the rate determining step constraining the overall batch cycle time. Early focus was applied to the WPEP process in order to understand the rate-determining step in WPEP and to identify improvements to remove this bottleneck.

Three particular processing issues have been identified and tackled to varying degrees over the past months. The three issues are 'shrinking' floc, high mixing torque and floc dripping / spillage. None of the issues are fundamentally understood at this time, however, a number of processing work-arounds and fixes have been implemented in the short-term to allow continued production whilst trying to understand the root-cause of the problems. It should be noted that EARP has two independent but similar ultrafiltration processing lines – the "bulks" line for continuous 24-7 support of site reprocessing operations and the "concentrates" line for batch processing of FRP floc. Both lines produce concentrated floc for export to WPEP. One of the main contributory reasons for not being able to identify any root-causes to date has been the variability of the mixed floc feeds being processed in WPEP. WPEP has only one receipt tank into which both "bulks" and "concentrates" floc feeds from EARP are received. EARP only has limited buffer capacity and so there is only limited flexibility with regards scheduling floc feeds into WPEP. This means that the concentration of the floc blends is continuously changing and is unlikely to be repeated exactly so that controlled experiments can be designed. This coupled with an ongoing improvement programme for "bulks" floc (floc incorporation and saltswash improvements) means that it becomes extremely difficult to determine the exact cause of an issue or the limiting conditions below which the problem doesn't exist. In this instance, the simultaneous running of 3 improvement activities all impacting on WPEP operability has negatively impacted on our ability to fully solve the problems. The drive for continuous improvement and short-term cost savings in all areas has meant we are managing symptoms rather than eliminating problems by tackling the root-cause.

'Shrinking Floc'
The concentrated floc appeared to exhibit a propensity to "shrinking". The first signs of this phenomenon became apparent when observing the level and volume trends in the WPEP floc receipt vessel which appeared to show a downward trend over time. This in itself wasn't so much of a problem as a simple fix

in terms of additional settling could be built into the receipt period so as to maintain accuracy of information for drum inventories.

It is not yet know if the phenomenon is caused by a surface froth, aeration of the floc or a combination of both. This is currently under investigation

Moving forward in time, it became apparent that this phenomenon was causing issues with the inactive capping process. The inactive cap sizes were larger in volume than they had been historically. This gave immediate problems in that it resulted in the need for as much as 3 or 4 times the volume of capping grout, resulting in a significant amount of additional hands-on manual work limiting the through-put. In addition to the extra work load, it is recognised that large cap-size translates into sub-optimal floc volume within the drum thus resulting in additional drums. A 6-sigma project is currently in tackling this issue. Again it appears to be floc-blend-dependant and hence difficult to pin-point due to the points mentioned above. What has been shown however is a statistical correlation that the calcium hydroxide powder addition promotes or accelerates this shrinkage such that it can be used as a control to optimise floc addition to the drum. This is currently under investigation but initial indications are such that up to 10% more floc could possibly be added to each drum without impacting on the final product quality. This has a potential cost saving in excess of £1m in material costs alone over the lifetime.

High Peak Transient Torque during Mixing at Cement

Since FRP operations commenced, a general steady increase in floc incorporation has been undertaken. This is good for WPEP in that it reduces the number of drums and hence the challenge to WPEP. As with many things however, there appears to be a balance as it has been observed that increased concentration can make the floc more difficult to process. The rotational paddle mixing torque is measured continuously during cement addition – a typical trend shows the torque rising steadily to a peak torque where all the cement powders have been added. Early FRP flocs behaved like this. However higher torque readings became evident as the floc concentration was increased. A number of quick-fixes to manage the symptoms were implemented e.g. the powder addition rate was reduced and controlled manually to prevent a system trip. This, although controlling the problem increases the cycle time and limits plant throughput. Statistical analysis has been carried out over a sustained period containing in excess of 1000 drums. This has not identified any limiting floc concentration but has identified the conditioning time pre cement addition as a contributor to the problem. Development work has been completed and implementation of a reduced conditioning time is be implemented. Implementation of this should reduce cycle times back to normal

Floc Dripping / Spillage and Decontamination

The FRP floc appears to exhibit different rheological properties to other flocs processed in that dripping from the floc delivery lines (following floc delivery to the drum) appears to be more prevalent. This causes problems due to contamination spread in a plant area used to operating at very low levels of contamination. This phenomenon is not fully understood yet and will be the subject of further assessment.

SUMMARY

A number of headline achievements have been made to date. A summary of the main achievements are listed below

FRP

- Demonstration of the process capability in re-suspending, homogenising and transferring the first Primary Sludge tank PS1 to the refurbished Buffer Tank.

- In so doing, transferring ~ 945TBq (50% of the total) mobile radiological inventory and hence risk to a higher standard of containment.
- Significant progress in buffer tank ullage creation in readiness for resuspension and transfer of the next tank PS4, which is known to have a slow leak to ground.
- Demonstration of an optimised use of wash liquor and a methodology for periodic management of accumulated supernate addressing a design shortcoming in ullage creation.
- Delivery of an improved hydrogen safety case allowing minimisation of resuspension liquor to provide significant schedule and environmental benefit.
- Safe recovery and restart following two major unexpected engineering failures.

EARP and WPEP

- Confirming the process flowsheet for floc treatment through EARP and WPEP and meeting the requirements of the long-term repository Waste Product Specification/Letter of Compliance and RSA and PPC discharge authorisations. In particular confirming environmental discharges are at or below flowsheet.
- Processing ~ 760TBq mobile radiological inventory into an immobilised safe and passive solid waste-form
- Substantial improvements in incorporation rates from encapsulation envelopes identified in the development phase delivering significant lifetime cost reduction and environmental benefits.
- Substantial management and optimisation of processing issues in WPEP

General

- Delivery of the above progress in a context of excellent safety statistics over a sustained period of time and within the very low dose targets associated with the Low Active Effluent Plants.

CONCLUSIONS

The programme of work undertaken on the Sludge Storage Tanks has changed the nature of the plant from an obsolete facility with a significant legacy waste inventory and challenging radiological environment, into an up to date nuclear facility capable of retrieving and treating the waste. The structured approach to the programme has allowed major capital project work to be delivered efficiently by first stabilising the plant and working conditions and then fully understanding the inventory before developing the retrievals technology.

The plant and equipment provided has successfully resuspended the long-settled solids in one 50+ year old tank (PS1) and transferred the contents to a modern tank thereby retrieving almost 50% of the plants radiological inventory and considerably reducing risk.

Over $1000m^3$ containing some 760TBq of active material has been processed through EARP, encapsulated in WPEP and transferred for passive storage on the Sellafield Site.

Significant progress has been made to date, however the remainder of the floc will be retrieved in an ongoing operations programme currently predicted to last up to 10 years.

Lessons Learned will need to be carried forward in order to ensure continued improvement in our strive to meet the strategic aim for accelerated remediation at reduced cost: -

- The fostering and continued use of a dedicated improvement community whether that be a service or embedded within the delivery organisation is invaluable and must be continued

- Continuous improvement has started and significant cost savings opportunities have been identified. These opportunities need to be explored however, they also need to be balanced with regards the operation of the plant and the impact they may have. This may manifest itself in a slowing down or indeed a short-term step back in terms of floc incorporation to allow some of the processing issues to be fully understood and resolved

- Our strive for numerous improvement activities delivering at the same time needs to be balanced such that the root-cause of issues can be targeted and resolved.

- The assessment and understanding of the ultrafilter spares strategy including the associated cost implications coupled with cycle time and bottleneck analysis must be completed to ensure the optimum acceleration / cost balance is struck.

- We have recovered from 2 significant and unexpected engineering breakdowns. This has however caused many months downtime. Further engineering assessment and improvement work will be required to ensure a quicker transition from the original operational intent to that of a continuous and accelerating plant as demanded by the stakeholders