Remediation of Sellafield Medium Active Tank Farm - 9570

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ABSTRACT

The Sellafield Medium Active Tank Farm was one of the earliest buildings constructed on site, being brought into active operations in 1952. This facility has had a key role in supporting site operations right up till this day and is expected to remain operational for a further decade yet, by which time it will be almost 70 years old.

The function of this facility has changed over the decades as site operations have evolved. One of the most significant changes occurred in the early 1980's when, in response to pressure to reduce environmental discharges, it started to be used for storage of Medium Active Concentrate liquor pending the design, construction and operation of a new suite of effluent treatment plants. By the late 1990's a significant inventory of approximately 6000m3 (1.6million US gallons) of Medium Active Concentrate liquor with a total radiological inventory of 3300TBq (90,000 Curies) had been accumulated. Around the same time concerns came to light over the ongoing structural integrity of the building roof. This resulted in strong regulatory pressure to address the significant perceived radiological risks associated with the building.

Processing the accumulated legacy Medium Active Concentrate liquor, through a new suite of effluent plants, had commenced by the late 1990's when concerns began to arise over the impact from technetium-99 discharges. This led to international pressure to reduce Tc-99 discharges associated with Medium Active Concentrate processing, conflicting with the desire to accelerate treatment to reduce the radiological risk associated with the accumulated inventory.

This conflict was successfully resolved through collaborative working with regulators and key stakeholders to endorse an innovative change to modify the routing of future Medium Active Concentrate liquor and to modify the treatment process of legacy stored material to slectively remove Tc-99 from discharges.
This success, together with further success in reducing the inventory of accumulated legacy spent solvent and salt Evaporator Concentrate liquor, reduced the stored inventory in the Medium Active Tank Farm to low enough levels to justify not constructing a replacement facility at an estimated cost of £300m to the UK taxpayer. The reduction in ongoing Tc-99 discharges was acclaimed by the Norwegian prime minister in a statement to the UK government.

This paper describes the circumstances surrounding the work undertaken, and ongoing, to remediate the Sellafield Medium Active Tank Farm and reflects on some of the potential key messages and lessons learned.

INTRODUCTION AND BACKGROUND

Sellafield site is a complex nuclear site, the activities of which have evolved over time since its origin as a Royal Ordnance Factory in the Second World War. It was chosen as the site of Britain's first nuclear reactors and reprocessing facilities in 1947 in support of the atomic weapons programme and subsequently the world's first commercial power generating reactors (Calder Hall) in the early 1950's. The main focus of recent decades has been the commercial reprocessing of spent nuclear fuel. In more recent years the importance of risk reduction from some of the oldest, and often highest risk facilities, has resulted in increased emphasis on remediation and decommissioning.

Over this time the function of some key facilities has evolved in response to the changing demands from changing site operations. One such facility on site is known as the Medium Active Tank Farm (MATF)

The Medium Active Tank Farm was one of the early buildings constructed on the Sellafield site. Construction started at the end of the 1940's with the plant brought into active operation by 1952. The building itself is mostly above ground, and is a box like reinforced concrete structure with thick walls to provide shielding. Within the building there are twelve stainless steel storage tanks which were built in situ as the building was constructed around them. Ten of these tanks are 1200m3 capacity open topped tanks. The other two tanks are 600m3 capacity with loose fitting lids. The tanks stand in seven compounds (two1200m3 per compound with 600m3 tanks in separate compounds) where the concrete floor acts as secondary containment which drains to sumps external to the main building walls.

Over the period of operations at Sellafield, the use of the MATF has varied, but eleven of the twelve tanks have remained in generally continuous use for storage of medium active (MA) liquors. One of the 600m3 tanks was damaged during commissioning, and has not been used for storage of bulk liquids. However this tank does contain an inventory of solid radioactive waste.

Fig.1 Aeria

The roof of the Medium Active Tank Farm was in the forefront of reinforced concrete technology at the time it was constructed.   It is constructed from a large number of post-tensioned, reinforced concrete beams which each span across the width of a tank-containing concrete compound. There have been some well-documented catastrophic failures of buildings and bridges constructed using similar, though not identical, methods. One of the problems with this type of construction is that there are great difficulties in gaining any knowledge of the strength and integrity of the post-tensioning tendons by non-destructive means.

Almost none of the original building features remain in use other than the structure, the sumps and the tanks. The pipework, transfer systems and instrumentation systems have been, and can be, replaced.

Receipt of liquors into the tanks is by gravity feed, and transfer of liquors is via steam ejectors. Control of operations is entirely manual by using extended spindle valves which protrude from shielded pipe ducts.

Fig.2 MATF layout Diag to insert

The reprocessing of Magnox fuel started in the mid 1960's resulting in the generation of a medium active waste stream containing a mixture of fission products and chemical constituents such as solvent degradation products. In the early years of reprocessing this medium active effluent stream was delay-stored for two to three years to allow for decay of short lived radioactive isotopes such as zircomium-95, niobium-95 and ruthenium-106 prior to discharge to the Irish sea with minimal treatment or activity abatement. In the mid 1980s, in response to growing environmental concern over the levels of radioactive discharges to sea, and in anticipation of a major investment programme to reduce site radioactive discharges, a decision was taken to further concentrate and contain medium active effluent arisings on site while a new suite of effluent treatment plants, later to be known as the Low Active Effluent Treatment Plants, were constructed and brought into operation. This Medium Active Concentrate (MAC) liquor was then stored and progressively accumulated in the Medium Active Tank Farm.

By the time the Low Active Effluent Treatment Plants came into operation in 1994 the accumulated MAC inventory had reached around 6000m3 (1.6million US gallons) with a total radiological inventory of 3300 TBq (90,000 Curies).

In addition to the storage of MAC the Medium Active Tank Farm was also utilised for the storage of spent solvent from the mid 1980's. By the year 2000 when a Solvent Treatment Plant was brought into active operation as part of the suite of Low Active Effluent Treatment Plants an inventory of around 2000m3 (0.5M US gallons) of waste solvent had accumulated. This was a mix of legacy stored medium active solvent from Magnox fuel reprocessing with additional arisings of mainly low active solvent following start up of reprocessing Oxide fuel in the Thermal Oxide Reprocessing Plant from 1994.

DEVELOPING REGULATORY ISSUES

Two significant competing issues came to the fore during the 1990's which shaped the forward strategy for the MATF. The first issue was in relation to increased discharges, particularly Tc-99 discharges, as a direct consequence of processing MAC through the Low Active Effluent Treatment Plants starting in 1994. The second issue was the increased awareness of the radiological risk associated with the MATF, and in particular uncertainty associated with the structural integrity of the building roof.

Tc99 discharges

One of the new suite of Low Active Effluent Treatment Plants, the Enhanced Actinide Removal Plant (EARP), came online in 1994 and commenced treatment of the legacy backlog of MAC. At the plant design stage of EARP during the late 1980s, in order to freeze the design and progress with construction, a decision was taken that Tc99, as a "soft" low-energy beta emitter, was sufficiently benign in the environment that it did not justify further enhancing the plant design to enable retention of Tc99. To have done so would have required further significant development programmes that would have delayed the design and ultimately start of active operations for EARP. It was therefore concluded that accelerating the design and construction of EARP to enable earliest possible realisation of the benefits in reducing critical group dose through removing actinides, and some key beta species like Cs137 and Sr90, far outweighed the impact of future Tc99 discharges. That decision was taken with agreement of the nuclear and environmental regulators.

However, a changing political, environmental and technical climate (partly caused by the aftermath of the Chernobyl event) brought a focus on fission product wastes in the environment and this focus included Tc99.

Discharges of Tc99 from Sellafield became particularly contentious in recent years attracting high profile media and political interest nationally and internationally; with particular attention emanating from Norway and Ireland. This is because the Tc99 isotope was found to concentrate in certain types of shellfish. This became a particular concern of the Norwegian and Irish governments and associated pressure groups because of the perceived impact on their sea fishing industries. In the late 1990s, British Nuclear Fuels (BNFL) placed a self imposed 90TBq (2430Ci) rolling annual limit (RAL) for Tc99 discharges from Sellafield, inside the "legal" limit of 200TBq (5400Ci), and in 2000 the 90TBq limit was incorporated into the Sellafield Site Discharge Authorisation by the Environment Agency. However, political pressure remained for further reductions to the Tc99 levels discharged. The only available means of achieving this was further limiting the rate at which MAC stocks would be processed.

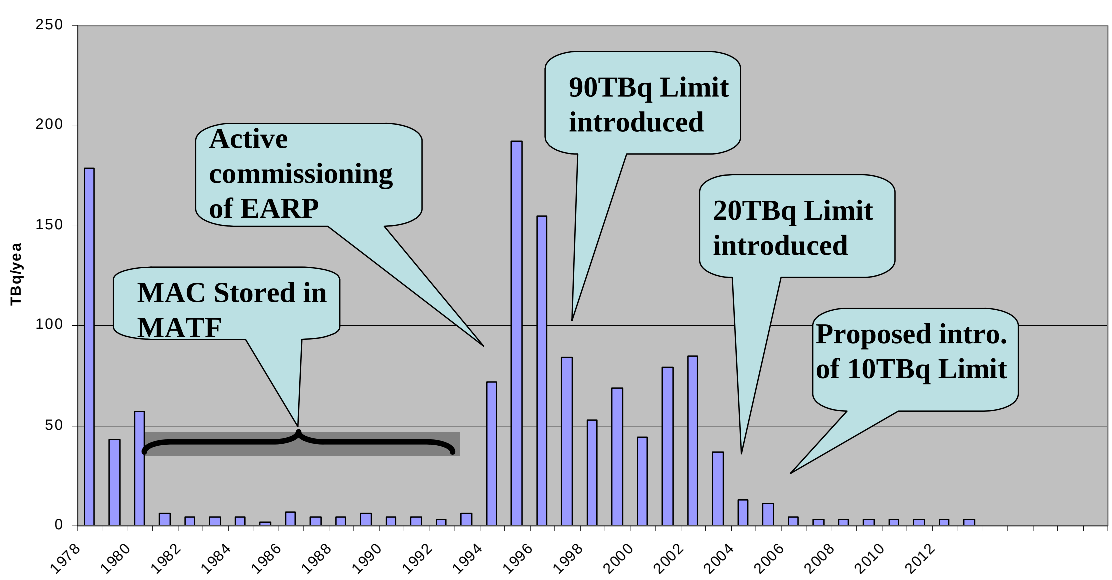

Fig. 3 Sellafield Site Tc99 Discharges to Sea

Radiological risk associated with MATF roof failure

A review of the MATF fully developed safety case in the mid 1990's raised reservations about the long term structural integrity, and in particular the difficulty in providing engineering substantiation of the building roof. The building roof is flat, and spans across the full length and width of the building, supported by the side walls of the building and by the internal walls separating the internal compounds. The roof is constructed of a large number of post-tensioned concrete beams, each beam spanning a compound that is 17metres (56ft) long. The spaces between the beams are filled by mass concrete, and a layer of concrete is laid over the beams.

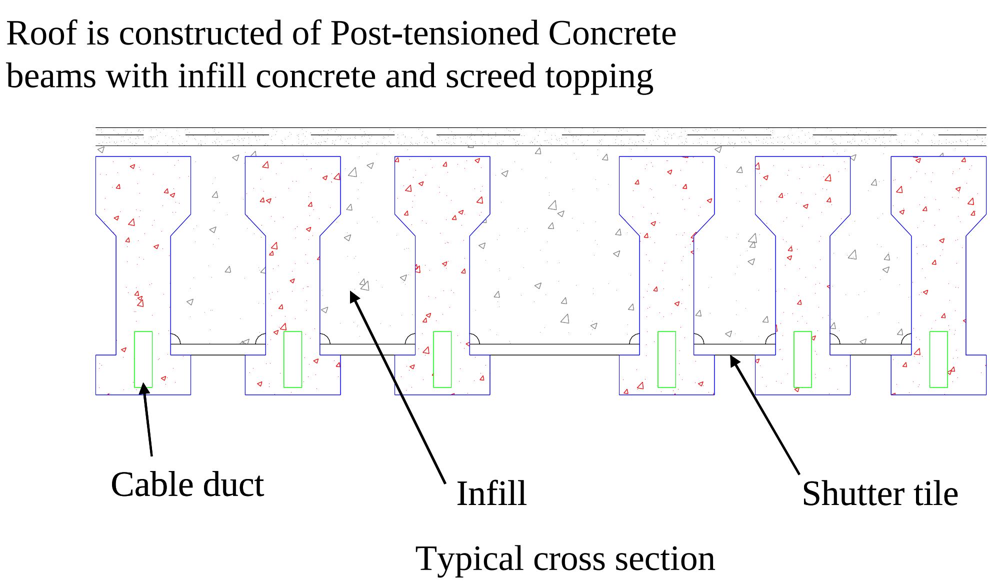

Fig. 4 MATF roof construction

This type of roof design was in its infancy when constructed, and subsequently went out of use following failures of other structures (buildings and bridges) which were constructed in a similar way. The failure mode is where the post-tensioning cables within the beams fail through corrosion or otherwise which then makes the beam unable to support its own weight. It should not be inferred that the MATF roof will necessarily fail. The "failed" structures were generally subject to more aggressive use, significant variable loading, or construction variation which exacerbated corrosion routes. Direct observation of the condition of the MATF roof beam post-tension cables is not generally possible, and inferring their condition through other means is difficult and open to challenge. The likely failure mode of an individual beam may be failure of the cable strength through corrosion, through loss of tension, or through damage, followed by that beam relying on adjacent beams for support. It is possible that this may result in a slight sagging of the roof which may be detectable. The likely failure mode of the MATF roof is catastrophic

failure of a roof panel over a single compound following failure and load transfer of sufficient individual beams.
At least two of the beams, both in the same compound, have lost their structural strength by historic core-drilling through the post-tension cables. The weight of these beams is now transferred to their neighbouring beams.

Two further issues in the late 1990's prompted the UK nuclear regulator, the Nuclear Installations Inspectorate (NII) to request action to mitigate the perceived radiological risks associated with the MATF.

1. In 1997 a leak of MAC liquor occurred on MATF roof during inter-tank transfer operations where active liquor reached the surface water drain system.
2. A House of Lords Select Committee Report raised concerns that a substantial radioactive inventory was stored in an ageing building which did not meet modern safety standards.

Engineering schemes developed for potential replacement facilities with the same functionality as the Medium Active Tank Farm estimated the capital cost at over £300M. Alternative schemes for overbuilding structures to bear the load of the existing roof were estimated at over £100M. However it was recognised that the most effective short term means of reducing the radiological risk to the workforce and the environment associated with the MATF was to substantially reduce the stored radiological inventory.

This clearly highlighted a tension between two competing regulatory objectives

- Environment Agency seeking a reduction in Tc99 discharges to levels experienced during MAC storage in 1980's and hence a driver to slow the treatment of MAC liquor.
- NII seeking accelerated reduction in the radiological inventory of MATF as quickly as possible, necessitating accelerated treatment of MAC through EARP, thereby increasing Tc99 discharges.

The ultimate resolution of this conflict was realised by two approaches to solving the Tc99 inventory issue

MAC Diversion

In July 2003, following an extensive research and development programme, and detailed consideration of the safety cases and operating envelopes of a number of Sellafield plants, plant and process modifications were implemented whereby the Tc-99 containing Medium Active effluent stream was diverted to the Highly Active (HA) effluent processing route. The Tc-99 containing stream is then evaporated within the HA process plants for immobilisation via the vitrification process of the Sellafield Waste Vitrification Plant (WVP). In this plant, fission products, separated from the Uranium and Plutonium streams in the early stages of the solvent extraction process used in reprocessing, are encapsulated in a glass based matrix for long term storage and return to customers. The effect of this innovative plant modification was to provide a solution to the ongoing arisings of MAC.
Other components within the existing stored MAC liquor meant that the legacy volume of stored MAC was not suitable for HA evaporation and vitrification. However having diverted fresh arisings of MAC this inventory could now be clearly bounded.

Tc99 abatement in EARP

Coincident with the MAC diversion project described above, BNFL were also working on a proposal to reduce Tc-99 discharges from the EARP plant during MAC treatment. A few options had been considered for Tc-99 abatement, including ion exchange, electrolysis and chemical precipitation. Most options required considerable capital spend and a long lead time for development and plant construction. Any new plant would also lead to additional radioactive liability on the Sellafield site with attendant maintenance and decommissioning costs. This level of investment was difficult to justify on the grounds of benefit to the critical group dose. However one option offered promise for use directly within the existing EARP plant with only minor modification.

The solution was to identify a chemical additive that would cause Tc-99 to be separated from the discharge in the existing EARP ultrafiltration process. The candidate process selected involved use of an organic salt Tetraphenylphosphonium-bromide (TPPBr) for selective precipitation of Tc99, allowing it to be separated from the effluent in the filtration stage of treatment.

However this process introduced a new set of challenges

- The safety case for the proposed UK repository had tight limits on the amount of mobile, soluble Tc99 that could be accepted in encapsulated waste form.
- The reagent is toxic introducing conventional safety issues during manual handling
- It was necessary to add the TPPBr reagent in excess to achieve good Tc99 removal efficiency resulting in a new environmental discharge of a toxic chemical.
- Regulatory concern that introducing a new reagent to EARP process could introduce significant risk to the plant that might threaten its key role in supporting site activities in risk reduction and abatement of actinide discharges.

Ultimately it took many months of detailed interactions with both nuclear and environmental regulators as well as NIREX, the owners of the future repository safety case, to identify and satisfactorily resolve all technical issues. This ultimately culminated in a successful plant trial followed by full implementation of the TPPBr process. By the end of 2007 all historic legacy MAC and all associated MAC contaminated tank heels had been successfully treated through EARP. Hence a win-win solution was achieved that met the objectives of substantially reducing the risk from the stored MAC inventory whilst supporting an early permanent reduction in the authorised site rolling annual limit for Tc99 to 10TBq/Yr.

The benefits of MAC diversion and introduction of TPPBr were acclaimed at the highest levels. In April 2004, the Norwegian Prime Minister, Kjell Magne Bondevik expressed his thanks to the British Government for putting a stop to the excessive Sellafield Tc-99 discharges, saying “I am very grateful that a successful solution has been found to this difficult issue in our otherwise close and good relationship with Britain”
Later that year, UK Environment Minister Margaret Beckett was awarded the Rogaland Liberal Party’s annual environment prize as a result of the work which lead to the reduction of Tc-99 discharges from Sellafield

Additional inventory reduction measures

Following successful resolution of the high profile MAC storage and Tc99 discharge issue, continued efforts at reductions in MATF inventory have further reduced the radiological risk to very low levels.

The next most significant radiological inventory associated with MATF after MAC was associated with transient storage of 1200m3 batches Salt Evaporator Concentrates (SEC) from a neighbouring storage facility, prior to processing in EARP. This had been necessary to allow sampling and characterisation of the SEC in order to satisfy regulatory requirements to obtain a Letter of Compliance from NIREX prior to conditioning and packaging of the waste as ILW for ultimate disposal to a repository. This typically resulted in interim storage of a 1200m3 batch in MATF for 9-12 months prior to treatment with a fresh campaign being treated every 2-3 years. Detailed technical arguments were developed and assessed in conjunction with NIREX and the Environment Agency to support a case for direct treatment of SEC without the more involved sampling and characterisation on a tank by tank basis. This together with plant trials demonstrating a viable bypass route culminated in the most recent SEC campaign being treated directly in EARP without extended storage in MATF. Hence the future risk from SEC storage in MATF has been effectively avoided.

The final significant legacy inventory associated with MATF was associated with the storage of spent solvent (up to 2000m3 0.5M US gal at its peak in the late 1990's). This solvent was a mix of tributylphosphate (TBP) and odourless kerosene (OK) used in fuel reprocessing in both Magnox and Thorp (Thermal Oxide Reprocessing Plant) plants. In addition to the radiological risk of leak to ground this inventory presented the additional risk from solvent fires. A process for treatment of this solvent through chemical transformation and combustion was developed in the 1990's leading to the design and construction of the Solvent Treatment Plant (STP), which commenced active operations in 2000. In parallel to the development of STP an additional 1200m3 solvent storage tank was refurbished to modern standards in a neighbouring tank farm. This facility does not have the same structural concerns as MATF. Through a combination of successful treatment of legacy waste solvent in STP and transferring the remaining residual inventory from MATF to the refurbished tank the inventory of legacy solvent was removed from MATF by the end of 2007. It is predicted that during 2009 the remaining inventory of legacy solvent will have been processed through STP. Hence only transient 'in-flight' volumes of solvent will be required to be stored in future.

The outcome of the successful programme of remediation of MATF is that the residual radiological risk is below a level of consequence justifying significant capital investment. While the integrity of the MA tank farm roof remains the subject of intense civil engineering assessment, it is agreed that there is now no need for either a new facility or an extensive overbuilding, thereby saving the British tax payer many million pounds.

Fig 5&6Insert updated graphs of MATF volume and rad inventory reduction profile

Additional stakeholder interest

The Nuclear Decommissioning Authority (NDA) was established under the Energy Act 2004 with the responsibility for the decommissioning and clean-up of the UK's civil public sector nuclear sites, including Sellafield. This shifted the emphasis somewhat from commercial reprocessing operations to nuclear clean-up and waste management. One visible outcome of this was creation of a shortlist of facilities at Sellafield targeted for review of opportunities to accelerate clean-up through remediation and decommissioning. Given its high profile at the time the MATF was one such facility selected for review through a process called Decommissioning Mandates. The intention was to review and clarify the most credible Lifetime Plan baseline for transition from the current operational state through decommissioning. In doing so it would identify risks and uncertainties and opportunities for further optimisation.

However this exercise was undertaken in parallel with detailed scrutiny and review of the overall Sellafield site lifetime plan funding. Consequently by the time the decommissioning mandate was published it had become clear that scope for early investment in accelerating decommissioning of the MATF could not be justified at the current time. This was in part at least a reflection of the good progress in reducing the overall risk associated with this facility to acceptable levels through a combination of inventory reduction and civil substantiation. In effect the strategy for early remediation of MATF had to some extent become a victim of its own success, in that early successful risk reduction had removed the impetus for significant further early investment towards decommissioning.

Asset care

Since 2002 significant investment in civil engineering studies associated with the MATF roof structure has been made. This has provided necessary assurance and confidence in the MATF roof structure going forward, but arguably has not resulted in any fundamental change in the roof integrity. The high level of political interest and regulatory scrutiny associated with MATF has however helped to secure funding for improved asset care and condition monitoring including investment in acoustic monitoring techniques and weatherproofing to minimise corrosion risks to the pre tensioned beams. Securing this level of funding for asset care may not have been achieved otherwise. Review wording
Following a recent competition process in line with NDA strategy a new parent body organisation, Nuclear Management Partners (NMP), has recently taken over the contract for managing the Sellafield site. A key strategic driver from this is to improve efficiency and deliver innovation. However already in the first few months NMP have signalled a change in focus from removing cost from operating the site to reinvesting those savings into improved asset care.

Complexity of site process interactions

Fig 7Insert daig of MATF interconnections

The MATF forms a central hub in providing key interfaces between a range of historic and more recent reprocessing plants, storage facilities and effluent treatment plants. The complex interconnectivity of the Sellafield site is a recognised issue. This presents significant challenges when considering the decoupling of such a facility for future decommissioning. A particular challenge for MATF is its link to upstream Magnox reprocessing plants. Latest revisions of the Magnox Operating Plan (MOP) have indicated an extension of several years to the programme of Magnox fuel processing to secure the processing of wetted fuel stocks. This leads directly to an extension of the planned lifetime of related ageing facilities such as MATF and inevitably more pressure on the ongoing substantiation of life limiting factors such as civil integrity. The planned timescale for MATF progressing into Post Operative Clean Out (POCO) in preparation for decommissioning has effectively doubled from approximately five years to nearer ten years. This highlights the issue of strategic drift and the impact of extending the life of one facility on all the interfacing facilities on a complex site like Sellafield. This emphasises the need for robust discipline in assessing the impact of any strategic changes both step change and iterative on the overall site strategy.

Significant advances have been made in recent years at Sellafield in establishing complex site models and detailed strategic plans that help model the impact of any strategic changes. This is further enhanced by ongoing development of an Integrated Waste Strategy (IWS) for the site.

FUTURE CHALLENGE

Although significant progress has been made over the last decade in progressing with the risk reduction and remediation of the MATF there remains a number of substantial technical challenges to be resolved over the full building lifecycle. Many of these challenges are already recognised as generic in nature and addressed by wider decommissioning strategies e.g. how to minimise the impacts of concrete demolition wastes, how to segregate and recycle metallic wastes etc. There will also be a number of challenges that may appear more localised or unique to MATF e.g. how to characterise; handle and package accumulate tank solids and how to manage anticipated solvent interfacial crud waste.

One of the deliverables required following establishment of the NDA was the development of a Technical Baseline Underpinning Research and Development (TBURD) document. This document sets out technical baseline for the Sellafield lifetime plan and as such identifies the future technology needs, and hence the technology gaps and areas of required development. In doing so it gives increased visibility across the site of common issues and challenges. One outcome of this is the identification of a common issue associated with the sampling, characterisation, mobilisation and handling of tank residue solids and sludges. Recent tank inspections within the MATF have identified a potential significant inventory of residue solids in the bottom of some tanks. Funding has been secured to initiate development studies into managing such solids, utilising MATF as a test case. This funding has been secured in recognition of the potential application of such work in addressing similar wider site issues. It would have been difficult to justify this investment at this time based on MATF needs alone.

CONCLUSIONS AND KEY MESSAGES FROM MATF REMEDIATION

Collaborative working with regulators and key stakeholders has been essential to the success of meeting the technically complex and politically sensitive remediation challenge associated with Sellafield Medium Active Tank Farm. The ‘partnering’ ethos of the recently appointed parent body organisation, NMP, therefore seems well aligned to meeting the future remediation challenges associated with the Sellafield site.

Substantial capital cost associated with replacement of the Sellafield Medium Active Tank Farm has been avoided through a combination of an innovative approach to risk reduction and recent and ongoing investment in asset care and engineering substantiation. Conversely a failure to adequately invest in effective asset care, with increasing emphasis on extending the life of existing ageing facilities, carries a significantly increased risk of additional lifetime cost in the future, in addition to associated increase in radiological risk. This fundamental issue has been recognised by NMP with the stated intention to invest savings from efficiencies into improved asset care.

The competing issues of radiological risk reduction versus increased environmental discharges highlighted by MATF remediation will inevitably be encountered a number of times in the future remediation of the Sellafield site. Such issues will never be easily resolved given the often subjective judgement associated with the application of the guiding principals such as ALARP (As Low As Reasonably Practicable) and BPM/BAT (Best Practicable Means/ Best Available Technique). Decision making processes on proportionality may be further complicated in an environment of competing radiological risks and constrained public purse. MATF experience highlights another dimension in that a decision considered today to meet the principals of proportionality may be challenged in future as a consequence of a changing political climate. There are no easy answers to such dilemmas.

The perceived level of risk associated with a facility such as MATF is a dynamic issue and has to be seen in the context of competing risks in a climate of constrained funding. In effect it can become a victim of its own success where its risk profile reduces it becomes more difficult to compete for and justify funding. However this is an entirely healthy reflection of the changing priorities as a result of successful remediation activities.

Sellafield is a complex site such that strategic decisions in one facility have a ripple effect on interfacing facilities and strategies. Hence for a complex site complex models and planning processes are required to fully assess the impacts of such changes. Sellafield has been developing the models and detailed planning processes that have helped develop and support an Integrated Waste Strategy. This has been instrumental in supporting the case for key strategic decisions such as extensions to the Magnox Operating Plan.

Developing the visibility of potential gaps in future technology needs, e.g. via the TBURD, has provided the opportunity to identify common issues and challenges. This helps avoid duplication of effort and facilitates co-ordination of development programmes on site. Furthermore the links provided by NMP to a much wider pool of experience beyond the Sellafield site experience can only further enhance these opportunities.

Whilst the future challenges associated with the ongoing remediation and future decommissioning of ageing facilities such as MATF should not be underestimated, experience over the last decade gives some confidence that with the right innovative thinking, collaborative working and appropriate funding, solutions to these challenges can and will be identified and delivered.