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Sellafield HA and MA Liquors Management: Summary Update

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1.0 Background

In August 2003, a BNFL presentation was made to NuSAC RG2 that summarised key Sellafield operational performance issues, developing remediation strategies and contingency plans. This presentation prompted questions from RG2 about emerging issues and policy, principally relating to the long-term management of medium active and high active liquid wastes. An update of progress in the management of both medium and high active liquid waste was made in 2004 (NuSAC(2004)P18 Closed Paper), with particular reference to those issues that NuSAC RG2 sought clarification / assurance. A progress update of the Legacy Ponds and Silos early remediation project was provided.

This paper updates NuSAC paper NuSAC(2004)P18 Closed Paper, encompassing:

- Medium Active Liquor related issues
- High Active Liquor related issues
- Legacy Ponds and Silos remediation update

2.0 Terms

Am ²⁴¹	Americium 241
BNFL	British Nuclear Fuels Limited
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
Cs137	Caesium 137
DG TREN	Directorate General of Transport and Energy
DTI	Department for Trade and Industry
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant.
EC	European Commission
HA	High Active
HAL	High Active Liquor
HALES	Highly Active Liquor Evaporation and Storage.
HAST	High Active Storage Tank
HMG	Her Majesty's Government
LoC	Letter of Compliance
LP&LS	Legacy Ponds and Legacy Silos
MA	Medium Active
MAC	Medium Active Concentrate.
MAL	Medium Active Liquor
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NTWP	Near Term Work Plan
ROV	Remotely Operated Vehicle
SAC	Salt Azide Conditioned liquor.
SEC	Salt Evaporator Concentrate.
SPP1	Solids Packaging Plant 1
STP	Solvent Treatment Plant.
TBP	Tributylphosphate.
Tc ⁹⁹	Technetium 99
Thorp	Thermal Oxide Reprocessing Plant
TPP	Tetraphenylphosphonium Bromide.
WPEP	Waste Packaging Encapsulation Plant
WVP	Waste Vitrification Plant

3.0 Contents.

Medium Active Liquor related issues

- Treatment of Medium Active Concentrate (MAC) with Tetraphenylphosphonium bromide (TPP) to retain Tc⁹⁹.
- The current liquor inventory stored in the MA tank farm
- The proposed operational strategy for the MA tank farm
- The current MA tank farm building status
- Treatment of historic alpha flocs

High Active Liquor related issues

- Vitrification update
- High active liquor evaporation and storage
- HALES cooling and tank integrity
- HA evaporator performance

Legacy Ponds and Silos remediation

- Product development
- First Magnox Pond inventory verification
- Project status
- Best practicable environmental options

4.0 Medium Active Liquor related issues

The MA liquor strategy is based on the reduction of the activity content and liquor volume within the aging MA tank farm facilities.

4.1 Treatment of MAC with TPP

Treatment of MAC with TPP has been very successful during 2004 and 2005. All of the available MAC in the MA tank farm has now been treated and only the heels of MAC remain in each of the storage tanks.

- Total MAC treated with TPP since November 2003 was 2224 m³ in eight separate campaigns through EARP and WPEP.
- Total Tc⁹⁹ in this feed was 220TBq. Tc⁹⁹ removal from feed has varied between 95% and 98% over the eight campaigns, leading to total site liquid discharges of up to 75% of the 20TBq/yr site discharge authorisation.
- Excess TPP was used to ensure good Tc⁹⁹ removal,
- The volume of MAC liquor remaining as heels in the MA tanks is approximately 120 m³. The highest inventory of MAC stored at Sellafield was 5805 m³ in 1993.

4.2 Current MA Tank Farm Inventory

Retrieval of the majority of the MAC stored in the MA tank farm has significantly reduced the radioactive inventory from 1488 TBq of total activity stored in April 2003 to approximately 200 TBq in January 2006. Current arisings of MAC from Magnox reprocessing continue to be routed for vitrification in HALES. There has been no apparent detriment to HALES operations due to incorporation of MAC and thus all future MAC arisings up to the end of Magnox reprocessing are destined for HALES. Some Hal containing MAC has been processed in WVP. To date, no adverse effects within WVP have been attributed to the MAC content. The MA tank farm will continue to be used for the buffer storage of various process liquors.

4.3 MA Tank Farm Operational Strategy

The strategy for operation of the MA tank farm is to progressively reduce the inventory of liquor stored. The following are key aspects of the strategy:-

- Spent solvent (odourless kerosene and TBP) exported from Magnox reprocessing operations can only be transferred into storage tanks in the MA tank farm. However it is part of the strategy to routinely export solvent and treat in STP.

- The three tanks previously used for MAC storage are now empty except for the residual heel liquor which cannot be removed with the existing ejector system. The intention is to dilute these heels by liquor addition and removal, followed by treatment in EARP. These tanks will then be taken out of routine use ready for final decommissioning.
- In future, SEC will be decay stored in an alternative facility to the MA tank farm prior to treatment in EARP. The MA tank farm will be used to establish SEC batches of about 1000m³ prior to transfer to the alternative facility. Nirex have recently issued a letter of compliance (LoC) for treatment of all future SEC within a defined compositional envelope - previously a LoC was required for each new tank of SEC treated. The new arrangement greatly helps scheduling.
- MA aqueous liquors associated with Magnox solvent transfers and other washout operations will be consolidated in the MA tank farm and treated in EARP periodically.

4.4 Active Tank Farm Building Status

The status of the civil structure has not changed since the last report. A remote TV inspection of the underside of the roof was performed during 2005, and this revealed no new areas for concern with respect to the roof deterioration.

The site strategy is to continue to use the MA tank farm rather than replace with a new facility. This strategy has been underpinned by the increased confidence in the building structure and by the reduction in the active inventory.

4.5 Treatment of Historic Alpha Floes.

Retrieval of stored historic alpha floc began in April 2005. More than 95% of the floc inventory in the first tank to be processed was transferred into a Buffer Tank. 350m³ have been successfully retrieved from the Buffer Tank, and processed in EARP prior to encapsulation in WPEP. The resulting permeate which was discharged to sea from EARP had low levels of radionuclides and in particular lower than expected levels of Am²⁴¹. Despite a good decontamination factor for chromium, the amount of soluble inactive chromium was a step change increase over previous discharges, thus an increase in the authorised limit (instantaneous discharge concentration and annual load) is being sought from the EA for chromium to avoid extending the alpha floc treatment period by many years.

Following maintenance, floc retrievals are scheduled to resume in March 2006. Improvement plans are in place to increase the concentration of the floc prior to

encapsulation, with a corresponding decrease in the number of drums of encapsulated floc produced.

5.0 Highly Active Liquid and related issues:

The HA liquor strategy is based upon reduction of HAL volumes in accordance with the HAL reduction specification.

5.1 Vitrification Update:

A Vitrification improvement plan was produced in 2001 to address the improvements required in the performance of the Vitrification Plants. The 10 point plan is being executed in 5 phases between August 2001 to 2006. Key achievements have been:

- A third vitrification line was completed in 2002 and entered full operation in 2004. WVP line 3 built on the experience gained in lines 1&2 and included many improvements to the original lines 1 & 2 design.
- New tough wall crossings have been successfully installed on Line 2 and 50Hz Melter inductive heating and control has been introduced to improve temperature control, reduce thermally induced stresses in the melter and enhance melter life. Premature failure of the line 2 inductor heating system has been resolved by improvements to manufacturing methods for the coil insulation.
- A new melter with thicker walls has been tested on Line 3 and has shown the expected enhanced melter life
- Dry Bead blast container decontamination has been installed on Lines 1 and 2, and demonstrated to reduce the pre-storage container decontamination bottleneck.
- The acceptance of a revised Thorp safety case that allowed the reduction in gadolinium addition to the Thorp dissolver, giving a reduction in the quantity of highly active liquid produced from Thorp operations and significantly enhanced incorporation of the HAL produced in vitrification.
- A vitrification test rig has been built, commissioned, and demonstrated to be representative of the process, providing the capability to test process improvements and to support sustained reliable vitrification performance.
- A vitrification assistance programme has been agreed with the French vitrification operator COGEMA, providing training, advice and equipment to improve the future reliability of the WVP process.

The key operational results have been:

- Container production rates have increased over the last 2 years.
 - 313 in 2002/03 (target of 250)
 - 341 in 2003/04 (target of 340)
 - 478 in 2004/05 (target of 460)

Targets for MA waste disposal to the Miscellaneous beta gamma waste store have been exceeded for the last 2 years, reducing the volume of waste in Lines 1&2 breakdown cells.

In 2005/06 382 containers had been produced by the 31/01/06. A number of reliability issues had compromised the year end target of 525 containers, however despite these issues several production records were broken, including:

- the greatest number of containers exported to the vitrified product store in a single week
- the greatest number of containers from a single melter crucible (149).

Successful removal of bottlenecks has made further issues visible. One example of this is that as throughput has increased the number of routine plant maintenance interventions has also increased, and this has led to small increases in particulate discharges of Cs137, increasing the risk that the plant discharge limit for Cs137 will constrain throughput. It should be noted that this plant limit is a small fraction of the site discharge authorisation for Cs137. Other key issues to be addressed include improving melter life and melter power supplies, ensuring container processing capability keeps pace with enhanced production rates, and eliminating HAL feed line blockages.

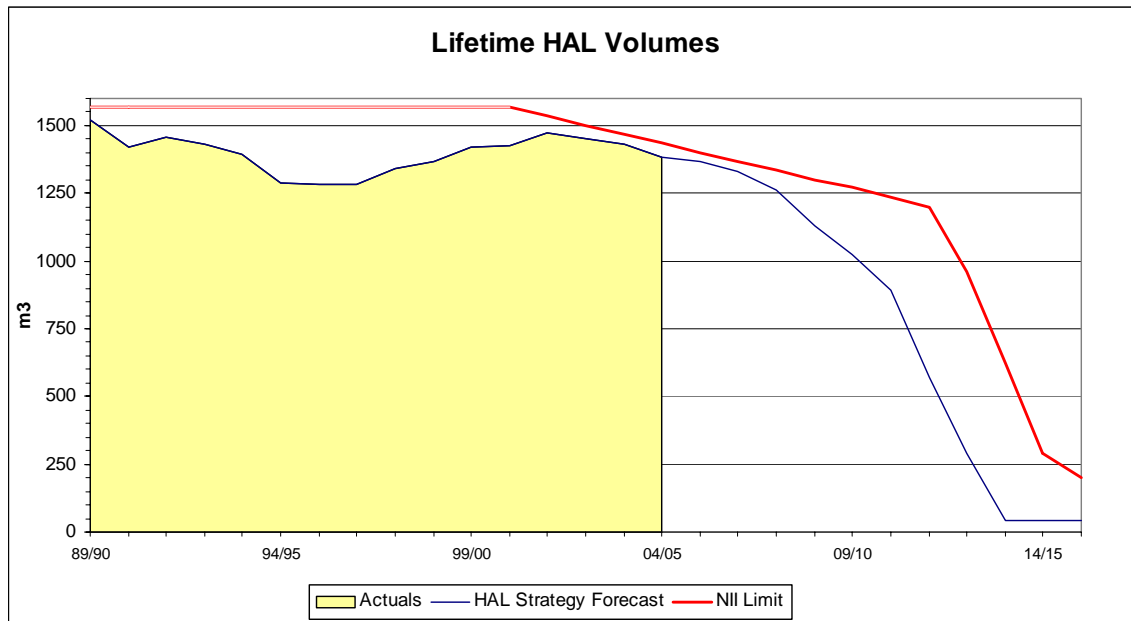
WVP targets are to deliver 450 containers in 2007/08 (when line 1 is shut down for much of the year to install improved systems), and sustained average production rate of 480 containers per year thereafter. Further performance improvement initiatives in hand or planned are:

- Achieve sustained / reliable operation of glass feed system, with glass frit reagent supply from the supplier's new continuous manufacturing process.
- Optimise effluent generation from the vitrification process
- Implementation of increased incorporation rate and throughput demonstrated on the Vitrification Test Rig, reducing lifetime container numbers.
- Implementation of the proposals for equipment and operating methods to improve plant performance and lifetime, reducing rebuild frequency, reducing waste and increasing throughput.

5.2 Highly Active Liquor Evaporation and Storage (HALES):

Highly active liquid evaporation and storage operations continue to control HAL stocks within the annually reducing limiting total stored volume as defined in the NII Specification dated 31st January 2001, and summarised in figure 1 from the Nuclear Decommissioning Authority (NDA) lifetime plan 2006.

Figure 1: Highly Active Liquor Stocks Control Volume and Actual Volume in Storage:



The current inventory of 1300m³ and forward strategy has been affected by the current Thorp shutdown which has delayed the production of oxide HA liquors. In order to maintain production in WVP, two Magnox only campaigns are now planned for 2006, which will reduce flexibility for blending to meet overseas customer specification for the rest of the programme.

5.3 HALES Cooling and tank integrity:

Throughout the life of the plant, the HAST cooling system capability and reliability has been scrutinised. The cooling system function and issues can be summarised as follows:

- (i) The purpose of the cooling water system is to prevent the self-heating of the HAL stored within the Highly Active Storage Tank (HAST) fleet.
- (ii) The existing flow of cooling water from the HAL tanks is referred to as “once through”, in that it passes through jackets and coils and then goes directly to cooling towers outside of HALES.
- (iii) The source of fresh water for the cooling towers is Wastwater, a local lake, the untreated water from which contains approximately 6 ppm chloride ions. If not managed, this chloride can have a detrimental impact on the materials of construction (18/13/1 stainless steel) of the HASTs.
- (iv) In 2000-01 a hotspot was detected on the base of one of the highly active tanks, and the hot spot was successfully removed by increased agitation. A major technical & safety evaluation and investigation programme was initiated to

better understand hotspots and to put in place measures to manage, eradicate and protect against them.

A number of projects and studies have been undertaken to ensure that HALES will meet its lifetime commitments:

- (i) The degree of redundancy in HALES when considered against forward business plans has been assessed, demonstrating a large margin for plant safety in terms of gross cooling capability vs. heat inventory, and operational HAST volumetric capacity vs. stocks. Even if a pessimistic estimate of cooling coil failure probability is assumed, there continues to be a substantial operability margin of the order of a factor of 3 before the use of spare tanks is required to complete the programme.
- (ii) Technical studies have been completed to identify the optimum cooling water chemistry to assure asset life.
- (iii) Plant improvements have been implemented to improve the control and monitoring of the performance of the Jet Ballast systems on the HAST tanks. The Jet Ballast systems prevent solids settling that result in hotspots.
- (iv) A project has been initiated to implement closed circuit cooling water systems with an intermediate heat exchanger for the base jackets of key HAST tanks, so that in the very unlikely event of a failure, any activity leakage will be contained within a low volume primary circuit.
- (v) A major technical programme is in hand to improve understanding of the HALES process chemistry envelope and of the properties of the solids formed in HAST conditions, and from this improved understanding, to identify flowsheet changes that will reduce the occurrence of hotspots.

5.4 HA Evaporator Performance

There are three HALES HA evaporators. Evaporators A and B were constructed in the 1960's and commissioned in 1970. Evaporator A was brought into active service in 1970, and Evaporator B was brought into active operation in 1985, both have been used to process Magnox liquors. Evaporator C was commissioned in 1990 with Magnox feeds. Since 1995 when Thorp came on line Evaporator C has processed both Oxide and Magnox batches.

Over the past 4 years significant improvements have been made to evaporator operations: control of feed chemistry, batch operation control and fault diagnostics. These have

resulted in significant improvements, with actual HAL storage concentrations very close to optimum.

Evaporator A has undergone refurbishment and engineering modifications to successfully bring it back into service. It is currently being used to process Magnox liquors.

Tests are currently ongoing on Evaporator B to determine cooling component status.

Blend batches, comprising of approximately 60 tonnes equivalent of Magnox raffinate and 40 tonnes equivalent of Thorp raffinate have been processed through Evaporator C. Evaporator 'A' currently supports Magnox and Evaporator 'C' will support Thorp.

Concerns have been raised that the HA evaporators may not have the remnant life required to deliver the current plan for Magnox and Oxide fuel reprocessing, support completion of the Vitrification and HAL stocks reduction and deliver site post operational clean out.

An evaporator strategy has been developed and agreed with regulators and NDA to manage these concerns. Key elements of the strategy are:

- Inspection of evaporators A and C.
- An assessment of the anticipated evaporator lifetimes, range of uncertainty, and operating strategies for optimisation.
- Measures have been adopted to minimise fouling, including improved control of the evaporators during start-up and a plant wash out strategy to clean the condenser on both waterside and process side.
- Optimisation of current cooling system, including refurbishing of cooling towers and balancing system flow rates.
- A project to construct a further HA evaporator has been initiated, and early feasibility studies are in progress. The extent to which this work is taken through to completion will depend on the outcome of the life assessment work. Provision of an additional HA evaporator would take risk out of the latter part of the reprocessing programmes, and provide evaporative capacity for post operational clean out and salt free liquor clean up activities.

The completion of the refurbishment of a Magnox Salt free MA evaporator has provided reassurance that MA evaporative capacity will be maintained to support HALES and WVP operations.

6.0 Legacy Ponds and Silos Remediation:

The Legacy Ponds and Silos area at Sellafield comprises four key legacy plants, 2 ponds and 2 silos. An approach to the management of Legacy Ponds and Legacy Silos was developed (the Legacy Ponds and Silos Early Remediation Strategy, Nov. 2003), endorsed by the BNFL

Board and presented to customers and Regulators. The strategy offers the potential for British Nuclear Group to meet the requirements of the Licence Specification dates as issued by the HSE in 2001.

6.1 Product Development

There are a number of projects within the strategy at varying stages of maturity, each strongly focussed on the relevant License Instrument(s). Finalisation of viable product forms, acceptable to stakeholders and compatible with the resource and time constraints is a key continuing challenge. Each project within the strategy is on-track with the appraisal and evaluation of the options. The first project product selection is due to take place within the next quarter-year. Positive progress continues in these areas and there is significant agreement with Nirex and the Regulators on the way forward for the majority of waste forms, however, there are a number of technical issues and tensions between the stakeholders requiring resolution. Notable amongst these products issues is finding an acceptable solution for the reactive metals arising from the Ponds and Silos.

The product form challenges for the silos are increased by the heterogeneous nature of the waste, with the constraint that the waste treatment processes must have the appropriate operability and throughput to achieve the specifications. Parameters currently being explored are segregation and characterisation requirements and the water content of the waste. A pragmatic approach is required to product waste form specification if the plan for early site risk reduction is to be achieved. Containerised buffer storage remains an option as a fall back position.

The cost and technical viability of recovering/treating residual metal fuel from the legacy ponds are aspects of an on-going issue, contributing to the assessment of whether fuel is categorised as waste or should be reprocessed. Ponds projects are evaluating the range of options in order to arrive at fuel strategies with a time base consistent with the sludge retrieval programmes.

6.2 First Magnox Pond Inventory Verification

The EC via the Directorate General of Transport & Energy (DG TREN) has indicated an intention to take HM Government to the European Court of Justice for infringements of the Euratom Treaty relating to historical nuclear material accountancy in the first Magnox Pond, for their perceived lack of access for verification and for their perceived lack of decommissioning plans. As part of the response to the directive, DTI produce a six monthly progress report to the Commission on behalf of HMG. BNGSL support DTI in producing these reports, the third of which was sent to the Commission in December 2005.

Since the infraction notice was issued, through DTI and through direct work with local inspectors, BNGSL has been able to demonstrate to the Commission that appropriate progress has been made for the retrieval and measurement of material. By use of a remotely operated submersible vehicle (ROV), access has been made for some plant inventory verification by DG TREN inspectors. (Although inspectors had been given access annually as is required, they had not been able to verify inventory as the engineered systems which would have allowed access are being re-engineered to support retrievals.) The same ROV has provided the basis for reconciliation of the historic records.

BNGSL has therefore shown that significant progress is being made against the infractions listed in the notice. DG TREN has issued acknowledgement of receipt of information and has not given any indication of whether progress is considered to be satisfactory. Whether or not the court proceedings continue is a matter for HMG and the EC.

6.3 Project Status

In addition to the process selection and design work associated with the above challenges, much work has already been completed and much is included in the NTWP for the coming year to reduce the risk across all the legacy ponds and silos.

- A silo has been inerted under an argon blanket, with improvements made to reduce the seismic and external hazards. Completion of plugging and sealing the charge hole openings in the silo roof has been carried out in the past year, along with the demolition of the 'tunnel' above the silo in June 2005. Retrieval plant design is currently underway for mechanical retrieval of the silo waste. Characterisation and container requirements for both buffer and final storage are currently being assessed.
- The redundant west end crane in the Magnox Swarf Storage Silos has been replaced, and the new crane is undergoing commissioning. This is a necessary step to enable removal of redundant equipment from the building and the installation of the silo emptying machines. Substantial progress has been made in respect of several aspects of the building infrastructure: cooling to compartments 7&8, enhancement of ventilation flows, hydrogen monitoring and data acquisition system upgrading - key factors in underpinning continued operations and retrieval safety cases.
- In the first Magnox pond, as part of the skip handler reinstatement work, the rails refurbishment is complete. A skip of fuel has been transferred to the Fuel Handling Plant to establish feasibility of this part of the reprocessing route. Another test demonstration involving export of a container of pond sludge for in-drum encapsulation is scheduled to take place in the new financial year. Knowledge of the residual fuel and sludge inventory has been enhanced by deployment of the submersible remotely operated vehicle (ROV).
- In the first site fuel pond the strategy for metal fuel retrieval and treatment is currently under development. In preparation for sludge retrieval, with attendant increase in pond water activity levels, a local effluent treatment plant is to be installed. A modular unit incorporating a sand bed filter and an ion exchange unit, operable on either once through

or recirculation basis, is in detailed design/manufacture and due to be delivered in mid 2006. Preparations are in hand regarding the sludge retrieval equipment and receiving tanks.

6.4 BPEO

To meet the accelerated programme schedule and to ensure that the selected LP&LS radioactive waste management reflects consideration of the Best Practicable Environmental Option (BPEO), BNGSL worked with the NDA and the Regulators to chart a way forward which would deliver the feedback necessary to support decision making in Legacy Ponds & Legacy Silos. To meet this requirement, LP&LS conducted a stakeholder workshop in December 2005 to discuss high level issues of concern to the projects. The audience included representatives of the local councils, the union representatives and the supply chain. Other non-governmental organizations were invited but did not participate. To obtain further feedback, the information was posted on the company website and feedback was requested. All of this information will be used to issue a report to allow projects to direct their more in-depth optioneering. This approach allows stakeholders to have input, but does not risk exhausting stakeholders with multiple engagements regarding LP&LS.

Conclusions

- Very good progress has been made with the reduction of MA liquor stock.
- Very good progress has been made with improving WVP performance and reducing HAL stock.
- Actions have been taken to quantify HA evaporator residual life and maintain capacity.
- Legacy ponds and legacy silos strategies have developed significantly, and key projects have been initiated.

Recommendations

It is recommended that NuSAC note

- The substantive progress made with MA liquors, HA liquors and Legacy Ponds and Silos
- The likely requirement for additional HA evaporator capacity
- That a pragmatic approach will be required to balance early Site risk reduction with the extent of waste form underpinning.