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**Hazard and Risk reduction from Highly Active Liquor (HAL)
ONR's Regulatory Judgement on the Justification for Evaporator C Continued
Operations**

Project Assessment Report ONR-SEL-PAR-15-009
Revision 0
October 2015.

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Published 12/15

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EXECUTIVE SUMMARY

Purpose

This Project Assessment Report (PAR) summarises the Office for Nuclear Regulation's (ONR's) regulatory judgement on Evaporator C, and makes a recommendation on whether the licensee's safety justification for continued operation is supportable.

Regulatory Background

At the Sellafield Licensed site, a number of evaporators are used to process highly active effluent arising from the reprocessing operations to produce a more concentrated form known as Highly Active Liquor (HAL). This HAL is subsequently vitrified (combined with molten glass), making a product form, which is suitable for long-term safe storage.

Evaporator C has a unique role in reprocessing in that it is currently the only evaporator that can process effluent arising from the Thermal Oxide Reprocessing Plant (THORP). This makes it strategically important to the UK. Evaporator C, along with the two other operational evaporators (A & B), provides the necessary evaporative capacity to support Magnox reprocessing in support of the Magnox Operating Plan (MOP), which is a national priority. Moreover, Evaporator C is the only evaporator capable of supporting the reprocessing of irradiated fuel from UK's AGR reactor fleet. A new evaporator (D) is currently under construction. When operational, this will provide adequate capacity to process both the Magnox and Oxide liquors.

The corrosive nature of the reprocessed liquors results in progressive thinning of the stainless steel components, which ultimately dictates the remnant life of the evaporator. It is, therefore, important that the licensee understands the relevant corrosion mechanisms to ensure that suitable conditions and limits are in place in the interest of safety. The purpose of ONR's regulatory focus in this area is to ensure that the licensee has put adequate arrangements in place to safely manage Evaporator C operations ensuring that risks to public are reduced so far as is reasonably practicable (SFAIRP).

In 2014, the licensee produced a radiological safety assessment, which considers the potential for a gross failure of the coils and the base. ONR's structural integrity assessment identified a number of gaps in the licensee's case, which resulted in reduced regulatory confidence. Primarily, these concerns were based on the understanding that the licensee had not been able to inspect the evaporator base and lower regions of the coils. This combined with the apparent reducing safety margins (Evaporator C is approaching its end of life safety case limits on the coils) meant that additional regulatory confidence was required.

I wrote to the licensee articulating my regulatory expectation that the licensee produces a suitable and sufficient justification for continued operations demonstrating that risks have been reduced so far as is reasonably practicable (SFAIRP). Furthermore, due to the evident gaps from modern standards, I asked the licensee to consider impacts on site-wide hazard reduction activities and wider strategic factors of Evaporator C operations.

Assessment and inspection work carried out by ONR in consideration of this request

ONR has carried out a programme of work to support its regulatory judgement on Evaporator C, continued operations. This included sampling the licensee's safety justification, targeted inspection of key safety systems, progress against a number of ONR recommendations and other ALARP improvements identified by the licensee.

ONR has also conducted a structural integrity assessment, and reviewed the findings of the most recent intrusive inspections of the evaporator coils and the base. The primary purpose of ONR's work was to ensure that the licensee can demonstrate that it has taken all reasonably practicable measures to prevent and mitigate a gross failure of Evaporator C component(s).

Conclusions

To arrive at a proportionate judgement on Evaporator C continued operations, I have carefully balanced the benefits and dis-benefits in the interest of nuclear safety, whilst being mindful of the wider strategic hazard reduction impacts on the licensed site.

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Based on targeted sampling of the licensee's arrangements, I am content that the licensee has a suitably conservative, robust, and transparent regime in place to understand and manage the remnant life of Evaporator C.

I am satisfied that the licensee's inspection of the base and coils have generated results, which give confidence that the minimum wall thicknesses measured provide an adequate safety margin.

Inspection of the Automatic Isolation System (AIS) has given me regulatory confidence in the licensee's arrangements for detecting, mitigating and recovering from a HAL breakthrough event – whilst operating within the extant safety case limits.

The licensee has implemented all of ONR's recommendations, and ALARP improvements it had identified in its safety assessment report. I am, therefore, satisfied that the licensee has adopted a proactive, open and transparent approach in accepting and implementing the necessary improvements in a timely manner.

On balance, I judge that the licensee's case for evaporator C continued operations, in accordance with its extant safety case limits is supportable. I am, therefore, broadly satisfied with the claims, arguments and evidence laid down within the licensee's ALARP justification and supporting documentation in favour of continued operations from Evaporator C.

Recommendation

I recommend that ONR writes to the licensee confirming that:

- ONR is content with Evaporator C, continued operations in accordance with the extant safety case limits.
- ONR has no objections to a progressive reduction of magnox reprocessing reservation from Evaporator C, subject to the licensee demonstrating through its extant arrangements that adequate evaporative capacity and sufficient contingency is maintained across the evaporator fleet in support of continued Magnox reprocessing for the remaining inventory.
- ONR's regulatory expectation is that Evaporator C will be removed from front-line operations in support of oxide reprocessing when either the extant safety case limits are reached or when Evaporator D comes into active service – whichever is sooner.
- ONR's regulatory expectation is that the licensee continues to demonstrate that it is doing all that is reasonably practicable to safely deliver Evaporator D into service as soon as practicable.

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LIST OF ABBREVIATIONS

AGR	Advanced Gas-cooled Reactor
AIS	Automatic Isolation System
ALARP	As low as reasonably practicable
C&I	Control & Instrumentation
HAL	Highly Active Liquor
HOW2	(Office for Nuclear Regulation) Business Management System
LSS	Lesser Safety Significant
MOP	Magnox Operating Plant
NDA	Nuclear Decommissioning Authority
ONR	Office for Nuclear Regulation
OSPAR	Oslo/Paris convention (for the protection of the Marine Environment of the North-East Atlantic)
PAR	Project Assessment Report
RGP	Relevant Good Practice
SAP	Safety Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
SS	Safety Significant
SSC	Structure, System and Component
THORP	Thermal Oxide Reprocessing Plant

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1 PURPOSE

1. This Project Assessment Report (PAR) summarises the Office for Nuclear Regulation's (ONR's) regulatory judgement on Evaporator C, and makes a recommendation on whether the licensee's safety justification for continued operation is supportable.
2. This report had been written in accordance with ONR guidance (Ref 1.), for writing reports.

2 REGULATORY BACKGROUND

3. Adequate provision for Highly Active (HA) evaporative capacity at Sellafield is necessary to support reprocessing of the remainder of Magnox irradiated fuel (no other safe means to deal with Magnox fuel has been identified), and oxide fuel reprocessing (arising from AGR reactor fleet) until the intended THORP shut down towards the end of 2018. Delivery of these projects is essential in continuing to deliver hazard and risk reduction work at the Sellafield site – a UK- level strategic priority.
4. Evaporator C has a unique role in reprocessing at the Sellafield licensed site, which makes it strategically important to the UK. Evaporator C, along with the two other operational evaporators (A & B), provides the necessary evaporative capacity to support Magnox reprocessing in support of the Magnox Operating Plan (MOP). Moreover, Evaporator C is the only evaporator capable of supporting oxide reprocessing, and therefore, is a pre-requisite for Thermal Oxide Reprocessing Plant (THORP) operations. A new evaporator (D) is currently under construction. When operational, this will provide adequate capacity to process both the Magnox and Oxide liquors.
5. Evaporator C is a stainless steel pressure vessel, with dual heat transfer capability supported by six coils and a thick-walled jacket. Low Pressure (LP) steam is used to heat the radioactive effluents in order to produce a more concentrated liquid (known as Highly Active Liquor (HAL)) prior to passivation (through Vitrification) and long-term safe storage. Recirculating cooling water is used to cool the contents. The heating/cooling system operates as an open circuit (i.e. there is no secondary circuit between the active process and the environment).
6. There are two principal corrosion mechanisms (Ref 2.) that challenge the integrity of the evaporators (coils and base). The first of these is generalised attack by the process liquors on the outer surface of the heating/cooling coils and inner surface of the vessel producing a generalised thinning of the steel. The second is waterside pitting corrosion, which occurs on the non-process side of the vessel (jacket and coils). This has resulted in pinhole failures in the past on evaporators A & B. On each occasion, the Automatic Isolation System (AIS) has successfully detected the radioactivity, facilitating prompt and safe recovery.
7. To safeguard the structural integrity of the evaporators Sellafield Ltd has set end of life limits for the coils and base (Ref 3.) to minimise the potential for a significant failure occurring. The end of life limit is 3 mm (cf 12.7 mm original thickness) for the coils and 10.5 mm (cf 31 mm original thickness) for the base. To date, Evaporator C has not suffered any pinhole failures but is subject to significant generalised corrosion as Oxide liquors are more corrosive than Magnox liquors. Three of Evaporator C's coils have already reached their end of life safety case limits and been removed from service. The remaining operational coils and base are approaching their end of life safety case limits.

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8. A significant failure of Evaporator C components could have significant public consequences. The licensee considers that (Ref 3.) the worst case radiological consequences are bounded by a gross failure of the evaporator base. A gross failure of a heating/cooling coil, would, nevertheless, result in significant public consequences and either would have serious political, socio-economic and reputational consequences.
9. The licensee maintains a detailed technical programme of work supported by intrusive inspections of the coils and use of statistical and thermal models to support the determination of evaporator remnant life.
10. In 2014, the licensee produced a radiological safety assessment (Ref 3.) which considers the potential for a gross failure of the heating/cooling coils and the base. ONR carried out a detailed assessment of this work focusing on structural integrity (Ref 4.), fault studies (Ref 5.), C&I (Control & Instrumentation) (Ref 6.), and process engineering (Ref 7.). ONR's structural integrity assessment identified a number of gaps in licensee's case which resulted in reduced regulatory confidence. Primarily, these concerns were based on the understanding that the licensee had not been able to inspect the evaporator base and lower regions of the coils (calculations were based on numerical models alone). This combined with apparent reducing safety margins (evaporator is approaching the end of life safety case limits on the coils) meant that additional regulatory confidence was required.
11. I wrote to the licensee (Ref 8.) articulating my regulatory expectation that the licensee produce a suitable and sufficient justification for continued operations demonstrating that risks have been reduced so far as is reasonably practicable (SFAIRP). Furthermore, due to the evident gaps from modern standards, I asked the licensee to consider impacts on site-wide hazard reduction activities and wider strategic factors of evaporator C operations.

3 ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST

12. ONR has carried out a programme of work to support its regulatory judgement on Evaporator C, continued operations. This included assessing the licensee's ALARP justification (Ref 9.), Strategic ALARP case (Ref 10.), System Based Inspection (SBI) of the Automatic Isolation System (AIS) (Ref 11.), review of Evaporator C base & coil inspection results and monitoring progress against a number of ONR recommendations and ALARP improvements identified by the licensee. The primary purpose of ONR's work was to ensure that the licensee can demonstrate that it has taken all reasonably practicable measures to prevent and mitigate a gross failure of Evaporator C component(s).
13. Using a targeted sampling approach and taking cognisance of ONR's previous assessment work in this area, I have restricted the scope of my assessment work to areas specifically identified as gaps within the structural integrity, C&I, Project Assessment Report (PAR) (Ref 12.) and the additional areas identified above, which in my opinion, are necessary to reach a balanced regulatory judgement.

4 MATTERS ARISING FROM ONR'S WORK

4.1 SPECIALIST ASSESSMENT – STRUCTURAL INTEGRITY

14. ONR's structural integrity specialist inspector, in his assessment of the licensee's gross failure case had judged that, the licensee did not demonstrate the necessary regulatory confidence in its structural integrity safety case – primarily due to the

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unavailability of direct thickness measurements from the lower regions of the coils and also the base. The licensee has completed intrusive inspections of both the lower regions of the coils and the base of the evaporator for the first time in July 2015. In his previous assessment, the inspector was satisfied that licensee's claimed frequency of gross failure of 5×10^{-3} is reasonable. He has, therefore, concentrated his efforts on reaching a regulatory judgement on the adequacy of licensee's structural integrity case taking into account the latest inspection results from the coils (including the lower regions) and the evaporator base.

15. The inspector concludes (Ref 19.) that he is satisfied that the licensee's inspection of the lower regions of the coils and that the base have generated results, which are of sufficient quality that the measurements are reliable and the minimum wall thicknesses measured exceed the extant safety case limits. He is, therefore, content that shortfalls he had identified have been adequately addressed by the licensee.
16. He has, however, noted that the licensee has not provided sufficient evidence to fully underpin its assessment of the base and coil welds. I have duly noted this conclusion. In response, my judgement is that for the base, the measured thickness of between 20-28mm against a safety case limit of 10.5mm, in my opinion, provides adequate safety margin to account for any uncertainties that may exist. For the coils, I accept that as the coils approach the 3mm safety case limit, there is an increased risk of coil failure. I, therefore, endorse inspector's associated recommendation that ONR should, therefore, continue to consider the licensee's assessment of the condition and remnant life of the coils. In accordance with its arrangements, the licensee conducts periodic inspections of the coils, which are independently interpreted and verified by three separate specialist organisations – the resultant report is routinely furnished to the ONR. Moreover, licensee follows a decision making process, which it considers to be suitably robust, prior to commencing every batch.
17. I consider this process to be suitably conservative. This meets the intent of the recommendation and, therefore, no additional intervention is necessary. That said, the risk of a coil failure can't be ruled out unless Evaporator C ceases to operate. I have, therefore considered this conclusion in my overall considerations (see section 5).
18. Overall, the inspector judges that he has not identified any evidence which would prevent ONR from accepting licensee's justification for continued operations.

4.2 SYSTEM BASED INSPECTION(SBI) OF THE AIS

19. In order to gain confidence in the key safety measures identified in the licensee's safety case, ONR conducted an in-depth inspection of the Automatic Isolation System (AIS) (Ref 11.). This system is the primary means, by which, a component failure is detected and mitigated limiting the potential consequences of HAL entering the cooling circuits.
20. This inspection was supported by specialist inspectors from C&I, Chemistry & corrosion and the site inspector for the facility. The primary purpose was to gain confidence that the Systems, Structures and Components (SSCs) that comprise the AIS system are adequately implemented and are subject to suitable and sufficient maintenance, inspection and testing in order to mitigate the consequences of a component failure. Moreover, we also sought confidence that operators were suitably trained and had access to adequate procedures.
21. Based on sampling of evidence during the two-day inspection and my fellow inspector's opinions, I am satisfied that the SSCs associated with the AIS system are adequately implemented. Furthermore, I have a high degree of confidence that if a

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failure was to occur, the licensee would be able to detect and appropriately recover from such a situation.

22. I did, however, identify a number of shortcomings in the licensee's arrangements for conduct of maintenance, supervision, and investigating of events. The licensee fully accepted these and put in place a programme of work (Ref 13.) in order to remedy these. I am satisfied that the programme of work is suitably robust and wide-ranging. I have continued to monitor progress against this plan in collaboration with the relevant site inspector. Moreover, the licensee has, recently, submitted an interim progress update (Ref 14.), which has provided confidence that the licensee is making good progress in the implementation of the said measures.
23. Overall, I have a high degree of confidence in the licensee's arrangements for detecting, mitigating and recovering from a HAL breakthrough event – whilst operating within the extant safety case limits.

4.3 ALARP IMPROVEMENTS/ONR RECOMMENDATIONS

24. ONR's Control & Instrumentation (C&I) assessment of the gross failure safety case had identified a number of recommendations (Ref.7). These were mainly focused on reasonably practicable improvements to the engineering and procedures associated with the SSCs that underpin the AIS system. The C&I specialist inspector has confirmed (Ref 15.) that all of these recommendations have been fully implemented by the licensee.
25. The licensee, during its own assessment had identified a number of improvements within the gross failure safety case and categorised them as three Safety Significant (SS), and six Lesser Safety Significant (LSS). I have monitored progress on these along with the ONR recommendations mentioned above, through routine regulatory interactions. The licensee has confirmed (Ref. 16.) that all of these recommendations have now been fully implemented.
26. It is my opinion that the licensee has adopted a proactive, open and transparent approach in accepting and implementing the necessary improvements in a timely manner.

4.4 MAGNOX REPROCESSING ALLOWANCE (MOP RESERVATION)

27. The licensee, a number of years' ago, reserved an amount of Evaporator C remnant life for evaporation of magnox related liquors equivalent to the total remaining magnox fuel inventory. There are, currently, no other identified means for safe long-term management of irradiated magnox fuel other than reprocessing and then Vitrification, which is suitable for long-term safe storage. In contrast, irradiated oxide fuel (originating from AGR reactor fleet) can be safely stored long-term under water without any significant degradation. Concerns relating to the remnant life of evaporators (A&B) coupled with the need to complete magnox reprocessing by 2020 - which is a UK obligation under the Oslo/Paris (OSPAR) convention drove the need for this.
28. In 2014, ONR agreed to a licensee proposal to reduce the reservation to half the remaining magnox inventory. ONR's judgement is documented in a Project Assessment Report (PAR), (Ref. 17.). The licensee's justification considered that better understanding of remnant life on evaporators (A&B), coupled with the fact that Evaporator B had been successfully returned to service (with A available in reserve) provided adequate capacity and contingency to meet the evaporative capacity needs entirely.

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29. The licensee, in its strategic case for Evaporator C is now proposing to further reduce this reservation and progressively allocate this to oxide operations. The licensee considers that this is necessary to ensure that oxide reprocessing can continue without an unnecessary pause until the new replacement Evaporator (D) comes online – currently scheduled to be available in 2017.
30. On balance, it is my opinion that the licensee’s argument is supportable. My judgement is underpinned by the following,
- The strategic landscape has changed significantly from when the reservation was first introduced; Evaporator B has been safely operating and managing the entire Magnox duty for a considerable time, which gives me regulatory confidence that the licensee has adequate arrangements in place to meet with the evaporative capacity requirements to deliver the MOP by 2020.
 - With Evaporator B in service, and Evaporator A as contingency, coupled with the understanding that the total remaining magnox inventory is now considerably less (circa 2300te due to reprocessing), there is increased confidence that risk of not managing the remaining magnox inventory is reduced.
 - Reducing and finally removing the reservation affords the licensee with the necessary operational flexibility for strategic planning and management of evaporative capacity across the fleet.
 - Maintaining the reserve capacity would almost certainly result in an evaporative capacity gap (until Evaporator D becomes available) – the benefit of avoiding a small, potential increase in risk to magnox reprocessing is, in my judgement, grossly disproportionate to the strategic detriment of pausing/ceasing oxide operations. I.e. strategy for remediation of legacy pond (FGMSP), increased operational risk in storage ponds, potential requirement to build additional storage capacity etc.
 - The licensee, in accordance with its extant arrangements under LI 836, provides a quarterly remnant life report to ONR for information. I have asked the licensee to consider including a specific provision which requires it to demonstrate that sufficient remnant life is available across the evaporator fleet to manage the entire magnox inventory. The licensee accepted this and has already fully incorporated this in its latest report (Ref. 18.). Furthermore, these arrangements will ensure that there is adequate contingency for the licensee to respond appropriately should any evaporator be taken out of service unexpectedly. This provides me with further regulatory confidence that Magnox reprocessing will receive the necessary priority and the regulatory oversight.

5 REGULATORY OPTIONS & CONCLUSIONS

31. Taking cognisance of the structural integrity specialist inspector’s conclusions (section 4.1), in relation to the confidence around the coil welds and recognising that the coils are approaching the safety case limits, I accept that a coil failure through accelerated corrosion at the welds can’t be ruled out. However, the only option that would completely remove this risk is to cease Evaporator C operations altogether. In reaching a proportionate regulatory judgement, I have balanced this against the likely consequences.
32. I accept the licensee’s argument that evaporator C operations are of strategic importance to support continued hazard reduction work on site; key claims are that,
- without Evaporator C, THORP would have to cease operations earlier than planned – this has far reaching implications on hazard and risk reduction in that additional fuel storage capacity may drive the need for construction of new

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facilities, no currently identified long-term solution (other than reprocessing) for a number of irradiated fuel types e.g. failed fuels. Remediation of legacy ponds relies on storage capacity which is based on the assumption that THORP operates until its scheduled end date of 2018.

- Without Evaporator C, the available evaporative capacity at site is substantially reduced which in turn increases the risk to completing the reprocessing of irradiated magnox fuel, for which, there are no other suitable means for long-term safe storage. Delays to Magnox reprocessing beyond 2020 could also risk the UK not meeting its OSPAR obligations.

33. A number of licensee measures provide further regulatory confidence, such as,

- Licensee continues to undertake an extensive programme of work to establish the condition of Evaporator C coils and the base, including the enhanced ability to measure the lower regions of coils and the base. This has provided me with increased regulatory confidence that the licensee understands the mechanisms of deterioration of the coils and the base.
- Inspection results from the base have indicated that there is sufficient safety margin between the extant safety case limits and the measured thickness, albeit the measurement covers a small section of the base only.
- I am content that the licensee has a suitably robust and transparent regime which interprets inspection results and generates remnant life reports involving three independent specialist organisations.
- There is suitable confidence in the AIS systems to detect and mitigate a HAL breakthrough event, should it occur.

34. Balancing these factors leads me to judge that the licensee's case for Evaporator C continued operations, in accordance with its extant safety case limits, is supportable. I am, therefore, broadly satisfied with the claims, arguments and evidence laid down within the licensee's ALARP justification and supporting documentation in favour of continued operations from Evaporator C.

35. I am also of the opinion that Evaporator C should be removed from front line oxide (in support of THORP) operations, when either the existing safety case limits (3mm coils, 10.5mm base) are reached or as soon as the replacement Evaporator (D) enters active operations – whichever is sooner. This means that the licensee has to continue to demonstrate that it is doing all that is reasonably practicable to safely deliver Evaporator D into service as soon as practicable.

36. On balance, I judge that the licensee's argument in favour of reducing the extant magnox reprocessing reservation on Evaporator C is justified.

6 RECOMMENDATIONS

37. I recommend that ONR writes to the licensee confirming that:

- ONR is content with Evaporator C, continued operations in accordance with the extant safety case limits.
- ONR has no objections to a progressive reduction of Magnox reprocessing reservation from Evaporator C, subject to the licensee demonstrating through its extant arrangements that adequate evaporative capacity and suitable contingency is maintained across the fleet in support of continued Magnox reprocessing for the entire remaining inventory.
- ONR's regulatory expectation is that Evaporator C will be removed from front-line operations in support of oxide reprocessing when either the extant safety

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- case limits are reached or when Evaporator D comes into active service – whichever is sooner.
- ONR's regulatory expectation is that the licensee continues to demonstrate that it is doing all that is reasonably practicable to safely deliver Evaporator D into service as soon as practicable.

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