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UK ABWR

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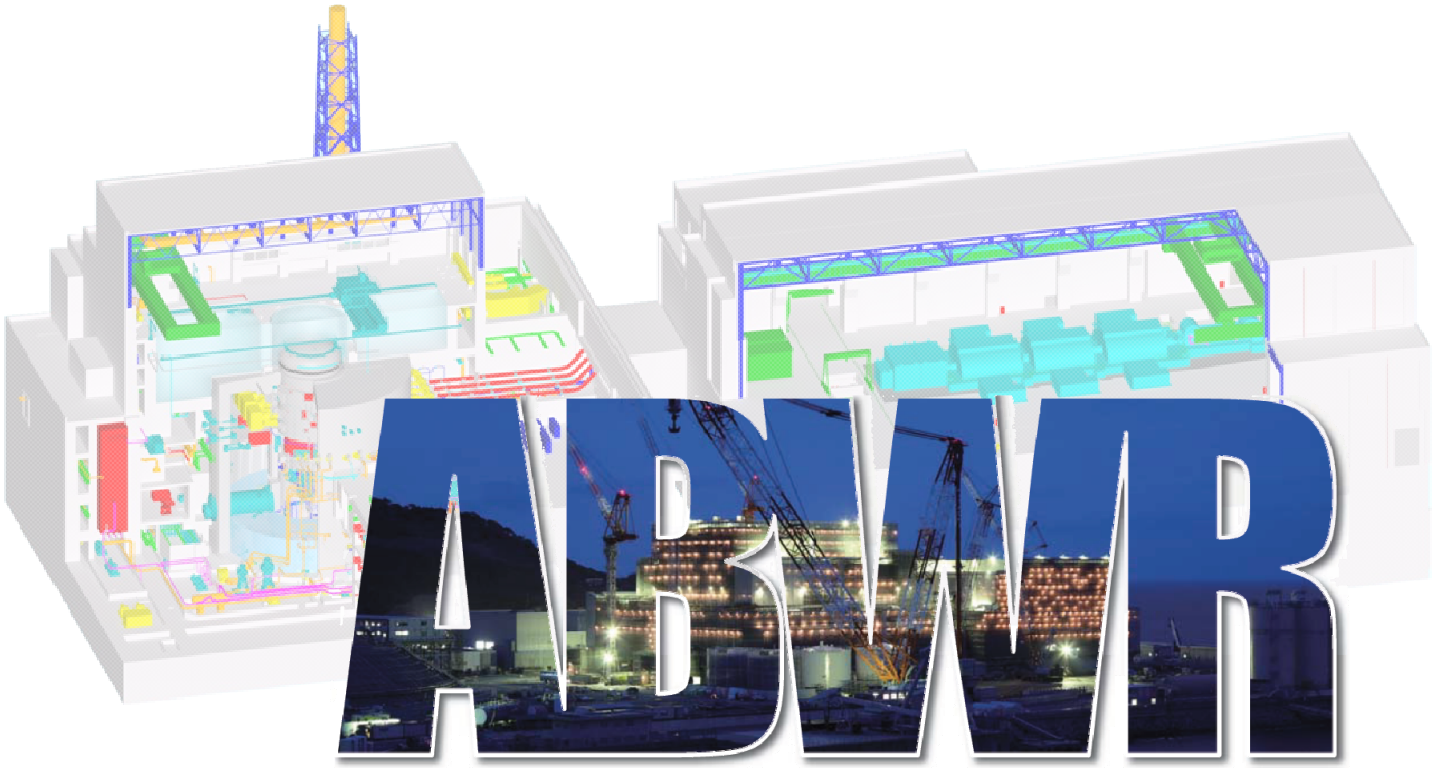
UK ABWR Generic Design Assessment

Response to RWM assessment report on UK ABWR waste and spent fuel disposability



Hitachi-GE Nuclear Energy, Ltd.

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Summary

Hitachi-GE is currently undergoing a Generic Design Assessment to enable their Advanced Boiling Water Reactor to be built and operated in the UK. Part of this process requires a demonstration of disposability of the wastes generated through the construction, operation and decommissioning of the reactor through the Disposability Assessment process. This report summarises the findings of the Radioactive Waste Management Limited assessment of the disposability of wastes and spent fuel generated by an operating Advanced Boiling Water Reactor in the UK (issued to Hitachi-GE in June 2016).

Radioactive Waste Management Limited concluded that sufficient information had been provided to produce valid and justifiable conclusions under the Generic Design Assessment Disposability Assessment process. Both spent fuel and Intermediate Level Waste from the operation and decommissioning from a UK Advanced Boiling Water Reactor should be compatible with plans for transport and subsequent disposal and the assessment process has not identified any issues that challenge disposability. A total of 27 potential issues / opportunities for improvement have been identified by Radioactive Waste Management Limited, none of which are considered problematic to address. A review of these suggests that all are best addressed at the site specific assessment stage as they are related to maturing packaging plans rather than fundamental issues with disposability (which would need to be addressed within the Generic Design Assessment process).

Radioactive Waste Management Limited will have the opportunity to review this report, so we can agree how to close out the Generic Design Assessment Disposability Assessment work.

Acronyms

ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
CCAD	Criticality Control Assurance Document
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAW	Higher Activity Waste
HLW	High Level Waste
ILW	Intermediate Level Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository site
LoC	Letter of Compliance
ONR	Office for Nuclear Regulation
RWM	Radioactive Waste Management Limited (formerly Radioactive Waste Management Directorate (RWMD); as from 1 April 2014 a wholly-owned subsidiary of the NDA)
UK	United Kingdom
WPrS	Waste Product Specification

1. References

[Ref-1] Radioactive Waste Management Limited, "Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK ABWR Part 1: Main Report", NXA/23788023, 28 June 2016.

[Ref-2] Radioactive Waste Management Limited, "Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK ABWR Part 2: Supporting Data", NXA/23718693, 28 June 2016.

[Ref-3] Radioactive Waste Management Limited, "Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK ABWR", NXA/23383092, 28 June 2016.

[Ref-4] Nuclear Decommissioning Authority, "Geological Disposal: An Overview of the RWM Disposability Assessment Process", WPSGD No. WPS/650/03, April 2014.

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., "Radioactive Waste Management Arrangements", GA91-9901-0022-00001 (WE-GD-0001) Rev. G, July 2016.

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., "The Activities of Solid Wastes", GA91-9201-0003-00073 (WJ-GD-0019) Rev 6, January 2015.

2. Introduction

Hitachi-GE is currently undergoing a Generic Design Assessment (GDA) to enable their Advanced Boiling Water Reactor (ABWR) to be built and operated in the United Kingdom (UK). Part of this process requires a demonstration of disposability of the wastes generated through the construction, operation and decommissioning of the reactor through the Disposability Assessment process.

This report summarises the findings of the Radioactive Waste Management Limited (RWM) assessment of the disposability of wastes and spent fuel generated by an operating ABWR in the UK ([Ref-1], [Ref-2]) submitted in June 2016. It also summarises the proposed approach to addressing remaining issues raised by RWM, in order to satisfy RWM, the Environment Agency and the Office for Nuclear Regulation (ONR) that the wastes are disposable. The principal conclusions and summary of the work undertaken by RWM within the GDA Disposability Assessment are also presented in a Summary Disposability Report [Ref-3].

2.1 Overview of the Disposability Assessment Process

The Disposability Assessment process [Ref-4] aims to minimise the risk that conditioning and packaging of radioactive wastes results in packages incompatible with geological disposal pending the formal development of repository waste acceptance criteria. Its remit is limited to spent fuel and Higher Activity Waste (HAW), including High Level Waste (HLW), Intermediate Level Waste (ILW) and Low Level Waste (LLW) unsuitable for disposal at the Low Level Waste Repository site (LLWR).

The process requires the submission of data for RWM to assess against the current plans for the repository with the findings issued in an Assessment Report. At the current stage of the Hitachi-GE GDA submission, the Assessment Report is the formal output of the process. It consists of a high level assessment to establish if the wastes are disposable based on proposed packaging plans, and to identify where further development of those plans or the underpinning data may be required.

Once the GDA is complete, the proposed operator of a facility or process will need to further develop the system for managing HAW. This is evaluated via the Disposability Assessment process and comprises the following stages:

- Pre-conceptual assessment – this primarily focuses on presenting potential options for packaging wastes,
- Conceptual stage – this establishes whether, in principle, and when suitably developed, the proposed waste packages are likely to be compliant with RWM requirements
- Interim stage – this determines whether the evidence allows demonstration that the as-designed waste packages are compliant with RWM requirements;
- Final stage – this determines whether the evidence allows demonstration that the waste packages, as they would be manufactured, would be compliant with RWM requirements.

There is no requirement to complete each stage in turn and under certain circumstances it is possible to go straight to the final stage assessment. Completion of the Conceptual, Interim, or Final stages results in the issue of a Letter of Compliance (LoC) for that stage. This acts as an endorsement of the proposed management plans. In this report the collection of the LoC phases is referred to as the site specific Disposability Assessment work.

Further detail for each of above phases is provided in an overview of the RWM Disposability Assessment process [Ref-4].

2.2 Findings of the Disposability Assessment

Based on the assessment carried out on data supplied by Hitachi-GE, RWM concluded that:

> ***'…sufficient information has been provided by Hitachi-GE to produce valid and justifiable conclusions under the GDA Disposability Assessment. RWM has concluded that ILW and spent fuel from the operation and decommissioning of a UK ABWR should be compatible with plans for transport and subsequent disposal of higher-activity wastes and spent fuel… and the assessment process has not identified any significant issues that challenge fundamental disposability of the wastes and spent fuel expected to be generated from operation of such a reactor.'***

The conclusions were made based on an assumption that further development of the inventories, packaging plans for the wastes and the performance of packaged wastes would be undertaken. This is communicated in the form of issues and opportunities listed within the Assessment Report.

While some issues may require immediate action, it can be appropriate to defer addressing the issue until the site specific Disposability Assessment phase. The review of RWM's findings makes recommendations as to when Hitachi-GE (as reactor vendor) and Horizon (as a future operator) would need to address the issues and what work will be required. The absence of any major issues at this stage suggests much of the future work is best addressed at the site specific Disposability Assessment phase.

3. Issues Raised in the Disposability Assessment Report

A total of 23 issues relating to ILW management and 4 issues relating to spent fuel management were raised. It is noted in the RWM assessment report that:

> ***'…numerous requirements and/or opportunities for further development were identified…is entirely consistent with expectations at this stage, due to the preliminary nature of the proposals…and the relatively high-level assessments performed.'***

The issues / opportunities raised are divided into ILW (general comments and by waste stream) and spent fuel in the following sections. The majority of the issues / opportunities raised by RWM would be addressed through continuing the Disposability Assessment process and further maturing the waste management plans for the UK ABWR. These are noted as reminders of required future work.

3.1 ILW

The ILW issues / opportunities were presented in the form of generic issues (which have a significant outcome on the Disposability Assessment) followed by waste stream specific issues of a more focused nature. Each individual issue / opportunity is presented along with a response and a proposed way forward.

3.1.1 Key Issues

The following key issues were raised:

1. **The optimum time for disposal of the ILW. In particular, Hitachi-GE has proposed disposing of the wastes shortly after they arise. For some of the waste streams, this raises concerns in meeting transport limits and operational limits at the GDF. These could be addressed by a period of decay storage of the relevant wastes.**

2. **Hitachi-GE proposed that the RPV decommissioning wastes were packaged in 4m boxes. The evaluations found that a significant period of decay storage would be required before some of the wastes from this waste stream could be transported and placed in the proposed GDF if these containers were used. It was therefore recommended that these wastes should be placed in 3m^3 boxes and transported in Standard Waste Transport Containers.**
3. **The control rods in the ABWR design differ from those in the previously assessed PWR designs where the potential exists to dispose of them with the spent fuel. In the case of the ABWR, the control rods, both hafnium and boron carbide variants, are separate from the fuel assemblies and are proposed to be disposed of as ILW. The nature of these wastes is inherently challenging and they will require a period of decay storage prior to Hitachi-GE's proposal for grout encapsulation in 3m^3 boxes. While they raise no insurmountable issues precluding disposal, they will need to be subject to further assessment as the disposal plans are further developed.**

Response: The initial waste management plans were all developed with the aim of minimising the on-site storage durations for raw and packaged wastes while ensuring there was a sufficient quantity of wastes for efficient processing and packaging. Current plans [Ref-5] include the potential for initial in-pond storage followed by interim cask storage of activated metals such as control rods, neutron source units, in-core monitoring equipment and channel boxes (arising during the reactor operational phase) prior to packaging for disposal. Activated reactor internals will be subject to decay storage before removal and size reduction as a means of dose reduction prior to processing. The use of 3m^3 boxes is likely to be adopted as the baseline disposal package. The assessed case bounds the revised plans highlighted above and therefore should not compromise disposability. RWM's advice is noted and will be considered further by operators during the site specific Disposability Assessment process.

Way Forward: As the design process continues, the management plans for the individual waste streams will be refined as indicated in the response above. It is proposed that the above issues are addressed as part of the site specific Disposability Assessment work in support of a conceptual stage assessment because of the additional inventory refinements needed for a revised submission.

3.1.2 Resins and Cruds

4. **Based on experience from Sizewell, RWM is of the view that the conditioning factor of 3 that has been applied for the resins may be optimistic; a conditioning factor of 10 may be more appropriate. More information and substantiation of the conditioning factors will be required during further interactions under the Disposability Assessment process.**
5. **Zinc (added for water chemistry control) could be incorporated into crud waste streams (e.g. if it plates out on steel surfaces) instead of, or as well as being taken up by ion exchange resins. The zinc could potentially act as a cement set retardant in crud and resin wasteforms if present in sufficient quantities. Therefore future interactions under the Disposability Assessment process should evaluate this potential route for zinc contamination of the crud and resins.**

Response: Both of these issues would be addressed as part of the wasteform development and testing work which would be required under the site specific Disposability Assessment, typically at the interim LoC stage. The scope for zinc contamination of the wastes will need to be measured or be subject to a review prior to the wasteform trials.

The experience at Sizewell (presumably Sizewell B) is not necessarily directly applicable here as the resins and cruds contain boron (also a cement set retardant) because of the dosing requirements of the storage ponds. The ABWR reactor water does not contain boron, further highlighting the need for trial work.

Way Forward: A package of work is required to optimise waste loadings / compositions and grout formulations and to demonstrate that the wasteform is sufficiently robust for disposal. Pre-existing work for similar wastes may be used to reduce or eliminate the amount of trials work and testing required. This work would be needed to allow completion of the Waste Product Specification (WPrS) which accompanies an Interim stage assessment.

6. **Information on the types of resins present in the wastes, and discussion of the expected degradation products, their potential for producing complexants and their impact on wasteform properties and radionuclide behaviour would be required as part of future submissions.**
7. **The Decontamination Resin waste stream inventory used in the assessment has a relatively high fissile content per packages, exceeding screening levels and not being declared fissile excepted packages. This would require further evaluation in any future Disposability Assessment.**
8. **In future interactions under the Disposability Assessment process a method for calculation of the maximum package inventories for Cruds and Resins should be proposed by the operator.**

Response: It is recognised that further information on the ion exchange resins used will be needed along with information on how their properties evolve over time. Further work on the radionuclide inventory for the resins as a whole is ongoing. For the current Disposability Assessment, RWM assumed the maximum package inventories were 12x the average package inventories. A method for calculating the maximum package inventories is required and would need to consider likely operating processes and timescales in order to understand the variability in the inventory.

Way Forward: A report on the behaviour of the resins during operations and storage (particularly under extended periods of irradiation) will be needed to address Issue 6. This can be a review of relevant operational experience rather than a series of laboratory trials, unless novel resins are selected.

The inventory for the decommissioning resins would be finalised for the site specific Disposability Assessment and part of this would include addressing the maximum package calculation issue. Specific attention will be paid to the fissile content of the decommissioning resins. This is particularly important as it informs the Criticality Control Assurance Document (CCAD) which needs to be submitted prior to the interim stage assessment of the decommissioning resins.

It is proposed that the above issues are addressed as part of the site specific Disposability Assessment work.

3.1.3 Control Rods (Hafnium and Boron Carbide)

9. **The Hitachi-GE submission states that 40 control rods will be packed in each 3m^3 box. Given the high levels of activity and heat generated by the control rods, RWM advises that to facilitate grout encapsulation and cooling, the control rods should be located in the boxes using internal frames. If such furniture is used to locate size reduced control rods, RWM estimates 15 control rods can be placed in each box. On this basis, the currently assumed packing density of control rods is considered optimistic. Future operators would need to consider this.**

See response to Issues 1 to 3.

10. **HF-178n is not modelled by ORIGEN but is a significant contributor to dose at short timescales (half-life approximately 31 years), and, therefore, should be included in any future inventories for the UK ABWR.**
11. **The assumption in this assessment that control rod metals contain 0.26% cobalt, leads to relatively high activities for Co-60 in the waste package inventories. The estimated activities can, in certain cases, challenge the limits on transport included in the IAEA Transport Regulations and the assumptions in RWM's operational safety case. In future, RWM would expect to work with a future operator to reduce pessimisms in the inventories for control rods and activated metals. This might include consideration of the steel alloys to be used in the UK ABWR, for example, consideration of low-cobalt steel for the control rods.**
12. **The methods for size reduction of control rods and activated metals should be described in a future submission. In particular, these should define how boron carbide rods are to be cut without the release of powder.**
13. **Future operators of a UK ABWR should give consideration to distributing the highly irradiated tips of control rods with lower activity parts of the size-reduced control rods.**
14. **For some steels, Hitachi-GE had provided information on the steel compositions, but for some steels no compositions had been provided. For the assessment, the composition of Type 304 steel had been used to fill gaps and to ensure the inventory was pessimistic. The steel used in the activated metals is unlikely to be Type 304 and a more corrosion resistant metal is likely to be used by the reactor operator. Future submissions should provide more detail on the composition of the steels to be used for each component.**

Response: It is recognised that further development of the inventory, processing and packaging of the control rods is required, including the development of an approach to packaging the wastes in a manner which avoids concentrating the more highly irradiated components.

Way Forward: It is proposed that the above issues are addressed as part of the site specific Disposability Assessment work. Because these issues are related to processing method development and resultant inventories, they should be addressed by the conceptual assessment stage.

RWM have supplemented the Hitachi-GE submitted inventories with data for Hf-178n, so it's exclusion from ORIGEN does not compromise the findings of RWM's Assessment Report. In future submissions, Hf-178n will need to be reported for all hafnium, hafnium precursor containing materials, and items which become contaminated with hafnium containing materials. Hitachi-GE recognises the requirement for assessing the Hf-178n contents of certain wastes as it is a gamma emitter with a 31 year half-life (and hence influences ALARP and disposability decision making). Hitachi-GE will proceed using the RWM data for Hf-178n in the near term. This will be addressed prior to the site specific Disposability Assessment phase.

Further steel compositions will need to be needed to ensure realistic inventory data is generated, particularly when considering the specific activities of activation products. This will result in further changes to the radionuclide inventory for these wastes.

3.1.4 Activated Metals

15. **The neutron sources included within the Activated Metals waste stream does not include antimony. This is a common element in modern neutron sources, although it is acknowledged that different sources may be used in the UK ABWR when it is implemented. Similarly, the monitoring probes may include fission chambers containing uranium. Although it is unlikely that the monitoring probes will contain significant quantities of uranium, any uranium**

within the probes should be reported in more detailed disposability assessments.

Response: Current plans for the UK ABWR reactor only uses Cf based neutron sources, avoiding the need to use chemotoxic neutron sources such as those containing antimony and beryllium. The absence of these are indicated in Table9-3-(2) of the report summarising the activities of solid wastes [Ref-6].

The monitoring probes used in the UK ABWR contain uranium. The inventory submitted to RWM [Ref-6] included specific activities for activation products such as Pu-239 and Am-241 but not unirradiated uranium isotopes. The radionuclide inventory for the monitoring probes will be updated accordingly.

Way Forward: It is proposed that the above issue is addressed as part of the site specific Disposability Assessment work. Confirmation that only Cf based neuron sources are used in the reactor and refinements of the monitoring probe inventory to include uranium will be addressed prior to completion of the site specific conceptual Disposability Assessment submission.

16. **Antimony and beryllium, which may be present in the Activated Metals wastes, may present chemotoxic hazards. Such materials are unlikely to be present in large amounts, but might lead to special consideration being required for the relevant waste packages. The possibility of such materials being present in the waste will need to be considered in future interactions under the Disposability Assessment.**
17. **The number of Mixed Metal ILW packages is based on a packing density of 8.25t of raw waste per package. This packing density is considered unlikely to be feasible on volume grounds and should be re-assessed in future interactions under the Disposability Assessment.**
18. **The heat output from the Mixed Metal waste stream exceeds transport limits at the proposed time of disposal. This would require further consideration in future Disposability Assessments.**
19. **The Disposability Assessment has not considered removal of metal items from storage baskets, but it is feasible that the storage baskets will be packaged with Activated Metals. This would reduce the dose. The management of Activated Metals including cutting for size reduction prior to packaging and the consequent impact on package inventories should be considered in more detailed interactions under the Disposability Assessment process.**

Response: A more detailed analysis of the constituent parts of the various waste streams would be conducted as the reactor design progresses in order to highlight the presence of any toxic or hazardous materials (noting the response to Issue 15 above). Reactor components which are most likely to contain such materials include the Reactor Pressure Vessel and Reactor Internals. If there are no such materials are present in the ILW disposal packages generated then a definitive statement to this effect will be made in the future Disposability Assessment submissions.

Work will also be undertaken to further develop the inventory and packaging proposals for the Activated Metals for the site specific Disposability Assessment.

Way Forward: Refinements to the inventory (to allow heat generation rates to be determined) will need to be completed at the site specific assessment, the remainder of the issues would need to be finalised by the Interim stage.

3.1.5 General Issues

20. **No details on the presence of toxic or hazardous materials in the wasteforms are given in the submission. These would be required in any future submission.**

See response to Issues 15 and 16.

21. **Details need to be provided on the use of in-box furniture and the resulting residual void space in Decommissioning ILW packages at more detailed stages of the Disposability Assessment process.**
22. **Details of specific grouts, their properties and formulation development, will be required in future Disposability Assessment submissions.**

Response: Both of these issues would be addressed as part of the wasteform development and testing work which would be required under the site specific Disposability Assessment, typically at the interim Disposability Assessment stage. See the response and way forward for Issues 4 and 5 above.

23. **Hitachi-GE has stated that there will be no miscellaneous contaminated items that would be classified as ILW. If it remains an assumption for future disposability assessments, this will need to be stated in the design and operation protocols, as some reactors do produce ILW contaminated items during operations. Potential future operators need to be aware that this is a potential route for the generation of operational ILW and should confirm that such material is to be consigned as LLW.**

Response: The potential for generating miscellaneous contaminated items during the operational phase of the reactor will be reviewed periodically during the site specific phase of the Disposability Assessment and into reactor operations.

Way Forward: It is proposed that the potential generation of miscellaneous contaminated items is reviewed on a regular basis. This could form part of the periodic review of the Best Available Technique (BAT) for metallic wastes. Should the waste strategy change then a wastestream specific Disposability Assessment would be needed. Based on the current progress against GDA, this would be undertaken at the site specific assessment stage.

3.2 Issues Relating to Spent Fuel

1. **The storage of spent fuel in water ponds means that drying techniques will need to be put in place to avoid the potential for internal pressurisation of storage/disposal containers and to ensure that they would comply with existing transport regulations.**
2. **Storage conditions will need to be managed to maintain integrity of the fuel assembly (particularly the fuel cladding) and any storage/disposal container during storage operations. If a wet storage strategy were to be implemented, a key requirement would be to maintain conditions to preserve the integrity of any stainless steel components (e.g. tie bars). If a dry storage regime were implemented, control of temperature and relative humidity would be required to minimise the potential for degradation (e.g. by hydride embrittlement) of fuel assembly components and any disposal container.**
3. **RWM recommends that a future operator considers the extension of safeguards provisions through to disposal, particularly for spent fuel, and considers, working with RWM, whether and how the safeguards status of spent fuel will be terminated.**
4. **Further confirmation would be sought during future interactions under the Disposability Assessment process that all chemotoxic species have been identified in the UK ABWR SF.**

Response: The development of the above detail will occur as the overall design of the reactor site supporting facilities matures. It is recognised that these issues would need to be addressed as part of the site specific Disposability Assessment for spent fuel.

Way Forward: It is proposed that the above issues are addressed as part of the site specific Disposability Assessment work.

4. Conclusions

RWM has conducted their Disposability Assessment of the data submitted by Hitachi-GE as part of the GDA process and has concluded that the wastes generated are disposable at the level at which the assessment has been carried out. RWM has identified a total of 27 Issues with regards to the proposed packaging plans. These Issues have been reviewed and we believe it is most suitable that all are addressed as part of future site specific Disposability Assessment work as they are related to maturing packaging plans rather than fundamental issues with disposability. The exception to this is the quantification of Hf-178n which should be addressed earlier than the site specific stage as it is a long lived gamma emitter and hence influences ALARP assessment for some control rods processes.