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Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste

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WP6 Disposal Behaviour of Graphite & Carbonaceous Waste

Task 6.3: Waste packages

Deliverable T-6.3.4 Report on UK waste packaging conception for irradiated graphite

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Report to EC CARBOWASTE PROJECT

WP6 Disposal Behaviour of Graphite & Carbonaceous Waste

Task 6.3: Waste packages

Deliverable T-6.3.4 "Report on UK waste packaging conception for irradiated graphite"[1]

Introduction

This report is provided as input to Work Package 6.3 of the EC CARBOWASTE project, and meets the requirements of Deliverable T6.3.4, entitled "*Report on UK waste packaging conception for irradiated graphite*" in the CARBOWASTE *Description of Work*. It presents information on the UK plans for packaging irradiated graphite, e.g. from reactor decommissioning work, in a form suitable ultimately for disposal in a Geological Disposal Facility (GDF) and notes the inter-relationship between the desired package performance in the transport and operational periods (following waste packaging and any encapsulation), and post-closure behaviour in a GDF. This note refers out to published NDA reports for more detailed information where necessary, and therefore forms an entry point to the NDA literature and thinking on the management of UK irradiated graphite, current as at May 2011.

Background

The UK has accumulated a legacy of higher activity radioactive waste from electricity generation, defence activities and other industrial, medical, agricultural and research activities. The UK Government has undertaken a wide-ranging consultation on the best means of dealing with these wastes and has concluded that geological disposal, preceded by safe and secure interim storage, is the way forward for their long-term management. The *Managing Radioactive Waste Safely* (MRWS) White Paper explains the Government's envisaged way forward for implementing a GDF in the UK.

The Nuclear Decommissioning Authority (NDA) has been charged with implementing Government policy for the long-term management of higher activity radioactive waste by planning, building and operating a GDF, which is an engineered facility for the disposal of radioactive waste. A GDF is likely to be located at a depth of between 200m and 1,000m below ground, in a stable geology that provides long-term isolation of the wastes from the human environment.

The wastes for disposal in a GDF include high level waste (HLW), intermediate level waste (ILW), and low level waste (LLW) unsuitable for near-surface disposal. The UK's significant volume of irradiated graphite is part of this waste inventory. There are also other nuclear materials that have not been declared as wastes by the Government (because they are still considered to be of potential use), but which might be the subject of geological disposal in the future, namely spent nuclear fuel, separated plutonium and uranium.

By drawing on UK and overseas experience, the NDA's Radioactive Waste Management Directorate (RWMD) has developed illustrative geological disposal concept examples that are relevant to the UK context, inventory and available geological environments. These illustrative examples are all based on the principle

[1] See CARBOWASTE *Description of Work* for further information.

of passive safety provided by a combination of engineered barriers designed to complement the natural barrier provided by the geological environment. The system of multiple barriers will ensure that the radioactivity in the wastes is sufficiently contained so that regulatory requirements are met and that exposures resulting from any releases to the surface will be as low as reasonably achievable and, in any event, less than a small fraction of the exposures everyone receives each year from naturally occurring sources of radioactivity in the environment.

The implementation of a GDF for higher activity radioactive wastes requires RWMD to demonstrate its confidence that such a facility would be safe, during both the operational period and after it has been sealed and closed. As part of that process, RWMD has developed the Disposal System Safety Case (DSSC), the prime purpose of which is to demonstrate that a GDF can be implemented in a safe manner and in such a way that would meet all regulatory requirements.

Packaging Specifications

RWMD has recently published a report, "*Radioactive wastes and assessment of the disposability of waste packages*"[2], as part of the suite of documents that make up the DSSC. A key purpose of this report is to provide background information regarding the radioactive wastes (including those radioactive materials which may in the future be considered as such) that are assumed to be destined for geological disposal in the UK.

For many years RWMD, and the predecessor organisation Nirex, has produced specifications for packaged radioactive waste, including irradiated graphite. These specifications, which are considered in the above report[2], define generic standards and performance requirements for waste packages which will be compatible with the systems and safety cases for transport to and disposal in a GDF, therefore ensuring that packaged radioactive waste has characteristics that are compliant with the assumptions made in the DSSC.

These generic specifications (sometimes referred to as 'waste package specifications') play an important role in ensuring the safe and efficient preparation of waste for disposal in a GDF by providing a baseline which waste packagers can use to determine how to package wastes and meet the requirements for passive safety and compatibility with transport and disposal. Generic specifications are important part of our disposability assessment process and act as the preliminary waste acceptance criteria (WAC) for the GDF.

RWMD has established a methodology for the production of generic specifications (Figure 1) which ensures that such a specification is founded on:

- The definition of a disposal concept for the waste;
- The designs of the systems for transport and disposal developed to meet the relevant Disposal System Specification (DSS);
- Safety cases for transport, disposal facility operations and the post-closure period; and
- Regulations for the storage, transport and disposal of radioactive material.

Each generic specification also provides a definition of the standardised waste containers that can be used for the manufacture of waste packages containing the particular type of waste.

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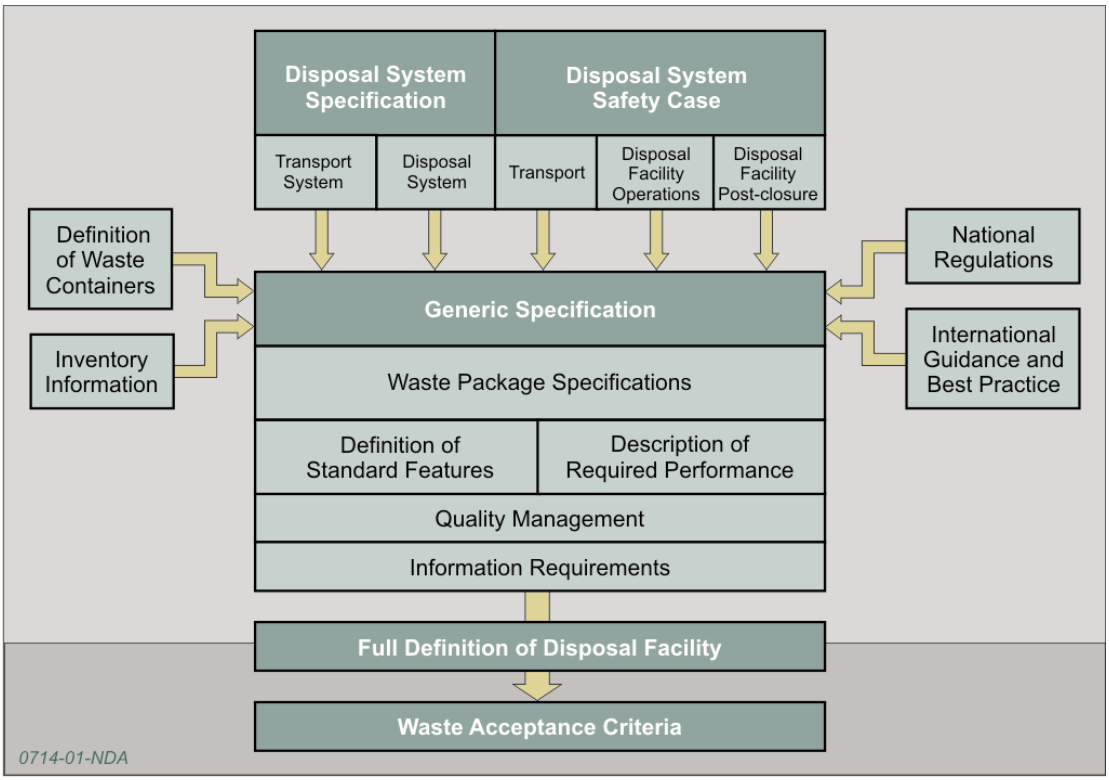
[2] Nuclear Decommissioning Authority, *Radioactive wastes and assessment of the disposability of waste packages*, NDA Report NDA/RWMD/039, 2010.

Currently generic specifications exist for two broad categories of waste, the *Generic Waste Package Specification* (GWPS)[3], for waste packages containing ILW and LLW (which includes irradiated graphite) and a specification for waste packages containing vitrified HLW and spent nuclear fuel[4].

Following publication of the DSSC suite of documentation, RWMD intends to revise these documents and extend the range of generic specifications to encompass all categories of waste that could be destined for geological disposal[5].

Figure 1 Methodology for the production of generic specifications



Disposability Assessment Process

The RWMD disposability assessment process exists to support UK Site Licence Companies (SLCs) that wish to condition and package higher activity wastes – including irradiated graphite - in a form that is compatible with plans for the implementation of a GDF. It is also used to support the ongoing development of the safety cases for geological disposal by the provision of information regarding the numbers and properties of the waste packages that will eventually require transport to and disposal in a GDF.

The disposability assessment process was originally developed back in the 1980s primarily as a means to assist site operators to convert intermediate level wastes into

[3] Nirex, *Generic Waste Package Specification*, Nirex Report N/104 (Issue 2), 2007.

[4] Nirex, *Specification for waste packages containing vitrified high level waste and spent nuclear fuel*, Nirex Report N/124, 2005.

[5] RWMD, *Proposals for updating the RWMD packaging specifications for higher activity radioactive wastes*, NDA Document Reference 10893921, 2010.

passive safe and disposable forms. The assessment process continues today to provide the same service to SLCs albeit in a far more structured and rigorous way and in line with regulatory expectations for the long term management of all higher activity waste.

The '*Letter of Compliance*' (LoC) disposability assessment process also plays an important role in underpinning the DSSC, as it provides confidence that the safety cases, which are based on generic assumptions regarding the wastes and the form of packaging, are compatible with 'real' waste packages being developed by industry. Through application of the disposability assessment process RWMD, together with the site operator and regulators, gain confidence that proposed waste packages will ultimately be compliant with requirements for transport and disposability. This may involve relevant parties together considering different packaging approaches and determining which combination of barriers (wasteform and waste container) best meet the needs for waste retrieval, processing, storage and ultimately, disposal. This is important as it gives confidence that packaging strategies, and ultimately investment decisions, are soundly based and will result in waste packages designed in line with transport and disposal requirements. Confidence in the developing DSSC is built up over time through a periodic review process by which the validity of disposability assessments are maintained by ensuring that they remain up to date and consistent with the DSSC as concepts for geological disposal evolve towards an operational GDF.

The main purposes of disposability assessments are therefore to:

- Give confidence to site operators (and waste owners) that the implementation of their proposals for waste packaging will result in waste packages that best meet the needs for processing and storage whilst being compliant with the eventual needs for transport to and disposal in a GDF;
- Provide us with confidence that the disposal concepts considered within the DSSC will be appropriate for the wastes they will be expected to cover; and
- Permit the identification of wastes that could challenge current disposal concepts and allow early consideration of what changes may be required to these concepts to permit the wastes to be accommodated.

Since the mid-1980s, waste producers in the UK have made significant investment in waste retrieval and packaging plant as a means of ensuring that such wastes are rendered passively safe and suitable for disposal in a GDF. Historically Nirex was responsible for the assessment and endorsement of the suitability of waste packagers' proposals to package waste for these needs, a responsibility assumed by RWMD in 2007 following Nirex's incorporation into the NDA.

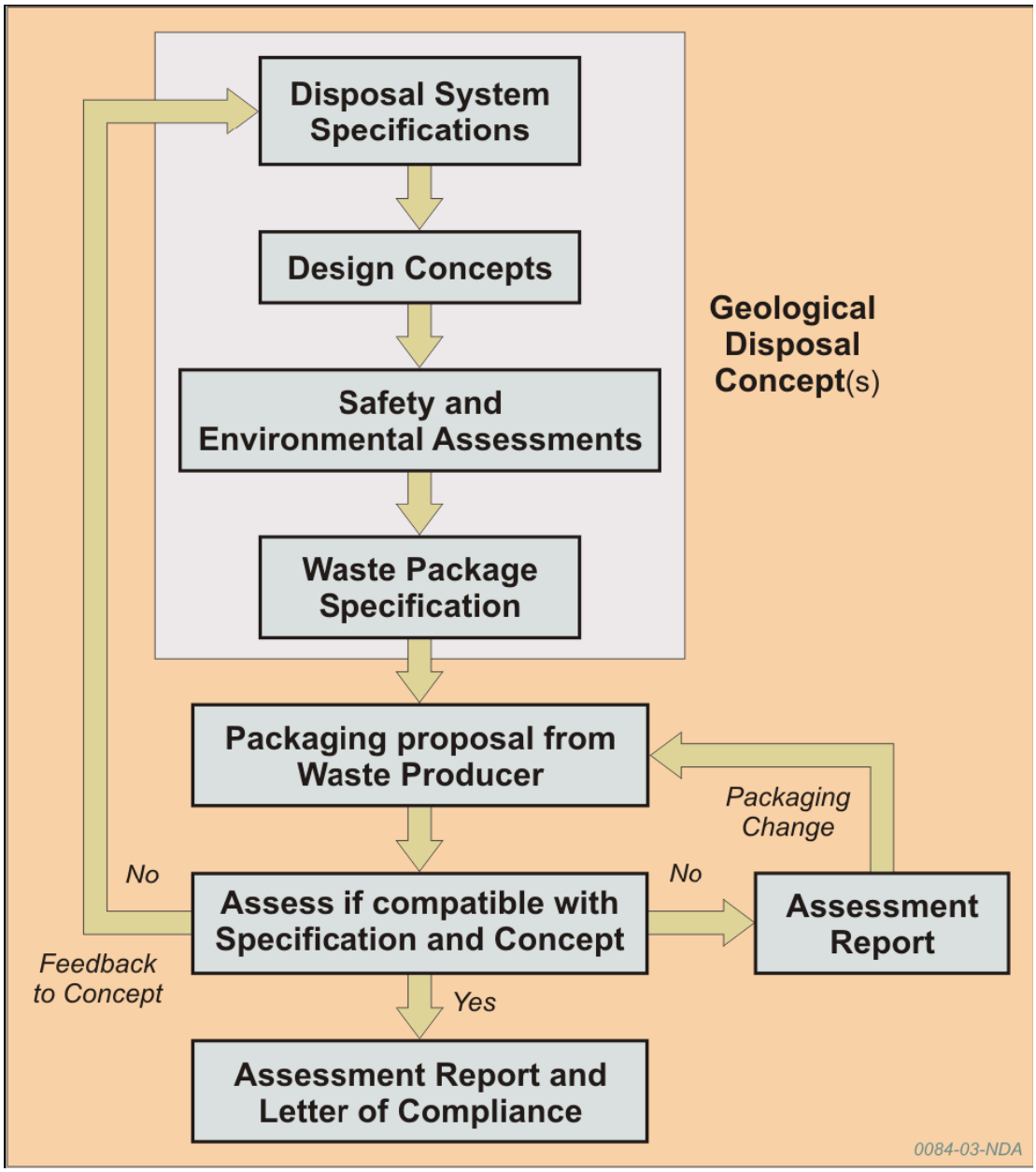
The assessment of the disposability of waste packages was originally carried out by way of the 'Letter of Comfort' assessment process which, following two decades of use and development, has evolved into the current LoC disposability assessment process[6].

The role played by the disposability assessment process is summarised in Figure 2 which also illustrates the relationship between the process, the DSS, the safety and environmental assessments and the packaging specifications. In practice the process requires the waste packager to provide information to RWMD regarding the wastes, any pre-treatments proposed, conditioning techniques and form of

[6] RWMD, *Guide to the Letter of Compliance Process*, WPS/650/02, 2008.

packaging. Following assessment RWMD will provide detailed advice on transport and disposability issues and where necessary to ultimately complete the assessments, request further information or flag the need for further development and/or research.

Figure 2 Summary of the disposability assessment process



In undertaking disposability assessments RWMD determines whether packaged wastes will have characteristics compliant with the safety case requirements for transport to, and operations at a GDF, and ultimately whether the wastes could be accommodated within a GDF post-closure safety case, i.e. that the packages are 'disposable'. The main output of the assessment is an Assessment Report detailing the work undertaken and which may be accompanied by a Letter of Compliance. The LoC is simply a statement to the effect that the waste package as described in the submission has been assessed and found to be compliant with transport and geological disposal as currently defined.

Figure 2 illustrates that the disposability assessment process has the potential to allow site operators and RWMD to iterate through the assessment cycle – this is particularly useful where the operator and/or RWMD recognises that there would be benefit in exploring alternative packaging options, particularly where there is a need to balance potentially conflicting requirements from site safety cases and disposal safety cases.

Regulators' guidance[7] requires that waste packagers (Site Licensees) produce a radioactive waste management case (RWMC) which includes reasoned argument why packaged waste will be disposable – the disposability assessment and accompanying LoC will provide an important component of such a case.

An example of a summary of a disposability assessment report relevant to UK irradiated graphite is included as Appendix A[8]. This relates to graphite-bearing waste derived from the Hunterston A nuclear power plant (NPP). The current baseline strategy for Hunterston A NPP operational graphite waste (together with associated wastes in the Solid Active Waste Building (SAWB) Bunkers 2-5) essentially follows the above reference UK national strategy - the waste is to be retrieved during the Care and Maintenance (C&M) Preparations Period and encapsulated in cementitious grout in stainless steel $3m^3$ boxes according to RWMD Letter of Compliance specifications[8]. The C&M Preps phase is due to end in 2020 at Hunterston A; the waste would then be stored in the ILW Store, pending the availability of the planned GDF.

[7] HSE/EA/SEPA, The management of higher activity radioactive waste on nuclear licensed sites. Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees, February 2010.

[8] Radioactive Waste Management Directorate. Solid ILW at Hunterston A Decommissioning Site (Interim stage) Summary of Assessment Report. November 2008. http://www.nda.gov.uk/documents/upload/Executive-Summary-Letter-of-Compliance-Assessment-Report-Packaging-of-Solid-ILW-at-Hunterston-A-Decommissioning-Site-November-2008.pdf

Current NDA and RWMD Graphite Activities
Decisions on the long-term management of the large volume of irradiated graphite present in the UK waste inventory have not yet been made, noting that the reference position is geological disposal and that relevant waste packaging specifications have been developed.

The processes and procedures summarised in the above text are applicable to UK higher activity radioactive wastes, including irradiated graphite. They provide a reference approach for the production of specifications for the packaging of these wastes that is consistent with Government policy.

Complementary to such processes and procedures, NDA has an Integrated Waste Management strategy that is driving a more holistic approach to waste management including increased treatment etc. This strategy recognises that a significant opportunity also exists to reconsider disposal options for several waste streams to improve value for money and reduce environmental burden. This will be undertaken following NDA's Value Framework process and will require specific consideration as an area significant stakeholder interest. Key decisions exist for reactor decommissioning wastes, checking our approach to Very Low Level Waste management against supply chain developments and how we manage waste close to category boundaries (for example short lived Intermediate Level Waste).

The NDA graphite-relevant projects are a component of the overall Higher Activity Wastes strategy and interface with the following topic strategies:

- Low Activity Waste (because of the potential for use of the Low Level Waste Repository (LLWR) or a similar facility for disposal and learning from the LLWR environmental safety case)
- Decommissioning and Clean-up (because that could affect the rate and form of graphite arisings)
- Transport and logistics (because of the potential need to move waste between sites)

Four options for the management of UK graphite have been identified. NDA is undertaking a number of projects to further develop the understanding of these options. It is worth noting that selection of a single option is not necessarily a predetermined outcome of the work and any forward strategy could include a combination of options. Future work will consider:

- Option 1 – **Geological Disposal** (reference position): The intention is to work with NDA RWMD's "Upstream Optioneering" project to determine where there are opportunities to "optimize" the baseline option for the management of graphite. NDA will also work with sites in Scotland to investigate who best to develop their baseline plans in accordance with Scottish Higher Activity Waste Policy.
- Option 2 – **Condition to Enable Disposal at the Low Level Waste Repository** (or similar facility): LLWR Limited is due to complete and submit to the Environment Agency (the UK's relevant regulatory body) the revised Environmental Safety Case for the Low Level Waste Repository (which is sited near the village of Drigg) in May of 2011. At an appropriate time NDA will work with LLWR Limited to better understand the potential capacity at LLWR for graphite wastes in order to improve our understanding of this option and enable it to be compared with other options for the management of graphite wastes.

- Option 3 – **Condition Graphite to Remove Contamination and Enable Free Release or Re-use**: Complete the active trials at the Studsvik facility and monitor the progress on international developments, for example research into pressure swing absorption.
- Option 4 – **Near Surface Disposal**: NDA will consider the outputs of the Hunterston A project and review the business case for continuation of the project. NDA will then also determine how this project will contribute to its understanding of near surface disposal of other graphite wastes.

Additional to the above, and as noted in the RWMD R&D Programme overview[9], R&D is required to support future decisions regarding irradiated graphite: the release of gaseous carbon-14 has been identified as a key issue with regard to the post-closure performance of a GDF[10]. NDA and RWMD are undertaking UK irradiated graphite-related R&D.

The NDA and RWMD work programme relevant to irradiated graphite also involves international interaction with the EC CARBOWASTE project and the IAEA's Coordinated Research Project (CRP) on "*Treatment of irradiated graphite to meet acceptance criteria for waste disposal*".

Summary

This report is provided as input to Work Package 6.3 of the EC CARBOWASTE project, and presents information on the UK plans for packaging irradiated graphite and notes the inter-relationship between the desired package performance in the transport and operational periods (following waste packaging and any encapsulation), and post-closure behaviour in a GDF. This meets the requirements of EC CARBOWASTE Deliverable T6.3.4, entitled "*Report on UK waste packaging conception for irradiated graphite*" in the CARBOWASTE *Description of Work*.

Decisions on the long-term management of the large volume of irradiated graphite present in the UK waste inventory have not yet been made, noting that the reference position is geological disposal and that relevant waste packaging specifications and a disposability assessment process have been developed. Ongoing NDA and RWMD activities relating to UK irradiated graphite are noted, including the NDA Integrated Waste Management strategy and R&D.

[9] Nuclear Decommissioning Authority, *Geological Disposal R&D Programme overview – Research and development needs in the preparatory studies phase*, NDA Report NDA/RWMD/073, 2011.

[10] Nuclear Decommissioning Authority, *Geological Disposal: Gas status report*, NDA Report NDA/RWMD/037, 2010.

Appendix A

Radioactive Waste Management Directorate

Solid ILW at Hunterston A Decommissioning Site (Interim stage)

Summary of Assessment Report

Issue date of Assessment Report: 28 November 2008

Introduction

Magnox North has provided Interim stage proposals for the packaging and conditioning of solid Intermediate Level Waste retrieved from the Bunkers of the Solid Active Waste Building at Hunterston Decommissioning Site, in a form that will allow for their acceptance at a future disposal facility.

This document summarises the results of the assessment carried out by NDA Radioactive Waste Management Directorate in response to the submitted proposals. The assessment has been carried-out using the Letter of Compliance process, whereby NDA examines the disposability of the proposed waste packages by assessment against ILW packaging standards and specifications and the Geological Disposal Concept. Further information on the Letter of Compliance process is available elsewhere[1]. The Regulator's view is that packages conditioned in anticipation of geological disposal, and assessed under the Letter of Compliance process, will also be suitable for long-term storage in accordance with Government policy in Scotland.

Scope of the Proposals

Solid intermediate level waste has been produced during operation of the twin Magnox reactors at Hunterston A Power Station. The waste corresponds to 22 solid ILW waste streams in the 2007 National Radioactive Waste Inventory.

At Hunterston A, solid intermediate level waste (ILW) was generated from the treatment of spent Magnox reactor fuel prior to transport to Sellafield for reprocessing. The Hunterston solid ILW comprises Fuel Element Debris including Magnox items known as splitter blades and braces (splitters) and Graphite sleeves that were removed from the outside of fuel elements to assist with the packing and transport of fuel for reprocessing. The resulting waste is predominantly composed of Graphite, with some Magnox metal (a magnesium-based alloy that corrodes relatively easily) and steel items including fuel support members.

The total packaged volume of these wastes is expected to be approximately 3,650 m^3. These wastes therefore constitute approximately <2% of the total volume expected to form the waste inventory in the 'unshielded ILW' category being considered by NDA Radioactive Waste Management Directorate. The activity of these wastes are low in comparison to the average inventory of ILW.

It is suggested that the proposals be considered as MEDIUM priority under the current regulatory prioritisation scheme. The principal reasons for this

[1] *Guide to the NDA Radioactive Waste Management Directorate Letter of Compliance Process*, NDA Document WPS/650, March 2008.

judgement are the significance of the waste volume, comprising more than 1% of the capacity of the anticipated repository for ILW.

Packaging Proposals

The strategy for Hunterston solid ILW involves early retrieval and packaging to NDA standards and specifications through a process of mechanical retrieval from storage bunkers, sorting to quantify any pieces of nuclear fuel and remove mobile particulate material, placement in stainless steel standard $3m^3$ Boxes and immobilisation using a cement grout. The mobile particulate material would be transferred into $3m^3$ Drums and immobilised through in-drum mixing with cement grout. The waste packages would then be transferred to a purpose-built, shielded ILW store on the Hunterston site.

Magnox North has previously submitted proposals for the management of solid intermediate level waste based on retrieval, sorting, segregation and solid waste packaged into $3m^3$ Box and Drum waste containers, which are manufactured from stainless steel and would be compliant with NDA waste packaging standards. These proposals were endorsed at Conceptual stage.

The waste would be fully encapsulated using a cement grout based on a mixture of blast furnace slag and ordinary Portland cement for solid waste and immobilisation of particulate using in-drum mixing of waste with pulverised fuel ash ordinary Portland cement. After setting of the cement grout a final capping grout based on a blend of pulverised fuel ash and ordinary Portland cement (PFA/OPC) would be added before the package is lidded.

Completed packages would be transferred using a shielded cross-site transporter for continued storage in the new ILW store.

Assessment of Disposability

The assessment has highlighted the importance of positively identifying the components of the waste requiring further treatment or characterisation, during retrieval and/or packing operations. This will be necessary to ensure that any limits on specific components of the waste or the mixing of wastes, are adhered to and to ensure that objective evidence of such adherence is recorded and retained. The successful diversion of such waste items and the treatment undertaken will need to be verified and recorded. Furthermore it has been recommended that additional work is undertaken to ensure that systems are developed to facilitate this requirement given that some of the relatively old stored wastes may not be readily identifiable on retrieval.

Magnox North has recognised the importance of controlling the storage environment to maintain humidity and chloride levels within appropriate bounds and will apply controls defined within NDA guidance and the Magnox Electric Ltd code of practice for care of intermediate level waste packages. These should be applied throughout the period of storage to give confidence that package containment and integrity is maintained and that they are fit for onward stages of management.

The proposed $3m^3$ Box and Drum waste packages examined herein are, at this Interim stage, judged to be generally consistent with NDA standards and specifications for waste packages. Although it is noted that further work is required to develop the detailed container designs to be compatible with the proposed packaging route. Wasteform development, provided supported by work assessed previously by

NDA provides confidence that an adequate wasteform could be produced for the Hunterston solid ILW. Confirmation of proposals for treatment of bagged and containerised waste is required as are details of the proposals for effective immobilisation of particulate associated with the solid waste.

The assessments of transport safety show that it should be possible for the $3m^3$ Box and Drum packages containing Hunterston solid waste to comply with all relevant transport safety criteria when transported using the Standard Waste Transport Container (SWTC). It is noted that the on-site conditioned waste storage facility should be designed to provide access and compatibility for the interfaces of the SWTC, to enable transfer of the waste packages to any future disposal facility.

Similarly, the assessments of operational safety also show that it should be possible for $3m^3$ Box and Drum packages containing Hunterston solid waste to be handled and stored safely within the Geological Disposal Facility.

The post-closure safety assessment revealed no significant areas of concern that could prejudice disposal of packages containing Hunterston solid waste. This is due to the relatively low and short-lived radionuclide inventory associated with them relatively and distributed nature of toxic materials.

The waste stream is expected to contain some fuel and fuel related materials. A simple Criticality Compliance Assurance Document has been developed for the proposed packages, which can be developed to demonstrate control of fissile material in the waste packages, so that they would not present a criticality hazard.

Assessment of these proposals for Hunterston solid ILW has concluded that the process should lead to the production of compliant waste packages, subject to a number of conditions including particulate segregation and identification and diversion of wastes that require additional treatment. A number of detailed Action Points that Magnox North will need to address within the development programme for Hunterston solid ILW have been identified.

Requirements for further development work

The assessment by NDA Radioactive Waste Management Directorate has been based upon development work reported at this stage. At the Interim stage, it is required that all the supporting research and development required to demonstrate disposability should be complete and confirmation should be provided that the waste packages will be compliant with the geological disposal concept. Hence the following should be agreed and demonstrated:

- development of final waste container designs and manufacturing specifications;
- evidence that all development work has been, and will be, performed under a suitable Quality Management System
- demonstration of adequate grout infiltration for particulate associated with solid wastes and treatment for emptied containers and bags.

Conclusions

The updated Interim stage proposals from Magnox North for the retrieval, segregation, characterisation and packaging of solid ILW at Hunterston have been assessed.

The assessment of the proposals has concluded that packages containing conditioned solid ILW retrieved from the Bunkers at Hunterston Decommissioning Site are expected to be consistent with requirements for passive safety and geological disposal.

The consistency of the proposed waste packages with geological disposal has been demonstrated through the provision of an Assessment of Disposability (at this stage to be regarded as a draft of an eventual Disposability Safety Case).

A number of Action Points raised during previous Conceptual stage proposals for the packaging of solid ILW have been closed out and a small number of additional Action Points have been generated as part of this assessment of the Interim stage proposals. Close-out of four Action points is required to enable issue of an Interim stage Letter of Compliance for the proposed waste packages.