Nuclear
Decommissioning
Authority

Industry Guidance

Interim Storage of Higher Activity Waste Packages – Integrated Approach

Effective from November 2012

Interim Storage — Integrated Approach

Interim Storage — Integrated Approach

FOREWORD

Waste storage is an essential component of the higher activity waste (HAW) management lifecycle and provides a safe, secure environment for waste packages awaiting final disposal.

A system of robust storage arrangements provides high confidence that packages will be disposable at the end of the storage period and will be unaffected by any variance in the availability of disposal routes. In line with UK and Scottish Policies and CoRWM recommendations, NDA will ensure that its strategy allows for the safe and secure storage for a period of at least 100 years. The NDA's 2009 UK Radioactive Higher Activity Waste Storage Review also recognised the importance of an integrated and standard approach to HAW storage.

As the UK's nuclear clean-up mission progresses, additional packaged HAW will be held within interim storage facilities reflecting the current status of the waste retrievals, waste processing and indeed, the disposal programmes. Hence, the packaged HAW is of high intrinsic value in terms of environmental, safety and security benefit and cost and programme investment. Therefore, it is highly appropriate that the industry takes the right precautions in managing the storage system and ensuring the waste packages remain in a disposable form.

To support the strategic position of a robust storage programme, including a more co-ordinated approach, the NDA welcomed the opportunity to take the lead in setting up a cross-industry Integrated Project Team (IPT), which was responsible for delivering the Industry Guidance on the storage of packaged HAW.

The Guidance has been developed, over the last three years, by representatives from all the NDA's Site Licence Companies (SLCs) with packaged HAW, RWMD, EDF Energy, MOD, AWE and supply chain organisations through the NDA's Direct Research Portfolio. The Regulators and CoRWM observed the development of the Guidance and provided input by attending workshops and commenting on draft versions.

The first issue was published in August 2011 for a period of 'road-testing' by industry and other stakeholders. Following updating, based on this feedback, the Guidance was re-launched at an industry seminar on HAW storage in September 2012. It is expected that SLCs will implement the Guidance to maintain and improve existing waste storage systems and when planning new stores. Other organisations will continue to be able to freely access and use the Guidance.

It is intended that the Guidance remains fit-for-purpose through continual improvement and will be re–issued when necessary. If you have any comments on the Guidance, please email these to strategy@nda.gov.uk.

James McKinney, Head of Integrated Waste Management, NDA

November 2012

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ABSTRACT

A cross-industry team assembled by the NDA has developed this Industry Guidance on the interim storage of packaged higher activity waste (HAW). Since 2009, the project team has engaged with the industry through workshops, commissioned development work and interacted with Store Operators and Regulators. It is intended that the Guidance will be used by those involved in managing any aspect of current and future UK stores of packaged HAW.

The Guidance seeks to cover all the significant technical issues arising from interim storage of packaged HAW, be practicable in implementation, and relevant to all UK storage system designs. The Guidance is arranged into two inter-related components:

(a) an 'Extended Summary', which provides higher-level overview of the Guidance;
(b) an 'Integrated Approach', this document, which provides the detailed Guidance with references to additional guidance and underpinning work including R&D.

The Guidance comprises of four primary sections which cover the key elements of a robust approach to interim storage. These sections are: package performance and design; store performance and design; operation of the storage system and provision of assurance of the system over an intergenerational timescale.

To accommodate the diversity of UK HAW, the Guidance describes six common principles and 26 approaches covering the lifecycle of interim storage and variation in HAW properties. When these are implemented as a coherent set then the Guidance forms an 'integrated approach' to interim storage that may be especially useful to the design and planning of new stores. When specific approaches are applied, in the context of an existing storage system, then the Guidance may be used to improve existing arrangements through comparison with identified good practices and toolkits based on operational feedback.

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1. Introduction

1.1 Background

The Nuclear Decommissioning Authority's (NDA's) review of the UK's arrangements for interim storage of Higher Activity Waste (HAW) was published in March 2009 [1]. The review addressed the concluding recommendations from the Committee on Radioactive Waste Management (CoRWM) to Government in 2006 [2], notably 'Recommendation 2', which stated that:

"*A robust programme of interim storage must play an integral part in the long-term management strategy. The uncertainties surrounding the implementation of geological disposal, including social and ethical concerns, lead CoRWM to recommend a continued commitment to the safe and secure management of wastes that is robust against the risk of delay or failure in the repository programme*."

This recommendation on interim storage was subsequently affirmed in the Managing Radioactive Waste Safely (MRWS) white paper [3] where Government confirmed that the NDA would continue to provide interim storage of waste on its sites for as long as it takes to site and then construct a geological disposal facility (GDF).

The Scottish Government, having withdrawn its support for deep geological disposal, published its Higher Activity Radioactive Waste Policy [4]. This states *"The long-term management of higher activity radioactive waste should be in near–surface facilities..."* and that storage facilities should have the capability to last for at least 100 years, with the capability of extension beyond this. This latter aspect is broadly the same as the position for interim storage facilities in England and Wales, where there is a requirement for safe and secure storage of waste in stores for a period of at least 100 years [3]. Therefore, the position on HAW *storage* is essentially equivalent across the UK.

Following their high–level recommendations in 2006, CoRWM published a more detailed report on interim storage [5]. Its first recommendation to Government stated that there should be greater UK-wide strategic co-ordination of the conditioning, packaging and storage of HAW. It noted the need to consider future transport arrangements, and the co-ordination should include agreement on priorities. The CoRWM report concluded that:

"*At all nuclear sites the current plans for storage of higher activity wastes are adequate to meet the CoRWM 2006 recommendation, and Government commitment, that there should be arrangements for safe and secure storage for at least 100 years.* ***However, the present UK approach to storage lacks robustness: it is fragmented and too few sites have contingency plans. A more strategic approach is required.***"

The Government [6], including the Devolved Administrations, accepted this recommendation from CoRWM. The Government highlighted the need to meet the high safety, security and environmental standards required by the Regulators and noted the formation of an Integrated Project Team (IPT) led by the NDA, made up of its Site Licence Companies (SLCs) and other waste owners, to consider many of these issues arising from the two reviews [1,5], and which are addressed within the Industry Guidance – referred to as the 'Guidance' from this point.

1.2 Guidance Overview

The Guidance seeks to cover the technical challenges arising from interim storage, be practicable in implementation, and be relevant to most waste package and store designs. It recognises that while some of the issues are short term in nature, many are longer term and span inter-generational timescales and require a risk management approach.

The Guidance has been arranged into two components:

(a) **Extended Summary**, which provides a high-level overview of the Guidance;
(b) **Integrated Approach**, this document, which describes principles, approaches, good practices, and toolkits as guidance for current and prospective Store Operators.

An accompanying database provides further details concerning UK waste-storage systems, referred to as 'storage systems' from this point, and other supporting information. Where a reader has access to the database then additional information can be found by clicking the hyperlinks identified with a superscripted '[D]'. For example, this includes provision through the database of a bibliography [D] which was developed as part of the IPT's work programme.

The Guidance should be considered alongside the vision for interim storage as 'an assured UK asset' as outlined in the NDA's Strategy [7].

The topics considered in the Guidance are largely those covered by the NDA's Storage Review [1], notably those in Chapter 5 [D]. These topics have been subject to considerable engagement with industry stakeholders. For example, a Store Operations Forum (SOF) is now established. This meets annually and comprises representatives from current and planned UK HAW stores. The SOF will continue to provide oversight of those aspects of the Guidance covering operational experience – see subsection 2.3.2. The interface with technological development is described in subsection 2.3.1.

The strategic need to provide adequate HAW storage capacity in the UK was a major topic in the 2009 CoRWM and NDA reports. Work is on hand to consider this provision, in liaison with other organisations, as part of implementing the NDA Strategy – see for example Reference [8].

1.2.1 Objectives

The objectives of the Guidance are to provide:

(a) standardised and practicable methods (i.e. approaches) and options for solutions (i.e. toolkits) for Store Operators across the following issues, which were raised in the CoRWM and NDA reviews, concerning:
- package performance criteria – see subsection 3.2;
- store environmental controls – see subsection 4.3;
- avoiding the need for package reworking – see subsection 5.3;
- optimisation of store longevity – see subsection 5.6;
- package monitoring & inspection – see subsection 6.3.

(b) examples of good practice to inform future store designs and operations, and where feasible improve current store operations.

(c) an integrated approach which can be used to demonstrate that packages will remain safe and disposable during storage to the Licensees, Regulators, and the Waste Owner, including:

- assurance that waste packages and key store life-limiting components continue to meet the safety case;
- assurance that waste packages remain readily exportable for eventual disposal or continued storage elsewhere;
- industry standard reporting practices.

1.2.2 Audience

The intended audience, which is assumed to have a pre–existing understanding of the issues surrounding storage, for the Guidance is:

- Licensees and their Store Operators;
- Nuclear Waste Research Forum (NWRF) and its working group covering storage, see subsection 2.3.1;
- NDA;
- other owners of HAW;
- Regulators.

1.2.3 Changes since last issue

The following changes, since Issue 1 was published in August 2011, are highlighted:

- additional ‘road-mapping’ and highlighting of factors to consider when developing or modifying a storage system – see Section 2;
- enhanced clarity provided on the interplay between tools, toolkits and approaches, and their relevance to different storage systems – see subsection 2.1;
- development of an approach to baseline the initial conditions of the storage system – see subsection 6.2;
- improved consideration of good practices, and their relevance to different storage systems – see subsection 7.1;
- development of a supporting database [D] with information on the UK store designs.

1.2.4 Future issues

Any further issues of the Guidance will be sponsored by the NDA’s Head of Integrated Waste Management. The change control process is described in subsection 2.3.3.

1.3 Scope

The Guidance covers the interim storage of packaged HAW, across the UK, in surface facilities before its eventual transfer to a disposal facility or another storage facility. A list of current and planned stores, in the UK, is summarised in subsection 7.2. The following aspects define the scope of the Guidance:

(a) **Surface stores** which have been, or will be, purpose built or adapted to store HAW packages.
(b) **Storage periods of up to about 100 years**, within a surface store, with consideration beyond this limited to qualitative consideration as appropriate.
(c) **HAW packages**, within surface stores for up to about 100 years, which are subject to assessment through the NDA's Radioactive Waste Management Directorate (RWMD) Letter of Compliance (LoC) process, and which:
  (i) have been or are planned to be conditioned for disposal or long–term storage; or
  (ii) although currently unconditioned may require future conditioning, e.g. for disposal; and
  (iii) have been demonstrated to be appropriately 'passively safe' to the Regulators.

Limited additional applicability:
In addition to the Guidance being informed by facilities outside the defined scope above, it might also find useful application, in part, to the following waste storage contexts:

- near-surface stores with packages stored below ground level, which may require additional consideration of flood prevention and water ingress;
- long-term stores for LLW packages;
- stores for exclusively short–lived Intermediate Level Waste (ILW), which will become LLW during the storage period and be suitable for disposal in near–surface facilities.

The Guidance might also have some useful application to stores containing dry spent fuel and nuclear material.

Principal exclusions:
- geological disposal facilities such as a GDF;
- short-term stores for LLW packages;
- raw and unretrieved radioactive waste which remains in an unpackaged state;
- stores, or ponds, containing wet spent fuel and nuclear materials;
- non-radioactive waste storage.

It should also be noted that there is only limited consideration of socio–political and economic issues within the Guidance. These issues may, in addition to the technical issues considered, strongly influence decision making.

1.4 Principal Legislation, Standards and Guidance

1.4.1 International

The following International Atomic Energy Agency (IAEA) Safety Standards is highlighted as essential background:

- General Safety Requirements (GSR) Part 5 [9], which establishes the safety requirements that apply to all facilities and activities that are involved in the management of radioactive waste before disposal.
- TS-R-1 [10], which establishes standards of safety to provide an acceptable level of control of the radiation, criticality and thermal hazards to persons, property and the environment that are associated with the transport of radioactive material.

It is understood that an IAEA Technical Document (TECDOC) on the long–term storage of radioactive waste is imminent and will provide additional guidance on storage. An extant technical report on interim storage [11], which provides guidance on various technological aspects of radioactive waste package storage, should also be noted.

More facility specific requirements are set out in a report prepared by the Western European Nuclear Regulators' Association (WENRA) [12] which details safety reference levels (SRLs) for radioactive waste and spent fuel storage facilities.

1.4.2 UK legislation

The following fundamental legislation relevant to radioactive waste management is highlighted:

- Nuclear Installations Act 1965 as amended (NIA 65) [13] and standard conditions applied to nuclear site licences;
- Health and Safety at Work etc. Act 1974 (HSW) [14];
- in Scotland: the Radioactive Substances Act 1993 (RSA93) [15] and conditions attached to authorisations under RSA93; in England and Wales, the radioactive substances regulation form part of the Environmental Permitting Regulations (EPR) 2010 [16], as amended in 2011 [17];
- the Ionising Radiations Regulations 1999 (IRR99) [18];
- the Nuclear Industry Security Regulations 2003 (NISR 2003) [19].

1.4.3 Regulatory guidance

Recent regulatory 'Joint Guidance' on storage [20], as part of a suite of waste management guidance documents, has been published. It is derived from internationally agreed standards and guidance, national legislation and regulatory principles contained in the:

- Health and Safety Executive's (HSE's) Safety Assessment Principles (SAPs) [21], and Technical Assessment Guides (TAGs) which cover both new and existing storage facilities;
- Environment Agency's (EA's) Radioactive Substances Regulation Environmental Principles [22].

The Joint Guidance [20] also states that the Government continues to develop a policy and regulatory framework which aims to ensure that:

(a) *radioactive wastes are not unnecessarily created;*
(b) *such wastes as created are safely and appropriately managed and treated;*
(c) *they are then safely disposed of at appropriate times and in appropriate ways.*

Included in the suite of documents, is one on Radioactive Waste Management Cases (RWMCs). RWMCs [23] are highly relevant to interim storage since they include consideration of information required to substantiate the long-term safety and environmental performance of all radioactive waste streams on a licensed site. Store Operators should maintain and utilise the RWMCs during the period of storage.

As well as applying the Joint Guidance appropriately, Store Operators will need to maintain a continuing dialogue with the safety, security and transport Regulators, that is the Office for

Nuclear Regulation (ONR), the relevant environmental Regulator (EA or SEPA) and the local planning authority. In all cases it is recommended that the Store Operator should engage with Regulators [24] from an early stage of planning storage systems to reduce the risk of non–compliance against Regulatory requirements and for consistency with developing cost-effective solutions. See GP1.

1.4.4 RWMD packaging standards

For HAW, in England and Wales, waste packages will need to meet the Waste Acceptance Criteria (WAC) of a geological disposal facility (GDF). Until the WAC are established, the LoC process provides assessment against likely requirements. In Scotland, as an interim measure, waste packages continue to be assessed through the LoC process. The Scottish Environment Protection Agency (SEPA) currently advises that any waste suitable for disposal will also be suitable for long–term storage in accordance with Scottish Government policy. Work is ongoing at RWMD to ensure further consistency between the LoC process and Scottish Policy.

RWMD, as the organisation responsible for delivering a GDF, has defined the package performance necessary to meet the transport and disposability requirements of a GDF within the Generic Waste Package Specification (GWPS). Additionally, RWMD has established user level Waste Package Specification and Guidance Documentation (WPSGD) to assist interpretation of these requirements.

It is recommended that Store Operators consult the following documents, and other references contained therein, for further guidance on RWMD packaging standards:

(a) *The Generic Waste Package Specification* [25] for the high level generic requirements for waste packages;
(b) *An Introduction to the Waste Package Specification and Guidance Documentation* [26] for details of many of the underlying documents (this is being updated by NDA);
(c) *Radioactive Wastes and Assessment of the Disposability of Waste Packages* [27] for the latest published description of the LoC assessment process which forms part of the Disposal System Safety Case (DSSC) documentation suite.

The LoC process can be considered a risk management approach [5]. Following the LoC assessment process, and utilising the supporting guidance, should greatly reduce the risk of packages requiring rework during interim storage as discussed in Section 5.

The Store Operator should maintain a continuing dialogue with the prospective disposal facility operator, especially when: establishing and updating store WAC, updating RWMCs, and developing store safety cases. Engagement with RWMD should occur at an early stage of the development of the storage system, and with any emergent disposability issues. See GP1.

2. Integrated Approach Overview

2.1 Outline

The relationship of the Guidance compared with the hierarchy of other sources of Interim Storage information is shown pictorially in Figure 1. This illustrates the intended 'pitch' of the Guidance as an interface between national legislation and regulatory guidance, with the operational experience and detailed underpinning provided by R&D. Additionally, it also signifies the important co-relationship with the Licensee's own tailored arrangements and that of the NDA's specifications and guidance for a GDF.

Figure 1 Illustrative Strategic Position of the Guidance

The Guidance comprises several elements that when integrated seek to achieve the objectives described in subsection 1.2.1. These elements are:

- **(a)** **Principles (A to F),** which provide a consistent framework– see subsection 2.1.1;
- **(b)** **Good Practices (GP1 to GP30)**, which highlight recommendations to Store Operators – see subsection 2.1.2;
- **(c)** **Approaches (A0 to A26),** which are defined to be processes and methods to assist Store Operators select appropriate tools and/or take appropriate actions according to the context of their storage system. Approaches may also include the consideration of key attributes and factors which can be used to discriminate between different potential options to help select optimal solutions – see subsection 2.1.3;
- **(d)** **Toolkits (TK1 to TK23),** which comprise of a collection of potential techniques, solutions or other options which have been derived from operational experience and R&D – see subsection 2.1.4;

(e) **Tools,** which are user selected techniques, solutions or other options that are relevant to a particular storage system's context and may be identified by application of an approach.

These elements, their derivation and their inter-relationship, are shown pictorially in Figure 2. Throughout the Guidance, common terminology is applied. It is recommended that the terminology concerning storage be used consistently by Store Operators. See the Glossary, listing of Abbreviations and Acronyms and GP2.

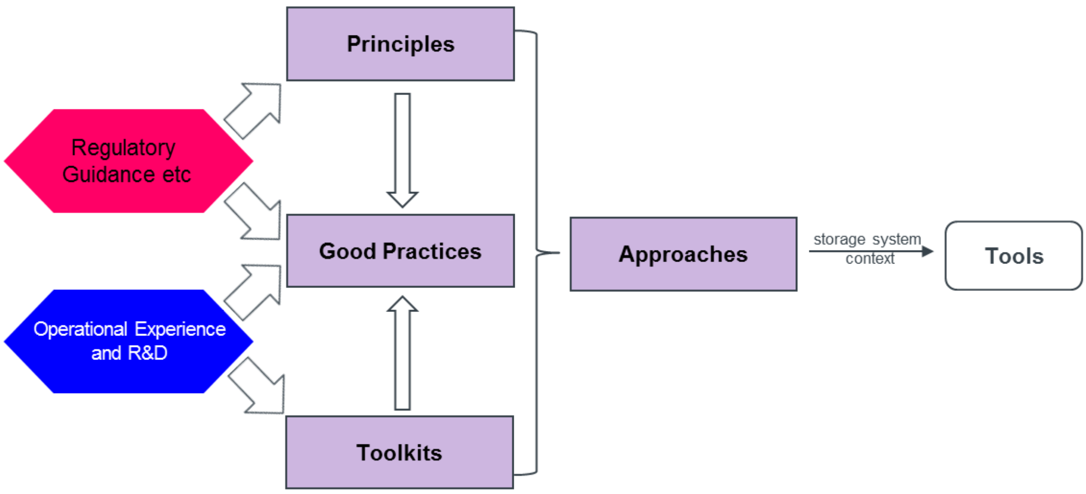

Figure 2 Guidance Elements and their Inter–relationship

2.1.1 Principles

The following principles, derived from stakeholder expectations [D], provide a framework for the Guidance:

A. **Cradle-to-grave lifecycle**. Packages should be managed to protect their overall longevity as part of the lifecycle from manufacture of the container through to closure of a disposal facility. As interim storage is transitory, packages should be readily retrievable and exportable to a disposal facility or another store for continued storage.

B. **Right Package ↔ Right Store.** Good package design should be matched by appropriately good store designs with due consideration of the hazards presented by the waste packages and the quality of storage required. The overall storage system, i.e. the wasteform and its container, the store environment and the store structure, should have limited need for active safety systems, monitoring or prompt human intervention. Overall value for money through both avoiding over- and under-engineering should be demonstrated.

C. **Minimising waste generation.** The waste hierarchy should be deployed across the system's lifecycle, from design through to decommissioning of the store to avoid unnecessary generation of waste while utilising resources sustainably.

D. **Prevention is better than cure**. The storage system should be managed to minimise the risk that intervention will be required to maintain safety functions. The storage system should be subject to regular and proportionate monitoring and inspection to demonstrate performance and enhance the understanding of how the system may evolve in the future.

E. **Foresight in design**. The storage system design should be flexible to meet likely future needs that take account of uncertainties and incorporate proportionate contingencies. Designs should take account of the need for the store to be part of the UK-wide storage asset.

F. **Effective knowledge management**. The experiences and lessons learned from existing store operations should be shared between Store Operators to inform development of store standards and designs. Learning from relevant overseas storage facilities should also be utilised effectively through collaboration. This collective information should be used to further inform development of UK storage standards and there should be emphasis on exploiting the insights and experiences gained, i.e. continual improvement. Appropriate records must be maintained throughout.

2.1.2 Good Practices

Throughout the Guidance, 30 headline recommendations to Store Operators are highlighted as good practices and assigned a specific label, GP*n*. These are summarised in subsection 7.1, and listed below. While the majority of the good practices are generic and applicable to all storage systems, additional text is provided that describe any limits on its applicability, or attention is drawn to notable features.

GP	Outline Description (subsection)	GP	Outline Description (subsection)
1	Stakeholder engagement (1.4.3; 1.4.4; 5.3)	16	Store design – environmental controls (4.3.1, 4.4.2)
2	Technical terminology (2.1)	17	Store design – contaminants (4.3.2)
3	Technical competence (2.1.3a, 3.2, 5.3)	18	Operational limits and conditions (4.4.1)
4	Human factors (2.1.3b)	19	Import contaminant checks (5.1.1)
5	Research and development (2.3.1)	20	Minimising movements - opportunities (5.1.2)
6	Peer groups (2.3.2)	21	Package sentencing groups (5.3.3)
7	Package designs (3.1)	22	Maintaining contingency space (5.3.3)
8	Package materials (3.1, 6.6)	23	Maintaining intervention plans (5.3.3, 5.4)
9	Maintaining transportability (3.1.3, 5.1.3)	24	Access to rework facilities (5.3.4)
10	Package evolutionary processes (3.2.2)	25	Extending store operational lives (5.5)
11	Package care and management – controlled (3.4)	26	Establishing system baselines (6.2)
12	Package care and management - uncontrolled (3.4)	27	Recording system performance (6.3)
13	Local planning constraints (4.1.2)	28	Monitoring and inspection rates (6.4)
14	Store design - monitorability (4.1.3)	29	Maintaining an archive (6.5)
15	Store design - life-limiting components (4.2.2)	30	Deployment of dummy packages (6.6.1)

2.1.3 Approaches

Throughout the Guidance, 27 approaches are described and assigned a specific label, A*n*, with A0 being defined as the overall integrated approach, the others are listed below.

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A	Outline Description (subsection)	A	Outline Description (subsection)
1	Package Performance (2.1.3, 3.2, 4.4.2, 5.3.2, 6.1, 6.4.1, 6.6.2)	14	Package Emplacement (5.2)
2	Integrated Human Factors (2.1.3)	15	Maintaining Package Safety Functions (5.3)
3	Modifications to Existing Stores (2.1.3)	16	Maintaining Environmental Conditions (5.4)
4	Selecting Package Designs (3.1)	17	Maintaining Store Life-limiting Features (5.5)
5	Package Evolution and Assessment (3.3)	18	Extending Store Lifetimes (5.6)
6	Lifetime Package Care and Management (3.4)	19	Baselining (6.2)
7	Development of Outline Store Design (4.1)	20	Monitoring and Inspection Techniques (6.3)
8	Store Longevity (4.2)	21	Monitoring and Inspection Rates (6.4)
9	Environmental Controls (4.3, 4.4)	22	Archiving (6.5)
10	Environmental Operational Limits and Conditions (4.4)	23	Inactive Samples and Simulants (6.6)
11	Package Movements - Import (5.1.1)	24	Auditing (6.7)
12	Package Movements - Operations (5.1.2)	25	Knowledge Management (6.8)
13	Package Movements - Export (5.1.3)	26	Human Resources (6.9)

While the majority of the approaches are outlined within specific subsections of the Guidance, see subsection 2.2, some are applied generically across the Guidance; these are described in outline below, and expanded, as appropriate, in specific subsections.

(a) Package Performance Approach

Approach A1 is used widely within the Guidance. It describes package performance zones across the waste management lifecycle from packaging through to disposal. A1 [28] is integrated within many of the other approaches, e.g. see A15 on maintaining package safety functions.

The purpose of A1 is outlined below and shown figuratively in Figure 3; further details of its implementation are in subsection 3.2. A1 was established through workshops and engagement with the NWRF. It can be utilised by Store Operators as an aid to:

- prevent package failure, through defining when intervention may be required to maintain safety functions;
- highlight package components which would benefit from being monitored and/or inspected;
- derive robust store WAC;
- target appropriate and effective R&D;
- frame the importance of 'interim storage' as a component of the waste management cycle;
- provide transparent and consistent 'yardsticks' for long–term package safety to stakeholders.

Although the approach is focussed on the waste package, it may be adapted to include aspects of maintaining the storage environment and life-limiting components of the store itself, see subsection 4.2. Effective use of A1 will require that the Store Operator has access to Suitably Qualified and Experienced Persons (SQEP) on the long-term performance of packages. See GP3.

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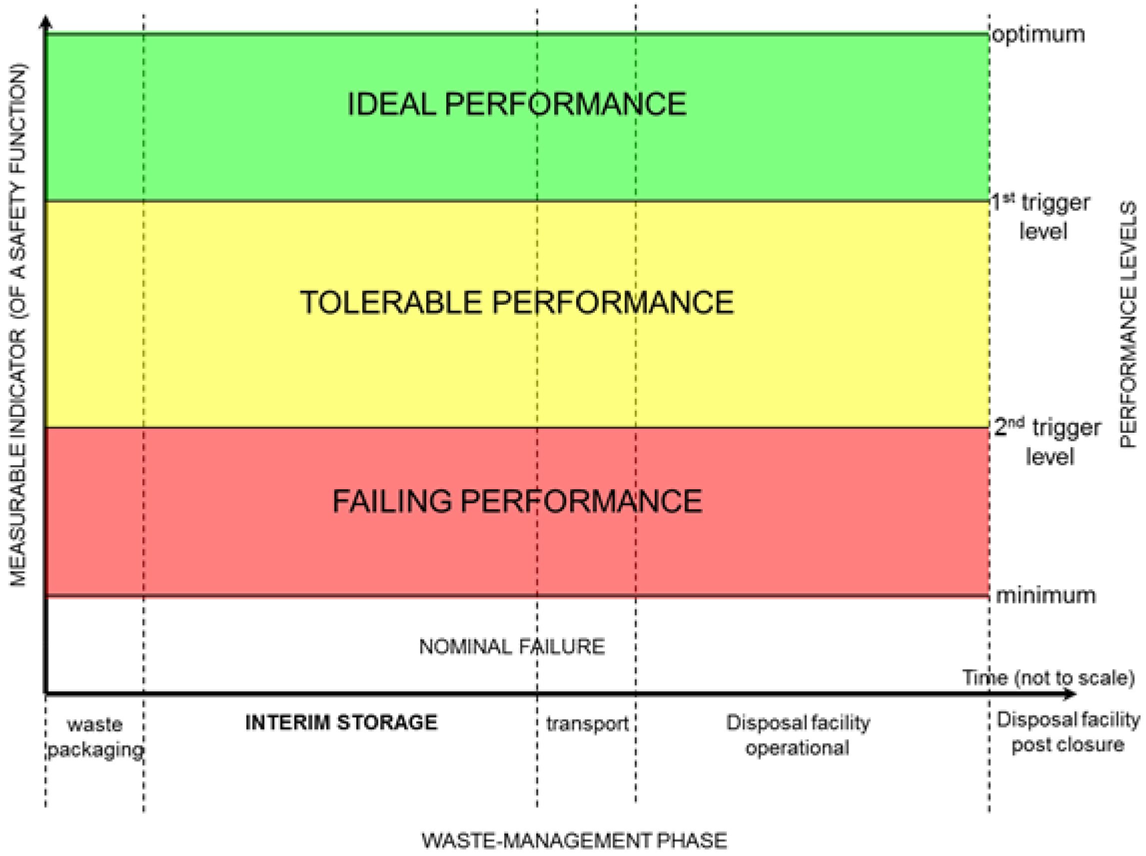

Figure 3 Basic Illustration of the Package Performance Approach

(b) Integrated Human Factors Approach

Approach A2 is taken from Reference [29]. Human Factors Integration, which considers the design of the *Job* (including facilities, equipment and tasks); the capabilities of the *Person* required to perform tasks and interface with the system; and the features of the *Organisation* in which the system operates. Consideration of Human Factors (HF) should be widely applied across the lifecycle of the storage system, i.e. from design through to decommissioning. A more detailed description of this common three pronged model of HF is given in the UK's Health and Safety Executive (HSE) publication HSG 48 [30].

The HF Approach should be instigated as early as possible in the storage system's lifecycle. By following A2, and the identified toolkit – see HF2-HF15 [D] in Reference [29][TK1] – appropriate tools may be selected to support the design, operation and assurance of the storage system according to the current stage of the lifecycle. Additional guidance on HF is provided on the Energy Institute website. See also GP4.

(c) Modifications to Existing Stores Approach

Approach A3 may be used to determine how any gaps between current practice in an existing store and the guidance should be addressed. Much of the Guidance is based on the operational experiences of existing storage systems in the UK. However, this collective operational experience was not available during the design and planning phases of these older stores. Indeed, many of the stores were designed before the current long-term management strategies of HAW were established – see Section 1. Additionally, new technologies continue to emerge with the potential to improve the operations of the storage system and ongoing R&D activities provide a firmer understanding of how the storage system may evolve in the longer term. However, the design of many older stores, especially those designed for non-contact handleable packages, may severely constrain any proposed improvements.

Briefly, A3 - see Figure 4 - consists of:

i. carrying out a gap analysis between relevant sections of the Guidance with the storage system, such as good practices and toolkits;
ii. assessing the significance of the gap, e.g. with respect to as low as is reasonably practicable (ALARP) considerations, commercial risks and any opportunities to manage the gap strategically, e.g. through inter-site 'store consolidation', informed, as appropriate, through stakeholder consultation;
iii. justifying the decision to change a feature of an existing store, e.g. via a business case;
iv. incorporating the decision through appropriate channels, e.g. modification to the safety case(s) affected, or updating the store risk register;
v. implementing and then periodically reviewing the decision.

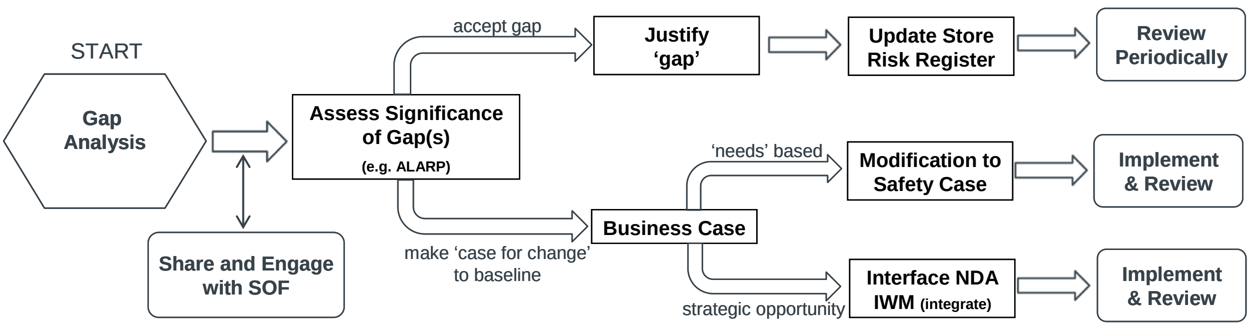

Figure 4 Simplified Flow–diagram of A3

Throughout the staged approach, outputs should be shared with and informed by other Store Operators, e.g. via the SOF, with an objective to feedback outcomes into future issues of the Guidance; see subsection 2.3.

2.1.4 Toolkits

Toolkits, which are assigned in the text with a superscripted '^{TKn}', are listed below:

TK	Outline Description (subsection)	TK	Outline Description (subsection)
1	Human factors (2.1.3b)	13	Non-physical package intervention (5.3.3)
2	Basic container designs (3.1)	14	Physical package intervention (5.3.3)
3	Container materials (3.1)	15	Environmental control changes (5.4)
4	Encapsulants (3.1)	16	Life-limiting component repairs (5.6)
5	Package evolution models (3.3.3)	17	Baselining (6.2)
6	Packaging innovations (3.5)	18	Sample types (6.3)
7	Outline store designs (4.1.1)	19	Package inspection and monitoring (6.3.1)
8	Store life-limiting features (4.2.2)	20	Environmental condition monitoring (6.3.2)
9	Temperature and relative humidity controls (4.3.3a)	21	Monitoring life-limiting components - unshielded stores (6.3.3)
10	Moisture controls (4.3.3b)	22	Monitoring life-limiting components - shielded stores (6.3.3)
11	Contaminant controls (4.3.3c)	23	Monitoring and Inspection rate models (6.4.1)
12	Microbial and animal controls (4.3.3d)		

2.2 Roadmap

To aid readability, the Guidance is presented in four main inter-related colour-coded sections:

(a) **Waste package** performance requirements, management and design - Section 3;
(b) **Store** performance requirements, environment, management and design - Section 4;
(c) **Operation** of the storage system - Section 5;
(d) **Assurance** of the storage system - Section 6.

When the sections are integrated and applied in an iterative manner, as shown in Figure 5, the Guidance may be used to help determine a suitable overall storage system. Alternatively, it may be applied to an existing storage system as a benchmarking exercise, or to optimise its operation or develop contingencies as part of risk management.

The Guidance may also be used to as a reference, for example to identify potential solutions to specific issues which may arise during the operations of the storage system. Additionally, through the accompanying database, the Guidance can be used to identify suitable contacts and underlying detailed work to support development of new tools and encourage dissemination of lessons learned.

For planned stores, key factors which may discriminate between storage system designs are shown in Figure 6. See also Section 3 and Section 4. However, as shown in Figure 5, the process is iterative with the store design and package design intimately linked and pre-determining either a package or store design may yield a sub-optimal result noting Principle B. These 'key' discriminators, shown in Figure 6, are also used within many of the approaches to identify storage system specific tools.

It should be noted that the broad waste groups outlined in Figure 6 are taken from Reference [31]. These and the specific waste characteristics will have a major impact on the storage system design, and underlines the importance of adequate characterisation to drive decision making [32].

Interim Storage — Integrated Approach

The Joint Guidance [24] outlines a categorisation approach which may be used to guide proportionality based on the safety and environmental challenges presented by the waste. Financial considerations are an important aspect of determining the design and operation of a storage system. While detailed consideration is outside the scope of the Guidance, a balance will be needed between the lifecycle costs of the storage system compared with the risk mitigated and the value of the asset managed; this will need to be agreed with appropriate stakeholders such as the NDA, Regulators and the relevant local planning authority.

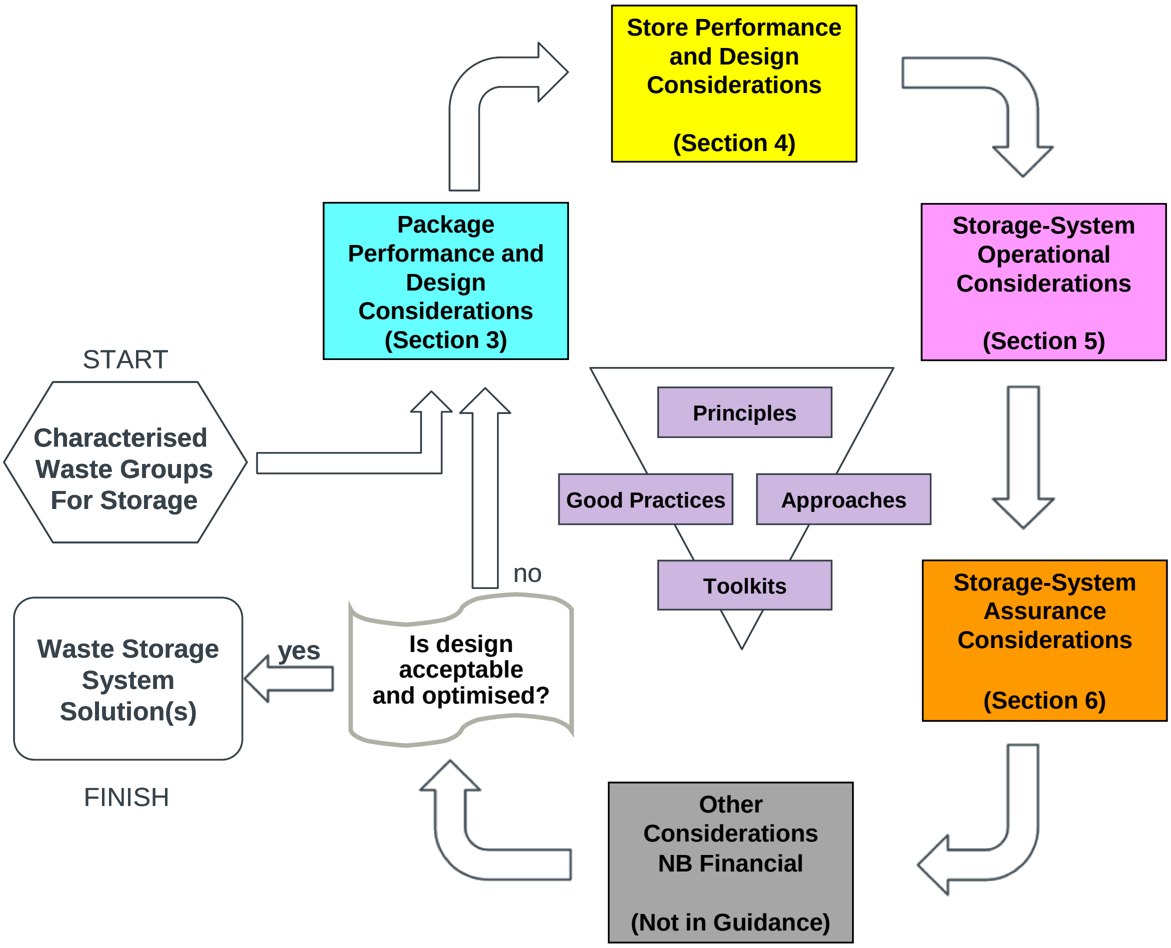

Figure 5 Schematic Representation of the Integrated Approach A0

Interim Storage — Integrated Approach

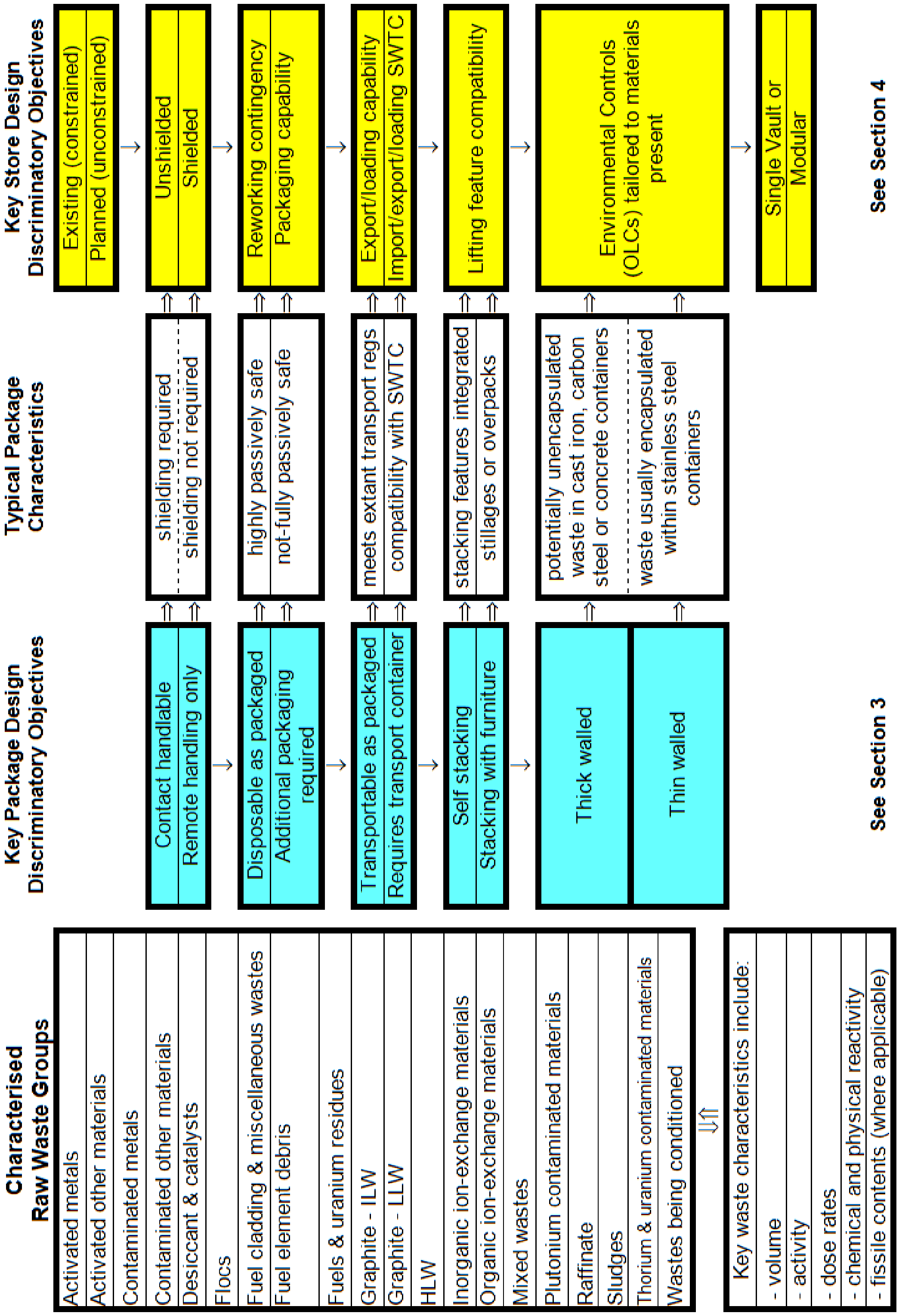

Figure 6 **Key Storage System Design Discriminators and Characteristics**

2.3 Continuous Improvement

2.3.1 Research & development

Users of this Guidance either seeking information on current or historic waste packaging and storage R&D or considering carrying out R&D should consult the NWRF's Waste Packaging and Storage Working Group. See also GP5.

Licensee based Users are advised to contact their representative on the Working Group [D] to co-ordinate any additional work and/or establish output from any pre-existing work. Other Users should contact the Group's chair. Representatives from ONR, EA, SEPA and CoRWM attend this Group, which is sponsored by the NDA's Head of Integrated Waste Management, as observers.

2.3.2 Operational learning from experience

Store Operators seeking information on UK-wide store operational experience are advised to contact the appropriate member of the NDA's SOF [D], or its chair, for more information. See also GP6.

2.3.3 Change control process

The NDA Sponsor of the Guidance is the Head of Integrated Waste Management, with implementation through the Head of Programmes. Additionally, three industry groups provide continuing oversight, these are the:

- Integrated Waste Management Theme Overview Group (IWMTOG) for waste strategy;
- NWRF's Waste Packaging and Storage Working Group for R&D;
- SOF for store operations and learning from experience.

Enquiries about future changes to the Guidance should be made through one of these groups, as appropriate, to represent any substantive requested changes to the NDA Sponsor. Comments may also be channelled through the email address provided in the Foreword.

3. Package Performance and Design

This section comprises of six good practices, three approaches and five toolkits to promote robust package performance and design. It includes guidance on:

- Current standard container and package designs and materials
- Emerging innovations which may affect future interim storage requirements
- How to establish a credible baseline for new designs and materials
- Generic and specific package safety functions
- Relating safety functions to performance criteria
- The latest understanding on package evolutionary processes
- Good package care practices before import into a store

3.1 Package Design Approach

Approach A4, set out below, describes steps to establish a robust waste package design:

(a) Determining appropriate package design objectives - see also Figure 6. It should be noted, in Figure 7, the essential role of the waste package in providing two fundamental barriers of protection - i.e. the conditioned wasteform and container - which will need to be provided across the packages' lifecycle. There are several package design objectives to consider which will influence the design, these include:

- handleability - see subsection 3.1.1;
- prompt disposability - see subsection 3.1.2;
- transportability - see subsection 3.1.3;
- stackability - see subsection 3.1.4;
- containment functionality - see subsection 3.1.5.

(b) Reviewing existing package designs for suitability. RWMD has published specifications for several standard designs of waste containers; see, for example, NDA Packaging Specifications and Guidance Notes link[TK2]. Common variants of the standard container designs, based on licensee requirements, are outlined in Reference [33]. It is recommended that Store Operators base their waste system storage designs around these standards unless there are compelling reasons to adopt different package or store designs - see GP7.

(c) Establishing suitable materials to meet the design objectives. Various materials may be considered in the package design which will strongly influence, inter alia, the nature of any environmental controls. Materials employed[TK3] in the external features of container designs and will be directly affected by the storage environment, include:

- stainless steel grades, including austenitic such as 316L and duplex such as 2205;
- carbon steels, including lower carbon grades such as mild steel;
- ductile cast iron;
- reinforced concrete, such as used in $6m^3$ boxes;
- other materials [D] remain under consideration in the UK for specific applications.

In all cases, the materials chosen in the package design must be shown to be sufficiently robust for the intended lifecycle [34]. It is recommended that samples of materials are incorporated into a monitoring programme at an early stage of planned development, and consideration be made of accelerated ageing techniques, to establish a credible baseline. See GP8.

(d) Ensuring the potential for adequate package performance - see subsection 3.2.

(e) Considering emerging innovations which may enhance the packaging toolkit - see subsection 3.5;

(f) Ensuring consistency with the store design and vice versa - see Section 4.

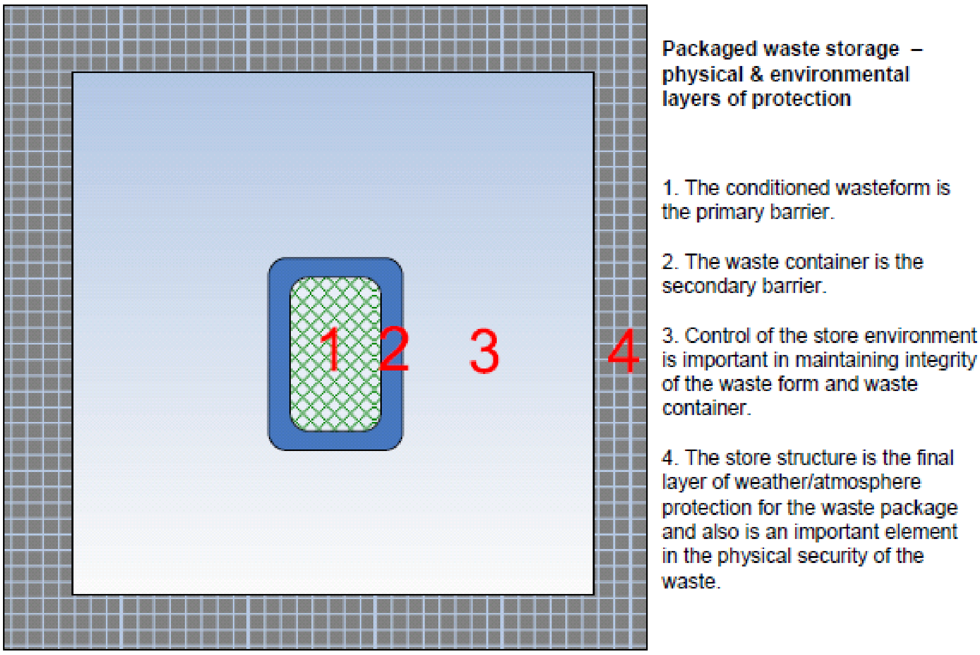

Figure 7 Representation of the Storage System [1]

3.1.1 Handleability

(a) Contact handleable. The direct radiation arising from such packages, by virtue of the wasteform properties and/or those of the container and any deployment of internal 'shielding material' is sufficiently small to *permit direct handling of the package under normal operating conditions*. These limits may vary dependant on whether the packages are moved on–site or in the public domain. Examples include: 2m, 4m and 6 m^3 boxes, and Ductile Cast Iron Containers (DCICs), which are usually considered exclusively in this context.

(b) Non-contact handleable. The direct radiation arising from such packages requires remote operations to manage and move them under normal operating conditions and use of transport containers, which are shielded overpacks, to transport them. The 500 litre drum and 3 m^3 box are the typical basic designs, although these are also be suitable for some contact handleable waste packages with limited shielding requirements.

3.1.2 Prompt disposability

Unless there are compelling reasons, packages should be designed to be *capable* of being promptly disposable without the need for additional packaging steps before export. Notable exceptions include:

- required use of a transport container at export to meet transport regulations;
- contingencies in the package design which may accommodate significant evolution, such as expansion, that otherwise may have led to an unacceptable risk of rework. For example container designs with a double skin with the option to encapsulate between skins later if necessary.

3.1.3 Transportability

Although the nature and composition of the inventory is restricted, many containers for contact-handleable packages are also designed to meet the requirements for an Industrial Package as specified by IAEA Transport Regulations [10]. The need to maintain the transport licence, during storage, should be carefully planned and managed and the appropriate Design Authority engaged. For such packages a clear linkage between the transport safety case and the storage safety case should be maintained and documented. Transport packages must be shown to be robust to certain prescribed threats. New and existing designs, may be required to meet future regulatory requirements, e.g. in response to future security needs. See GP9.

Non-contact handleable packages will *generally* require the use of a transport container, for example the Standard Waste Transport Container (SWTC), as specified by IAEA Transport Regulations [10] for transport as a Type B transport package. However, given the timescale of interim storage, it may be that some packages will have had sufficient radioactive decay to permit less onerous transport requirements when exported from the storage facility.

Codes of practice on radioactive materials transport are maintained and developed by the UK nuclear industry's Transport Container Standardisation Committee (TCSC). Further guidance can also be found on the Radioactive Materials Transport (RMT) Programme's website.

3.1.4 Stackability

There are many advantages from package designs which permit direct stacking. However, for greater flexibility, stillages are commonly used to support stacking arrangements of 500 litre and similar packages. Other approaches include use of concrete overpacks for $3m^3$ boxes and drums. Use of such furniture is discussed in Section 4, and hence not further considered as part of the package design.

3.1.5 Containment functionality

The design of the package requires consideration of the relative contribution from the container and wasteform to the overall barrier [35] afforded from the waste package as shown in Figure 8. Where thick–walled containers are selected, i.e. with a wall thickness typically > ~10 mm, and generally much more, the containment is usually provided to a significant extent by the walls with limited contribution from or need for an encapsulant. Depending on the waste characteristics, thin-walled containers typically often require that the underlying wasteform be encapsulated for added passivity.

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In the UK, cementitious materials are the most widely used encapsulants to immobilise radioactive waste. The cementitious materials most commonly used are hydraulic blends of ordinary Portland cement (OPC) and either ground granulated blast furnace slag (GGBFS) or pulverised fuel ash (PFA). Other materials, such as thermoset polymers, are also used, particularly where it is desirable to keep waste components dry and minimise gas generation.

Two advantages of using OPC based cementitious encapsulants during *interim storage* are their high pH which promotes low rates of internal steel corrosion, and their capacity to neutralise any acidic by-products which may arise as some waste groups evolve, e.g. organics. However, the long-term supply of appropriately specified cementitious materials is under threat [36]. Until packaging is completed, alternative encapsulant materials, and suppliers, should be kept under regular review supported by proportionate research as necessary to maintain credible alternatives. Additional materials [D,TK4] may be considered as part of an encapsulation toolkit.

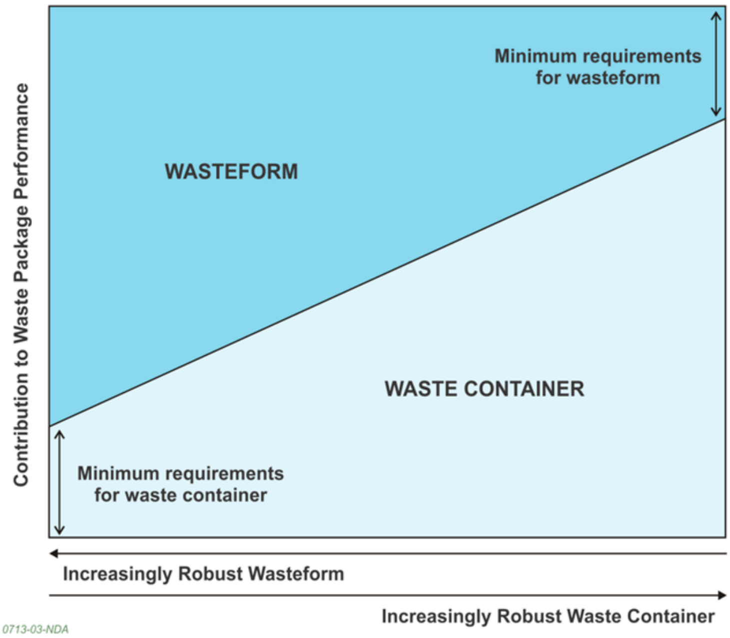

Figure 8 Illustration of Wasteform Versus Container Contribution to Performance

3.2 Package Performance Approach

3.2.1 Overview

A1 [28], see subsection 2.1.3a, consists of the following steps:

- defining the stages of the relevant lifecycle, e.g., see *x*–axis in Figure 3;
- identifying waste package 'groups' likely to evolve in similar ways within the store - see Figure 6;
- identifying the package safety functions over the lifecycle for each identified waste package group - see subsection 3.2.2;
- identifying evolutionary processes that may affect the performance of the safety functions and measurable indicators of these processes – see subsection 3.2.3;

- calibrating the indicators, where practicable, to provide indicative package performance zones in order to guide appropriate actions in response to any measured or inferred evolution - see subsection 3.2.4.

A1 should be applied proportionately according to the categorisation of the waste package(s) - see Appendix 1 [D] of Reference [24] – and quantified to the extent of available data to underpin the performance zones and expert judgment applied as necessary; see GP3. A worked example of A1, applied to identification markings, is provided in Reference [37].

3.2.2 Storage safety functions

The following primary safety functions [D], see Table 1, have been defined for waste packages during *interim storage* - see also References [25,28,35]:

(a) **Containment during normal operating conditions** of hazardous, notably radioactive, inventory with minimal and predictable release of content.

(b) **Containment under accident conditions** arising from:

- **(i)** **impact events** with minimal and predictable release of hazardous content during impact of relevant magnitude;
- **(ii)** **fire** with minimal and predictable release of hazardous content during fire of relevant magnitude.

(c) **Identification** by unique markings and these must relate to accessible package records [38].

(d) **Handling**, including retrievability, by use of designed lifting features.

(e) **Stacking** once emplaced can withstand stacking stresses and remain in position.

(f) **No over–pressurisation** through effective dispersion of any gases through filters/vents.

(g) **Shielding** to provide adequate radiation shielding for the store safety case and/or transport.

(h) **Criticality safety** by preservation of a safe distribution of fissile material within a package and with neighbouring packages.

The relative significance of the safety functions will vary between packages depending on its characteristics. Some safety functions will always be highly relevant, including: containment, identification and handling. Within a particular store the requirement for stackability might be relaxed, but appropriate consideration will still be necessary with respect to future store or disposal facility requirements.

Not all the safety functions will be relevant to all waste package groups. The potential for over-pressurisation will be waste package specific, and most likely relevant to packages with reactive metals, and degradable organics. Shielding requirements will be package dependent. Similarly, criticality will be highly waste package specific, with only stores with fissile inventory of potential concern. The distribution of such packages and interaction with moderating materials will, however, be an important consideration.

One method to identify prioritised safety functions is Failure Modes and Effects Analysis (FMEA), which is a procedure in operations management for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system [28]. See GP10.

Table 1 Example safety functions, evolutionary processes and potential indicators.

Storage safety function (main component delivering function)	Example evolutionary processes	Potential indicators
Containment - normal operations (wasteform and container)	(i) wasteform expansion (ii) container corrosion	(i) package expansion, internal strain (ii) direct measurement of corrosion or salt deposition as risk factor
Containment - impact accident (wasteform and container)	(i) wasteform expansion, cracking, fragmentation, embrittlement (ii) container corrosion	(i) package expansion, internal strains and properties (ii) direct measurement of corrosion or salt deposition as risk factor
Containment - fire accident (wasteform and container)	(i) wasteform physico-chemical properties (ii) container corrosion	(i) internal properties (ii) direct measurement of corrosion or salt deposition as risk factor
Identification (container and records)	(i) container corrosion (ii) loss of records	(i) direct measurement of readability, corrosion or salt deposition as risk factor (ii) quality assurance audits
Handling (container)	(i) container corrosion (vicinity of lifting features)	(i) direct measurement of corrosion or salt deposition as risk factor in vicinity of lifting features
Stacking (wasteform and container)	(i) wasteform expansion (ii) container corrosion	(i) package expansion, internal strain, strength (ii) direct measurement of corrosion or salt deposition as risk factor
Prevent over-pressurisation (wasteform and container)	(i) wasteform physico-chemical properties (ii) container corrosion / properties filtered vent	(i) internal properties (ii) direct measurement of corrosion or filter performance
Shielding (provided by wasteform and container)	(i) wasteform physico-chemical properties (ii) container corrosion	(i/ii) dose rates
Prevent criticality (provided by wasteform)	(i) wasteform physico-chemical properties / distribution of fissile material	(i) internal properties

3.2.3 Evolutionary processes and indicators

Effective application of A1 requires suitable understanding of how the waste package may evolve under the conditions provided by the storage system. While there has been considerable R&D since the 1980s, for example the Product Evaluation Task Force (PETF), the potential for longer storage durations and new waste packaging techniques, has meant that research has continued to be commissioned by RWMD, SLCs, and universities to understand the longer-term performance of waste packages.

Waste packages, and hence their properties and performance, will inevitably evolve during interim storage. However, safety function performance must be suitably maintained over the full package lifecycle. For example, it would not be acceptable to target 'just safe' performance at the point of package export from the store.

The evolutionary processes, which may affect the safety functions, should be identified by the Store Operators' SQEP backed up, as necessary, by engagement with RWMD and assessment through the LoC process. The **measurable** indicators of these evolutionary processes, which can be related to the safety function performance, should then be identified. This should also form part of an effective monitoring and inspection approach (see subsection 6.3), i.e. an approach focused on the measurable properties that have the most significance.

Table 1 outlines example evolutionary processes which could affect the package safety functions and suggests indicators of the degradation processes which could, in principle, be measured. It is important to note that 'indicators' is used to identify both direct evidence or measurements of processes, such as the extent of corrosion, as well as factors that are known to cause or increase the risk of degradation such as salt contamination. An overview of evolutionary processes is provided in subsection 3.3 and Reference [35].

3.2.4 Performance zones

For each safety function, see also Reference [25], the performance defined by relevant measurable indicators should be assigned to exist in a one of three performance zones, as illustrated in Figure 3:

- **Ideal** where any evolution has no negative bearing on the safety performance. Initially, a waste package that has been produced in conformance with plant processing parameters should have ideal performance in all relevant functions.
- **Tolerable** where evolution has led to a notable but insignificant reduction in performance.
- **Failing** where evolution has led to a significant loss in performance, but a 'margin of safety' is retained.

'Measurements' of the indicator(s) of the safety function, rather than the safety function itself, should be presented on the *y*–axis. Many indicators provide performance information for several safety functions, as shown Table 1.

The performance zones in the Guidance are represented as being constant throughout and between phases. This is a simplification. For example, during transport, IAEA prescribed requirements [10] may be provided to a significant extent by a transport container such as the SWTC.

For each safety function the indicators of performance should be calibrated - see subsections 5.3 and 5.4 - to describe:

- **Optimum** performance, which defines the target specification.
- **1st trigger level**, which defines the transition from ideal to tolerable performance. It acts as a 'flag' that the package may require additional management intervention to maintain safety functions.
- **2nd trigger level**, which defines the transition from tolerable to failing performance. It acts as a 'flag' that the package may require physical intervention, i.e. reworking, to maintain safety functions.
- **Minimum** performance, which defines the lowest performance at which the safety function is still provided. Performance below this can be considered as nominal package failure, and reworking will be required to restore the safety function(s).

If there is any doubt about the safe performance of the waste package during packaging operations and import into the store, or any other stage of the lifecycle, the Store Operator should establish a package sentencing group to advise on appropriate actions to take. See subsection 5.3.

3.3 Package Evolution Assessment Approach

Approach A5 consists of the following steps, many of which may be iterative steps when the applied to storage systems being planned:

(a) characterising the waste, especially with respect to chemical and physical reactivity after packaging;
(b) defining container and shielding materials and encapsulants as appropriate;
(c) identifying the environmental conditions to be provided by the storage system;
(d) identifying the wasteform, waste–container and container–environment interactions by SQEP and engagement through the LoC process, including consideration of:

  - external and internal corrosion, see also subsection 3.3.1, which should also provide relevant background to the setting of Operational Limits and Conditions (OLCs) and the development of an Environmental Control Approach;
  - wasteform evolution processes, see subsection 3.3.2;
  - long–term package evolution, see subsection 3.3.3.

(e) assessing the implications from evolution, see Figure 3;
(f) feeding back the findings, as appropriate, to the storage system design, see Section 4.

A more thorough overview of processes relevant to the evolution of waste packages is provided in the Reference [35].

3.3.1 Container corrosion

The main factors affecting the external and internal corrosion of the waste container, see Reference [35], during interim storage, include the:

- type of metal and its metallurgical and mechanical history;
- presence of liquid water in contact with the surface, notably in crevices;
- temperature of the surface;
- presence of ionic species in solution and in contact with the surface;
- presence of nutrients able to sustain microbial growth;
- radiation dose rates.

The forms of corrosion [35,39,40,41], most relevant to interim storage are:

(a) **General corrosion.** Stainless steel most commonly used in the UK as the container material, i.e. 304L and 316L, is highly corrosion resistant under normal operating conditions. Duplex grades [40] are expected to be at least as corrosion resistant. Unprotected carbon steel and cast iron surfaces are more susceptible [41].

(b) **Localised corrosion and stress corrosion.** Specific forms of localised corrosion include crevice and pitting corrosion. In areas of mechanical stresses localised corrosion may lead to the development of stress corrosion cracking (SCC) [39]. Stainless steel, under normal operating conditions, especially at coastal sites, may be expected to require active controls to prevent the initiation and propagation of localised corrosion and SCC. However, duplex grades are typically more resistant to SCC [40].

(c) **Other forms of corrosion.** These include microbiologically influenced corrosion (MIC), galvanic corrosion, radiation assisted corrosion and corrosion at welds. Current container materials, under normal operating conditions, may require consideration of these processes on a case-by-case basis, but quality controls and good engineering practices should adequately control these processes.

There has been extensive testing [D] since the 1990s on predominately stainless samples under laboratory conditions to investigate localised corrosion and SCC mechanisms and establish operational 'limits' [42]. Work also evaluated the effects from MIC [42,43]. However, evidence to date from UK stores and other monitoring programmes, see for example [44,45], suggests that the experimental studies are overly cautious in determining performance needs during interim storage as described in subsection 4.4.2. Further work is being carried out through the RWMD research programme to define operational limits under realistic storage conditions. Until this is completed, it is recommended that the laboratory based work continues to be used as the primary line of evidence.

3.3.2 Wasteform evolution

Assuming appropriate quality control and due observation of LoC conditions, it is expected that wasteforms will be robust over interim storage timescales. The following processes are considered notable, see also Reference [46], as potentially affecting package performance during interim storage and which the Store Operator should consider when defining store WAC, OLCs and package emplacement - see subsection 5.2:

(a) **Corrosion of reactive metals,** which has the potential for expansive chemical reaction and generation of hydrogen gas. Where practicable this reactivity should be removed before packaging, however, reduced temperatures are beneficial to control these effects. Experimental work which has demonstrated that mechanical 'shocks' to packages [47] may disturb protective corrosion products leading to short-term enhanced corrosion rates until the corrosion layer reforms.

(b) **Internal cementitious reactions**, where these may lead to gross swelling or shrinkage of the wasteform. Good encapsulant formulation, and long-term inactive development trials, should reduce the risk.

(c) **Radiolysis** of sensitive organic materials, which may break down into reactive species. Segregating sensitive packages in areas of lower dose is a potential method to mitigate the effect.

(d) **Carbonation** of cementitious encapsulants and concrete containers [35], which will change the wasteform properties, such as gas permeability and pH buffering capacity, over time. The implications from carbonation, if any, are context specific.

(e) **Microbial action**, in wasteforms where the pH is not uniformly high and in the presence of microbial nutrients, may result in gas generation and formation of reactive species. Reduced temperatures and low moisture levels may control microbial activity.

3.3.3 Evaluation of package evolution toolkit

The following comprises a toolkit[TK5] of models which may establish package evolution:

(a) Gas generation

It is recommended that Store Operators use one of the existing standard tools to predict gas generation arising from the three most relevant processes: metal corrosion, microbial degradation of organic materials, and radiolysis. For example, MAGGAS [D] [48], which was endorsed by the NWRF for its industry-wide suitability in 2009. A dataset of corrosion rates, based on extensive experimental research and measurements over the last few decades, is provided in Reference [49]. Other suitable models are also available.

Such models are also valuable in helping to determine suitable ventilation rates when applied with Computational Fluid Dynamics (CFD) techniques - see subsection 4.3.3. In principle, the models could also be used as a diagnosis tool to help identify any unusual patterns of gas generation or explore emplacement approaches to inform underpinned future management practices - see subsection 5.2.

(b) Wasteform expansion

RWMD has developed tools to estimate the effect of wasteform expansion caused by the formation of corrosion products. Depending on the strength of the wasteform, and container design, it has been estimated that 10-25% volume expansion, could be accommodated by thin-walled stainless steel containers before rupture. However, other safety functions, such as handling and stackability, may be affected before this point this work should be utilised to frame package performance considerations.

(c) Localised corrosion

RWMD is developing a prototype model to predict localised corrosion and SCC of stainless steel containers during interim storage and the operational period of a GDF. It is recommended that Store Operators maintain a watching brief on its development, as the model has the potential to be a useful tool for existing and planned stores with stainless steel containers.

3.4 Lifetime Package Care and Management Approach

A good package care approach is outlined in a report [50] and provides a framework for Approach A6. A6 is based on the premise that effective waste package and container care should start well before import into a store; see GP11 and GP12. While the focus is on packages based around austenitic stainless steel containers, A6 is applicable more widely. Key stages considered, across the lifecycle up to import into a store, include:

- manufacture of container;
- storage of container at manufacturer's site;

- transport to site;
- receipt of containers at site;
- storage and inspection prior to use;
- repair of damaged containers;
- handling, filling and immobilisation as appropriate;
- cross-site transfer of package to the store.

The following practices are highlighted:

(a) Waste containers should be kept dry, away from corrosive chemicals and protected from contamination by chlorides, grease, dirt and dust. Containers should remain wrapped wherever possible using non-halogenated plastics. If any material is deposited on the container it should be removed as soon possible to avoid the potential for corrosion.

(b) Target waste package surface chloride concentration should be well below the maximum values considered in the store's environmental control, see subsection 4.3. If the surface chloride level is above the target level cleaning will be necessary using chloride -free detergent solutions, followed by a demineralised water wash, until the required degree of surface cleanliness has been achieved. The containers should then be thoroughly dried and promptly sealed in a suitable non-halogenated plastic covering. A chloride-free desiccant in the space between the waste container and the plastic covering should be used.

(c) Lifting and handling of stainless steel containers should, where practicable, use equipment made from corrosion resistant materials especially where these may contact the package directly. Ferrous particles from carbon steel tools or handling equipment can become embedded in the container surface and suffer corrosion. The presence of corroding ferrous material may initiate corrosion of the underlying stainless steel and make it more difficult to assess whether corrosion of the stainless steel itself might be occurring.

(d) For carbon steel and cast iron containers lifting and handling procedures should minimise the potential for scratches and damage of any corrosion protection system which may be applied.

(e) The use of adhesive films on the container surface such as packaging tapes and labels, should be avoided, since this may leave residue which is difficult to remove and lead to contamination with organic material which may favour the development of microbes.

(f) During transport and on–site transfers precautions should be taken to protect the packages from physical damage and exposure to de–icing salt as these typically contain high amounts of chloride. Ideally, the choice of de-icing salt on a site should exclude the use of specific salts such as sodium chloride and magnesium chloride, where import of these salts may have an impact on the store environmental control. Typically this might be most relevant for the import of shielded containers over salted roads, or use of transportable equipment used to access (unshielded) stores.

3.5 Innovations toolkit

The following waste-package initiatives[TK6] are noted as potentially influencing future storage systems. Store Operators planning new stores should consider the current status of these to inform decision making:

(a) Management

- direct disposal of waste packages, which could reduce the volume for interim storage or the time necessary to maintain packages in interim storage, if a disposal facility was available in the near term;
- decay storage opportunities to result in LLW packages;
- improved implementation of the waste hierarchy principle, with segregation of components for reuse, recycle and prompt disposal as Lower Activity Waste (LAW).

(b) Processing

- including thermal treatment and dissolution. Both processes which could reduce the chemical reactivity and volume of wastes, but might result in packages with higher specific activities and shielding requirements.

(c) Encapsulants

- use of alternative encapsulants, tailored to the waste material to reduce reactivity and potentially reduce internal corrosion and gas generation during storage;
- use of additives such as superplasticisers to improve the workability of encapsulants.

(d) Containers

- use of steels with enhanced localised corrosion and SCC resistance, such as duplex grades;
- use of ‘flexible’ container designs which minimise the need for size reduction of raw waste components, but may require more flexible store lifting capability.

4. Store Performance and Design

This section comprises of six good practices, four approaches and six toolkits to promote robust store performance and design. It includes guidance on:

- Functions and purpose of a store for waste packages
- Current standard store designs
- Summaries of regulatory requirements
- Fundamental design requirements and system components
- How to define store longevity from life-limiting features and components
- Key factors to consider when developing environmental controls
- Setting robust operational limits and conditions

The primary function of a waste package store is to protect workers, the public and the environment from hazards associated with the interim storage of waste packages until they are exported. This function may be conveniently divided into two components:

(a) Maintain the waste packages through:
- provision of safe, secure, reliable and monitorable storage space for packages;
- preserving the package safety functions;
- ensuring the continued operation of handling, monitoring and other equipment;
- ensuring the integrity of key components of the storage system;
- retaining knowledge and records of the wastes, equipment and infrastructure;
- retaining the ability to promptly retrieve packages for export.

(b) Protect workers, the public and the environment through:
- containment of radioactive material;
- protection against ionising radiation so as to ensure doses are ALARP;
- protection against criticality, where appropriate.

4.1 Store Design Approach

Approach A7 provides key factors to identify a suitable outline store design, see also Figure 6, including:

(a) **waste package derived requirements**; see Section 3. The design must cater for the number of packages expected and manage the associated hazards such as shielding requirements. Where there is uncertainty in the capacity required then designs that ease future extension of the store should be considered. For example, the control room, offices and maintenance areas could be located at one end of the facility, enabling the vault to be extended more easily if this became necessary;
(b) **existing basic designs** to act as a template for the design; see subsection 4.1.1;
(c) **fundamental store design requirements**; see subsection 4.1.2;
(d) **system components requiring up-front consideration**; see subsection 4.1.3.

4.1.1 Current designs

There are several basic HAW stores designs[TK7] used in the UK and overseas [51]. These designs strongly influence the tools which are applicable to manage the waste packages, and hence it is important to consider the designs, and their constraints, when establishing a design to take forward. A major differentiator between the designs relates to the shielding requirements necessary, and hence is strongly influenced by the characteristics of the waste packages as previously described in Figure 6. The basic designs of stores are identified as:

(a) Stores for Non-contact Handleable Packages:

- **Vault designs**, with packages stored in flexible bay areas and shielding an integral part of the store design;
- **Charge plug**, with packages stored in fixed vertical arrays and shielding an integral part of the store design;
- **Overpack**, with packages stored in and shielding predominately provided by thick–walled overpacks.

Such stores allow only restricted operator access, and with the exception of overpack designs may limit ease of maintenance, monitoring and inspection of the storage system.

(b) Stores for Contact Handleable Packages:

- **Vault designs**, with no additional shielding necessary from the store structure compared with the examples above;
- **Hangar-type** with sheet metal walls and roof constructed over a load bearing and waterproof floor.

Such stores allow operator access to fill the store and also undertake more readily maintenance, monitoring and inspection of packages and store features.

A further consideration is the use of stillages, which may be used to stack packages efficiently. These are used widely in the UK. Their potential deployment should be a design consideration, and treated as a component of the store's infrastructure and a potential life-limiting feature - see subsection 4.2. However, it is recommended that stillages be well managed before import into the controlled store environment in an analogous way to packages - see subsection 3.4. They should be designed to be compatible with a suitable transport container as necessary.

4.1.2 Fundamental requirements

The most significant design discriminators that should be noted in determining the outline store design, include:

(a) **Location**. The store should be sited above groundwater levels, not in flood plains, and ideally situated so as to facilitate future expansion if required. Coastal locations, in particular, may require consideration of chloride deposition rates. See subsection 4.2.2.

(b) **Hazards**. The design must take due account of all foreseeable hazards relevant to the site [52,53]. Notably, these include climate change effects [D] such as sea level rise, see Reference [51], and tsunami. The design of the facility should prevent in–leakage of water. See subsection 4.2.2.

(c) **Regulatory and legal requirements**, including:

- **Health and safety**, including nuclear safety. For example, the Construction (Design and Management) Regulations 2007 (CDM) [54], see also HSE guidance on its implementation, which require clients, designers and contractors to consider health and safety during the construction, use, maintenance and demolition. Store designers must make adequate provisions to ensure that store and associated equipment can be safely maintained. The design of a store should be carried out in accordance with good engineering practice and focus on the primary need of the store to manage the waste packages.

- **Environment**. For example, minimising carbon footprint, waste hierarchy, avoiding secondary wastes, authorised discharges and preventing animal ingress. Consideration should be made of the eventual need to decommission the facility [55] and minimising its impact [32].
- **Security**. For example, measures outlined in the ONR's Civil Nuclear Security (CNS) 2010 Technical Requirements Document [19], which is soon to be superseded by National Objectives Requirements Model Standards (NORMS). Stores must incorporate security measures that meet the model standard described in extant security guidance. These measures are intended to provide 'defence in depth' so an intruder can be detected and intercepted in good time. Thus a combination of physical measures will be needed, although the exact requirement will depend on the physical properties of the store, the storage medium and the inventory held. Operators must confirm the categorisation of the inventory and carry out a vital area assessment to identify the standard they will be required to meet. The design must take account of likely changes to security arrangements on the site as a whole while the store is operational. They are advised to discuss their plans with the relevant ONR-CNS site inspector at the earliest opportunity, see GP1, to ensure these are acceptable and to see what impact the plans may have on existing security arrangements at the site. It is recommended that the applicable security standards and measures to be implemented are agreed with ONR-CNS at an appropriate stage in the design process to avoid the additional costs of retrofitting.
- **Transport**. For example, consideration of access to rail heads and/or suitable road network for compliance with extant Transport legislation.
- **Planning**. It is recommended that planning constraints, which may impact on the import schedule of a GDF, or seeks to restrict the import of packages, be managed strategically; see GP13.

(d) **Strategic and economic factors**. All future designs should be based on the need for the store to be part of an overall storage asset in the UK and compatibility between different package designs should be considered where practicable. Consideration of opportunities to consolidate package storage, potentially at other licensed sites, and developed as part of a wider stakeholder consultation process should be made when consistent with government policy, regulatory requirements, and shown to be cost effective.

4.1.3 Significant system components

The principal system components which will benefit most from upfront consideration include:

(a) **Ventilation**. The need for a forced ventilation system should be assessed given its significance. Comprehensive Guidance '*An Aid to the Design of Ventilation of Radioactive Areas*' is available [56]. See also subsection 4.3.3e.

(b) **Environmental monitoring systems**. Monitoring systems and alarms will need to be provided to record normal conditions and detect off-normal conditions. Depending on storage philosophy and environmental control approach, monitoring may include parameters such as air temperature, relative humidity, chloride levels, build-up of flammable gases and water ingress. See subsection 6.3.2.

(c) **Import and export infrastructure**. This includes the need for handling equipment (e.g. cranes, forklift trucks) with the capability to deliver adequate throughputs of packages and upgradeability to accommodate other package designs if necessary in the future. The export facility must be capable of interfacing with the transport system design set out in the Generic Transport System Design for a GDF as appropriate. See subsection 5.1.

(d) **Emplacement approach**. The design should consider the practicability of package emplacement approaches with due consideration of package inventory and planned package arisings. However, the safety of the store, and hence its design should not be dependent on a particular configuration of packages. See subsection 5.2.

(e) **Storage system inspection and maintenance**. The design should cater for monitorability of the storage system, and provide a proportionate amount of space, e.g. based on the package categorisation, for intervention if packages evolve in an unexpected manner, including space for overpacks and quarantine areas, and provide maintenance bays for cranes and other life–limiting components as appropriate. See GP14 and subsections 5.3.4 and 6.3.

4.2 Store Longevity Approach

Approach A8 comprises the following steps to determine the store longevity and assess its adequacy of both existing and planned stores:

(a) establishing the target design life - see subsection 4.2.1;
(b) identifying the life-limiting features - see subsection 4.2.2;
(c) establishing appropriate quality controls - see subsection 4.2.3;
(d) considering the need for refurbishment and replacement - see subsection 4.2.4.

4.2.1 Target design life

For new stores, the design life should typically be at least 100 years and any requirement for store replacement should be avoided. For any existing stores where the design life does not meet this design target, consideration should also be given to store refurbishment or transfer of packages into a modern store [1]. If it is proposed to use an existing structure, modified as appropriate, as a store, it should be demonstrated that the structure meets modern construction standards and the materials chosen for any modification work are appropriate and the resultant store is consistent with a design life target of at least 100 years.

4.2.2 Identifying life-limiting features and components

In order to assess the longevity of an existing store or identify detailed design criteria for a future store it is necessary to consider the store's life-limiting features and components [51]. Once these are identified this can be used to inform the maintenance and refurbishment schedules. See GP15.

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Generic life-limiting features and components[TK8] can be separated into those related to the design, management and continuing operation of the store and equipment.

(a) Life-limiting features relating to the **design** of the store and its equipment include:

- Design life, which should include consideration of the external factors such as: floods, earthquakes, tsunami, strong winds, climate change, malicious actions, aircraft impact, snow/ice, animal action.
- Siting requirements, in so far as they affect the external factors listed above, and:
  - storage capacity
  - local demographics
  - hydrogeological properties.
- Regulatory and stakeholder views, including:
  - planning and permitting issues
  - stakeholders' perceived environmental and safety considerations
  - socio-economic factors and cost issues
  - changes in regulatory requirements.

(b) Life-limiting components relating to the **continued operation** of the store and its equipment include:

- Structural integrity of the facility, which may be affected by:
  - subsidence and settlement
  - concrete degradation, strength, hardness and carbonation
  - corrosion of concrete reinforcing bars
  - elements, such as floors, to bear loads,
  - elements to exclude water and control inadvertent surface water deposited on the floor
  - integrity of external cladding.
- Operation of plant and equipment, including:
  - general obsolescence of components and replacement parts
  - package handling equipment
  - lighting
  - smoke detectors and alarms, fire suppression systems
  - physical protection systems
  - electrical systems
  - communication systems
  - passive or active ventilation and/or heating systems
  - auxiliary systems, including water supply, drainage, gas and compressed air.

(c) Life-limiting features relating to the **management** of the store and its equipment include:

- Knowledge management issues, see A25, including:
  - availability of staff with appropriate skills, knowledge and experience
  - organisational learning and knowledge capture
  - records management for waste packages, environment, store equipment and store maintenance.
- Security.

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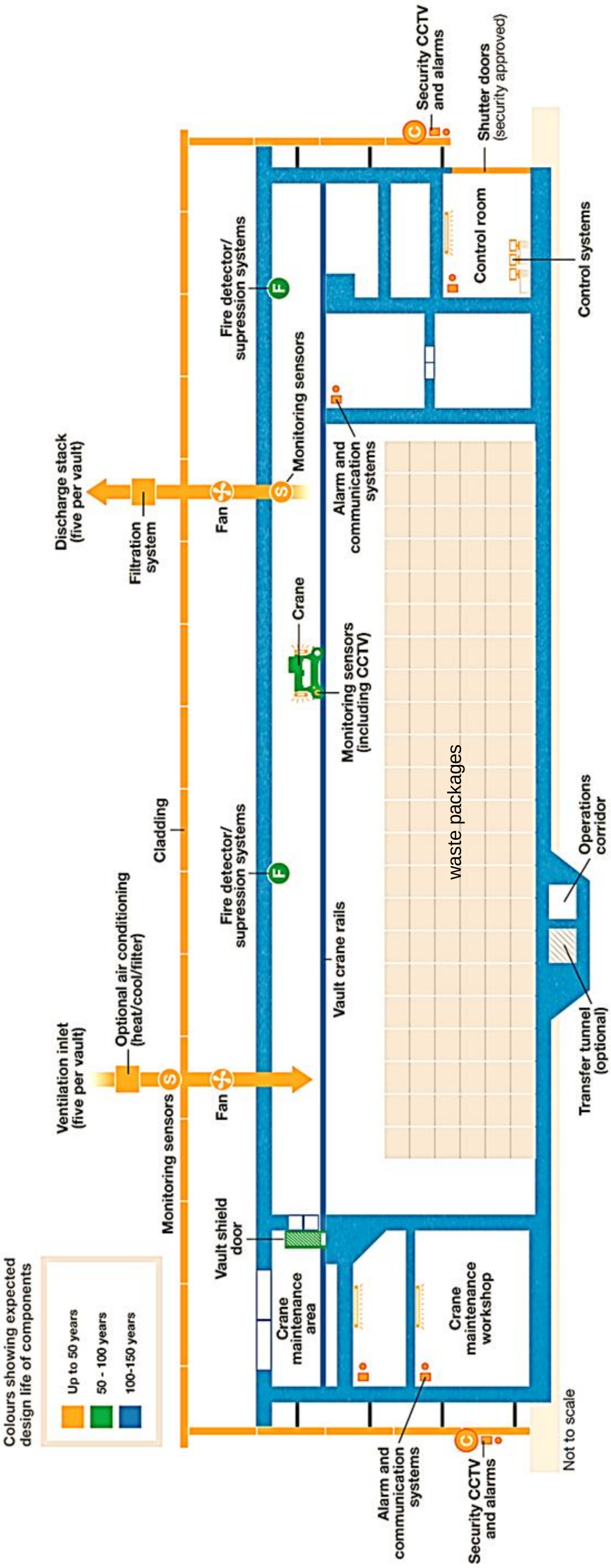

Figure 9 **Representation of a Shielded Vault Store with Component Lifetimes**

4.2.3 Establishing Quality Standards and Controls

All life-limiting features should be subject to appropriate quality standards and control. For example, use of appropriate concrete grades, where levels of chlorides and other components within the mix during construction and level of penetration post construction, is a key component to meeting the design life. Provision can also be made to enhance the quality of design and increase design life by, for example: provision of additional concrete cover over any rebar; use of high performance concrete; designing and constructing the structure according to the relevant codes with consideration given to reducing design crack width limits; provision of additional safety margins; and the use of stainless steel reinforcement.

4.2.4 Refurbishment and Replacement

Not every component in a store need last for the whole design life. At the design stage it is possible to plan to replace or refurbish various components periodically and to include specific features to enable this work to be conducted. It is considered relatively straightforward to consider replacement and refurbishment of building envelope fabrics, external ventilation systems and power supplies, but potentially considerably more complex for cranes and equipment within the active area for some store designs, control systems, software and major reinforced concrete or structural steelwork building structures to be replaced and/or refurbished. Figure 9, taken from Reference [51], illustrates the components of the store that would be expected to remain in place for a full design life of at least 100 years, and the components that would need to be maintained and replaced. Replacement of complete stores should be avoided where practicable [3].

The store longevity may be defined by the life-limiting feature with the shortest lifetime and which cannot practicably be replaced or refurbished. If the store longevity is lower than the target lifetime, then for planned stores the design of the storage system should be reconsidered, or other opportunities be explored to transfer the packages elsewhere.

4.3 Environmental Control Approach

Approach A9, as outlined in this subsection, should be considered for both planned and existing stores given the fundamental importance of the store environment - see Figure 4.

A9 comprises the following steps:

(a) setting control objectives, see subsection 4.3.1;
(b) identifying constraints, see subsection 4.3.2;
(c) identifying which parameters to control and how, see subsection 4.3.3.

4.3.1 Objectives

The overall objective should always be to protect the package and the store's life-limiting components over the period of storage. This will usually mean:

- avoiding extremes of heat and cold;
- avoiding bulk condensation, that is keeping the temperature above the dew point. Where control of contaminants cannot be assured, it is also important that the RH is maintained below or sufficiently above the deliquescence point of any contaminant salts on sensitive materials. It is important that cycling of wetting and drying events -

see GP16 - are avoided, since, in the presence of contaminant salts, such cycles of are likely to maximise the probability of initiating corrosion processes as any salt solutions become concentrated as drying occurs, or dried salts initially re-dissolve;

- controlling potential contaminants, for example aerosols or biological residues;
- providing homogeneous environmental conditions spatially through the store;
- considering issues associated with **transient conditions**, for example when packages are imported into or exported from the store.

Once these generic needs are considered, store specific OLCs should be derived that take account of the store's specific context - see subsection 4.4. For example, where overpacks are used, the environment within the overpack should also be considered and suitable controls established alongside those for the main store. For such systems, there may be flexibility in developing two sets of OLCs (i.e. 'internal' and 'external' to the overpacks), depending on the materials employed in the storage system.

4.3.2 Constraints

(a) the **storage system design**, should adopt a weakest link principle such that the package or life-limiting feature most dependent on environmental controls is used as the 'yardstick'. If the resulting requirements are then judged disproportionate then consideration should be made of alternative: waste processing, package designs, store design, or storage arrangements of the packages. In stores with non-contact handleable packages, store equipment may be difficult to access, and the environment controls should take this into consideration.

(b) **passive systems** should be favoured where feasible, but adopt active systems as required with due consideration of response speeds required under fault conditions. For example, Reference [20] states that it may be necessary or advantageous for some active systems to be in place. In such cases, the systems should be designed for minimum maintenance and, in the event of failure, immediate repair or replacement should not be necessary in order to ensure continuing safety of the storage system. Where active systems are adopted they should incorporate passive features, and be reliable, long lived and easily maintained. Hence, the environmental control approach needs to reflect carefully on this latitude to achieve the most appropriate end point.

(c) **maintaining disposability**, should take due consideration of guidance available from RWMD, see Reference [57], and any other future storage or disposal requirements. Any caveats noted in relevant LoCs, concerning the environmental controls, should be observed. Maintaining the environmental conditions of transportable packages, where prescribed, should also be observed.

(d) **location**, including:

- whether the site is inland, or coastal and specifically the composition of salt deposition in the locality of the proposed store - see GP17;
- the long-term trends for local temperature and relative humidity. It is also necessary to take account of potential extreme weather events, and likely future climate changes over the next 100+ years;

- prevailing winds, and ensuring that access points and ventilation systems (including orientation of air inlets) are designed accordingly, particularly if passive ventilation systems are adopted, to ensure a suitable store environment.

(e) **availability of existing site infrastructure** such as ventilation systems and its adequacy to provide suitable environmental conditions.

4.3.3 Key parameters

The following parameters may need to be controlled as part of an effective approach:

(a) Temperature and relative humidity. The following key aspects are noted:

- stores relying on steam heating may be vulnerable to cycles of condensation in the event of heating failure and should be avoided where practicable;
- the target RH of the environment should be tailored around the nature of the contaminants potentially deposited on store life-limiting features and waste packages.

Controls[TK9] include:

- passive controls reliant on the store design features;
- actively managed Heating, Ventilating, and Air Conditioning (HVAC);
- a contingency plan should be established if the primary method fails to deliver the required performance or breaks down during operation [56].

In all cases, the performance of the temperature and relative humidity controls should be established as part of the commissioning process. Off the shelf solutions are preferred to bespoke equipment so that any repairs necessary can be more readily undertaken, with a reduced potential for operator errors. Internal package stacking arrangements may affect air flow through the store and have the potential to create stagnant spots where temperature and humidity depart from ambient conditions. See also bullet (e).

(b) Moisture. Pertinent aspects include consideration of:

Internal sources, which should be controlled, but which are likely with time to diminish or at least tend towards the ambient conditions exerted by the store, include:

- the store materials, including concrete;
- waste packages where conditioned with hydraulic cements and / or encapsulation of ‘wet wastes’, and any concrete overpacks.

Other sources, which should be avoided where practicable, include:

- deployment of water based fire suppressants;
- water bearing pipes within the store;
- in-situ decontamination of containers using water. Any washing of packages in the store should be in dedicated cells, and packages dried afterwards.

External sources, include:

- migration from surrounding soil into the store's foundation or transfer tunnels, where present;
- unconditioned damp air condensing on 'cold' surfaces within the store;
- inadequate performance of guttering, roofs, or cladding or other advantageous openings leading to infiltration;
- infiltration of rainwater during import and export operations;
- equipment and materials brought into the store wet, e.g. tarpaulins with pooled water.

Controls[TK10], include:

- designing out the risk of moisture ingress;
- provide detectors, e.g. in sumps, so any ingress can be detected quickly and a plan a credible method for the prompt removal of water if required;
- proscribing practices that risk ingress, where practicable;
- effective maintenance of relevant store life-limiting components, e.g. roofs and any gutters;
- dehumidification, which is best performed on inlets to the store to prevent the possibility of collecting tritium which may have to be disposed via special routes and lead to secondary wastes;
- internal or external tanking, cladding or roof decking to raft, walls and roof respectively.

(c) Contaminants. Potential sources of chloride, and other 'corrosive' materials, should be identified and an assessment made of the potential impact on waste packages and life-limiting features. For coastal locations chlorides may be especially prevalent. The sources should be eliminated where practicable, or controlled, or accepted if shown to be of insignificant threat to the integrity of the storage system. Other types of contaminants, such as sulphates and nitrates, should also be identified, assessed and controlled as appropriate.

Internal sources include: dust, dye-penetrants, grout spills, oil, grease, paint, crayon, chalk, adhesives, graphite particles, inks, salts arising from concrete structures, radioactive contamination and perspiration from fingerprints. Presence of iron, such as carbon steel, has been observed by RWMD [45] to form superficial rusted spots on stainless steel containers.

External sources include: sea salt aerosols, combustion of fossil fuels, agricultural use of fertilisers, soil, de-icing salts, animal ingress and resulting debris such as guano - see also (d).

Controls[TK11] include:

- proscribing the use of unapproved writing media to mark packages;
- limiting practices that may result in deposition of salts onto containers, such as dye testing and direct contact;
- prescribing appropriate personal protective equipment (PPE) for use during both normal and abnormal operations;
- filtration of inlet air to prevent ingress of saline, other potentially harmful particles and microbes as necessary;
- cladding or coating the internal or external concrete store/vault walls;

- any transportable packages should be covered or moved seasonally to avoid contamination by road de-icing salts.

Irradiation of atmospheric nitrogen, oxygen and water, is a potential process for the formation of nitric acid, which may accelerate corrosion of some materials. Monitoring and the use of corrosion resistant materials in high radiation areas are recommended.

(d) Microbial and animal activity. It is recommended that, as far as is reasonably practicable, preventative measures be adopted to minimise the risk to the storage system, noting that microbes can also be transported as airborne particles.

Potential controls[TK12] include:

- avoiding surface contamination by organic nutrients, such as adhesives and debris arising from animal activity such as guano;
- keeping wastes and waste packages under controlled light conditions will eliminate the possibility of algal growth which is a typical initiating event in microbial colonisation [43];
- maintaining a low RH, and certainly avoiding condensation events;
- ensuring the store design takes appropriate account of preventing animal ingress especially aerially mobile animals such as birds, bats and insects;
- prompt removal of any animal ingression while observing relevant legislation for protected species [D].

(e) Ventilation. Relevant considerations include:

- using CFD modelling to develop a fit for purpose approach to avoid 'stagnant spots' and environment heterogeneities; and avoids accumulation of any flammable gases, e.g. when combined with output from computational tools, such as MAGGAS, see subsection 3.3.3. The build-up of other gases involved in atmospheric corrosion of metals, e.g. nitrogen oxides, sulphur oxides, hydrogen sulphide, should also be controlled as far as practicable. Deployment of modular units to provide uniform conditions across the store may be considered;
- recirculation of air should be considered in the design of the ventilation system to limit the intake of 'fresh air'. This could reduce operating costs, and would ensure lower intake of contaminant aerosols and provide more stable temperature and relative humidity but may raise issues in terms of accumulation of hazardous gases;
- ducted mechanical air systems may lead to negative pressures and may promote infiltration of external (unfiltered) air. Poor store maintenance or design could also result in uncontrolled pathways forming. Slight positive pressures would be beneficial;
- air outlets may also need filtration to scrub radioactive gases or prevent infiltration if the ventilation system were to fail. Appropriate filters should be matched to particulate sizes, e.g. HEPA or coalescer.

4.4 Environmental OLC Development Approach

Approach A10, set out in this subsection, describes steps to establish a robust set of environmental OLCs with which to maintain the storage system in a safe state. A10, which should be applied in parallel to A9, comprises the following steps:

(a) establishing which OLCs parameters to prescribe - see subsection 4.4.1;
(b) establishing robust limits - see subsection 4.4.2;
(c) maintaining set OLCs - see subsection 4.4.3.

4.4.1 Defining parameters

It is recommended, as a minimum, OLCs be set for the key environmental control parameters; these are: RH, temperature and potentially corrosive contaminants such as chlorides - see GP18. Whereas, the significance, and hence any latitude concerning their setting, may vary between different storage systems designs, these parameters are considered to usually be the most significant to waste package performance and life-limiting features.

Operationally ‘dew point’, that is the highest temperature at which the relative humidity would be 100% resulting in surface condensation with all other factors being equal, may also be used as an OLC. Hence, the bigger the difference between the dew point and actual temperature the better. However, care needs observing as salt contaminant on surfaces may lead to deliquescence in conditions of RH below 100%.

In theory, each of these parameters could be independently controlled to virtually exclude the possibility of potentially deleterious corrosion and other evolutionary processes. However, in practice all three parameters should be managed in concert to provide a practicable solution and defence in depth.

Additionally, the Joint Guidance [20] states that OLCs should be considered for other parameters and factors; these include: heat generation from packages; gas generation which may present hazards such as fires; radiation protection aspects; and criticality. Such consideration is likely to be highly context specific.

4.4.2 Setting OLCs

It is recommended that when setting OLCs, Store Operators apply an approach analogous to A1, and hence that setting OLCs should be considered, partly, as a risk management endeavour. Thus, OLCs should be set with consideration of:

- a de-minimus level of risk such that observance of the OLC, if practicable, would essentially result in a very low risk that the storage system would not perform as safely as expected due to the environmental conditions;
- a tolerable level of risk such that observance of the OLC would be result in an acceptable level of risk throughout, although contingencies may be necessary and the system subject to additional monitoring and inspection if necessary;
- a time-limited level of risk which may be acceptable during transient conditions and would require, ordinarily, high levels of monitoring and inspection with credible and rapidly deployable contingencies.

The OLCs should be established for the waste package and or life-limiting feature most vulnerable to the planned environmental conditions, and will usually be determined by the material of construction of that component.

Illustrative environmental OLCs for a storage system dominated by ‘exposed’ 316L, with the possibility of contamination by chlorides [D], is shown in Table 2. This material is the most widely used container material and the largest body of data exists for this and similar grade stainless steels in the literature and under most relevant conditions. As described in subsection 3.3.1, the values are considered to be cautious, being based on experimental studies under relatively aggressive conditions. Further, where temperature ranges are described, the limits referred to are determined for the higher end of the range and are hence cautious. It is recommended that cycling of conditions, as indicated by the bands below, be avoided - see GP16.

Table 2 Representative risk based OLCs for storage system with 316L based packages

		Temperature (T/°C) [Cl/ $\mu g\ cm^{-2}$]				
Relative humidity (RH)		<-10(a)	-10 to 10	10 to 30	30 to 50	>50(b)
	<~15% below nominal deliquescence point of dominant Cl contaminant(c,d)					
	~15% below → ~15% above nominal deliquescence point of dominant Cl contaminant(c,d)		<[10]	<[1]*	<[0.1]*	
			>[10](e)	[1-10]*	[0.1-1]*	
				>[10]*	>[1]*	
	>~15% above nominal deliquescence point of dominant Cl contaminant→90%(c,d)		<[10]	<[1]	<[0.1]	
			>[10](e)	>[1](e)	>[0.1](e)	
	< 90%(c) in absence of Cl contaminants		[0]	[0]	[0]	
	>90%(f)					

Key:

De-minimis - ideal conditions to avoid localised corrosion

Tolerable - moderate risk of pitting corrosion

High - risk of SCC; only potentially tolerable as a transient condition without periodic cycling

Notes:

(a) Potential metallic-phase changes, at low temperature, *might* preclude such an approach for 316L with respect to providing adequate safety functions under, for example, accident conditions. Hence, it is not currently recommended.

(b) Limited data, hence cautious setting of maximum temperature recommended.

(c) Unacceptable desiccation of waste packages and store features may define a lower OLC for RH, but no data is presently available to quantify a minimum level.

(d) In presence of chloride salt contaminants RH should be set below the appropriate salt deliquescence point (ideal) or *well above* (tolerable) as it would generate relatively dilute solutions, which are less corrosive.

(e) Care must be taken to control the quantity and nature of contaminants likely to deposit on the surfaces to ensure any deposited salts are not excessively concentrated.

(f) An upper limit for the RH is recommended, in part, to reduce the risk of MIC.

* Following assessment of the latest findings by RWMD the possibility of raising these limits is being further reviewed and discussed with stakeholders.

It is noted that materials with superior corrosion resistance, such as duplex grade 2205 [D] will provide greater flexibility and wider tolerances of OLCs due to their greater resistance to chloride induced SCC, and improved resistance to localised corrosion [39]. Similarly, for DCICs, and other thick walled iron based containers, the presence of salt contaminants is likely to be less significant than for stainless steel [41].

4.4.3 Maintaining OLCs

Given the uncertainties associated with long-term performance of life-limiting components and waste packages, and the expectation that current practices are overly cautious, it is recommended that all stores share their ongoing environmental condition monitoring against their established OLC. With time this may provide justification to change OLCs based on collective experience. An approach to modify environmental conditions, as necessary, is described in subsection 5.4.

5. Storage System Operations

This section comprises of seven good practices, eight approaches and four toolkits to promote robust operation of the storage system. It includes guidance on:

- ➢ Package movements during import and export
- ➢ Package configurations as part of an emplacement strategy
- ➢ Maintaining packages, life-limiting features and the storage environment
- ➢ Avoiding package reworking
- ➢ Reworking techniques to restore package safety functions if necessary
- ➢ Changing the store environmental conditions as necessary
- ➢ Extending store lifetimes

5.1 Package Movements

5.1.1 Import approach

Approach A11 describes steps to consider during the import phase of packages, e.g. from a packaging plant, into a store. These are:

- complying with international requirements for any public domain transport [10];
- complying with local on-site transfer requirements;
- making despatch and receipt checks against store WAC, see below;
- handing over of package records;
- managing any out-of-specification packages, see below and subsection 5.3;
- establishing the package baseline condition, see subsection 6.2.

Packages should not be despatched from packaging plants or donor stores unless shown to meet the receiving store's WAC; see, for example, GP19. Temporary storage of packages might be required before import to manage throughput or an effective emplacement approach. However, appropriate environmental conditions should be maintained to protect the package under any such temporary storage arrangements and be consistent with the store's OLCs and WAC. The Store Operator should ensure all packages received are subject to a current final LoC with any conditions being understood and complied with. Where packages are not subject to a final LoC, the Store Operator should ensure that credible plans are in place to complete the development of an appropriate disposability case.

Any packages which are out-of-specification may still be acceptable into the store, where for example the store has capability of dealing with such packages, or where there are overriding safety implications, e.g. at the donor facility. Generally, it is expected that packages arising from an extant packaging plant would be more suitably and safely reworked, if required, at source. Acceptance of any out-of-specification packages must not compromise the store's safety case following any appropriate modification as appropriate. Legal and facility requirements, for transport, storage or disposal, may also change over time potentially requiring package rework to assure compliance.

5.1.2 Store operations approach

Approach A12 outlines steps to consider regarding package movements during the operational phase of the store. The movement of packages should be minimised as far as is reasonably practicable to reduce the risk of accidental collisions or packages becoming 'stuck' in lifting gear which is especially relevant in stores with remotely handled packages. In particular, the need to consider retrievability of 'target' packages for monitoring and inspection, without undue requirement to access large numbers of spectator packages, should therefore be optimised.

After import, drivers for package movements include:

- package inspections and monitoring, see GP20 and subsection 6.3.1;
- store maintenance, e.g. to access life-limiting components;
- demonstrating lifting equipment is still functioning safely;
- maintaining operator skills and training and demonstrate SQEP;
- emergency response;
- regulatory requirements;
- waste receiver audits;
- export.

5.1.3 Export approach

Approach A13, outlines steps necessary to export packages to another off-site store or to a GDF:

(a) Pre-consignment planning, including:

- inspection of the waste package to ensure that it is suitable for *transport* against IAEA regulations and the Transport Safety Case - see also GP9;
- confirming that each package is acceptable to the disposal facility operator, or next store, and handshake arrangements including the status of the LoC and consistency with WAC;
- ensuring approved security measures are in place, including the Transport Security Plan;
- additional substantiation or rework be carried out if the above cannot be assured;
- confirm export throughput, status of lifting equipment, and access potential for interference such as possible maintenance outages;
- develop and implement a communication plan with key stakeholders and Regulators, e.g. with respect to route -planning, transport and security.

(b) Implementation, including:

- checks of the SWTC, or equivalent, on receipt, including identification, confirm empty and not contaminated;
- provide suitable control of transient conditions such as temperature, and contaminants;
- re-confirm that each package is acceptable to the disposal facility operator, or next store, before transport and that any modifications made following pre-consignment planning are approved by the receiver;
- completion of package records for the store and receiving site.

5.2 Package Emplacement Approach

Approach A14 outlines steps to optimise the operation of the storage system through a planned configuration of packages within the store. However, any *requirement* for a particular package configuration to assure safety should be minimised through good package and store design - see Sections 3 and 4. The configuration should be justified within an emplacement plan, which should also note the presence of any configurations of packages to avoid. It is noted that existing vault stores may have extremely limited capability for significant reconfiguration of packages. Additional information is provided in a supporting Reference [58].

(a) Assessment of benefits, pre-import planned configuration

For stores yet to receive packages, a planned emplacement approach can be used to *improve* the operation of the storage system, during filling, include package configurations that for example:

- enhance shielding and security objectives;
- improve access for monitoring and inspection of targeted packages;
- reduce the overall life-time package movements, e.g. through specific layouts of aisles and package configurations;
- reduce some package evolutionary processes, e.g. reducing the irradiation received by 'targeted' packages as may be shown to be beneficial through the LoC assessment process;
- where relevant, mitigate the risk of cross-contamination between conditioned waste packages and any containerised waste pending conditioning;
- enhance the effectiveness of the environmental controls.

The benefits should be compared with any identified detriments, for example, the potential need to buffer store packages to enable a planned configuration or 'package shuffling'.

(b) **Assessment of benefits, post-import reconfiguration**

Following import of packages, there may be benefits from reconfiguration of packages. For example, package configurations that:

- facilitate package maintenance and monitoring, e.g. moving a package with unexpected evolution into a quarantine area to safeguard neighbouring packages or facilitate additional monitoring;
- enhance the effectiveness of environmental controls - see subsection 5.4;
- facilitate exporting, e.g. packages planned for early export, where known, are re-assigned to convenient locations;
- improve access to store infrastructure, including ensuring acceptable operator circulation space provisions, to allow for maintenance, refurbishment or repair.

A3 should then be followed, as appropriate, with due regard of any identified detriment from package reconfiguration, e.g. from additional movements and dose to workers.

5.3 Maintaining Package Safety Functions Approach

Approach A15 outlines steps to consider with the primary objective to avoid package rework being necessary, but if rework is required that it be carried out using appropriate tools at appropriate times, as shown in Figure 10.

Rework, to restore one or more package safety function, is defined [59] as:

Any process *involving* ***physical intervention*** *of packaged waste arising from* ***deviation from the planned storage****, treatment, or intended disposal process for that* ***packaged waste****.*

A15 comprises these steps:

(a) avoiding the need for intervention - see subsection 5.3.1;
(b) assessing package evolution - see subsection 5.3.2;
(c) identifying intervention tools - see subsection 5.3.3;
(d) considering the location to rework packages as necessary - see subsection 5.3.4.

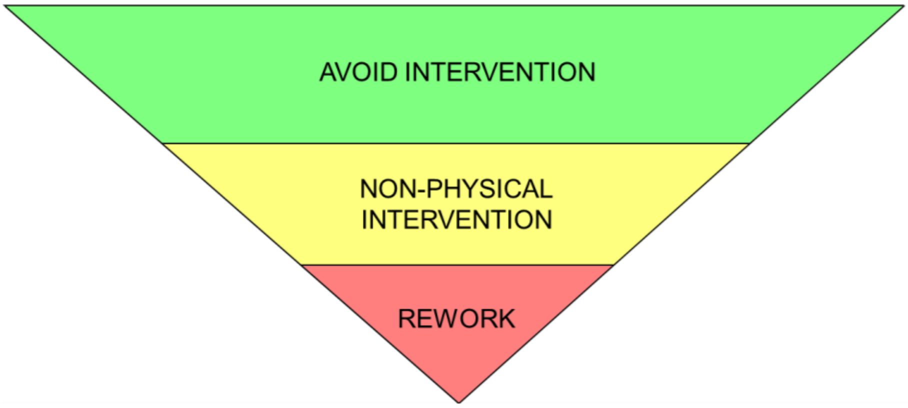

Figure 10 Package Maintenance Hierarchy

It is strongly recommended that Store Operators:

- make provision for a sentencing body to properly sentence any packages which may be considered 'out-of-specification' before and during storage - see GP21;
- provide a proportionate amount of contingency space in each store to respond flexibly to unexpected package evolution - see GP22;
- establish credible intervention plans for plausible scenarios according to the storage system context - see GP23.

5.3.1 Avoiding intervention

Store Operators should follow the other approaches and good practices where practicable, backed up by a robust assurance programme, see Section 6, to minimise the risk that packages may need to be reworked to restore their safety functions.

However, some packages might evolve more rapidly or in an unexpected manner, or the storage system might not be operated as set out in the store's safety case and as assessed in appropriate final LoCs, which if left unchecked might lead to the package becoming ‘out-of-specification’ and potentially needing rework to restore safety functions.

Packages might also become out-of-specification before receipt into the store, e.g. following packaging. While the principles in restoring such packages’ safety functions may be similar, the expectation is that any intervention or reworking would be better carried out before import into the store - see subsection 5.1.1. Guidance is provided by RWMD on the sentencing of such packages [60]; this also outlines the constitution of a ‘sentencing body’. RWMD notes the possibility [60] that as the GWPS is developed into WAC then previously defined out-of-specification packages might be redefined as being compliant with a GDF.

5.3.2 Assessment of package evolution

A1 should be used to assess the implications of (unexpected) package evolution. It is assumed that packages are subject to a monitoring and inspection regime focussed on the appropriate indicators - see subsection 6.3. However, A1 should additionally be applied across groupings of packages, to identify four potential different patterns of potential unexpected behaviour:

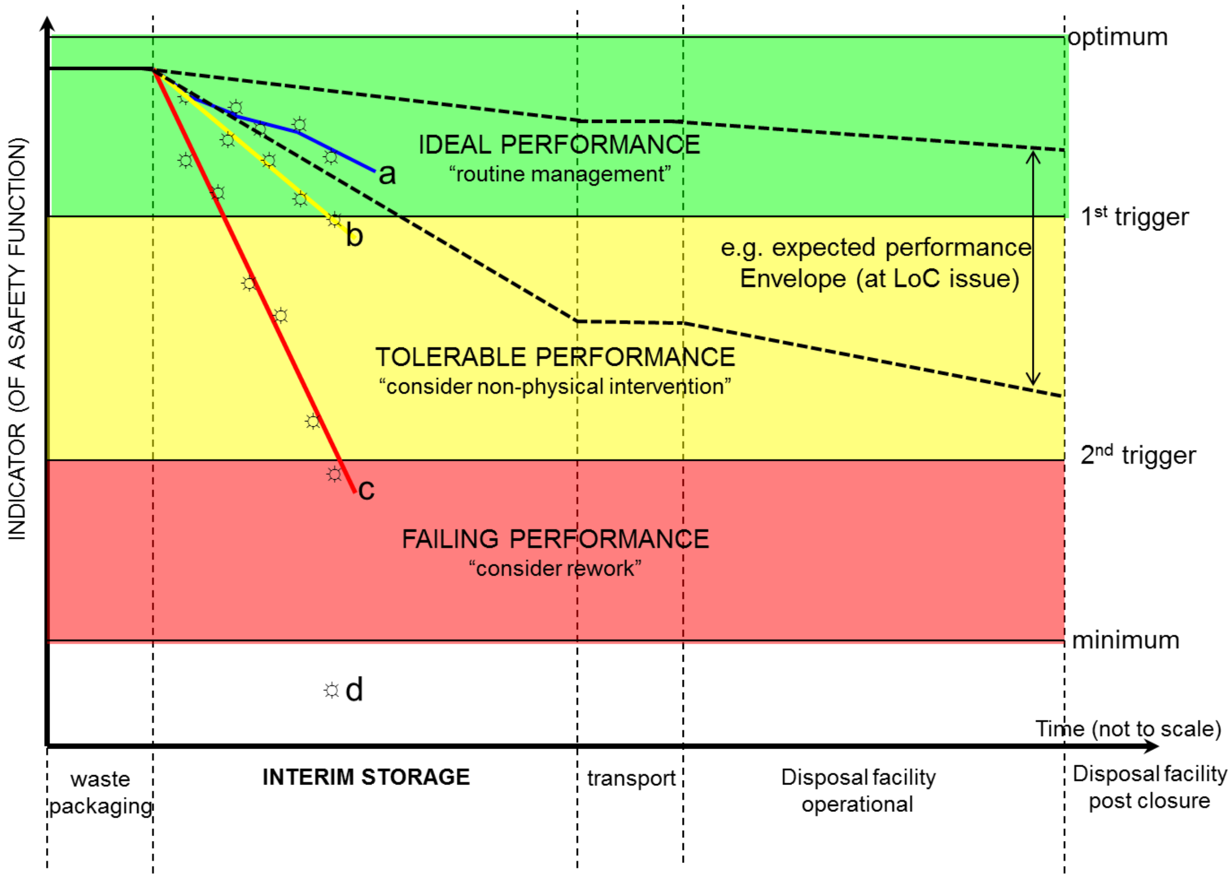

Figure 11 Hypothetical Patterns of Package Evolution

Type I one-off or sporadic packages without any obvious correlation or pattern;
Type II groups of packages with similar composition and packaging history;
Type III groups of packages with similar location in a store;
Type IV widespread throughout a store largely independent of package type or location.

This will also have a bearing on appropriate tools. For example, issues relating exclusively to Type III and IV occurrence may benefit from changes to environmental control as discussed in subsection 5.4.

The fundamental consideration concerning package evolution is the **extent of 'threat' to the relevant safety functions** required to preserve the disposability case and continued safe storage - see subsection 3.2.2. Examples of stylised package evolution are shown in Figure 11, which also includes a hypothetical 'envelope' of performance expected at the time the LoC was issued. Thus for:

Case (a) where performance has declined, is within the **ideal zone**, and within the expected 'performance envelope' established when the LoC was issued, then **'no intervention'** would be necessary.

Generally, within the **ideal zone**, the performance should be recorded and any trends identified to inform future monitoring or environmental control opportunities identifying any behaviour Types as appropriate. If downward performance is widespread - that is Type II, III or IV behaviour - and unexpected - that is outside the expected performance envelope - then non-physical intervention may be optimally deployed. Additionally, for Type III or IV behaviour, changes to the environment controls may also be beneficial - see subsection 5.4.

Case (b) where performance has evolved to be just below the 1st trigger level and is within the **tolerable zone,** but just outside the expected performance envelope, then prompt non-physical intervention should be considered to maintain safety functions in the first instance.

Generally, within the **tolerable zone**, the performance should be recorded and any trends established to identify the behaviour type. Any intervention should, in the first instance, seek to establish the cause of the performance decline as soon as is reasonably practicable - see toolkit in Table 3. Then an assessment of any implications to the safety functions should be made. Once the behaviour is understood, and the implications bounded, the timing for any further intervention if required, including later planned reworking if necessary - see Table 4 - will include consideration of the following factors:

- the gradient of any decline in performance and when 2nd trigger level is likely to be crossed with respect to the overall lifecycle;
- the extent, if any, to which the actual performance is outwith the expected performance envelope;
- whether it is defined to be 'out-of-specification' with respect to WAC;
- the number of packages and safety functions affected;
- the categorisation of the package [24];
- availability of reworking facilities - see subsection 5.3.4;

- expected export timing / or other planned package movements.

If future performance can be maintained, using non-physical intervention, then any necessary reworking to restore safety functions could be delayed until shortly before package export. For Type III or IV behaviour changes to the environment controls are likely to be necessary - see subsection 5.4.

Case (c) where performance has evolved to be just below the 2nd trigger level and is within the **failing zone,** and substantially outside the expected performance envelope, then prompt rework should be considered to restore the safety functions.

Within the **failing zone**, the performance should be recorded and any trends established to identify the behaviour type if not already. If not known, the cause should be established as soon as is reasonably practicable - see toolkit in Table 3 - and followed up by appropriately timed rework, see case (b) criteria and toolkit in Table 4, with due consideration of the current stage of the lifecycle and availability of reworking facilities to restore package safety functions. Where reworking capability is not readily available, affected packages should be moved to quarantine zones as soon as is reasonably practicable in preparation for reworking and isolate failing packages. For Type III or IV behaviour changes to the environment controls should also be carried out to control future evolution - see subsection 5.4.

Case (d) where performance has evolved to be below the minimum performance level, and indicates package failure, then reworking should be considered to restore safety functions as soon as is reasonably practicable. Proceed as for the failing zone, noting the additional safety risks implied. If, for example, the containment safety function has been lost, the implications are likely to be significant and the store may need to be operated under ‘abnormal operating conditions’. The response to such an eventuality is not within the scope of the Guidance.

5.3.3 Intervention toolkits

Factors influencing the identification of appropriate tools include the:

- number of safety function(s) affected and the performance zone(s);
- evolutionary processes involved and if cause unknown, noting the precautionary principle;
- categorisation of affected packages [24] and related hazards;
- number, location of packages affected, and category (Type I to IV);
- availability of reworking facilities - see subsection 5.3.4;
- risks from intervention versus ‘do nothing’;
- internal - see GP3 and GP21 - and external - see GP1 - stakeholder views;
- lessons learned from any similar package evolution in the UK and overseas.

A toolkit comprising of non-physical intervention tools is presented in Table 3. This includes tools which seek to maintain packages safety functions, establish underlying causes of the evolution, and/or justify that the status quo is acceptable. Tools suitable for restoring package safety functions are presented in Table 4.

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Given the anticipated rarity in encountering unexpected performance it is especially important that any event is well documented. GP1 is highlighted in this regard. The Store Operator will need to have adequate arrangements in place to determine an appropriate approach to meet these eventualities.

Additional guidance to determine appropriate tools is outlined in Reference [61]. The possibility of deploying multiple techniques in parallel and or series should be noted. The techniques are in approximate order of increasing impact and cost. Generally, the intervention tool chosen should represent the minimum impact technique that is capable of either: underpinning a permanent and potentially higher impact response, or restore the safety function. Many of the identified tools will require the availability of space within the store if not available elsewhere on site. See GP22.

The 'intervention' approaches have been classified into five categories - see GP23:

(a) **Zero Implication**. In which any action is restricted to desk studies, and expert assessment to develop an appropriate response.
(b) **Low Implication**. In which any action is restricted to collating additional physical information about package performance without contacting active packages.
(c) **Active**. In which any action requires changes to the operation of the storage system.
(d) **Non-invasive Physical Reworking**. In which any action seeks to restore the safety function(s) by direct contact with the container and/or its components but without direct contact with or changing the wasteform.
(e) **Invasive Physical Reworking**. In which any action seeks to restore the safety function(s) by direct contact with and/or changing the wasteform.

For Type I and Type II evolution, and where the cause is known, the following baseline techniques [D] are recommended:

- **In the tolerable zone** - additional monitoring to establish the 'rate of change' more accurately. If performance continues to decline, and reworking is required, and it relates to small areas of the package then localised repairs be carried out to restore the safety function otherwise 'overpack' as for a failing package.

- **In the failing zone** - overpacking is likely to be a suitable method to restore overall package safety function for a wide variety of processes at least for unshielded packages. However, it does not treat the underlying cause. It may also hamper additional monitoring and inspection. Repeated overpacking, 'Russian doll' approach, is unsustainable. Under such circumstances overpacking should only be considered as a temporary measure until a more sustainable method can be deployed.

See subsection 5.4 for suggested toolkit for Type III/IV evolution.

Table 3 Non-Physical Intervention Toolkit[TK13]

Zero Implication
Do nothing, other than note in package and store records
Justify change to safety case such as modify performance criterion
Seek concession from disposal facility operator
Modelling to predict future performance
Additional inspection of relevant inactive simulant samples
Low Implication
Additional inspection on relevant in-store dummy packages
Increase monitoring frequency on a specific package
Increase monitoring frequency for a group or type of package
Active
Introduce new monitoring/inspection capability into store
Move package to an easier accessed area of store
Move package to dedicated quarantine area - see GP22
Move package to inspection cell for targeted inspection
Remote re-assay package
Change environmental controls - see subsection 5.4
Move package to alternative store with suitable environmental controls

Table 4 Physical Intervention - Reworking - Toolkit[TK14]

Physical, non-invasive
Decontamination - removal of salts/inactive contaminants
Container repair - remote localised welding
Container repair - apply coatings
Overpacking, temporary
Overpacking, permanent - with infilling as appropriate
Replace container components such as bolts, filters, seals and/or lids
Physical, invasive - repackaging
Taking active samples from wasteform
Wasteform stabilisation, such as fluid grout / polymer injection
Re-containerise wasteform
Reconstitute package, such as through thermal treatment

5.3.4 Location of rework facilities

Store Operators should establish access to credible reworking facilities. See GP24. Possible locations for rework facilities are identified as:

- in-store - with provision for import of equipment within a reserved space of the store OR with permanent equipment installed in a dedicated area;
- on-site - with mobile facilities transported to site as necessary OR in a nearby facility such as packaging/processing plant or neighbouring store with suitable capability;
- off-site - at a GDF or other disposal or processing facility.

5.4 Maintaining Environmental Conditions Approach

Approach A16 outlines aspects to consider if package evolution exhibits exclusively Type III/IV behaviour, see subsection 5.3.2 and GP23, or store life-limiting components are exhibiting unexpected behaviour related to the environmental conditions. Regular environmental monitoring, see subsection 6.3.2, will be necessary to establish whether:

(a) the environment has been controlled in a way consistent with the adopted environmental control approach

(i) and the storage system is behaving in a way that indicates the controls are adequate then maintain the approach as long as necessary;

(ii) but the storage system is behaving in a way that indicates the controls are inadequate then the approach should be reviewed and controls established, including new OLCs as appropriate, to establish adequate performance as soon as is reasonably practicable. It may be necessary to restore safety functions of packages and store components to acceptable levels.

(b) the environment has not been controlled in a way consistent with the adopted environmental control approach

(i) but the storage system is behaving in a way that indicates the controls are adequate then seek to establish the approved conditions or demonstrate current conditions are adequate as soon as is reasonably practicable, and make appropriate changes to the safety case;

(ii) and the storage system is behaving in a way that indicates the controls are inadequate then promptly seek to establish approved conditions. It may be necessary to restore safety functions of packages and store components to acceptable levels - see Tables 3 and 4.

A toolkit[TK15] for environmental control changes includes:

- reviewing safety case and justify conditions are adequate, or may even be relaxed;
- changing the OLCs;
- providing additional dehumidification and/or heating or cooling;
- improved filtration or replace existing filters;
- changing ventilation rates;
- reconfiguring packages to improve effectiveness of ventilation system - see subsection 5.2;
- moving packages to another store as last resort noting Principle B.

5.5 Maintaining Store Life-limiting Features Approach

Approach A17 describes key considerations to maintain the store life-limiting features, see also subsection 4.2.2. It is recommended that the Publicly Available Specification, PAS55 [62], which has been developed by the Institute of Asset Management and industry representatives, be applied. PAS55, updated in 2008, provides a 28-point requirements specification for establishing and verifying a joined-up, optimized and whole life management system for all types of physical assets. Further information can be found on the PAS 55 Asset Management website.

Store facilities should be maintained and inspected to ensure that structures, systems and components are able to function in accordance with the design intent and safety requirements. This should include both preventative and corrective maintenance, including:

(a) the integrity of the storage facility and life-limiting components, for the required duration;
(b) the ability to control the environmental conditions;
(c) the ability to operate the store and manage packages;
(d) knowledge of the structure, plant and equipment.

It should be recognised that throughout the operational life it will be subject to safety case review where expected improvements will be made, see A2. For example, site life time plans, as appropriate, should include provision for regular maintenance including major refurbishment programmes such as store re-cladding if planned operational lifetimes are significant. See GP25.

It is considered good practice that an Ageing Management Programme (AMP) be adopted and maintained during storage; see for example the IAEA Report [63], which while aimed at reactors the fundamental principles are transferable. The transfer of information at various stages in the lifecycle of a facility is critical to the quality of information available for the lifetime management of the facility and, ultimately, at decommissioning. Considerable effort and cost may have to be expended in order to recreate the required supporting information in such circumstances. The existence of an effective AMP from conceptual design through to final decommissioning can greatly assist in the periodic assessment of a facility. See also Reference [64].

5.6 Extending Store Lifetimes Approach

Approach A18 outlines key considerations when seeking to extend the lifetime of a store noting that the predicted lifetime should be regularly reviewed.

Guidance [D] on techniques for extending the lifetime of existing stores and achieving design life for new stores, by the maintenance/refurbishment or replacement of life-limiting components, is detailed in Reference [51] and includes the following steps:

- correct diagnosis of the cause of any damage/failure;
- selection of a repair approach that addresses the cause;
- choice of appropriate repair materials and methods;
- management of the diagnosis and repair process;
- post repair maintenance approach supported by comprehensive records.

For each generic life-limiting component a toolkit [D,TK16] for remediation and/or replacement is described in Reference [51] taking account of various potential ageing processes which might affect the components.

6. Storage System Assurance

This section comprises of five good practices, eight approaches and seven toolkits to promote robust assurance of the storage system. It includes guidance on:

- Key components of an assurance programme
- Defining monitoring and inspection rates
- Techniques to demonstrate the system is evolving safely
- Benefits from dummy packages and inactive samples and simulants
- Benefits from periodic LoC reviews and audits
- Knowledge management and record keeping
- Maintaining SQEP resource into the future

6.1 Overview

The main objectives for providing assurance of the storage system include:

(a) demonstrating to the Store Operator and their stakeholders, including Regulators and RWMD, that the system is evolving as expected;

(b) alerting the Store Operator promptly if the system is not evolving as expected and thus facilitate improvements without undue safety, environmental or economic detriment and avoid rework being necessary where practicable;

(c) providing an opportunity to demonstrate 'strategic learning' of the performance of different storage systems to inform future store designs and current operational practices.

All storage systems should have a well underpinned monitoring and inspection approach. This should be proportionate to the 'risk' from the waste packages [24] and the operational experience of the storage system type. Innovative storage systems and stores with the most challenging waste packages should have a greater emphasis on monitoring and inspection. Should results arising from monitoring and inspection be consistent with expectations, then, with time the frequency of inspections may be reduced in dialogue with stakeholders such as the Regulators and RWMD.

To assure the storage system during interim storage, should include consideration of the following approaches, in addition to A1 - see subsection 2.1.2:

- baselining - see subsection 6.2;
- monitoring and inspection - see subsection 6.3;
- monitoring and inspection rates - see subsection 6.4;
- archiving - see subsection 6.5;
- inactive waste package simulants and samples - see subsection 6.6;
- auditing - see subsection 6.7;
- knowledge management - see subsection 6.8;
- human resources - see subsection 6.9.

To demonstrate robust interim storage arrangements the Store Operator should:

- follow these approaches and good practices to identify, develop and deploy appropriate assurance tools;

- regularly engage Regulators and RWMD to ensure the proposed and implemented tools meet their requirements;
- ensure the waste package design and proposed arrangements have been assessed through the LoC process - see also Section 3;
- adopt good engineering practices and industry recognised standards and codes during the planning, construction, operations, care and maintenance and decommissioning of the store - see also Section 4;
- feedback the findings from assurance programmes, including other relevant UK stores, into store operations - see also Section 5 and A3.

6.2 Baselining Approach

Approach A19 [65], outlined in Figure 12, describes steps to establish the baseline condition of the storage system.

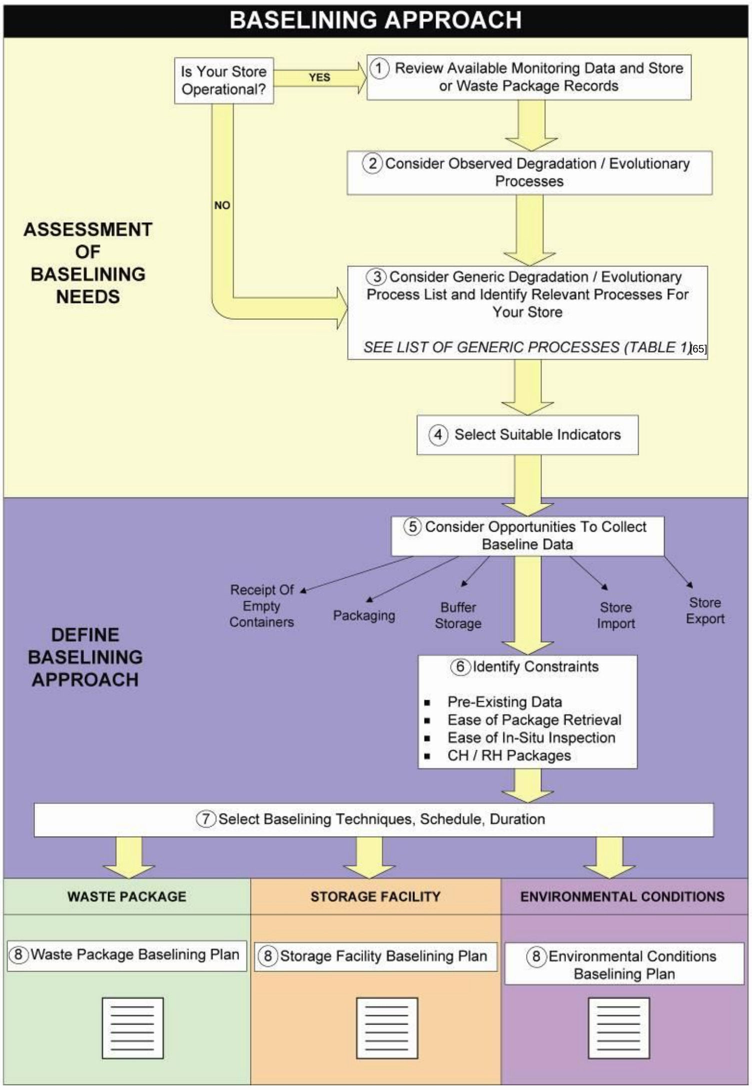

Figure 12 Schematic Representation of Approach A19

The baseline condition relates to each of the storage system components. Once established any departure from these initial conditions can be detected through regular monitoring and inspection as described by A20, and any necessary intervention can then be planned using A15 - package, A16 - environmental conditions, A17 - store life-limiting features. Thus, A19 consists of:

(a) Reviewing, for an existing storage system, available monitoring data and records and consider observed evidence to date for evolutionary phenomena for the system components. Compare this list with generic phenomena [D] described in the Guidance, information arising from engagement with RWMD, and store safety cases reviews, and amend as necessary.
(b) Identifying, for a new storage system, a list of plausible evolutionary phenomena based from generic phenomena [D] described in the Guidance, information arising from engagement with RWMD, and store safety cases reviews.
(c) Identifying safety functions and life-limiting features threatened by relevant evolutionary phenomena and prioritise these [A5,A8].
(d) Selecting suitable indicators associated with the evolutionary phenomena. Indicators for the environmental phenomena should be selected according to their significance to waste package and storage facility evolutionary processes.
(e) Identifying opportunities for baselining, considering each stage of the store and waste package lifecycle such as receipt of empty containers, production of waste packages, buffer storage, store import, store export.
(f) Identifying constraints on baselining, including relative ease of in-situ inspection of the waste packages and store building, plant and equipment, ease of waste package retrieval, availability of an inspection station, and presence or absence of monitoring data and records for existing stores.
(g) Identifying appropriate tools and timing for baselining, considering the constraints and opportunities identified above. Develop a schedule and duration for baselining data collection. A toolkit of baselining techniques[TK17] is described in Reference [66] to support Best Available Techniques (BAT) assessment.

The baseline condition for each waste package would ideally be fully established prior to import to the interim store, with opportunities to collect baselining data on receipt of empty containers, during and after production of the waste packages and during transport of waste packages to the interim store. Baselining may also be used to establish consistency with store WAC. A baseline established after import, while still valuable, may lead to uncertainty about the likely cause and rate of progress of any package evolution. This may hamper the selection of an appropriate intervention approach - see subsection 5.3.

The baseline store life-limiting features and environmental conditions are best established during store commissioning and over the first few years of operation. However, this will not be feasible for existing waste packages and stores; available monitoring data or store and waste package records should then be used, supplemented as needed by additional baselining data collection activities.

Throughput requirements may make baselining of each package impracticable using currently available technology. Measurements of a particular indicator for some waste packages could be used to establish whether existing baselining data collated at an earlier stage are still valid for the storage period. Packages that are already in storage could be baselined at their next inspection or on a campaign basis. For existing stores, the baseline for some of the store life-limiting features could be established during the next inspection. However, the baseline for store environmental conditions needs to be established over at least one calendar year.

Baselining is likely to be considerably easier for contact-handleable packages and stores containing them. However, given the importance of baselining, it is strongly recommended that all waste storage systems identify fit-for-purpose tools. See also GP26 and A3.

6.3 Monitoring and Inspection Approach

Approach A20 describes steps to establish a robust monitoring and inspection regime:

(a) **Selecting sample types**[TK18]. These include:

- (i) in-situ components of the storage system, i.e. packages - see subsection 6.3.1; life-limiting components - see subsection 6.3.2; store environment - see subsection 6.3.3;
- (ii) full scale simulants or copies of system components, e.g. 'dummy packages' held under relevant store conditions - see subsection 6.6.1;
- (iii) reduced scale simulants of system components, e.g. coupons of key components held under relevant store conditions - see subsection 6.6.2.

Additional sources of relevant information may include:

- storage system components held in other relevant stores;
- storage system components maintained in archives, see subsection 6.5;
- analogue materials either in a store or elsewhere, see subsection 6.6.3;
- use of 'canary' materials, in a store, which may be more sensitive to store conditions than the actual storage system components so as to provide 'lead times' or 'early warning';
- use of pre-aged materials so as to provide 'lead times' or 'early warning';
- deployment of modelling and theoretical studies.

(b) **Selecting attributes** to discriminate between potential monitoring and inspection techniques as part of a BAT demonstration. Recommended attributes include:

- (i) **Safety function related**, such that output information can be related to the performance of the safety functions, see also subsection 3.2.2.
- (ii) **Practicable**, such that disruption to the operation of the store is minimised and application is ALARP. Techniques employed in stores requiring remote operations should embrace 'passive' features with limited requirements for maintenance or ideally provide remote inspection capability.
- (iii) **Credible**, such that the technique has a high Technical Readiness Level (TRL) in the nuclear industry or widespread application elsewhere.
- (iv) **Predictive value** such that the information may forewarn of future issues such that any intervention required is straightforward and can be adequately planned.
- (v) **Reassurance value** such that the output utilises recognised metrics which may reassure a wide range of stakeholders.
- (vi) **Reliable**, such that false positive and false negative results are avoided.

(vii) **Interpretable**, such that any output should require limited interpretation to minimise potential human error.
(viii) **Lifetime cost**, which should be proportionate to the risks mitigated.

(c) **Selecting tools from relevant toolkits**. See subsections 6.3.1-6.3.3.

(d) **Establishing frequency of monitoring and inspections**. See subsection 6.4.

(e) **Sharing results** with other store operators, see GP27.

(f) **Feeding back** findings into operations, see A2 and Section 5.

(g) **Reviewing** approach periodically for example, as confidence in the storage system performance grows, there may be opportunities to reduce inspection rates.

A20, as applied to packages, is represented in Figure 13.

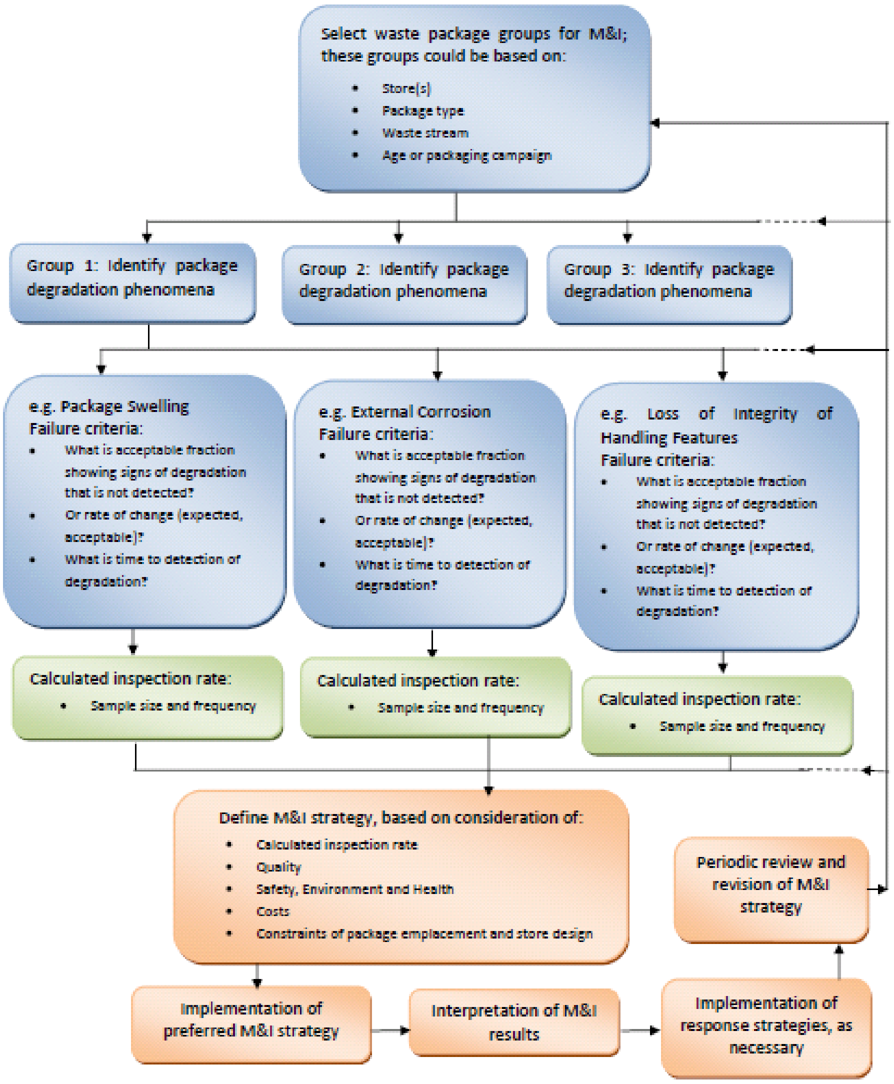

Figure 13 Simplified Flowchart of Approach A20 Applied to Waste Packages

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6.3.1 Packages

A toolkit [D,TK19] of over 50 techniques with the potential to provide useful information concerning the evolution of waste packages has been identified, see Reference [67]. The choice of tools should be strongly influenced by those that are capable of reliably indicating the performance of the relevant package safety functions - see subsection 3.2.2 - in addition to the other attributes noted in A20. For existing stores, with remote handling constraints, the incorporation of additional monitoring and inspection technologies may be extremely limited. Under such circumstances, greater emphasis should be placed on practicable techniques which minimise disruption in addition to use of information gleaned from other store operations.

Further, the potential for damaging packages during monitoring and inspection operations, and the radiological doses associated with deploying the selected tool needs to be considered as part of an ALARP argument.

In all cases comprehensive records must be made of the actual measurements and their interpretation and reference to these made in appropriate package records. Such data should be shared with other store operators so that strategic benefit can be realised using a standard reporting format.

6.3.2 Environmental conditions

Installation of monitoring equipment is best incorporated before active commissioning. Monitoring equipment will require maintenance, calibration and testing to ensure accurate results are obtained.

The ability to monitor the environment can provide valuable information concerning the effectiveness of the overall storage system, and whether it is operating as expected - see subsection 5.4. Measurements should be made to provide a statistically significant average of internal conditions, as well as at key locations throughout the store which may provide diagnostic information, for example, near ventilation inlets and outlets. Measurements, external to the store and in other site facilities, e.g. without environmental controls, should also be made to provide a comparison with; this may inform any necessary changes to the environmental controls.

A toolkit [D,TK20] of environmental monitoring techniques is provided in Reference [51]. Good records must be made of the measurements and reference to these made in appropriate package records. Both the absolute value of the measurements and commentary of its variation with time, noting any periodicity, and spatial variation should be recorded. Results should be shared with the SOF - see GP27.

The following aspects are noted for additional guidance:

(a) **Surface concentration of corrosion-accelerating substances**, particularly chlorides, and microbes to provide assurance that corrosive conditions are not developing within the store. Approaches include: swabbing, direct flushing, conductivity measurements and use of coupons.

Analysis should include determination of particulate deposition density and size distribution, for both cations such as sodium, magnesium, calcium and ammonium, and anions such as chloride, nitrate and sulphate.

(b) **Concentration of gases**. Monitoring for gases with potential explosive, radioactive, toxic or corrosive effects should be carried out while there is a credible risk - see also subsection 3.3.3. Notably, radon gas concentrations measurements, before and after commissioning, should be made [18].

An example of a recent study of environmental conditions within an operational store, sponsored by RWMD, is provided in Reference [68]. This includes a description of tools deployed, results gleaned and interpretation.

6.3.3 Store life-limiting components

It is a Licence Condition 28 that all plant that may affect safety if scheduled to receive *regular and systematic examination, inspection maintenance and testing* and that this be carried out by SQEP and records made.

Provision for maintenance, testing and inspection should be established to address the ageing of structures, systems and components and that the results from this programme should be used to review the adequacy of the design at appropriate intervals. This could include monitoring for fatigue, stress corrosion, erosion, chemical erosion or radiation induced changes.

Two toolkits applicable to unshielded [D,TK21] and shielded [D,TK22] stores are identified in Reference [51] respectively for a range of store life-limiting components. Processes affecting concrete and reinforced steel evolution and monitoring technologies are outlined in Reference [69]. Tools include visual inspection, concrete/rebar degradation monitoring, and crane monitoring. Corrosion coupons made from store life-limiting components, e.g. crane materials, may also provide valuable information. Evidence for any animal intrusion events should be noted and acted upon as appropriate.

6.4 Monitoring and Inspection Rates Approach

Approach A21 describes steps to determine a robust level for inspection and monitoring of waste packages. Aspects of A21 may also be considered for environmental monitoring and inspection of life-limiting components. It is recommended that all stores establish a target inspection rate to achieve a high level of confidence of package storage across the period of interim storage, and that the actual frequency proposed be established based on ALARP considerations, noting the positive safety benefits realised by monitoring and inspection, and agreed with stakeholders. See GP28.

6.4.1 Waste package

A21, which is widely applicable to all storage contexts, is described in detail in Reference [70] along with a supporting toolkit [D,TK23] to calculate an inspection rate based on a set level of confidence, or on the level of confidence given a certain rate of inspection. Both results should inform the establishment of a robust rate.

As shown in Figure 13, A21 comprises a number of steps including:

(a) selecting common groups of packages;
(b) establishing relevant package evolutionary processes for these groups, see A5;
(c) applying A1, and selecting appropriate monitoring and inspection tools. Where information about a process, which may affect a required safety function can be obtained, it is recommended that a Bayesian statistical method is used. These data may be obtained or estimated from first principles, or based on knowledge of the evolutionary processes and store environment conditions. Alternatively, the information can be empirical, based on evidence from other monitoring and inspection surveys elsewhere or accelerated ageing trials. Best estimate evolutionary rates can come from a combination of these approaches. For the Bayesian method, each common group of waste packages will need to have estimated distributions for each parameter to be monitored. Where this information cannot be reliably obtained, a simpler sampling method can be used based on classical probability theory, but this may result in a larger number of samples being required to achieve the *same* level of confidence;
(d) defining an inspection rate based on sample size and inspection frequency;
(e) applying cost benefit analysis, see example [D] in Reference [70], to assess the practicability of implementing the proposed package monitoring and inspection approach. The outcome of such an analysis might suggest that the rate proposed is impracticable. In which case the approach should be used to establish the confidence level, and the use of inactive samples exploited as fully as practicable;
(f) implementing agreed monitoring and inspection regime;
(g) interpreting output, recording and sharing of results;
(h) reviewing applied ‘approach’ periodically.

For existing stores with an already established monitoring and inspection rate, it is recommended that A21 be considered when the current approach is next periodically reviewed.

For new stores, minor changes in parameters related to the building or emplacement approach during the design phase may result in different output values for the frequency and number of packages to be inspected, allowing the broader cost benefit implication of the different potential inspections regimes to be explored. The cost benefit analysis takes into account factors such as the expected long-term package performance, the cost and risk associated with inspection and the potential benefit to be gained from monitoring and inspection. The selected monitoring and inspection rate should be ALARP.

The following opportunities are noted to reduce the number of active package movements for inspection:

- use of dummy packages - see subsection 6.6.1;
- exploitation of reduced scale samples and simulants - see subsection 6.6.2;
- sharing monitoring and inspection results from similar stores to maximise learning via the SOF.

6.4.2 Store environment

Continuous monitoring, as opposed periodic inspections, of the store environment is generally appropriate for many environmental parameters which may be subject to daily and seasonal cycling. Unless the store environment is demonstrably stable and predictable, the frequency, and quantity, of environmental measurements are unlikely to be greatly reduced with time as demonstrating a stable environment helps assure package and store life-limiting components. The inspection frequency of coupons, used to support environment monitoring, may be defined using A21.

6.4.3 Store life-limiting components

For civil structures inspection should routinely be carried out at least every five years. The rate of inspection should be increased where evolution is proceeding faster than expected. Maintaining lifting equipment is a key enabler to ongoing store operations, see Reference [71] and extract [D], and more regular inspection may be necessary.

6.5 Archiving Approach

Approach A22 outlines types of materials which might usefully be maintained to assure the storage system and support timely and safe export. It is recommended, see GP29, that each store develops an archiving plan which identifies archiving needs and how the Store Operator will retain access to:

(a) **Strategic spares** of vulnerable components subject to refurbishment and maintenance, e.g. crane parts, especially where these are bespoke and unlikely to be readily available in the future. These should be utilised as necessary to preserve safe operation of the store in the future. Such an archive should be in a low radiation field environment and be under controlled conditions in an auxiliary part of the store.

(b) **Components of the store's life-limiting features** taken during construction and preserved such as. samples of reinforced concrete. These may inform future studies looking to establish extensions to the stores lifetime. Such an archive should be in a low radiation field environment but be under controlled conditions in an auxiliary part of the store.

(c) **Inactive waste package samples and simulants** generated during waste packaging design where these represent the eventual packages and are not otherwise subject to a UK programme [74]. These could be placed in any spare full scale container within the store, or a low–radiation field environment in an auxiliary part of the store. Such an archive could be used to supplement monitoring/inspection, provide lead times for evolution performance and provide materials to test package repairs. See subsection 6.6.

(d) **Records**. Copies of the package records and store performance might usefully be retained within the store.

6.6 Inactive Samples and Simulants Approach

Approach A23 describes opportunities to exploit the value from inactive waste package simulants and other storage system samples. Each store should develop a plan that describes the intended use and management of inactive samples and simulants across the store's lifecycle. The principal advantages from using simulants and samples is their cost effectiveness and potential for reduced worker doses compared with like-for-like inspections of actual packages and potentially difficult to reach life-limiting components, see also Reference [72].

Simulants and samples should be retained and information about them shared with other Store Operators to maximise their strategic value. Any decision to discontinue the storage of inactive samples and simulants should be made strategically, see GP8, and offered to other stakeholders such as RWMD for long-term stability underpinning, and universities carrying out fundamental research, before being disposed of.

6.6.1 Dummy packages

Deployment of 'dummy packages', see GP30, can represent a valuable complementary method to support the monitoring and inspection of active waste packages [72] and otherwise support store operations with minimised operator risk. The specific potential benefits from deploying dummy packages, which are non-radioactive full scale packages that are demonstrably representative of active waste packages as produced, include:

(a) **Improving the knowledge base on package evolution**. Used in this context it is important that the package is a realistic simulant of the active waste package(s), especially the wasteform, or can be readily related to such packages. The possibility of additional instrumentation [D] within the dummy package to be provide evolutionary in-situ information, which may not be practicable for active packages, is noted. Dummy packages may also be used to **forewarn of unexpected package evolution** thus providing 'lead time' samples. While dummy packages may be most effectively deployed early in the stores' active commissioning phase, it is noted that any significant later updates to waste product specifications may justify additional or replacement dummy packages. Information arising from dummy packages not held within the store may also be usefully applied.

(b) **Storage environment measurements**. Instrumented dummy 'containers' may be used to augment the environmental monitoring regime, and be especially valuable in shielded stores, providing a route for direct measurements of contaminants on realistic surfaces. If used exclusively in this context, the wasteform simulant chosen is usually unimportant.

(c) **Test packages to support store operations.** If used exclusively in this context, choice of the wasteform simulant will be less important and it may be permissible to utilise containers otherwise deemed unsuitable for use as part of an active package, e.g. heavy scratches. Specific uses include: deployment as part of the commissioning process for import and export, store modifications, maintenance - notably of lifting features, maintaining SQEP of store operatives, and developing package intervention and reworking tools - see subsection 5.3.

6.6.2 Reduced scale simulants and samples

It may not be economically viable to deploy sufficient dummy packages in a store so as to be statistically representative of the full range of active packages, or properly represent spatial variations of environmental conditions within a store. Instead, reduced scale inactive simulants can be deployed within the store and/or under controlled conditions in other facilities to provide similar information to dummy packages, i.e.:

(a) **Improving the knowledge base of package and life-limiting components evolution.** After identification of relevant evolutionary processes, using for example. A1 and A5, samples of relevant materials may be left in easy to access positions in the store or elsewhere to support effective monitoring and inspection.

(b) **Storage environment measurements**. Corrosion coupons, see for example [73], are often deployed in stores to measure contaminant deposition. It is recommended that these are deployed throughout the store, including near ventilation inlets and outlets and to explore spatial variations.

A suite of documentation [D], including a sample database, [74] is available which describes the deployment of inactive samples across the lifecycle and package designs. There are over 8000 samples, mostly wasteform related, which cover most current UK packaging concepts and many are up to 30 years old. They include a wide range of simulant wasteforms and encapsulants, containers and metallic wastes. Many of the samples have been irradiated to high levels of dose well beyond that expected during interim storage.

While the benefit from the samples is largely strategic, i.e. demonstrates the sustainability of the UK baseline for waste packaging, there are a number of specific benefits, including:

- early warning of evolutionary processes, including accelerated ageing and using 'canary materials' which are more sensitive to the environment than employed materials;
- direct insight to how the wasteform is evolving including destructive testing and supporting fundamental understanding of evolutionary processes;
- exploration of extreme formulation envelopes;
- testing of innovative materials using a standard testing approach to establish underpinned baselines.

Most of these samples are held under laboratory conditions. A proportionate approach, based on the categorisation of the waste package, is described in Reference [75] for the design, production and addition of samples to the long-term monitoring programme and is outlined in Figure 14.

A typical set of standard samples required for effective product evaluation testing of the waste, process and formulation envelope over the long term is assessed to be between 10 and 20 samples. For container corrosion experiments, a single small scale package can usually provide sufficient re assurance of long-term internal corrosion trends. Irradiation sample trials normally require four to eight samples to provide sufficient control and duplication of results. In contrast to long-term monitoring samples, irradiation tests are accelerated for which most of the useful data is obtained within 12-18 months of testing. Applicable testing regimes are described in Reference [76].

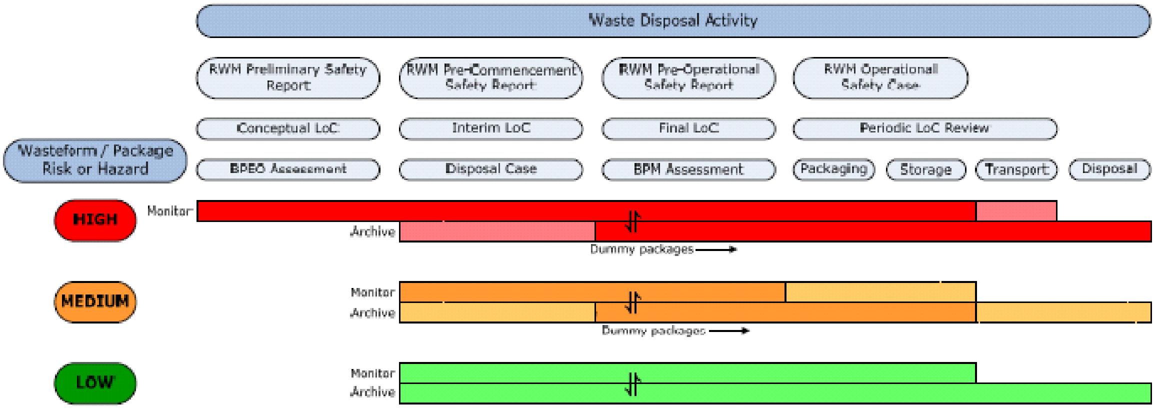

Figure 14 Recommended Timeline for Sample Addition by Waste Package Category

6.6.3 Analogues

Materials which are analogous to those employed in the storage system may also provide valuable information concerning its long-term evolution. Examples include: ageing structures and samples [D] on existing nuclear sites and elsewhere, and similar materials utilised under harsher conditions such as on oil rigs, and coastal structures like piers and bridges.

6.7 Auditing Approach

Approach A24 concerns demonstrating, so far as is reasonably practicable, that packages remain in a disposable form and will be accepted into future disposal facilities such as a GDF.

Store Operators should ensure that the relevant LoCs are maintained throughout the storage period, and any conditions attached are observed and action points closed out on a timely basis. To provide additional assurance, RWMD expect to carry out that periodic reviews of final LoCs, at a flexible frequency, with a recommended time interval of not more than 10 years [77].

The detailed scope of the review should be determined by the licensee and RWMD. While the remit of periodic review is broader than interim storage, and ultimately seeks to revalidate the currency of the LoC and maintain the disposability case, the following aspects of the review are noted:

- whether conditions, restrictions and caveats on the LoC have been observed;
- the status of the quality management systems employed by the Store Operator;
- the condition of stored waste packages, compared with expectations;
- the maintenance of appropriate package records;
- any emerging issues since the final LoC was issued, or previous review;
- consistency with and adequacy of store WAC;
- whether any changes to the store safety case may have implications or relevance to the disposability case. It should be noted that stores will be subject to periodic safety case review throughout the operational life of the store ensuring any necessary and timely improvements are made.

Benefits to the Store Operator from the periodic review include opportunities to: share good storage practices; establish the significance of any emerging WAC for a GDF on the store operation and environmental controls; and seek advice on the management of any packages showing unexpected evolution.

6.8 Knowledge Management Approach

Approach A25 outlines steps to ensure effective knowledge management, including but not limited to records management across the storage system's lifecycle noting the inter-generational timescales. See, for example, Reference [78] and [79] for guidance on long-term records management.

Knowledge management practices should be deployed throughout the lifecycle from the conceptual design through to decommissioning. Knowledge management practices should also support the development and maintenance of competence to operate throughout the store lifecycle.

Good practice in the management of knowledge should be based on these foundations:

- a competent workforce for the design, build, operation, maintenance and decommissioning of the facilities throughout their lifetime, see subsection 6.9;
- lessons are captured, retained and acted upon;
- valid records of contents and plant configuration are kept and are retrievable and interpretable throughout the lifecycle of the store;
- location of the various stores and an accurate inventory of the contents is recorded and readily understood by any agent who has the potential to disturb, be affected by or require legitimate access to the store.

A typical approach to knowledge management should consider the following aspects:

(a) Ensure that sites are mapped and described so that their locations, configuration and the inventory can be established at all times. Sites should be physically marked with universally recognisable signage compliant with IAEA guidance.
(b) Processes are in place to ensure that information ownership is maintained and transferred during management and operational transitions over the full lifetime.
(c) Undertake critical knowledge audits to manage knowledge risk, establish baseline and future requirements and the necessary management actions to fulfil those requirements. These need to be repeated at intervals of no more than 10 years.
(d) Maintain essential proficiency by, inter alia: training and coaching, R&D, targeted recruitment and supply chain engagement.
(e) Maintain accessible libraries of documents, images, videos, drawings, graphs, other information artefacts and knowledge assets.
(f) Maintain interaction with national and international communities of practice.
(g) Undertake knowledge risk assessments of personnel and groups that hold critical knowledge and establish plans to retain that knowledge.
(h) Systematically capture, retain, resolve and share lessons learned through national and international collaborations between operators and regulators.
(i) Maintain, as part of the ageing management programme an interactive and searchable Facility Information Management system that includes the history of the facility on a variety of essential criteria, which includes: design rationale, design documentation,

inventory records, plant modifications, key personnel and other operating site licence requirements.

(j) Maintaining records of the operation of the storage system including package records [80] and applicable dummy packages, simulants and samples.

(k) Create a plan for the long-term preservation of information to manage the inevitable series of media obsolescence over the total operating period of the facility.

Additionally, Store Operators are referred to a top down approach developed by the NDA [81] for which a high level compliance programme is underway. This aims to provide a framework across the NDA sites for managing information and knowledge assets throughout their lifecycle, to maintain consistency in their application and processing and ensure compliance with regulatory and statutory obligations. Attention is also drawn to the importance of maintaining RWMCs to provide an accurate overview of HAW management on each site [23].

6.9 Human Resources Approach

Approach A26 comprises the following considerations. The NDA has published its People Strategy (incorporating Skills and Capability) [82]; see also Reference [7]. These highlight the importance of skills development and training, developing and maintaining networks and setting standards. NDA continue to work with the various skills bodies, acknowledging the National Skills Academy for Nuclear as the strategic lead, via the Nuclear Energy Skills Alliance (NESA) - a grouping of the key skills bodies with an interest in nuclear skills, and Government Departments. Reference [82] also states that its approach is to ‘understand the need’ by identifying current resources and future requirements across the estate. To help to understand the future needs of the UK nuclear industry programme a Nuclear Workforce Planning System is being developed by Cogent Sector Skills Council where work is being undertaken to identify and address the future skills needs and agree a common evidence base for action.

Interim storage is a long-term activity that requires effective workforce planning to determine the best approach especially for those sites who will enter a significant period of abeyance. A skilled workforce must be available to support ongoing storage activities such as monitoring and inspections, planned maintenance, reviewing safety cases and package exports. Over time the number of stores will increase and is therefore likely that an important storage activity will be going on somewhere within the UK at any one time. Therefore, NDA and other waste owners may want to consider a number of workforce planning options including:

- a continued workforce activity at the site level as per the current baseline;
- a regional or SLC approach to workforce planning that could involve activity specific mobile expert groups;
- a NDA or national approach to workforce planning that could involve activity specific mobile expert groups;
- a local approach that would involve more than one waste owner, e.g. one interim storage workforce plan for a co-generation site.

Therefore, Store Operators should maintain a watching brief concerning industry-wide initiatives and ensure their future resourcing needs, informed by the Guidance, are represented through their lifetime plans to the Waste Owner.

7. Summary

7.1 Good Practices

GP	Description	Subsection
1	The Regulators and RWMD should be engaged throughout the storage system's lifecycle including during the early planning stages. Other stakeholders should also be engaged as appropriate [24]. Relevant to all storage systems, especially for proposed new packages and stores, and modifications to existing storage systems.	1.4.3; 1.4.4; 5.3
2	Consistent technical terminology should be used to describe all aspects of the storage system across its lifecycle. Relevant to all storage systems.	2.1
3	Throughout the period of interim storage, SQEP must be available, who: • understand the relevant package evolutionary processes and the expected pattern of package evolution during interim storage; • understand the significance of any indicators of package evolution outwith the expected performance at the time the packages were assessed by RWMD via the LoC process (and any updates thereafter); • can act as an intelligent customer for any related work carried out by the supply chain. Relevant to all storage systems. Noting there is greater potential to share SQEP between common storage systems.	2.1.3a; 3.2; 5.3
4	Human Factors should be applied at all stages of store design and operation, and be implemented as an integrated component of robust interim storage arrangements. Relevant to all storage systems and stages of the lifecycle.	2.1.3b
5	The NWRF Working Group on Storage should be consulted, before commissioning R&D to support development or operation of the storage system, to avoid duplication and promote co-operation. Relevant to all storage systems, noting the likelihood that unique designs will more likely require bespoke R&D.	2.3.1
6	The Store Operations Forum should be regularly engaged to share and benefit from operational 'lessons learned'. Relevant to all storage systems and stages of the lifecycle.	2.3.2
7	Unless there are compelling reasons to seek alternative designs, current generic container designs which are compatible with existing stores' infrastructure and, so far as can be anticipated, within future disposal facilities should be adopted. Alternative designs, with significantly different handling and stacking requirements, should be agreed on a UK-wide basis. Relevant to planned stores or stores which may accept new package designs in the future.	3.1
8	On the basis of available operational information over the last 20+ years, currently used austenitic stainless steel grades are considered suitable materials for containers under the controlled environmental conditions in current UK stores. Where alternative materials are considered these should be incorporated into the proposed UK's Long-term Monitoring Programme, or	3.1; 6.6

GP	Description	Subsection
	similar arrangement, at the earliest opportunity to establish a credible baseline to inform decision making. Relevant to planned storage systems considering materials and/or environmental conditions for which there is limited operational experience.	
9	A clear linkage should be provided and then maintained between the transport safety case and the storage safety case to reduce the risk that packages may not be transportable when required. Most relevant to storage systems comprising of any packages not reliant on a transport container such as a SWTC.	3.1.3, 5.1.3
10	Plausible evolutionary processes for all package types during storage should be determined and a recorded assessment made of the significance to the package safety functions. Package performance criteria should be derived for all package types. Relevant to all waste packages, and should be applied proportionately according to the categorisation - see [24].	3.2.2
11	Containers and packages, destined for interim storage, should be subject to appropriate care and management from the earliest stages of the package lifecycle. This should include setting appropriate store WAC to prescribe an effective approach. Relevant to all waste packages and any storage system which may receive additional packages.	3.4
12	If containers or packages are temporarily outside of a controlled environment then they should be covered, including the base, to protect them. Especially relevant if containers or packages may be 'buffered stored', and during transfer or transport.	3.4
13	The implications of any constraints set by local planning authorities for the removal of packages from a site, e.g. based on the assumed availability of a GDF, and building capacities for storage should be made known to the authority as this may not be practicable to achieve and have considerable UK-wide implications. Relevant to stores being designed and planned.	4.1.2
14	Designs should ensure ease of monitoring package and store life-limiting components. The degree of monitorability required should be proportionate with the categorisation of the stored packages. Most relevant to future stores. Any opportunities to improve arrangement for existing stores should be considered - see A3.	4.1.3
15	The life-limiting components should be identified, and claims made for component longevity substantiated. Future stores should be constructed with a minimum design lifetime of 100 years. Relevant to all stores and stages of the lifecycle.	4.2.2
16	Cycling of wetting and drying events should be avoided. A robust approach should keep the RH below the deliquescence point of the relevant contaminant salts, or be sufficiently above this to ensure any surface contamination is diluted. The duration of any excursion outside the target ranges should be minimised. Relevant to all stores, especially those with packages and life-limiting features liable to localised corrosion.	4.3.1, 4.4.2

GP	Description	Subsection
17	The composition of potential contaminant deposition, in the locality of the store, and within the store before it is actively commissioned should be assessed to inform the setting of robust OLCs. Specifically the identification and size distribution of salts should be determined. Most relevant to stores during the planning and design stage.	4.3.2
18	Operational Limits and Conditions (OLCs) should, as a minimum, be prescribed for RH, chloride salt deposition and temperature as appropriate to the storage system's context. The environmental controls should be optimised to meet the set OLCs. Most relevant to stores during the planning and design stage.	4.4.1
19	At import, packages should be checked to ensure they are contaminant free and consistent with the store's environmental control approach and WAC. Relevant to storage systems still to receive waste packages, and storage systems with materials sensitive to contaminant deposition	5.1.1
20	Any necessary package movements, which are not already planned for inspections, should be exploited as a monitoring and/or inspection opportunity where practicable and appropriate. Conversely, movements for planned inspections should be exploited, where appropriate, for the others drivers considered. Most relevant to storage systems with constrained package movements, e.g. with non-contact handleable packages, and with high-category packages [23].	5.1.2
21	A packaging sentencing group should be established to advise on suitable actions to take concerning package performance issues across the lifecycle. The group should comprise of SQEP, and during operations may also be involved in product quality issues arising during packaging, setting WAC, and import surveillance. Relevant to all storage systems, especially those with a high rate of import and with high-category packages [23].	5.3.3
22	A proportionate 'contingency' space should be established so that any future requirement to alter package configurations can be achieved practicably and flexibly where this cannot be achieved through additional on-site storage capability. This should include the ability to manage a proportionate number of overpacked packages. Relevant to all storage systems, especially those without additional on-site storage capacity and with high-category packages [23].	5.3.3
23	Credible contingency plans for the possibility of requiring intervention to maintain package safety functions should be established in addition to a package quality management system. This may include consideration of changes to the store environment controls. Relevant to all storage systems, especially those with high-category packages [23] and where there is a high dependency on the environmental controls	5.3.3; 5.4
24	There should be access to rework facilities or credible plans should exist. Facilities should have the potential capability to deal with plausible reworking requirements. Overpacking is currently considered the most flexible method to deal with a wide range of plausible reworking scenarios for unshielded packages. Especially relevant to storage systems, with high-category packages [23].	5.3.4

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GP	Description	Subsection
25	The replacement and refurbishment requirements should be established together with any proposed enhanced operating and maintenance regimes to extend current store operating lives. Schedules for appropriate maintenance, refurbishment and replacement of store structures, plant and equipment need to be underpinned and clearly identified on asset management programmes. Relevant to all storage systems, especially older stores where designed before current HAW strategies were established.	5.5
26	The baseline condition of: the store life-limiting components, the store environment, and the waste package (ideally related directly to all the relevant safety related functions) should be established at appropriate times. The information should be recorded and shared strategically. Relevant to all storage systems. However, for existing stores the practicability of establishing the baseline conditions may be both low (for non-contact handleable packages), and of lower potential value.	6.2
27	The performance of the storage system should be recorded and shared on a regular basis with other store operators to ensure maximum learning. Information recorded should include deposition rates and composition of salts and note any correlation with package performance and impact on store life-limiting components. Relevant to all storage systems following construction.	6.3
28	A target rate of monitoring and inspection, to provide a high level of confidence over interim storage, should be established. Cost benefit analysis should be used to justify the actual rate proposed and the approach agreed with stakeholders. Relevant to all storage systems.	6.4
29	A strategic archive of spares and materials to inform future decision making should be established. The inventory should be recorded, updated regularly and made available to other Store Operators. Relevant to all storage systems noting the opportunity for stores of similar design and those on a common site to share this resource, in addition to any UK-wide approach.	6.5
30	An optimum number of dummy packages should be established for each store. This should be proportionate to the packages' categorisations, monitoring/inspection benefits afforded, and any unique features or properties of packages in the store. It is recommended that all stores have access to at least one full scale representative dummy package to assist store operations. Information arising from dummy packages deployment should be shared. Relevant to all storage systems especially those with non-contact handleable packages and high-category packages [23].	6.6.1

Further discussion of Good Practices compared with external stakeholder guidance is provided here [D].

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7.2 UK Stores List

Status	Store Name	Description
	AWE (Aldermaston)	
	HAW Stores 1-4	Contains predominately plutonium and uranium contaminated material packaged in 200 litre drums pending future conditioning.
	DSRL (Dounreay)	
	Dounreay Cementation Plant (DCP) Store	Contains immobilised raffinates in 500 litre packages. Overpacked RHILW is also stored pending conditioning.
	Unshielded Waste Store	Proposed modification to an existing LLW store at Dounreay for storage of shielded ILW packages including 6m^3 concrete boxes, TRU-Shield® packages (316L on the outer and inner liner with 2" lead walls) and 500 litre packages.
	SL (Sellafield)	
	Box Encapsulation Plant Product Store (BEPPS) 1	For 3m^3 packages.
	BEPPS 2-4	For 3m^3 packages.
	Class 2 ILW Store	For lower hazard decommissioning packages. Option to extend storage capacity.
	Engineered Drum Store 1 (EDS1)	Contains plutonium contaminated material (PCM) packages.
	EDS2	Contains PCM packages.
	EDS3	Contains PCM packages.
	EDS4-5	For PCM packages.
	Encapsulated Product Store 1 (EPS1)	Contains 500 litre packages in stillages.
	EPS2	Contains 500 litre packages in stillages.
	EPS3	Undergoing commissioning. Will take 500 litre packages in stillages and 3m^3 packages.
	Miscellaneous Beta Gamma Waste Store (MBGWS)	Existing store containing packages yet to be sentenced as being disposable.
	Windscale ILW Store	For Windscale decommissioning waste.
	Vitrified Product Store 1 (VPS 1)	Contains HLW packages.
	VPS 2	To replace VPS1.
	Windscale Advanced Gas-cooled Reactor (WAGR) Store	Contains 6m^3 concrete boxes, also referred to as WAGR boxes.
	Waste Packaging and Encapsulation Plant (WPEP) Store	Contains immobilised waste from effluent treatment plants in 500 litre packages.
	RSRL (Harwell and Winfrith)	
	Harwell ILW Store	For decommissioning wastes in 6m^3 boxes.
	Harwell Vault Store	Contains 500 litre packages.
	Winfrith 2m ILW Box Store	For decommissioning waste packages.

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Status	Store Name	Description
	Winfrith Treated Radwaste Store (TRS)	Contains 500 litre packages of encapsulated sludge.
	MXL (multiple sites)	
	ILW Store, Hunterston A	Existing store to take $3m^3$ packages after active commissioning due early 2013.
	Interim Storage Facility (ISF), Berkeley	Detailed design phase ongoing. Construction phase to commence in autumn 2012. Will take DCIC packages.
	ISF, Bradwell	Design completed. Early construction phase ongoing. Will take DCIC packages.
	ISF, Chapelcross	Location selected, with initial groundworks. Early stages of detailed design phase commenced, with option to 'replicate' Bradwell design. Will take DCIC packages.
	ISF, Dungeness	Location selected. Early stage of detailed design phase. Will take DCIC packages.
	ISF, Hinkley Point A	Enabling groundwork completed. Detailed design phase. Construction due to complete summer 2013. Will take DCIC packages.
	ISF, Oldbury	Proposed store for DCIC packages.
	ISF, Sizewell A	Proposed store for DCIC packages.
	ISF, Wylfa	Proposed store for DCIC packages (see [31])
	ILW Store, Trawsfynydd	Contains overpacked $3m^3$ packages, and planned to take stillages with '1803-type' drums of resin wastes.
	EDF Energy (multiple sites	
	Sizewell B Store	Contains waste which is awaiting agreement and implementation of packaging proposals.
	AGR Sites (Hunterston B, Dungeness B, Hinkley Point B, Heysham 1 & 2, Torness, Hartlepool)	Proposed store at each site for packages of resin and sludge wastes; detailed packaging proposals to be agreed.

	Key – status as at Sept 2012
	Operational store
	Under development
	Future or planned store

GLOSSARY

approach	a process or method described in the Guidance to assist Store Operators select appropriate tools or options, and/or take appropriate actions according to the context of their storage system.
baselining	measurements of safety related aspects of the storage system, usually taken at the beginning of major lifecycle events, against which ongoing monitoring and inspection results can be compared.
buffer storage	short-term storage, up to about 10 years, of raw waste as a precursor to its conditioning or short-term storage of packaged waste pending its import into a store.
conditioned	waste which has been recovered or removed from its plant of origin and has been processed such that it meets the passively safe criterion for storage and/or disposal.
corrosion coupons	retrievable test pieces of container material or life-limiting components placed in stores from which the likely surface conditions of the container or life-limiting components can be inferred through surrogate measurements. Coupons can also be embedded within packages to measure internal corrosion rates.
decay storage	the process of allowing material containing short-lived radionuclides to decay so that the final waste is easier to dispose of as radioactive waste, or until the point where the waste becomes exempt from specific regulatory requirements.
disposable	a waste package that has been shown to comply with anticipated requirements for transport and disposal.
disposal	emplacement of waste in an appropriate facility without the intention of retrieval. See also retrievability, and reversibility.
dissolution	a process whereby waste is dissolved in order that the radioactive material can be subsequently recovered as a smaller volume of material.
dummy package	non-radioactive full scale packages that are demonstrably representative of active waste packages as produced.
environmental monitoring	relates to measurements on the levels and chemical form of chloride, temperature and relative humidity at appropriate positions throughout the store. Measurements of other particulates and pollutants, and gases generated from packages may also be appropriate.
gas generation	corrosion, degradation of organic materials and radiolysis are the principal mechanisms by which gas can be formed from radioactive waste packages. The generated gas may include radioactive gases such as tritium, ^{14}C gases and radon, as well as bulk inactive gas (e.g. hydrogen and methane).
gas migration	the movement of gas (e.g. advective or diffusive) through the wasteform, and engineered vents into the store environment.
good practice	highlighted recommendations to Store Operators presented in the Industry Guidance based on the findings arising from the IPT’s work programme.
Higher Activity Waste	HAW includes high level waste, intermediate level waste, and some low level waste unsuitable for prompt disposal at the LLW Repository.
hazard	the potential for harm arising from an intrinsic property or disposition of something to cause detriment.
High Level Waste	waste in which the temperature may rise significantly as a result of their radioactivity, so that this factor has to be taken into account in designing storage or disposal facilities. IAEA guidance is that thermal power >2 kW/m^3
Intermediate Level Waste	waste with radioactivity levels exceeding the upper boundaries for low level wastes, but which do not require heating to be taken into account in the design of storage or disposal facilities. IAEA guidance is that ILW thermal power is below about 2 kW/m^3.

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immobilisation	conversion of waste into a wasteform by solidification, embedding or encapsulation.
inactive samples	these are non-radioactive components or simulants of packages that are demonstrably representative of one or more aspect of an active package. They may be maintained either within the store, or elsewhere under known conditions.
inspection	the examination, or measurement, of the properties of a waste package to obtain data which are used to assess the extent of any degradation processes, potentially including any degree of damage that has occurred.
knowledge management	a coherent set of activities to support analysis, prioritisation and continuity of explicit knowledge (information) and tacit knowledge (held by individuals). It also includes the competence of current and future staff to operate and maintain storage facilities as well as the development of new knowledge.
licence condition	a condition attached to a licence issued under the Nuclear Installations Act 1965.
Low Level Waste	radioactive waste having a radioactive content not exceeding 4 GBq/te of alpha or 12 GBq/te beta/gamma activity.
monitoring	continuous or periodic observations and measurements to determine changes in the physical condition of a waste package over time.
near surface disposal/ storage	disposal or storage in a facility which is at the surface of the ground or at depths down to several tens of metres below the surface.
overpack	a secondary (or additional) outer container for one or more waste packages, used for handling, transport, storage and/or disposal.
package evolution	chemical and physical changes of the package components over time that affects the package performance.
package expansion	gross package expansion which may be caused by expansive corrosion products, some waste degradation products and formation of certain cement phases.
packaging	preparation of radioactive waste for safe handling, transport, storage and/or disposal by means of enclosing it in a suitable container.
package performance criteria	measurable safety related package features and evolutionary processes that when integrated define the status of the stored package.
passively safe	the provision and maintenance of safety functions which minimise the need for active safety systems, monitoring or prompt human intervention.
periodic safety review	a systematic reassessment of the safety of an existing facility (or activity) carried out at regular intervals to deal with the cumulative effects of ageing, modifications, operating experience, technical developments and siting aspects, and aimed at ensuring a high level of safety throughout the service life of the facility (or activity).
radioactive waste management case	the purpose of a RWMC is to provide a transparent demonstration of how the key elements of long-term safety and environmental performance will be delivered for the management of the waste stream or streams covered. This should cover the period from their generation through their conditioning, storage and to their removal from site for eventual disposal.
raw waste	waste in its original untreated, unpackaged and bulk form.
retrievability	a characteristic of the design of the waste package and/or the storage/disposal facility that facilitates recovery of waste after emplacement.
reversibility	the capability for a process to be reversed. An example would be the ability of withdrawing wastes from a storage/disposal facility where they have previously been emplaced.

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rework	any process involving physical intervention of packaged waste arising from deviation from the planned storage, treatment, or intended disposal process for that packaged waste to restore safety functions.
	Repackage - a type of rework that involves placing the original wasteform into a new container or the original (repaired) container if still suitable.
	Recondition - a type of rework that involves additional processing of the original wasteform.
safety case	a collection of arguments and evidence in support of the safety of a facility or activity
shielded store	a facility which provides a substantial barrier to reduce direct radiation dose rate outside the facility.
simulant package	non-radioactive reduced scale package representative of either specific or generic features of active waste packages.
simulant wasteform	non-radioactive materials developed to be representative of some or all of the chemical and/or physical properties of the anticipated / actual wasteforms.
smart coupons	corrosion coupons with sensors to provide a wireless and real time measurement of local humidity, temperature and salt deposition.
stillage	a frame designed to hold multiple packages so that they can be handled and stacked as a single unit.
storage	placing waste in a suitable facility with the intent to retrieve it at a later date.
	interim storage - storage of waste packages within a purpose built facility, which aims to maximise the lifetime of waste packages, where there is the **planned intention** for a final management step, e.g. transport / transfer of the packages to a licensed disposal facility. Storage will typically be up to about 100 years.
	long-term storage - storage of waste packages within a purpose built facility, which aims to maximise the lifetime of waste packages, pending a defined endpoint. Storage will typically be for at least 100 years and potentially considerably more.
	waste storage system - a multiple-barrier system comprising the wasteform; the waste container; the store environment; and the store structure.
Store Operator	is taken to mean all those in a licensee with direct responsibility for managing the storage system across any part of its lifecycle, including: design and planning, construction, commissioning, import of packages, care & maintenance, export of packages, and decommissioning of the storage facility. Notably, it is taken to include those responsible for store safety cases, and technical support.
thermal processing	use of substantial heat to render waste into a more passive form and/or to reduce the bulk volume.
toolkits	a list of potential techniques, solutions or other options which have been derived from a collective of operational experience and R&D. When applied, with a suitable approach, context specific tools may be identified.
tools	practicable techniques which may be used to manage one or more aspect of interim storage and which are relevant to the particular storage system's context.
transport container	a reusable container into which waste packages (raw or conditioned) are placed for transport, the whole then qualifying as a Transport Package under the IAEA Transport Regulations. Some waste packages are also transport packages.

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transport package	the complete assembly of the radioactive material and its outer packaging, as presented for transport.
	Type B transport package - a type of transport package defined by the requirements in the IAEA Transport Regulations.
	Industrial package - a type of transport package defined by IAEA Transport Regulations. Industrial Packages may be classified as Type 1 (IP-1), Type 2 (IP-2) or Type 3 (IP-3). Industrial Packages are restricted to the carriage of Low Specific Activity and/or Surface Contaminated Object material.
treatment	operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are: volume reduction, removal of radionuclides from the waste and change of composition.
trigger levels	graded package performance thresholds, described using suitable measurable indicators, which define when intervention may be required by the Store Operator to preserve storage system functionality.
unshielded store	a facility where the package and any over-packs provide an adequate barrier to direct radiation dose rate outside the facility. Typically packages, in their over-pack as appropriate, can be handled without the need for remote handling within the facility.
waste acceptance criteria	these are the facility specific criteria that waste packages must meet to be acceptable into the facility without requiring package specific substantiation of its properties. The waste acceptance criteria should include consideration of future disposal requirements or planned management strategies, and be bounded by the relevant safety cases, e.g. store and transport.
waste container	the vessel into which the wasteform is placed for handling, transport, shielding, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions. The waste container is a component of the waste package.
waste package	the wasteform and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/or disposal.
	out-of-specification waste package - waste packages, or their safety related components, that exhibit or are reasonably believed to exhibit properties that fall outside the specified range, as endorsed by RWMD as part of the LoC process or the store's WAC.
	non-conforming package - waste packages, or their safety related components, that exhibit or are reasonably believed to exhibit performance that is likely to fall outside the eventual WAC for a GDF.
waste storage system	comprises the conditioned wasteform, the waste container, the store environment and the store structure components and the interactions between the components.
wasteform	waste in the physical and chemical form in which it will be stored/disposed. This can include any conditioning media and container furniture, i.e. in-drum mixing devices, dewatering tubes etc, but not including the waste container(s) itself or any added inactive capping material.

ABBREVIATIONS AND ACRONYMS

304L	Austenitic stainless steel grade (BS EN 1.4307)
316L	Austenitic stainless steel grade (BS EN 1.4404)
2205	Duplex stainless steel grade (BS EN 1.4462)
AMP	Ageing Management Programme
A*n*	Approach n
AGR	Advanced Gas-cooled Reactor
ALARP	As Low As is Reasonably Practicable
AWE	Atomic Weapons Establishment
BAT	Best Available Technique
BEPPS	Box Encapsulation Plant Product Store [D]
CDM	Construction Design and Management Regulations
CFD	Computational Fluid Dynamics
CNS	Civil Nuclear Security (see also ONR)
CoRWM	Committee on Radioactive Waste Management
DCIC	Ductile Cast Iron Container
DCP	Dounreay Cementation Plant
DRP	NDA's Direct Research Portfolio
DSRL	Dounreay Sites Restoration Limited
DSSC	Disposal System Safety Case
EA	Environmental Agency (of England and Wales, compare with SEPA)
EDF	EDF Energy (sites at: Hinkley Point B [D], Dungeness B [D], Sizewell B [D], Hartlepool [D], Heysham [D], Hunterston B [D], and Torness [D])
EDS	Engineered Drum Store [D]
EPR	The Environmental Permitting (England and Wales) Regulations 2010
EPS	Encapsulated Product Store [D]
FMEA	Failure Modes and Effects Analysis
GDF	Geological Disposal Facility
GGBFS	Ground Granulated Blast Furnace Slag
GP	Good Practice
GSR	General Safety Requirements
GWPS	Generic Waste Package Specification
HAW	Higher Activity Waste
HF	Human Factors
HLW	High Level Waste
HSW	Health and Safety at Work etc Act 1974
HVAC	Heating, Ventilating, and Air Conditioning
IAEA	International Atomic Energy Agency (an United Nations agency)
ILW	Intermediate Level Waste
IP	Industrial Package
IPT	Integrated Project Team
IRR99	Ionising Radiations Regulations 1999
IWMTOG	Integrated Waste Management Theme Overview Group
IWS	Integrated Waste Strategy
LAW	Lower Activity Waste

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LLW	Low Level Waste
LoC	Letter of Compliance
MBGWS	Miscellaneous Beta Gamma Waste Store [D]
MIC	Microbiologically influenced Corrosion
MoD	Ministry of Defence
MRWS	Managing Radioactive Waste Safely
MXL	Magnox Limited (sites at: Berkeley [D], Bradwell [D], Chapelcross [D], Dungeness A [D], Hinkley Point A [D], Hunterston A [D], Sizewell A [D], Trawsfynydd [D], Oldbury [D] and Wylfa [D])
NDA	Nuclear Decommissioning Authority
NIA65	Nuclear Installations Act 1965 as amended
NISR 2003	The Nuclear Industries Security Regulations 2003
NORMS	National Objectives Requirements Model Standards
NWRF	Nuclear Waste Research Forum
OLC	Operational Limits and Conditions
ONR	Office for Nuclear Regulation
OPC	Ordinary Portland Cement
PAS	Publicly Available Specification
PCM	Plutonium Contaminated Material
PETF	Product Evaluation Task Force
PFA	Pulverised Fuel Ash
PPE	Personal Protective Equipment
RH	Relative Humidity
RHILW	Remote–handled Intermediate Level Waste
RMT	Radioactive Materials Transport (see also ONR)
RSA93	Radioactive Substances Act 1993
RSRL	Research Sites Restoration Limited (operates sites at Harwell and Winfrith)
RWMC	Radioactive Waste Management Case
RWMD	Radioactive Waste Management Directorate
SAPs	Safety Assessment Principles
SCC	Stress Corrosion Cracking
SEPA	Scottish Environment Protection Agency (compare with EA)
SL	Sellafield Limited
SLC	Site Licence Company
SRL	Safety Reference Levels [D]
SOF	Store Operations Forum
SQEP	Suitably Qualified and Experienced Person
SWTC	Standard Waste Transport Container
TAG	Technical Assessment Guide
TCSC	Transport Container Standardisation Committee
TRL	Technical Readiness Level
TRS	Treated Radwaste Store [D]
VPS	Vitrified Product Store [D]
WAC	Waste Acceptance Criteria
WAGR	Windscale Advanced Gas–cooled Reactor
WENRA	Western European Nuclear Regulators' Association
WPSGD	Waste Package Specification and Guidance Documentation

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