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THE DEVELOPMENT OF A ROBUST SHIELDED BOX TRANSPORT CONTAINER (RSBTC)

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ABSTRACT

In recent years, a number of the organisations responsible for managing the clean-up of the UK's nuclear licensed sites have adopted the use of Robust Shielded Boxes (RSBs) for the packaging of Intermediate Level Waste (ILW). RSBs are thick-walled, ductile cast iron containers with a gross mass of up to 35 tonnes. They do not require remote handling and can use lightly-shielded, personnel-accessible stores.

To have confidence that waste packaged in RSBs could, in the future, be disposed of at a geological disposal facility (GDF), a key factor is the feasibility of transporting the packages through the public domain. While some RSB designs are suitable for transport as Industrial Packages (Type IP-2) in their own right, a reusable Type B(U) transport container for RSBs would offer benefits to waste packagers by enabling the packaging of more active wastes, allowing greater flexibility in waste management strategies. This could include supporting the implementation of a consolidated store strategy, or avoiding the need to repackage certain wastes following interim storage.

Radioactive Waste Management Limited (RWM) has developed a conceptual design for a Robust Shielded Box Transport Container (RSBTC, Figure 1). The first step in the development was to identify the requirements that the design of an RSBTC would need to satisfy in order to be a feasible solution for waste packagers and for RWM as the developer and future operator of a GDF.

This paper discusses the need for an RSBTC in the UK and its potential applications, setting out the key requirements and constraints that the design of an RSBTC needs to satisfy, and the resulting challenges for the design. Two further papers relating to the RSBTC have been selected for presentation at PATRAM 2019; one discusses the design aspects of the development, the other focuses specifically on the structural design and analyses to demonstrate the impact performance of the container, including the innovative double spigot arrangement and the design of the impact limiting system.

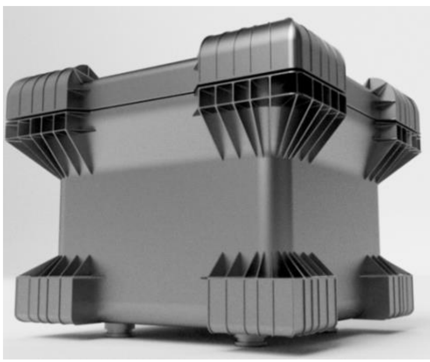


Figure 1. Conceptual design for an RSBTC

INTRODUCTION

Since the late 1940s, the UK has accumulated radioactive waste, which is currently stored at more than 30 sites around the UK. Low Level Waste (LLW) is typically managed by treatment or disposal at the UK's LLW Repository, while ILW in England and Wales will be disposed of in a GDF[1]. RWM's mission is to deliver a GDF and provide radioactive waste management solutions [1].

Plans for the construction of a GDF in England and Wales are at an early stage. In order to have confidence that the conditioning and packaging of radioactive waste will result in waste packages that would be compatible with future transport to and disposal in a GDF, RWM has implemented a Disposability Assessment process [2]. This process considers the performance and safety of waste packages against a suite of waste packaging specifications [3], which set out the bounding package requirements anticipated for transport to and disposal in a GDF. A key aspect of the process is to consider the feasibility of safe, compliant transport of waste packages through the public domain to a GDF.

In recent years, a number of waste packagers have proposed the use of RSBs for the packaging of ILW. RSBs are thick-walled (up to a few hundred millimetres), typically made from ductile cast iron, and have a gross mass of up to 35 tonnes; they are suitable for packaging of waste with a wide range of specific activities and fissile nuclide contents. Due to the shielding provided by their thick cast iron walls, RSBs do not typically require full remote handling and can use lightly-shielded, personnel-accessible stores.

Some RSB designs are suitable for transport as Type IP-2 packages in their own right [4]. However, through engagement with waste packagers, RWM identified that a reusable Type B(U) transport container could enable RSBs to be used for packaging and disposal of more active wastes, de-risking current waste packaging campaigns and allowing greater flexibility in the development of future waste management strategies.

This paper sets out the case for development of an RSBTC and its potential applications, describes the requirements-led approach to design development, and discusses the key requirements and constraints that the design of an RSBTC needs to satisfy.

DRIVERS FOR DEVELOPING AN RSBTC

The Magnox reactors were the first generation of commercial nuclear power stations to operate in the UK. All of these reactors have now shut down, and Magnox Ltd is responsible for the management of the reactor sites through to final site clearance. A key step in decommissioning these sites is the retrieval of operational ILW from temporary storage and packaging it in a more passive state that is suitable for interim storage, pending future transport and disposal in a GDF.

Magnox Ltd has adopted a range of waste containers for packaging ILW including, at some sites, the GNS Yellow Box® ductile cast iron container (DCIC). The GNS Yellow Box® meets the RWM Waste Package Specification for a 3 cubic metre RSB [4], which is one of a range of standardised designs of waste container that have been shown to be compatible with disposal in a GDF.

[1] The Scottish Government Policy is that the long-term management of higher activity radioactive waste should be in near-surface facilities

Originally, it was proposed that these waste packages would all be transported as Type IP-2 packages. However, engagement between Magnox Ltd and RWM through the Disposability Assessment process identified a risk that some of the waste packaged in these containers could be challenging to justify as Low Specific Activity LSA-2 material, as defined in the IAEA transport regulations [5], and so might not be transportable under IP-2 arrangements. A Type B transport solution could mitigate the risks associated with the future transport of these waste packages to a GDF. In addition, it could support the implementation of a consolidated stores strategy, and potentially offer greater flexibility in the wastes that can be packaged in 3 cubic metre RSBs.

On the Sellafield site, the legacy ponds and silos were historically used to prepare fuel for reprocessing and to store the resulting waste; radioactive materials have remained in the facilities since routine operations ended. There is now a need to retrieve the wastes from these ageing facilities and place them into safer and more secure, modern storage conditions [6]. Some of these wastes will be placed in Self-Shielded Boxes (SSBs), with the boxes providing the principal means of containment and shielding of the waste within a lightly-shielded interim store.

Sellafield Ltd has engaged with RWM to explore whether waste packaged in SSBs could be suitable for disposal in a GDF. This could avoid the need for repackaging of the waste following interim storage, with associated cost, safety and environmental benefits. RWM identified that a key risk to the disposability of SSBs was the feasibility of transport through the public domain under Type B arrangements.

A reusable Type B(U) transport container for RSBs could therefore offer benefits to Magnox Ltd and Sellafield Ltd. and has the potential to benefit other waste packagers in the development of future waste packaging proposals. To support waste packagers, RWM has undertaken a programme of work to develop a conceptual design for an RSBTC, aiming to demonstrate a Technology Readiness Level (TRL) of 3 [7], that is, proof of concept. Figure 2 summarises the TRL scale.

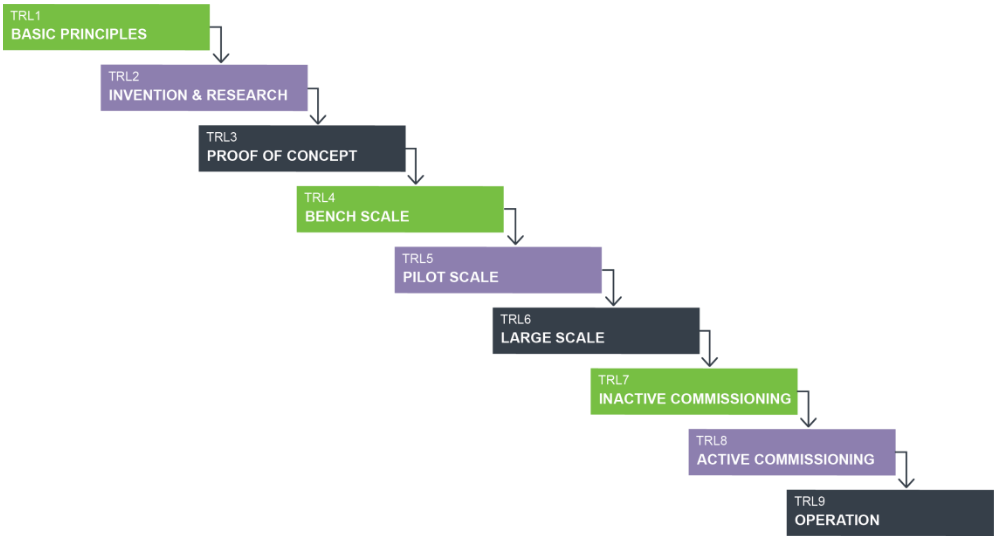


Figure 2. Technology readiness scale [7]

For a transport container, the demonstration of TRL3 includes:

- An analytical demonstration that the key structural, thermal and shielding load cases are met
- A manufacturability assessment to provide confidence that the concept could be produced cost effectively

Demonstrating that the RSBTC is a feasible concept with a TRL of 3 provides the necessary confidence that RSB waste packages could, in future, be transported in a safe, compliant manner as part of a Type B package. This will enable RWM to endorse waste packaging proposals through the Disposability Assessment process, de-risking current waste packaging campaigns and enabling greater flexibility in future proposals for use of RSBs.

REQUIREMENTS-LED APPROACH

The development began with comprehensive phase of identifying and prioritising requirements, following the best practice given by the Ministry of Defence (MOD) approach to Capability Management [8]. Figure 3 illustrates the requirements-led approach.

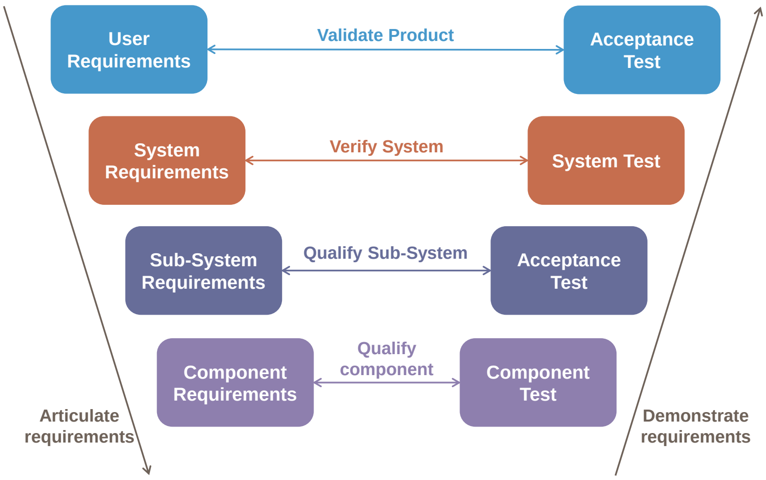


Figure 3. Overview of the requirements-led approach

In effect, this approach involved developing:

- A single statement of need, which is the highest level expression of requirements
- A User Requirements Document (URD), which sets out the outcomes and capabilities required by the future users
- A System Requirements Document (SRD), which identifies the functions needed to fulfil the user requirements
- An Integrated Test, Evaluation and Acceptance Plan (ITEAP), which defines the testing and evaluation strategy that will be used to verify the design against the requirements

The approach requires that user and system requirements are independent of the solution, and must also be concise, unambiguous, justified, testable and measurable. RWM used a series of questionnaires and structured workshops with Magnox Ltd and Sellafield Ltd to establish the requirements, including agreement on the single statement of need:

> *The United Kingdom has a need to safely transport Robust Shielded Box waste packages through the public domain, as part of a Type B transport package, to either an off-site interim storage facility or a GDF for final disposal.*

As part of the requirements capture phase, measures of effectiveness were defined for each requirement, to enable assessment of whether or not the requirement has been met by the design. The requirements were also prioritised in order to determine:

- The mandatory and key requirements, which constitute the minimum requirements the design has to fulfil in order to be considered feasible
- The lower priority requirements, which can be traded-off against one another if necessary

Following this approach enabled the definition of a clear framework for the subsequent design development, with the URD and SRD setting out the requirements that the design of an RSBTC would need to fulfil in order to represent a feasible, practical solution for the future users (Magnox Ltd and Sellafield Ltd as waste packagers, and RWM as the developer and future operator of a GDF), as well as defining unambiguous measures to verify that the design fulfils the required capability.

KEY REQUIREMENTS

Compatibility with the Waste Containers

As the fundamental purpose of the RSBTC is to transport RSBs, it needs to be compatible with external dimensions, geometric interfaces and mass of the different RSBs to be transported. Table 1 summarises the external dimensions and mass of the 3 cubic metre RSB and the SSB, while Figure 4 provides a schematic illustration of external geometric interfaces of the two containers.

Table 1. External dimensions and mass of RSBs

	3 cubic metre RSB	SSB
External height (mm)	1740	1740
External length (mm)	2010	2140
External width (mm)	1610	1940
Gross mass (tonne)	25	35

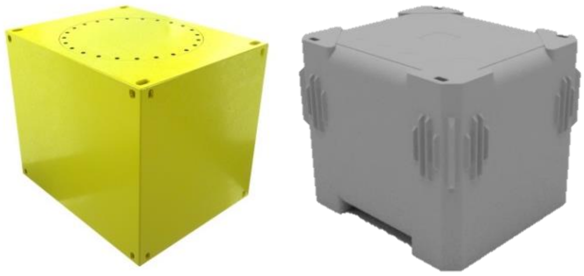


Figure 4. Schematic illustrations of 3 cubic metre RSB (left) and SSB (right)

Ensuring compatibility with the waste containers presents a number of challenges for the design of an RSBTC, as summarised in Table 2.

Table 2. Summary of challenges for the design of an RSBTC in order to ensure compatibility with RSB waste containers

Challenge	Description
Large external dimensions of RSBs	A transport container large enough to contain the 3 cubic metre RSB and the SSB could have challenges for manufacturing, handling and operations
High payload mass of RSBs	The high payload mass of the 3 cubic metre RSB and the SSB could challenge the design of the closure system of a transport container

Challenge	Description
Compatibility with multiple RSB designs	While similar in size, the SSB is longer and wider than the 3 cubic metre RSB and has different geometrical interfaces; designing one transport container to be compatible with both could introduce complexity to the design

Compatibility with the Restrictions of the UK Rail Network

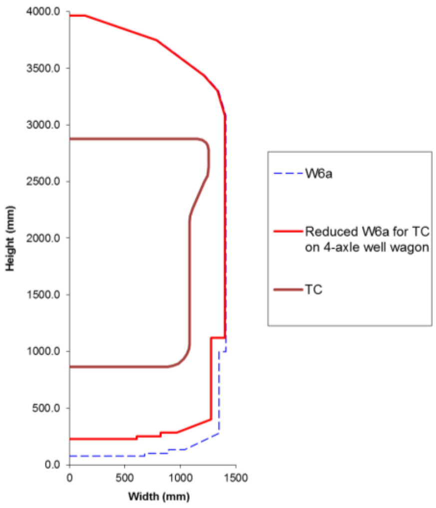
The future transport of waste packages to a GDF needs to consider the principles of the Nuclear Decommissioning Authority (NDA) Transport and Logistics Strategy, which include the use of rail over road where practicable [9]. As the location of a GDF is not currently identified, the design for an RSBTC needs to be compatible with the most restrictive sections of the UK rail network to ensure that transport by rail will be possible wherever a GDF is ultimately sited.

In respect of rail transport, the two main issues that need to be considered are:

- The rail gauge, which reflects the geometrical constraints due to bridges, tunnels, etc. along the route
- The Route Availability (RA), which reflects the maximum permissible load on the rail wagon axles along the route

In order to allow usage of as much of the UK's rail network as possible, it was determined that, when loaded on a suitable rail wagon, an RSBTC should be:

- Compatible with the dimensional constraints of the W6a rail gauge, as illustrated in Figure 5
- Compatible with the mass constraints of the RA8 network (maximum load of 22.8 tonnes per axle), although use of the less restrictive RA10 network (maximum load of 25.4 tonnes per axle) could be acceptable



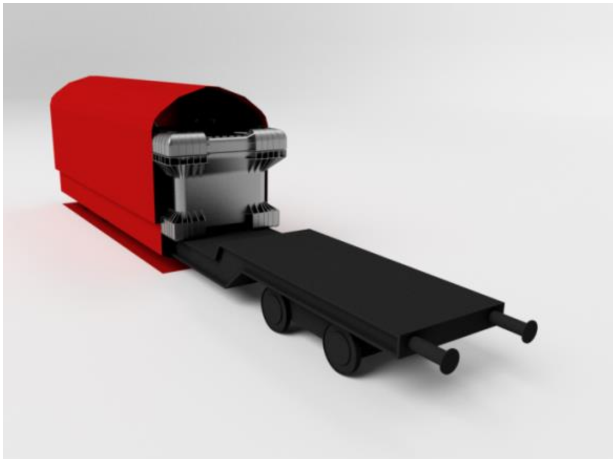


Figure 5. UK W6a rail gauge adjusted to account for rail wagon design

Coupled with the large phyical size of the RSBs, the dimensional constaints of the W6a rail gauge present a significant challenge for the design of an RSBTC, restricting the space available for impact limiting structures.

Considering the high payload of the RSBs, the mass restrictions of the rail network also present a challenge for the design of an RSBTC. In effect, a 4-axle rail wagon is preferred, as more axles would result in a further reduction of the rail gauge due to kinematic effects, leading to more onerous dimensional constraints. As shown in Table 3, in order to enable transport on the RA8 network on a 4-axle wagon, the maximum tare mass of the RSBTC would be 31.2 tonnes; this could be a challenge for the design of the closure system, as the ratio of the mass of the RSB to the tare mass of the RSBTC would be approximately 1.

Table 3. Calculation of the maximum possible tare mass of the RSBTC for transport on the UK rail network on a 4-axle wagon

	RA8	**RA10**
Maximum axle load (te)	22.8	25.4
Gross mass of laden 4-axle wagon (te)	4 × 22.8 = **91.2**	4 × 25.4 = **101.6**
Mass of 4-axle wagon (te) [10]	25	25
Maximum payload mass of RSB (te)	35	35
Maximum tare mass of RSBTC (te)	91.2 - 25 - 35 = **31.2**	101.6 - 25 - 35 = **41.6**

Operability at a GDF and at Waste Packagers' Sites

In accordance with the generic process for receipt and emplacement of robust shielded ILW packages, described in the current baseline Generic Disposal Facility Design [11], it is assumed that following receipt at a GDF, an RSB in an RSBTC would be transferred underground in its transport configuration and moved by overhead crane to a vault reception area. The RSBTC would then be unloaded in the vault reception area, and the RSB emplaced in a disposal vault.

Depending on the geological environment in which a GDF is ultimately sited, access to the underground facilities may be via a drift, using a rack and pinion railway as illustrated in Figure 6, or via a vertical shaft. The design of an RSBTC therefore needs to be compatible with the geometrical constraints of the drift and the shaft; the current baseline for a GDF assumes:

- A drift would have a cross-sectional profile similar to the W6a rail gauge
- A shaft would have a diameter of 9 m, with a cage plan area of 7.2 × 3.5 m

The mass of an RSBTC would also need to be compatible with load limits of the GDF handling equipment along the route from the surface to the vault reception area. The most restrictive limit along this route is 65 tonnes, based on the baseline capacity of the drift and shaft. The dimensional and mass constraints required for compatibility with a GDF are therefore similar to the constraints for transport on the UK rail network, although feasibility studies have shown that the capacity of the GDF handling equipment could be increased if required [12].

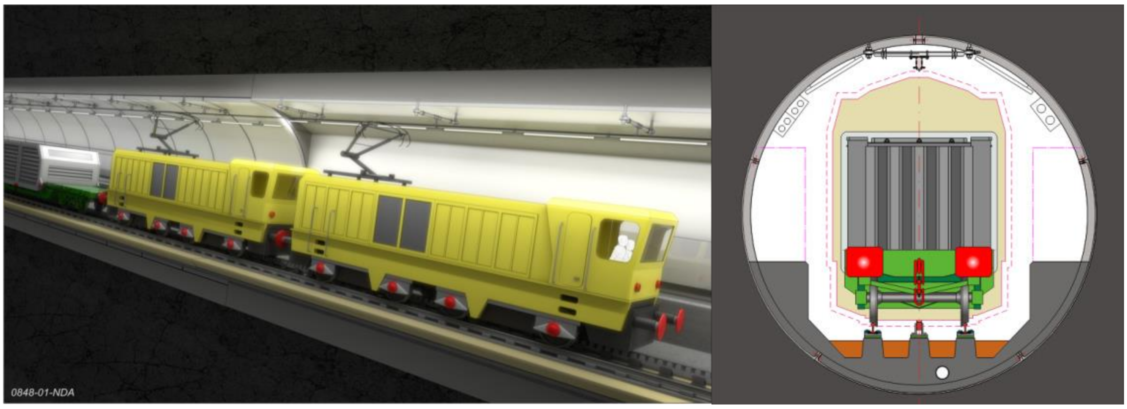


Figure 6. Rack-and-pinion drift transport system (left) and drift cross-section (right)

With respect to operation at waste packagers' sites, no facilities currently exist for loading and export of an RSBTC. It was therefore assumed that the mass and dimensional restrictions for rail transport would be bounding of any constraints on waste packagers' sites.

Regulatory Compliance

In order to enable RSBs to be transported through the public domain as a Type B package, the design for an RSBTC needs to comply with the IAEA Regulations for the Safe Transport of Radioactive Materials SSR-6 [5].

As robust shielded containers, the 3 cubic metre RSB and SSB have a high inherent level of containment and shielding integrity. However, apart from shielding integrity, it was agreed that it would be appropriately conservative for the design of an RSBTC to assume no performance contribution from the RSB, as this could avoid the need to qualify the RSB containment for transport following long periods of interim storage. Based on previous experience of the design of large Type B transport containers [13], the large size and mass of a fully laden RSBTC could present a significant challenge to maintaining containment in the impact accident conditions defined in the IAEA transport regulations [5].

In addition to compliance with the transport regulations, the design of an RSBTC needs to be cognisant of other regulations, notably those applicable to safe handling and operation of the RSBTC at waste packagers' sites and at a GDF including the Ionising Radiation Regulations (2017), Lifting Operations and Lifting Equipment Regulations (1998) and Health and Safety at Work etc. Act (1974).

Taking account of these regulations requires the design of an RSBTC to incorporate appropriate lifting and handling features, to minimise operator exposure to ionising radiation so far as is reasonably practicable, for example by not foreclosing the option of remote loading/unloading operations, and to apply appropriate standards and relevant good practice.

Summary of Key Requirements

Figure 7 summarises the key requirements that the design of an RSBTC would need to fulfil in order to be a feasible solution for Type B transport of RSB waste packages in the UK, including the 3 cubic metre RSB and SSB.

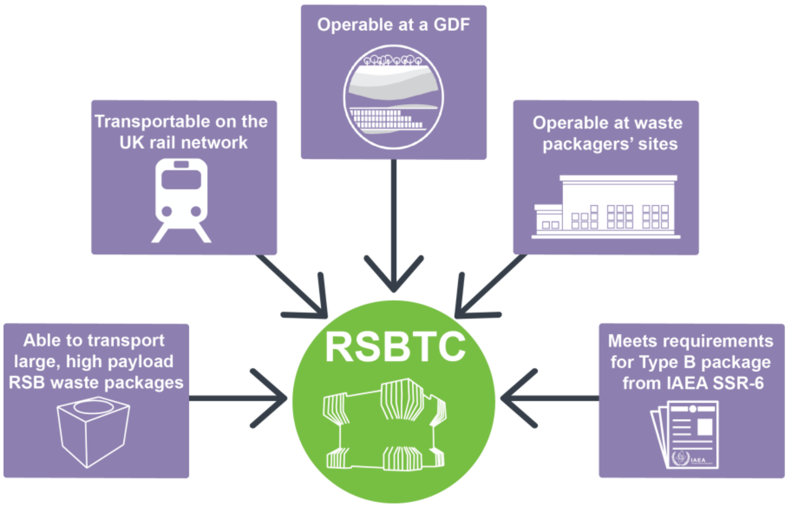


Figure 7. Summary of key requirements for the design of an RSBTC

DESIGN DEVELOPMENT

Following the initial phase of work to establish the user and system requirements for an RSBTC, a conceptual design was developed, including the use of Finite Element Analysis (FEA) to substantiate the structural and thermal performance of the concept and a manufacturability assessment to provide confidence that the design could be manufactured cost effectively using existing technologies. Two further papers at PATRAM 2019 discuss the RSBTC conceptual design development, including the design of an innovative double spigot arrangement and impact limiting system [14], and the structural design and analyses to demonstrate the impact performance of the container [15].

Following the completion of the conceptual design, a systematic review was carried out against the user and system requirements, using a Verification and Validation Requirements Matrix (VVRM) defined in the ITEAP. This review confirmed that the conceptual design meets all of the key requirements and that the design substantiation demonstrates a TRL of 3, in other words, it has been demonstrated that the RSBTC is a feasible concept that would allow transport of RSBs within a Type B package from waste packagers' sites, via the UK rail network, to a GDF.

In terms of future work, an implementation plan has been developed which identifies the scope of work, together with the costs and timescales, to develop the RSBTC concept to a level of maturity suitable for implementation. This supports the work undertaken to demonstrate the technical feasibility, by providing confidence that the RSBTC is also a viable concept from a cost and schedule perspective. Figure 8 summarises the principal stages involved in developing the RSBTC through to the point of deployment, along with indicative timescales, although it would be possible to shorten this programme by undertaking some activities in parallel, depending on the required timeframe for deploying an RSBTC.

Figure 8. Principal stages for future development of an RSBTC

CONCLUSIONS

Through engagement with waste packagers, RWM identified that a reusable Type B(U) transport container for RSBs could offer benefits, including:

- Mitigating risks relating to the future transportability of waste already packaged in RSBs
- Enabling RSBs to be used for the packaging of more active wastes
- Avoiding the need to repackage certain wastes following interim storage

A conceptual design has been developed for an RSBTC, using a requirements-led approach whereby the capability and functionality required by future users of an RSBTC (notably, waste packagers and RWM as the developer and future operator of a GDF) was captured through a set of user and system requirements. The user and system requirements provided a clear framework for the subsequent design development, setting out the requirements that the design of an RSBTC would need to fulfil in order to represent a feasible, practical solution for the future users, as well as defining unambiguous measures to verify that the design fulfils the required capability.

The key requirements identified for the design of an RSBTC included the need to be compatible with the 3 cubic metre RSB and SSB waste packages, the need to be transportable on the UK rail network and operable at a GDF and at waste packagers' sites, and the requirement to comply with the IAEA transport regulations.

The combination of these requirements presented a significant technical challenge for the subsequent design development, as the large physical size and mass of the RSB waste containers coupled with the dimensional and mass constraints of the UK rail network made it challenging to achieve the structural performance necessary to maintain containment under the impact accident conditions defined in the transport regulations.

A conceptual design was developed, and a review against the user and system requirements demonstrated that the RSBTC meets all of the key requirements, using an innovative double spigot arrangement and impact limiters to achieve satisfactory performance in impact accidents while still being compatible with the dimensional and mass restrictions of the UK rail network. The RSBTC is therefore a feasible concept with a TRL of 3. The scope of work required to develop this concept to the level of maturity required for implementation has also been identified, providing confidence that the RSBTC is a viable concept from a cost and schedule perspective. Work is underway to incorporate the RSBTC into the baseline design for a GDF, which will enable benefits to be realised in terms of de-risking current waste packaging campaigns and allowing greater flexibility in future proposals for use of RSB waste packages.

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REFERENCES

[1] RWM, *Corporate Strategy 2019: Our approach to provide a safer future by managing radioactive waste effectively, to protect people and the environment*, 2019, ISBN 978-1-905985-37-1
[2] NDA, *WPS/650/03 An Overview of the RWM Disposability Assessment Process*, 2014
[3] RWM, *Packaging of radioactive waste: specifications and guidance*, Updated 2018
[4] RWM, *WPS/381/01 Waste Package Specification for 3 cubic metre robust shielded box waste packages for transport as part of a Type IP-2 package*, 2015
[5] IAEA, *Regulations for the Safe Transport of Radioactive Materials SSR-6*, 2012, ISBN 978–92–0–133310–0
[6] NDA, *Nuclear Decommissioning Authority Strategy Effective from April 2016*, 2016, ISBN 9781474130448
[7] NDA, *Guide to Technology Readiness Levels for the NDA Estate and its Supply Chain*, 2014
[8] MOD, *Guidance: Knowledge in Defence*, 2019
[9] RWM, *DSSC/411/01 Geological Disposal: Generic Transport System Design*, 2016, ISBN 978-1-84029-558-0
[10]United Kingdom Nirex Ltd, *Design of a Rail Wagon for Transporting all Nirex Packages*, 1994
[11]RWM, *DSSC/412/01 Geological Disposal: Generic Disposal Facility Design*, 2016, ISBN 978-1-84029-559-7
[12]RWM, *NDA/RWM/141 Geological Disposal: Design Status Report*, 2016, ISBN 978-1-84029-533-7
[13]I A Grainey, *Development of a Large Waste Transport Container for Disposal of Legacy ILW to a Geological Disposal Facility in the UK*, PATRAM, 2013
[14]M Johnson, *Conceptual Design of Robust Shielded Box Transport Container Type B(U) Package Design*, PATRAM, 2019
[15]C B Izatt, *Designing the Robust Shielded Box Transport Container to satisfy the impact performance requirements defined in the IAEA Transport Regulations for Type B Packages*, PATRAM, 2019