Submarine Dismantling Project (SDP)

Consultation on the Site for Interim Storage of ILW - Supporting Information on RPVs and RPV store

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Ministry of Defence

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Revision Notes

This is the first issue of this Supporting Information Document.

Contents

1. Introduction

Submarine Dismantling Project

1. The Submarine Dismantling Project (SDP) is MOD's programme to deliver a safe, secure and environmentally responsible solution for dismantling 27 defuelled submarines. This involves recycling the bulk of the submarine and safely disposing of the remainder. For the radioactive Intermediate Level Waste (ILW), the disposal process includes storing the Reactor Pressure Vessels (RPVs), whole, for an interim period until the ILW in the RPVs can be sent to a Geological Disposal Facility (GDF) some time after 2040. The current Public Consultation will help to determine where the interim RPV storage site should be located.

This Document

2. The MOD has published a Consultation Document and associated Factsheets to help potentially involved communities and other stakeholders understand more about the project and to seek their views on three main topic areas:

   - the Strategic Environmental Assessment;
   - the process and criteria being used to compare the shortlisted storage sites;
   - the shortlisted sites and the differences between them.

3. This Supporting Information Document addresses some specific technical information requirements identified during Pre-engagement with stakeholders by providing additional technical information the RPVs and their transport and storage. It generally does this by expanding on the text in the main Consultation Document and by providing links to online resources.

   - Section 2 describes the RPVs. Section 3 and 4 then describe the containers used to transport and store them and provide more detail on RPV transport arrangements.
   - Sections 5 to 6 describe the proposed RPV storage arrangements.

4. This document inevitably includes a higher proportion of technical language and specialist terms than the main Consultation Document and so a supplementary technical glossary is included as Annex A.

5. Further Annexes cover the RPV store technical requirement (Annex B) and Regulatory frameworks (Annex C). There are supplementary information and pictures of existing or planned Nuclear Decommissioning Authority (NDA) interim Intermediate Level Waste stores in Annex D.

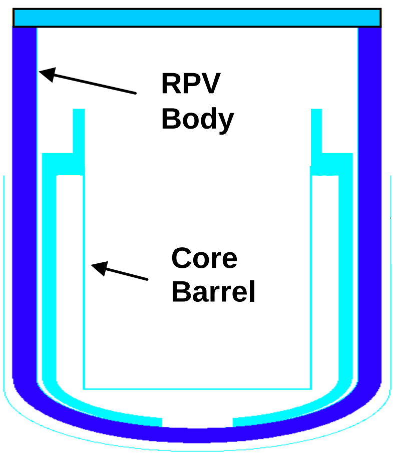
6. Annex E comprises a collection of previously published pictures of several previous civil RPV removal and transport operations around the world. Note, however, that they are all very much larger and heavier than the SDP's RPVs.

2. RPV Characteristics

Introduction

7. The nuclear energy that powers Royal Navy submarines is created by a Pressurised Water Reactor (PWR). The PWR design is the most common type of nuclear reactor in Western countries and is used for civil power generation as well as for propulsion in large military surface ships and submarines[1].

8. The main feature of a PWR is the Reactor Pressure Vessel (RPV), which is housed within a Reactor Compartment. The RPV consists of a main RPV body and the RPV head which is bolted to it. It contains a number of internal steel components, including the core barrel which holds the fuel. There are connections in the RPV body for the primary cooling circuit pipework and in the RPV head for the control rods.



9. High pressure, high temperature water circulates through the RPV and then through what is known as the primary circuit. The water transfers the heat generated by the nuclear fission reaction in the fuel to the steam generators where steam is raised for conversion to propulsion and electrical power.

10. At the end of a submarine's operational life the submarine is stored pending its eventual dismantling and the nuclear fuel is removed. After the reactor plant has been defuelled it can be removed from the submarine.

11. Three generations of reactors have been used in the submarines that fall within SDP's scope. There is one S5W reactor, which was used in HMS Dreadnought, the UK's first nuclear-powered submarine, 22 of the PWR1-type, which were used in subsequent submarines up to the Trafalgar-class, and four of the PWR2-type, which are used in the current Vanguard-class submarines[2].

Size and Weight

12. PWRs, whether for power stations or propulsion, are designed to operate under high temperature (typically around 300°C) and pressure (typically around 15 MPa). RPVs are made of forged steel tens of centimetres thick. Depending on the type, a defuelled RPV is typically around three metres in diameter and four metres high and weighs between 50 and 80 tonnes. A PWR1 submarine RPV is typically around 3 metres in diameter and 4 metres high. The S5W reactor is slightly smaller than the PWR1 and the PWR2 slightly larger and quite a lot heavier.

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[1] In the UK, the military use of the PWRs is limited to those associated with submarine propulsion systems. Other countries have used nuclear propulsion in large cruisers, aircraft carriers and icebreakers.

[2] PWR2s are also used in the current Astute-class submarines but these are outside the scope of SDP.

Radiological Characteristics

13. With the removal of the used fuel, the vast majority of the radioactivity is also removed from the RPV. However, during the operational life of a reactor, the internal components and the RPV body and (to a lesser extent) RPV head were exposed to the neutrons that are responsible for initiating and sustaining the fission reaction in the nuclear fuel. Some of these neutrons are absorbed by the atoms that make up the components of the reactor and radioactivity is induced in the steel in a process known as 'neutron activation'[3].

14. The closer a component is to the nuclear fuel during operation of the reactor the higher the exposure to neutrons and hence the higher the degree of activation. The majority of the radioactivity is therefore concentrated in the innermost components of the RPV. Radioactive dose rates here are significant, though radioactive decay means that they will reduce by about 50% every 5 years or so[4].

15. Although they are themselves radioactive to some degree, the outer components and the RPV body and head help shield the higher radioactive inner components so that the amount of radiation reaching the outer wall is significantly reduced and overall dose rates on the outside are very much lower.

16. It is estimated that after the used fuel has been removed just over 60% of the remaining radioactivity will be in the core barrel, about 39% in the other internal components and only 1% in the RPV body. However, because the RPVs are being stored whole - as agreed following the previous Public Consultation - the entire RPV body and its internal components will be is treated as ILW for the purposes of storage.

Preparations for Removal and Transport

17. Prior to entering the SDP for removal of its RPV, the submarine will have undergone a De-fuel, De-equip and Lay-up Preparation (DDLP) process at the dockyard. During this process, all of the nuclear fuel is removed and the primary circuit drained.

18. Some other components of the reactor system, for example the primary coolant circuit, primary shield tank and steam generators, will also be either activated or contaminated but predicted levels are much lower and they will be removed and consigned as Low Level Radioactive Waste (LLW). All levels of radioactivity will have to be measured, monitored and formally demonstrated to the Regulators.

19. In preparation for the extraction of the RPV body from the submarine, any remaining free liquid will be removed from the RPV. The drying procedure is not yet finalised and therefore subject to change but might include inert gas dehumidifying. The amount of residual water, if there is any, will be minimal. A precise limit will be finalised in due course.

20. The RPV head will then be removed and a simpler replacement head fitted based on the existing bolting system. The original RPV head is known to be LLW and will be disposed of through established LLW waste streams. The nozzles connecting the RPV body to the primary cooling circuit pipework will also be cut and the nozzle openings closed with blanking plates to ensure that the RPV remains sealed.

21. The replacement head will hold the core barrel in place and provide shielding against the high dose rates from the internal components of the RPV. It will also facilitate lifting the RPV from the submarine.

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[3] Described in Wikipedia at http://en.wikipedia.org/wiki/Neutron_activation

[4] The principal radionuclide responsible for the dose rate is cobalt-60, which has a half-life of 5.27 years.

22. There should be no loose materials inside the RPV although some corrosion products will be coated on to the internal surfaces of the RPV. The quantity should be very low and the replacement head will ensure it remains contained.

23. The current assumption is that there is no means by which the sealed RPV could become pressurised. This will be assured by the drying process, keeping organic materials from the RPV, and an assessment of the potential for the carbon-14 and tritium inventory to pressurise the RPV. The RPV store is therefore not expected to contribute to the storage site's radioactive discharges and will not require routine discharge monitoring.

Removal and Transfer of the RPV to its Container

24. The details of the RPV removal process have yet to be confirmed but the main steps are: cut an access hole in the submarine hull; put containment in place; then detach and remove the RPV from the submarine.

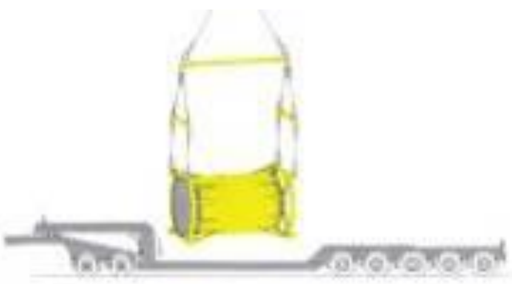
25. Once an RPV has been removed from a submarine, it will need to be packaged into a container (described below) for transport from the dockyard to the interim RPV store, where the RPV will remain until it is transported to a size reduction facility prior to final disposal at a GDF (see para. 61).

26. The radiation and contamination levels on the external surfaces of the RPV will be monitored prior to it being loaded into its container. Any radioactive contamination on the outside of the RPV will either be removed or covered before it is sealed into the container.

27. Before shipment from the initial dismantling site to the storage site, the transport container will be checked for external contamination and dose rate levels as well as general structural condition to ensure that it complies with all Regulations.

RPV is lifted out of Submarine

The Container lid is removed and RPV is loaded into container



The Container is lifted onto transport trailer

3. RPV Container

Introduction

28. The transport regulations specifying the standards applicable to the design, construction, testing, approval and use of transport packaging are based on the International Atomic Energy Agency (IAEA) safety standards[5]. These are incorporated into UK legislation through The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009[6] via, for road transport, the European Agreement Concerning the International Carriage of Dangerous Goods by Road (known as the ADR).

29. The Regulations are enforced by the appropriate Regulator. For civil material this is ONR[7] and for the MOD it is the Defence Nuclear Safety Regulator (DNSR).

30. The current pre-concept design described here would allow a robust thick-walled steel container with internal shock-absorption and external impact protection for both transport and storage. The containers will have to meet applicable national and international standards for both purposes. Alternative approaches will, however, continue to be explored, including the use of different materials and different packaging combinations for transport and storage.

Container Types

31. There are different categories and types of packaging, depending on the characteristics of the radioactive material being transported.

32. The SDP is currently assessing two types of packaging for practicability and suitability for the transport of the RPVs: 'Industrial Package Type 2' (IP-2) and 'Type B'. The choice will be made in consultation with the appropriate Regulators and the pre-concept design described below will then be developed into a detailed IP-2 or Type B design as appropriate.

33. Whichever type is used, two sizes of container will almost certainly be required, one for the PWR1 RPVs and one for the PWR2 RPVs. As the S5W reactor is only slightly smaller than the PWR1, it is expected that that this will be transported in the PWR1 container.

Design Considerations

34. The generic characteristics below will be a feature of the RPV packaging irrespective of whether it meets the IP-2 or Type B standards. The principal differences between the two will be the detailed construction, the dimensions and the test regimes.

35. The container walls will be designed to withstand impact loads as prescribed by the Regulations. Depending on the wall thickness, it may be necessary to include additional shielding material to meet the dose rate requirements on the outside of the container. Maximum allowed dose rates are specified in the Regulations as 2 mSv/h on contact and 0.1 mSv/h at 2 m during transport.

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[5] Regulations for the Safe Transport of Radioactive Material (2012 Edition), SSR-6, IAEA Safety Standards, IAEA, Vienna, 2012. Available from http://www-pub.iaea.org/MTCD/publications/PDF/Pub1570_web.pdf.

[6] See www.legislation.gov.uk/uksi/2009/1348/contents/made

[7] See www.onr.org.uk/transport

36. If required, shock absorbing features or material will be incorporated in the container design or external packaging added to provide increased protection so that the forces and stresses experienced by the RPV are less than those experienced by the containment vessel under normal and accident conditions of transport. Additionally, an outer impact frame or impact limiter may be attached to the containment vessel to provide primary impact protection.

37. Various tests and limits are mandated for different types of containers and their contents to demonstrate that they will be intrinsically safe during transport under both normal and accident conditions. Test regimes may (depending on the type of packaging) include impact (drop) tests, punch and penetration tests, engulfing fire tests and spray and immersed water tests, amongst others.

Size and Weight

38. Based on pre-concept studies for an IP-2 type / PWR1 container, the bounding container masses are estimated as follows. The estimated mass of the laden PWR2 transport container is based on an extrapolation from the PWR1 equivalent using a 150% multiplication factor.

- PWR1 laden RPV container: about 90 tonnes.
- PWR2 laden RPV container: about 135 tonnes.

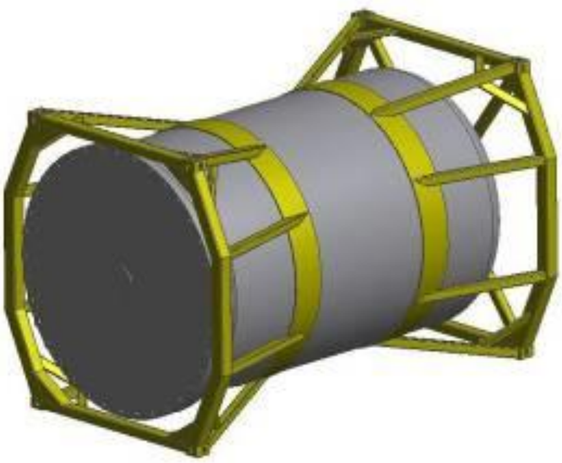
39. Based on the pre-concept IP-2 design for a PWR1 RPV, typical overall dimensions of the transport container are estimated as follows. PWR2 figures are approximately scaled from the PWR1 equivalents.

- PWR1 transport container: Length 4.8 m x Width 3.2 m x Height 3.2 m.
- PWR2 transport container: Length ~6 m x Width ~4 m x Height ~4 m

40. If a Type B container were to be used, it is expected that the external dimensions and bounding masses of the laden container would substantially increase.

41. For reference, a selection of the key regulations, Standards and Codes of Practice relevant to the design of the RPV container are listed in Annex C.

42. The picture below is illustrative only. The eventual design may well differ.



4. RPV Transport

Introduction

43. In the UK, over half a million shipments of radioactive materials of all kinds are transported safely every year. These consignments, which are carried by road, rail, sea, air and inland waterways, can range from smoke detectors and cobalt sources for medical uses to nuclear fuel cycle materials for electricity fuel generation and submarine propulsion.

44. The transport of radioactive materials is governed internationally by a stringent Regulatory regime, which includes codes and regulations which have been regularly revised and updated.

45. The Office for Nuclear Regulation (ONR) supports work to compile, analyse and report accidents and incidents that occurred during the transport of radioactive materials. Annual reports have been produced since 1989. The report for the year 2012, prepared by Public Health England is the latest in the series[8].

46. The container plays an important role in protecting the public, workers and the environment against the effect of radiation and release of the radioactive contents as described above. However, in addition to the regulations associated with the transport of radioactive materials there are regulations associated with the size and mass of the load.

47. Historically, safety justifications have been made for all three generic transport methods (road, rail and sea). RPV movements would have to meet the prevailing regulations and policy in each case. For instance:

    - The RPV plus container will be very heavy and will exceed the 44 tonne standard maximum load on UK roads. As a consequence, the RPV packages would be transported as an 'Abnormal Indivisible Load' (AIL) under The Road Vehicles (Authorisation of Special Types) (General) Order 2003[9].
    - If they were to be transported by rail, they would be subject to limits placed on the laden railway wagons to meet loading gauges (width and height restrictions) and axle weight restrictions.

48. Initial assessments suggests that road transport would have clear advantages over rail and sea alternatives and is therefore currently assumed.

    - All options will require some element of road transport.
    - The size of the transport container will almost certainly exceed the national rail loading gauge.
    - The cost of provision of a nuclear justified ship/shore interface for sea transport will significantly increase the cost above that of road transport alone.

49. Final confirmation will be required once the container design is finalised, which may be will probably be after the storage site is chosen.

[8] See www.gov.uk/government/uploads/system/uploads/attachment_data/file/345814/PHE-CRCE-014.pdf

[9] See www.legislation.gov.uk/uksi/2003/1998/made

Road Transport

50. The IP-2 pre-concept container is not particularly large. At approximately 3.2 wide x 3.2 high x 4.8 m long (for a PWR1) it is slightly wider than the standard maximum width of an articulated lorry under the Road Transport (Construction and Use) Regulations but within the length and height requirements. A Type B container would be expected to be larger in all three dimensions but would still meet the road transport requirements for maximum height and lengths.

51. The laden PWR1 pre-concept IP-2 is approximately 90 tonnes. Transport of heavy loads under the AIL regulations is normal business for heavy haulage companies and loads of several hundred tonnes are routinely moved on UK roads. It is estimated that there are over 150,000 escorted movements on British roads every year.

52. To limit damage to the roads, the container would have to be transported on a long wheelbase heavy transport vehicle to spread the load over a large number of axles. A Type B container would be heavier still and would therefore need a longer and wider trailer.

53. For reference, a selection of the key regulations, standards and codes of practice relevant to the transport of the RPV container are listed in Annex C.

Example of type of lorry suitable for RPV transport

5. Interim Storage Requirements

RPV Store

54. This section sets out the functional requirements which will underpin the design of a store to achieve SDP's objectives. The next section presents an illustrative Baseline Concept based on these requirements.

55. All design, manufacturing and construction will be carried out in accordance with prevailing legislation and appropriate British and International standards and industry codes of practice. SDP's RPV store project will also comply with 'joint guidance' on the management of higher activity radioactive waste issued by the Office for Nuclear Regulation (ONR) and the environment agencies[10] and the store design and operation will be consistent with accepted Industry Guidance on the Interim Storage of Packaged Higher Activity Waste[11].

56. This guidance requires that waste should be stored in a passively safe condition (that is, physically and chemically stable), in packages that are transportable and ultimately disposable as soon as reasonably practicable (in SDP's case, with size reduction and repackaging as described below). Storage arrangements should minimise the need for control and safety systems, maintenance, monitoring and human intervention.

57. The initial top level requirements for the RPV store provided to the SDP are listed below. Note that they are still subject to review and further development.

    - The store will be designed to contain 27 RPV packages securely and safely - including the receipt, inspection, storage, maintenance, monitoring, inspection, handling and dispatch of the RPVs at the end of the interim storage period.
    - In order to demonstrate that these processes can be undertaken to the required level of safety, a safety case will be produced as required by the nuclear site licence.
    - In addition to the safe storage of the RPVs, appropriate measures will also be designed into the store and supported by managerial procedures to ensure their security.
    - The store will be commissioned and approved to receive RPV packages early in the next decade to meet the programme schedule for the removal of RPVs from the initial submarines at Rosyth.
    - The store will provide an environment to enable storage of the RPV packages for duration of up to 100 years, in line with Government recommendations. It will be designed, constructed and operated in cost-effective manner to minimise whole life costs. Industry guidance requires that it be designed for easy refurbishment.
    - In line with guidance and good practice, the store will be designed and built in a manner and using materials that enable cost-effective decommissioning to enable the land to be returned to the initial state at the end of the storage period.

58. Detailed technical requirements are tabulated in Annex B.

[10] Available from http://www.onr.org.uk/wastemanage.htm.

[11] Available from http://www.nda.gov.uk/wp-content/uploads/2012/11/Industry-Guidance-Interim-Storage-of-Higher-Activity-Waste-Packages-Extended-Summary-November-2012.pdf

Repackaging at the RPV store

59. At the end of the interim storage period, the RPVs will be sent for size reduction. The current assumption is that the original transport/storage container will not be used for this purpose, mainly because of the length of time it has been in store, so a repackaging capability would be added when needed.

60. The radioactivity in the RPV will have significantly decayed which means a lighter container ought to be suitable but the transport regulation requirements cannot be predicted so far in advance and no detailed design work has been done.

Future Size Reduction

61. Size reduction would involve dismantling and/or cutting up the RPVs into smaller pieces in a shielded facility before they can be sent to a GDF. After size-reduction, any parts which may be LLW will be segregated for separate disposal.

62. Size reduction would not take place until sometime after 2040. There will by then be other wastes from MOD and civil decommissioning activities that need to be size-reduced so a national facility might be available by this time which the MOD could use. The SDP cannot, therefore, make any assumptions about the location of any RPV size reduction at this time.

63. Specifically, it is not assumed that size reduction will be on the same site as the RPV store and therefore the ability to do it at the storage site has not been a factor in the SDP's analysis. Since the respective locations of the size reduction facility and GDF are not known, associated transport distances cannot yet be taken into account either.

Direct Disposal Opportunity

64. The project's plans currently assume size reduction will have to be carried out at the end of the interim storage period. However, the project team is also discussing with the responsible authorities whether it may be possible to send some of the RPVs to a GDF without size-reduction. Size reduction is a safe process but it is expensive and would require precautions to prevent the release of radioactive material. The SDP will monitor developments and send the RPVs to a GDF without size reduction if it proves more practical and cost-effective to do so.

6. Baseline Concept

Overview

65. An RPV store Baseline Concept has been developed by the project team to assist initial costing. It is not intended to constrain or prevent licensees from developing alternative or more robust site proposals. The final design may well differ significantly but the project Baseline Concept is included here to help local communities understand what a store might be like and what sort of operations would be carried out inside.

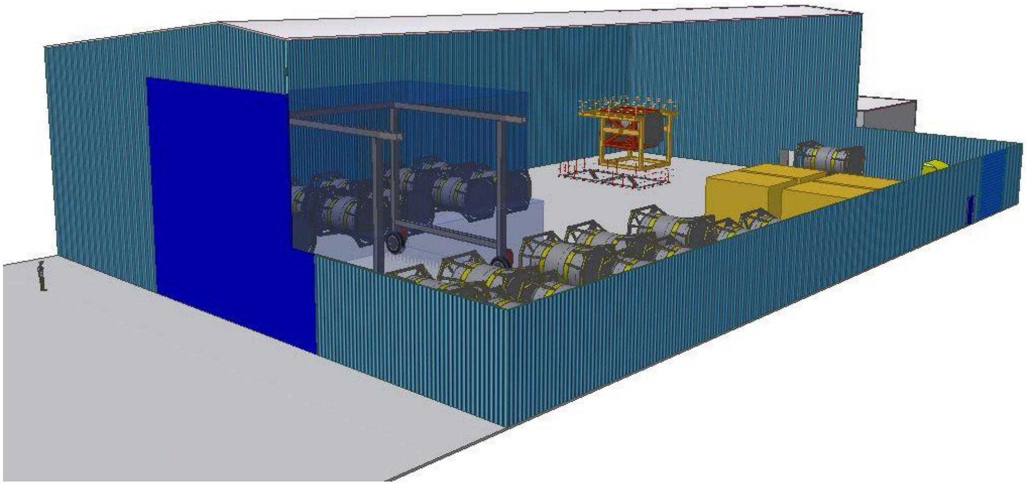
66. The RPV store will have a design life of at least one hundred years and will be designed for easy refurbishment within that timeframe. The RPVs and containers already provide a significant degree of shielding. This distinguishes them from many other types of ILW where their interim storage facilities need thick walls to keep radiation levels on site low. The RPV store's main function would be to provide a weatherproof, secure environment and it could be of unshielded steel-framed construction with only limited additional internal shielding. The inside of the building will be designated as a supervised area, with controlled access to internally shielded areas

67. Interim stores comparable to that proposed for the RPVs have already been constructed or designed for nuclear sites around the country and civil and MOD ILW is already being packaged and placed into them. Some pictures are included in Annex D, although again it has to be emphasised that the RPV store may differ significantly.

    - Existing stores at NDA sites: Berkeley, Bradwell; Hunterston; and Sellafield.
    - Stores planned at NDA sites: Chapelcross; Dounreay; Harwell; Hinkley; Sizewell; and Wylfa.

68. Because these stores have already been designed and some built, the safety and environmental performance and the cost and characteristics of the RPV store can be predicted with greater confidence.

69. The cost of an unshielded store for the RPVs is currently expected to be significantly less than the cost of building and storing waste in a fully shielded store, even when the cost of the containers is included.



Operations

70. The RPV store project contains five distinct phases.

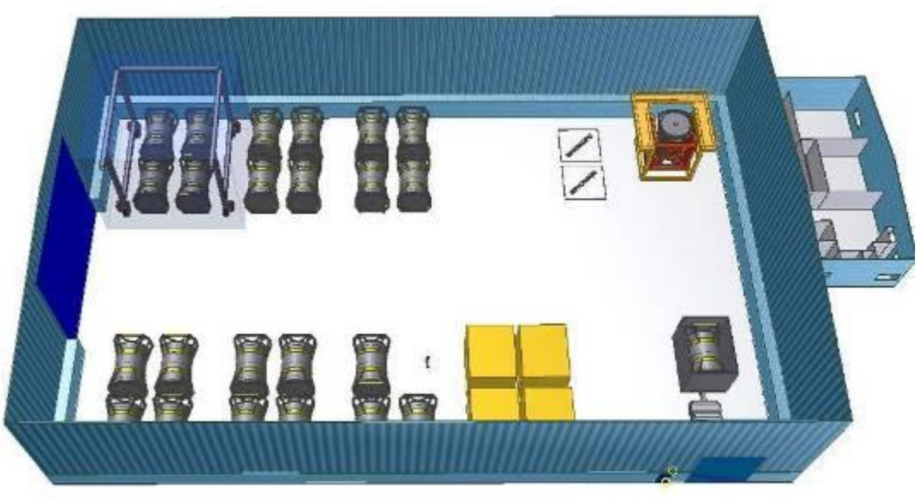
- Phase 1 Design, construction and commissioning is estimated to take up to 4 years (based on the indicative functional design).
- Phase 2 Filling of the store is estimated to take around 27 years, based on initial dismantling of one submarine per year and typically one container transfer per year[12].
- Phase 3 Care and maintenance during the lifetime of the store will last up to 100 years from receipt of first package (dependent on availability of a GDF and agreed conditions of acceptance) with periodic refurbishment, as necessary.
- Phase 4 Emptying of the store is currently estimated to take up to 15 years. This timescale may change. It could be significantly shorter but will be dependent on the design of the size reduction facility and agreed GDF emplacement schedule.
- Phase 5 Decommissioning is estimated to take around 2 years (based on the indicative functional design).

Store Layout

71. RPV containers will not be designed to be stackable so the store must be large enough to take the 27 RPVs in their containers side by side and allow for inspection, access and local shielding. The Baseline Concept has a building floor area of approximately 47m x 44m (around 2000m^2, or about a third of the area of a typical football pitch). A typical store height is anticipated to be 20m.

72. The Baseline Concept also includes an additional 50% footprint for the future repackaging facility and to give some operational flexibility. This equates to an overall maximum facility footprint of about 3100 m^2.

73. The layout is only illustrative but does give an impression of how the contents might be arranged out. The precise footprint will depend on the site's design and layout. Note that for simplicity internal shielding is not shown in these pictures.



[12] There may be up to 3 RPV transports in the first year. Based on initial dismantling of the submarines at Rosyth and then those at Devonport, the long-term rate is expected to be around 1 a year thereafter. If there were some parallel work at Devonport and Rosyth, it could be around 2 a year for a few years.

Shielding Requirements

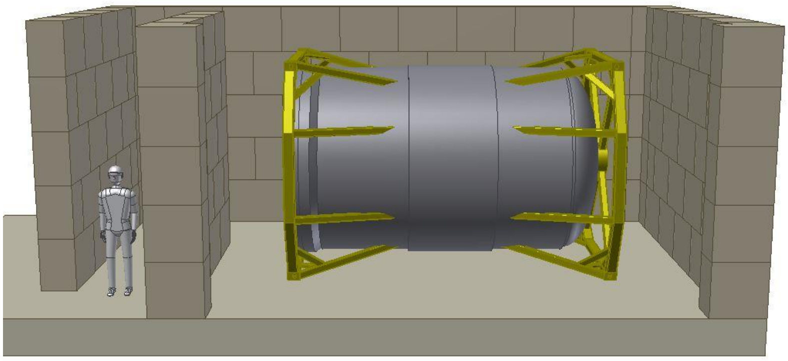
74. Although the RPV transport containers are designed to meet the regulations for transport, it is assumed that additional shielding will be required around the container so that the general access areas within the store have dose rates in line with Basic Safety Objectives and ALARP.

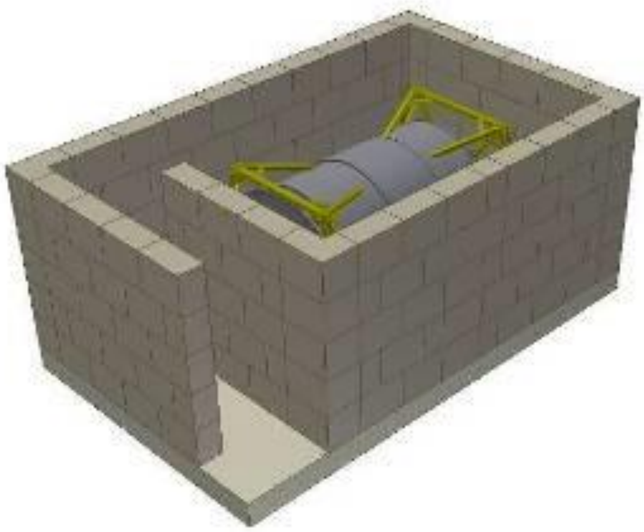
75. The amount of shielding would be determined based on the projected annual occupancy levels required to allow personnel access to the store to undertake container receipt, inspection and store maintenance activities.

76. Various options to add additional shielding to the store layout to achieve the required store dose objectives have been considered. The additional shielding could be made from a number of materials. Both steel and concrete have suitable characteristics.

77. The gated labyrinth shield wall around each RPV container shown below is one possibility but other arrangements might be equally effective and potentially more space efficient. Access inside the shielding, where the dose rates would be higher than the general access areas, would be under managerial control with a written safe system of work.

78. Radiation levels at the container surface fall by around 50% every 5.3 years. Some submarines have been laid up for up to three decades already and the activity of the RPVs will reduce further in store so they will not always require the same degree of shielding and some rearrangement of store contents may be possible during interim storage.

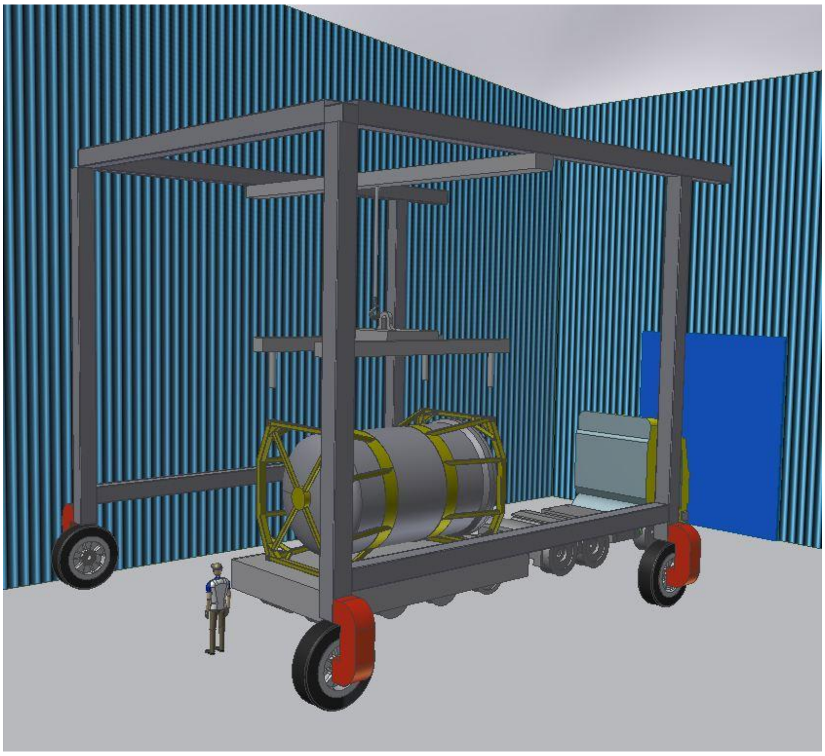




Container Handling Arrangements

79. The RPV container is expected to arrive at the store on a low loader transport vehicle in a horizontal orientation. The Baseline Concept has been developed around the use of a straddle carrier for handling of the containers within the storage hall. The use of straddle carrier means separation is required between an individual or groups of stored containers to allow its body and wheel units to pass between the groups of packages. Since the straddle carrier can operate within the building envelope and acts independently of it, maintenance can be undertaken away from the sources of radiation and it could be easily replaced.

80. Some consideration has been given to the potential use of an electric overhead travelling crane instead of a straddle carrier. One benefit would be that the crane can accurately position packages in close proximity to one another, thereby minimising the overall footprint of the storage area (although it is not envisaged that packages would be lifted over one another). However, a crane would place additional loads on the store structure which would require a more robust (and expensive) design and routine maintenance may be more difficult.



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Annex A: Supplementary Technical Glossary

AIL	Abnormal and Indivisible Loads. See Section 4.
ALARP	See www.hse.gov.uk/risk/theory/alarpglance.htm
DDLP	De-fuel, De-equip and Lay-up Preparation.
IAEA	International Atomic Energy Authority. See www.iaea.org
IP-2	Industrial Package Type 2. See Section 3.

Annex B: Baseline Store Technical Requirements

This table sets out the functional requirement for the RPV store Baseline Concept, developed by the project team to assist initial costing. It is not intended to constrain or prevent licensees from developing alternative or more robust site proposals. It is based upon a minimally shielded or unshielded store containing the RPVs in their transport containers, with additional portable internal shielding around each individual container as required to meet operational dose targets.

Requirement	**Baseline Specification**
Lifetime	The store will be designed for a 100 year operational life.
Protection against natural elements	The store will protect the containers and their contents from adverse weather (rain, snow, ice, flood, etc.).
Legislation	The store should have the appropriate legislative and Regulatory approval to store ILW.
Standards	Store will be designed to be as energy efficient as practicable, with an aim to minimise whole life costs.
Standards	All design, manufacturing and construction will be carried out in accordance with prevailing legislation and appropriate British and International standards and Industry codes of practice.
Seismic qualification	ONR Safety Assessment Principles for Nuclear Facilities, 2006, edition 1 applies.
Masses	PWR1 container 90,000 kg PWR2 container 135,000 kg
Dimensions	PWR1 container Length 4.8 m, Width 3.2 m, Height 3.2 m PWR2 container Length ~6 m, Width ~4 m, Height ~4 m
Floor loading	The floor of the store will be sufficient to withstand a loading of a laden container, the shielding erected around it and any required handling equipment.
Area of store/ quantity	The floor space of the store will be sized to store an initial population of 27 containers (23 PWR1s and 4 PWR2s). A suitable clearance between each container will be provided in order that additional shielding and any required equipment (e.g. straddle carrier) can pass between either individual or groups of containers.
Storage extension requirement	The store will be capable of extension by ~50%, for example to allow the addition of a re-packaging capability.

Requirement	**Baseline Specification**
Stacking	Containers should not be stacked during interim storage nor should the arrangement of containers in the store require a container to be lifted over another container.
Inspection	Inspection will be required to ensure continuing safe material state to meet container safety and disposability obligations. The design basis maintenance regime for the containers, and the post receipt regime for individual containers should they differ from the design basis, will be provided to the site when available. Inspection by ONR, DNSR or the environment agencies may be requested at their discretion. Potential inspections include: visual inspection, corrosion monitoring, environmental monitoring, preservation defect repair work and inspection of records associated with the containers.
Receipt and dispatch inspection	The containers will require inspection / survey prior to dispatch.
Radiological contamination	A capability will be provided whereby swabs (or other means) can be taken and analysed to verify that the external surfaces of the container are clean from external contamination before acceptance into the store.
Non radiological contamination - cleaning of containers	A facility will be provided to remove the general dirt, grime and other non-radiological contaminants acquired on the external surfaces of the container during transportation.
Transport	The containers will be transported to and from the site by road.
Location/ layout	Layout of the interim store and its relationship with roads and other infrastructure will take into account the requirement for access for a container transporter and site vehicles delivering supplies.
Internal transport	A method of moving containers to their storage location within the store will be proposed. The method of internal movement should also, if required, be capable of moving shielding materials.
Lifting equipment	The store lifting equipment capability should meet legislative requirements for lifting and moving the containers (PWR1 and PWR2)
Receipt rate	Typically 1 per year, but up to 3 per year initially.
Dispatch rate	Empty store of RPVs in 15 years, or potentially faster.
Container dose rates	The containers are designed to meet the external dose rate limits applicable to the safe transport of radioactive materials.

Requirement	Baseline Specification
Store dose rates	In order to ensure that dose rates inside the store are ALARP, additional shielding will be proposed. Thickness of shielding material will be such that dose rates on contact with the outside of the shield wall is no more than 7.5 µSv/h (in order to achieve a 1 mSv/y dose objective when typical occupancy and work patterns are considered). In addition to shielding around each container, either store wall thickness or an appropriate shielding method will be designed so that dose rates on the external walls of the store are no more than 0.5 µSv/h, so that areas external to the store do not have to be designated as supervised areas.
Ventilation	A ventilation system will be installed to ensure that the temperature and humidity of the store minimises the corrosion of the steel containers. It is assumed that the containers will be sealed so there will be no discharges during storage. The ventilation system will comply with industry standard. Monitoring equipment/ instrumentation will be provided to control and maintain the store conditions.
Venting	The RPV is sealed, will not pressurise, and contains no significant loose contamination or liquids.
Package type	To be determined; Likely to IP-2 with Special Arrangement or a Type B.
Physical security	Appropriate levels of physical security as required by the Security Policy Framework
Records management	Radioactive inventory detailed.

Annex C: Regulatory Framework

RPV Container

For reference, a selection of the key regulations, standards and codes of practice relevant to the design of the RPV container are listed below.

- The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended).
- Regulations for the Safe Transport of Radioactive Material (2012 Edition), SSR-6, IAEA Safety Standards, IAEA, Vienna, 2012.
- Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, TS-G-1.1 (Rev. 1), IAEA Safety Standards, IAEA, Vienna, 2008.
- Guide to an Application for UK Defence Nuclear Programme Competent Authority Approval of a Transport Package for Radioactive Material (IAEA 2009 & 2012 Regulations), Issue 19, Defence Nuclear Safety Regulator, April 2013.
- Shielding Integrity Testing of Radioactive Material Transport Packaging, Transport of Radioactive Material Code of Practice, Transport Container Standardisation Committee, TCSC 1056, December 2005.
- Leakage Tests on Packages for Transport of Radioactive Materials, Transport of Radioactive Material Code of Practice, Transport Container Standardisation Committee, TCSC 1068, March 2008.
- Good Practice Guide to Drop Testing of Type B Transport Packages, Transport of Radioactive Material Code of Practice, Transport Container Standardisation Committee, TCSC 1086, December 2009.

RPV Transport

For reference, a selection of the key regulations, standards and codes of practice relevant to the design of the RPV Container are listed below.

- The Road Vehicles (Construction and Use) Regulations 1986 (as amended).
- The Road Vehicles (Authorisation of Special Types) (General) Order 2003 (as amended).
- The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended).
- Regulations for the Safe Transport of Radioactive Material (2012 Edition), SSR-6, IAEA Safety Standards, IAEA, Vienna, 2012.
- Safety of Loads on Vehicles, Third Edition, Code of Practice, Department of Transport, 2002.
- Guide to the Securing/Retention of Radioactive Material Payloads and Packages during Transport, Transport of Radioactive Material Code of Practice, Transport Container Standardisation Committee, TCSC 1006, December 2012.
- Format for Supplementary Labelling of Packages used for the Safe Transport of Radioactive Material, Transport of Radioactive Material Code of Practice, Transport Container Standardisation Committee, TCSC 1073, March 2011.

ILW Storage Policy

Some of the key references relating to ILW management policy are listed below.

- Implementing Geological Disposal, A Framework for the Long-term Management of Higher Activity Radioactive Waste, Department of Energy and Climate Change, July 2014.
- Scotland's Higher Activity Radioactive Waste Policy 2011, Scottish Government, January 2011.
- Managing our Radioactive Waste Safely: CoRWM's Recommendations to Government, Committee on Radioactive Waste Management, July 2006.
- Response to the Report and Recommendations from the Committee on Radioactive Waste Management (CoRWM), UK Government and the Devolved Administrations, 2006.

Annex D: Examples of ILW Stores

This Annex is available as a separate file, because of its file size.

Examples of UK ILW Stores

Hunterston ILW Store

Future Harwell ILW Store Artists Impression

Trawsfynydd ILW Store

Berkeley ILW Store

Bradwell ILW Store

An ILW Store at Sellafield

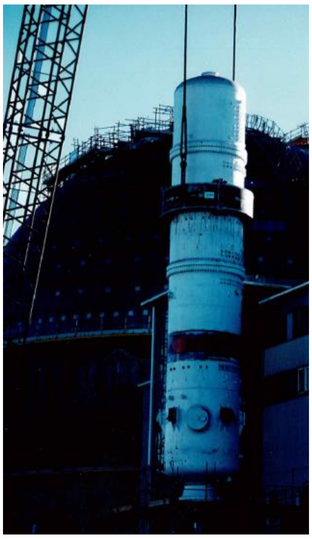
Annex E: Examples of RPV Transport

This Annex is reproduced from SDP: Reactor Pressure Vessel Transport Feasibility Report. Issue 2.0, Aug 2011. That report (now superseded) was published in 2011 in support of the previous public consultation.

It includes pictures of several previous civil RPV removal and transport operations around the world. Note that most are very much larger and heavier than the SDP's RPVs.

E.1 WAGR Heat Exchangers

Although they were much larger and heavier than SDP's RPVs, the removal of the Windscale AGR heat exchangers is nevertheless probably the closest UK equivalent to RPV removal in terms of loading and potential hazard. The heat exchangers were 21 m long, 3.4 m diameter, and each weighed 190 te. The operation was carried out towards the end of 1995. Prior to removal, the Heat Exchangers had been lifted from their original positions and holes cut in the outer containment sphere. Each Heat Exchanger was taken 2-3 miles through a number of villages to the Low-Level Waste Repository at Drigg.



E.2 Rheinsberg

Rheinsburg was a PWR type WWER-70 constructed in what used to be East Germany. The reactor was shut down, and a key decommissioning milestone achieved in 2007 when the RPV was removed and transported to the Interim Storage North (ISN) store at Greifswald NPP.

The reactor was rated at 70 MW(e) and 265 MW(t). The RPV is 11.162 m long with a maximum diameter of 3.275 m. For transport it was placed inside engineered shielding which enclosed the sides and base of the vessel. The weights are: RPV, 109 te; shielding 60 te; gross weight 169 te. The shielding thickness of up to 120 mm limited the maximum dose rate to 24 μSv/h at 2 m.

The vessel was lifted from its operating position and laid on its side: the photographs seem to imply that some sort of bogie on rails was used for this. The shielding was slid into position and the assembly loaded onto a road vehicle for transport to the rail-head. The journey to the ISN was completed by rail, with another short road trip to the vault.


SCHULZ


KRUSE

E.3 La Crosse Boiling Water Reactor – LACBWR

La Crosse, Wisconsin was a 50 MW(e) Boiling Water Reactor (LACBWR). It was built in 1967 and shutdown in 1987 because the small size of the plant made it no longer economically viable.

A key decommissioning activity occurred in 2007 when the plant operator, Dairyland, contracted with Energy Solutions to facilitate the removal and disposal of LACBWR's RPV and other low-level, non-fuel waste to Chem-Nuclear's low-level waste disposal facility at Barnwell in South Carolina.

It is clear that the RPV was shipped in a shielding jacket and required both road and rail transport; though unlike Reinsburg the jacket enclosed the entire vessel. The shipment weighed approximately 285 te and required a specially designed rail car.

The following photographs give a good appreciation of the removal and shipment processes.

Removal of the Reactor Pressure Vessel (RPV) from the reactor building

Set down of the RPV in the lower half of transportation canister

Placement of the upper half of transportation canister

Downending of RPV transportation package for transfer

Transfer of the RPV transportation package to the rail siding

Transfer of RPV transportation package from the heavy hauler to the rail cars

RPV transportation package in-transit

Final placement of RPV transportation package in disposal trench

E.4 Connecticut Yankee

Located in Haddam Neck, Connecticut the 590 MW(e) Connecticut Yankee began commercial operation in 1968 and ran for 28 years. The decision to close it was taken in 1996. After two years of planning and preparation, actual decommissioning began in 1998 and was completed in 2007.

The RPV was removed, loaded into a containment vessel and shipped to Barnwell, South Carolina by road and barge.









E.5 Yankee Rowe

Yankee Rowe, Massachusetts was a 167 MW(e) PWR that was shut down in 1991 after 30 years service.

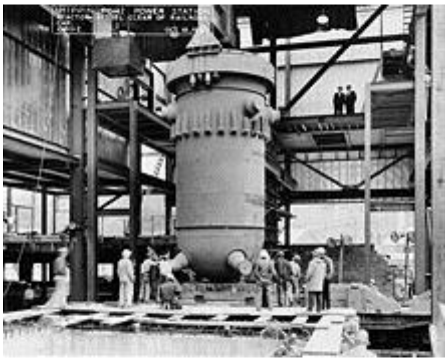
The RPV was removed from containment in November 1996 and placed in a specially designed, NRC-approved shipping container. The reactor vessel was stored in the container on-site until April 1997 when it was shipped to a low-level waste disposal facility in Barnwell, South Carolina for burial.

The RPV weighs 150 te and is approximately 8.235 m long and 3.66 m maximum diameter and with 200 mm wall thickness. The steel container weighs 82 te and is 8.54 m long and 3.965 m in diameter; its wall thickness is 75 mm.

Prior to the removal, the container was moved into an upright position underneath the containment sphere. The opening of the shipping container was matched to the opening of the equipment hatch on the underside of the containment sphere. About 73 te of concrete was injected into the RPV and the spaces between the vessel and its shipping container: the container lid was then permanently welded in position. The package, which weighed 330 tons including 18 te of wire rope tie-down equipment, was the last large component removed from the plant as part of decommissioning.

The 1100 mile journey to Barnwell was carried out by road and rail. The rail wagon, leased from TransAlta Utilities Corporation of Alberta, Canada, was chosen because it was designed to transport large, heavy loads and has the ability to shift the load from side to side to clear obstacles.

E.6 Shippingport NPP



The Shippingport NPP in western Pennsylvania is the first nuclear power station to be decommissioned with the goal of restoring the site to a radiologically clean condition that is acceptable for unrestricted use. It was an experimental, light water moderated thermal breeder reactor notable for its ability to transmute 232Th to 233U. The reactor had an output of 60 MW(e) and operated from 1957 until 1982.

In 1988 the 870 te RPV/Neutron Shield Tank assembly was lifted out of the containment building and loaded onto road transport equipment for subsequent removal from the site and shipment to a burial facility in Washington State. (Note: the accompanying photograph was taken during construction.)

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