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WAGR 6m^3 Boxes, Re-license as IP-2 Transport Package under IAEA SSR-6 Transitional Arrangements

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Abstract

In September 2017, Sellafield Ltd. successfully applied to re-licence the Windscale Advanced Gas Reactor (WAGR) 6m^3 boxes as IP-2 packages under the IAEA Transport Regulations [1] Transitional Arrangements. The transitional arrangements allow packages not requiring competent authority approval to be transported in the future, when properly maintained, based on compliance with the 1985 Edition of the Transport Regulations [2]. As a result, packages prepared in accordance with the 1985 or 1985(As Amended 1990) Editions of the Transport Regulations [2] may be stored for many years prior to further shipment, so long as they are prepared for transport prior to a defined date.

The WAGR 6m^3 boxes were designed to provide containment and shielding of the dismantled WAGR pressure vessel and core during storage, transport and disposal to a geological disposal facility. The packaging design is essentially a rectangular box with top entry, made from reinforced concrete. Internal voids are filled with grout and a reinforced concrete lid is cast. The maximum weight of the compiled package is 50t. In 1994 the UK Atomic Energy Authority (UKAEA) successfully applied for an IP-2 transport licence under the 1985 (As Amended 1990) edition of the IAEA regulations for the safe transport of radioactive material [2]. In a programme spanning 12 years, the decommissioning of the reactor pressure vessel and core led to the production of 110 intermediate level waste and 75 low level waste WAGR 6m^3 boxes, resulting in an overall packaged volume of approximately 2500 cubic metres containing an estimated 460 cubic metres of the reactor structure.

The package design safety report was maintained by UKAEA and a licence granted under the 2005 edition of the IAEA Transport Regulations until June 2009. As of September 2017, 106 6m^3 boxes remained in storage in a dedicated facility on the Sellafield site. To increase space for storage of ILW in this facility, Sellafield Ltd. took over the design authority role in a bid to re-licence the WAGR 6m^3 boxes under IAEA Transport Regulations (2012 edition) transitional arrangements [1]. This application was successful and the first boxes were transported to the UK Low Level Waste Repository in the summer of 2018.

Introduction

The Sellafield site measures 6 square kilometers with over 1,000 nuclear facilities and is considered to be the one of the most congested nuclear sites in the World. As decommissioning at the Sellafield Site ramps up following end of reprocessing, the volume of intermediate level waste (ILW) production will increase. With space at a premium, the safe storage of ILW on site is a significant challenge.

Due to radioactive decay of the ILW during 15-20 years of interim storage, the transfer of a number of WAGR 6m^3 boxes from the Sellafield site to the Low Level Waste Repository in Drigg became a viable option however, the IP-2 transport license for the boxes had lapsed.

Sellafield Ltd. took over the design authority role in a bid to re-licence the WAGR 6m^3 boxes as IP-2 packages under the IAEA regulations for the safe transport of radioactive material (2012 edition). As the safety case already existed, the decision was made to licence under the IAEA transitional arrangements, as production of a new PDSR would provide no additional design or manufacture detail. This paper describes the waste history, package design and the supporting evidence to meet the requirements of the IAEA Transport Regulations under the transitional arrangements.

Windscale Advance Gas-Cooled Reactor

The Windscale Advance Gas-Cooled Reactor (WAGR) was the prototype industrial scale development model for the CAGR nuclear power stations, the UK's second generation of reactors. Constructed between 1957 and 1961 and operated successfully by the United Kingdom Atomic Energy Authority (UKAEA) until its shutdown in 1981, the reactor containment building was an all welded hemispherical dome, 41m in diameter, providing a controlled area and pressure containment, to totally envelop the reactor and its associated biological shielding.

Reactor Decommissioning

In 1999, decommissioning of the WAGR reactor was undertaken as a pilot project to demonstrate the feasibility of safely decommissioning a nuclear reactor. Fuel and associated equipment were removed shortly after shutdown. The waste material from within the bio-shield was transferred from the reactor into the sentencing cell via remote handling machinery. The reactor was decommissioned using a top down approach in a series of campaigns spanning a period of 5 years.

The empty WAGR waste boxes were transferred into an encapsulation plant where the wastes were loaded in baskets. Once loaded a cementitious grout was added to immobilize the waste and a reinforced concrete lid cast. Following curing, the completed WAGR 6m3 boxes were transferred to a specifically designed store. In total, 185 ILW and LLW WAGR 6m^3 boxes were prepared in this way.

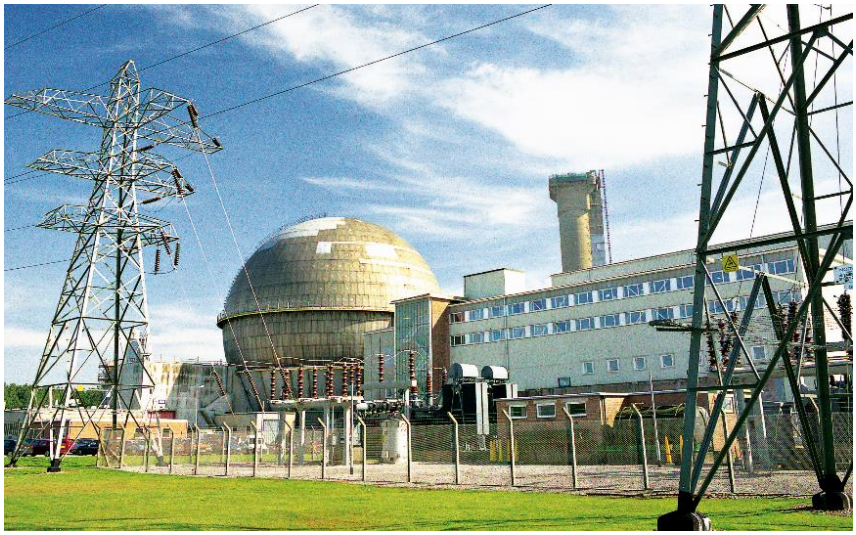

Figure 1: Photograph showing the Windscale advanced gas-cooled reactor (WAGR)

WAGR 6m^3 Box – Package description

The WAGR 6m^3 Box is constructed from reinforced concrete, with a cast reinforced concrete lid and cast steel twist lock pockets located in the top and bottom corners for handling and stacking purposes. The maximum external dimensions are 2210mm x 2438mm x 2200mm height. The box walls are 240mm thick and provide both containment and shielding of the waste. The cavity dimensions are sized to accommodate WAGR thermal shield plates and graphite moderator blocks without the need for size reduction. The maximum gross mass of the box is 50te. Figure 2 shows a cutaway sketch of the WAGR 6m^3 box.

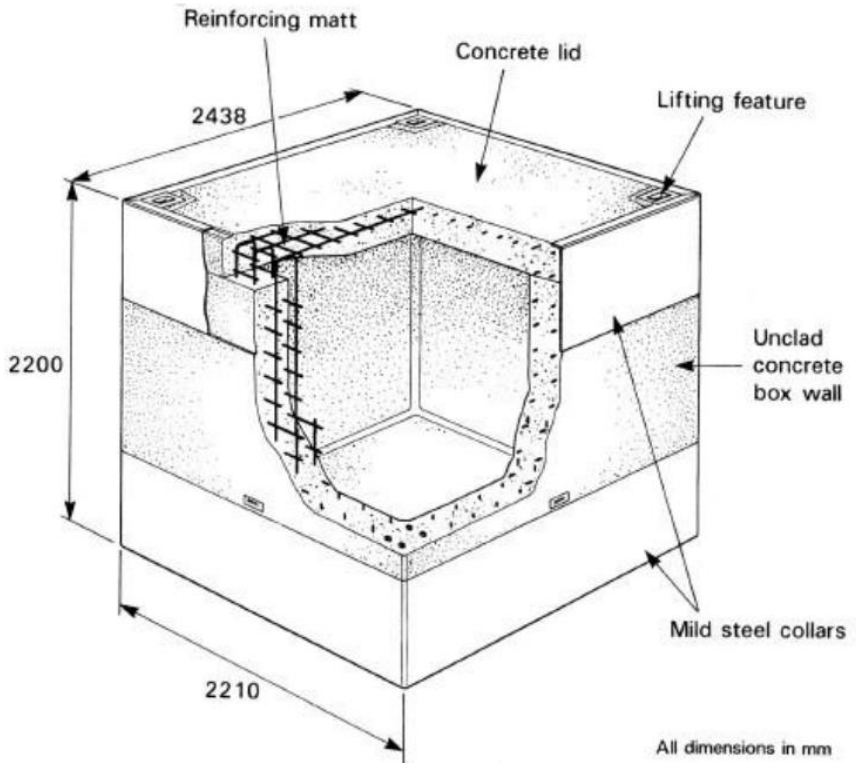

Figure 2: Cutaway sketch of the WAGR 6m^3 Box

There are two nearly identical variants; the only difference is the density of the concrete. One is made in normal density (ND) concrete and the other in high density (HD) concrete. The higher density concrete provides more effective shielding against nuclear radiation.

In June 2000 water tests indicated that there were small cracks running from the inside bottom corner to the twistlock casing in some of the normal density boxes. As these cracks provided a potential leak path, a waterproof slurry was applied to the inner surface of the boxes. In order to prove that this design change was not detrimental to safety, finite element analysis was completed to assess the impact response of the boxes with reduced grout bonding.

This coating also provided an additional benefit in preventing the risk of radionuclide migration through the concrete walls.

Transitional Arrangements – SSR-6 para.819

The IAEA Transport Regulations [1] allow self-approved packages to be used, when properly maintained, based on compliance with historic editions of the Transport Regulations. As a result, packages prepared in accordance with the 1985 or 1985(As Amended 1990) Editions of the Transport Regulations [2] may be stored for many years prior to further shipment, so long as they are prepared for transport prior to a defined date.

For this type of approval, the IAEA Transport Regulations [1] emphasizes the requirement to apply management system measures to ensure that such packages only remain in use when they continue to meet the original design intent and regulatory requirement. The provisions of the latest Edition of the Transport Regulations apply to the controls for transport, including consignment and conveyance limits; package content limits, including activity and fissile exemption limits; and approval and administrative requirements.

The following text is copied from the 2012 edition of the IAEA Transport Regulations [1].

819. Packages not requiring competent authority approval of design (excepted packages, Type IP-1 , Type IP-2, Type IP-3 and Type A packages) shall meet this Edition of these Regulations in full, except that packages that meet the requirements of the 1985 or 1985 (As Amended 1990) Editions of these regulations:

(a) May continue in transport provided that they were prepared for transport prior to 31 December 2003 and are subject to the requirements of para. 822, if applicable;

(b) May continue to be used, provided that:

i) They were not designed to contain uranium hexafluoride.

ii) The applicable requirements of para. 306 of this Edition of these Regulations are applied.

iii) The activity limits and classification in Section IV of this Edition of these Regulations are applied.

iv) The requirements and controls for transport in Section V of this Edition of these Regulations are applied.

v) The packaging was not manufactured or modified after 31 December 2003

Evidence to comply with IAEA SSR-6 para 819

The following requirements in bold are copied from the 2012 edition of the IAEA Transport Regulations [1]. The text following each bold statement outlines the evidence submitted against each of the IAEA transitional arrangements during the application for IP-2 transport license renewal.

819(a) Packages may continue in transport provided that they were prepared for transport prior to 31 December 2003 and are subject to the requirements of para. 822, if applicable;

104 of the 106 of the boxes stored in the dedicated facility on the Sellafield site were packed and prepared for transport between November 1999 and December 2003. Details of preparation dates are recorded in the specific boxes UKAEA document dossier. The document dossiers also include waste inventory, grout mix data, inspection and test reports and a certificate of conformity. The two packages prepared in Feb/March 2004 were not included in the application. These will have their own application outlining the impact of this preparation date on safety.

822. Packages containing fissile material that is excepted from classification as "FISSILE" according to para. 417(a)(i) or (iii) of the 2009 Edition of these Regulations prepared for transport before December 2014 may continue in transport and may continue to be classified as non-fissile or fissile-excepted except that the consignment limits in Table 4 of the 2009 Edition of these Regulations shall apply to the conveyance. The consignment shall be transported under exclusive use.

A Criticality Compliance Assurance Document (CCAD) was produced in 1997 to demonstrate that the WAGR boxes contained significantly less than the 15g limit specified for fissile exemption in the IAEA Transport Regulations 1985 edition. As the fissile excepted limits were unchanged between 1997 and 2009, this CCAD substantiates this requirement.

819(b) (i) Package may continue to be used, provided that they were not designed to contain uranium hexafluoride.

The WAGR boxes were not designed to contain Uranium Hexafluoride.

819(b) (ii) Package may continue to be used, provided that the applicable requirements of para. 306 of this Edition of these Regulations are applied.

The IAEA Transport Regulations [1] transitional arrangements require the applicable sections of paragraph 306 (Management Systems) to be applied to all activities within the scope of the regulations outlined in para. 106 including design, manufacture, maintenance, repair, storage and consignment of the WAGR boxes.

Quality control during design, manufacture and construction of the WAGR 6m3 boxes is outlined in Issue 3 of the existing Package Design safety Report. The design and manufacture conformed to the British Standard Quality Assurance Programme for Nuclear Installations at the time. Production of the box mould design was to BS 5750-1 [3], and box manufacture was in accordance with BS 5750-2 [4]. Nirex, as the planned eventual recipients of the WAGR boxes, also specified their own quality assurance as stated in their "Waste Package Specification" document [5] which was applied to all WAGR 6m3 boxes stored on the Sellafield site. All boxes covered by the license application have an individual UKAEA Certificate of Conformity that states:

"All the work carried out in the manufacture of box 41000XXXXX, in the sentencing of the waste which is now stored in it and in its final grouting and concreting was carried out in accordance with Quality standard: BS EN ISO 9001:1994 (Quality systems: Model for quality assurance in design, development, production, installation and servicing)"

Evidence of this is collated for each box in its individual document dossier.

A full QA regime also exists for the dedicated storage facility on the Sellafield site since the preparation of the WAGR boxes for transport. This is a purpose built engineered store designed to provide weather protection for the WAGR boxes. Temperature and humidity is monitored weekly as well as a general inspection of the building structure. The WAGR boxes are also routinely monitored for Caesium 137 migration on a monthly basis.

An assessment of multiple academic studies gave confidence to ensure that the long term structural strength of the concrete does not affect the ability of the boxes to meet their original design intent. The assessment concluded that, in both wet and dry conditions, the long term concrete strength (>10 years) increases above the 28 day cured strength, therefore increasing the 6m3 box performance in the regulatory drop tests.

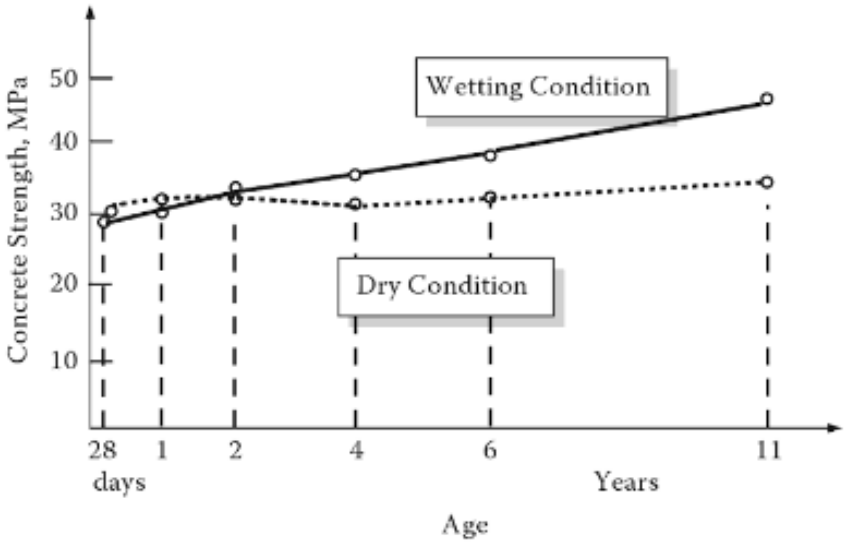

Figure 3: Variation of concrete strength with time from Baykof and Sigalof (1984) [6]

The WAGR boxes incorporate steel reinforcing bars in the concrete wall that are essential for its strength. In December 2009 Radioactive Waste Management Directorate (RWMD) completed a corrosion assessment that discounts carbonation occurring at ambient conditions and also discounts chemical attack. The report concludes that chloride corrosion of the reinforcing bars could lead to degradation of the WAGR boxes if they are stored in a high chloride environment. To minimise the risk of corrosion, the boxes are protected from adverse conditions such as condensation and extreme temperature variants by the WAGR box storage facility. To further reduce the risk of corrosion associated with chloride deposition on the package surface, the design of the package concrete cover thickness complies with the severe exposure classification of BSI BS 8110 [7]. An assessment of the chloride deposition on the boxes was completed by RWMD in 2012, the outcome of which outlined that WAGR $6m^3$ boxes do not need to be covered when stored in an environment that is protected from adverse weather conditions. Visual inspections are completed on a weekly basis with no sign of staining caused by general corrosion, pitting or cracking of the concrete reported.

Figure 4: Purpose built WAGR 6m3 Box Store

819(b) (iii) Package may continue to be used, provided that the activity limits and classification in Section IV of this Edition of these Regulations are applied.

The waste items encapsulated in the WAGR boxes during filling operations were classified as LSA-II material, with the exception of the boxes containing operational items of waste and loop tubes (campaign 2 and 4). On package preparation, these items had an average specific activity that classified them as LSA-III material. Evidence of this is collated in the document dossier for each box.

During initial submission for approval of the package design in 1991, an assessment of the natural decay of the waste form was completed. This assessment concluded that all loop tubes and operational items of waste had average specific activities that would fall within the LSA-II limits as defined by the 1985 edition of the IAEA Transport regulations by 2010. This activity limit is unchanged in the 2012 edition of the Transport Regulations [1].

Each box document dossier outlines the maximum dose rates at contact, 1m and 2m when the boxes were prepared for transport. The WAGR box store conditions for acceptance requires all waste dose rates to be below the transport limits (2mSv/h @ contact, 0.1mSv/h @2m). To ensure this is still the case for transport, each box dose rate will be monitored prior to consignment.

819(b) (iv)Package may continue to be used, provided that the requirements and controls for transport in Section V of this Edition of these Regulations are applied

Requirements of the IAEA Transport Regulations [1] Section V are controlled, through the Sellafield Ltd. consignment team. This includes the nuclear matter consignment command and control arrangements that are required to consign radioactive material from the Sellafield site. The consignment team also own procedures for emergency arrangements, which were submitted as part of the license application.

819(b) (v)Package may continue to be used, provided that the packaging was not manufactured or modified after 31 December 2003.

The WAGR boxes have not been modified since filling and preparation for transport prior to November 2003.

One package had been damaged during storage and subsequently repaired. A notice of proposed alteration was raised for this package and additional evidence supplied to ensure the repair did not affect the safety case. This package has been successfully transported to the UK Low Level Waste facility.

Conclusions

The IAEA Transport Regulations [1] transitional arrangements allows packages prepared for transport in accordance with the 1985 or 1985(As Amended 1990) Editions of the Transport Regulations [2] to be stored for many years prior to further shipment, so long as they are prepared for transport prior to a defined date. The IAEA emphasizes the requirement to apply management system measures, according to the latest Edition of the Transport Regulations, to ensure that such packages only remain compliant (in use) when they continue to meet the original design intent and regulatory requirement.

This graded approach to licensing as opposed to producing a new PDSR was deemed appropriate and the safety case deemed proportionate for a type IP-2 package. The license application was approved by INS based on the existing safety case and the evidence gathered against the IAEA Transport Regulations' specific safety requirements during the submission.

At the time of writing this paper, 15 boxes have been moved to LLWR via rail.

Figure 5: On-site package movement

Acknowledgments

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