Abstract

This paper will describe the Reactor Pressure Vessel (RPV) inspections that were undertaken to the Trawsfynydd decommissioning site between September 2011 and July 2013. It will describe why the inspection was undertaken, what the requirements were and how this was achieved technically and commercially. It will also discuss some preliminary findings, the outputs from the inspection and some conclusions drawn from the entire project. Finally it will show how the project mapped against the Institute of Asset Management’s (IAM) ‘Key Principles’ [2].

1 Introduction

Trawsfynydd is a nuclear power plant, in the process of being decommissioned, located within the Snowdonia National Park in North Wales. It operated between 1965 and 1991 and defueled between 1993 and 1995. It has been in a period of decommissioning since. The reactor buildings, known as Safestores and identified as R1 and R2, each contain a steel RPV. The RPV is contained within a concrete bioshield which was designed to provide secondary radiological containment. Other major components include the diagrid, taking up much of the RPV’s internal volume; chargepan, to the top surface of the diagrid, and fairing plates, to the lower part of the RPV. The area between the RPV and bioshield is known as the reactor void.

From January 2017 Trawsfynydd is scheduled to enter a period of Care and Maintenance (C&M). After this time the site is designed to be in a largely passive state until the Final Site Clearance beginning in 2076 [5]. Magnox Ltd (known as Magnox) is the Site Licence Company that is currently undertaking C&M Preparations to the two reactor buildings. A significant part of this is the production of a safety case for acceptance by the Office for Nuclear Regulation (ONR). This safety case is a fundamental requirement to underpin the asset management strategy for the reactor buildings for the planned C&M period of almost sixty years.

It was determined that in order to support the safety case arguments for C&M a technical assessment of the current and anticipated rates of steel corrosion of the structural elements of the two RPVs would need to be made. It was agreed that this evidence would be qualitative and in the form of digital stills and footage provided through a detailed camera survey. The inspection would also satisfy actions arising from dialogue between Magnox and the ONR with regards water ingress into the R2 reactor void and RPV during 2006. Additionally this project satisfied Magnox’s Asset Management Plan and represented a part of a larger ‘holistic’ and ‘systematic’ approach as advocated by IAM [2].

This type of inspection had not been undertaken at Trawsfynydd since the 1990s and access was thought to be limited, especially through R1’s bioshield. Though radiological issues were much reduced since the days of power generation they were a major constraint. This coupled with known airborne asbestos contamination to the basement areas and reactor void area would make an inspection challenging to implement.

The inspection would be undertaken by the Magnox’s Asset Care department. Their role is to implement actions that satisfy the site’s Asset Management Plan and thus ensure environmental, conventional and nuclear safety compliance of large areas of the site. This includes activities that are planned; including general building maintenance and infrastructure upgrades, and those that are reactive and typical of an industrial site that was built in the early 1960’s. As a part of their role they also undertake surveys and enabling works that assist in decommissioning the site.

It must be noted none of the personnel upon the Asset Care team had previous experience of undertaking a RPV inspection. However engineering expertise in mechanical and electrical, controls and instrumentation disciplines was available.
2 Scope

The drivers for this project centred on providing information on the condition of regions both inside the RPV and between the RPV and bioshield. This would allow a predication of corrosion rates over the long-term and provide assurances as to the current condition. Specifically the inspection was to:

- Provide a comparison of the condition of the two reactor vessels in sufficient detail to allow detailed analysis of any degradation since the last inspection.
- Provide sufficient detail and records to establish a baseline to allow future comparisons to be made.
- Provide sufficient information for a technical review to consider the results of the inspection work.
- Provide sufficient inspection and analysis to underpin the long term reactor buildings safety case.

The resulting inspection report was to provide photographic evidence of the condition of the remaining primary circuit components. It would detail the equipment used, the scope and limitations of the inspection and provide information for a technical metallurgical assessment. It would also close out an outstanding action to provide reassurance as to the integrity of plugs that were used to seal apertures created to R2’s RPV following the removal of steel samples in 1997.

To successfully implement the inspection detailed requirements were developed. These were obtained through negotiations with the safety case officer, subject matter experts and other key stakeholders. This balanced a number of technical and commercial constraints in a ‘systemic’ manner [2] to provide an optimal solution. Additionally a ‘risk based’ [2] approach to scope determination mitigated the many health and safety issues relating to the inspection environment. The project would provide information and deliver activities, benefiting future asset management of these systems and thus be ‘sustainable’ [2].

Ultimately a strategy of inspection was agreed that would limit scope by undertaking surveys and making comparative assessments based on the inspection data between R1 and R2. The project would be divided into two campaigns, namely chargeface access and basement access.

The chargeface is the 75’ floor level from which fuelling was undertaken. It is shown on Figure 1 as the floor level directly above the cylindrical RPV. Inspections from this location would be undertaken to both R1 and R2 and consist of the following:

- Vessel viewing hole survey between bioshield and RPV:
  - Showing un-lagged exterior vessel surfaces
  - Vessel skirt and skirt support structure.
- Standpipe channel assemblies survey of vessel internals:
  - Chargepan.
  - Diagrid and below the diagrid.
  - Diagrid support and restraints.
  - Vessel fairing plates.
  - Inside of debris pot region.

This campaign is shown as the vertical red dashed arrows to the section in Figure 2.

The basement campaign would access primary circuit components and the reactor void using routes gained in the -17’9” basement level. It was agreed that access to R1 would be restricted because no suitable routes or opening had historically been made through the bioshield at the basement level. These inspections consisted of:

- Debris duct to R2.
- Behind flange plate access only to R1 debris duct.
- Cold gas ducts to R1 and R2.
- Areas within the reactor void:
  - Vessel skirt and skirt support structure to R2.
  - Interior of vessel skirt and outside of debris pot to R2.
  - Un-lagged exterior vessel surfaces to R2.
  - Below reactor void floor plates R1 and R2.

This campaign is shown as the red dashed lines in both the section and plan in Figure 2.

Figure 2. An overview of the RPV inspection routes showing the RPV in section and in plan [6][7].
3 Technical requirements

Inspections of this depth and detail have not been undertaken within the fleet of Magnox sites for some time. The necessary expertise was available through the existing Remote Operations (Remote Ops) team. They are based on the Wylfa site and is engaged in outage inspections and repairs to the UK’s remaining Magnox operational reactor. However the equipment necessary to undertake the Trawsfynydd inspection had to be procured and, in several instances, completely designed and manufactured.

The first phase of the project required the collation of as-built and survey information to confirm radiological and asbestos environmental conditions and those relating to the built environment. This proved challenging and reiterated the importance of record keeping, indexing and good archiving. Information gathered included that from the original operations and maintenance manuals, drawings, engineering change control proposals, previous inspection reports and circa 100 hours of S-VHS and U-matic video tape footage taken from previous inspections. The latter was converted to digital format. Underpinning this information a large number of asbestos, radiological, dimensional and photographic surveys were undertaken. These provided reliable information to allow design and safe systems of work to be produced.

All gathered information was used to produce a document that provided the basis for all design, enabling works and inspection activities. It also provided pre-construction information that was deemed necessary under the Construction, (Design and Management) Regulations, 2007.

Figure 3. Drawing of the chargeface showing the location of vessel viewing holes which provided a route in the void between the bioshield and RPV [8].

The first campaign was to begin via the vessel viewing holes (see Figure 3) and accessed the area to the reactor void. It was to be undertaken using a number of different camera systems chosen for reliability and performance. A camera and a manufactured LED light bomb were to be lowered from the chargeface on an umbilical which also provided power and data transmission capability. Though this inspection was not technically challenging it would require the construction of asbestos containment tents and engagement of licensed asbestos workers to lower the camera system. This was due to the high level of airborne asbestos contamination that was present within the reactor void and prevented spread of asbestos and inhalation by personnel.

The first campaign would conclude with internal inspections to the RPVs. These would require the deployment of short arm manipulators (SAM) to manage the lowering of a camera and a light bomb. Once inside the RPV the camera and light bomb would have to be independently manipulated horizontally across the chargepan to allow them to lowered directly through or to the outside of the graphite diagrid. The design and manufacture of two SAMs, as shown in Figure 4, was one of the project’s first challenges.

Figure 4. Small arm manipulator for use along with the camera and light bomb [1].

Figure 5. The route required for the camera to access the diagrid support [9].

The SAM would be operated using hydraulics and controlled with the aid of several cameras. It was designed to be assembled in 2.5m long lightweight and de-contaminable aluminium circular hollow sections and lowered from the chargeface. The maximum distance it would need to traverse the camera or light bomb would be approximately 1500mm to allow the inspection to the diagrid restraint. This is indicated in Figure 5.
An important facet of the pre-works related to mock-ups and rehearsals. This was achieved by constructing a scaffolded mock-up of the RPV in an offsite industrial building. The SAM was successfully trialled and its deployment rehearsed before its use at Trawsfynydd, thus identifying a number of necessary minor modifications, facilitating training and providing assurances that the inspection would proceed smoothly. Figures 6 and 7 shows the concept of the mock-up arrangements and the Remote Ops team in action.

Figure 6. The concept design for scaffold mock-up of chargeface and chargpan for SAM deployment trials [3].

Figure 7. Photographs showing the mock-up of the chargepan and the trialled deployment of the SAM [3].

The second campaign, via the basement, would require the design and assembly of a variety of remote operated vehicles (ROV), camera skids and a pantograph. Standard Micro and Mini ROV systems from Inuktun were procured to provide tracks upon which the chassis and camera could be mounted. These were operated using an umbilical. The pantograph was manufactured by BICO Ltd and provided the ability, using a combination of a scissor jack and rack and pinion, to lift the camera by approximately 1.5m from floor level and pitch it 1.2m forward to access the vent holes to the RPV skirt. These vent holes can be seen in Figure 8 and elevations of the pantograph and photos of the ROV in Figure 9.

Figure 8. Composite photograph from an inspection in 1998 showing the lower section of the RPV and the vent holes through which the pantograph would access [3].

Figure 9. An elevations of the pantograph (mounted on Mini Inuktun tracks) and photographs of an ROV tracks (LH inset) and Micro Inuktun tracked ROV (RH inset) complete with an under slung Spectrum 45 camera [3].

Inspections to the cold gas duct and debris duct were to be accessed using a camera on a skid for simplicity. The inspections to the reactor void to R2 would access the following areas.

- Below sub-floor using a Micro Inuktun ROV.
- Above floor using Mini Inuktun ROV.
- Below RPV and looking through vent holes to skirt using the pantograph.

Inspections through the bioshield would require significant enabling works to control personnel exposure to airborne asbestos fibres and radiological dose. Again licensed asbestos workers would be used to deploy the camera from within an asbestos enclosure. The inspection itself would be controlled by the Remote Ops team in an adjacent area. Radiological dose assessments were also necessary due to the ‘shine path’ through the bioshield opening and proximity to the RPV. These arrangements are shown in the plan in Figure 11.

This arrangement was to be repeated to R1 though access into the reactor void to above floor level was not possible without intrusive and radiologically significant works. This scope was omitted early in the project with the agreement of the safety case officer.
4 Contractual arrangements

The inspection was to be carried out by the Magnox Remote Ops team but would require a large amount of enabling works and support. Asset Care was able to provide all of this through allocation of resource from their attendant building and scaffolding/asbestos framework contractors. This allowed work areas to be established, access scaffolding to be erected and asbestos enclosures and licensed asbestos works undertaken.

An important part of this project related to the design and manufacture of the camera systems, light bomb, SAMs, ROVs and pantograph. This was achieved through a combination of the Remote Ops team and the local supply chain. High specification machining and fabrication was provided by BICO Ltd of Beaumaris who undertook detailed design and manufacture of the SAMs, light bomb and pantograph. Remaining inspection equipment was assembled by the Remote Ops team. This approach proved highly effective.

5 Implementation of inspection activities

The inspection works began in November 2011 with the simple task of removing a flange to the debris duct to R1. This was completed without incident and levels of corrosion were as expected.

October 2012 saw the beginning of the inspection to R2 chargeface which was followed by that to R1. Inspections to the vessel viewing holes to both R1 and R2 showed displaced floor plates. It is thought that steel corrosion had triggered floor plates to lift on one edge. R1 had historically suffered significant water ingress through a high water table with the source of water in R2, as previously described. The water ingress to R2 had also thought to have caused the fall of aluminium cladding over asbestos lagging. Figures 12 to 14 show examples of what was found.
Inspections to the inside of both R1 and R2 RPVs were undertaken between October 2012 and February 2013 and showed no significant corrosion. Figure 15 shows the deployment of the SAM and Figures 16 to 20 the inside of a variety of areas within R1 and R2. Overall the SAM, light bomb and camera systems performed as expected.

Inspections to the reactor void to R2 began in March 2013. They provided additional information on the lifted floor plates (Figure 13) and fallen cladding and provided the first glimpse to within the RPV skirt. Undertaken using Micro Inuktun tracks and a Spectrum 90 camera they gave invaluable information for the later pantograph survey. The inspection to below the floor plates was also completed despite high levels of debris and can be seen in Figure 21. The inspection to below the floor to R1 however proved impossible due to the orientation of ventilation dampers within the reactor void.

The manufacture of the pantograph was completed in June 2013 and it was immediately put to work to view below the skirt to the R2 RPV. The pantograph operated as predicted, providing proof of the good condition of the plugs to the R2 RPV and as expected levels of corrosion. Photographs of this region can be seen in Figures 22 and 23.

The remaining areas that were to be inspected were finished during July 2013 and without incident. The cold gas ducts to both R1 and R2 and debris duct to R2 again showed no corrosion issues and photographs can be seen in Figures 24 and 25.
Figure 20. The fairing plates and inside the debris pot to R1 RPV [3].

Figure 21. Skirt support structure to below R2 floor [3].

Figure 22. The outside of the debris pot to R2 from inside the skirt showing a sample plug to the top right corner [3].

Figure 23. The plugs installed in 1997 after steel samples were taken [3].

Figure 24. Inside the debris duct looking up from the debris pot [3].

Figure 25. The inside the cold gas duct to R1 showing a steel sample coupon carrier [3].

6 Outputs from inspections

The output of the inspections will be two reports:

- Survey report covering all of the inspections detailing areas accessed and those which were excluded. It will explain the scope and method of inspection.
- Technical assessment report of the survey including other environmental monitoring and corrosion data. This will be undertaken by a metallurgist.

The reports will be used to provide information to allow the long term reactor building safety case to be produced and provide information to allow an assessment of the requirements for a future inspection regime.

Additionally the inspection will deliver a number of small but significant modifications which will improve the radiological and asbestos conditions within the basement areas concerned. It will facilitate future asset management and decommissioning activities through the information gathered and new access routes that have been created or existing ones that have been proved viable.
7 Conclusions

There were no significant issues identified during the inspection though a number of findings relating to the displaced floor plates and fallen cladding are to be investigated further.

In terms of the project itself; the inspection was largely self-performed using Asset Care contractor team and Magnox resource. This suited the iterative manner in which the works progressed and negated excessive set-up costs and contractor variations. Any downtime was mitigated by reallocating the resource onto other Asset Care activities. The one downside to using the Magnox Remote Ops team related to constraints imposed by their commitments to outages to Wylfa’s operational Magnox reactor. However this risk did not materialise.

Detailed design and manufacture of the major items of inspection equipment was contracted to a local precision engineering company who proved extremely effective. Though not experienced in the nuclear industry design and quality assurance issues were managed through a strategy of careful concept specification, a collaborative approach and a design review process. The deployment of the BICO Ltd engineered SAM, light bomb and pantograph went extremely well as did all equipment manufactured by the Remote Ops team.

The project could be summarised as follows [3].

Strengths:
- Accident and incident free and works were carried out well within radiological dose budgets
- Inspection requirements did not change.
- Outside of the inspection requirements a large amount of useful information was gathered.
- Design and manufacture of inspection equipment went well and modifications undertaken quickly.
- Mock-ups and rehearsals in the use of inspection equipment were highly effective
- Equipment was effective during implementation.
- Excellent integration of inspection team.
- Inspections generally proceeded well once started.
- Positive feedback from ONR.
- Quality of inspection images and footage was good.

Weaknesses:
- Consistent legacy information management issues concerning the reliability, accuracy and availability and also archiving and indexing of records.
- Inertia experienced in getting the inspections started.
- Conflict between asbestos and ionising radiation regulations made definitive asbestos advice problematic.
- Several minor and unanticipated modifications were required during the inspection phase.

In terms of the remaining IAM ‘Key Principles’ it is argued that the inspection was ‘optimal’ [2] in terms of delivery of scope and the usage of resources within this type of highly regulated environment. There were several key system modifications and design activities that demonstrated an ‘integrated’ [2] approach as they will benefit a number of other projects and asset management activities.

A number of follow-on actions have been identified relating to gaining access to below the floor to R1 reactor void and the feasibility of accessing above the floor also. This will provide additional information on the corrosion mechanism to the floor plates. It is also important any learning needs to be communicated across not only the Trawsfynydd site but other sites within the Magnox fleet and that this gathered information is archived appropriately to optimise its future use.

This project has proved an overwhelmingly positive experience and has provided the evidence required for the C&M safety case. It will also pave the way for future inspections and decommissioning activities through the built environment information it has provided and the inspection equipment that has been manufactured.

Acknowledgements

My thanks to my the RPV Inspection team consisting of Rob Evans, Kev Lewis, Geoff Owen; the Remote Ops team of Graham, Dean, John and Fingers, and to Gron of Bico Ltd and Martin of PFS. Finally to Mark and Lee for your assistance in reviewing this paper.

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