Operational Experience with a Robotic Arm for Wet Waste Retrieval at Trawsfynydd Nuclear Power Plant – 14173

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ABSTRACT

During 2012 and 2013 Magnox Limited has operated two nominally identical manipulator systems to assist the retrieval of legacy wastes at Trawsfynydd NPP. The project was made particularly challenging by the access limitations into the tanks and vaults containing the waste. In addition the vaults contained a range of waste streams that required separation before they could be processed for final disposal. Significant progress has been made; one tank is now empty and clean, whilst another has been declared free of bulk wastes. Considerable operating experience has been achieved with the manipulators, tooling and support equipment. This project, although challenging, demonstrates how Magnox has looked to use innovative solutions to tackle legacy wastes in difficult radiological conditions. By applying a lead and learn approach, the learning from this project will be shared across Magnox. Now the project is entering its final phases, Magnox has proven equipment and techniques, along with a highly effective team of operators whose skills can be transferred to other decommissioning projects at Trawsfynydd and other Magnox sites.

INTRODUCTION

Magnox Limited, owned by Energy Solutions, is the management and operations contractor responsible for ten nuclear sites and one hydroelectric plant in the UK working for the sites' owner, the UK Nuclear Decommissioning Authority (NDA).

Trawsfynydd is one of the UK's first generation nuclear power plants. It started operation in 1965 and ceased generation in 1991. Both of its reactors were fully defueled and all fuel removed from site by 1995. The Magnox reactor type is named after magnesium alloy cladding used to hold the natural uranium fuel.

To complete the most challenging phase of decommissioning, a number of wet and dry waste stores around the site must be emptied and their contents made safe. Wet wastes include sludges and resins produced during the operating life of the NPP. The sludges and resins are stored in a number of tanks that differ significantly in terms of size, shape, internal features and access. Mixed with the sludges and resins are a wide variety of other solid wastes including fuel element debris (FED), nimonic alloy springs, pins and numerous items of redundant equipment. The retrieval project is particularly challenging because of the combined difficulties of access into a variety of tanks along with the need to handle significant quantities of mixed and varied waste streams.

BACKGROUND

A project to design, develop and commission two, nominally identical, robotic manipulators known as RDAs (Rotary Deployment Arms) and appropriate tooling to enable these tanks to be cleaned was started in 2008. The design and testing of the manipulators has been described at previous

WM conferences (ref 1 and ref 2). Since their commissioning in 2012 the manipulators have been put to work in a number of the waste tanks at Trawsfynydd.

The decommissioning work at Trawsfynydd is being undertaken through a program approach. All of the decommissioning projects across the ten Magnox sites have been grouped into common areas known as “Strategic Programmes”. Although every site is different, the core challenges are the same, so tackling work consistently helps drive value and innovation. At Trawsfynydd a hazard reduction program covering the period from April 2010 to December 2016 is being undertaken across the above program to prepare the site for its “Care & Maintenance” phase of decommissioning when it can be declared to be passively safe and secure.

WET WASTES AT TRAWSFYNYDD

To enable the site to enter the “Care and Maintenance” phase a number of wet and dry waste stores around the site must be emptied and their contents made safe.

Trawsfynydd has two large tanks, the Main Sludge Vault and Ponds North Void (PNV), containing Intermediate Level Waste (ILW) in sludge form. The liquid sludge waste (typically containing quantities of sand and Magnox corrosion products, primarily magnesium hydroxide) was produced by the site’s fuel cooling pond water and active effluent treatment plants.

Trawsfynydd also has three Resin Vaults (RV1, RV2, and RV3) that require emptying and removal to allow further decommissioning. The spent resin originated from the station’s effluent treatment plant (incorporating filters and ion exchange facilities) to remove particulate and dissolved radioactive species. A remotely operated vehicle was used inside RV1 to retrieve bulk wastes in preparation for processing via the resin solidification plant. The plant produces a polymer - encapsulated drummed product to be stored as ILW on site. More than 1,700 completed resin drums have been produced to date, with a further 250 expected to be produced from the residual waste in the two remaining resin vaults.

RESIN VAULT OPERATIONS

Resin Vault 2 is a cylindrical stainless steel tank approximately 5m diameter x 6m deep and is fitted with internal pipework. The tank has been used for storage of contaminated ion exchange resins throughout most of the operational life of the power plant. A view of the inside of the vault prior to the start of retrievals is shown in figure 1, most of the resin is accumulated in piles on the bottom of the vault covered by about 3m of liquid. Dried and solidified waste can be seen on all surfaces.

Working remotely, operators controlled the RDA using a human machine interface (HMI) system. This included numerous displays and a touch-screen PC, giving display of RDA parameters and control modes while operators used joysticks to control RDA movement. The RDA was used to manipulate a bulk suction tool under the supernate to retrieve contaminated resin. Much of this work had to be carried out blind as the liquor significantly affected the views available with in-tank and on-manipulator cameras.

Fig 1. RV2 contents before retrieval operations commenced.

Instrumentation on the RDA was expected to be crucial to successful and systematic removal of the bulk waste. However a number of challenges arose and retrieval was only achieved because of the skill of the operators and their ability to build on the experience gained during training and early phases of operation. Following removal of the bulk resins the supernate layer could be drained down to reveal residual waste as shown partially in figure 2. A combination of high pressure water and a vacuum tool, both deployed on the RDA, was then able to clear all remaining waste from the tank and from around the numerous items of in-tank furniture.

Fig 2. RV2 during retrieval operations.

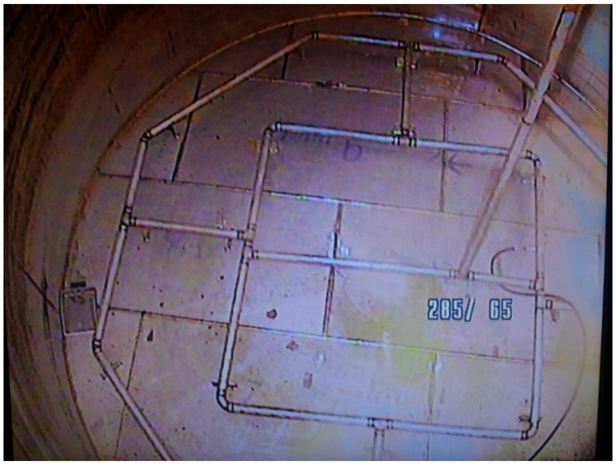

Fig 3. RV2 clean and empty.

RDA1 completed the clean-out of Resin Vault 2 in early 2013, visual (see figure 3) and radiological checks allowed the tank to be declared clean and empty. RV3 is nominally identical to RV2 and is housed in the same building. RDA1 has been transferred to RV3 and at the time of writing has completed retrieval of about half of the bulk resin.

PONDS NORTH VOID (PNV) OPERATIONS

In parallel, RDA2 has completed the first phase of clean out of PNV. The PNV is a rectangular concrete vault measuring approximately 8m long x 3m wide x 6m deep, and was historically used to store sludge and debris removed from the irradiated fuel cooling ponds during electricity generation and the early stages of decommissioning. In addition a number of much larger miscellaneous items had been placed in the void. Solid wastes (typically >4.5 mm) require a different disposal route to liquids and sludge. It is therefore necessary to separate these waste streams within PNV as part of the retrieval process.

A review of historical data supported by a number of in-vault inspections led to the conclusion that the waste inventory consisted of…

- sludge (<4.5 mm diameter) ~4.8 cubic meters of magnesium hydroxide (corroded FED)
- supernate ~1.75 cubic meters
- small solids (>4.5 mm diameter) – a mixture of both LLW and ILW debris, i.e. nimonic springs, spring pins, fuel element spiders, other FED material and miscellaneous LLW. The estimated total volume of small solids is ~215 liters and will be treated as ILW.
- large solids
    - A redundant pump (ILW)
    - Two FED trash bins, chains and pipes (LLW)
    - Numerous concrete cores (LLW)

WASTE SEPARATION

A key challenge is to separate, in-situ, waste streams that have to be treated and disposed of by different processes housed in different plant areas. Sludges could be disposed of through waste routes that were available at the start of operations. However solid wastes need to be treated differently and that route will not be available until long after bulk wastes have been cleared from PNV and therefore needed to be held in an intermediate store. The retrieval program started with installation of many ancillary components including a buffer store (figure 4) at one end of the vault.

The RDA was then used to position a submersible pump after it had been lowered into the PNV through an access hatch. A layer of sludge and supernatant liquor was transferred to another waste tank (the Main Sludge Vault) to improve visibility of the PNV contents (figure 5). Removal of large solid items, including two garbage bins, took place using the RDA. These items had been partially submerged in sludge and so were cleaned using the RDA jet wash tool within the PNV. Once the large solid items had been decontaminated, they were removed from the PNV using a recovery basket and then manually transferred to the appropriate container in an adjacent area on site.

Fig 4. Buffer store installed in PNV.

Fig 5. Supernate level lowered in PNV.

Before their removal from the PNV, these items were subjected to health physics monitoring to determine the container type required. Items of LLW were consigned to the site LLW store whilst ILW was placed in the site's active waste vault. All of the smaller solid waste was then transferred using special tooling, including a grab, scrapers and shovels, mounted on the RDA into specially designed mesh pots. The mesh pots were placed in a wash station (fig 6, 7) for cleaning and removal of sludges before being transferred to the buffer storage area within PNV.

Fig 6. Wash station installed in PNV.

Fig 7. Wash station in operation.

Use of the wash station added water to the tank and assisted in mobilization of further sludge which could be transferred to MSV for final processing. The initial project estimates of the volume of solids indicated that in the region of 25 – 30 mesh pots would be required for storage of this waste stream. The buffer store that was built and installed into the PNV held 38 mesh pots. By the time solid waste retrieval was completed almost 100 pots had been filled, so in addition to the buffer store it was necessary for operators to establish means of stacking pots in other areas within the PNV. Transfer of washed mesh pots containing solid waste from the wash station to the buffer store is shown in figures 8 and 9.

Fig 8. Mesh pot placed in buffer store.

Fig 9. Mesh pot held by RDA.

Waste retrieval in PNV has also presented a range of unexpected challenges to the operators and project team. Through a combination of innovation, determination and pragmatic decision making good progress has been made and bulk sludge retrievals have been declared complete.

Retrievals are currently on hold whilst other wet wastes are being processed. Removal of residuals wastes and final cleaning on the vault in currently scheduled to take place in early 2014.

LESSONS LEARNED

The diverse nature of the waste and the difficulties of access into the vaults presented some significant challenges to the project.

A number of key decisions were taken early in the project that shaped the retrieval methodology. Despite the different nature and size of the resin vaults compared to PNV it was decided that a single manipulator design would be capable of operating in all environments. It was also agreed that despite the challenges of submerged operation and limited space for cables and connectors that the manipulator should be fully instrumented. Full instrumentation would allow force feedback data to be provided to the operators in addition to a number of sophisticated control modes.

With the benefit of hindsight some of the decisions might have been taken differently. Simplification of instrumentation and a reduction in the number of connectors might have improved reliability of the system and reduced the test and commissioning schedule. However the project benefitted from its focus on a single goal and has reached the current state of plant clean-up more quickly than if some of the decisions had been reversed at various stages throughout the development and testing cycle. The challenges of developing equipment with a combination of features and functionality, even if none of them individually are particularly novel, to work in a range of difficult environments should not be underestimated.

Looking in back at the work now it is possible to identify a number of key lessons applicable to many future projects requiring the retrieval of large volumes of waste.

- An overall system design that is tolerant to failure of one or more sub-systems. In particular a control system that is able to function adequately after loss of instrumentation.
- A safety case for operation of equipment that is based on inherent design features rather than electronic or instrumentation based levels of protection.
- A team of operators and other key site staff determined to see the project as a success rather than look for excuses for failure.

FUTURE WORK

RDA1 has been transferred to Resin Vault 3 and has commenced a further campaign of waste retrieval. Following bulk retrievals residual waste will be removed and the tank cleaned to leave it in a similar final condition to RV2.

Meanwhile removal of the residual waste in PNV will be completed before RDA2 is transferred to the Main Sludge Vault for clean-up of the final wet waste storage tank on site.

CONCLUSIONS

This project, although challenging, demonstrates how Magnox has looked to use innovative solutions to tackle legacy wastes in challenging radiological conditions. By applying a lead and learn approach, the learning from this project will be shared across Magnox. Now the project is entering its final phases, Magnox has proven equipment and techniques, along with a highly effective team of operators whose skills can be transferred to other projects at Trawsfynydd and other Magnox sites.

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