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Practitioner versus analyst methods: A nuclear decommissioning case study

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ABSTRACT

A requirement arose during decommissioning work at a UK Magnox Nuclear Power Station to identify the hazards involved in removing High Dose Rate Items from a Cartridge Cooling Pond. Removing objects from the cooling pond under normal situations is a routine event with well understood risks but the situation described in this paper is not a routine event. The power station has shifted from an operational phase in its life-cycle to a decommissioning phase, and as such the risks, and procedures to deal with them, have become more novel and uncertain. This raises an important question. Are the hazard identification methods that have proven useful in one phase of the system lifecycle just as useful in another, and if not, what methods should be used? An opportunity arose at this site to put the issue to a direct test. Two methods were used, one practitioner focussed and in widespread use during the plant's operational phase (the Structured What-If method), the other was an analyst method (Cognitive Work Analysis). The former is proven on this site but might not be best suited to the novelty and uncertainty brought about by a shift in context from operations to decommissioning. The latter is not proven on this site but it is designed for novelty and uncertainty. The paper presents the outcomes of applying both methods to a real-world hazard identification task.

1. Introduction

As many nuclear sites around the world make the transition from operations to decommissioning, the problem space in which they operate is changing and so too is the appropriateness of methods aimed at managing risks therein. Stated simply, just because hazard identification methods have worked in the past no longer means they are guaranteed to work in the future. This paper describes an opportunity which arose at a UK Magnox nuclear site to subject this broad question to a more specific test through the comparison of two methods: the Structured What-If (SWIFT) approach and Cognitive Work Analysis (CWA). Underwood and Waterson (2013) make an interesting distinction between two broad method types. On these terms SWIFT might be termed a 'practitioner' method, one that was used extensively during the plant's operational phase. The latter might be termed an 'analyst' method of the sort more commonly found in the academic literature. The former is 'proven' in the present problem domain, but there are doubts about the extent to which it can cope with the uncertainty and novelty brought about by nuclear decommissioning. The latter is not proven at the present site – it has not been used before in this location – but it is designed to cope with uncertainty and novelty. This paper explores how these tradeoffs manifest themselves when both methods are applied in a real-world setting.

2. Nuclear decommissioning

2.1. Background and context

The nuclear power station at which this study took place is a 360 MW Magnox site constructed in the early 1960s. Magnox reactors are fuelled with uranium fuel elements which are loaded into a graphite reactor 'core'. The term Magnox refers to the non-oxidising magnesium alloy used to clad these elements. This design feature confers a number of technical advantages relating to containment of fissile material and the relative ease of material handling during reprocessing, and is a feature unique to British

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reactors of this era, albeit one that is now considered obsolete. The graphite in the reactor core, into which the Magnox encased fuel elements are placed, is known as the 'moderator'. So-called 'fast neutrons' released in the fission process have to be slowed in order to sustain an on-going chain reaction and graphite provides this function. Control rods are also raised and lowered into the reactor core in order to control the reaction by absorbing excess neutrons. The heat energy released by the fission process is continually moved from the reactor core by a coolant which, in the case of Magnox reactors, is pressurised carbon dioxide gas. The coolant flows from the core to heat exchangers where water is converted into steam which, in turn, powers a number of conventional turbo alternators which supply electrical energy to the national grid.

2.2. Cartridge cooling pond

Fuel rods have a finite lifespan and once they are 'spent', typically after a year, they are removed from the core, passed through a desplittering process to separate the fuel rods from the Magnox cladding, then loaded into crates and stored underwater in the Cartridge Cooling Pond (CCP). The cooling process takes several months. Once cooled the fuel is removed from the CCP, placed in flasks and transported offsite for safe storage or reprocessing.

The CCP at the present site has a capacity of over one million gallons. It consists of a 1.2 m thick reinforced concrete slab with reinforced concrete internal and external walls and has a depth of 6.7 m. The pond enclosure is divided into three sections; fuel handling bay (FHB) 1 and 2 and the CCP Main Enclosure. During the operational life of the station FHB 1 was used to accept and desplitter discharged fuel cartridges, while FHB 2 was available for emergencies and has the capacity to store all fuel from the reactor. The main enclosure was used to store spent desplittered fuel cartridges in skips. A skip crane runs the width of the pond and was used to transport the skips from one area to another Fig. 1.

2.3. Decommissioning

In the mid-1990s, following a successful generating period of over twenty years, the power station ceased operation and preparations began for decommissioning. At the time of writing, the Station is currently undertaking a programme to preserve the site in a 'safe state'. During safe-state no further projects will be undertaken and only care and maintenance regimes are required to assure the integrity of the civil structures on the Station until such time that the structures can be safely removed and the site returned to its original condition. Under the programme of decommissioning a project has been established to decommission the CCP. This project involves retrieval, decontamination and safe disposal of pond furniture, followed by removal of sludge (desludging) which has built up on surfaces within the CCP, and then eventual draining of the CCP (dewatering). Before this stage is reached, however, two High Dose Rate Items (HDRIs) have to be removed. These HDRIs give a dose reading of 14Sieverts (Sv) which is the equivalent of a 5.25 s unshielded exposure time before the annual legal allowable dose uptake of 20 mSv is exceeded. It should be pointed out that 20 mSv is a maximum dose. In practice, workers would not be expected to exceed half of this value in a year. It is vital, therefore, that all required measures are taken to protect operators against such a scenario, and it is this specific risk that the methods described in this paper are orientated around.

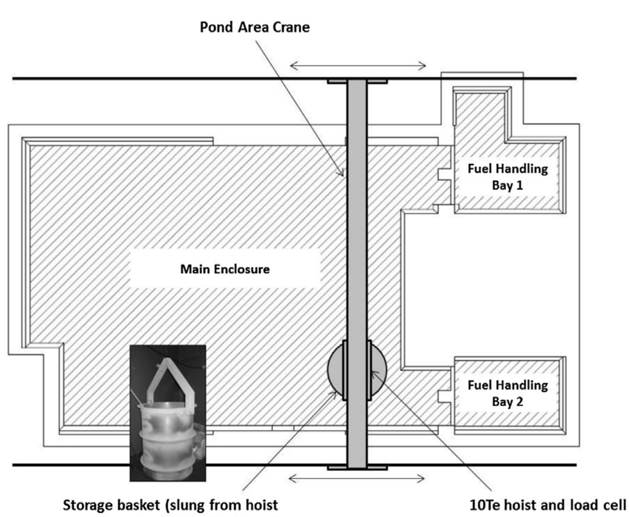

Fig. 1. Layout of Cartridge Cooling Pond (CCP) showing two Fuel Handling Bays (FHB1 & 2) and the Main Enclosure.

3. Hazard identification

3.1. Practitioner methods

The imperative to ensure operator safety when dealing with these HDRIs is compounded by the change in circumstances from 'operations' to 'decommissioning'. Many of the tasks required to decommission the CCP have, by definition, never been performed before on this site. Added to which, over the 40 years since the plant was commissioned it has naturally degraded and aged, creating as yet unforeseen conditions such as CCP sludge, unusual 'left-over' HDRI's, non-standard removal tasks and complex storage requirements. This increase in complexity also increases the chance of unexpected yet still highly credible hazards to personnel.

The first strategy for dealing with this is to use hazard identification methods that were routinely employed during the operational life of the facility. On this site the 'Structured What If' (SWIFT) method was common. This method can be described as a practitioner tool and was originally developed for use in the chemical and petrochemical sectors, but has since become established as a useful technique throughout a number of high risk industries (BS EN 31010, 2010 pg.49). SWIFT is similar to the HAZOP technique in that it requires a multi-disciplinary team to work through the system in a systematic manner, asking questions of the form 'What if …' or 'How could …'. SWIFT relies on task decomposition and a systematic application of 'what if' questions applied to each and every identified task. In other words, the task is taken apart, assessed for hazards, then re-assembled on the tacit assumption that the reassembled 'whole' should not be more than the sum of its parts (Walker et al., 2010).SWIFT, therefore, has a large deterministic element well matched to stable problems involving well understood parts.

3.2. Analyst methods

The presence of various age-related degradations in the system, combined with the need to perform novel tasks, makes it potentially more difficult to discern final states from initial conditions. This property is referred to as 'emergence' (Gleik, 1987; Halley and Winkler, 2008; Walker et al., 2010). Emergence creates an analytical problem in that "calculation of system level emergent properties [such as unforeseen hazards and risks] from the component level rapidly becomes intractable" (Halley and Winkler, 2008, p. 12). In