REMOTE DISMANTLING OF NUCLEAR FACILITIES IN THE UNITED KINGDOM EXPERIENCE TO DATE

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ABSTRACT

The United Kingdom has had a wide ranging nuclear program since the late 1940's. Consequently many of the first generation facilities have now reached the end of their useful lives and hence a significant program of decommissioning is now ongoing.

Within certain decommissioning projects, factors such as radiation environments, access limitations, or productivity requirements have, on occasions, necessitated the use of remote technology for duties ranging from initial plant inspections to dismantling and final waste handling.

Experience to date in the use of remote dismantling techniques within the UK nuclear decommissioning program is outlined in this paper. Various projects undertaken by BNFL and AEA Technology are used to illustrate the range of remotely operated systems employed, the reasons for their adoption and the diversity of tasks undertaken.

INTRODUCTION

Nuclear operations within the United Kingdom began in the late 1940's since when a complete spectrum of plant types have been constructed from enrichment, fuel manufacture and reactors to spent fuel storage and cooling ponds, fuel reprocessing, uranium and plutonium finishing and all the associated waste handling and effluent treatment systems plus various research and prototype facilities.

Over the years, several of the plants have been shutdown and decommissioning is now proceeding in line with operators declared programs. Details of the policy, planning and strategy behind the programs of British Nuclear Fuels and AEA Technology, two of the major UK operators, are described in Refs. 1 and 2 respectively.

Substantial UK decommissioning began in the early 1980's, since when a considerable knowledge base has been acquired. Capabilities in all aspects of decommissioning ranging from strategy definition, project planning and plant inventory assessment to decontamination, size reduction and waste management have all been, and continue to be, enhanced as a result of practical experience gained from the full scale projects undertaken. Application of remote technology to decommissioning is a further notable case inpoint.

As remote operations are likely to feature in a significant number of future decommissioning projects it was vital from the start to ensure that safe and cost effective systems could be provided. Examples of how this has been achieved for a range of remote dismantling tasks within the UK are now given.

THE WINDSCALE PILE CHIMNEYS

The Chimneys, which discharged cooling air from the two pile reactors, operated until 1957 when a fire in the core of Pile 1 resulted in the decision to shut down both units.

Decommissioning work is now ongoing with the objective of partially dismantling the complex, massive, concrete, brickwork and steel chimneys, together with the removal of filter handling and washing equipment from plant rooms near the tops of the 125m tall structures. Isolation from the reactors and removal of all thermal insulation lining from the chimneys is also being carried out.

In all these areas the project strategy is to develop, where possible, existing technology transferred from other industries.

During the 1957 fire the glass fibre insulation in the upper and concentrator sections of Pile 1 Chimney became contaminated with Caesium 137. Contamination levels are such that to minimize radiation uptake and so meet the principles of ALARP remote removal of the insulation has been necessary. A manipulator deployment system with CCTV (3D) has been developed to allow the use of two Schilling manipulators (Fig. 1) to cut away the insulation and feed it via a purpose built Waste Packaging Machine into 200 liter stainless steel drums.

Following full inactive trials the remotely deployed manipulators were installed on Pile 1 Chimney upper section in August 1990. Insulation removal from the upper section was successfully completed in December 1990.

The manipulator system was removed from the Chimney for planned overhaul and fitment of new manipulators with longer reach. All equipment was again tested inactively on a test rig built to reproduce chimney geometry. The modified manipulator system and waste packaging machine were redeployed onto the Chimney in June 1991 in order to remove insulation from the concentrator section. Completion of this work is due in February 1992.

As manual dismantling of the upper and concentrator sections of Pile 2 Chimney was possible the opportunity to directly compare costs for manual and remote operations is being taken. Although work on Pile 1 Chimney is not yet complete, initial indications are that, taking into account all costs such as engineering, safety documentation and waste arisings, remote operation costs are for this project roughly

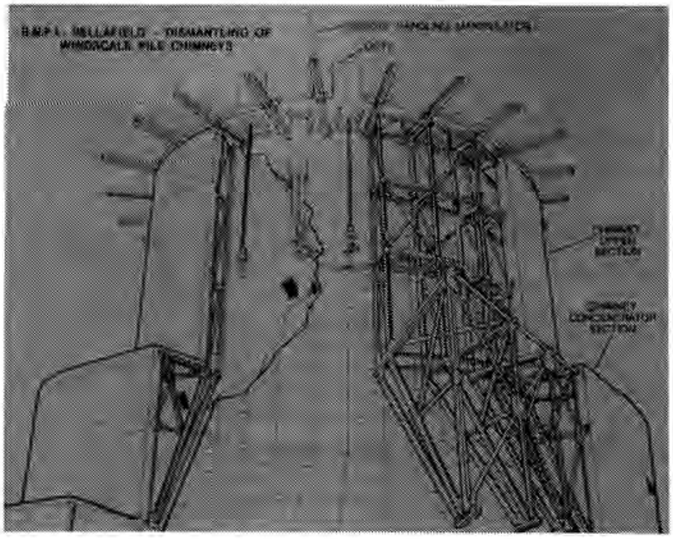

Fig. 1. Deployment of manipulator in upper section of pile 1 chemney.

four times those for manual work. Further evaluation of this data is now ongoing to quantify the influence on costs of the different radiological conditions present on the two chimneys. When validated, the data will be used to evaluate costs associated with various dismantling options within future projects were dose levels permit a choice.

The next major phase of remote work, namely the removal of Pile 2 Chimney filter bank and stripping of insulation panels from the chimney shaft, will be undertaken by a 12Te tracked excavator, made capable of being remotely deployed within the chimney base. A command radio transmitter is installed in the control room with a receiver housed in the excavator. The control system utilizes digital radio commands for proportional control of all machine functions.

The functions (joystick operated) replicate the controls in the drivers cab. A 'Quickhitch' attachment, also remotely operable, enables bucket removal and replacement with hydraulically powered tooling/attachments. Two auxiliary hydraulic power supplies are available at the boom and which are suitable for ram or hydraulic motor applications. The machine has three 'on-board' CCTV cameras, forward viewing stereo and zoom cameras with motorized 'pan and tilt' facilities, and a fixed position rearward facing camera. A directional microphone provides ambient sound information and engine parameters are continuously displayed on one of the CCTV monitors.

The current phase of work at Pile 2 Chimney is the installation of a lift platform and winches to carry the vehicle up to all levels within the chimney (Fig. 2).

All controls for the lift will be located in a central control room.

The unique nature of this project has resulted in the novel application of some familiar tooling. Notable examples of this are the use of the reciprocating hedge trimmer principle as a basis of a system to cut insulation from the cavity of Pile 1 Chimney and the use of a part of a hay baling machine to feed insulation into the Waste Packaging Machine (later superseded by a hopper with powerful suction outlet). Other tooling now being modified to permit remote operation includes

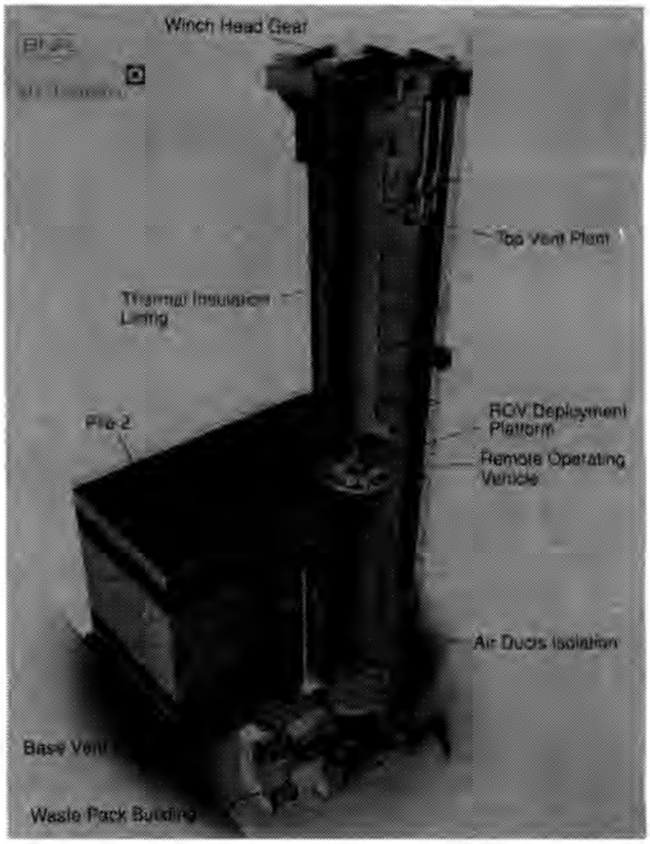

Fig. 2. Deployment of remotely operated vehicle inside chimney stack.

abrasive disc cutters, concrete scabblers and plasma arc cutters.

The project has demonstrated how standard industrial technology can be adapted to provide cost effective solutions to a difficult situation.

DECOMMISSIONING OF THE WINDSCALE ADVANCED GAS COOLED REACTOR (WAGR)

This prototype reactor was closed down in 1981 since when it has become the lead UK power reactor decommissioning project (3).

A major task within the project involves the size reduction of the reactor pressure vessel. Here demanding physical requirements and extreme environmental conditions have ruled out the use of a standard industrial robot.

The working environment is dark, hostile, inaccessible and confined. Also oxy-propane cutting equipment manoeuvred by the arm generates heat and fume. These factors are compounded by the presence of radiation and contamination.

The machine is required to operate for approximately 1000 hours per year averaged over the six year decommissioning program.

Current machines have not been designed to resist radioactive environments, and the outside dimensions for the payload and reach are not compatible with the WAGR reactor constraint. The low cost of industrial robots would have soon been outweighed by the cost of modifications required to permit decontamination, and to provide the necessary radiation resistant components.

A purpose built system comprising a mast, manipulator platform, module support structure and manipulator has, therefore, been designed (Fig. 3). This assembly is used to position the manipulator at specific work heights within the reactor vault and is mounted on the rotating floor shield with the mast at a fixed radius from the reactor center line.

The mast is constructed as a rigid fabricated box section structure which can be progressively extended and lowered into the reactor vault by addition of appropriate sections as work proceeds. Support for the mast is by a retractable pin

Fig. 3. Mock-up of WAGR dismantling machine.

and lifting/lowering activities are carried out by the pile cap crane.

The manipulator platform which is guided on the mast by wheel assemblies is the mounting feature for the manipulator, tooling, CCTV systems and the termination point for all the service line requirements for the equipment. It is raised/lowered by a twin wire lift winch which permits easy retrieval of the manipulator and associated systems for maintenance and tool changing. During dismantling operations the platform is lowered to the bottom of the mast and fixed in position.

The lifting winch is provided with dual speed for fast retrieval/deployment combined with fine positioning, overspeed sensing, emergency braking and load monitoring to register platform loading conditions.

The manipulator arm (Fig. 4) is mounted on the mast platform and provides the means of deploying various tools within the reactor vault in a dexterous manner. It is a fundamental piece of equipment, which requires the functional capacity to carry out work in a controlled and flexible manner, many meters away from the operator.

Associated systems including operator controls, tooling, lighting and viewing have also been developed. Inactive testing has been undertaken in the vault of the decommissioned

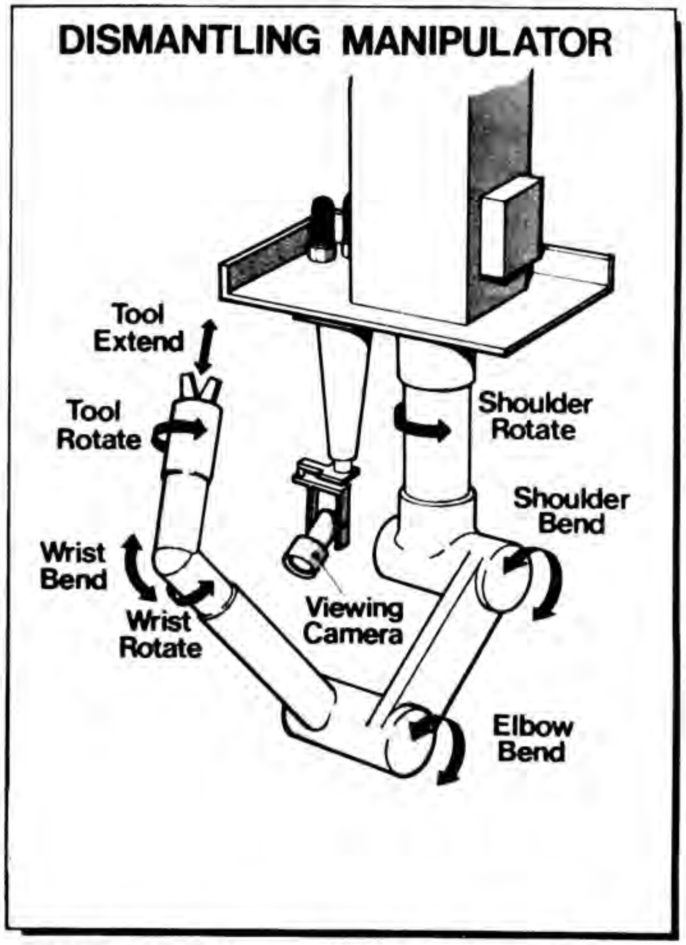

Fig. 4. Manipulator arm for WAGR dismantling.

HERO reactor with final deployment into WAGR scheduled for June 1992.

During an earlier phase of the WAGR project some 253 refuelling channels or stand pipes were removed from the reactor top dome by means of a remotely operated plasma arc system. A suite of 4 shaft mounted cutting units were developed to perform a series of cutting operations from the bore of each 143mm diameter channel. The final cut for each channel was performed a distance of 7 meters below the level of the operator and within a tolerance band of 25mm. To hold and then remove the cut lengths a ball grab was developed to grip the bore of the channel. The grab is an adaptation of a patented pipe interconnection system and consists of a series of 35mm balls which roll up and down grooves of varying depth in the central body. The balls are retained by an outer sleeve, movement of which allows the balls to grip tubes of varying diameter up to 150mm.

This project has already provided vital experience in the specification, design, testing and deployment of specialist systems to undertake tasks for which no commercially available unit is suitable. In addition, the standpipe removal has again demonstrated how standard industrial technology can be adopted to solve novel decommissioning problems.

SIZE REDUCTION OF DIFFUSION PLANT COMPONENTS

As decommissioning of the UK Diffusion Plant is the subject of another paper at this conference (4) only brief mention is made here of the remote dismantling achievements.

Following the initial removal of the plant items further *size reduction* of a significant quantity of various components was necessary to facilitate decontamination and disposal. A typical case in point were the 700 $3m^3$ stage units, each of which weighed some 7Te. Whilst radiation levels were very low, the size, number and complexity of the units meant that manual size reduction techniques would not be acceptable on safety and productivity grounds. A semi-automated 'production line' philosophy was, therefore, adopted.

Two work stations, each comprising a turntable mounted industrial robot fitted with a plasma arc torch, were constructed within a ventilated containment building (Fig. 5). Operations for both stations are remotely controlled from a central location with manual intervention not normally required during cutting. CAD simulation was used to confirm the process ergonomics.

To date some 500 (out of 700) stage units have been successfully segmented. The robots have proven to be very reliable with system down time averaging no more than 10%.

This work has clearly demonstrated the benefits of automation in terms of improved productivity and operator safety when applied to a large scale dismantling project in which a number of similar items require processing.

ISOLATION OF WATER DUCTS IN A FUEL STORAGE POND

Fuel transfers from the Windscale Pile Reactors were conducted using rail mounted bogeys which passed along submerged ducts to the storage pond. The ducts have been disused since the Piles were shut down in 1957 and decommissioning is now ongoing. To permanently isolate the ducts from the main pond it was necessary to cast, in-situ, concrete barriers. Site preparation prior to casting of the concrete included a number of remote dismantling tasks.

Using a hydraulic saw mounted on a vertical mast the rails and channels, along which the bogeys ran, were cut and removed. Throughout this exercise strict control over depth of cut was vital in order to prevent damage to the asphalt membrane in the pond floor. This was achieved by a combination of mechanical design, namely screw driven control of saw head movement and extensive inactive trials using a full-scale mock-up.

In order to provide a good bond between the existing concrete surfaces in the pond and the new barriers it was necessary to roughen the concrete surface. This required removal of the cement sand matrix up to a depth of 5-10mm to expose the aggregate.

As a result of the concerns about vibration caused by techniques such as scabbling, high pressure water jetting (15,000 psi) was selected. Equipment was designed to mount on the suspended mast previously used to support the cutting saw. The jetting head could be raised and lowered, rotated from horizontal to vertical and traversed, all from the one mast.

Serviceability was very good with just over 200 hours operation required to prepare a total area of $17m^3$ despite extremely poor water visibility.

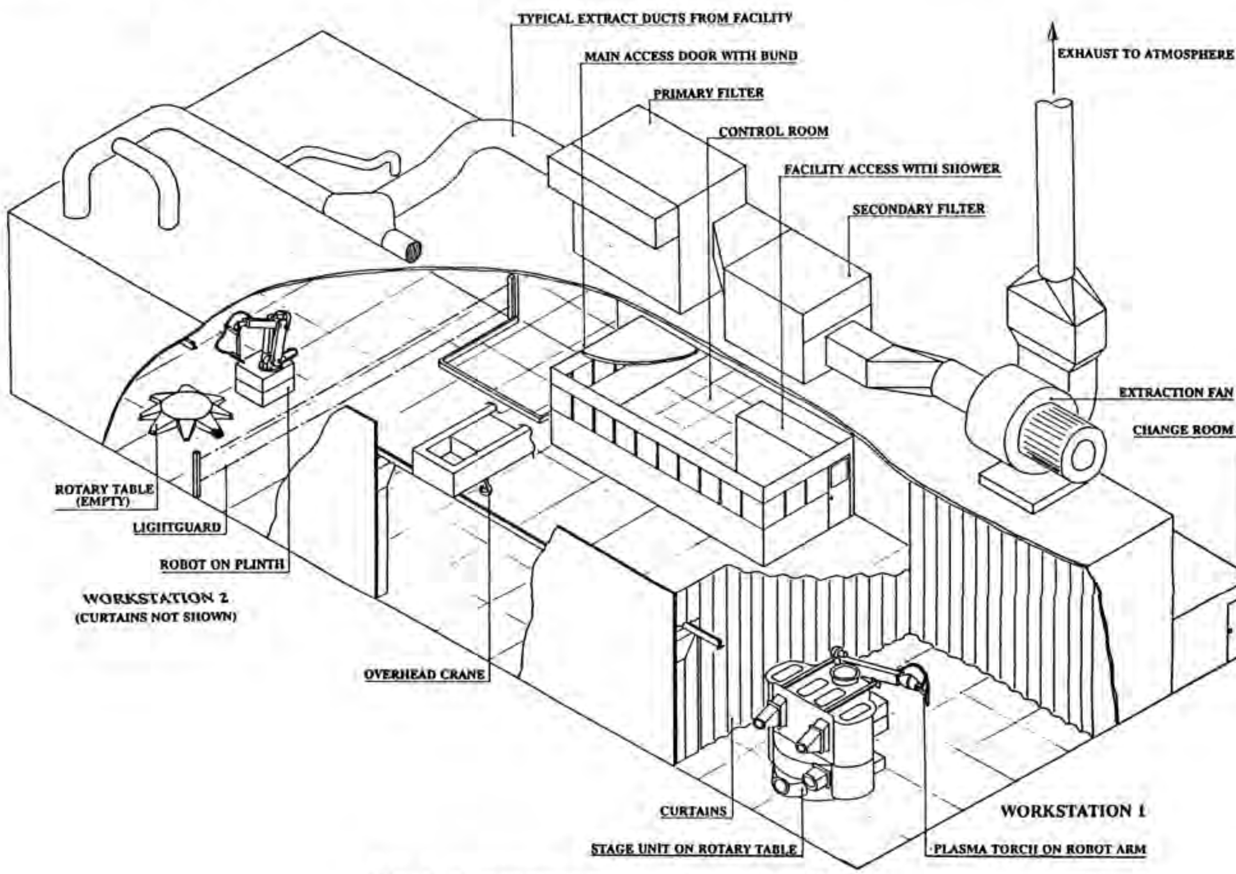

Fig. 5. Capenhurst remote dismantling facility.

SUPPORTING PROGRAMS

Both BNFL and AEA Technology have extensive company-wide remote handling development programs into which respective decommissioning requirements are integrated. The objective of this work is to reduce the cost of decommissioning both in radiological and financial terms. Significant current effort is directed at enhancing the performance and suitability of proven, commercially available, machines. Specific topics include:-

- Telepresence (including collision avoidance and tactile feedback)
- Computer simulation for planning and training
- Nuclear Engineering (including radiation hardening and improved decontaminatability, eg NEATER)
- Manipulator deployment systems
- Viewing (including virtual reality)
- Manipulator/tooling interfaces
- User friendly control modules (to permit operation by non-technical personnel)

Experience from ongoing remote inspection, repair and modification programs (5) (6), in a number of operational nuclear facilities, can also be drawn upon to meet decommissioning needs.

A computer spreadsheet based model has been produced to calculate costs in both financial and radiological terms of deploying various remote technology for any particular task. By enabling cost evaluation of equipment and strategy options, the model provides assurance that the most cost effective methods of decommissioning have been adopted.

A two-pronged policy for utilization of remote technology has emerged, again with the objective of minimizing costs. Firstly, wherever practical, proven, currently available systems are used, modified as required, in order to limit development requirements and also permit some standardization.

Secondly, combining the deployment of remote technology with the use of operators to optimize the effectiveness of their dose budgets. A strategy of Contact Deployment Remote Operation (CODRO) is being developed. This seeks to retain, where practical, a human input for the system deployment, adjustment and maintenance tasks thus permitting some "de-skilling" of the remote systems utilized and so avoiding the cost burden from, for example, autonomous or otherwise sophisticated robotics.

CONCLUSIONS

A variety of remote dismantling tasks have already been undertaken within the UK. Expertise gained during years of remote operation and maintenance of nuclear facilities is being supplemented by decommissioning experience, which, together with output from supporting development programs, is now being targeted at future decommissioning requirements to ensure costs are kept to a minimum.

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