NEATER - A TELEROBOT FOR THE NUCLEAR INDUSTRY

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ABSTRACT

A new telerobotic manipulator has been produced for use in nuclear and other industries where teleoperation or robotics is required, and environmental conditions exclude the use of standard manipulators. NEATER, the Nuclear Engineered Advanced Telerobot, is based on the adaption of a commercially available industrial robot to the particular needs of the nuclear industry. AEA Technology has worked directly with a robot manufacturer to ensure that NEATER benefits from the long term reliability that is common in industrial robots. Radiation tolerant sub-systems have been included in NEATER's design and three different versions are available to meet a wide range of application areas. A telerobotic controller is connected to the standard robot controller. The prototype NEATER has successfully operated for over a year, with more than 1200 operating hours. Trials using telerobotically deployed tools for glovebox decommissioning have proved the concept, and robotic operations such as swabbing have been completed. The paper describes the background to the design, identifies the main features of NEATER and gives details of application areas.

INTRODUCTION

The Remote Handling and Robotics Department [RHRD] of AEA Technology has just completed the development of NEATER - the Nuclear Engineered Advanced Telerobot. [Figure 1] NEATER represents a new approach to remote handling, and is based on the adaption of a commercially available industrial robot design to the particular requirements of the nuclear industry. The result is a manipulator which is significantly cheaper than a purpose-built design, and which benefits from the experience gained of millions of operational hours of thousands of similar models working in non-nuclear applications.

The NEATER concept has evolved over the last five years under the Department of Energy funded Active Handling Programme. The potential for using modified industrial robots came from a study completed in 1985 [1]. A telerobotic controller that could be interfaced easily with a standard

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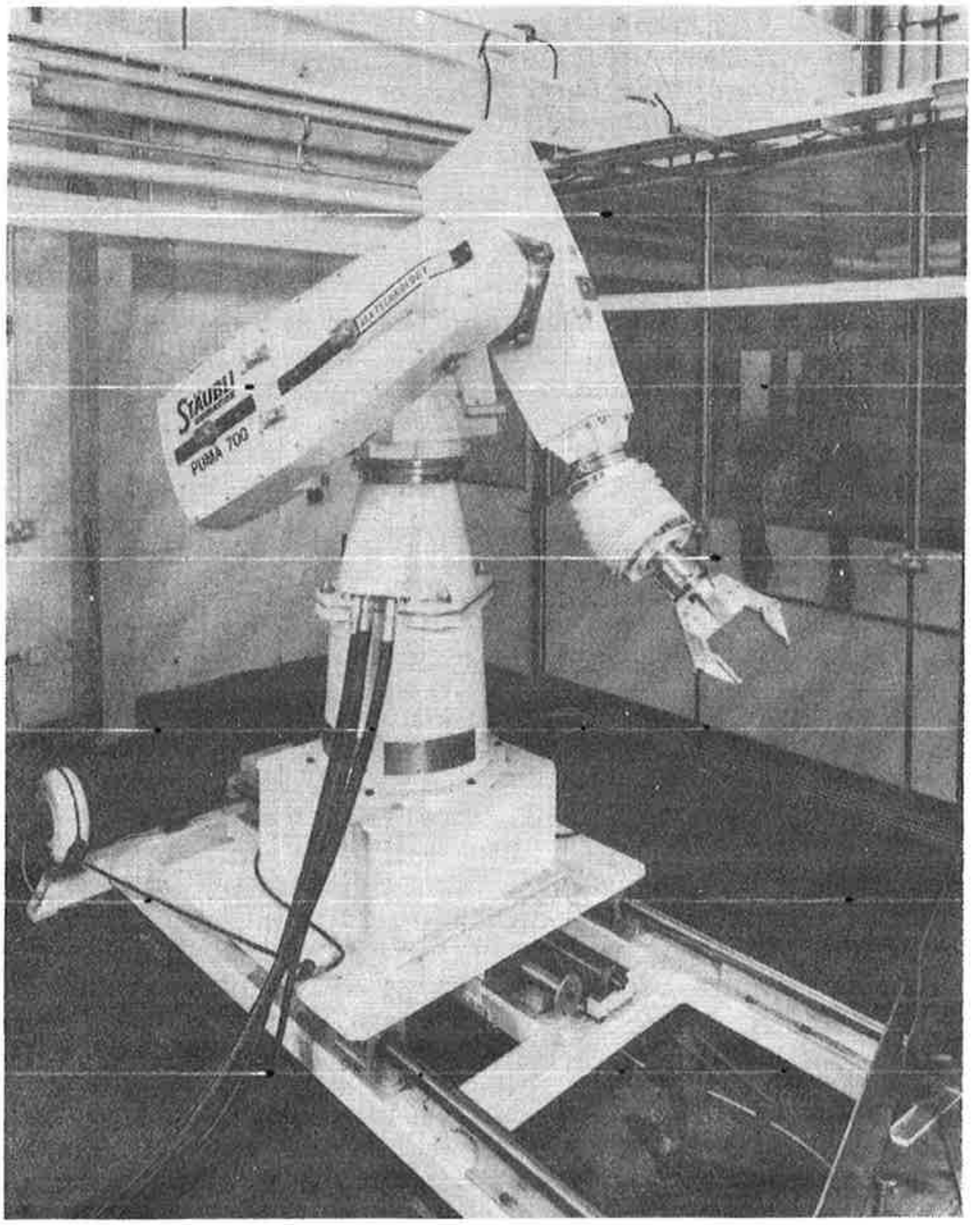

Figure 1 NEATER in the Robotics Demonstration Facility[a)]

a) The Robotics Demonstration Facility is described in References 2 and 3. Several different robotic or telerobotic systems can be used to carry out inactive feasibility trials of tasks such as surface monitoring, decontamination, decommissioning, waste handling and packaging.

robotic controller has also been built.[2,3] Input devices such as joy-sticks or force balls are available to drive the robot [acting as a slave manipulator] in a tool or world co-ordinate system. The robot acts as a man-in-the-loop controlled manipulator, or telerobot. Programmed operation is still available, and off-line programming techniques can be used, in conjunction with a proprietary kinematic modelling system, GRASP. New input devices will allow force reflection.[4]

Teleoperation needs good viewing, and also in RHRD, a parallel programme of work in 3-D TV for nuclear applications has produced robust hardware. [5] The design of 3-D TV is based on guidelines that have been tested in human factors evaluations of tasks using the 3-D TV and other TV combinations, often with a manipulative task. [6]

Stäubli-Unimation and AEA Technology combined experience to develop NEATER. Stäubli-Unimation carried out the mechanical design and manufacture of a prototype machine based on their 20kg capacity PUMA-762 Clean Room Robot. AEA Technology assessed the original design for radiation tolerance, and specified the new materials and subsystems which were incorporated in the design process. The machine has been at the Harwell Laboratory for over one year and has accumulated over 1200 operational hours experience without failure. Variants of the design have been built and tested for a high activity application [10^6 Gy] and inactive trials have continued using NEATER to investigate telerobotic decommissioning of gloveboxes.

APPLICATION AREAS

The majority of remote handling operations in nuclear plant are carried out by master slave manipulators, power manipulators, cranes and special purpose machines. In general, except for low radiation environments robots are not used because radiation soon damages sensors, cabling and any electronics. Many tasks would now be carried out using industrial robots if the radiation hazard was removed, and the corollary is that a radiation tolerant robot would be immediately useful to the industry. Uncertainty in tasks and their precise description and the complexity of non-repetitive operations is another factor that precludes strict robotic operation of manipulators, and relies on the skills of human operators. Telerobotic control is possible and our approach has been to use as much of the supplied robotic controller as possible, but condition operator commands for tool deployment before they are sent to the standard robot controller. This provides a more robust system design because the development effort applied to the robot controller is incorporated in the overall product, and not lost to the customer. Pure robotic operations and hybrid telerobotic/robotic control produces a easy-to-use interface for the operator.

The mainstream applications for NEATER are thought to lie in the areas of decommissioning and waste management. However, because of the flexibility of application of the machine, it is envisaged that it will also be applied to:

- fuel fabrication [including Mox fuels]
- filter changing
- waste drum handling
- inspection, monitoring and assay
- swabbing at any contamination level
- posting and bagging operations
- decontamination
- routine manipulation and tool deployment
- decommissioning, gloveboxes to reactors

FUNCTIONAL REQUIREMENTS

The development of NEATER was envisaged as a two stage process. [3] Initially the robot design would be reworked with Stäubli Unimation to produce a machine that was easy to service, had high reliability with the attendant long service intervals, and use as many industrially sourced components as possible. It would be a low-cost machine, compared to a special purpose one-off design. This first stage would include a target specification that would be useful for the majority of contaminated environments. The high-radiation-tolerance applications would be tackled in the second stage of the development programme. Wherever possible, the first stage version would be designed to accommodate high radiation tolerant components in the second stage up-grade.

The design was based on the PUMA 762 clean room robot, and the good surface finish of this machine meant that it would be potentially easy to decontaminate. The production of a prototype machine would allow many radiation tolerant components to be included and tested for their compatibility of operation. Longer lead time developments would be added on to the prototype machine in the second stage to bring its anticipated radiation tolerance to beyond 10^4 Gy. Radiation testing of components and subsystems was carried out at Harwell and the results were fed back into the design and manufacturing process. It was found that a radiation tolerance of 10^6 Gy was possible through careful selection of components, and so the two stage process has been completed through one prototype.

The robot and telerobotic controllers would be outside the radiological controlled area, as shown in Figure 2. A maintenance review of the machine was carried out to establish a procedure for dealing with failures of a contaminated machine. The review identified the benefit of having a removeable forearm [equivalent to a detachable wrist in a conventional master-slave-manipulator]. A weight reduction of 100kg to ease the burden on in-cell handling equipment, was also shown to be possible, by simply making the base in two pieces which could be remotely mated in cell, if a plinth was not available. [Figure 3] Split-ring seals were added at major joints to increase the sealing efficiency and allow the use of a free-running pressurised decontamination wash down, prior to maintenance.

Basic performance parameters of the machine are unchanged. It has the same load capacity as the 762 PUMA and the same reach. However it was realised that variants were required to cover the vast range of potential nuclear environments. The machine can be configured to suit three main combinations of activity and contamination.

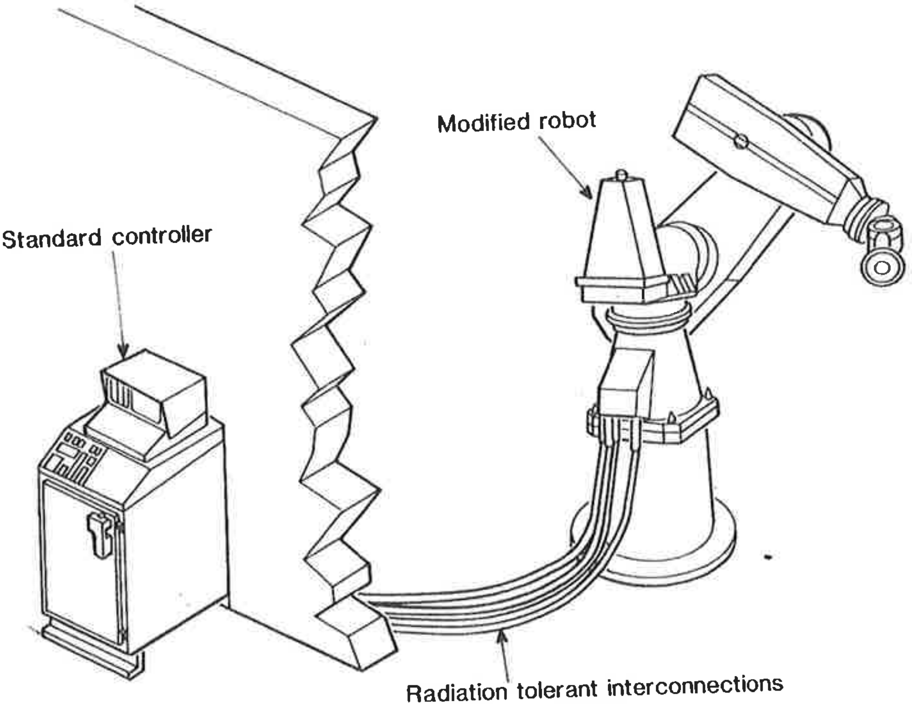

Figure 2 Separation of the Modified Robot System

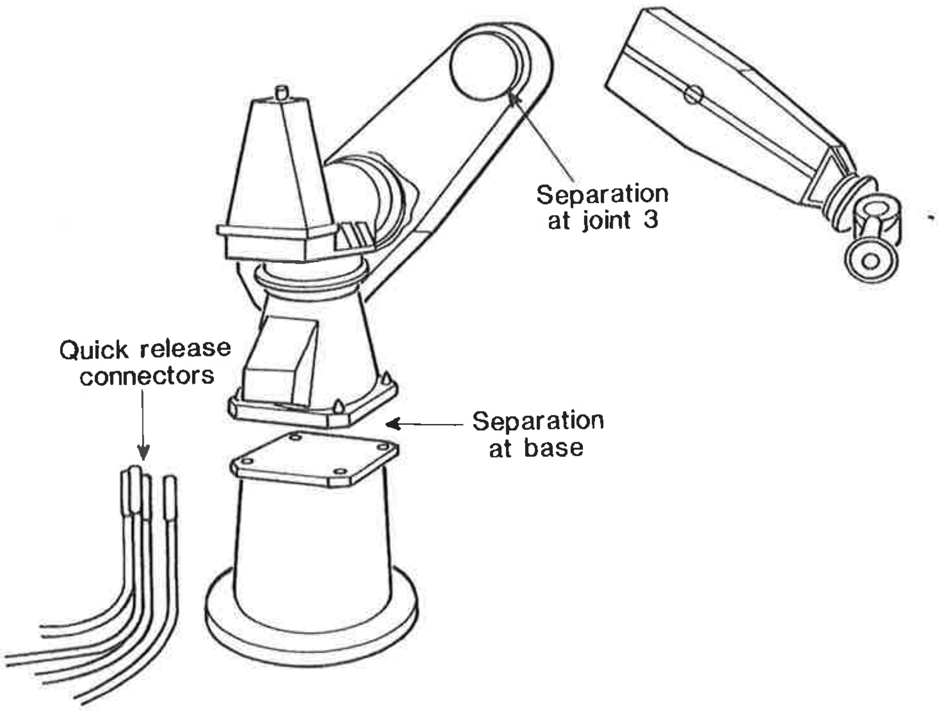

Figure 3 Modularity of the Modified Robot System

1) A basic radiation tolerant version of the clean room PUMA without modularity or improved sealing, for high radiation, low contamination applications [for example in waste drum handling or swabbing] - designated PUMA 762N [N for nuclear]

2) A modular version, with improved seals but not highly radiation tolerant, for applications where decontamination is necessary but radiation levels are low [for example in replacement of or assistance to pressurised-suit operations] - designated PUMA 762M [M for modular].

3) A radiation tolerant decontaminable version, which can be used in the most extreme environments with modularity to help maintenance - designated PUMA 762NM [nuclear and modular].

The prototype NEATER at Harwell began as Version 2, with modularity, improved seals and some radiation tolerant components. It is now being brought to the target tolerance of 10^6 Gy, [Version 3] by the addition of specially redesigned radiation tolerant encoders.

SPECIFICATION OF PRODUCTION NEATERS

As mentioned, the 20kg capacity of the 762 PUMA is available in the NEATER design at a top speed of $0.4ms^{-1}$. At $1ms^{-1}$ this is reduced to 12kg. An increased reach version [the 761 PUMA], is also available in all three nuclear environment versions.

The final specification for the most advanced model, the 762NM is summarised as:

Load Capacity	20kg at a reach of 1.4m
Maximum velocity	$0.4ms^{-1}$[20kg] or $1.0ms^{-1}$[12kg]
Repeatability[robotic operation]	±0.2mm
Operational temperature	10-50°C
Radiation Tolerance	10^6Gy [100M rad] integrated βγ dose anticipated before major overhaul-based on sub system & component test irradiations.
Contamination protection	double seals on all axes and covers including grease packed labyrinth seals on axes 1-4 and wrist gaiter on axes 5 and 6.
Modularity	splittable at elbow [joint 3] & at base.
Maintainability	all bolts, fixings & electrical interconnects designed for remote assembly/disassembly
Weight	whole robot 568kg forearm only 66kg base stand 112kg

EXPERIENCE WITH NEATER

Maintenance of NEATER

All components on NEATER are designed to be easily removed if maintenance operations are required. All the bolts and fixings may need to be manipulated by pressurized suit operators, and they are designed to accept tools that can also be deployed by another manipulator. Electrical and service connectors are the quick-release type. The maintenance sequence is made up of the following steps

- detect failure
- diagnose fault and identify remedial action
- separate robot arm at joint 3 remotely, if appropriate
- transfer forearm and wrist <u>or</u> upper arm, shoulder, and trunk to decontamination area
- decontaminate, remove gaiters, and monitor exterior of machine
- transfer to low radiation and contamination maintenance area
- remove arm covers and monitor interior
- dismantle, repair, replace and readjust assemblies to correct fault; hands-on or semi-remote maintenance in a glovebox.
- undertake preventative maintenance tasks; recalibrate potentiometers
- replace arm covers and seal, external seals and gaiters
- carry out functional tests
- transfer to working cell
- reassemble robot arm at joint 3 remotely
- operate machine.

Glovebox Decommissioning

Inactive trials at Stäubli Unimation's Telford works and at Harwell Laboratory have been carried out over the last year. More than 1200 operational hours have been experienced without failures of the special components in the manipulator or in the standard controller. The telerobotic controller [originally consisting of three communicating PCs] has been rebuilt using a single 486 PC. Work on glovebox decommissioning trials has continued, using a range of cutting tools that are currently used in manual glovebox decommissioning [Figure 4].

Many tools such as nibblers, bandsaws, hacksaws, jigsaws and drills have been tried, to investigate the best performance in cutting up to 6mm steel plate. [Figures 5,6] Most of the tools require compliant mountings

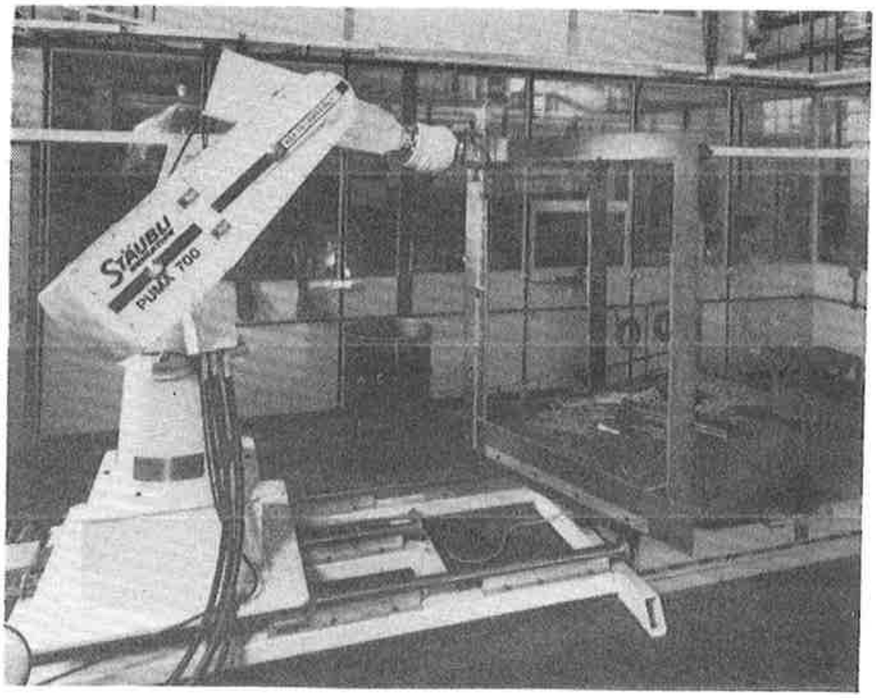

Figure 4 NEATER Completing Glovebox Decommissioning Trials

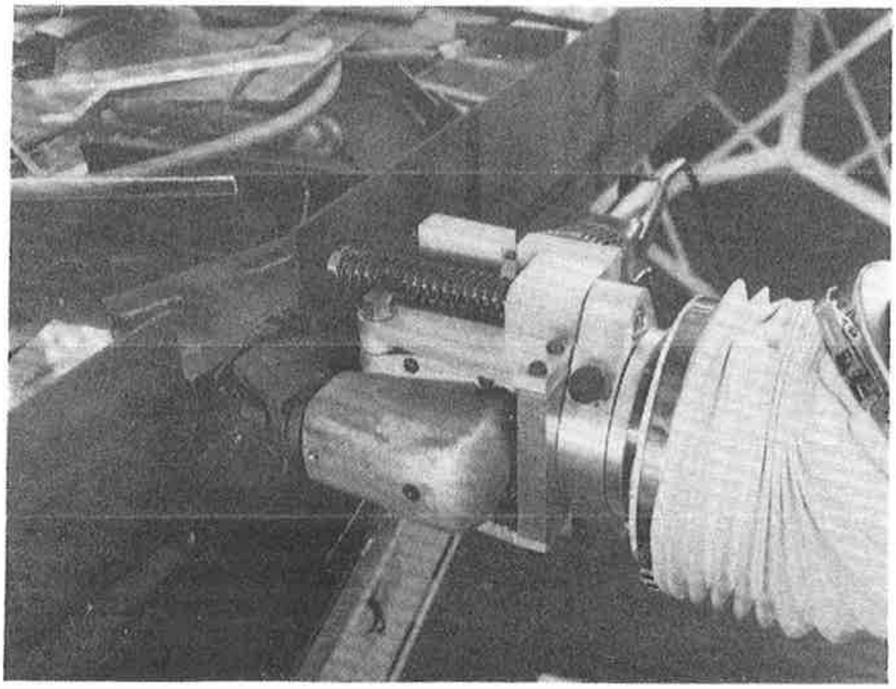

Figure 5 Electric Nibbler

to isolate the telerobot from parasitic vibrations, and to prevent tool jams. The tools have a common interface with the robot which allows easy exchange either through a gloved change or through a tool change station.

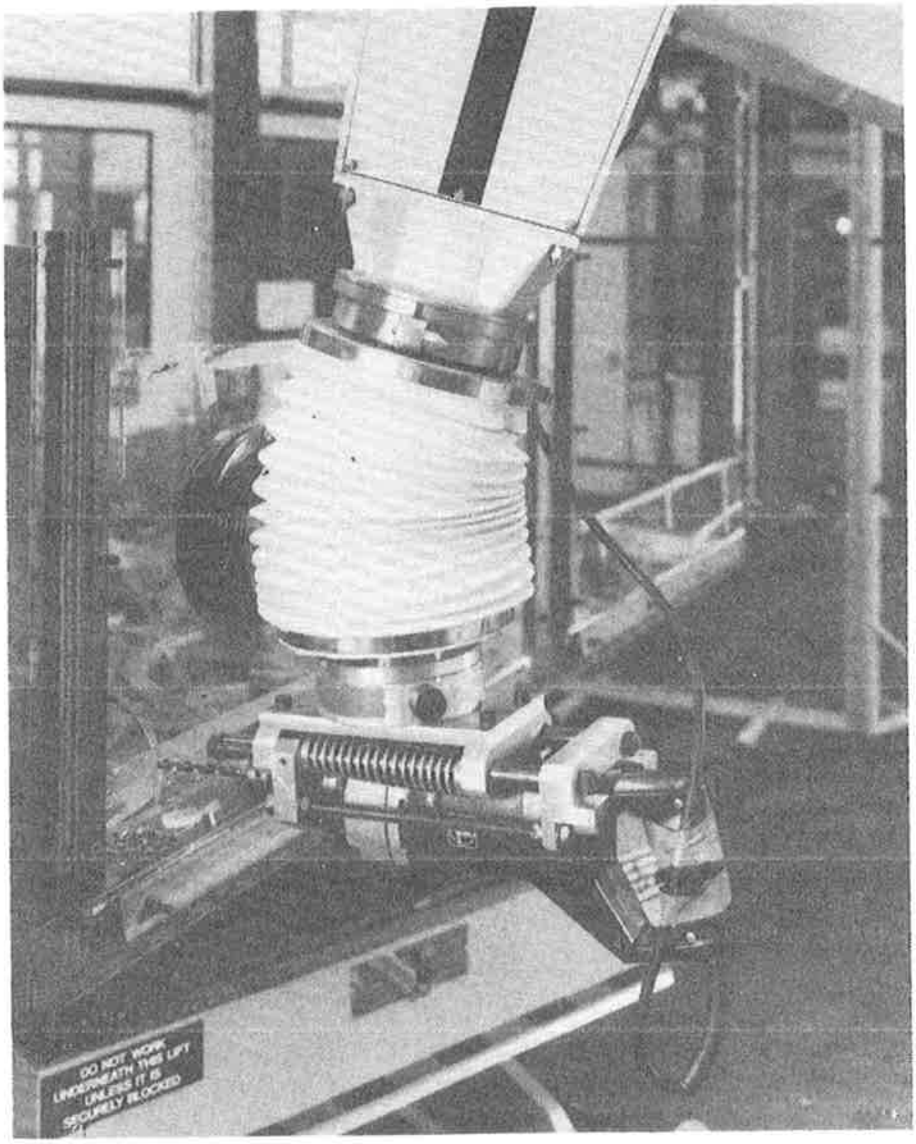

Figure 6 Electric Drill

Contamination Survey

Two NEATER robots have been supplied to swab the outsides of high level vitrified waste containers. The specification called for 50°C operation, with a contact dose of up to 5.10^3 Gy per hour. 750 cycles per year are demanded from the manipulators, and over a two year period an integrated dose of 10^6 Gy could be expected. Because there is unlikely to be a contamination hazard to the machine, PUMA 761N versions [radiation tolerant, no modularity or extra sealing] were supplied.

Inactive demonstrations of the system were performed following a simulation using GRASP. The robots had to perform complete surface swabbing, providing a fixed contact pressure, and then exchange the swab at a transfer station. The first robot was produced and delivered after customer acceptance trials, and was followed by the second machine. Radiation tolerant encoders have been fitted and it is anticipated that the first manipulator will be installed in an active area in late 1990.

CONCLUSIONS

The development programme has lasted two years and has resulted in a commercially available telerobot which can easily be used in a variety of nuclear applications. The short development timescale was possible because of the co-operation of an established robot manufacturer, and the ability to test, specify and re-engineer radiation tolerant components at Harwell. The use of the prototype and subsequent machines in active trials is anticipated within AEA Technology's Decommissioning and Radwaste programme, following the conclusion of inactive proving trials, and commercial versions have been supplied to a high radiation tolerance application.

ACKNOWLEDGEMENT

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