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A NEATER advance in active handling technology

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The NEATER robot, commercially launched in December 1989 by AEA Technology and Staubli Unimation, arose from the recognition that technological advances in the non-nuclear robotics industry were beginning to outstrip those in the nuclear active handling sector.

Within the nuclear world, handling of radioactive materials is largely undertaken using relatively cheap but low-tech master-slave manipulators (MSM). They have a limited operational reach of a few feet from the biological shield. In addition, their initial costs can be greatly inflated over their lifetime by decontamination, maintenance and repair costs. Power manipulators, also extensively used in the nuclear industry, tend to have limited functions and may not be designed with maintenance in mind. New developments such as high-tech custom-built servomanipulators are very expensive and have failed to make their expected widespread impact on facility designs.

By contrast, within the non-nuclear industrial world, robot manipulators with high reliability and considerable dexterity have become available, offering high-speed repetitive manipulation of loads up to 100kg in a suitably structured environment, at comparatively low cost.

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DESIGN WORK

AEA Technology set itself the task of adapting an industrial robot to meet the specific needs of the nuclear industry. These needs include radiation tolerance, easy decontaminability and maintainability, and the ability to operate under close human control in an unstructured environment. The aim was to meet these specific requirements without sacrificing the outstanding advantages of the industrial robot — its cheapness, speed, load capacity and reliability.

It was recognized at the outset that it would be necessary to work in close collaboration with an industrial robot manufacturer, so as to retain as much as possible of the proven mechanical design and good manufacturing standards. However a considerable redesign of the internal electrical systems would be required to achieve the necessary radiation tolerance.

As for the electronic control systems, it was decided that the best strategy would be to select an industrial robot controller which was able to accept external input commands to individual robot joints. A "telerobotic controller" would then be added as a front-end to accept human operator commands and transform them into the electrical input format required by the industrial robot controller. In this way, the considerable body of non-nuclear experience would remain available to be tapped into wherever the robot was required to operate in autonomous (or teach and repeat) mode, although it would still be possible to put man in the loop and work in teleoperator mode when needed.

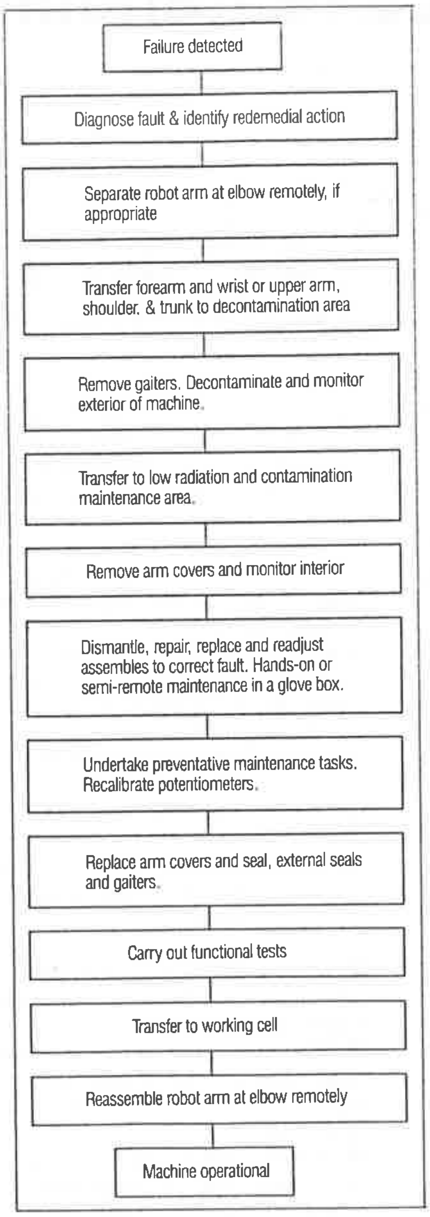
Choosing an industrial robot. The choice of Staubli-Unimation as the robot manufacturer, and the use of its PUMA 762 robot and VAL controller, was made for a number of reasons:

- Staubli Unimation was willing to collaborate with AEA Technology in the redesign of the robot.
- The PUMA was a well-established design with proven reliability over millions of machine-hours of operating experience.
- The Clean-Room version of the PUMA 762 already featured improved sealing with a good surface finish.
- The PUMA 762 had a load capacity of 20kg at a reach of 1.4m with a maximum operating speed of 1m/s: these figures were more than adequate for a wide range of potential nuclear applications.
- The internal design of the PUMA was relatively modular, with enclosed actuators, thus facilitating replacement of non-radiation-tolerant components by radiation-tolerant equivalents without affecting performance or reliability.
- The VAL controller supported a user-friendly robot control language (VALII) and had an input port for direct joint control instructions.

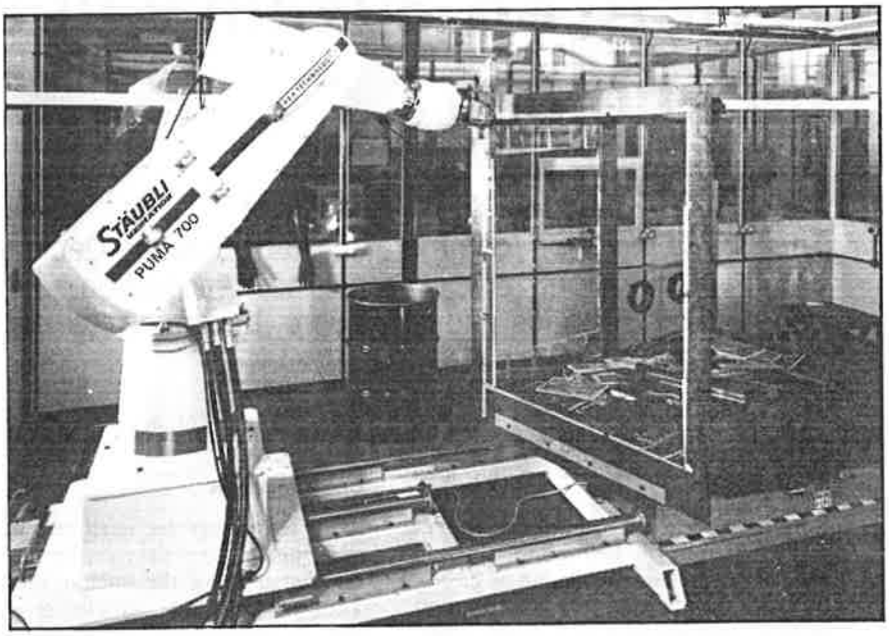
Nuclear requirements. In developing the specification for the nuclear engineered version of the PUMA 762, AEA Technology performed a design and maintenance

Specifications of PUMA 762NM robot

Load capacity	20kg at maximum reach (1.4m)
Maximum velocity	0.4m/s at 20kg; 1.0m/s at 12kg
Repeatability	±0.2mm
Operational temperature	10-50°C
Radiation tolerance	10^6Gy (100Mrad) integrated beta/gamma dose before major overhaul
Contamination protection	Double sealing of all axes and covers, including grease-filled labyrinth seals on axes 1-4 and a wrist gaiter on axes 5 and 6
Modularity	Easy splittability at elbow (joint 3) and at base to permit separate removal of forearm and base stand, and reduce the slung weight. All bolts, fixings and electrical interconnects designed to permit remote assembly and disassembly by MSM
Weight	Whole robot 568kg Forearm 66kg Base stand 112kg



▲ Sequence of maintenance operations for NEATER.



▲ The first NEATER robot is being used at Harwell to validate design specifications and to continue glovebox decommissioning trials.

review, taking account of the requirements of a number of rather different nuclear operations:

● In plutonium-contaminated environments, the primary requirement is ease of decontamination and maintenance using remote handling techniques (eg by MSM). All crevices where contamination can accumulate must be eliminated. All joints must be water tight, both to prevent ingress of contamination, and so that decontamination can be undertaken.

● In intense beta/gamma environments, the primary requirement is for radiation tolerance (though decontaminability and remote maintenance may also be required). After assessing a range of possible applications, it was decided to aim for tolerance to a cumulative dose of 10^6Gy without need for significant maintenance.

● In hot cells, it might be difficult to post a whole robot in or out of the cell. Thus, in the event of component failure or damage, it would be highly desirable to have the ability to recover parts of the robot and post them out separately. In particular, since the part most likely to be damaged is the wrist/forearm, it might be advantageous to be able to make a quick replacement of this unit as a whole. It was therefore decided that the robot should be redesigned to make it modular, with parts being readily removeable using remote handling techniques.

It was recognized that many nuclear applications would not require all three features of the specification — easy decontaminability, high radiation tolerance and modularity. It was therefore decided to develop an initial version —the PUMA 762M — which would be modular and decontaminable, but not in all respects radiation tolerant. This was then enhanced to form the PUMA 762NM, which is fully radiation tolerant, by backfitting improved encoders with the necessary radiation performance.

Progress. This has now been followed by the development of a third version —the PUMA 761N — which is fully radiation tolerant, but which does not have the same modularity and easy decontamination features, and is consequently significantly cheaper.

To achieve the final specification of the most advanced model — the 762NM — a substantial R&D programme was undertaken, of which the mechanical engineering was performed by Staubli Unimation and the radiation tolerant design, development and testing work by AEA Technology. Every component of the robot which was judged susceptible to radiation was tested, and where necessary redesigned and retested. Particular attention was paid to the encoders, which are of critical importance in joint control.

WHAT ARE THE USES?

All three versions of NEATER are now commercially available, and considerable interest is being expressed worldwide in this new development. Among the applications for which it is being considered are:

- Fuel fabrication (including MOX).
- Filter changing.
- Waste drum handling.
- Inspection, monitoring and assay.
- Swabbing at any contamination level.
- Posting and transfer operations.
- Decontamination.
- Decommissioning of gloveboxes, process plant and reactors.
- Routine manipulation and tool deployment within hot cells.

For some of these applications, NEATER will operate purely in robotic mode, ie it will be programmed to perform a set sequence of operations (eg those involved in flask swabbing). For some applications it will be used only in teleoperator mode, with the operator controlling every movement using a ▷

master arm or other input device to control its six degrees of freedom. However, for many applications, a hybrid, semi-autonomous mode of operation is likely to be the best option, and work is in progress at Harwell to extend the range of semi-autonomous functions which the equipment can undertake. Examples which have already been demonstrated include tracking a monitor head over a metallic surface in a regular raster, maintaining a fixed stand-off distance, and moving a cutting tool along a prescribed line, with only the cutting rate under operator control. More sophisticated examples, such as automatic nut-running, drilling a matrix of holes, or making and breaking electrical or pneumatic connections, should be well within its capability.

The first NEATER is being used at Harwell to validate the design specification and to continue glovebox decommissioning trials which had previously begun using a standard 761 PUMA.

WEIGHING UP THE OPTIONS

A nuclear operator, faced with an active handling problem, is now in a position to choose between three options — carrying out a hands-on procedure (if radiation levels permit), developing a special one-off machine or manipulator for the job, or using a telerobot such as NEATER. The first option, even if acceptable from a health physics point of view, may be slow and expensive and expose the staff involved to risks of contamination or irradiation. The second option may involve long development delays, and prove very expensive or unreliable. Increasingly, the third option looks like being the most attractive.

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