CONF-921102--41

ANL/FE/CP--76226

DE93 004231

ELRA - THE EXPOSURE LIMITING ROBOTIC APPARATUS

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September 1992

Summary submitted to the
International Symposium on Fuels for Liquid Metal Reactors
as part of the ANS/ENS International Conference

Chicago, Illinois
November 15-20, 1992

Work supported by the U.S. Department of Energy, Office of Reactor Systems, Development and Technology, under contract W-31-109-Eng-38

DISCLAIMER

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ABSTRACT

A problem situation involving the handling of radioactive material at Argonne National Laboratory - West (ANL-W) was solved through the use of remote handling techniques, providing significant exposure reduction to personnel. Robotic devices can be useful, but the cost of a robot is often prohibitive for many jobs. A low cost, disposable robot was built which successfully removed a highly radioactive and potentially explosive system from a hot cell at ANL-W.

INTRODUCTION

A group of hot cells at ANL-W has been used for examining spent fuel as part of an ongoing breeder reactor research program. The hot cells had become highly contaminated over the years and had accumulated waste requiring removal to support an upcoming facility refurbishment. To further complicate the situation, perchloric acid had been fumed into an acid scrubbing system contained in one of the cells. Adequate levels of perchlorates had accumulated in this system to create a real potential for explosion during removal of the system.

A team of engineers was assembled to devise a cleanup method with two major concerns to be considered: (1) personnel safety from the explosive hazard presented by the perchlorates and (2) minimizing personnel radiation exposure. Because of these conditions, the job presented an excellent opportunity to employ a robotic apparatus. The decision was made to manufacture a robot as cheaply as possible, and if necessary, dispose of it as waste upon job completion.

DESIGN CRITERIA

The robot needed to be versatile since the magnitude of its tasks could not be defined until the hot cell containing the acid scrubbing system was opened and the disassembly operation had commenced.

Several design criteria for the robot were established. First, the size of the hot cell access door dictated a maximum width of 0.7 m (28 inches). The heaviest anticipated load the robot would be required to handle was the system's HEPA filter that could weigh up to 50 kg (110 pounds). The robot would need to be capable of setting items on a working tray that was about 1 meter (40 inches) above the floor. The most important criterion, however, was the ability of the robot to handle various power tools to be used in the disassembly of the numerous components of the acid scrubbing system. Low maintenance was particularly important since the robot would likely become highly contaminated. Finally, consideration had to be given to the ease of disassembly of the robot in the event that disposal became necessary.

DESIGN DESCRIPTION

Robot

The design of the robot evolved into a tricycle type assembly as depicted in Figure 1. Steering of the robot was accomplished by two sprocketed wheels independently driven through chains by reversible gear motors, in conjunction with the swiveling casters on the rear of the robot. The motors could be operated independently or at the same time, and allowed a maximum ground speed of about 2 m/min (7 ft/min).

A boom that pivoted (in a vertical plane) from the back of the frame was supported by two linear actuators. A joint on the boom, in-line with the front wheels, allowing the boom to swivel from side-to-side, was driven by an additional actuator. The entire boom forward of the pivot point powered by a gear motor rotated 360° in a bearing tube. The end of the boom was designed to accept the various attachments shown in Figure 2. All attachments were powered by the same linear actuator. Figure 1 is shown with the large hand attached to the robot. To counter balance heavy loads such as the system HEPA filter, the hook at the rear of the robot was designed to be raised and lowered with the boom to allow a counter weight to be picked up remotely. A light was mounted at the base of the robot as shown in Figure 3.

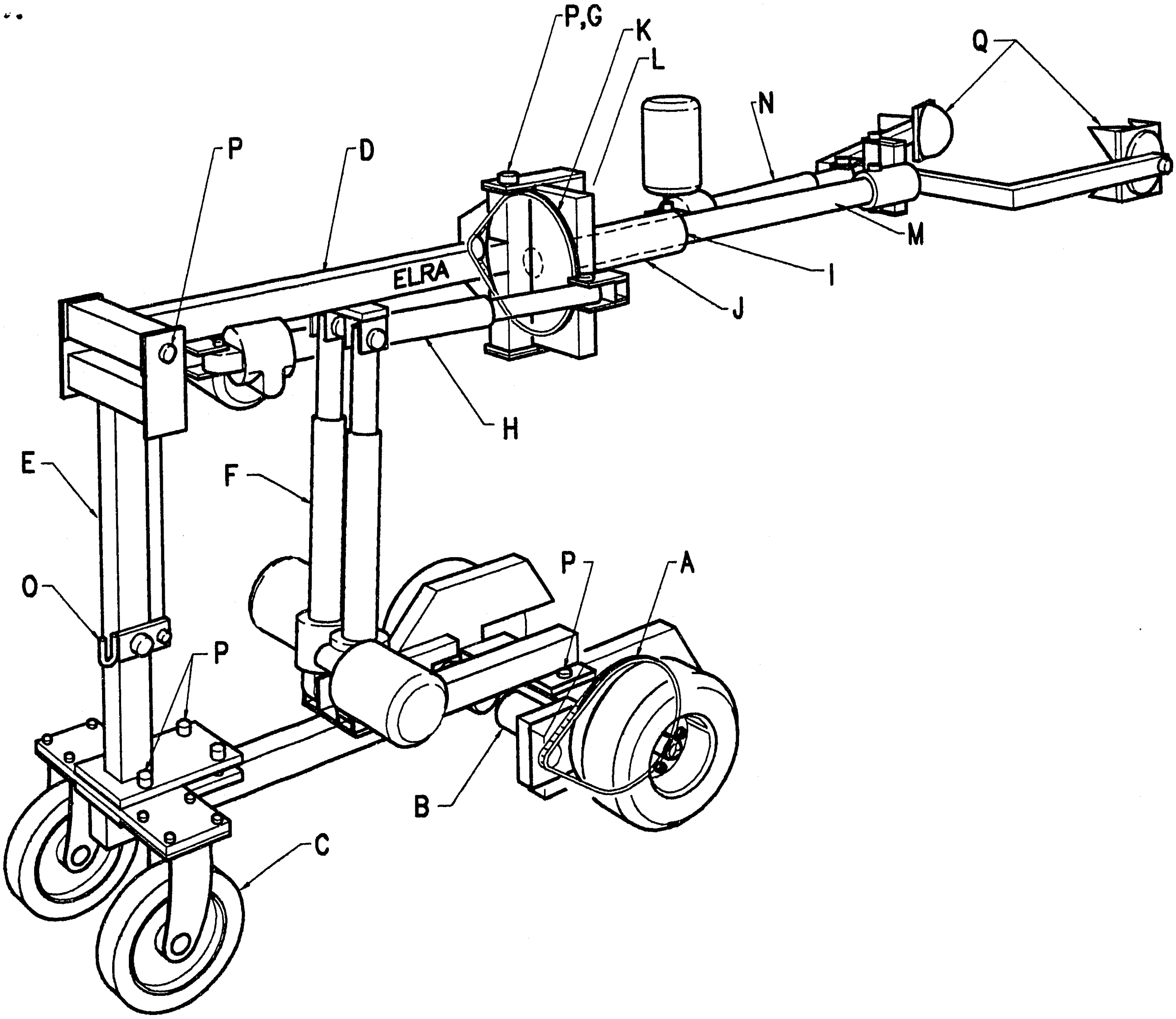
ROBOT ATTACHMENTS

Different hands and extension arms were designed for the various anticipated operations the robot would be called upon to perform. Four attachments were made to fit on the robot's boom, as shown in Figure 2. All could be changed-out remotely using the in-cell master-slave manipulators.

Hands

Two hands were designed for the robot. A large hand that could grasp objects up to 45 cm (18 inches) in width was fabricated for use in handling large items. A rubber hemisphere worked opposite a free revolving gripper allowing large objects to remain relatively level as they were lifted and manipulated. The hand was designed to grab the larger components as they were disassembled and in particular, the system filter housing which was quite bulky.

A smaller hand, very similar in design to the large hand, was also fabricated. The gripper that



A SPROCKETED WHEEL
B REVERSING GEAR MOTOR
C CASTER
D BOOM
E FRAME
F LINEAR ACTUATOR
G BOOM JOINT
H ACTUATOR
I ROTATION POINT
J BEARING TUBE
K SPROCKET
L GEAR MOTOR
M BOOM TUBE
N LINEAR ACTUATOR
O WEIGHT HOOK
P DISASSEMBLY JOINTS
Q HANDS ARRANGEMENT

FIG. 1 ROBOTIC APPARATUS

SEPTEMBER 1992
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opposed the rubber hemisphere had a device that allowed it to be locked at any angle. This adjustment made it possible for the hand to hold power tools such as drills and reciprocating saws in working position. This hand was utilized most often during system removal.

Crane

A crane arm was used to transport waste and lower it into shielded casks. The arm employed a slider operated by the same accuator used for the hands and a block and tackle which allowed approximately 1.5 m (5 feet) of cable travel when lifting and lowering objects. A solenoid actuated cleavis attached to the cable allowed remote release of the waste material into the disposal casks. Further details pertaining to the waste removal process are contained in Reference 1.

Boom Extension

The hot cell is about 170 cm (66 inches) from front to rear. In order to assure the robot could reach the entire distance, an extension to the boom was designed. This extension increased the reach of the robot by about 1 m (3 ft) permitting the robot to reach the full depth of the cell without requiring the wheels to enter the cell. The robot was then able to aid the master-slave manipulators in lifting operations. Although the manipulators could access areas of the cell above the working tray, they were limited in the distance they could reach below the tray as well as having a limited lifting capacity of 9 kg (20 pounds) maximum.

The boom extension was designed to be compatible with all of the other attachments. During operation, however, the extension was used with the small hand only.

REMOTE CONTROL

The robot was controlled remotely through a multi-wire cable that was approximately 30 m (100 ft) long. Each motor was controlled with a double throw switch allowing it to be reversed. All motors on the robot could be operated independently or at the same time. The front wheels were independently driven by high torque gearhead motors. The control panel layout was ergonomic, with drive motor control switches in the same relative position as the member of the robot they controlled. This layout minimized the training time required for operators to become proficient. An electrical outlet located on the robot's arm was powered through a silicon controlled rectifier which allowed variable speed control of the power tools.

VISUAL ACCESS

A horizontal working tray existed in the hot cell between the cell window and the acid scrubbing system. Prior to removal of the tray, the majority of the work done by the robot was in locations which had limited or no view through the cell window. (See Reference 2 for details of acid system removal.) Several access holes which were about 7.5 cm (3 inches) in diameter penetrated the hot cell front wall below the working tray level. A viewing apparatus was designed for holding and aiming a small video camera, via pan and tilt. The camera assembly was inserted through a penetration adjacent to the working area. The camera assembly was designed such that it could be manually positioned at various depths within the cell while the camera was aimed at objects for viewing. This allowed the operator to see the working area during operation of the robot.

An additional video camera was initially mounted on the top of the robot. During the mockup stage, it became evident that vibrations created during drilling and sawing operations interfered with the picture. The decision was made to move this camera to the rear of the contamination containment barrier facing the rear of the hot cell. This provided another visual reference used in guiding the robot during system removal.

During the disposal phase of the project, a video camera was mounted above the waste cask, allowing the operator to view the waste as it entered the cask, assuring the robot was positioning the waste in the correct location prior to releasing it.

COSTS

Since the likelihood was high that the robot would become severely contaminated and would be disposed of upon completion of the acid scrubbing system removal, cost minimization was important. When possible, parts were purchased from surplus catalogs. Components were fabricated at the ANL-W machine shop, and the robot was assembled by the designer.

It is difficult to assess the exact cost of the development of the ELRA. A summary of costs is presented in Table 1. If the current design is used, a similar device could be built for less than $5000.

TABLE 1. Estimated Costs To Fabricate Robot

Electrical Components and Wiring	$1350
Wheels	$ 100
Frame	$ 700
Miscellaneous Parts and Attachments	$1400
Painting	$ 250
Design / Drafting	$1500
TOTAL	$5300

PERFORMANCE

The robot performed its designated tasks well and with minimal problems. The entire perchlorate contaminated system was removed from the hot cell without personnel having to enter the hot cell. The biggest problems encountered with the robot included a flat tire and bolts that had vibrated loose.

Improvements to the design were identified. Variable speed on the drive wheels would have permitted the robot to travel faster as well as aid in the steering of the device. An additional degree of motion on the smaller hand would have permitted better alignment of hand-held power tools with the working surfaces.

The robot was equipped with dosimetry that was changed and monitored on a daily basis. During the four week removal effort the ELRA received 911 Rem non-penetrating radiation and 141 Rem penetrating radiation . ANL-W administrative control limits on penetrating dose radiation exposure to personnel over a four week period is 0.5 Rem.

CONCLUSIONS

A robotic device, such as the ELRA, can be manufactured for a fraction of the cost of most commercial designs. Although the design was basic, the ELRA performed its designated tasks well, in addition to other tasks unforeseen during the design phase. With a modular unit, modifications can be made such as the design of additional attachments to tailor the robot's capabilities to a particular application.

The ELRA provided a significant savings in personnel exposure to radiation and hazardous conditions. The significance of the savings are two-fold. First, the ELRA allowed this task to carry fairly insignificant personnel radiation exposures. As ANL-W and DOE continue to lower administrative radiation exposure limits, the personnel exposure savings become very important. Secondly, and of potentially greater significance, were the explosion risks associated with the perchlorate contaminated system. Not exposing personnel to these risks was an obvious implementation of DOE/ANL-W Environmental, Safety, and Health policies

REFERENCES

1.) Disposal of Radioactive Waste from a DOE Analytical Laboratory Hot Cell Complex, by S. G. Johnson, and J. R. Krsul, dated September, 1992.

2.) Removal of an Acid Fume System Contaminated With Perchlorates Located Within a Hot Cell, by K. E. Rosenberg, S. P. Henslee, W. R. Vroman, J. R. Krsul, G. C. Knighton, and J. A. Michelbacher, dated September, 1992.

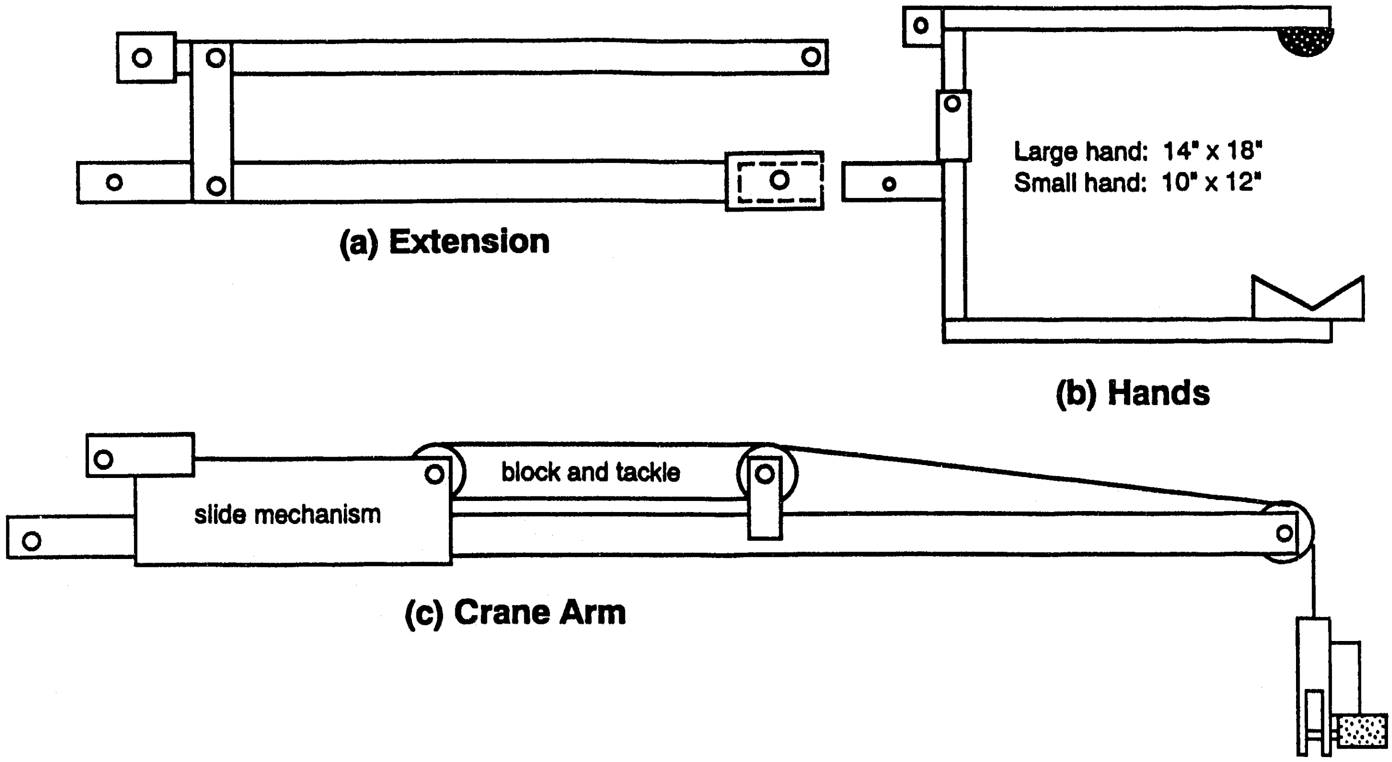

FIG. 2 ATTACHMENTS

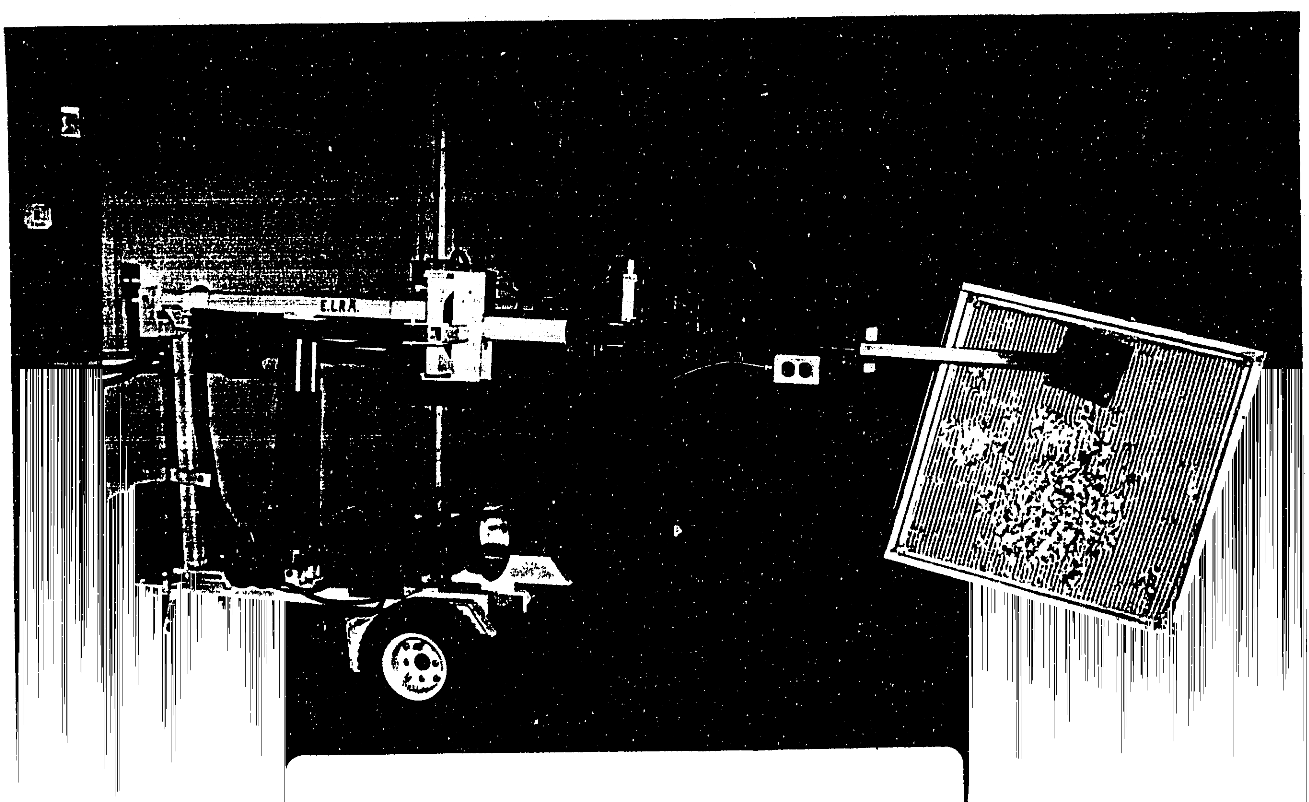

FIG. 3 ROBOT LIFTING HEPA FILTER IN MOCKUP

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