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USE OF ROBOTICS FOR RADIOACTIVE WASTE SHIPPING AND RECEIVING*

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Abstract

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Radioactive waste shipping and receiving facilities presently planned for commercial and defence high level nuclear waste will handle waste packages at frequencies far in excess of those in common practice today. If current limits for radiation levels at the cask surface and current handling methods are used, high cumulative personnel exposure to ionizing radiation is projected to occur. To reduce these exposure levels, alternate handling methods are being developed and demonstrated. The production nature of cask receiving operations suggests commercial robotics be incorporated into a remote handling system to reduce predicted worker exposure to acceptable levels while maintaining or increasing throughput. The first phase of cask handling system development culminated in a proof-of-principle test demonstrating the feasibility of performing cask receiving and unloading operations in a remote and partially automated manner.

INTRODUCTION/BACKGROUND

Development work has been proceeding since 1983 on new methods of handling high level waste casks in proposed radioactive waste shipping and receiving facilities.[1] While radioactive material transportation casks are designed to provide shielding that meets regulatory requirements, the high frequency of shipments can expose occupational personnel to

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undesirable cumulative levels of radiation. Recent studies indicated that plant personnel exposures could be reduced significantly below the current design guidelines, using remote-automated handling techniques[2].

An evaluation of equipment and procedural concepts for controlling worker exposures during shipping and receiving operations has been performed.[3] It was concluded from this evaluation that worker exposures can be significantly reduced if remote handling systems are developed and used to perform what have been typically hands-on tasks. Remote handling can be used to meet current federal guidelines for the design of new facilities and to meet the most conservative occupational exposure criteria in practice. It is also possible through automation to reduce manpower requirements and the time required to perform cask loading and unloading at shipping and receiving facilities.

To bring these exposures within As Low as Reasonably Achievable (ALARA) objectives,[4] remote handling methods are being developed and demonstrated. A key aspect of this work is to establish required features on future generations of casks and to demonstrate the applicability of advanced handling techniques on those cask designs. Because of the production nature of cask receiving operations, it was determined that commercial robotics might be incorporated in a remote handling system used to reduce predicted worker exposure to acceptable levels while maintaining or increasing throughput. The radiation level in the cask handling area,[5] while too high for full-time personnel occupancy, is low enough to permit entry for short periods. This means that maintenance operations on remote handling equipment can be performed using conventional techniques while the equipment remains in place, thus eliminating the need for remote maintenance. Our efforts have therefore included using the commercial robot systems as both flexible automation components that can accommodate a variety of cask configurations, and as electric manipulators with full man-in-the-loop control to allow rapid response to unstructured off-normal events. Thus robotics are employed as master-slave and programmed manipulators.

In parallel with design activities, a telerobotic workstation was installed and work was concentrated in the area of feature and proof-of-principle testing of elements of the system. While each of the components were generally commercially available, system integration, initialization of the sequences, and recovery from off-normal events needed to be convincingly demonstrated. The task was started in 1984 with a Cincinnati Milicron HT3 robot. As part of the design verification phase, selected equipment items and systems were designed, built, tested and revised in an iterative process to verify the operability of the more difficult subsystems. The equipment created in design verification was used in conjunction with a full-scale cask mockup of the Defense High Level Waste (DHLW) truck cask[6] and a floor-mounted robot to confirm the viability of selected portions of the cask handling system.

CASK HANDLING SEQUENCE

A generic flow diagram for unloading truck transported casks is shown in Fig I. The sequence of cask handling operations begins immediately upon arrival of the truck at the site. The truck is first pulled through a fixed survey instrument and then through a wash to remove road dirt and/or ice and snow. The protective cover is then removed and the tiedowns are loosened. A fixed shielded survey instrument and a robotic arm with a radiation smear end effector are used to check both the direct radiation levels and the removable free surface contamination on the cask surfaces. Then a lifting yoke is attached, and the cask is uprighted and placed in a cask cart. The cart transports the cask to the preparation area. Here the dust cover is removed, the cavity gas is sampled and then to minimize cell activities, the closure bolts are loosened. The cart next transports the cask to the receiving cell where the cask is mated to the unloading port and the port cover is removed. A receiving cell grapple is then used to remove the cask closure plate and the waste canister. The cask interior is visually inspected and surveyed for radiation; swipe samples are taken and gross (dry) decontamination may be performed. These steps are reversed as the cask is reassembled and readied for shipment. During reassembly, the outer closure seals are leak tested in the preparation area.

Systems or equipment necessary to accomplish the above tasks in a high volume waste shipping/receiving facility include the following:

- Track mounted overhead robot manipulator system
- Floor mounted robot system
- Overhead crane system
- Cask component lifting equipment
- Radiation survey and analysis system
- Cavity gas sampling and analysis system
- Outer closure seal leak test and analysis system
- Cask cavity inspection and cleanup system
- Auxiliary equipment components/system
- Integrated operator control system
- Intrafacility transfer cart system

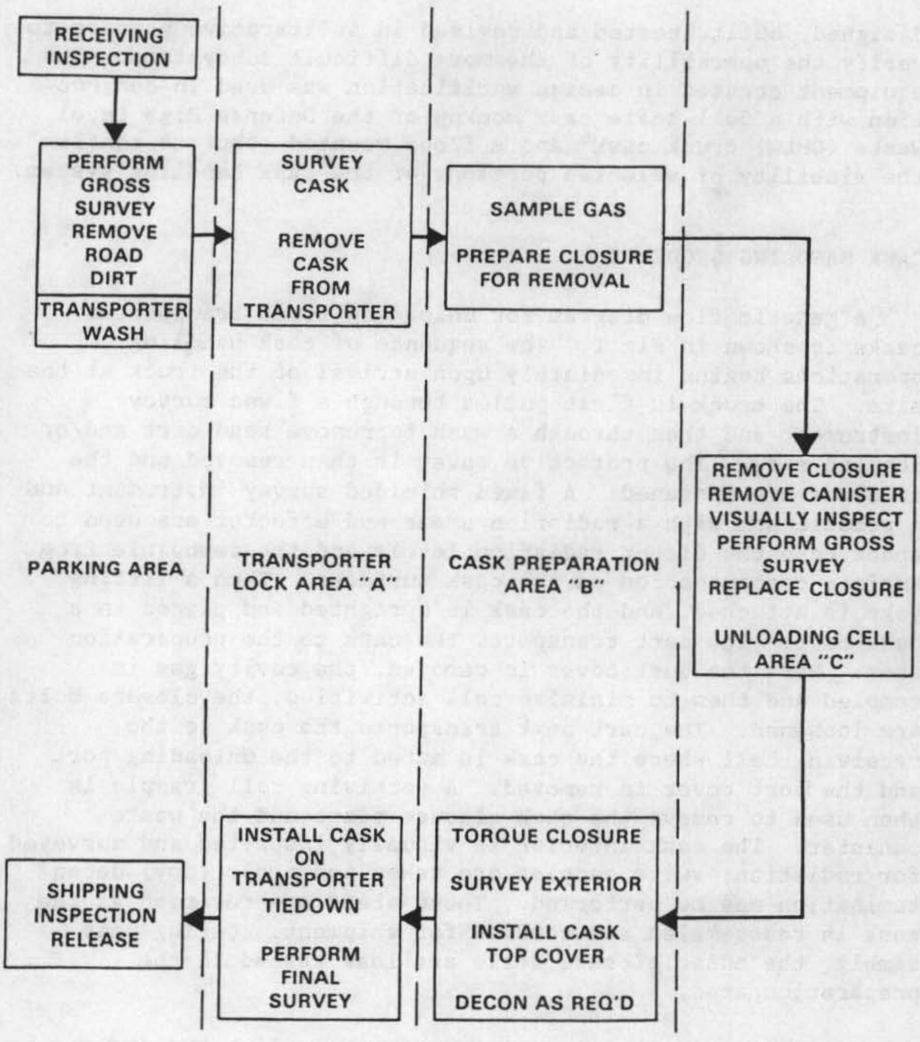

FIG. 1. Cask handling system flow diagram.

- Transporter wash facility system
- Hot cell crane system
- Viewing and lighting system

Each of the systems noted above includes associated controls for efficient automatic remote operation.

PROOF-OF-PRINCIPLE TESTING

In order to demonstrate proof-of-principle for conceptual cask handling systems, a full scale carbon steel mockup of the

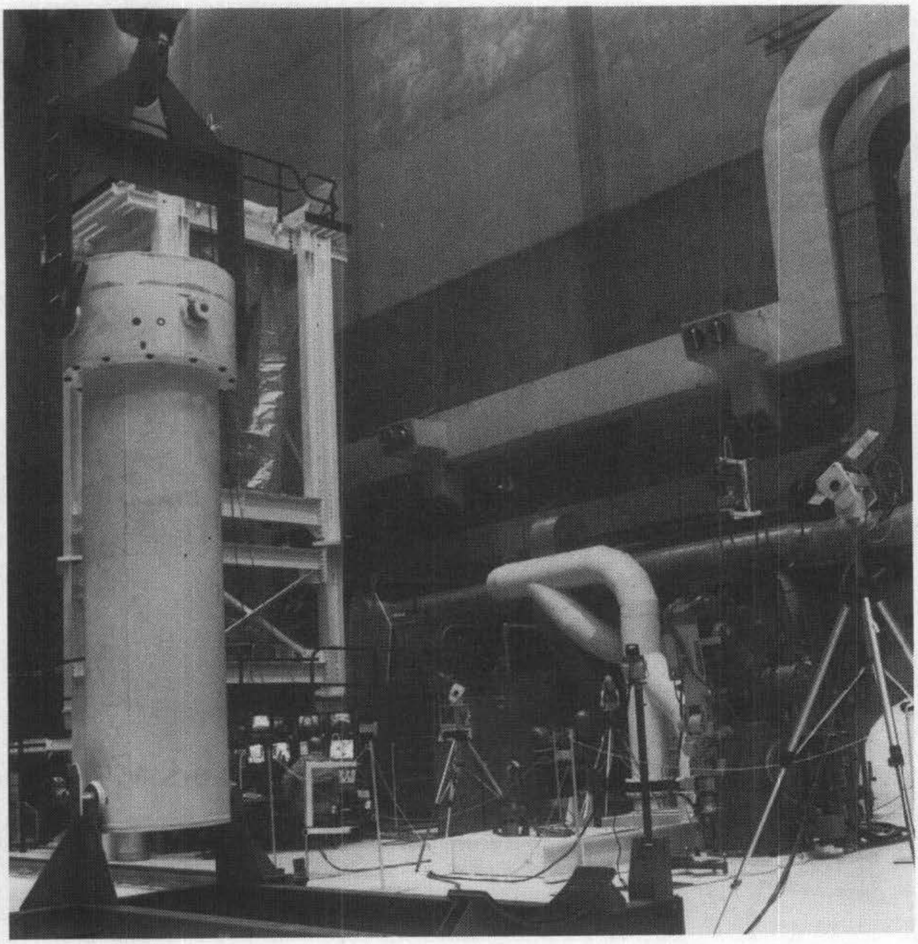

FIG. II. Defense high level waste (DHLW) cask mockup and shipping skid.

Defense High Level Waste (DHLW) cask was built, complete with functioning seals and captive fasteners. Also a nonradioactive DHLW canister was obtained for use during unloading operations. A shipping skid with captive hinged tiedowns was fabricated to simulate features which could be designed into a dedicated trailer (Fig II).

The primary tool in demonstrating proof-of-principle was a pedestal mounted commercial robot modified for man-in-the-loop control. A heavy duty commercial six degree-of-freedom hydraulic robot was used in a cask handling work cell simulating cask preparation activities. While an electric robot would be required for the final system application, the late

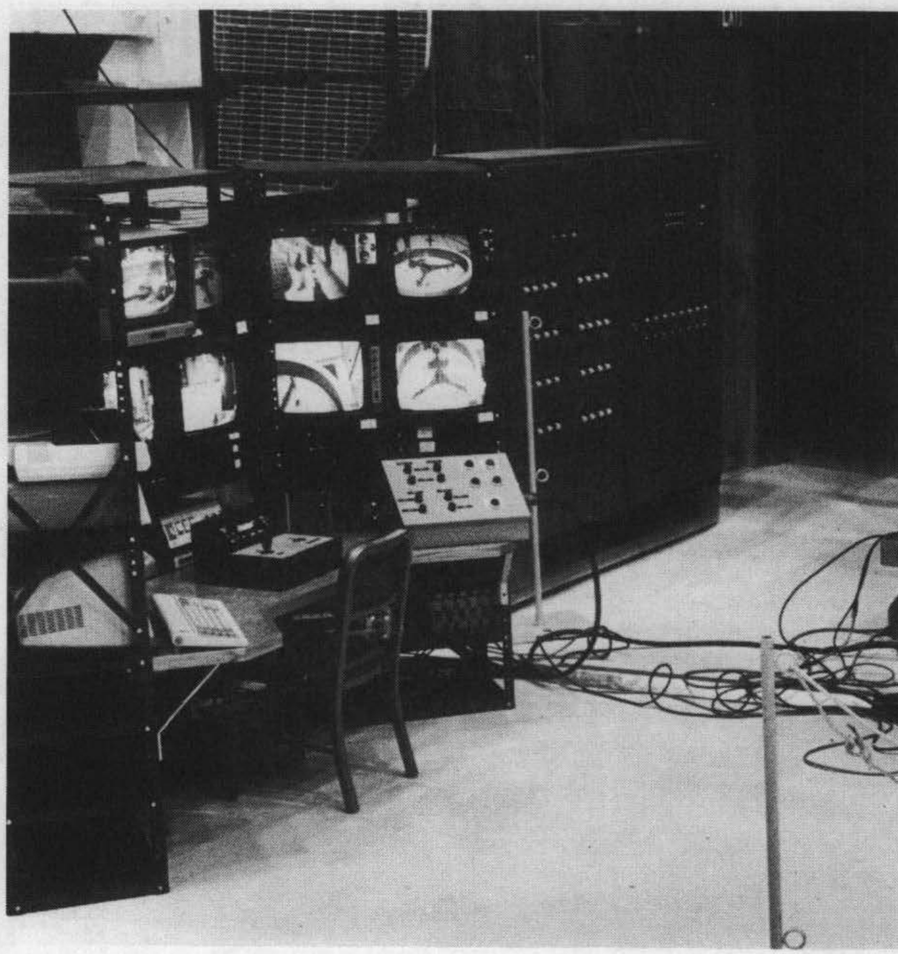

FIG. III. Workcell control station.

model hydraulic unit was an economical alternative with sufficient capability to perform initial proof-of-principle tests. In order to recover from unplanned events and to meet the need for performing unstructured activities, real time manual control of the robot was achieved by replacing the teach pendant with a more functional joystick controller, developed at the University of Illinois, and by operating the robot in the teach mode. The control station, shown in Fig III, includes the joystick controller, the microprocessor, CCTV monitors and controllers, remote crane control pendant, and a programmable controller. Dual three-degree-of-freedom joysticks were used on the controller, one for positioning the tool and the other for orienting the tool. The joystick allows the operator to use natural motions instead of push buttons to control joint movements, making manual control much easier.

A communications package was also developed to interface the robot controller with a microprocessor. The package includes protocol for establishing the computer link and the capability of transferring data to and from the robot controller. Included in the communications package was the capability to store program data and to adjust coordinates of cask features based on receipt of relocated reference points. Since the cask may be presented to the robot in a slightly different position, coordinates of the cask features relative to the robot base must be adjusted.

Specially designed fixtures and tools were used to conduct a proof-of-principle test demonstrating the feasibility of remote cask handling. Some of the specially designed handling fixtures are included in the cask component lifting equipment. A simple rigid lifting yoke with long lead-ins and seating indicators (Fig. II) was fabricated to lift the cask mockup during remote handling operations. A remote electromechanical grapple was designed and fabricated to support the testing program. It lifts both the cask closure plate and the waste canister. The grapple is electrically actuated and includes redundant engagement indication. A lifting fixture was designed for handling the dust cover (Fig. IV), which also provides restraints for the torque wrench during dust cover fastening/unfastening operations.

Previous studies[7] have shown that a major portion of remote handling times have been devoted to tool changeout. In a cooperative program with the National Bureau of Standards, a universal tool quick change system was implemented, reducing this operation to a programmed procedure taking less than 30 seconds to perform. This system allows rapid and automatic interchange of gripper, torque wrench, and gas sampling equipment. The automatic tool changeout system consists of a tool rack, a tooling adaptor plate and the robot tool quick change fixture attached to the end of the robot arm. Services provided in the quick change fixture include air, hydraulic and electrical. A two speed torque wrench was selected for remotely unfastening and fastening bolts on the cask mockup (Fig V). Remote handling features were added to the torque wrench which include: vertical compliance during bolt runout and rundown, torque reaction device, a rotational compliance allowing for contact of the torque reaction device with the cask head, and an adaptor for attachment to the robot quick change fixture.

This remotely operated handling test demonstrated removal of a full scale DHLW cask mockup from a shipping skid and

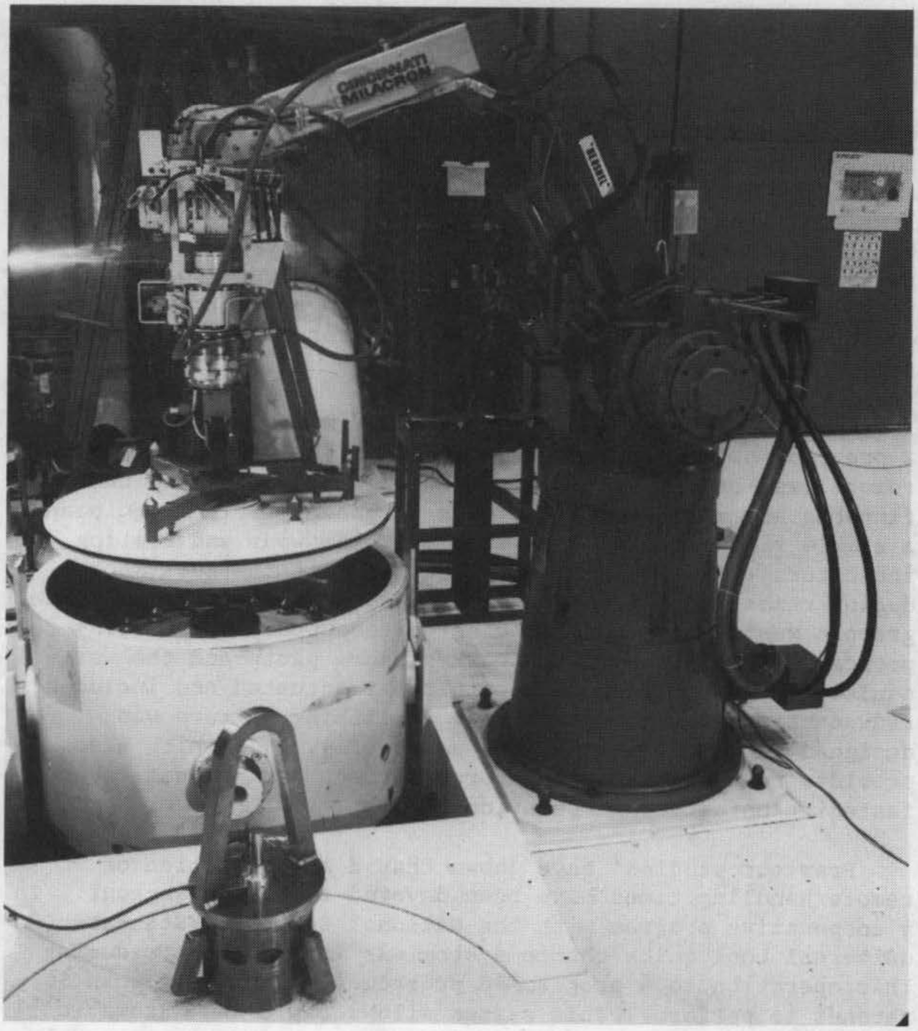

FIG. IV. Dust cover and lifting fixture.

placing it into a vertical support fixture that simulates a facility cask cart. Location of the cask was determined by establishing new reference point coordinates on the dust cover and then the dust cover was removed using a gripper end effector and the dust cover lifting fixture. The cask mockup was then prepared for unloading, using a commercial robot under both master-slave and automatic, preprogrammed control. The captive bolts on the cask lid were loosened after a simulation of the gas sampling operation. A grapple was used to remove the closure and waste canister, and then to reinstall them,

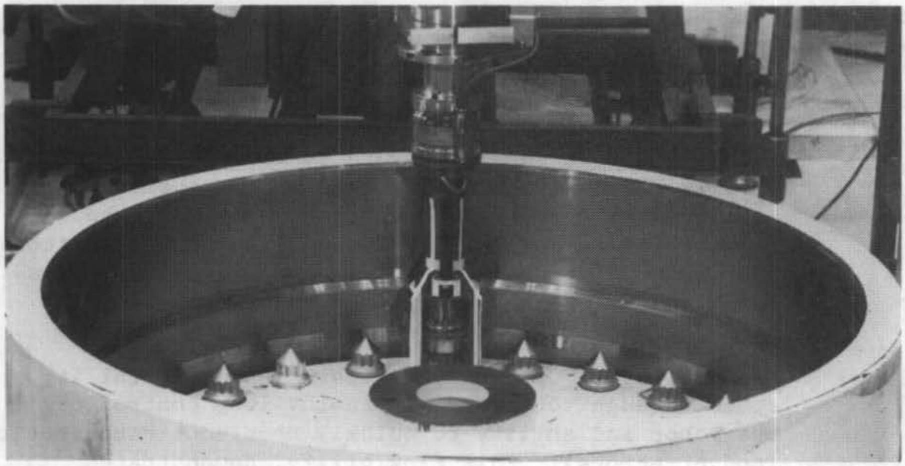

FIG. V. Torque wrench unfastening closure bolts.

simulating a loading operation. Finally, the robot was used to retorque the bolts, reversing the initial operations.

The demonstration was conducted using simplified (low cost) laboratory systems in a worst case application. All operations were conducted with closed circuit TV (CCTV) and no direct viewing. System enhancements in the actual system will result in improved operation times. These include: an automatic computer vision imaging subsystem for locating reference points, better monitors and cameras, automatic camera positioning, and a rotating crane hook and crane digital position readout for crane positioning.

TESTING RESULTS

Laboratory feature testing demonstrated several operations involving remote handling of the waste cask. This development testing showed feasibility of performing all the cask receipt, preparation and unloading operations from a single control station using remote controls and viewing. A principal benefit of the test was the comparison of actual operating times with those predicted in the conceptual design report[1]. The times listed in the report are predicted times using enhanced equipment, procedures and programmable manipulators compared to those used in the demonstration. The operating times obtained during feature testing were in close agreement with the operating times predicted, which indicates the values in the report are conservative. It is estimated that using the enhanced equipment which is recommended in the conceptual design document, the total operating times would be reduced by approximately 30%.

SUMMARY/CONCLUSIONS

- Reduction Of Personal Exposure To Ionizing Radiation. A fully remote system would reduce personnel exposure to near zero for normal operation, providing the flexibility to deal with off-normal events. Laboratory feature testing demonstrated that all critical operations involving the waste cask can be handled remotely.

- Flexibility Of Operations. Operational flexibility comes through software, man-in-the-loop control of the robot and ability to quickly changeout robot tools (end effectors). This flexibility, demonstrated during the feature tests, makes it possible to handle any number of cask designs and sizes without need for new handling equipment.

A combination of conventional remote systems when coupled with robotics offers a solution to personnel exposure and facility throughput concern for future high capacity waste shipping and receiving facilities.

FUTURE DEVELOPMENT WORK

The information obtained during the design verification and proof-of-principle phases is being used to generate preliminary design of the overall handling system. Prototypes of critical systems will be procured, tested and analyzed to confirm performance criteria and to perfect the overall system for final design definition. An overhead robot (track mounted) will be used in a later prototype cask handling system to perform operations in the cask receiving areas. The system design will be available about FY 1989 for use by designers of high-throughput waste handling facilities.

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