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EXAMPLES OF ROBOTS AND TELEOPERATORS AT THE SAVANNAH RIVER SITE (U)

by

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Examples of Robots and Teleoperators at the Savannah River Site

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ABSTRACT

The Savannah River Site manufactures nuclear materials for the U. S. Department of Energy. In recent years robots and mobile teleoperators have been used to reduce the radiation exposure of personnel at this site.

Two examples of robots that have significantly reduced radiation exposure are the Shielded Cells Waste Handling Robot and the Shielded Cells Sample Handling Robot. The Shielded Cells Waste Handling Robot has been in operation for over four years. It removes cans of radioactive waste from the Shielded Cells, seals the can in a plastic bag, and places the cans in a waste drum. The Shielded Cells Sample Handling robot has been in operation for only a few months. It opens a door to one of the Shielded Cells, removes a radioactive sample from a shielded container, places it in the cell, and closes the door.

Two examples of tasks where mobile teleoperators have significantly reduced radiation exposure are removal of a contaminated junction box, and lead removal from radioactive vessels. In the first example, radioactive liquid had leaked into an obsolete junction box. This caused the box to be internally contaminated to a level of 200 Rem/hr. at the surface. A mobile teleoperator was used to remove the box. In the second example, deionizer vessels must have the lead counterweights removed before the vessels can be properly buried. Radiation levels at the surface of these vessels measure as much as 5 Rem/hr. A mobile teleoperator was used to remove the lead counterweights from several of these vessels.

INTRODUCTION

The Savannah River Site (SRS) continuously evaluates new and developing technology for its potential to keep radiation exposure of personnel below prescribed limits and to reduce exposure to "as low as reasonably achievable" (ALARA). With the advent of computer-controlled electric-powered robots, available in many different sizes and capacities by the early 1980's, this technology was deemed to have potential for use at the SRS. Also, in the early 1980's, mobile teleoperators were being developed primarily for use in bomb disposal. Because of the remote operational capabilities of these vehicles, they were considered for use in unique situations at the SRS to reduce radiation exposure to personnel. Since that time, in repetitive operations that can be well defined, such as the transfer of radioactive material, robotics have been used successfully to reduce radiation exposure to personnel at the SRS. In unique situations that are insufficiently structured to allow the use of robotics, and where that task only has to be completed once or just a few times, mobile teleoperators have been employed to reduce radiation exposure to personnel. Two examples of the use of robotics, and two examples of the use of teleoperators to reduce radiation exposure at the SRS are discussed.

SHIELDED CELLS WASTE REMOVAL SYSTEM

In 1984 the production of Californium increased by an order of magnitude. The waste generated by the production also increased by an order of magnitude. Up until this time the waste was removed manually. The waste was transferred in one gallon cans from a shielded cell to a glovebox on a remotely-operated, motorized cart. The glovebox is a barrier to prevent the spread of radioactive contamination. The glovebox allows operators to perform functions by reaching into the glovebox through gloves that are located at several locations on the glovebox walls. An operator would reach into the glovebox through a pair of gloves and push the can through a plastic sleeve to the outside of the glovebox. A second operator would gather the sleeve behind the can and wrap tape around this area. The operator would cut the tape in the middle to form a bag around the can and reform the sleeve to form a barrier at the glovebox. The can would then be placed in a large cask. If the waste from the increased production were handled by the same manual method, an unacceptably large increase in exposure would have resulted.

To prevent this increase in exposure, a system employing a robot and a sleeve gathering and clipping machine was developed and installed (see Figure 1.). A plastic sleeve, that is long enough to cover four cans, is placed on a port on the glovebox and a supply of clips for greater than four cans is placed in the clipping machine before a can is transferred into the glovebox. The radiation levels are quite low during this manual preparation. The operators then leave the room and go to a control room. The rest of the operation is controlled and monitored from this control room. The can is brought out of the shielded cell on the motorized cart. Then the robot reaches through the sleeve and into the glovebox. A specially designed end effector on the robot clamps the top of the can through the sleeve. The robot pulls the can out of the glovebox and the sleeve becomes inverted around the can. A set of horizontal arms and then a set of vertical arms on the clipping machine close on the sleeve between the can and the glovebox. This gathers the sleeve into a small area so that a clip can be formed around it, making a sealed bag around the can. The arms open, the robot pulls the can out about another inch away from the glovebox, and the arms close again. A second clip is formed around the sleeve to restore the barrier on the glovebox. A "V" shaped knife blade on the clipping machine cuts the sleeve between the two clips. The robot then places the can into a tall drum that will allow four cans to be stacked inside of it (see Figure 2.). The operation is repeated three more times. The drum, containing four cans, is then moved into a shielded cask with a remote-controlled overhead crane. The operators will then re-enter the room and replace the sleeve and restock the clips. A total of 10 to 11 drums (40 to 44 cans) can be placed in a shielded cask before it is removed from the facility for disposal.

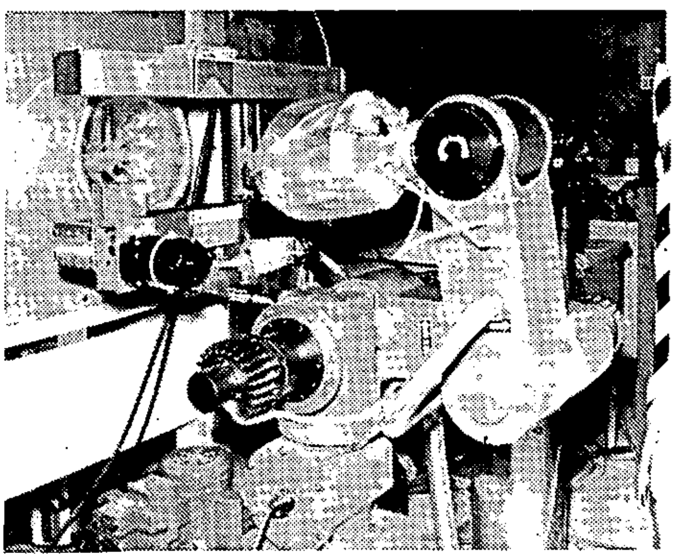

Figure 1. Robot with can and clipping machine

The control room is a sufficient distance from the glovebox room so that radiation levels in the control room during the operation are very low. The control room is equipped with a control panel, remote camera controls, and several video monitors. The cameras are mounted in different locations around the glovebox to permit vision of the entire operation. Most of the cameras have remote-controlled pan, tilt and zoom capabilities. At several points during the remote operation, the operator must verify the correct functioning of the equipment, and push buttons to allow the operation to continue or to be aborted.

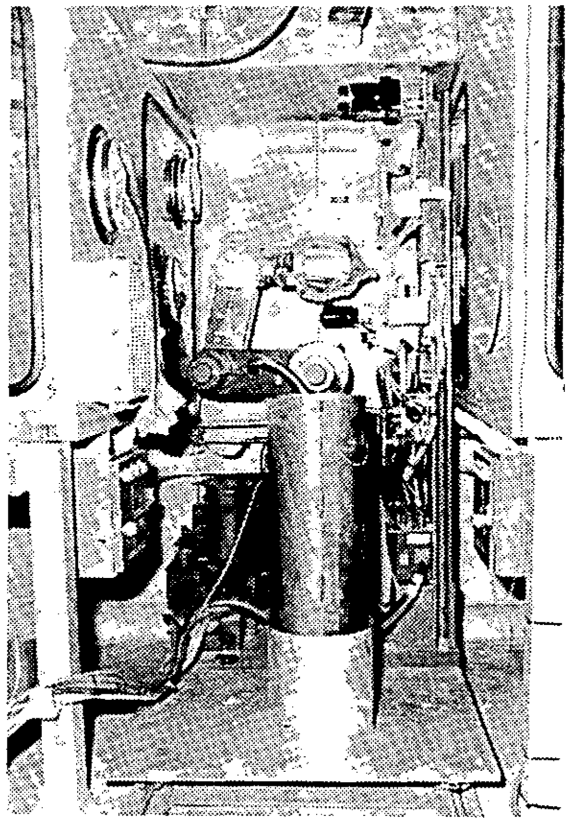

Figure 2. Robot and glovebox.

The production of Californium has ceased, but the robot system is still used occasionally to remove contaminated equipment and material from the shielded cell to decommission the cell. During production the robot saved approximately 35 rem of radiation exposure to personnel.

SHIELDED CELLS SAMPLE TRANSFER SYSTEM

Radioactive waste now stored in tanks at the Savannah River Site will be sent to the Defense Waste Processing Facility (DWPF) to be encapsulated in borosilicate glass. Before the waste is sent to the DWPF it will be processed in the tanks. Samples of the waste will be sent to the Savannah River Laboratory for analysis. The samples will be in vials about 1.5 inches in diameter and 4 inches high. They will be shipped inside shielded casks about 7 inches inches in diameter and 11 inches high. The vials must be removed from the casks and placed in a tunnel that is 3 feet long and services the shielded cells. Presently, this type of sample is placed by hand into the tunnel, which causes radiation exposure to personnel. Otherwise, a cover on the top of the shielded cell is removed, so that the cask can be transferred into the cell. The vial is removed by a manipulator, the empty cask removed, and the cover reinstalled on the cell. Whenever a cell cover is removed the possibility of the migration of radioactive contamination outside the cell is increased with its potential for personnel exposure.

A robot, with several different end effectors and tools available to it, has been developed and installed to insert the vials into the tunnel. The robot is mounted on a track that is 50 feet long so that it can complete the task and enter a maintenance room. The maintenance room provides a lower radiation environment to perform maintenance and repair. An automatic tool changer permits the robot to pick up 4 different end effectors. One of the end effectors is a parallel jaw gripper that allows it to pick up 2 different tools (see Figure 3.). The robot has 50 different programs stored in the robot controller. A force and torque sensor is mounted on the robot wrist. A supervisory computer provides menus from which the operator runs the robot, calls the proper programs to be run by the robot, and monitors the force and torque sensor for acceptable values during robot operation. During operation with radioactive samples, the supervisory computer is controlled from a remote computer in a control room 150 feet away from the robot. Three cameras, all with remote pan, tilt, and zoom, are operated from the control room where two monitors provide views of the robot during its operation.

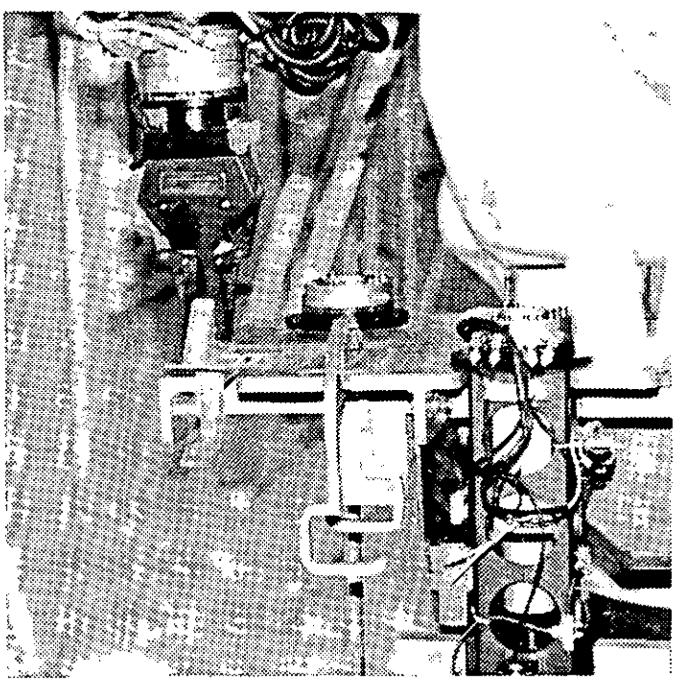

Figure 3. Robot with gripper and door tool.

To begin the operation, the robot picks up the parallel jaw gripper and then picks up the door tool with the gripper. It uses the door tool to grasp the handle on the door and open it. It then puts down the door tool and locates the exact position of the cask by touching 2 points on the outside of the cask. This is accomplished by monitoring the force and torque sensor as it approaches the cask from two different sides. With two points determined and the radius of the cask known, the exact location of the center of the cask is determined by the computer. The gripper picks up the lid tool, removes the lid from the cask, and places it adjacent to the cask. The lid tool and gripper are put down, and the vial tool is picked up. The robot lowers this tool, that has a three finger gripper, inside of the cask until the force and torque sensor indicates that the cap of the vial has been contacted. The gripper closes on the cap, and then retracts up inside the vial tool (see Figure 4.). Four pins around the vial extend to capture the vial. The amount of extension is checked with a photocell to assure that the vial is present. The robot inserts the vial tool into the beginning of the tunnel and the vial tool deposits the vial in the tunnel. The robot arm is not long enough to place the vial at the end of the tunnel that is 3 feet long, so it puts down the vial tool and picks up the push rod tool. This tool has a plate mounted at the end of a long rod permitting the robot to push the vial all the way to the far end of the tunnel. Using the appropriate end effector and tools, the robot closes the door and places the cask lid on top of the cask.

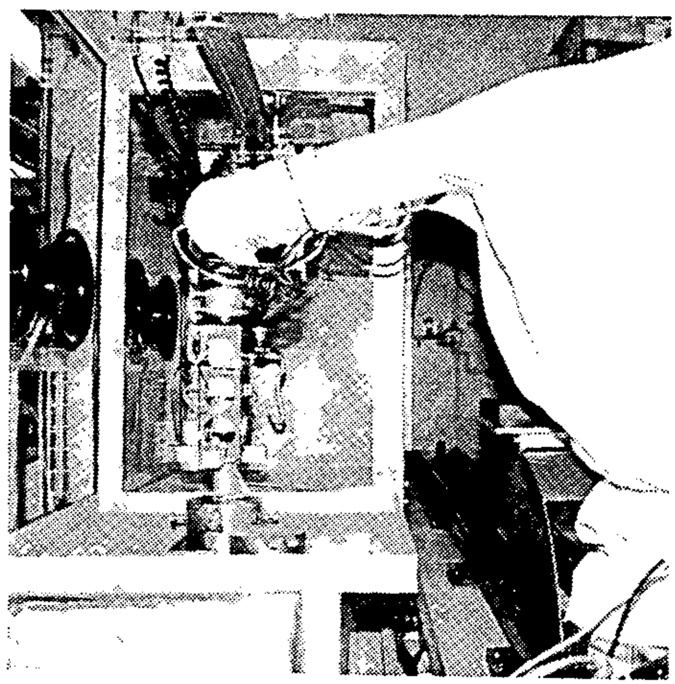

Figure 4. Robot with vial in vial tool.

This robot is ready for operation when the samples begin to arrive. It is expected that this robot will save radiation exposure for many years to come.

BOX REMOVAL MOBILE TELEOPERATOR

A leak of radioactive liquid in an equipment corridor at the Savannah River Site had contaminated the inside of a junction box to a level of 200 Rem/hr. measured at the exterior surface.

The box was located behind several air lines and above another junction box so that accessibility was difficult (see Figure 5.). The box had to be removed to allow normal maintenance and repair of equipment in this section of the corridor. It was estimated that a total exposure of 8 Rem would be required to remove the box manually, even with tools mounted on long poles. The Robotics group at the Savannah River Laboratory was asked to develop a method to remotely remove this junction box.

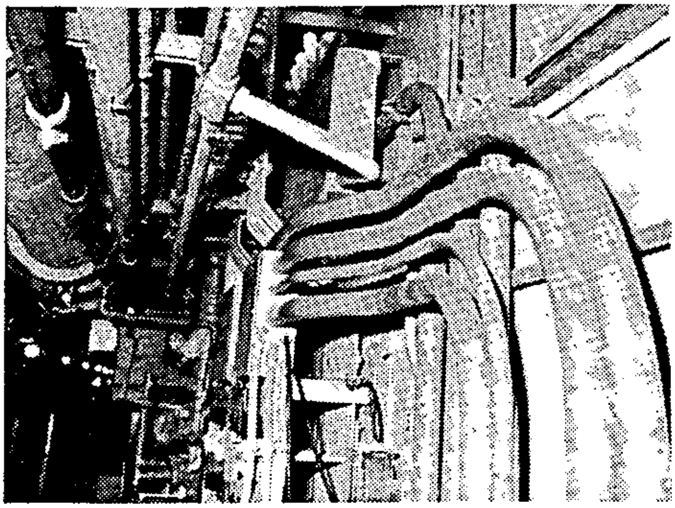

Figure 5. Contaminated junction box.

The Robotics group, with assistance from the Interim Waste group, obtained a hydraulic cutter that was capable of making the 13 cuts required to remove the box. The cutter blades were of a special design that could cut through the 2 inch conduit with minimum force (see Figure 5.). A Pedsco mobile teleoperator was extensively modified to manipulate the cutter. The standard design Pedsco has an elbow-up configuration to allow the end effector to reach the floor and moderately high on a wall. A new upper arm assembly in the elbow-down configuration was installed, which allowed the new end effector to reach up to 10 feet high (see Figure 6). A camera mounted on the end effector provided a close-up view of the jaws and proved to be extremely valuable during the operation. To manipulate the cutter into position to make all the cuts, two additional degrees of freedom were added: a wrist rotate and a wrist pitch. The cutter attachment was designed to allow the cutter to be placed in three different orientations on the wrist, so that it could reach all the cuts.

The design was tested and refined by removing a junction box four times in a cold mock-up of a section of the corridor. An uncontaminated junction box in the the corridor was also removed to prove the design and procedures were adequate. This test indicated that a bracket not present in the mock-up was obstructing access for the last cuts, and two additional cuts would be required to remove this bracket.

Three cameras were set up to view the contaminated junction box. A control station, consisting of the teleoperator control, hydraulic cutter control, monitors, and camera controls was set up about 50 m (150 ft.) away from the junction box. In June of 1987 the contaminated junction box was successfully removed. Because of small dimensional differences in the contaminated junction box, two of the fifteen cuts had to be finished manually, but the total radiation exposure for the task was still less than 1 Rem. Therefore, the use of the mobile teleoperator for this application reduced the exposure by more than 7 Rem.

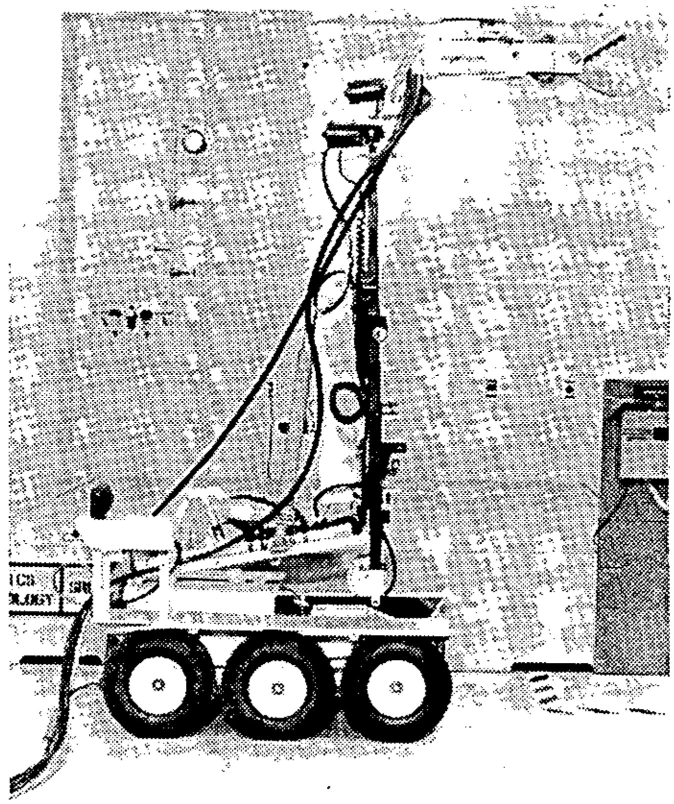

Figure 6. Teleoperator and cutting tool.

LEAD COUNTERWEIGHT REMOVAL MOBILE TELEOPERATOR

Lead shot and lead ingots sealed in stainless steel containers have been used to counterweight ion exchange process vessels and other equipment to facilitate their handling by remotely operated cranes. When a reactor area deionizer vessel is retired from service it is shipped to the burial grounds for disposal. However, recent changes in environmental regulations require that no lead be deposited at the burial sites.

The lead from the counterweights must be removed before the vessels can be properly buried. Approximately 30 spent deionizer vessels, each containing 34 kg (75 lb) of lead, were on hand when the new environmental regulation were enacted. All future vessels will use steel shot for counterweighting purpose, avoiding this problem. The deionizer vessels are 1.83m (6 ft) high by 1.52m (5 ft) in diameter and weigh nearly 454 kg (1000 lb). Radiation levels on the vessel surface measure as much as 5 Rem/hr. The radiation and contamination potential of the lead removal task precludes using plant personnel to manually remove the lead.

Additionally, the temporary space set aside to store spent deionizers had reached its maximum limit and more deionizers were approaching the end of their normal life cycle. An expedient lead removal solution minimizing personnel exposure was required. A teleoperated mobile vehicle with pneumatic tooling provided the best solution to the lead removal problem. The vessels would not have to be positioned accurately or have exactly equal measurement for the mobile teleoperator to manipulate the tool along the surface of the vessel. Pneumatic motors withstand mechanical abuse, stalling, and jamming.

A custom designed tool holder was designed and fabricated to adapt the pneumatic end grinder that could be picked up by the teleoperator gripper. The tool holder had springs to provide compliance so the accurate positioning of the end effector was not required. The grinder was extended and retracted from the tool holder by a pneumatic cylinder (see Figure 7.).

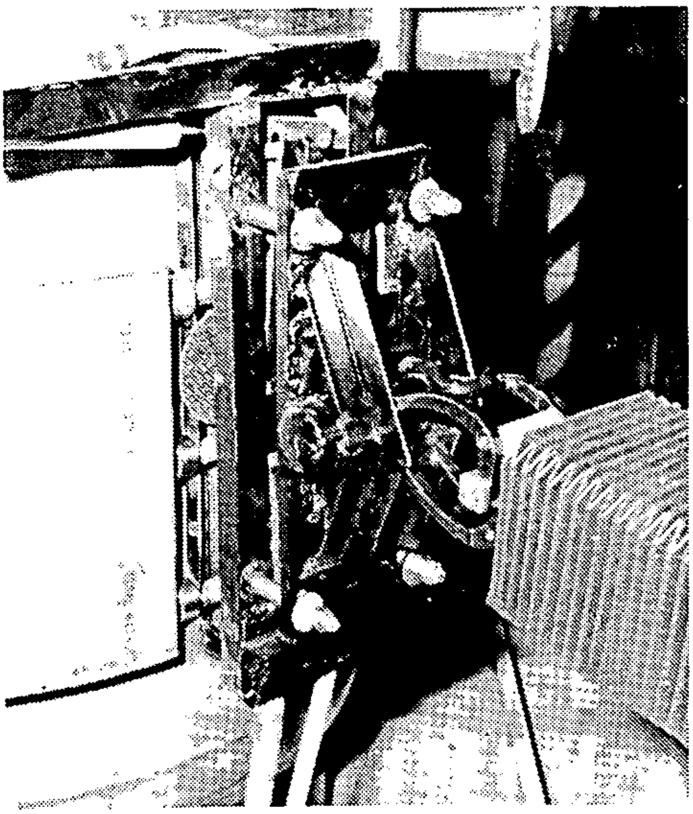

Figure 7. Teleoperator tool holder.

The teleoperator picked up the tool holder and placed it in a vertical position up against the side of the vessel so that the springs were compressed about halfway, and up against the upper right corner of the counterweight box. The grinder was turned on and then the cylinder on the tool holder extended it into the side of the box. A microphone was installed close to the teleoperator so that the extension of the grinder could be controlled, based on the sound of the operation. After the grinder was fully extended the teleoperator arm lowered the tool to cut downward on the side of the box. After the grinder cut all the way down the right side of the box, the arm rotated the tool 90 degrees and the bottom of the box was cut in the same manner. The teleoperator would then put down the tool and pry open the bottom right corner of the box with the gripper. To assure that all the lead shot had been removed, the teleoperator would then pick up a camera and manipulate it to observe the inside of the box.

The system was developed by cutting on a mock up vessel in a maintenance building (see Figure 8). The system was then placed in a cell in the reactor building and ten vessels were remotely emptied of lead, which relieved the problem. The flexibility of using a teleoperator instead of "hard" automation proved invaluable in being able to adjust to differences from vessel to vessel. An added benefit of the teleoperator was that it was able to augment the operation of the overhead crane as the vessels were brought into and taken out of the cell. The teleoperator was able to manipulate the vessels into the correct position and manipulate the lifting device for the vessel.

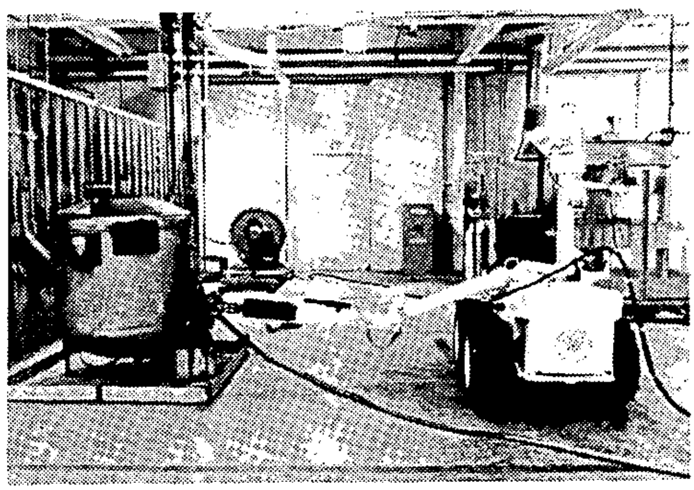

Figure 8. Teleoperator and mock-up vessel.

CONCLUSIONS

Robots and teleoperators have been used successfully for radiation exposure reduction at the Savannah River Site. At this time, experience with robots in high radiation fields and high radioactive contamination is limited. However, as experience is gained from the application of robots in nuclear facilities, they will be used to implement systems in environments with higher and higher amounts of radiation and contamination in the future.

Based on the success of mobile operators being adapted in relatively short periods of time to accomplish unique tasks, an emergency response fleet is being assembled. The fleet will consist of mobile teleoperators of different sizes, capacities, and capabilities along with remote-controlled video equipment. Equipment that is readily available will be purchased, other equipment will be developed at the Savannah River Site. This will allow mobile teleoperators and associated equipment to be deployed efficiently as situations arise on the site.

ACKNOWLEDGEMENT

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