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SHIELDED CELLS TRANSFER AUTOMATION

by

John J. Fisher

E. I. du Pont de Nemours & Company
Savannah River Laboratory
Aiken, South Carolina 29808

A paper proposed for presentation at the American Nuclear Society
National Topical Meeting on
Robots and Remote Handling in Hostile Environments
Gatlinburg, Tennessee
April 23-26, 1984
and for publication in the Proceedings of the Meeting

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John J. Fisher

E. I. du Pont de Nemours & Company
Savannah River Laboratory
Aiken, South Carolina 29808
Telephone: (803) 725-1297

ABSTRACT. Nuclear waste from shielded cells is removed, packaged, and transferred manually in many nuclear facilities. To reduce radiation exposure to operators, technological advances in remote handling and automation were employed. An industrial robot and a specially designed end effector, access port and sealing machine were used to remotely bag waste containers out of a glove box. The system is operated from a control panel outside the work area via television cameras.

* The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

I. INTRODUCTION

E. I. du Pont de Nemours & Company, Savannah River Laboratory (SRL) is employing state-of-the-art robotics and automation to reduce radiation exposure to personnel at its nuclear facilities. Operations involving the transfer and packaging of nuclear material are one of the largest contributors to radiation exposure. In one SRL production shielded cells facility, radioactive waste material is routinely removed, bagged in plastic, and packaged into drums. The SRL Robotics Technology Group has developed and demonstrated an automated system to perform these operations. The automated system will significantly reduce radiation exposure to shielded cells personnel. The components and techniques involved apply to other similar production areas.

II. BACKGROUND

Various chemical and metallurgical processing of nuclear materials are performed in the SRL Shielded Cells Facility. The cells are heavily shielded workstations which allow operators to handle radioactive materials with a minimum of radiation exposure. Nuclear processes are either remotely controlled or performed manually with master-slave manipulators. Nonrecyclable solid waste including glassware, used test equipment, and absorbent towels is generated in the cells. The waste is packaged into one-gallon paint cans, transferred to an access glove box behind the cell and removed from the facility.

Figure 1 is an illustration of a shielded cell and access glove box connected by a trolley system. Waste cans are positioned with manipulators on a trolley cart and transported into the glove box by opening the shield door. The exteriors of the cans are contaminated with radioactive material and cannot be handled directly. Therefore operators reach through glove ports and transfer the cans into a sealed plastic bag. A slight vacuum is maintained in the glove box to prevent radioactive material from contaminating the outside work area.

Figure 2 is a photograph of a manual waste can removal operation. One operator opens the cell door and surveys the waste can to determine the radioactivity of the waste can. If the radiation reading is too high, the can is returned to the cell and repackaged into two containers. Two other operators seal the waste can into the bag and deposit the can in a shielded drum. The quantity of waste that may be placed in a drum is restricted by a procedural radiation limit. Full waste drums are sealed manually, placed in a concrete cask with an overhead crane, and transported to underground burial areas.

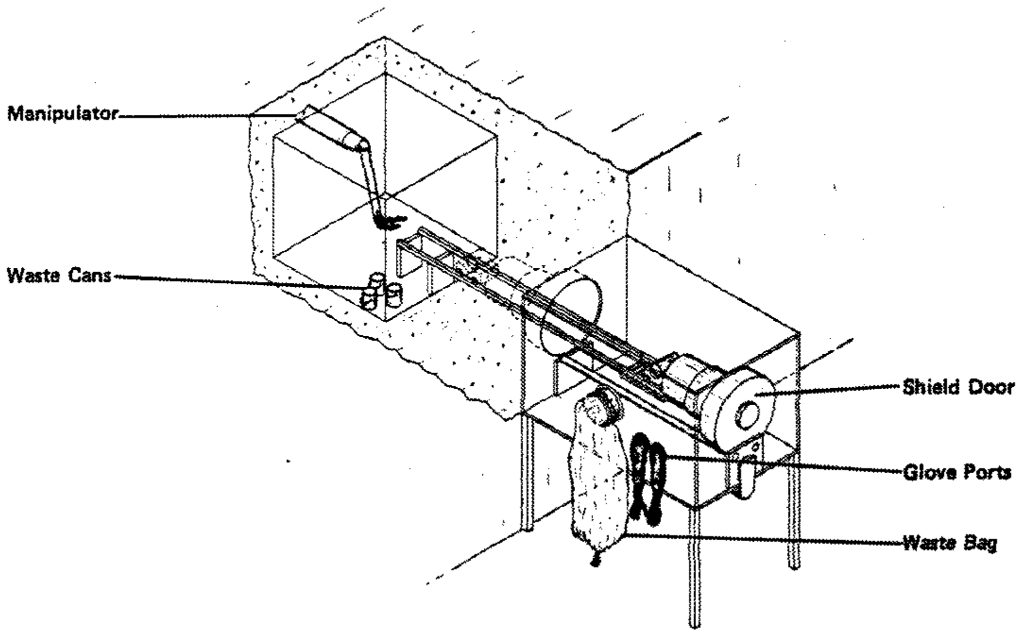

Figure 1
Shielded cell and access glove box

Figure 2
Operators pulling waste buckets from a glove box

III. AUTOMATION

Health Protection records indicated that operators received the highest radiation exposure while surveying and handling the waste cans. Consequently, an effective reduction in radiation exposure could only be achieved if operators were completely removed from the glove box operations. Automating the process required eliminating the following manual tasks:

1) Opening and closing the shield door
2) Surveying the waste pails with a radiation detector
3) Removing the waste pails from the glove box
4) Sealing the waste pails into the plastic sleeve
5) Cutting the plastic sleeve containing the pails
6) Depositing the waste pails into a shielded drum
7) Inserting full drums into a concrete burial cask

The Robotics Technology Group developed an automated, integrated system to perform these operations. An operator interactive control scheme is used instead of a completely automated process to avoid the consequences of an unnoticed system malfunction. If not quickly recognized and remedied, a dropped can or sleeve rupture could cause radioactive material to be released into the work area. However, with an operator viewing and controlling the process remotely, critical stages of the operation can be checked and problems corrected.

Figure 3 shows an automated work station to remove waste cans. A programmable industrial robot is mounted between two access glove boxes behind the shielded cells. One of the boxes contains a special access port fitted with a long plastic sleeve. The robot reaches through the port, grips the can through the sleeve, and removes the waste from the glove box. A combination bag gathering and clipping machine is mounted outside the access port. The machine seals the plastic sleeve by applying an aluminum clip. The gathering-clipping operation is repeated and followed by a cutting step which shears the plastic between the seals. This encapsulates the can in a bag and closes the remaining sleeve. The glove box is always maintained at a slight vacuum and closed to outside work area. The robot transfers the packaged can from the access port to a shielded drum by pivoting 90 degrees about its torsoe. After depositing a can at some programmed location, the robot automatically repositions itself in front of the access port to remove another can.

The waste removal operations are monitored remotely by the operators. Cans are surveyed with a specially designed neutron detector while the cans are positioned on the trolley cart. The detector is mounted outside the glove box and calibrated to measure the quantity of radioactive material inside the waste cans. Two television cameras are located in the work area to monitor the robots movement, the bag sealing and cutting operation, and the placement of the bags in the drum. Operators view and sequence the operations in the process from a control panel 30 meters from the glove box. Therefore, no operators are needed in the work area until the cans have been placed in the shielded drum and the shield plug is closed.

A conveyor is activated to transfer a full waste drum within reach of an overhead bridge crane. The crane is positioned to pick up the waste drum at the end of the conveyor. Operators transfer the drums with the crane into a specially designed shielded cask. A shielded cask lid, containing a gasket, is set over the cask and manually bolted in place. Sealing the cask lid eliminates the need to seal each drum. Radiation exposure to operators is low during these operations.

IV. SYSTEM COMPONENTS

The automated system required integrating a variety of commercially available components and specially designed devices. The major components including the robot, end effector, bag gathering-clipping machine, and control panel are discussed.

A. Industrial Robot

A GCA model 300V industrial robot was selected to remove waste cans from the glove box. The 300V is a programmable articulated arm which has five degrees of freedom and can lift as much as 20 pounds at low speeds. A GCA 2000 controller is used to control the robot. Programming was performed online by moving the robot to desired positions and teaching the points into memory. The robot passes through or stops at all learned points. However, the path between successive points can not be accurately controlled. Approximately sixty points were programmed to allow the robot to move smoothly in and out of the box. The 300V was selected over other commercial systems after carefully reviewing the work envelope in the Shielded Cells Facility. As shown in Figure 3, the robot is positioned between two glove boxes spaced only 3 feet apart. Through out system testing, the GCA 300V robot was very reliable and easy to use. GCA provided excellent technical support and clear operation and service manuals.

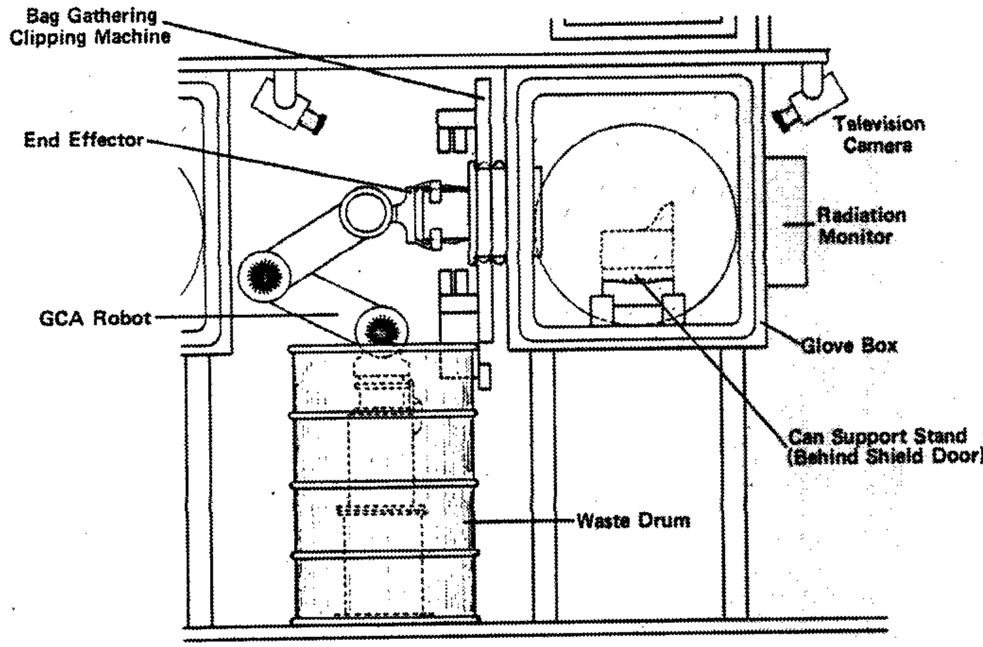

Figure 3

Automated waste removal system

The robot program uses delay functions and conditional jumps to allow operators to inspect the robots movement and wait for the sealing operations to take place. During normal operation, the robot program automatically moves the arm into the box, signals the end effector to grip the waste can, and deposits the can into the waste drum. The program frequently stops during operation to wait for an input signal from the operator. These stops allow the operator to inspect the robot's entrance into the access port, the alignment of the sleeve, and the position of the waste can trolley. Operators can also inspect if the waste can has been gripped, and if the sleeve has been sealed properly. In the event of a system malfunction, the operator has the capability to automatically back the robot out of the cell or move the robot by control from a manual pendant.

B. Robot End Effector

A special end effector was designed to handle the waste cans. It consists of a center support, two pivoting fingers, and two removable grippers. Two low profile air cylinders activate the gripper jaws which close independently and center on the waste can. This action compensates for slight can misalignments. Special precaution was taken to round off the edges of the grippers to avoid damaging the waste sleeve. A can is gripped at one end so that it is concentric with the access port on the glove box (see Figure 4). To minimize the moment on the robot's wrist, the can is gripped as close to the robot's face plate as possible. Figures 4 through 6 show the can end effector in the open and closed positions.

C. Automatic Gathering-Clipping Machine

The bag gathering-clipping machine was specially designed to seal and cut the plastic sleeve attached to the access port. As shown in Figure 7, the machine consists of a central support beam with two compressor bars cantelevered from one slide. The clipping machine is mounted in the bottom mechanism in a sliding dovetail track. When a sleeve is gathered, the top and bottom compressor bars slide vertically together to flatten the sleeve. Then the clipping machine and a pair of gathering plates slide together horizontally forcing the sleeve into the mouth of the clipping machine. The machine uses two hydraulic cylinders to apply a clip. The first cylinder activates a gate which closes the sleeve inside the mouth. The second cylinder pushes a clip from a spring-loaded magazine around the sleeve and closes the clip around a die. Two clips are applied to the sleeve in succession, then the sleeve is cut between the two clips with a cutting device attached to the top compressor bar. The clipping machine was custom designed and fabricated by the U.S. Clip Corporation to meet the specifications of the process.

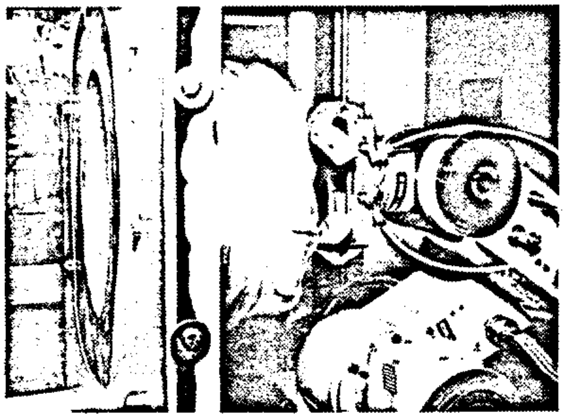

Figure 4

Position of robot before entering glove box port

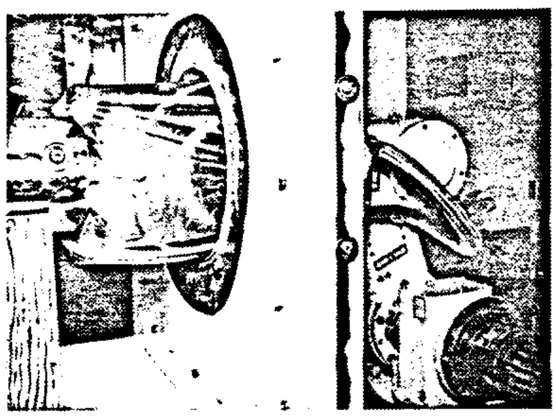

Figure 5

Robot manipulating the waste can through a plastic sleeve inside the glove box

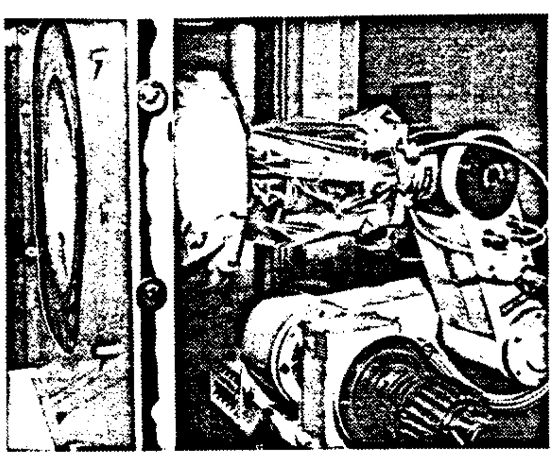

Figure 6

Robot outside glove box after removing can through port

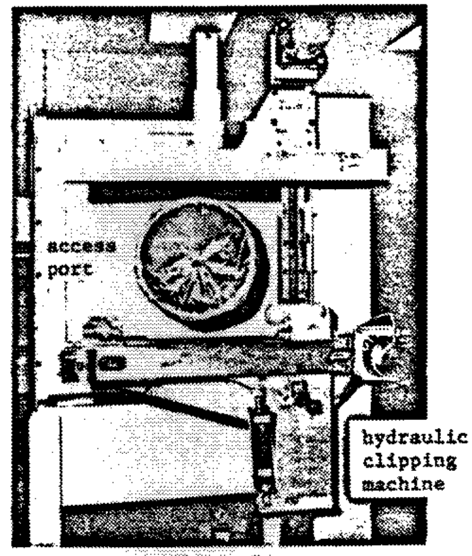

Figure 7

Bag gathering-clipping machine

D. Control Panel

Operators control all of the system components from a remote control panel (see Figure 8). The control panel interfaces with the robot controller to allow interaction with the robot during operation. Indicator lamps signal operators to check key steps in the program, then a continue switch is depressed to verify that the step has been completed. Another switch stops the robot program to enable manual control or to begin a subprogram to remove the robot away from the glove box. The control panel is equipped to remotely control the shield door on the glove box, the gathering-clipping machine, and the bag cutter. Similarly, all electric and hydraulic power supplies may be activated. Two television monitors, and camera controls for pan, tilt, focus, and zoom are located in separate cabinets near the control panel. All system operations are monitored with the television cameras. A digital display is attached on the neutron detector to allow it to be read remotely on a TV monitor.

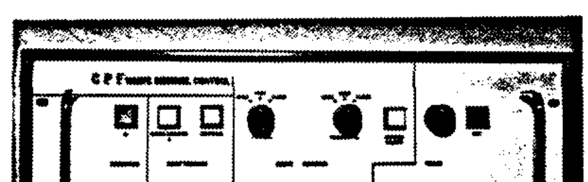

Figure 8

Operator Control Panel

V. SYSTEM TESTING

All components with the exception of the conveyer system were tested in a mockup area in a clean section of the laboratory. Tests were performed to determine critical factors and operations in the process. These included the behavior of the sleeve in the glove box and the sealing operations.

A. Access Port and Waste Sleeve Tests

A glove box mockup was fabricated to test the automated system. Figures 4, 5, and 6 show how the sleeve material is pulled off the access port as the robot enters the cell. Notice that the bag is expanded in Figure 5 due to the .4 mm Hg (.2 inch H_2O) vacuum inside the glove box. As the can is withdrawn from the cell the bag envelopes around the waste can. Figure 6 shows the final position of the robot prior to sealing the sleeve. The glove box access port is a 229-mm x 325-mm-diameter cylinder which extends from the box. It contains two O-ring grooves to hold on the plastic sleeve and a rounded front edge to allow the sleeve to slide inside the port. Figure 4 shows how the waste sleeve is attached and gathered on the port. Approximately 4 meters of .2 mm (8 mil) PVC sleeve can be gathered on the port at one time, enough to remove 5 cans. The waste can is supported on a rigid stand to align it with the access port. In the shielded cells facility, the support stand is attached to the cells waste trolley system.

The enveloping phenomenon was tested on a variety of port sizes, sleeve materials, and vacuum pressures. Initial tests proved that as small as a 215-mm-diameter waste sleeve could be used to completely encapsulate a one gallon, 168-mm-diameter waste can. The 325 mm port was selected for the automated system to allow clearance for the robot's end effector to reach through the port. Caution had to be taken to remove the cans slowly to prevent the glove box vacuum from increasing. Vacuums in excess of 3.8 mm Hg (2 inch H_2O) generated high enough vacuum forces to pull the can out of the robots end effector and in one case damaged the seal of the waste sleeve.

B. Sleeve Sealing Tests

An automatic clipping machine was chosen over other sealing methods to effectively close the waste sleeve. Thermal sealers were not used since they required the sleeve material to be flat and wrinkle free. The clipping machine successfully sealed the 325 mm, 8 ml PVC sleeve without difficulty. Clips were closed around the PVC as tight as possible without damaging the material. Due to the thickness of the material, tiny openings in the convolutions of the seal permit a slight leakage of air. However, the clip seals were much tighter than the seals made in the manual taping process. Water and air-tight closures were made with 6 ml and 3 ml sleeve materials respectively, but not used in the process because of poor durability. The amount of closure of the clip is easily adjustable to allow different thicknesses of sleeve material to be used.

VI. FUTURE DEVELOPMENT

Further development may be required for automating waste removal systems for other nuclear production applications. In dusty environments, an alternate sleeve cutting system may be required. Contamination may settle in the sleeve between the clips and escape after the sleeve is cut. Possible remedies include cutting the sleeve with a hot knife to melt it's edges, or using a sleeve made of a heat shrinkable plastic. In applications where large quantities of waste are removed, replacing the sleeve may become a problem. In this case, either a prepackaged sleeve could be designed to quickly adapt to the access port or a double door transfer arrangement could be set up (see Figure 9). GCA and other robot manufacturers offer controllers with continuous path capabilities including linear and circular interpolation. These functions can greatly reduce programming time and increase system flexibility.

VIII. CONCLUSION

This application has demonstrated that an intelligent automated system can be implemented to perform typical waste handling operations. The removal of waste material from glove boxes containing bagged access ports is very common in nuclear facilities, and a substantial reduction in radiation exposure can be achieved through automation. The automated operation integrates a variety of commercial and specially designed components which operate remotely. Operators are used to monitor and sequence the steps in the process to reduce the possibility of a system malfunction. The SRL Robotics Technology Group has plans to continue development in waste removal and nuclear material applications. The removal of personnel from radiation areas justifies the automation of these operations.

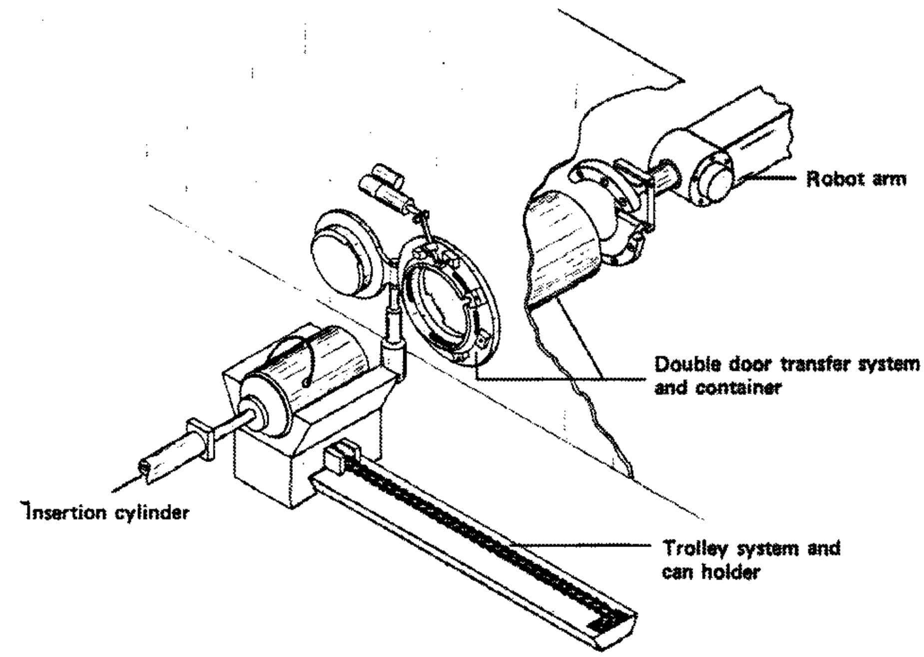

Figure 9

Automated waste removal system using a sealed double-door transfer port and container manufactured by Sargent Industries (Central Research Laboratories)