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AUTOMATIC BAGOUT SYSTEM

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ABSTRACT

Nuclear material entrained wastes are generated at the Plutonium Facility at Los Alamos National Laboratory. These wastes are removed from the glove box lines using the bagout method. This is a manual operation performed by technicians. An automated system is being developed to relieve the technicians from this task. The system will reduce the amount of accumulated radiation exposure to the worker. The primary components of the system consist of a six degree of freedom robot, a bag sealing device, and a small gantry robot.

INTRODUCTION

Many chemical processes, involving plutonium and other nuclear materials, are performed at the Plutonium Facility at Los Alamos National Laboratory. Waste by-products are generated from some of these processes. Because of the limited storage capacity within the glove box lines, these generated wastes must be extracted on a regular basis. The method used to extract these waste materials is the "bagout" method. The bagout allows materials to be extracted from a glove box without breaching the glove box.

As the name implies, the bagout involves the use of a polypropylene bag. The bag is attached to a port on the glove box. A technician in the gloves of the glove box passes the item through the port to another technician who slides it down the length of the bag. The bag is twisted just above the waste item in an effort to gain a seal between the glove box and the item. Wire is tied around the twisted portion of the bag in two places. Then heavy tape is wrapped around the twist to preserve the seal, as depicted in Fig. 1. The bag is then severed at the mid point of the twisted portion of the bag, between the tie wires, and a piece of tape is applied to the end of the newly created stub. The waste item is isolated in its own bubble of plastic and the glove box environment has not been breached. The stub that is remaining becomes the bottom of the bag for the next bagout item.

The bagout operation requires the presence of three individuals: a radiation monitor and two technicians who perform the operation. The bagout process is usually a one to two hour operation that is performed once or twice a week. The process necessitates the intimate handling of the waste item. There is very little shielding incorporated in the waste cans. As a result, the bagout is a relatively high exposure operation.

Fig. 1. Two technicians performing a manual bagout.

As mentioned before, the bagout entails the use of a plastic bag. It is a flexible membrane that provides the boundary between the glove box and exterior environments. Although it occurs very rarely, the possibility of the bag rupturing is a consideration that must be taken. To counter the threat of ingesting airborne contaminants, released due to a ruptured bag, the technicians wear a full face respirator and special anti-contamination clothing. Although extraordinary precautions are taken to insure that the respirator fits correctly and functions properly, there is still concern that the technician may ingest airborne contaminants in the event of a contamination release.

Bagouts have been performed since the early days of the nuclear industry. It has been a proven and inexpensive method of removing materials from glove box lines. However, due to the possible risks involved, it is advantageous to remove the individual from the bagout area. This would preclude technicians from the exposure and contamination risks associated with the bagout. Hence, the impetus for an automated bagout system.

SAVANNAH RIVER LABORATORY

The original idea of an automated bagout system was concieved at Savannah River Laboratory. A bagout system was designed and developed there. The primary goal in developing the system was to remove personnel from an extremely high radiation exposure situation. The primary components of the system consists of a BCA/DKP300V robot, a bag gathering and sealing device, a custom end effector, and a custom designed bagout port [1] The system has worked well without any major malfunctions or notable incidents. The system was instrumental in decreasing a hazardous exposure situation.

THE LOS ALAMOS SYSTEM

The Los Alamos Automatic Bagout System (ABOS) will be designed to extract waste materials that are contained in one gallon cans. The ABOS will initially have a bagout frequency of 30 to 40 cans per week. The cans will weigh up to seven kilograms (15 lb) each. The system will be capable of placing the extracted items into a barrel. The ABOS is being developed in three phases. The first phase is the development of the extra glove box equipment. The second phase is the development of the equipment interior to the glove box. The third phase is the development of a remoted control area for the operators. A description of each follows.

EXTRA GLOVE BOX AUTOMATION

The mode of operation for the extra-glove box automation of the ABOS will resemble the Savannah River bagout system. It is a proven method of extracting materials from a glove box. However, the components that make up the Los Alamos system differs in design from that of the SRL bagout system, even though the theory of operation is the same. The ABOS equipment has been designed to accommodate the constraints imposed by the Plutonium Facility. The equipment consists of a six axis robot, a gripper, a six axis force/torque sensor, a bag sealing device, and a bagout port.

The sequence of operation is as follows. Mounted on the side of the glove box is a modified bagout port that protrudes from the side of the box. A bag is gathered about its outer circumference such that the base of the bag is stretched across the end of the port. The robot extends its arm into the port, drawing in a portion of the bag with it. At the other end of the port is an awaiting one gallon can. The robot grasps the can through the plastic membrane and retreats with the item via the port. The robot withdraws to a point where the base of the can has cleared the end of the port. The robot holds this position while the bag sealing device closes down the bag between the base of the waste can and the front of the port. It then applies four aluminum clips, simultaneously, to the necked down portion of the bag. The bag is then severed between the two inner-most clips. The waste can, now isolated in a bubble of plastic, is deposited in a drum. The system is controlled and monitored from a remote site by the operators. The process is repeated until the length of bag is depleted. At that time, the operators enter the area and replace the bag.

The Port and Bag

The bagout port is a custom design specific to the ABOS. Rather than having the bagout bag hang from the port, as is done during a manual bagout procedure, it is gathered about the outside circumference of the port. It is gathered on the port such that the closed end of the bag is stretched across the opening of the port. The "lip" of the port is well rounded to prevent the bag from tearing as the bag is drawn into the port by the robot. The port will accommodate a bag 4.5 m (15 feet) in length. The bag is an open ended tube of eight mil, polypropylene. The tube diameter is 38 cm (15 in). Given this arrangement, twelve one gallon waste containers can be extracted per length of bag.

The Robot

The selected robot was required to satisfy the following general constraints:

1) The robot must be of physical dimensions such that it does not occupy a space with a radius greater than 0.75 meters (2.5 feet) and/or be capable of operating in an inverted or suspended mode.

2) The robot must be capable of handling a seven kilogram (15 lb) payload and a 20 N-m (180 in-lb) torque at the tooling face plate.

3) The robot must be able to make a straight line move of 0.9 meters (36 in) in a horizontal plane.

4) The robot must have the articulation and range of motion to reach into multiple 55 gallon drums arrayed in the robot's work envelope.

The robot that met the above criteria was the American Robot MR-6200. It is shown in Fig. 2. It is a six degree of freedom, anthropomorphic, industrial robot. Its payload capacity is 9.1 kg (20 lb). It is capable accelerating this payload to velocities of 1.5 m/s (5 ft/s). It has a repeatability of +/- 0.025 mm (0.001 in). The robot controller is based on a Motorola 68000 processor. The system has ample analog, digital and RS-232 I/O ports for controlling peripheral subsystems. The MR-6200 is capable of making coordinated straight line moves. It can also perform routines relative to user defined coordinate systems (i.e. translated and/or rotated coordinated axes). The robot is able to operate in an inverted or gantry mode as well.

The End Effector

The ABOS end effector was custom designed at Los Alamos (see Fig. 3). The design goals of the gripper were two fold: design it such that it will not tear the plastic bag and make it fail-safe such that it will not drop a can.

When the robot reaches into the port to extract a waste can, the end effector impinges on the plastic bag. The end effector draws it into the port back to an awaiting waste can. To minimize the risk of rupturing the plastic bag, the gripper jaws were designed to contact the bag with large and well rounded surfaces. This reduces stress concentrations experienced by the bag. The robot was cycled 70 times through the "reach in the port - grab the can - retract with the can" routine. This routine was repeated on the same portion of bag. There were no detectable ruptures in this area of the bag.

The typical robotic end effector is dependant on an external power sources to provide its gripping force, be it pneumatic, hydrulic or electrical. In the event of a power failure, a gripper dependant on external power sources are susceptible to losing grip force and dropping an item that may be in its grasp at the time. To avoid this problem, the ABOS gripper relies on mechanically stored energy, in the form of springs, to provide the

Fig. 2. MR-6200 American Robot.

Fig. 3. Fail-safe gripper.

necessary gripping force. The ABOS end effector does employ the use of pneumatics, but only to open the gripper jaws.

Bag Sealing Device

The Bag Sealing Device (BSD) is the single most important piece of equipment in the ABOS. Its function is to insure that the glove box is not breached, and that the bag out item is isolated in a bubble of plastic for safe deposit into a waste drum.

The BSD's work area is between the front end of the bagout port and the back end of a retracted waste can as shown in Fig. 4. Upon a signal from the robot controller, the BSD begins to neck down the bag between the can and the port. The bag is constricted down to a cross-sectional area of roughly 6.5 cm^2 (1 in^2). At this point, four aluminum clips are loaded in parallel track ways. The track ways conduct the four clips from the clip magazine to the area where the bag will be sealed. A ram drives the legs of the "U" shaped clips past the necked down section of bag. Then the four clips are simultaneously driven into dies that fold the legs of the clips tightly around the plastic. Four sensors embedded in the track ways detect whether or not the four clips did indeed get loaded and driven into the dies. If the senors relay a positive signal, the bag is cut between the inner most clips. The BSD then releases the bag. The waste item is now encapsulated and detached from the glove box. The envelope of plastic is closed at each end by a pair a clips as shown in Fig. 5. The robot then places the can in a disposal drum.

Force/Torque Sensor

A force/torque sensor is an "off the shelf" device that is capable of sensing forces and torques, and resolving them into components relative to user defined coordinates. These sensors are normally mounted between the robot face plate and the end effector. They can be programmed to send a warning signal if a predefined force or torque threshold is exceeded. This is the function that the JR3 Force/Torque sensor will serve in the ABOS.

The ABOS robot places cans, in succession, into a drum as they are bagged out from the glove box. The ABOS will not be able to immediately sense if the cans in the barrel move or shift from the location where the robot deposited the item. In the event that a can shifts within the barrel, there is a possibility that the robot will try to place the subsequent can into the space occupied by the shifted can. If a can has indeed shifted and is trespassing in the space designated for the next waste can, the force/torque sensor will sense a "non-normal" force and/or torque when the cans touch. To avoid damage to the waste cans, the robot will immediately retreat, and then make a pre-programmed evasive action

Fig. 4. Relative position of the Bag Sealing Device.

to try and place the can elsewhere in the drum. If the robot is unsuccessful at doing so, it will signal the operator to intervene.

The force/torque sensor will be updated with different "threshold" forces and torques through out the entire bagout cycle. This will allow the system to detect any other possible spurious conditions that may occur within other parts of the bagout routine as well as when placing waste cans into the barrel.

INTRA GLOVE BOX AUTOMATION

The second phase of the ABOS project involves automation within the glove box.* The objective of the intra glove box automation is to determine whether the waste items meet the criteria for a bagout and then to successively present these certified waste cans to the bagout port such that the American Robot is able to grasp the container. The intra glove box equipment will consist of a custom designed gantry robot with an appropriate end effector, a bar code reader and a thermal neutron counter.

As waste material is generated at the Plutonium Facility, it is transferred to the bagout glove box for storage. The cans are placed in predefined positions determined by a

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*At the date of this writing, preliminary designs of the intra glove box equipment have been completed. However, none of the equipment has been fabricated. The current designs are subject to modification. Any changes to the design of the equipment described herein will be orally noted when this paper is presented at the ANS International Topical Meeting on Remote Systems and Robotics to be held March 29 - April 2, 1987.

Fig. 5. Encapsulated waste can.

template on the glove box floor. As the waste containers are introduced to the bagout glove box, the gantry robot picks up a can and identifies it by passing it by a barcode reader. The robot then places the can in the thermal neutron counter (TNC) to determine the amount of nuclear material contained in the item. The robot retrieves the waste can and, depending on the results of the TNC, places it in an acceptance rack or a rejection rack. This process continues until all the incoming cans have been characterized and segregated. This operation is performed autonomously and does not rely on the concurrent operation of the bagout robot. For the most part, the waste cans will be counted during off hours. This will allow the TNC to perform a longer count for a more accurate measurement.

When enough waste cans have accumulated in the acceptance rack, the bagout equipment is used to extract them. This operation is continuously monitored and controlled by technicians from a remote site. The gantry robot selects the cans from the acceptance rack. It then verifies the item with the bar code reader. The gantry robot then positions the can at the back of the bagout port and positions it such that the bagout robot is able access it via the port. After having relinquished the can to the bagout robot, the gantry robot retrieves another can from the storage rack. This cycle continues until the length of plastic bag on the port is exhausted. Operators then enter the area to manually replace the bag. The cycle is continued until the waste cans within the glove box have been exhausted.

Intra Glove Box Gantry Robot

The constraints that were defined for the intra glove box can manipulation robot were as follows:

1) The robot must be capable of accessing the entire floor space of the glove box.

2) The robot cannot have a work envelope that extends beyond the physical extents of the glove box.

3) The robot must be able to lift a weight of seven kilograms (15 lbs) and have a rotational torque of 20 N-m (180 in-lb) availible at the end effector's wrist.

A market search was done to find a commercially availible robot that could satisfy the above constraints. None were found

A decision was made to design and build a custom gantry robot that would meet the above criteria. A gantry robot configuration was selected because it is physically conducive to the interior of a glove box. The limits of travel are confined within the support structure of the robot itself. The possibility of the gantry robot breaching the glove box by striking a window or puncturing the skin of the box is practically nil. A gantry type robot also leaves the floor space of the glove box open for other manual operations when the robot is not in use.

The robot has three cartesian spacial axes. The Z axis (the vertical axis) is mounted on a fixed boom. The end effector travels up and down the length of the boom. This is atyipical of most gantry type robots. On most conventional gantry robots, the end effector is fixed to the end of a boom that moves up and down. This neccessitates an equal amount of open space above robot (equivilant to the robot work envelope) to avoid collisions when the boom is retracted. The fixed boom eliminates the need for space above the robot. This minimizes the size and cost of the glove box required for this application. However, the boom will always protrude into the work envelope of the robot. Care must be taken to avoid striking any obstacles within the glove box. To minimize this problem, the boom was designed such that its lower end will clear any one gallon cans resting on the floor of the glove box. The three cartesian axes are driven by stepper motors, via ball screws. The robot will be capable of performing coordinated moves (i.e. straight line motion). The repeatability will be plus or minus .12 mm (0.005 in). Its maximum velocity will be 25 cm/sec (10 in/sec). The robot will be capable of dead lifting 23 kg (50 lbs) and will have the required wrist torque.

The gantry robot end effector will grasp the one gallon cans end on. The end effector will have a yaw axis that will be able to rotate the can such that its central axis is in a horizontal plane. The yaw rotation will enable the gantry robot to place cans in the storage racks and to also orient the one gallon cans such that the bagout robot can grab them via the port.

The gantry robot will be controlled by a multiple axis indexer. The indexer, manufactured by Compumotor Corporation, will receive ASCII instructions from the bagout robot controller. The indexer will translate the instructions and command the stepper motors to move accordingly. Incremental optical encoders, mounted on each axis, will monitor the execution of the commands.

Bar code reader

The bar code reader will be a commercially available model. It will be mounted outside the glove box. The reader will peer through the glove box window to the barcode label affixed to the waste can. The gantry robot will present the bar coded cans to the bar code reader at the window. The control system will associate the number to the information that is about to be gathered by the TNC on the material within the can. The system will remember where the can is placed on the storage racks and retrieve it when it is time to be bagged out. The bar code will be read again to verify that it has the item that the system intends to bagout.

Thermal Neutron Counter

The thermal neutron counter will determine the amount of nuclear material contained in the waste can to insure that the item meets the discard limit. The TNC will be controlled by an IBM personal computer. The counter information will be retrieved and stored until the data is requested. The TNC will be software calibrated for each particular waste stream of material currently being counted.

REMOTED CONTROL STATION

To achieve the goal of reducing personnel radiation exposure, the system operators will be located in an area outside of the bagout room. All the control systems necessary to operate the ABOS will be remoted to this site. The equipment that will compose the remote station consists of the American Robot controller and associated terminal, video monitors, a warning light panel and an acoustical speaker. The operator will not have a direct view of the ABOS. The emphisis in developing the remoted control area will be to give the operator has much information as possible so that the ABOS can be operated safely.

The software for the ABOS is written with numerous "software stops" or break points. These break points occur at critical steps in the bagout routine. At each break in the routine, the operator analizes the situation from the given information supplied to him. When the operator is satisfied that all is well, he signals the ABOS to continue until the next break point, all the while monitoring the warning light panel and viewing the system via the monitors. The technicians will have the capability of arresting the robot motion at any time. The operator also listens to the ABOS. A microphone in the immediate area of the ABOS to allow the technician to hear the system and detect any abnormal sounds indicating a problem.

SUMMARY

As stated earlier, the primary goal in automating the bagout procedure is to reduce the relatively high exposures received during a typical manual bagout. The system will also eliminate the possibility of an individual becoming contaminated, internally or externally. Even though the probability of ingesting any airborne contaminants is remote, the concern exists. If a contamination release does occur during an automatic bagout routine, the situation can be evaluated and proper measures can be taken to rectify the problem without the initial danger to personnel.

The system will also simplify records keeping of the waste items by automatically documenting counts performed by the TNC. The ABOS will also keep track of which waste items were grouped together and bagged out into a given drum.

A further advatage is the enhanced working conditions of the technicians who now perform the bagouts manually. The current manual bagout operation is a hands and knees procedure beneath a glove box. The manual bagout operation is an undesirable job that most technicians would prefer not to do.

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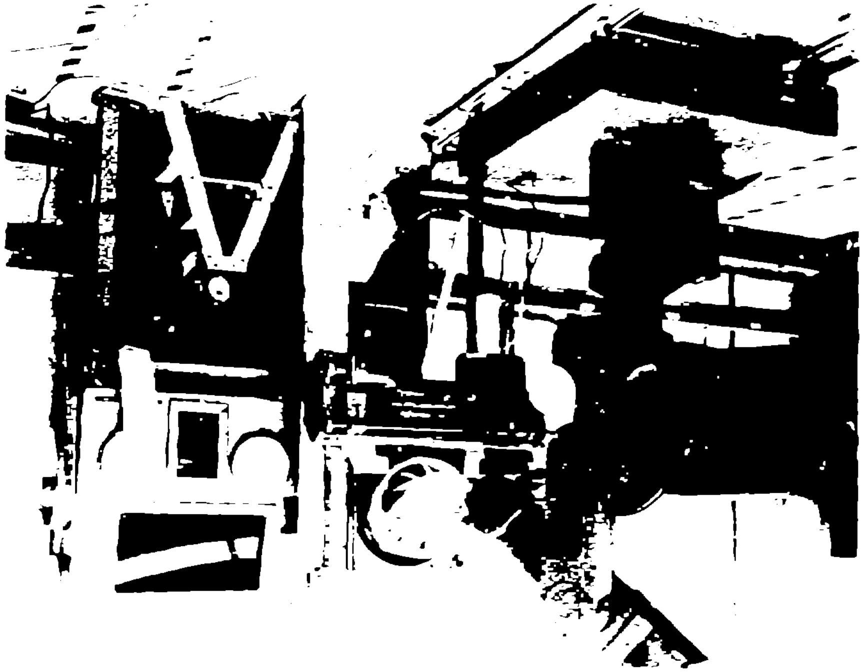

Fig. 3

Fig. 4

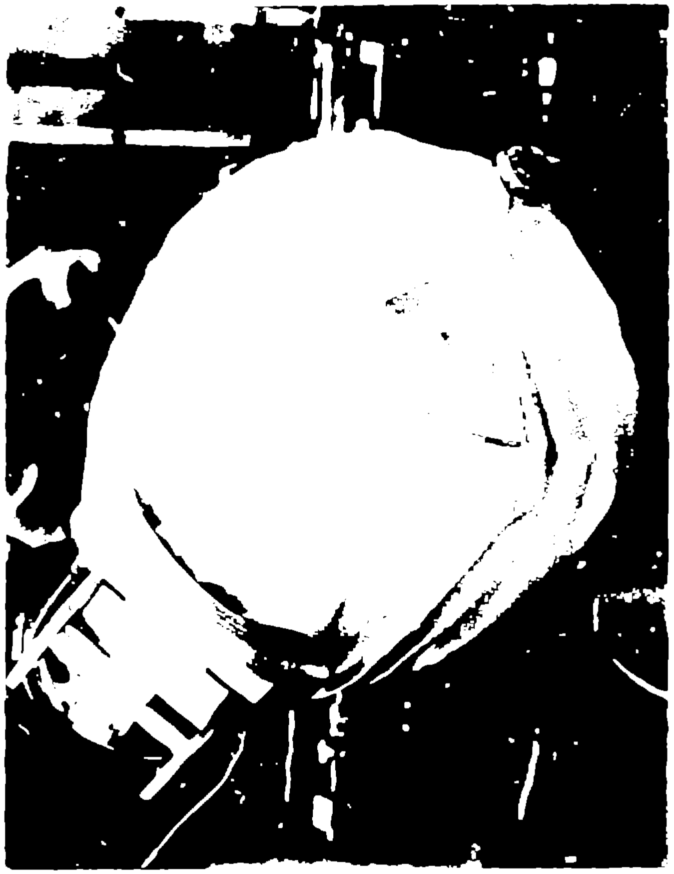

Fig. 5.