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AUTOMATED SYSTEM FOR HANDLING TRITIATED MIXED WASTE

ABSTRACT

Lawrence Livermore National Laboratory (LLNL) is developing a semi-automated system for handling, characterizing, processing, sorting, and repackaging hazardous wastes containing tritium. The system combines an IBM-developed gantry robot with a special glove box enclosure designed to protect operators and minimize the potential release of tritium to the atmosphere. All hazardous waste handling and processing will be performed remotely, using the robot in a teleoperational mode for one-of-a-kind functions and in an autonomous mode for repetitive operations. Initially, this system will be used in conjunction with a portable gas system designed to capture any gaseous-phase tritium released into the glove box. This paper presents the objectives of this development program, provides background related to LLNL's robotics and waste handling program, describes the major system components, outlines system operation, and discusses current status and plans.

INTRODUCTION

Approximately 2,000 mixed and low-level waste containers listed on the LLNL Hazardous Waste Management database contain quantities of tritium ranging from about 10^{-6} µCi to about 5,000 Ci. These items are stored in various containers such as DOT 7A boxes, 55-gallon drums, and carboys. In many cases the physical status of the stored waste is unknown. Therefore, to properly characterize the waste for either treatment on site or shipment off site, LLNL has been developing various methods for examining the contents of the waste containers. Some of the non-obtrusive methods being developed are real time radiography, digital radiography, and active and passive computed tomography. Also, head space gas sampling techniques are being developed to determine types and quantities of gases inside 55-gallon waste drums. But in addition to these methodologies, LLNL determined that a facility was needed that could provide a safe method for opening containers, in a sealed environment to minimize any chance for release of tritium gas to the environment. Opening containers is necessary to obtain quality assurance data in support of non-obtrusive methods, to separate and repackage mixed and hazardous wastes for shipment and disposal, and to examine the contents of those containers that cannot be identified by other means.

The short-term objective of this program is to provide a practical tritium legacy waste handling and characterization system incorporating existing LLNL-developed robotics and tritium processing technology. The long-term objective is to demonstrate that a glove box/robotics system can be used reliably to perform other types of U. S. Department of Energy (DOE) hazardous or mixed waste handling, processing, and characterization functions.

This development effort is being sponsored by both the DOE Waste Management Program (EM-30) and the DOE Office of Technology Development/Robotics Technology Development Program (EM-50). The overall project is being managed by the LLNL Environmental Protection Department's Hazardous Waste Management Division, which will also own and operate the system after it has been completed.

The LLNL Environmental Technologies Projects/Robotics Section is responsible for supplying the robot and controller, checking out the robot system, developing the operational software, and defining the design criteria for the control console and robot interface. It is also responsible for managing the robot controls and manipulator hardware procurement contract that was placed with the IBM Corporation in August 1993.

The LLNL Tritium Facility Projects Group has responsibility for designing and fabricating the waste processing enclosure and associated support systems. This includes design of the glove box and container handling tools, robot integration, building layouts, tritium monitoring, and tritium processing using an existing portable tritium processing system.

BACKGROUND

DOE and LLNL have been developing glove box automation technology for Defense Programs and Environmental Restoration and Waste Management (ER &WM) activities over the last four years. The work has been focused largely on a collaborative effort with the IBM Corporation to adapt an existing commercial robot system to perform glove box processing applications. Initial developments were funded as part of LLNL's Special Isotope Separation program. Later funding was continued through DOE Headquarters, Office of Technology Development, Robotics Technology Development Program. Several demonstration glove box/robotic facilities have been in operation at LLNL since April 1991. One system, developed as an automated nuclear material processing system, combined technological advances in robotics with an advanced pyrochemical processing furnace. Another system was used to demonstrate fully automated, remote disassembly of nuclear weapon components and surface decontamination of surrogate lead material. Both of these demonstration test beds utilized an existing IBM Series I autonomous controller. Current robot technology development has been focused in two areas: the development of an improved controller (dubbed the Series II) to replace the now obsolete IBM Series I controller; and the development of a more robust manipulator (higher lift and torque handling capacities) for handling of hazardous waste.

In May of 1993 these robot technology development areas were combined with LLNL's tritium legacy waste removal project, and a cooperative effort of the Environmental Technologies Projects/Robotics Section, the Hazardous Waste Management Division, and the Tritium Facilities Projects Group was initiated. The effort consists of developing, fabricating, installing, and operating a system to open the LLNL legacy waste containers suspected of retaining quantities of tritium; the system will use developed robotics technology in conjunction with an existing LLNL-developed portable gas treatment system.

SYSTEM DESCRIPTION

Robot Manipulator

The robot manipulator is a gantry system that was originally designed by IBM for use in large-scale manufacturing operations at both the IBM and Ford Motor Company assembly plants, where it has a proven record of reliability and performance. The robot manipulator is suspended from two rails that are mounted on each side of the system glove box and extend along its entire length. For this application, modifications were made to the robot manipulator to maximize its vertical travel while minimizing required overhead space for the vertical mast (i.e., minimize required glove box height and volume) and to allow it to lift heavier loads. The robot is able to reach 1.07 m (42 in.) down into a DOT 7A type storage box (nominally 1.07 m deep, 1.17 m wide, and 2.18 m long [3.5 ft × 3.8 ft × 7.2 ft]), grasp objects that weigh up to 27 kg (60 lb), and lift them out of the box and onto a working surface inside the enclosure. The robot pitch axis can handle torque loads of up to 34 N·m (25 ft-lb).

The robot manipulator has six degrees of freedom, three linear and three rotary. The primary linear axis (Axis 1) allows the robot to move back and forth a total of 7.16 m (282 in.) in the direction parallel to the length of the glove box. This axis consists of a truss structure mounted perpendicular to the two glove box rails and supported at each end by roller bearings that ride on the rails. The truss structure is designed to maintain absolute orthogonality with respect to the gantry rails. Axis 2 allows movement of the robot manipulator in a direction perpendicular to the glove box length (back and forth across the glove box) for a total travel of 0.69 m (27 in.). This is done by means of a carriage assembly (dual joint) that supports a vertical axis (Axis 3B) and rides back and forth on a cross bar attached to the Axis 1 truss. Vertical movement of the manipulator is accomplished by using two different third-axis systems. Axis 3A consists of two synchronized motors mounted on each end of the truss structure. These motors drive the Axis 2 cross bar and dual joint assembly up and down for a vertical travel of 1.07 m (42 in.). Axis 3B consists of a motor that drives a single vertical bar up and down the Axis 2 dual joint for a vertical travel of 0.46 m (18 in.). The combination of Axes 3A and 3B motions allows the robot manipulator to have a total vertical travel of 1.53 m (60 in.). Pressurized gas cylinders are used to counterbalance the weight of each of the vertical axes, thereby requiring the Axes 3A and 3B motors to support only the weight of lifted process components. Figure 1 is a sketch of the robot manipulator assembly showing only the linear axes (the gimbal with the rotary axes is not shown).

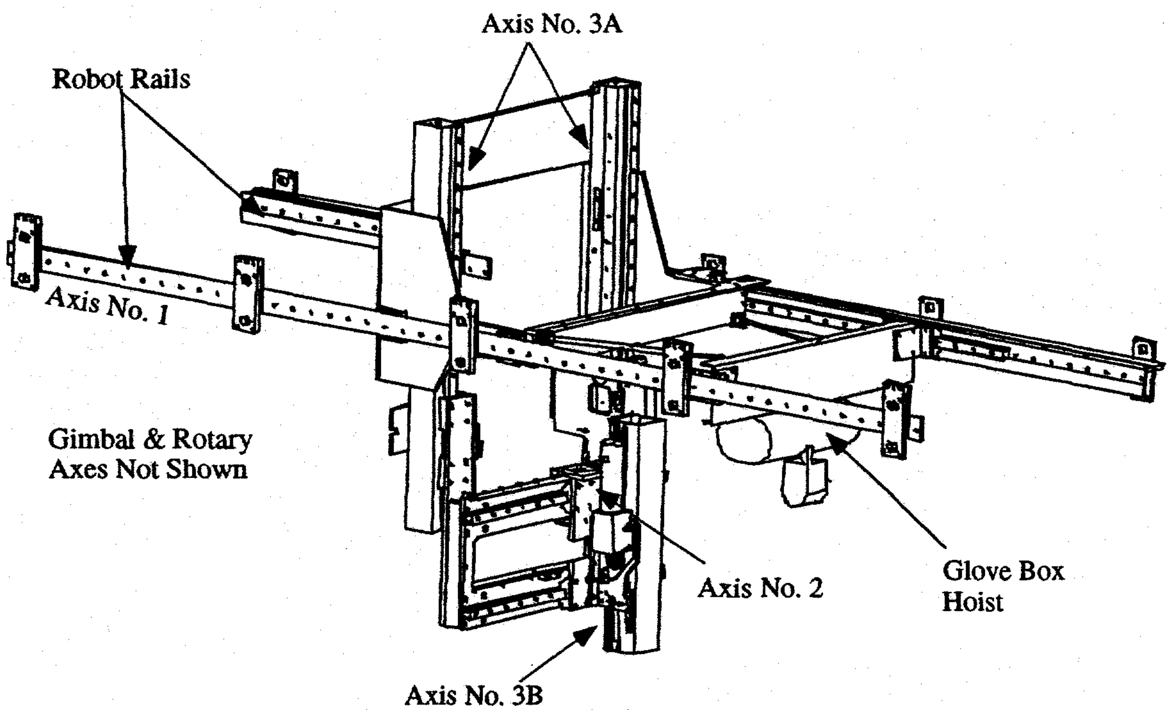

Figure 1. Robot Manipulator (Linear Axes Only)

A gimbal assembly is mounted on the bottom of the Axis 3B vertical bar and supports all three rotary axes motors. The yaw axis (Axis 4) allows the entire gimbal assembly to be rotated through a total of 360° of motion. The pitch axis (Axis 5) allows the robot gripper to be swiveled up and down through a 180° arc. The roll axis (Axis 6) allows the robot gripper itself to be rolled through a total of 360° of rotation. An air-operated, quick disconnect end effector is used to hold specially designed grippers that can be picked up from a storage rack as needed to perform the various tasks.

Two television cameras are mounted on the robot arm. One is at the upper level of the carriage assembly (dual joint) of the robot. It provides a field of view directly down the vertical axis (Axis 3B) to assist the operator in orienting the gimbal inside a waste container. The other camera uses a fiber optic light pipe mounted down at the robot gimbal, just above the gripper. This camera can be used by the operator for observing detailed, close-in operation of the gripper. In addition to these cameras mounted on the robot, two other cameras with wide fields of view are mounted at each end of the glove box enclosure for overall viewing of the operation.

Robot Controller

A new Series II controller is being developed by IBM and LLNL for use with this facility. This controller will have the capability to allow both teleoperational (operator-driven) and autonomous (pre-programmed) control of the robot. An integral part of this capability will be a seamless mode transfer feature that will enable the operator to transfer easily between the teleoperational and autonomous modes of robot control and select from an ensemble of established robot programs to accomplish specific, well-defined tasks. Only general information describing the controller is presented here. More specific details related to the robot controller design are outlined in Merrill et al. (1).

The robot controller system consists of a computer workstation, an operator console, and an annunciator console. The workstation consists of electronics racks containing an IBM RISC 6000 computer, a power control unit, and a robot controller. The station will be used by an experienced computer/robot programmer to develop detailed autonomous robot motions with simulation software as well as perform some limited operational teaching of the robot. The workstation and all the electronics are in racks located next to the glove box and are connected to the robot through a conduit channel from the racks to the top of the glove box. Additional control cables run through a flexible line between the workstation racks and the operator console.

The operator console is an assembly that has been designed to be moved back and forth along the length of the glove box as required during robot operation. This console contains a force ball manipulator for performing telerobotic functions, two television camera monitors, gripper controls, hoist system controls, emergency power shutdown (crash) switch, and a computer terminal monitor. This console is tethered by flexible cable to the stationary robot work station racks described above. A sketch of the operator console is shown in Figure 2.

The annunciator console contains all the alarm panels and interlock devices for the overall robotic/glove box system. A programmable logic controller is used to monitor and control all the various alarms and interlocks.

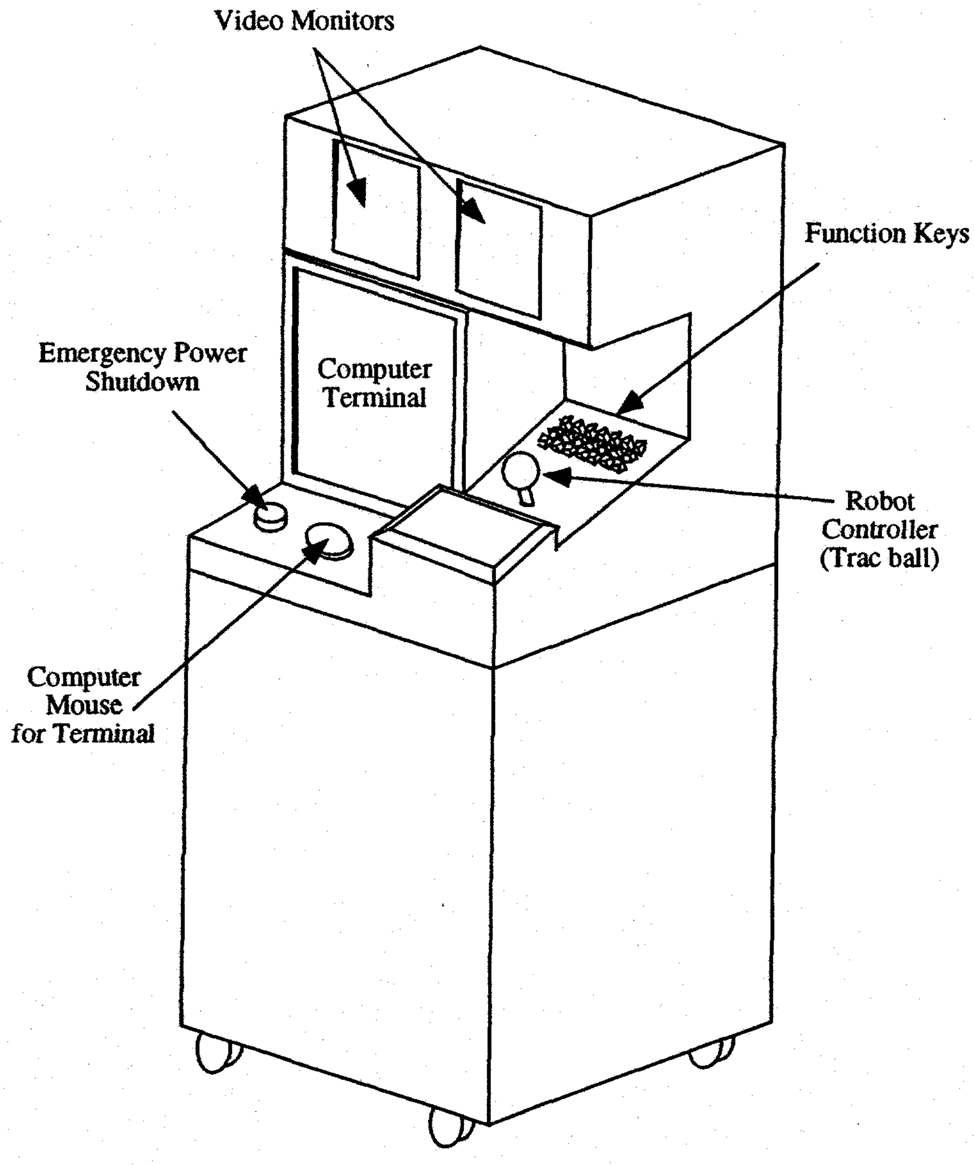

Figure 2. Operator Control Console

Enclosure

An enclosure is being built to accommodate the robot and to be compatible with tritium handling considerations. The enclosure has been designed to hold two DOT 7A storage boxes, one on each end, separated by a working surface at gloved worker level. An overhead hoist, which is attached to the robot truss structure and is supported by the robot rails, will be used to lift items that weigh more than the 27-kg (60-lb) limit of the robot. Feed-throughs are provided to accommodate the connections from the robot controller, the portable tritium gas treatment system, the video cameras, and other various support equipment inside the glove box. Various other tools and grippers are provided to accomplish specific unloading and decontamination tasks.

The enclosure itself consists of a glove box approximately 8.23 m long, 1.52 m wide, and 3.05 m high (27 ft × 5 ft × 10 ft) containing the gantry robot and the various tooling required to support the waste characterization and handling procedures. This system will be built in three modular sections in order to make it transportable for hazardous waste treatment operations at other facilities.

The center section is about 3.81 m (12.5 ft) long and contains a waist-high work table for sorting and characterization activities and a pass-through chamber that is sized large enough to allow an entire 55-gal drum to be inserted into the glove box. Attached to each end of this center section are two 2.13-m (7-ft)-long, full-height end sections. These end sections contain sealed doors which, when open, allow a full-size DOT 7A waste storage container to be passed into the glove box. Glove ports are located in enough locations in the enclosure walls to allow an operator to reach all critical points inside the glove box. Two wide-angle television cameras are mounted in each end of the glove box to assist the operator in maneuvering the robot arm. A sketch of the enclosure is shown in Figure 3.

The enclosure is designed to be operated in a closed mode with no detectable leaks greater than 1×10^{-12} m^3/sec (helium). Operation will be in the closed mode when the possibility exists for tritium levels inside the enclosure to be greater than 0.1 Ci/m^3. A portable abort system, which uses an evacuated abort tank, will be used to manage overpressure conditions without requiring venting to the building stack. The internal atmosphere of the glove box can be either air or nitrogen.

The enclosure can also be operated in a fume hood mode by opening one of the end doors. This is only allowed when tritium levels are less than 3 mCi/m^3. In this mode, a gate valve is opened and ventilation to the building stack is maintained at 38.1 linear meters per minute (125 linear feet per minute).

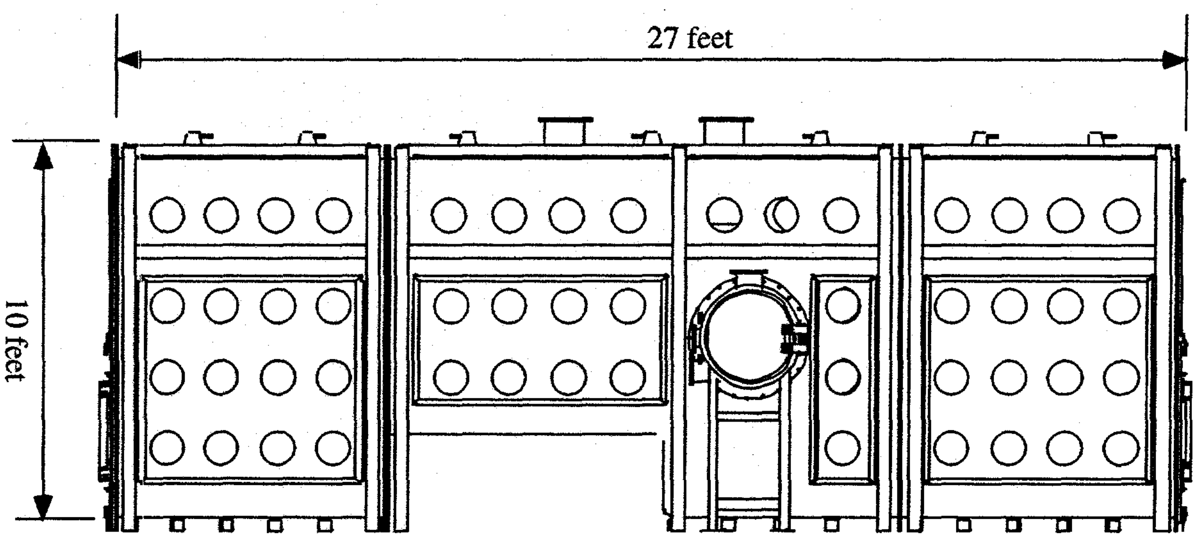

Figure 3. Robot Enclosure/Glove Box

Tritium Processing System

The portable tritium processing system will be used with this robotic/glove box system to process any tritium that may be released to the glove box atmosphere during container handling. The processing system was initially designed and developed to remove tritium from the LLNL Tritium Facility. It consists of three modules/carts that accommodate the hardware necessary to perform the various tritium processing functions.

The operations performed by the system include: oil-free pumping, oil-free gas transfer, gas analysis, and gas-phase tritium scrubbing. The system is completely self contained. Gas samples are analyzed with the on-board partial pressure analyzer. Gases containing tritium are passed through a catalytic oxidation system that converts the tritium gas to tritiated water. The tritiated water is then captured on molecular sieve dryers which are ultimately disposed of at an appropriate low-level radioactive waste site.

The tritium processing system is operated through a programmable logic controller and system status is displayed on a CRT. All pertinent information is displayed and easily accessible to the operator. More detailed information on the system is outlined in Reitz et al. (2).

SYSTEM OPERATION

The robot/glove box can handle both DOT 7A storage boxes and 55-gal drums of hazardous or mixed waste. Typical DOT 7A storage boxes at LLNL are made from steel and have outer dimensions 2.18 m long, 1.17 m wide, and 1.07 m deep (86 in. × 46 in. × 42 in.), for a total of 2.71 m^3 (96 ft^3). The box lids are attached with clips held on by special catches on the sides and lid of the box. Each box weighs about 286 kg (630 lb) when empty and can hold up to 2,270 kg (5,000 lb) of waste. The drums are standard 55-gal drums that are 0.88 m (34.5 in.) high and 0.57 m (22.5 in.) in diameter.

Before loading the DOT 7A box into the enclosure, the lid clips are replaced with temporary lid clamps. The box is then manually loaded into the enclosure on conveyer rollers mounted on the floor. If desired, several waste drums can be loaded into the glove box in place of a DOT 7A container. The robot/glove box is operated in the ventilated hood mode when containers of tritiated waste are being loaded into the system. In this mode, the exhaust gas is released through HEPA filters to the facility stack and either one (but not both) of the end doors can be opened. After the waste container(s) is inserted, the enclosure door is shut and the entire system is converted to the isolated glove box operational mode by closing the gate valve to the building ventilation system.

Once the system is in the isolated glove box mode, the lids are removed from the waste container (the 55-gal drums or the DOT 7A box) either manually through the gloves or, if the operation is straightforward and there are no unforeseen circumstances, by using the robot. The robot in the teleoperational mode can enter the waste container, remove the various waste items, and transfer the items to the glove box work table for subsequent characterization and sorting. Any accidental release of tritium gas to the enclosure would be detected, removed, processed into tritiated water, and trapped on the molecular sieve that is connected to the glove box through the umbilical line. The tritiated and mixed waste items would be sorted and repackaged in new containers, as required, for off-site treatment and storage.

Autonomous functions would be programmed to allow the robot to perform operations that are routine and repeatable. These functions would include, for example, removing waste container lids and storing them within the glove box, weighing items on a scale, decontaminating the inside of the glove box, and loading the sorted waste into the new containers. One-of-a-kind operations such as container unloading, waste sorting, and container reloading will be performed in real time in the telerobotic mode.

STATUS AND PLANS

The robot and controller are currently being fabricated and assembled by IBM Corporation in Austin, Texas. The checkout and acceptance tests on the robot and controller are scheduled for March/April 1995 in Austin; the complete robotic system is scheduled for delivery to LLNL during April 1995. Initial plans are to assemble the robot inside a structural framework and perform system testing and operator training while awaiting completion of the glove box enclosure assembly.

Design, fabrication, and assembly of the glove box enclosure are scheduled for completion during the first calendar quarter of 1996. The glove box will be fabricated by an appropriate glove box vendor to LLNL specifications. It will be shipped to LLNL and installed in a selected facility by November/December 1995. Installation of the robot and other systems into the enclosure should be completed by February/March 1996. Initial operation and check out of the entire system is expected to be initiated in March 1996 with full operation scheduled for July 1996.

Future plans include the development of equipment to allow processing and treatment of low-level radioactive wastes and reactive hazardous wastes. Other plans are to use the system for size-reducing radioactively contaminated equipment. The system could be used to handle or open any container or piece of equipment that potentially could contaminate the environment if opened under non-contained conditions.

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