MATERIAL HANDLING FOR THE LOS ALAMOS NATIONAL LABORATORY NUCLEAR STORAGE FACILITY

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ABSTRACT

This paper will present the design and application of material handling and automation systems currently being developed for the Los Alamos National Laboratory (LANL) Nuclear Material Storage Facility (NMSF) renovation project. The NMSF is a long-term storage facility for nuclear material in various forms. The material is stored within tubes in a rack called a basket. The material handling equipment range from simple lift assist devices to more sophisticated fully automated robots, and are split into three basic systems: a Vault Automation System, an NDA Automation System, and a Drum Handling System. The Vault Automation system provides a mechanism to handle a basket of material cans and to load/unload storage tubes within the material vault. In addition, another robot is provided to load/unload material cans within the baskets. The NDA Automation System provides a mechanism to move material within the small canister NDA laboratory and to load/unload the NDA instruments. The Drum Handling System consists of a series of off the shelf components used to assist in lifting heavy objects such as pallets of material or drums and barrels.

I. INTRODUCTION

The Nuclear Material Storage Facility (NMSF) is an existing facility at Los Alamos National Lab (LANL) currently under renovation. The facility was built by the Corps of Engineers and occupied in 1987 but material was never stored there due to design and construction deficiencies. The NMSF Renovation project is currently in the Title I Conceptual Design Phase and is scheduled for completion in the year 2003.

The NMSF is a long-term storage facility and is capable of storing 6.6 Metric Tons of material and up to 4.4 kg per container. The material enters the facility at the Loading Dock and is then distributed throughout the facility as seen in Figure 1. Material is stored within the facility in the form of bulk material or in the form of pit parts. The bulk material is stored within 3013 approved canisters within deep wells called drywells. Pits or components are stored in another area within their shipping container or containment vessel.

The material handling within the facility varies greatly from manual lift assist devices to full robot systems. The goals in the Title I work to date have been to define requirements,
define a baseline design and to begin the selection process. The requirements definition includes all operations and requirements such as tasks, payload, workspace, safety, and interfaces. A baseline design was required for each individual system and the selection process was started to ensure that the systems were reasonable.

**Figure 1:** Material Flow within the NMSF. Lines with arrows represent movement and boxes represent operations or stations.
The material handling systems are broken into three categories within NMSF. The Vault Automation Systems are automation systems that move material in and out of the drywells. The NDA Automation System is a robot that moves material within the NDA laboratory. The Drum Handling Systems are manual pieces of equipment that provide lift assistance for moving heavy objects throughout the facility.

These material handling systems are required due to the difficulty of the tasks as well as the environment constraints. Most of the systems provide a mechanism to minimize worker exposure to radiation. This is discussed in detail later. In some cases, the equipment is required to provide lift assistance for heavy or unmanageable material. Material throughput is optimized by allowing for autonomous, unattended operation where necessary. Operator safety is improved by allowing the tasks to be performed from some distance.

The general approach to automation in this project is to take advantage of existing technologies as much as possible in order to minimize system costs. This includes both installation cost as well as the long term operating cost. Off the shelf equipment and technologies are used where possible. In addition, operations are consolidated where possible and consistent controls design is used to reduce operations costs.

This paper is organized as follows. Sections II, III and IV discuss the Vault Automation, NDA Automation and Drum Handling Systems accordingly. Section V provides some detail on the operator exposure estimates. This section was originally presented up front as it is one of the justifications of using automation. It is presented here at the end of the paper, however, as it is easier to discuss the operations after a thorough description of each task is given. Finally, some concluding remarks are made in Section VI.

II. VAULT AUTOMATION SYSTEMS

This section presents the design and operation of equipment used to load and unload the material stored within cans. The material cans are stored within deep wells called drywells. The array of these drywells is considered the vault and is shown in Figure 2 along with the Vault Automation Systems.

Material is stored within 3013 approved material cans that are approximately 5 inches in diameter and 10 inches tall. Up to five material cans are placed within a Drywell Basket as seen in Figure 3a. The cans are held in place with three springs as shown. Two of the baskets are then placed within the drywell followed by a plug as seen in Figure 3b. The baskets ensure that the cans maintain the required spacing and are simply stacked while in the drywell.
The Vault Crane system provides the mechanism to load and unload the drywell plug and baskets. It is essentially a gantry crane with a 2000 lb capacity. However, there were some design details that make the design unique. This is an automated system that is required to operate in a room with minimal operator assistance in most cases. Several designs were considered to address an anti-swing requirement. These included both using the controller to minimize swing as well as telescoping tubes to guide the endeffector.
The final design chosen may be seen in Figure 4 and consists of a gantry crane that uses a mechanical Constraint Tube.

**Figure 4:** Vault Crane shown lifting a Drywell Basket.

**Figure 5:** Vault Crane operation sequence removing Drywell Plug.
This approach allows the crane to be simple and cost effective in that it requires little change or deviation from existing gantry crane technology. With this approach, all horizontal motion is performed with the crane endeffector captured within the Constraint Tube as seen in Figure 5.

The crane endeffector is essentially a tube that fits snugly within the drywells that are approximately 17 inches inner diameter. The Constraint Tube is approximately the same size. A pneumatic gripper is located in the bottom of the endeffector to pick up the plug or basket. In addition, the endeffector may contain a Continuous Air Monitor (CAM) to sample the air around the drywell as it is opened.

To retrieve material, the Vault Crane removes the Drywell Plug and sets it aside, then moves a Drywell Basket to the Basket Loading Robot area. The basket is placed within a Basket Receptor that holds the basket in place. In addition, some instruments may be mounted to the Basket Receptor to perform confirmatory tests on the material cans. The Basket Loading Robot is a large, off-the-shelf, robot as seen in Figure 6.

Figure 6: Basket Loading Robot shown with three Drywell Baskets sitting within Basket Receptors and the Material Transfer Cart.
This robot removes a can from the basket with a side gripping endeffector, places the can on a table to change tools, then places the can in the Material Transfer Cart with a top gripping endeffector. The cart is standardized within the facility and provides a shielded platform to move material and is described later. The Basket Loading Robot controller is the stock controller shipped with the robot and requires no modification for implementation. Programming is relatively simple with the tools provided with the controller.

III. NDA AUTOMATION SYSTEM

The Nondestructive Assay (NDA) Laboratory provides a mechanism to perform measurements on material stored within the NMSF. The laboratory includes a gamma ray isotopic system, two calorimeters, and passive and active neutron counters. The NDA Automation System consists of a gantry style robot called the NDA Robot that moves material cans within the NDA Laboratory between instruments and the material staging area as seen in Figure 7.

![Figure 7: NDA Robot shown with NDA Instruments, the Material Transfer Cart, and material can staging areas.](image_url)

The NDA Robot is modeled after the robot used in the Advanced Retirement and Integrated Extraction System (ARIES) developed at LANL for decommissioning weapon pits. In addition, the robot makes it possible for the laboratory to be run attended to optimize material throughput.
The NDA laboratory is capable of measuring both 3013 cans as well as food pack cans since it uses an overpack can to provide consistency to the instruments. The overpack can is an oversized can into which all material is placed before measurement. After the cans are placed in the overpack cans, they are delivered to the NDA Laboratory using the Material Transfer Cart. The robot transfers all material to the NDA Staging Area from the cart which allows the cans to be identified. The robot is controlled by the NDA Laboratory Host Computer via a serial line. The host tracks all material throughout the measurements.

IV. DRUM HANDLING SYSTEMS

The Drum Handling Systems include a conventional gantry crane, drum storage racks, fork and drum lift machines, and the Material Transfer Cart. These smaller pieces of equipment are scattered throughout the facility and are all manually operated rather than automated. This section will focus on the storage racks and carts as the other equipment is conventional off-the-shelf equipment used in most warehouse operations.

The NMSF is required to store up to 80 Shipping Containers and 300 Inner Containment Vessels for FL containers, AT-400A, PC2, DT-22, and the Sealed Insert. These drums are held in an actively cooled vault with the Shipping Containers in one room and the Inner Containment Vessels in another room. The storage racks have three main requirements. The first is the quantity and various types mentioned above. This presents a challenging problem as the container types vary greatly in size, shape, and external features. The second requirement was to provide an open design to allow air to flow freely around the containers for cooling. The third requirement was to provide shielding to reduce exposure to operators while in the room. Figure 8a shows the two storage rooms with drums in the racks. Figure 8b shows the method with which the drums are stored in the racks.

![Figure 8a: Drum storage racks.](image1)

![Figure 8b: Drum storage basket.](image2)
Note that the racks shown give only a basic idea of the size and configuration but do not reflect the use of the Drum Basket. All containers are first placed within the Drum Basket then the basket is inserted into the rack and secured. This method satisfies the three primary design requirements as discussed above.

Several alternatives were discussed for moving material cans throughout the facility in a safe and cost effective manner that also addressed the operator exposure issue. A simple cart as seen in Figures 6 & 7 was finally selected as the method of transporting material. The cart shown is capable of holding five material cans. These cans may be 3013 cans or the NDA overpack cans. The shielding shown reduces operator exposure while working with the cart or moving material from one room to another. The docking feature (kinematic mount) on the floor allows the cart to be placed in any automated workspace with the required repeatability for a robot to retrieve the cans. Note that all carts are interchangeable so that any cart may be used at any station.

V. OPERATOR EXPOSURE ESTIMATION

One of the reasons for using automation in the NMSF is to reduce operator exposure to radiation while working within the facility. This section therefore presents some of the results of the study that was done to estimate the operator exposure without this automation. Note that this isn’t the only reason for using automation but rather an easily quantifiable one, which leads to this study. In addition, only the dose savings represented by the equipment presented in this paper is given, although there will be additional dose benefits not discussed here. The goal in this study was to compare the expected exposure with and without automation. Each of the operations discussed above were broken down into a sequence of steps with an estimated time and number of people required to perform the tasks. The estimate times are shown in Tables 1, 2, and 3.

<table>
<thead>
<tr>
<th>Vault Crane operation</th>
<th>Time (min)</th>
<th>Operation comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move crane to drywell plug</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Attach crane to plug</td>
<td>1</td>
<td>Both operators working</td>
</tr>
<tr>
<td>Move plug to set down</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Move crane to drywell</td>
<td>2</td>
<td>Both operators away from crane load</td>
</tr>
<tr>
<td>Attach crane to upper basket</td>
<td>2</td>
<td>Looking in well</td>
</tr>
<tr>
<td>Lift basket</td>
<td>2</td>
<td>Away from basket some of time</td>
</tr>
<tr>
<td>Move basket to loading area</td>
<td>4</td>
<td>Away from basket some, at basket some</td>
</tr>
<tr>
<td>Deposit basket in receptor</td>
<td>2</td>
<td>Both people working, holding basket</td>
</tr>
<tr>
<td>Move crane to drywell</td>
<td>2</td>
<td>Away from load</td>
</tr>
<tr>
<td>Attach crane to lower basket</td>
<td>3</td>
<td>Looking into well some</td>
</tr>
<tr>
<td>Lift basket</td>
<td>3</td>
<td>One person away from load</td>
</tr>
<tr>
<td>Move basket to loading area</td>
<td>4</td>
<td>Away from load</td>
</tr>
<tr>
<td>Deposit basket in receptor</td>
<td>2</td>
<td>Both people at basket</td>
</tr>
<tr>
<td>Unload material can</td>
<td>0</td>
<td>See basket loading estimate</td>
</tr>
</tbody>
</table>
Table 1: Vault Crane manual operations.

<table>
<thead>
<tr>
<th>Basket Loading operation</th>
<th>Time (min)</th>
<th>Operation comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place ladder/stool</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Remove retainer clip</td>
<td>2</td>
<td>Adjacent to full drywell basket</td>
</tr>
<tr>
<td>Retrieve material can</td>
<td>1</td>
<td>Adjacent, holding can or pass to another operator</td>
</tr>
<tr>
<td>Replace retainer clip</td>
<td>1</td>
<td>Adjacent to basket</td>
</tr>
<tr>
<td>Place can and replace ladder</td>
<td>1</td>
<td>Holding can</td>
</tr>
</tbody>
</table>

Table 2: Basket Loading manual operations.

<table>
<thead>
<tr>
<th>NDA Laboratory operation</th>
<th>Time (min)</th>
<th>Operation comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieve can from cart</td>
<td>0.5</td>
<td>Holding can on all operations</td>
</tr>
<tr>
<td>Load NCC instrument</td>
<td>1</td>
<td>Moving active NCC plugs</td>
</tr>
<tr>
<td>Unload NCC instrument</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Load Calorimeter</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unload Calorimeter</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Load SGS instrument</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unload SGS instrument</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: NDA Laboratory manual operations.

After a manual execution time was calculated for each operation, it was necessary to determine the number of operations expected on a yearly basis. This was completed for each operation.

In the case of the Vault Crane and the Basket Loading Operations: (1) 200 containers received per year, (2) 100 containers sent to other facilities per year, (3) 100 containers sent to 3013 surveillance per year. This adds up to a total of 800 per year including the reverse operations. This study assumes: (1) Two people are required for each of these operations, (2) Center drywells are accessed as this provides an average for the charge hall, (3) Both baskets may remain out during basket loading operations, and (4) Baskets remain out during 3013 can surveillance measurements.

In the case of the NDA Laboratory, it is assumed that the 200 containers received per year must be measured. This study assumes: (1) All instrument tests are performed on each can, (2) The NDA instruments may be modified from their current design to allow easy access to the wells, and (3) A staging area is not required as unattended operation is not possible with a manual system.

The estimated dose for each operation was then calculated. This was accomplished by calculating the dose for an individual can and may be seen in Figure 9. Then this information was applied to each manual operation, the times for the operation, the number of cans, the distance from the can, etc. This then gives a collective dose
equivalent per operation. The summary of the results may be seen in Table 4 for each of the operations discussed above.

![Graph showing Dose Rate (man-rem/hour) relative to the distance from the center of a material can (cm). Note that the 30cm data point given represents contact with the material can.](image)

**Figure 9:** Plot showing Dose Rate (man-rem/hour) relative to the distance from the center of a material can (cm). Note that the 30cm data point given represents contact with the material can.

<table>
<thead>
<tr>
<th>Manual Operation</th>
<th>Collective Dose Equivalent Per Operation (mrem)</th>
<th>Annual Frequency of Operations</th>
<th>Annual Dose Equiv. for each Operation (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vault Crane</td>
<td>21</td>
<td>800</td>
<td>16.8</td>
</tr>
<tr>
<td>Basket Loading</td>
<td>9.6</td>
<td>800</td>
<td>7.7</td>
</tr>
<tr>
<td>NDA Laboratory</td>
<td>12.6</td>
<td>200</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Table 4:** Individual doses for each manual operation.

The totals in Table 4 show that automation in the NMSF save approximately 27 man-rem per year. The LANL administrative requirement is to stay below 1.0 rem per year per person and the NMSF is currently expected to require six to eight technicians for operation. Using automation within the facility therefore represents a significant saving in operator exposure.

**VI. SUMMARY**
The NMSF is currently wrapping up the Title I design activities and will await word to start the Title II work this summer. The automation systems within the facility are interesting applications, but for the most part, do not require pushing the current state of robotics technology. Therefore, every attempt has been made to make these automation systems as simple as possible and to use existing industrial technologies. The automation is required for a variety of reasons including reducing operator exposure. In short, this is an interesting although relatively straightforward application of robotics and material handling technologies.

VII. ACKNOWLEDGMENTS

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