EQUIPMENT FOR THE HANDLING OF THORIUM MATERIALS

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ABSTRACT

The Feed Materials Production Center (FMPC) is the United States Department of Energy's storage facility for thorium. FMPC thorium handling and overpacking projects ensure the continued safe handling and storage of the thorium inventory until final disposition of the materials is determined and implemented.

The handling and overpacking of the thorium materials requires the design of a system that utilizes remote handling and overpacking equipment not currently utilized at the FMPC in the handling of uranium materials. The use of remote equipment significantly reduces radiation exposure to personnel during the handling and overpacking efforts. The designed system combines existing technologies from the nuclear industry, the materials processing and handling industry and the mining industry.

The designed system consists of a modified fork lift truck for the transport of thorium containers, automated equipment for material identification and inventory control, and remote handling and overpacking equipment for repackaging of the thorium materials. The radiation exposure to operations personnel using the remote handling and overpacking equipment is expected to be reduced by 98% over conventional direct drum handling practices with no dose reduction controls.

INTRODUCTION AND PROJECT OVERVIEW

InItroduction

The Feed Materials Production Center (FMPC), located near Fernald, Ohio, is a United States Department of Energy (DOE) integrated facility for the production of high-purity uranium metal. The uranium metal produced at the FMPC is used in the fabrication of fuel cores and target elements for reactors operated by the DOE. A wide variety of chemical and metallurgical process steps are utilized for the conversion of the ore concentrates and recycle materials. The Westinghouse Materials Company of Ohio (WMCO) currently operates the FMPC under prime contract with the DOE.

In the time period between the 1950s and 1970s the FMPC also produced thorium materials for use in the thorium/uranium fuel cycle. In a nuclear reactor, thorium can be converted to a form of uranium that can be used as a nuclear fuel. The use of a thorium/uranium fuel cycle was studied extensively in the 1960s for its potential as an efficient energy source. A uranium fuel derived from thorium was used in the 1970s to demonstrate commercial production of electricity at the Shippingport Atomic Power Station in Pennsylvania. Thorium/uranium nuclear fuel is not currently in use in the United States. The thorium materials now stored at the FMPC were originally slated for use as part of the thorium/uranium fuel cycle.

Since about 1972, the FMPC has served as the DOE storage site for thorium. Approximately two-thirds of the thorium materials at the FMPC were processed onsite, with the remaining portion originating at other DOE facilities. The thorium compounds stored at the FMPC are primarily mixtures of thorium metal, thorium oxides, and processing residues.

FMPC Thorium Inventory

The current inventory of thorium materials stored at the FMPC consists of approximately 1100 metric tons (thorium weight) of various thorium compounds. The total weight of thorium compounds (thorium plus additional materials) is approximately 1,870 metric tons. Nearly 175 metric tons of this material is thorium oxide in bulk storage in an above grade silo and double bin. These materials are planned for removal and packaging into smaller containers for interim onsite storage as a part of a separate thorium disposition project.

The balance of the thorium materials, approximately 975 metric tons (thorium weight), are in storage in four FMPC warehouses, and in outside storage on a controlled pad, in over 13,300 individual containers. The containers consist of 322, 208, and 114 liter drums (85, 55, and 30 gallon), 19 and 4 liter size cans (5 and 1 gallon), and various sized wooden boxes.

The thorium materials have been in storage at these facilities since the mid-1960s and 1970s. Long term storage has resulted in environmental deterioration of both the storage facilities and the containers that normally results from weathering over a prolonged periods.

To provide for the continued safe storage of the thorium materials, it is necessary that they be removed from their current storage areas, identified, repackaged (or overpacked into new containers), and stored onsite for interim storage until final disposition of the materials is determined. This action precludes the potential for environmental releases that could occur if the materials continue to remain in their current containers and locations.

The outside controlled pad storage location stores 241 containers within 212 208-liter (55 gallon) steel drum overpacks. These materials have been in outside storage at this location since the early 1970s. The drum overpacks have suffered varying degrees of environmental deterioration due to their direct exposure to the environment.

The overpack drums in outside storage are stored in three horizontal rows and stacked several drums high. The stacks of drums have developed a slight list over the years and some of the container markings are no longer legible. This storage configuration, in conjunction with the deterioration of the overpack containers, presents unique handling concerns.

Compounding the handling and overpacking problems is the presence of potentially pyrophoric thorium metal fines in 21 of the overpack drums in storage. The presence of these pyrophoric materials requires that all the overpack drums be handled as if they contain pyrophoric fines until the contents of the container are positively identified. The containers in outside storage will be addressed first in the thorium handling and overpacking effort to minimize further deterioration of the containers.

The condition of the thorium storage containers in the warehouses is significantly better than those in outside storage. The containers within the warehouses have also been in storage since the mid-1960s and 1970s, but they are protected from the environment. There is little direct environmental deterioration of the containers. The deterioration that has occurred is as a thin layer of rust forming on the drums and containers and extensive drying of the wooden boxes that are used for the storage of the solid thorium metals. In addition to the environmental deterioration of the containers, there is some minor damage to the containers attributable to handling.

The thorium storage containers in the warehouses are vertically stored and do not present the specific handling concerns of the horizontally stored containers on outside pad storage. Two of the containers of materials in the warehouses contain potentially pyrophoric thorium metal fines.

Project Overview

WMCO is designing a handling, identification and overpacking system for the 13,300 containers of thorium materials in warehouse storage. The system will require the use of remote handling equipment in order to maintain the As Low As Reasonably Achievable (ALARA) philosophy for personnel exposure and provide ease of system operations.

The project requires the design of a system that will allow for: the handling and movement of various size containers in storage to a processing area; the identification and confirmation of the container contents through the use of existing inventory records, drum identification numbers, drum weights and radiological scans; and, the overpacking of the containers for onsite storage and possible future offsite disposition. Selected overpack containers will be suitable for interim onsite storage, will meet Department of Transportation shipping criteria, and suitable for offsite disposition.

Specific design areas being addressed in the project include: a system for the handling of individual drums and containers; a system for weighing each of the containers; a system for the radiological survey of each container; a system for the overpacking of deteriorated containers; a method for verification of container contents; and, a data handling system to maintain inventory records and gather overpacking system data.

SYSTEM DESIGN CONSIDERATIONS

The goal of the thorium handling and overpacking effort is to handle and overpack in excess of 13,300 containers of thorium materials without releasing materials to the environment and, using the ALARA philosophy to stay within the established total dose budget of 0.145 milliSieverts (mSv) (14.5 rem). Several methods to accomplish this goal, cognizant of the project constraints, were considered. The systems and methods considered ranged from traditional FMPC manual methods of drum handling by fork truck and personnel handling, to fully automated systems which minimize or eliminate human handling.

Time, distance and shielding are the principal methods used to reduce or eliminate personnel exposure during container handling and overpacking operations. Minimizing personnel exposure time during the handling and overpacking operations (by keeping at a minimum the time personnel are permitted or required to be in the work area) is accomplished by using Administrative Controls and is constant in each of the systems considered.

Administrative Controls include: specific Standard Operating Procedures (SOPs) for handling and overpacking operations; extensive orientation and training programs; Radiation Work Permits specifying clothing and special equipment requirements and time/dose limitations; and, self-reading dosimetry devices that enable personnel to monitor their exposure. Site Radiation Technicians will be at each work area to monitor working conditions.

Distance and shielding are the two remaining variables in the manual system methodology. The use of distance in the container handling operations can be done through the use of fork extensions on the standard fork lift trucks in use at the FMPC. The use of 2.3 meter (90 inch) fork extensions would reduce the fork lift operator exposure from about 0.4 mSv/hour (40 mRem/hour) to about 0.13 mSv/hour (13 mRem/hour), with 0.07 mSv/hour (7 mRem/hour) ambient background, at minimal cost. The use of the fork lift extensions does, however, impact on the ability of the fork lift operator to handle the containers and maneuver the fork lift truck.

The use of fork lift truck cab shielding will reduce the fork lift truck operator exposure to an even greater extent and would not impact the handling ability and maneuverability of the fork lift truck. The use of shielding on the cab of the fork lift truck will reduce the operator exposure to about 0.01 mSv/hour (1 mRem/hour).

The use of distance and shielding was also considered during identification and overpacking operations. The dose rate to unprotected personnel during the identification and overpacking effort would range between almost 0.5 mSv/hour (50 mRem/hour) and 1.10 mSv/hour (110 mRem/hour), depending on the materials being identified and overpacked.

The use of distance becomes impractical in the manual system since it is necessary for the operators to be in proximity to the containers in order to manually identify and overpack the thorium containers. Shielding also appears impractical. Two types of shielding can be used: stationary shielding and individual personnel shielding. Stationary shielding is awkward for operators to work around and still manipulate the containers as required for the identification and overpacking process. Personnel shielding is also cumbersome and does not provide the reduction in exposure required to remain within the established Dose Budget.

Based on the study of the manual system approach, it is apparent that shielding the fork lift truck is an acceptable method for reducing the exposure to the fork lift operator during the container handling operations. However, other than manual systems are required to minimize exposure to operating personnel during the identification and overpacking of the thorium containers. The use of semiautomated and fully automated systems were evaluated for the thorium identification and overpacking operations.

SELECTED SYSTEM DESIGN

An engineering study, in conjunction with a cost benefit analysis, is the approach used to design the handling and overpacking system. In conjunction with the engineering design of the system, a Risk Analysis and Assessment (RAA) was performed on each handling step and overpacking procedure. The RAA helps to assure the safe handling of the thorium materials and minimize the possibility of accidents during the overpacking operations. A Quality Assurance Analysis (QAA) was also performed to identify potential problem areas that may result in accidents or system failure.

The results of the studies show that a shielded and modified fork lift truck for the retrieval and transport of the thorium containers is the preferred handling system based on the project scope and project constraints. The use of an automated container identification and overpacking system with remote capabilities and shielding of specific areas is the preferred system for container identification and overpacking.

Modified Fork Lift Truck

A modified FMPC fork lift truck is the basic unit to be used by personnel involved in the thorium handling and overpacking effort. The fork lift has a 2.7 metric ton (6,000 pound) rated capacity. This allows for the addition of equipment to be mounted to the fork lift and also provides for the handling of containers at the anticipated weights.

The fork lift will be modified (see Fig. 1) to have the additional capability to perform minor tasks beyond the movement and transport of the thorium containers. These additional tasks include: the ability to handle additional objects up to 90.9 kilograms (200 pounds); the ability to manipulate small tools such as a torch, impact driver, breaker bar, and drum opener; the ability to operate a High Efficiency Particulate Air (HEPA) vacuum sweeper; and the ability to perform minor equipment moving tasks. All of these functions will be done remotely by the operator in the shielded cab of the fork lift truck.

The addition of shielding to the fork lift consists of the use of leaded blankets to the sides and top of the truck for operator protection from the gamma radiation. The blankets contain lead within a Kevlar blanket system that can be easily mounted to the fork lift truck. It was initially thought that

plating should be used as shielding for the fork truck, but the blanket system is preferred in that it can easily be transferred to another fork lift in the event that the primary fork lift is out of service. The use of blanket shielding also allows for system flexibility without restricting the other applications of the modified fork lift truck.

Shielding of the cab consists of installing leaded glass to replace the existing glass on the front, sides and rear of the fork lift truck. The leaded glass provides the equivalent of lead shielding. This total shielding protects the operator from the anticipated gamma fields while providing the same level of visibility that currently exists.

Besides providing shielding for the operator of the fork lift truck, it is necessary to provide an environment safe from the thorium particulates associated with the handling effort.

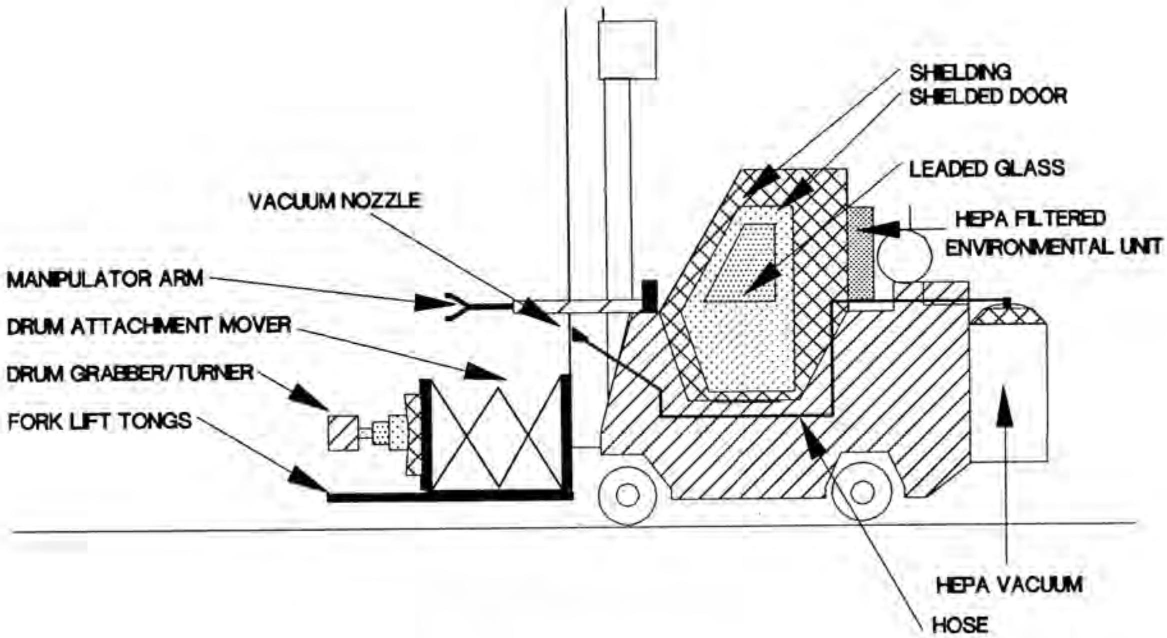


Fig. 1. Modified Fork Lift.

The two options for providing this environment are to require the operator to wear a full-face respirator during the handling operations, or to provide an environmentally isolated cab through the use of a HEPA filtered, positive pressure, air supply system. The restrictions and operational problems involved with the prolonged use of full-face respirators, in conjunction with personnel lose of efficiency, make the use of the HEPA filtered air supply system the preferred option despite the additional costs associated with the HEPA air supply system.

The container handling attachment to the fork lift consists of a unit that can handle drums in either the vertical or horizontal position as well as handling odd sized drums, containers and boxes. This system is a hybrid modification to a telescoping-jaw drum grip and tilt attachment normally used on mining equipment. The unit is designed to be attached to a drum pusher unit to provide movement capabilities in the x, y, and z axis.

The manipulator arm attachment is capable of standard manipulator functions as well as being able to manipulate a torch, impact driver, breaker bar, and drum opener. The manipulator arm unit will be attached to the side of the fork lift truck to allow for its use in performing remote functions.

Automated Identification and Overpacking System

The automated system (see Fig. 2) for the identification and overpacking of the containers is designed to accept containers in either a horizontal or vertical position. The containers will be placed by the shielded fork lift truck on the end of the conveyer system. The conveyer will move the container and position it at stops to obtain the following information: container weight; container gamma readings; external container alpha readings; and, numeric identification data. The compilation of this data will be done on a computer data system controlled by the operator. The method planned for the identification of the materials will use existing historical inventory data for container location, material types and container weights. This data will be used in conjunction with the data obtained on the container weight and radiological data obtained from the identification equipment.

The belt conveyer system is designed so that deteriorated drums requiring 322 liter (85 gallon) overpack containers can have the overpacking task accomplished remotely. Drums that contain pyrophoric thorium metal fines will also be overpacked into individual 322 liter (85 gallon) overpacks. The entire overpacking operation will be remote except for the lidding of the individual overpacks. This work will be done by operations personnel in "bubble suits" to protect them from potential airborne contamination.

Once the material is tentatively identified by the radiological readings the cross reference to the container weight and material type (available from historical inventory information) will allow for correlation of the unidentified container to a known container. This method is being

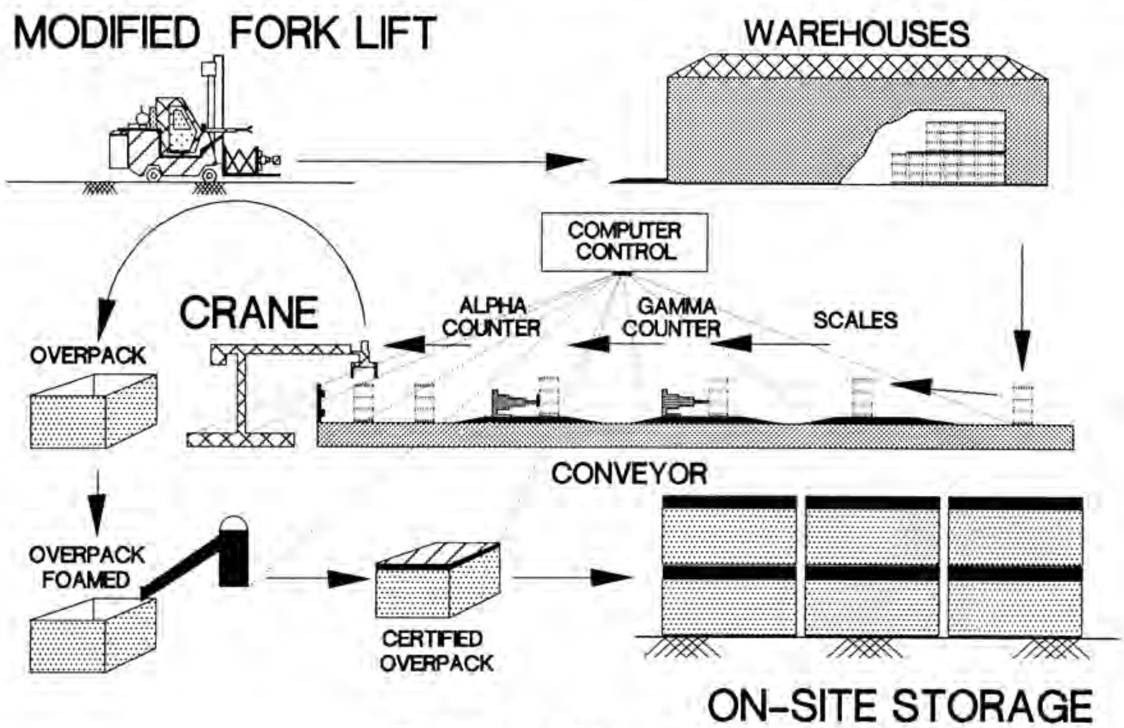


Fig. 2. Thorium Movement Plan.

used to preclude the need for opening containers that do not have legible identification markings.

Each thorium material type produces a unique gamma field related to the type and amount of material in the container. The method of calculation is based on the reverse method of determining shielding calculation. The formula that is used, and the geometry considered, is shown in Fig. 3. The method for performing this analysis takes into consideration the geometry of the container, detector geometry, shielding and attenuation effects, and the effective gamma energy. Figure 3 shows the assumptions and data used to perform the calculations.

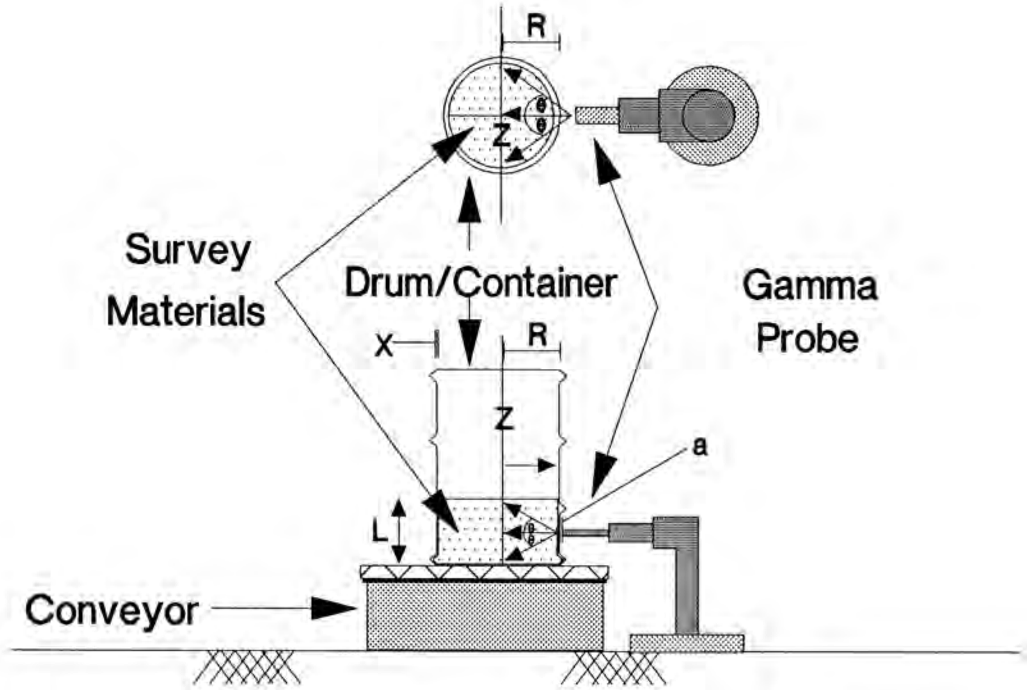
The proposed layout of the automated identification and overpacking system is shown on Fig. 4. The control logic for the operation of the system is shown on Fig. 5. Major components of the system include: check stations for container weighing, alpha swipes and gamma field readings; the computer control and operations station; the overpack foaming unit; and, the overhead crane and container handling units. All control operations will be remotely operated and will provide for the shielding of personnel from the gamma fields and the isolation of personnel from potential contamination.

Shielding will be used around the operator control station and around the container overpacking area. The shielding to the operator control station consists of leaded glass viewing areas surrounded by solid cinder blocks. This arrangement will form a wall around the entire operator work area. The shielding around the overpacking area will consist of lead sandwiched between stainless steel plates the height of the overpack container.

Personnel will be protected from potential airborne thorium exposure during the identification and overpacking operations through the use of positive pressure, air supplied "bubble suits." The "bubble suits" will be used because operations personnel will be working for periods of up to four hours, will have the potential for exposure to airborne contamination, and will be required to perform exacting and precise tasks. The "bubble suits" are preferred over full-face respirators because they have the highest level of protection, do not produce the strain usually associated with full-face respirators, and allow for more normal movement during work activities.

Dose Reduction

One of the primary drivers during the development and design of the systems for the thorium handling and repackaging effort is the need to adhere to the ALARA philosophy and design a system that minimizes radiation dose to personnel involved in the project. The ALARA Review and Analysis indicates that the use of the designed system will reduce dose to the operation personnel by over 98% compared to uncontrolled handling and overpacking operations. The total dose to operations personnel during the warehouse operations is expected to be reduced from approximately 2.7 Sv (270 rem) to less than 0.05 Sv (5 rem). A summary of the ALARA Review and Analysis report is shown in Table I. The information in Table I shows mRem during different operations for each warehouse building. In-



$$I = \frac{S_L}{4\pi r} B\left[f(y+\mu_s Z, \theta_1) + f(y+\mu_s Z, \theta_2)\right] \quad \text{(Ref. 1)}$$

I = gamma ray intensity, MeV, $cm^{-2}\,sec^{-1}$
S_L = source strength, MeV $cm^{-2}\,sec^{-1}$, (2.6 MeV $cm^{-2}\,sec^{-1}$)
B = build up factor,
r = a+Z, cm,
a = distance from cylinder to the measuring dose point, cm,
Z = the effective center of the container, self attenuation distance, cm,
$f(y+\mu_s Z, \theta)$ = sievert function,
$y = \Sigma\, \mu_i X_i$,
X = thickness of container shield, cm,
μ_s = macroscopic cross-section of source material. cm^{-1},
θ = angle formed by lines drawn from the dosage point to each end of the cyclinder

Fig. 3. Material Identification Methodology.

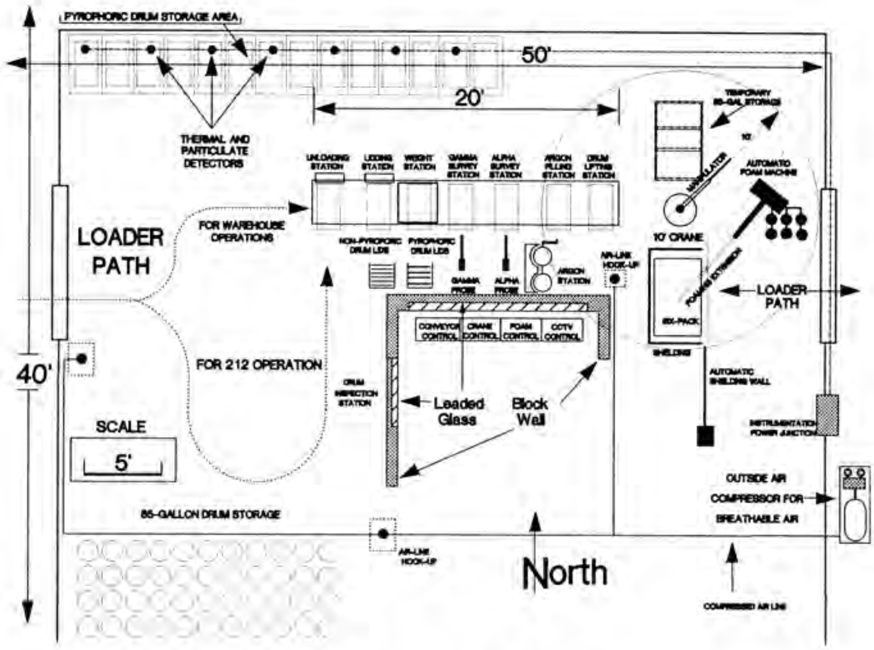


Fig. 4. Operational Layout.

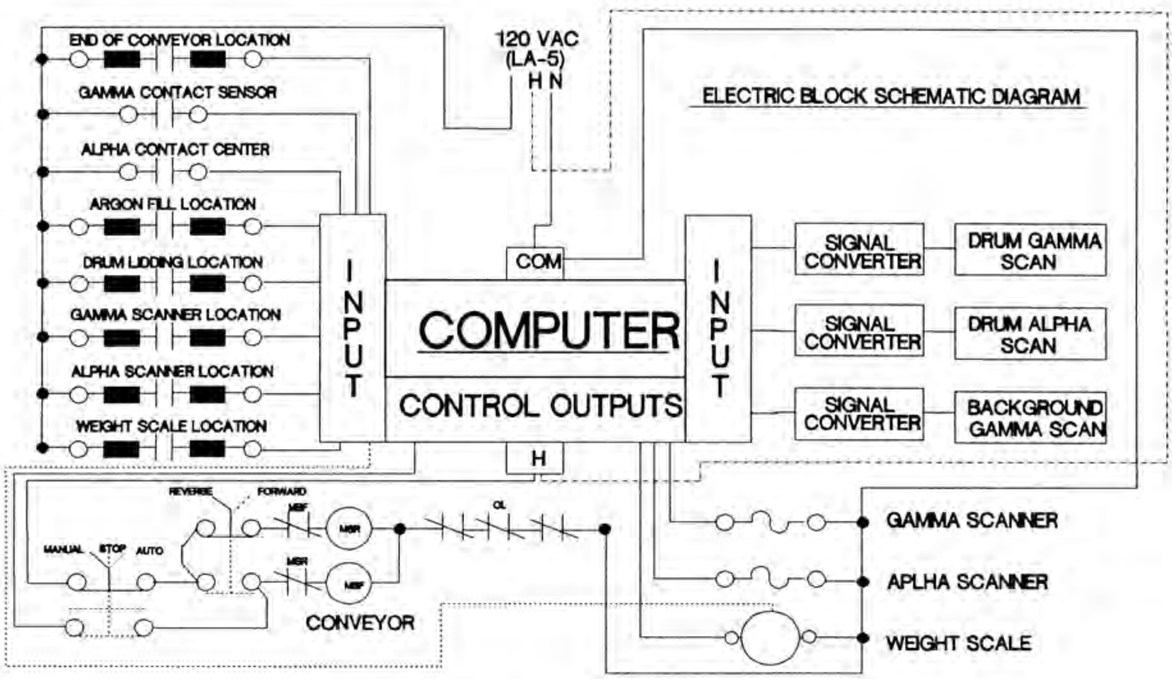


Fig. 5. Block Diagram.

dividual operations are listed with no controls and with the designed system controls.

Date Management and Recordkeeping

The current FMPC inventory of thorium materials is in excess of 13,300 containers. The materials are stored in bulk storage, warehouse storage and on controlled pad storage. Each container has an associated net and gross weight, material type and storage location, and percent thorium content. The identification process will also generate additional data for each container: container weight, alpha swipe readings information and gamma survey readings.

Both the historical inventory information and identification process data must be available to the system operator to ensure proper recordkeeping and overpack coding.

TABLE I

Alara Report Composite

AREA	mRem Dose	mRem Dose
BUILDING A	NO CONTROLS	W/CONTROLS
Handling Oper.	2,624.50	30.17
Overpacking	2,715.00	12.07
Lidding	470.60	0.00
Banding	1,647.10	58.83
Loader	487.69	40.22
Sub-Total	7,944.89	141.29
BUILDING B	NO CONTROLS	CONTROLS
Handling Oper.	53,190.50	933.17
Overpacking	55,990.00	373.27
Lidding	8,336.29	0.00
Banding	20,840.72	1,042.04
Loader	8,865.08	155.53
Sub-Total	147,222.59	2,504.01
BUILDING C	NO CONTROLS	CONTROLS
Handling Oper.	26,087.00	457.67
Overpacking	22,883.33	373.27
Lidding	1,222.83	0.00
Banding	1,916.48	95.82
Loader	815.22	14.30
Sub-Total	52,924.86	941.06
BUILDING D	NO CONTROLS	CONTROLS
Handling Oper.	21,291.50	219.50
Overpacking	24,145.00	87.80
Lidding	3,424.20	0.00
Banding	8,560.50	428.03
Loader	4,280.25	36.58
Sub-Total	61,701.45	771.91
TOTAL:	NO CONTROLS	CONTROLS
	269,793.79	4,358.25

Data management, recordkeeping, and instrumentation control will be facilitated through the use of a microcomputer-based operating system utilizing hard wired I/O (Input/Output) control modules with direct voltage conversion of signal input. Accumulated data during the thorium overpacking effort will be stored on a laser disk storage system.

SUMMARY

The objective of the thorium handling, identification and overpacking efforts at the FMPC is to safely and efficiently overpack the current inventory of thorium materials for continued safe storage. To accomplish this goal, a system that utilizes remote handling equipment and technologies from several different industries is being designed.

Throughout the design effort concurrent studies in Risk Analysis, Quality Assurance and ALARA Reviews were performed to ensure the design of a system that is safe and reduces exposure to operating personnel to a level As Low As Reasonably Achievable.

The successful installation and operation of the system will reduce exposure to personnel by over 98% and minimize the potential for accidents and releases to the environment. The completion of the overpacking effort will provide for the continued safe storage of thorium materials at the FMPC site.

REFERENCES

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