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HOT CELLS FOR PLUTONIUM REACTOR FUEL RESEARCH

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LOS ALAMOS SCIENTIFIC LABORATORY
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HOT CELLS FOR PLUTONIUM REACTOR FUEL RESEARCH

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ABSTRACT

A hot cell facility, now under construction, is to be used for kilocurie scale research and development work on fuel reprocessing techniques in support of plutonium-fueled fast reactors. The facility consists of four cells, served by Argonne Model No. 8 manipulators, with a common corridor served by a General Mills Mechanical Arm. The experimental work is done in glove boxes within each cell. Manipulator access to the boxes is through plastic booting.

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INTRODUCTION

A hot cell facility, now under construction at the Los Alamos Scientific Laboratory for use with plutonium-rich reactor fuels, is described. Since these cells are to be used for pyrometallurgical and aqueous processing development work on kilogram quantities of plutonium containing kilocuries of gamma activity, the main consideration in their design is versatility. To satisfy this condition, the ability to change experimental equipment safely and with relative ease is a necessity. To make these setups as simple and reliable as possible and to minimize expensive remotely controlled equipment for each experiment, it is considered necessary to have access to the equipment by manipulators. The health hazard associated with plutonium imposes a further requirement of absolute containment of the plutonium. These conditions led to the conclusion that the experiments should be conducted in a glove box type of enclosure within the cell. The box would contain the alpha and gamma contamination and, by removal of the box, personnel could enter the cell to prepare the next experiment.

It is believed that by proper design of the experimental equipment, the bulk of the fission products removed from the plutonium can be placed in disposable containers. Further, by decontamination of the box interior through the use of the manipulators, it is hoped that the balance of the gamma activity can be reduced to a point where personnel can work inside the box through gauntlet gloves and accomplish a final cleanup. In the event that any part of this procedure fails, it is believed that the design is such that the box can be removed remotely and disposed of or sent to storage until the radioactive material decays sufficiently to permit re-use of the box.

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A major problem in the design of such a system is the method of transferring material in and out of the box without contaminating the cell. To accomplish this a remotely operated transfer mechanism was designed. The unit, which is described later in this report, can handle the transfer of the fuel to and from the box, but is limited in size. For this reason large items of equipment must be introduced through a plastic bag prior to the box becoming contaminated with gamma activity. This requires that each experiment be carefully designed and tested before introduction of the irradiated plutonium. Spare parts must also be introduced where equipment failure can be anticipated.

CELL STRUCTURE

A plan view of the cells is shown in Fig. 1 and a typical cross section of the cell structure in Fig. 2.

This plan was chosen in preference to others because it provides the most efficient use of available space and best fulfills the requirements of transfer and storage of radioactive material. A corridor serving all four cells is considered necessary to provide space for in-process storage wells. Shielding around the corridor protects operating personnel during transfer of gamma-active material. The lightly shielded equipment room at the south end of the structure houses a vacuum pump and circulating water system serving the glove boxes. These items are likely to become slightly contaminated.

The bulk of the shielding is ordinary concrete, which was used everywhere except where spatial limitations existed. Wall thickness was kept to a minimum on the front face of the cells to minimize window thickness, through-the-wall plug lengths, and to keep the operator closer to his work. By using a high density aggregate, a concrete density of 220 lbs. per cubic foot was attained and shielding values were not sacrificed. The higher density concrete was also used on the walls and roofs of the cells to keep the over-all dimensions within the limits of an existing building.

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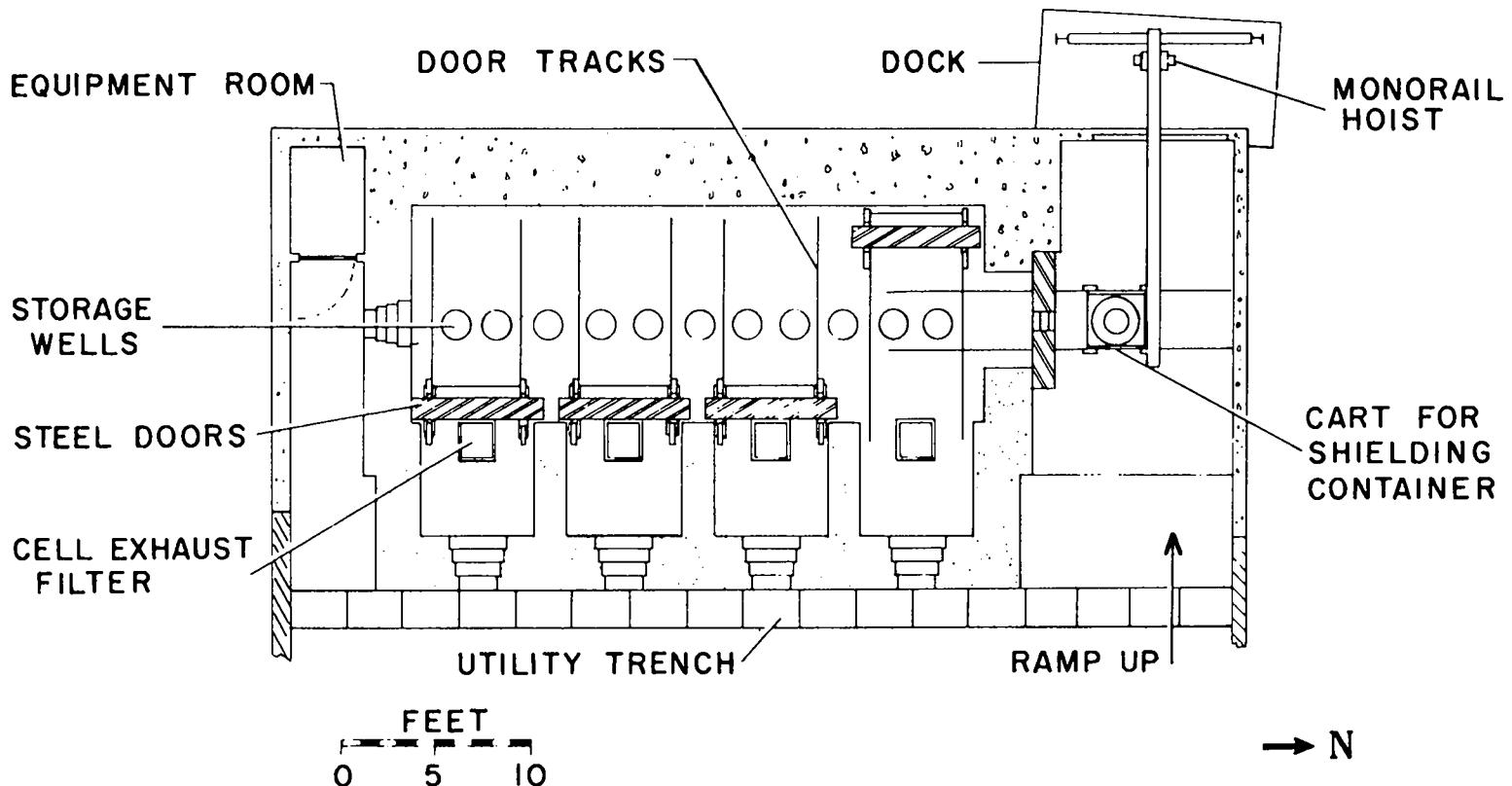


Fig. 1. Plan view of hot cell structure.

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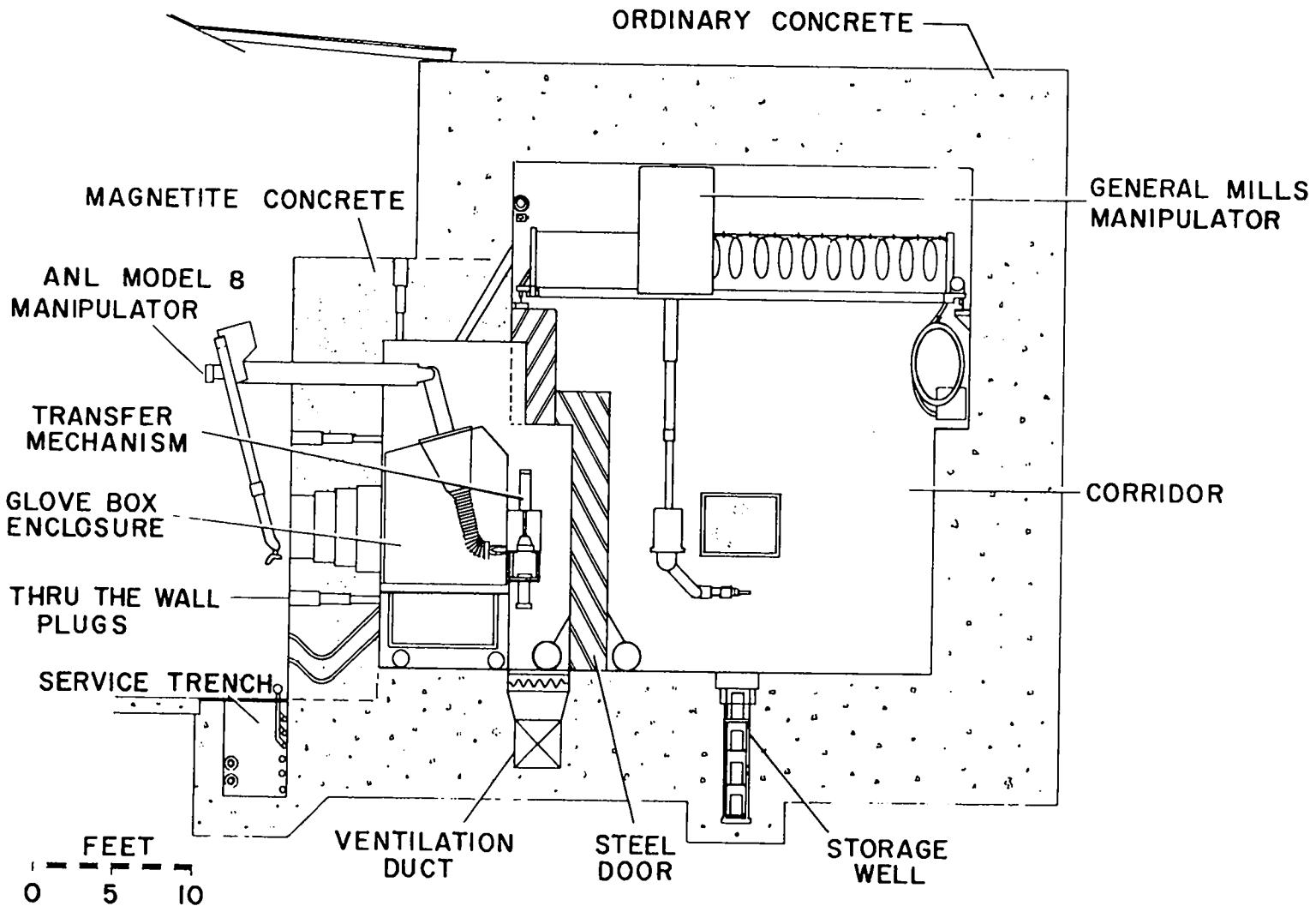


Fig. 2. Typical cross sectional view of hot cell structure.

The interior of each cell was lined with steel plate to present an easily cleaned surface in the event of contamination escaping from the glove box. The readily cleanable surface also permits the cell to be used in a conventional manner when gamma-active material not containing plutonium is used.

At the rear of each cell a steel door and steel lintel are used for shielding. The use of steel for the lintel permits the manipulator in the corridor to reach further into the cell than would be possible were the lintel made of an equivalent amount of concrete shielding. Steel was chosen for the door because the required passage clearance in the corridor could be obtained with a saving on the concrete required for the roof, floor and end walls. The doors are operated by electric gear motors and can be remotely controlled from the cell face. They ride on heavy railroad-type tracks laid in the concrete floor.

There are 22 storage wells, 5 ft. deep, located in the corridor floor. Racks capable of holding four transfer containers fit into these wells, which are covered by a lead plug. The plugs and racks are handled by the corridor manipulator.

Viewing windows for the structures are of a standard type made of high density glass. There is one window per cell and one window at each end of the corridor. A portable window is available for insertion into any one of four sleeves in the west corridor wall so that any portion of the shielded area can be viewed if required.

Services pass into the cells, in most cases, through bent pipes in the concrete face of the cells. Additional passageways are available in the form of stepped steel plugs in the face and ceiling of the cells and straight concrete plugs in the west corridor wall. The stepped plugs in the ceiling were specifically included for entrance of lines carrying reagents from reservoirs on the cell roofs. In the center face of each cell one 8 in. diameter plug has been inserted about a foot below the level of the manipulator ports. If necessary, this port can accept a manipulator which is capable of reaching most of the cell floor area.

MANIPULATION

One pair of Argonne National Laboratory Model No. 8 manipulators services each of the four cells. These are used for performing the lighter work within the glove box and for maintenance on the equipment therein. For general convenience and to facilitate extreme reaching requirements, these manipulators have a lateral and a forward indexing motion and may be locked in any position. A lead shielding plug is installed in the manipulator tube extending through the wall to prevent radiation streaming. Experience obtained from a cell and glove box mock-up indicates that, for the type of work involved, these manipulators are quite adequate.

Within the corridor is a General Mills Mechanical Arm capable of lifting weights up to 750 lbs. This is used for handling the storage well racks and plugs and for transfer of materials from the corridor to the glove boxes. This unit is so positioned that it can reach any part of the corridor floor as well as the rear portion of the cell floors. Several plug-in control points are provided, enabling the operator to position his control console at any of the cell or corridor windows or within the corridor.

GLOVE BOXES

A rigid enclosure was chosen, in preference to a flexible plastic envelope, to ensure better contamination containment and to provide a structure on which equipment could be mounted. The latter capability considerably increases the floor space available for each experiment. The materials of construction are stainless steel and polymerized acrylic resin sheet. The box as shown in Fig. 3 consists of a stainless steel bottom pan about 6 ft. wide and 4 ft. deep with rigid plastic walls and roof. The roof is peaked and has a pair of 20 in. square holes to allow insertion of the manipulators. The box height and form of the roof are a compromise to allow maximum manipulator movement with a minimum manipulator hole size. The enclosure is mounted on a metal

frame with the bottom pan about 40 in. above the operating area floor level. The frame is equipped with casters to permit easy movement of the unit into and out of the cell. Because of the large amount of plastic material used, each glove box is equipped with a lead storage safe which will be used to store the more active gamma emitters to minimize radiation damage to the plastic.

MANIPULATOR BOOTING

The manipulator booting system is designed to meet three basic requirements. These are complete contamination containment, minimum restriction of manipulator movement and remote insertion and removal of the manipulators.

To accomplish complete contamination containment, the boot is made so that no part of the manipulator is exposed to the atmosphere of both the glove box and the cell. Figure 3 shows a schematic illustration of the booting and Fig. 4 is a photograph of the booting installed in a mock-up of the glove box and cell. In Fig. 4 can be seen the lower portions of the tapered polyvinylchloride sheath which is sealed to the roof of the box. The sheath is built up of pieces made of 0.030 in. thick sheet stock electronically sealed together. Sealed to the bottom of the sheath by a hose clamp and internal ring is a polyvinylchloride bellows of about 5 in. I.D. This bellows, like the sheath, consists of pieces made of 0.030 in. thick sheet stock electronically sealed together. Connected to the bottom of this bellows section is a second polyvinylchloride bellows of about 3 in. I.D. The bellows are sealed together by two bolted clamping rings. The smaller bellows is a molded section terminating in a glove that fits over the stubs that actuate the manipulator tongs. Its average thickness is about 0.030 in. The glove permits translation of hand movement through the plastic contamination barrier to the manipulator tongs which are exposed to the box atmosphere. Figure 5 shows a more detailed view of this section of the booting. Commercially available fixtures are used to remotely attach and remove the tongs which remain inside the glove box.

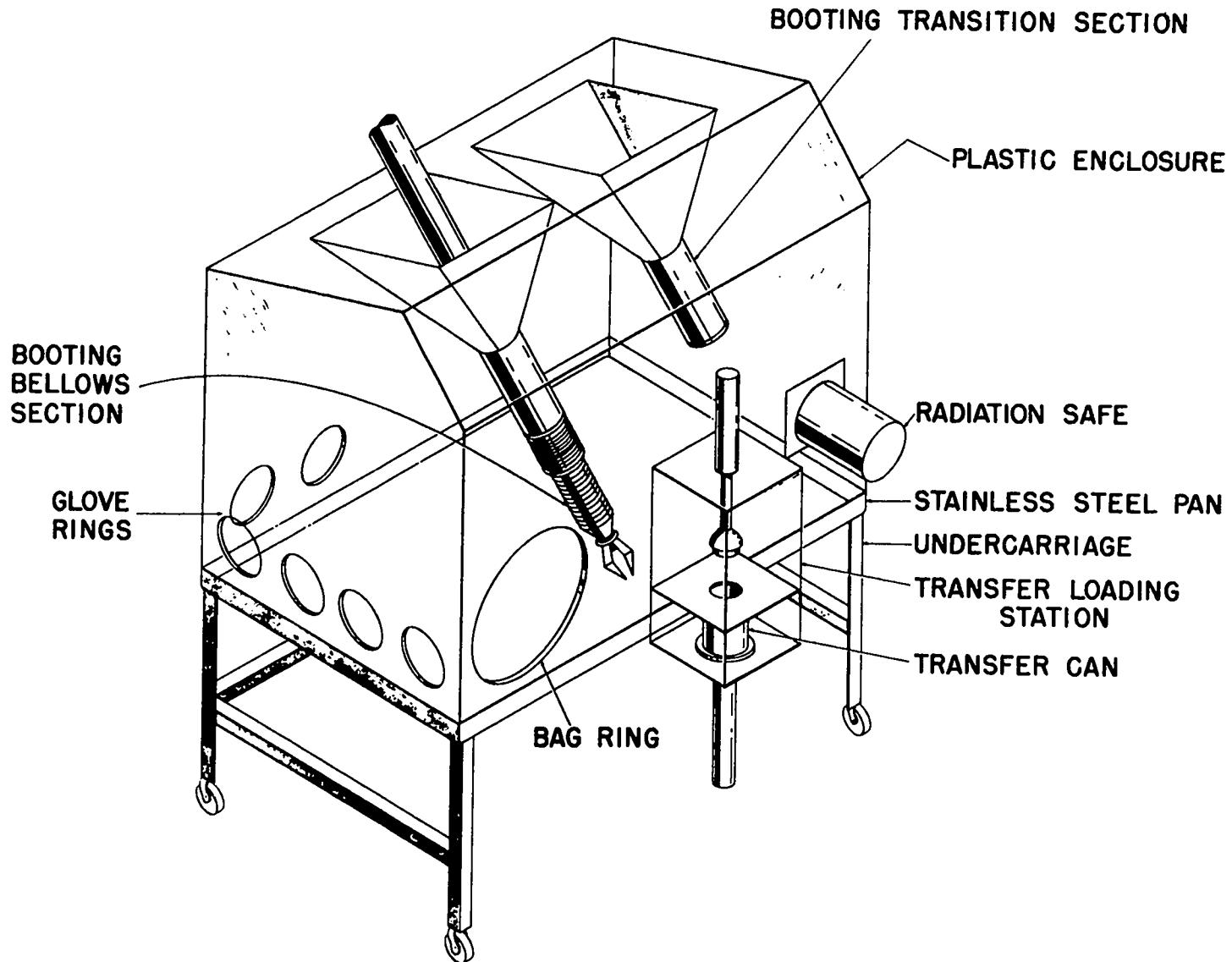


Fig. 3. Rear view of glove box.

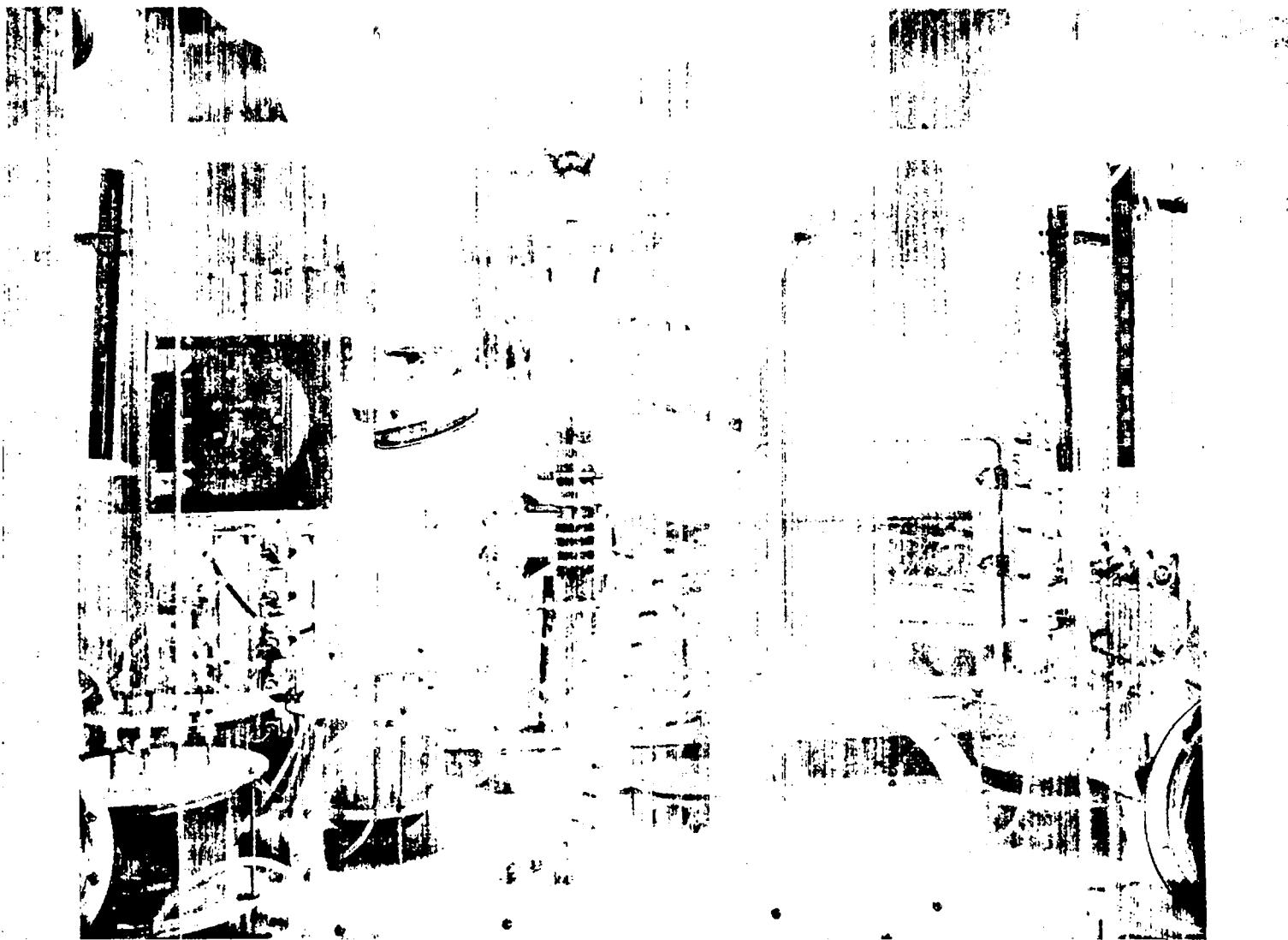


Fig. 4. Manipulator booting arrangement.

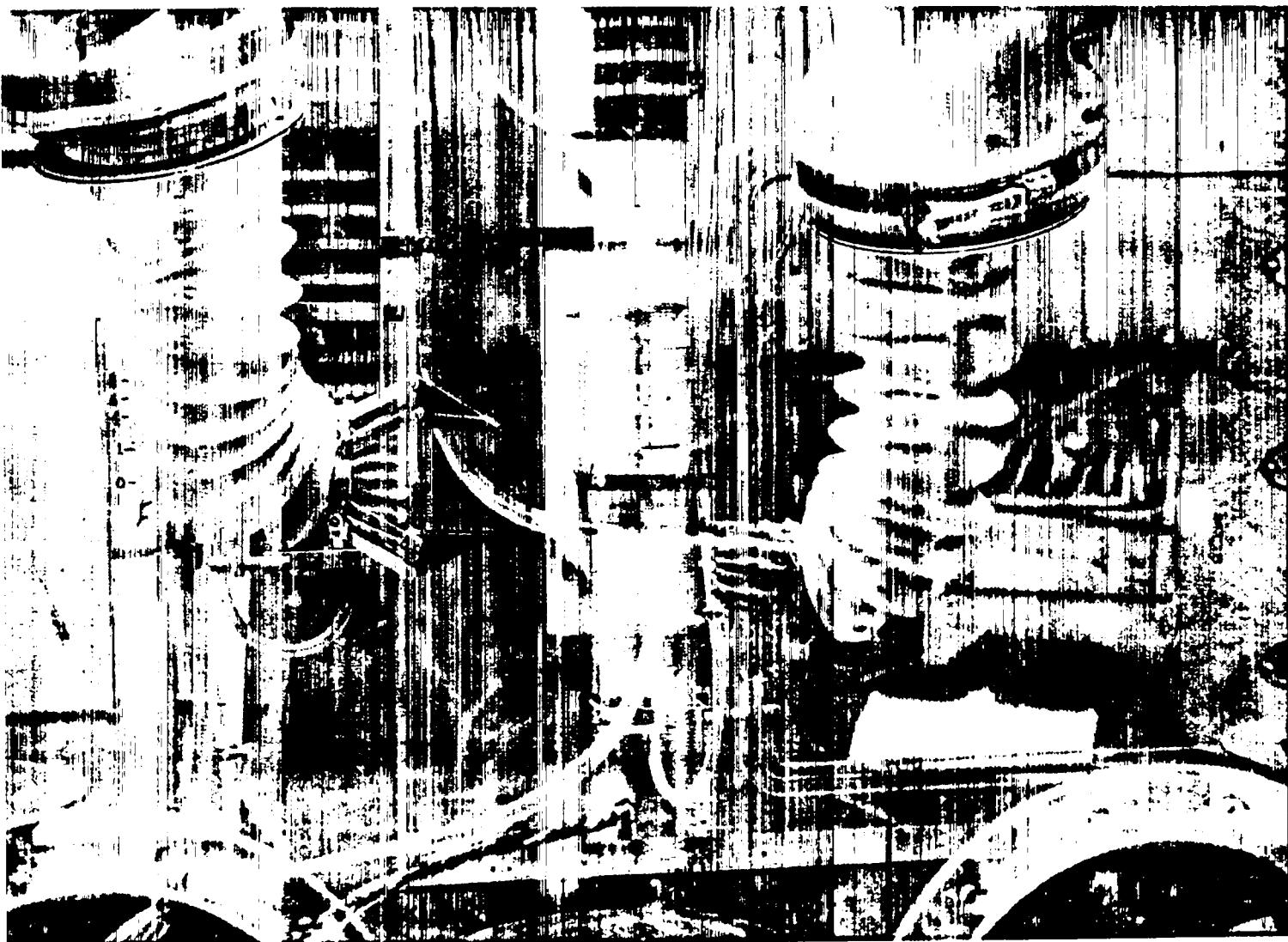


Fig. 5. Bellows section of manipulator booting.

A spring lift, not visible in the illustrations, was devised to prevent the larger bellows section from hanging down and bunching about the manipulator wrist and to decrease movement resistance. This consists of two spiral springs on the box roof connected by wires to a lift plate at the lower end of the larger diameter bellows. These springs support the weight of the bellows and counteract the downward force on the bellows due to the negative pressure in the box, but still permit bellows expansion.

Experience gained from mock-up studies has shown that resistance to movement of the manipulator by the booting is small enough to be compatible with the intended function of the manipulator. The bellows sections are flexible enough to allow rotational freedom and of sufficient length to accommodate the full range of the telescoping action of the lower manipulator arm.

It is necessary that the manipulators be remotely removed and re-introduced to permit maintenance work on the manipulators and remote removal of the glove box. It has been demonstrated in the cell and glove box mock-up that it is possible to remove and re-introduce one manipulator at a time or to remove both manipulators. For re-introduction, an operable manipulator is required to fit the molded glove on the one being inserted. The likelihood of both manipulators being completely inoperable at the same time is remote, so the foregoing limitation is not a serious one. The initial insertion of the manipulators is done manually. To remove a manipulator for maintenance during an experiment, the tong is first removed, and the molded glove is easily slipped off the manipulator. The glove box is then moved back about 2 ft., permitting the manipulator to be slipped out of the booting and lifted clear. The remaining manipulator is held in the booting by the tong assembly. Spatial relationships between the manipulators, glove box and cell require the backward movement of the box. Box movement is accomplished by connecting the box to the remotely operated cell doors by tie bars which can also be remotely connected and disconnected. After maintenance,

the manipulator is slipped back into the booting and the box is moved to its operating position. The operable manipulator is then used in fitting the molded glove onto the actuating fingers, and the tong assembly is replaced using the changing fixture.

For remote removal of the glove box, both manipulators are removed as previously described and the box pulled into the corridor. Here the mechanical arm can be used to disconnect the box from the door and to attach ropes. Thereafter, the box will be handled by ropes until it is picked up by a crane truck.

TRANSFER MECHANISM

Figure 6 shows the container, a can about 7.5 in. high and 6 in. in diameter, for moving active material from one location to another. The can is fitted with a lid pulled down against an O-ring gasket by three spring-loaded lock pins set in the wall of the can. These pins are sealed against contamination leakage by two O-rings, with grease filling the void between them. Surrounding the container proper is a frame with a beveled surface that bears against the pins. Springs located between the bottom of the frame and the container pull this beveled surface down and force the pins inward to clamp the lid down. Compression of the bottom springs moves the beveled surface up, permitting the spring-loaded lock pins to retract and free the lid.

At each of the loading locations there is a mechanism to receive this standard container. This consists of a hole in the box floor large enough to pass the lid with a few thousandths inch clearance. An air cylinder directly below the hole pushes the container up until the O-ring gasket used to seal the lid also seats against the floor. The air cylinder will continue moving until the bottom springs are fully compressed and the lid is freed. On the contaminated side of the hole there is a lid-lifting mechanism which seals the hole when there is no container in place. The mechanism has a diamond-shaped gasket which seals around the hole and also seats against the container lid when the container is lifted up

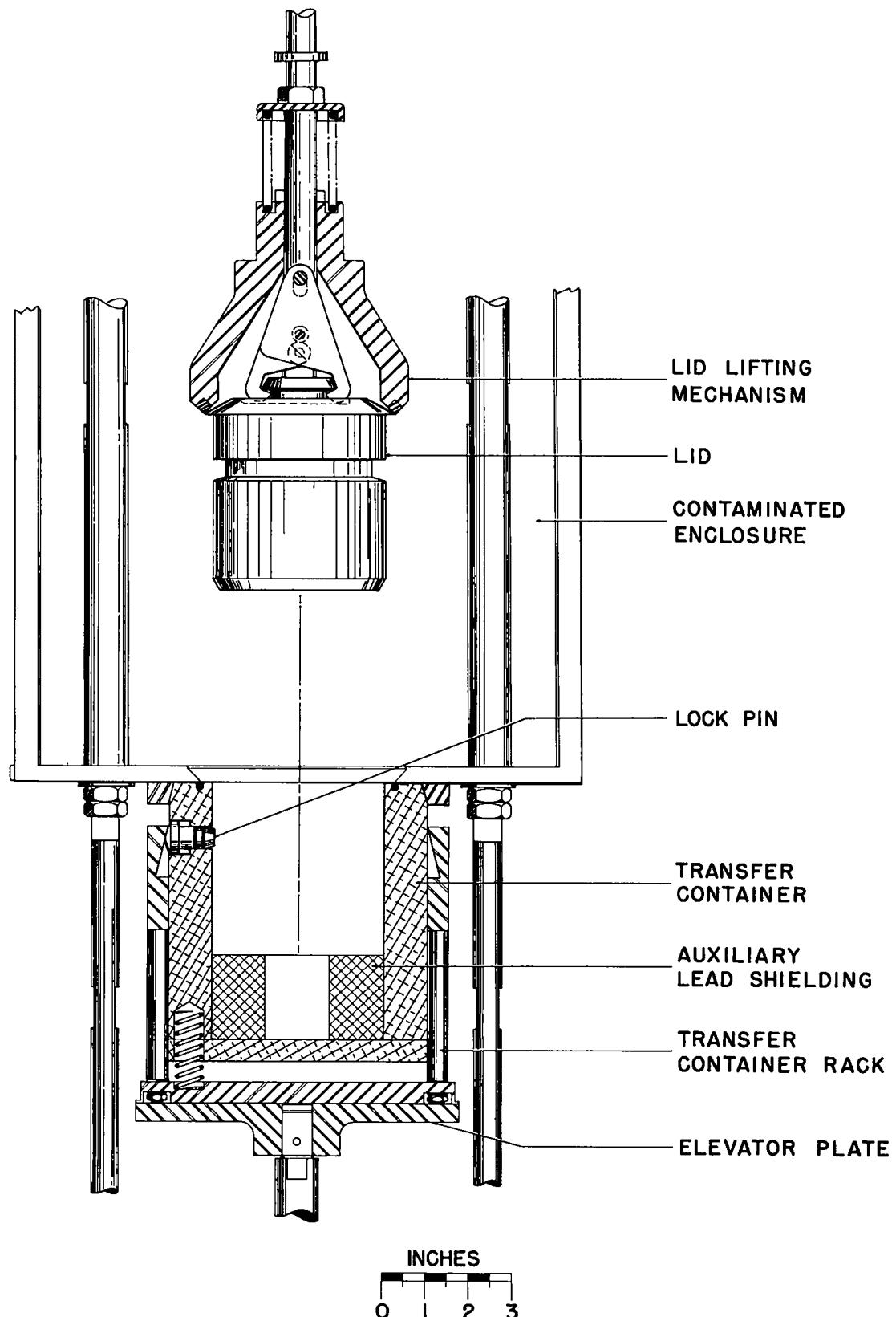


Fig. 6. Transfer mechanism.

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against the hole. To lift the lid from the container, an air cylinder directly above the hole is raised, and spring-actuated clamps in the lid-lifting mechanism grasp the knob on the top of the lid and lift it. These clamps are so constructed that they pull the lid against the diamond-shaped gasket and keep the top of the lid from becoming contaminated while inside the glove box. The only container area that is exposed to both the box and room atmosphere is that area of the O-ring gasket that is exposed by the few thousandths inch clearance between the lid and the hole. To remove the container the lid lifting mechanism is driven down, sealing the hole in the floor and releasing the lid. The container is then dropped by its air cylinder and the lock pins automatically clamp the lid down. This mechanism has been in use in the plutonium processing area for some time without difficulty. The containers have been pressure-tested at 2 atmospheres with no leakage.

SERVICES

The bulk of the services to the cell are of the nature of standard laboratory services and are located in a trench immediately in front of the cell. At the start of an experiment, those services required are brought up from the manifolds in the trench through plastic tubing, passed into the cell through the bent pipes in the cell face and manually connected to the glove box. At the conclusion of an experiment, if the dry box cannot be approached, the flexible tubing is disconnected at the manifolds, plugged and removed with the glove box.

Ventilation of the cells is accomplished by pulling air into the corridor through a dust filter at the south end of the corridor. From the corridor it moves into the cells through the adjustable opening around the cell door and is exhausted from the cell through an absolute filter in the floor. The ventilation duct runs beneath the cells to the north end of the structure and is discharged through a stack on the roof of the corridor. The glove box exhaust is filtered twice by absolute filters and is discharged into a duct located near the ceiling on the

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east wall of the corridor. This duct discharges into the exhaust stack on the roof. Connection of the dry box ventilation to the duct in the corridor is made by flexible neoprene tubing through a hole in the ceiling of the cell and, during box removal, is handled like the other services. The main ventilation system is designed for a flow of about 2,500 cu. ft. per minute and the glove box ventilation will be about 15 cu. ft. per minute. The glove box pressure is kept at about 0.5 in. of water negative with respect to the cell. Volatiles liberated in the processing experiment are to be condensed or absorbed near the point of liberation to prevent their escape through the filter.

One unique service to the glove boxes is a negative pressure circulating water system. Water is sucked through the coolant passages from a refrigerated reservoir by a vacuum pump capable of handling mixtures of air and water. With such a design, any discontinuities in the coolant passages will permit air to leak into the system rather than let water leak out. This minimizes the chance of a nuclear accident due to water tampering and also lessens the possibility of having to dispose of large volumes of contaminated water from a flooded glove box.

In two of the cells, induction heating power leads from a 15 k.w. motor-generator set will be brought to the glove box through a hole in the roof of the cell.

SUMMARY

A hot cell facility, now under construction, is to be used in support of plutonium-fueled fast reactors. Experiments will be conducted on a kilocurie scale to develop pyrometallurgical and aqueous reprocessing techniques for spent fuel.

The structure consists of four 6 ft. by 6 ft. by 10 ft. high cells in a line, backed by a common corridor 11 ft. by 30 ft. long.

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One pair of Argonne Model No. 8 manipulators are used in each cell and a General Mills Mechanical Arm, in the corridor. The former will be used for actual experimentation and the latter to transfer material into and out of the cells.

Because of the toxicity of plutonium, the material will be processed within a portable enclosure located in a cell.

The Model No. 8 Manipulators will have access to the interior of the enclosure through contamination-tight plastic booting and can be remotely introduced and withdrawn.

Services to the enclosure can be remotely disconnected and the enclosure can be remotely removed.

Plutonium is transferred to and from the enclosure in an alpha container by the Mechanical Arm. The container is attachable to the enclosure and the plutonium removed by remote operation without spread of contamination.

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