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DESIGN PHILOSOPHY AND OPERATING EXPERIENCE WITH THE WNRE HOT CELL FACILITY

by

R.G. HART, C.G. SEYMOUR and M.A. RYZ

Paper IAEA-SM-125/7 presented at the IAEA Symposium on
Radiation Safety Problems in the Design and Operation of "Hot" Facilities
held at Centre d'Etudes Nucleaires de Saclay,
Gif-sur-Yvette, France, October 13-17, 1969

Whiteshell Nuclear Research Establishment
Pinawa, Manitoba

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ABSTRACT

The objectives of radiation safety and operating efficiency often conflict. The key to preventing this conflict is proper design. In this paper we discuss how both objectives have been met in the WNRE Hot Cell Facilities.

The first requirement for good design is a careful specification of the materials flow. Once this is done the hot cell features and the building features can be settled relatively easily.

In detailed design it is extremely important to use as many features as possible that have operated successfully in other facilities. Many irradiation incidents occur as a result of an "improved design" that does not work properly. Proven methods of transferring irradiated fuels, storing highly active samples, disposing of highly active garbage, disposing of liquid wastes, removing and reinstalling experimental equipment, decontaminating highly radioactive cells, and filtering contaminated air are described in some detail.

A flaw in the design of the ventilation and ventilation alarm system resulted in one gross release of activity to the air in the operating area. This incident is discussed and the minor alteration required to avoid such an incident is described.

Operating efficiency in the metallurgical sample preparation line would be improved if we had a rapid pneumatic or electrical means of transferring small samples.

The all-inclusive cost of providing three 10^6 curie cells, three 10^4 curie cells, five 10^3 curie cells and the necessary building and auxiliaries was about \$2,200,000 Canadian. Outlets for all services such as air, vacuum, steam, and water, are inside the cells. Operating experience indicates that neither operating efficiency nor radiological safety would be significantly affected if many of these outlets were outside the cell and the services were run into the cells as required through existing access ports. This would lead to a cost saving of about \$50,000.

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Cellules chaudes de Whiteshell: philosophie de leur concept et expérience opératoire

par R.G. Hart, C.G. Seymour, M.A. Ryz

Résumé

L'objectif de la radioprotection entre souvent en conflit avec l'objectif de l'efficacité opératoire. Pour éviter ce conflit il faut une planification appropriée. Dans ce rapport nous disons comment les deux objectifs ont été atteints dans les cellules chaudes de Whiteshell.

Une bonne planification commence par l'établissement de diagrammes concernant les différents circuits de matières. Il est alors relativement facile de déterminer les caractéristiques de la cellule chaude et celles du bâtiment.

Dans la planification détaillée, il est extrêmement important d'avoir recours aux caractéristiques ayant fonctionné de façon réussie dans d'autres installations. De nombreux incidents d'irradiation se produisent par suite d'un "perfectionnement" qui n'a pas fait ses preuves. Nous décrivons de façon assez détaillée des méthodes éprouvées pour le transfert des combustibles irradiés, pour le stockage des échantillons très actifs, pour l'enfouissement des déchets radioactifs solides et liquides, pour l'enlèvement et la réinstallation de dispositifs d'essai, pour la décontamination de cellules très radioactives et pour le filtrage de l'air contaminé.

Une défectuosité dans le concept du système de ventilation et du dispositif d'alarme de ce système a eu pour résultat un grand dégagement d'activité dans l'air dans la zone opératoire. Cet incident fait l'objet de commentaires et la petite modification requise pour éviter un tel incident est décrite.

L'efficacité opératoire de la ligne de préparation des échantillons métallurgiques serait améliorée si nous avions des moyens pneumatiques ou électriques rapides pour transférer les petits échantillons.

Le coût global de trois cellules de 10^6 curies, trois cellules de 10^4 curies, cinq cellules de 10^3 curies, d'un bâtiment et de ses auxiliaires s'est élevé à environ 2,200,000 dollars canadiens. Des robinets pour l'air, le vide, la vapeur et l'eau se trouvent à l'intérieur des cellules. L'expérience pratique a montré que ni l'efficacité opératoire, ni la sécurité radiologique ne seraient grandement réduites si de nombreux robinets se trouvaient à l'extérieur et si les cellules étaient desservies par les orifices actuels. Cela permettrait une économie d'environ $50,000.

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INTRODUCTION

Design of the Hot Cell Facility of the Whiteshell Nuclear Research Establishment (WNRE) was started early in 1963 and was completed in February 1964. The facility was built in two contracts. The first contract, for the construction of cells 1 and 2, started in May 1964 and was completed in July 1965. Construction of the remainder of the facility started in July 1965, and was completed in September 1966. The facility has been in continuous service since that time, except for one three-week period in September 1968 that will be discussed later. It should be noted that the design reflects 10 years of operating experience at the Chalk River Nuclear Laboratories (CRNL). Features that were working well at CRNL were incorporated without change. We cannot emphasize enough the importance of using as far as possible design features that have been proven out in practice in other facilities. We are convinced that adoption of this policy saved us at least a year in construction and commissioning, and probably avoided some radiation incidents during the commissioning period.

GENERAL

The essence of good design is a careful specification of the materials flow. The resultant design requirements can then be specified[1]. The layout of our facility including some major materials flow items is shown in Figs. 1 and 2. The first cell is for fuel string examination and disassembly, the second is for detailed fuel pin examination, the third for chemistry, the fourth, fifth, sixth, seventh and eighth for metallographic sample preparation, the ninth for metallography, the tenth for metallographic sample storage and the eleventh for mechanical testing. Access to the back of the cells is from a lightly shielded isolation room. The exhaust ducts run under the floor of the isolation room. The active filters and active equipment and wastes from the cells are removed through this room. Sample storage facilities are provided in a concrete storage block opposite cells 1 and 2, and flask storage is provided in a heavy-floor-load area near the building entrance. The entire facility is serviced by a 10-ton bridge crane (15 would be better), and heavy flasks are handled by a 35-ton fixed hoist located near the entry port of the first cell. All cells and the isolation area are accessible from above through roof ports.

TRANSFER OF IRRADIATED FUELS

Irradiated fuels are transferred in flasks on dollies, which move on rails to the face of the cells. The transfer into the cell is made through ports of the types shown in Fig. 3. Type (a) is a six-inch tubular entrance through the wall of the cell with a revolving gate to enable two, four and six-inch ports to be interchanged. Inserts can be attached to guide the materials between the flask and the cell. Type (b) contains an interchangeable three or six-inch square port. The type (a) port is installed in cell 1 only. Type (b) ports are installed in cells 1, 2, 3, 4, 10 and 11.

Port/insert clearances are 1.5 mm, which is considerably larger than the clearances used previously at CRNL. This avoids serious alignment problems and has not caused any difficulty from radiation beams. A typical flask on a dolly at the cell face is shown in Fig. 4.

If non-standard flasks containing samples are received in the facility, they can be unloaded or loaded by lowering the flask into the cells through the roof ports. Cell 1 is also equipped with a flask well, which is accessible from the isolation room using a dolly and rails. The dolly is pushed into the cell using a remote manipulator, which will be discussed later. Fig. 5 shows the access area in the cell. The manipulator is also often used to transfer small samples from cells 1, 2 or 3 to the metallography line through the isolation room.

Transfer ports, as shown in Fig. 6, exist between cells 1 and 2 and cells 4, 5, 6, 7, 8, and 9. Metallographic samples are transferred from cell 9 to cell 10 in spherical containers using roll-through tubes, as shown in Fig. 7. Operating efficiency in the metallography line would be improved if we had a rapid pneumatic or electrical means of transferring small samples, but this would have to be backed-up by a transfer port system in the event of breakdown of the rapid transfer system.

STORAGE OF HIGHLY ACTIVE SAMPLES

Research personnel often must retain fuel bundles, fuel pins, pieces of fuel material, sections of pressure tubes, burnup samples and the like for extended periods until the results have been fully interpreted and cross-checked with other results to ensure they are valid. At CRNL samples were stored in vertical wells where one sample was stored on top of the next one, and if the sample required for rechecking was at the bottom of the well, all samples had to be moved to obtain the one desired. To avoid this problem at WNRE, we constructed the horizontal storage block shown in Fig. 8. Fuel bundles and fuel pins are stored in drawers of the type shown in the insert and two drawers can be held in each receptacle. Thus there is room for 24 fuel bundles, and since each pin drawer will hold 15 fuel pins, there is room for 1620 fuel pins. This distribution is not quite right. Experience has indicated that we should have room for about 50 fuel bundles and that room for about 1200 fuel pins would be quite adequate. The drawers containing the pins or bundles are removed from the cells in a standard flask shown in Fig. 9, and the flask is positioned using a simple hand elevated dolly on tracks. The secret of successful operation of this type of storage block is to avoid making the drawer/receptacle clearance too small. If the clearance is too small, the problem of lining up the flask becomes prohibitively difficult. Our clearance is 2 mm, which means we can have a 4 mm gap between the drawer and the sleeve. Gamma beams from this size of gap are surprisingly small - less than 1 R/h at the face of the block - but we eliminate them completely by fitting a low clearance plug (clearance 1 mm) into the receptacle after the storage drawers are in place.

Small samples are stored in a vertical type of storage facility shown in Fig. 10. Samples are removed from the cells in flasks and are placed on the storage shelves using long tongs. Radiation exposures during these transfers are negligible.

DISPOSAL OF HIGHLY ACTIVE GARBAGE

The active garbage is collected inside the cell in a normal home garbage can. The procedure for disposing of this can is as follows.

The garbage can flask, shown in Fig. 11, is lowered into the isolation room through a roof port. An operator enters the isolation room and removes the shackle holding the flask lid down, and the lid is lifted with the bridge crane. The operator then leaves the isolation room and the cell door is swung open as shown in Fig. 12. The remote manipulator then reaches into the cell, picks up the garbage can and deposits it in the disposal flask as shown in Fig. 13. The flask lid is closed by pulling on it with the crane hook as in Fig. 14. The operator then returns to the isolation room, replaces the lid shackle and decontaminates the outside of the flask if this is required. The flask is then removed to the disposal area and the procedure reversed using a mobile hoist.

There are two features connected with this operation that are worthy of particular note, viz., the hinged doors of the cells and the remote manipulator.

Most hot-cell doors open and close on rails, and when this is feasible it is certainly a good method. In our particular case, door rails would have interfered with filter removal, so we developed an alternative arrangement. The method chosen was to suspend the doors on large hinges and balance them so they could be opened simply by the friction between two small motor-driven wheels and the floor as shown in Fig. 15. To give you an idea of the simplicity of this system, our largest doors weigh 17 tons, and can readily be opened and closed by hand. Any bank vault manufacturing company can design, build and balance such doors easily and economically. Our doors are made of heavy concrete identical to the cell walls.

The remote manipulator shown in Fig. 16 is an invaluable feature of the facility, not only for removing active wastes but for inserting and removing equipment and for transferring samples from one cell to another. The manipulator has a carrying capacity of 500 pounds at the end of its arm and has eight motions: east, west, north, south, up, down, rotate right, rotate left. Thus it can cover the entire isolation room, and can reach through the cell doors and into the cells without difficulty. This manipulator can be installed complete with track and motors for about $20,000 and is well worth the price.

DISPOSAL OF LIQUID WASTES

The disposal of liquid wastes, particularly slurries from cutting and polishing operations, has always been a problem in hot cell facilities. Active particles from the slurries get trapped in valves and pipe elbows, and cause radiation problems when the drainage system has to be maintained.

The problem has been overcome in the WNRE facility in two ways.

First, cutting is done with a high speed Con-O-Saw[1], shown in Fig. 17,

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1 Trade name for a saw manufactured by Continental Sensing Inc., Melrose Park, Ill., U.S.A.

that minimizes both the amount of cuttings and the amount of cooling liquid required. The blades are 0.4 mm thick and rotate at 11,000 rev/min. The cooling is provided as a spray mist, and only about a millilitre of coolant is required to cut a sample. Normal fuel pins are cut in about 20 seconds. The coolant and cuttings are collected in the tray at the bottom and the coolant evaporates. The cuttings could be collected from the tray and disposed of dry, but there are so few produced that in our operation they are just left in the tray. The saws cost only $150, so if one breaks it is just replaced.

Wastes from the polishing wheels are handled in the filter system shown in Fig. 18. The filter assembly fits into a well in the floor of the cell and the polishing slurry enters the well above the filter through a hole in the side. The solids are collected in the filter, and the liquids pass through into an active sump tank and thence to the plant disposal tanks. When the filter starts to plug, the filter assembly is pulled into the cell, Fig. 19, and the filter replaced immediately. Initially there was a suction pump on the liquid exhaust line to assist filtration. It has now been removed since it required some maintenance and was found to be unnecessary.

REMOVAL AND REINSTALLATION OF EQUIPMENT

Large pieces of equipment are moved in and out of the cells through the rear doors to and from the isolation room using the remote manipulator discussed earlier. If the equipment is to be used again shortly, it is stored in the isolation room. If not, it is packaged and either stored in the storage room or sent to the decontamination area.

Small pieces of equipment such as tools or measuring instruments are inserted and removed through access ports near the roof of the cell. These access ports are serviced by elevators inside the cell, which transport the equipment to and from the operating floor as shown in Fig. 20. These ports are extremely convenient and save much opening and closing of the rear doors.

DECONTAMINATION OF CELLS

In operating a hot cell facility, one must always retain the option of decontaminating the cells to a level where people can enter the cells and make modifications. The cells should therefore be decontaminated on a regular basis, the period being dependent on the operations performed in the cell. In a cell where fuel pins are cut open for examination, the period should not be more than two years.

We recently decontaminated cell 2 to make modifications to our stereomicroscope. We removed all the equipment and swept up any particulate matter. The entire cell was then remotely wiped down with rags soaked in an aqueous solution of strong detergent and EDTA. The cell was then remotely steam cleaned with the steam detergent cleaner shown in Fig. 21. The steam condensate was not flushed down the active drains but was soaked up with rags which were then sent to solid disposal. This reduced the general activity to a level where hot spots could be identified, and the steam jet was concentrated on these hot spots until the general activity level was reduced to 300 mR/h gamma and about 2 rad/h beta. This was low enough to allow the maintenance work to be completed with the aid of lead and asbestos sheet over hot spots without exceeding permissible exposure levels. The cell was out of service for a period of 3 weeks.

EXHAUST AIR FILTRATION

In our facility the air from the cells is exhausted through ducts under the floor of the isolation room, and the filters are removed and replaced through the isolation room as shown in Fig. 22. Each filter well is supplied with a low efficiency and a high efficiency filter made of fiberglass. If we were building the cells again, we would leave room in the filter well for a charcoal filter. Although we have never had any problems with radio iodine release, the question has been raised, and we will undoubtedly have to contend with radio iodine if we choose to cut open fuel pins that have had short cooling periods.

A RADIOACTIVE CONTAMINATION RELEASE INCIDENT

It was mentioned earlier that the cells had operated continuously since September 1966 except for a 3-week period in 1968. This shutdown was caused by a release of activity into the operating area, which resulted in minor internal contamination of seven people.

Air is exhausted from the cells by an exhaust fan backed up by a second fan, which is supposed to start automatically if the first exhaust fan stops. In August 1968, one exhaust fan stopped, and because of a faulty switching arrangement the second fan failed to start. Since there was no audible alarm in the operating area to indicate that both exhaust fans had stopped, the hot cell staff continued to perform normal operations. One of these operations was to open the back door of cell 2 to remove garbage. The actions of opening and closing the door caused an airborne release of activity through the doorway into the isolation room and mainly through the manipulator ports to the operating area. The operating area was evacuated when the contamination monitors indicated abnormal airborne contamination in that area.

A better fan switching arrangement or a supply/exhaust fan interlock system could have prevented the incident, but we believe that the most important omission was a simple audible alarm in the operating area to warn the staff that the exhaust fans had stopped. If such an alarm had been installed, the cell door would not have been opened and the incident would have been avoided.

As a result of the incident it was necessary to spend three weeks decontaminating the entire operating area from ceiling to floor.

CONCLUSION

We have described just a few of the features which have made the WNRE Hot Cell Facility a safe, yet efficient operating unit. In the three years it has operated, average staff exposures have been about 1.3 rem/yr per man. None of the features are excessively expensive. The entire unit of eleven cells plus building and all auxiliaries cost about $2,200,000.

REFERENCE

(1) R.G. Hart, Design Requirements for the Whiteshell Hot Cell Facilities, Unpublished report WDI-7, Atomic Energy of Canada Limited.

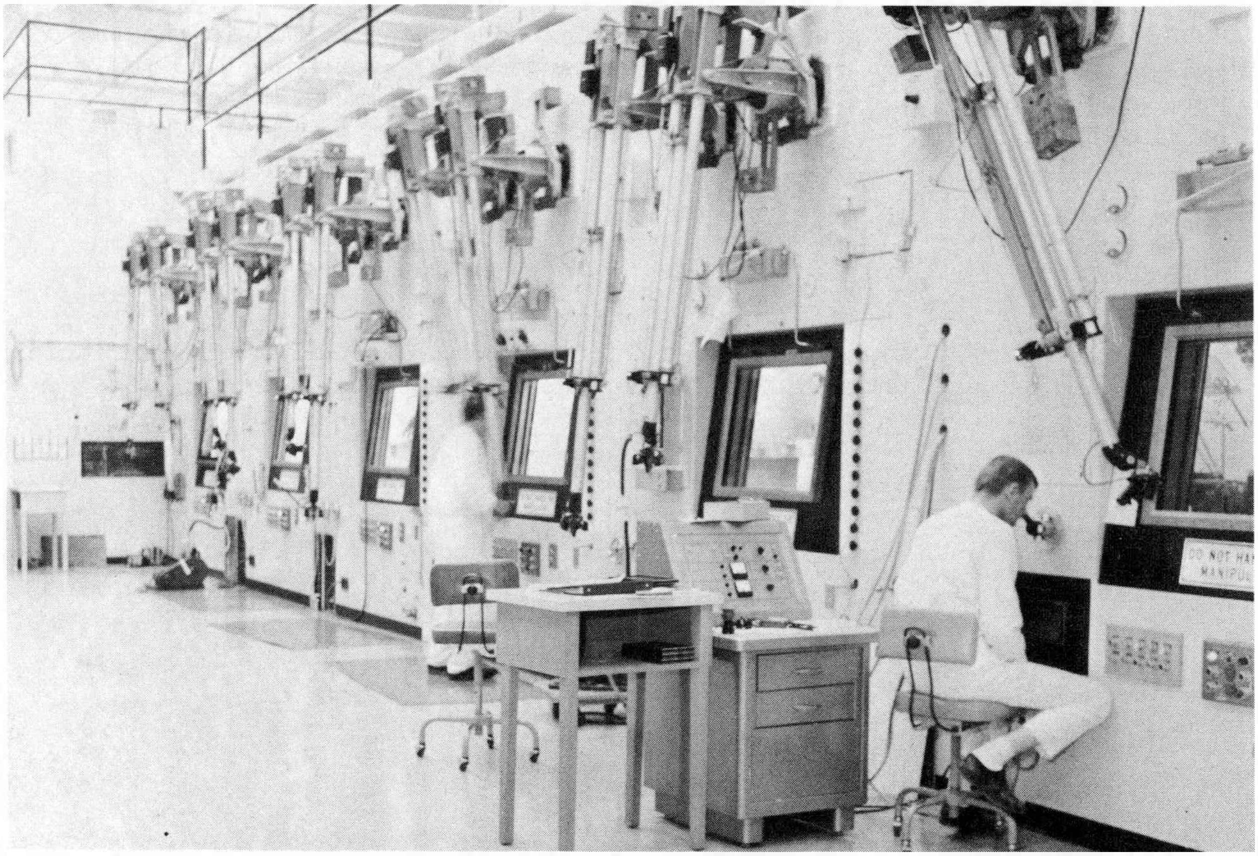
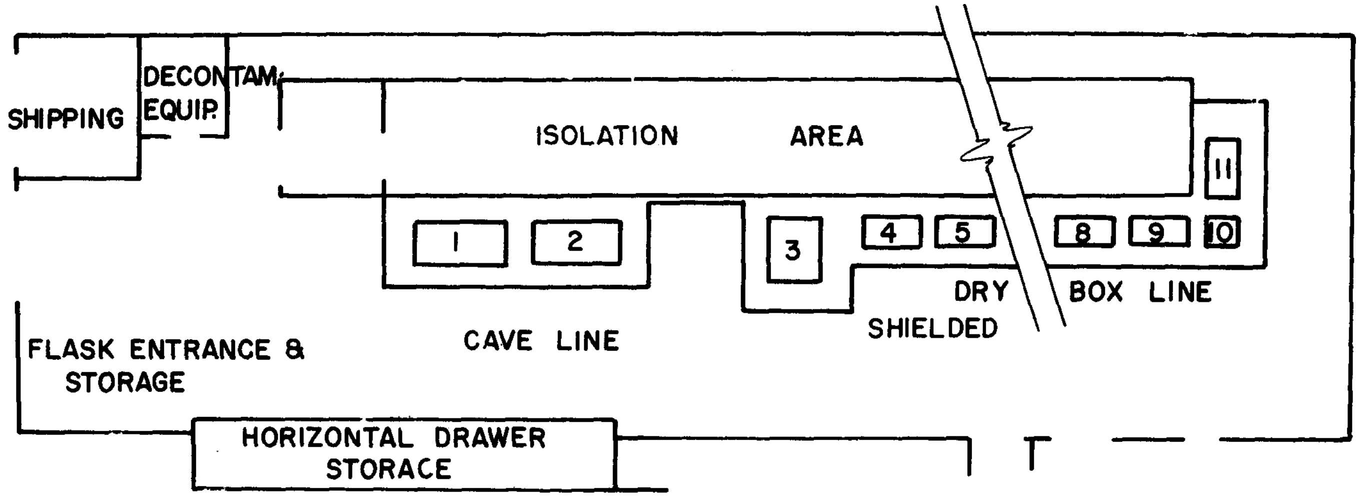


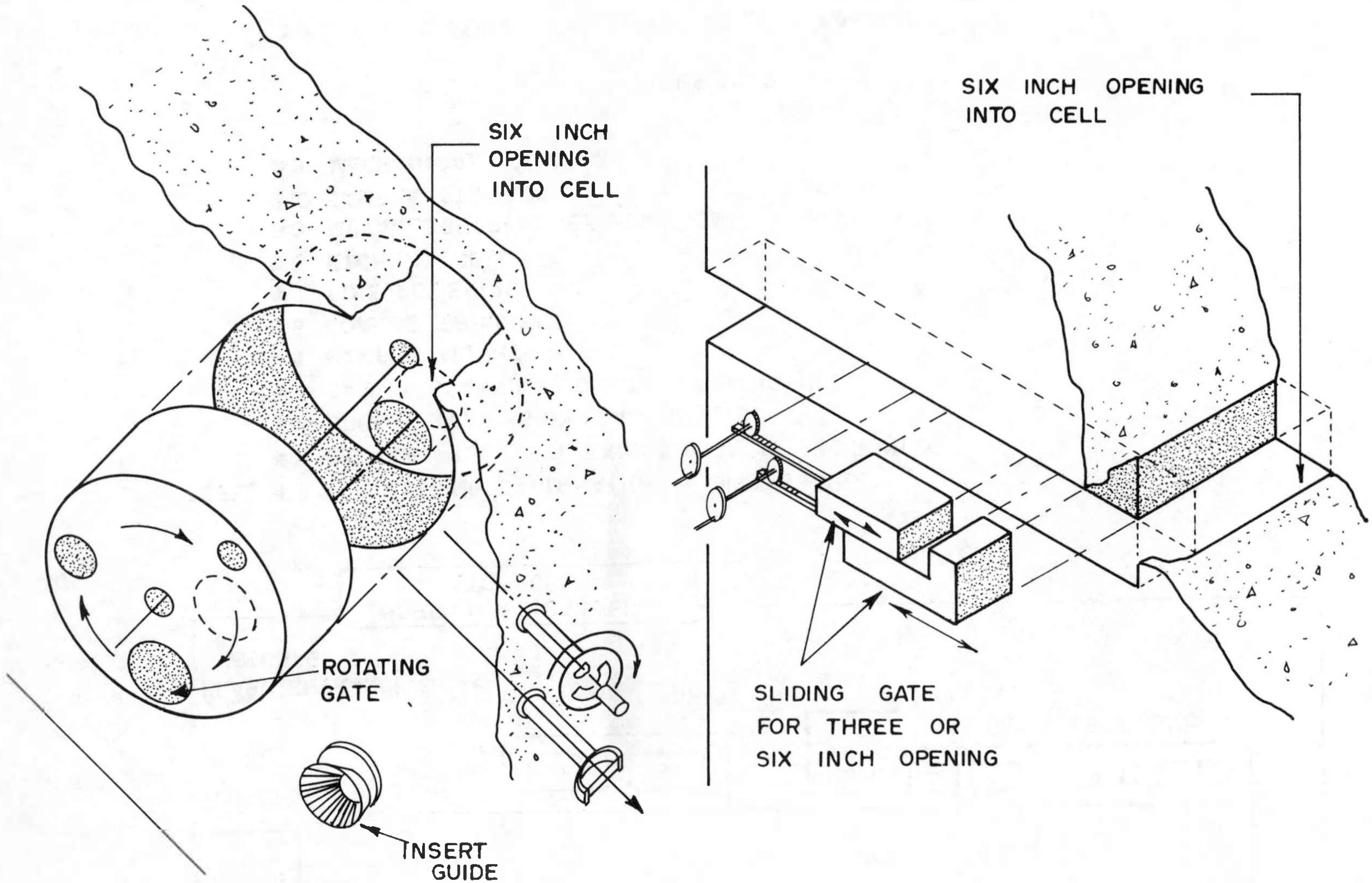
FIGURE 1: Front Face of Hot Cell Facility



CELL #1 FUEL STRING EXAMINATION & DISSASSEMBLY
#2 DETAILED FUEL PIN EXAMINATION & SECTIONING
#3 CHEMISTRY, FISSION GAS ANALYSIS
#4 GAMMA SCANNING, DENSITY SECTIONING
#5 SAMPLE MOUNTING
#6 COARSE GRINDING
#7 FINE POLISHING
#8 ETCHING CELL
#9 METALLOGRAPHIC EXAMINATION
#10 SAMPLE STORAGE
#11 MECHANICAL TESTING

FIGURE 2

LAYOUT OF HOT CELL FACILITY



Type (a). Exploded view

Type (b). Exploded view

FIGURE 3

DIAGRAMMATIC SKETCH OF CELL PORTS

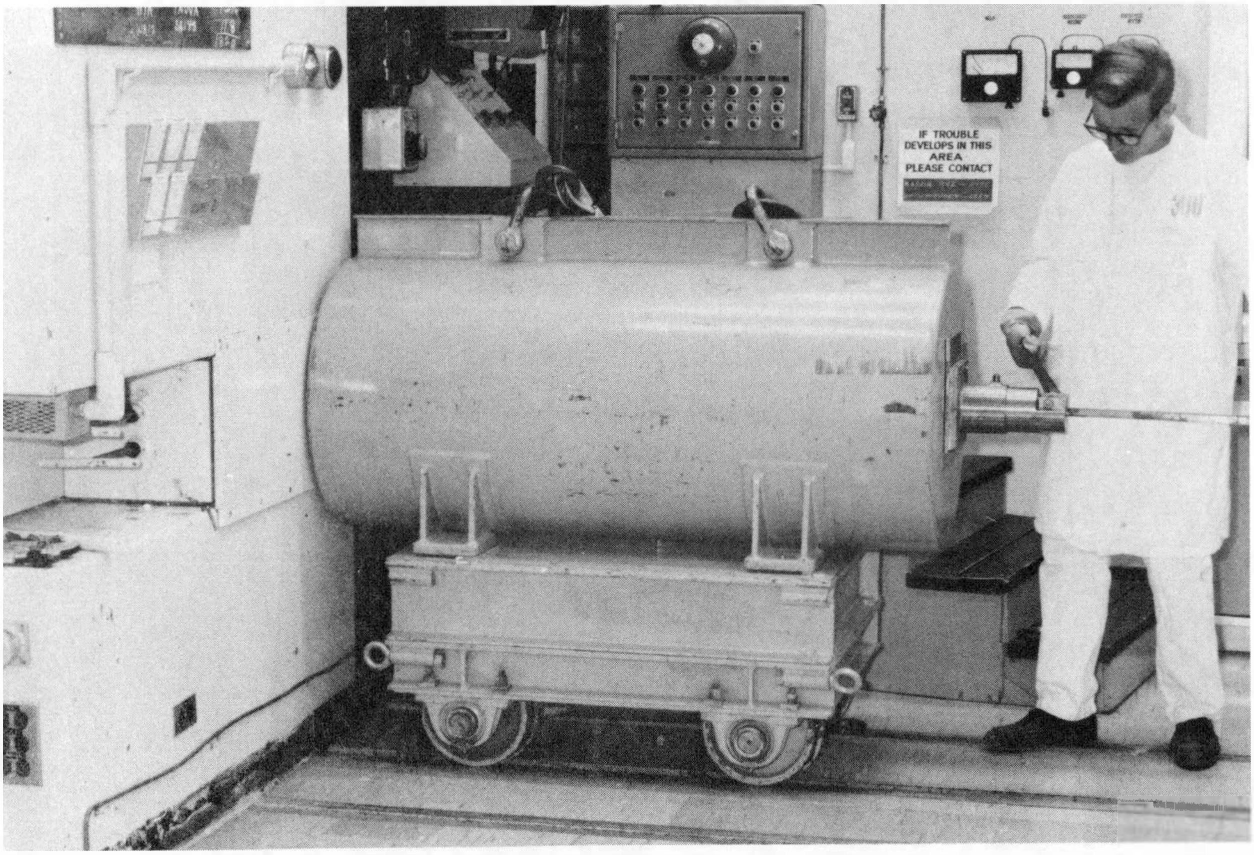


FIGURE 4: Transfer Flask on Dolly at Cell Face

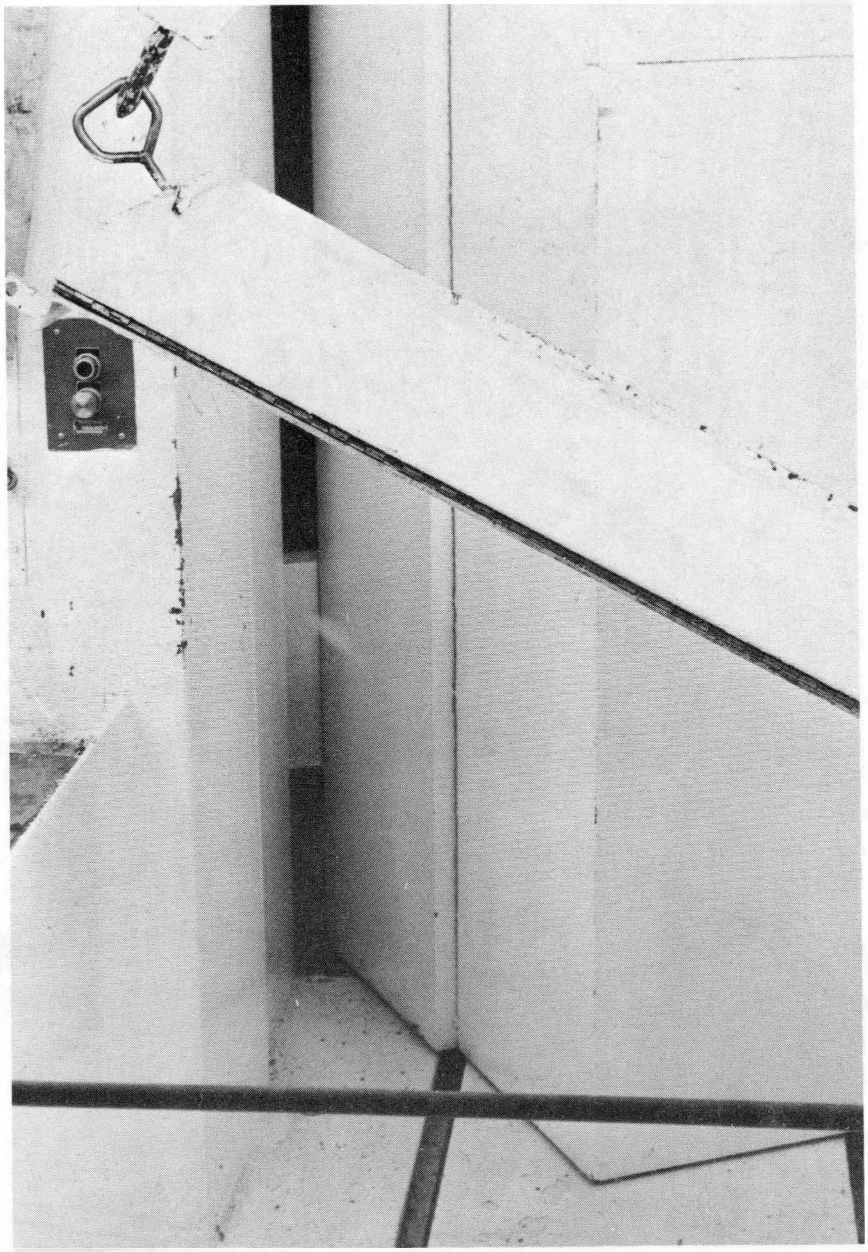


FIGURE 5: Access Area for Flask and Dolly in Cell

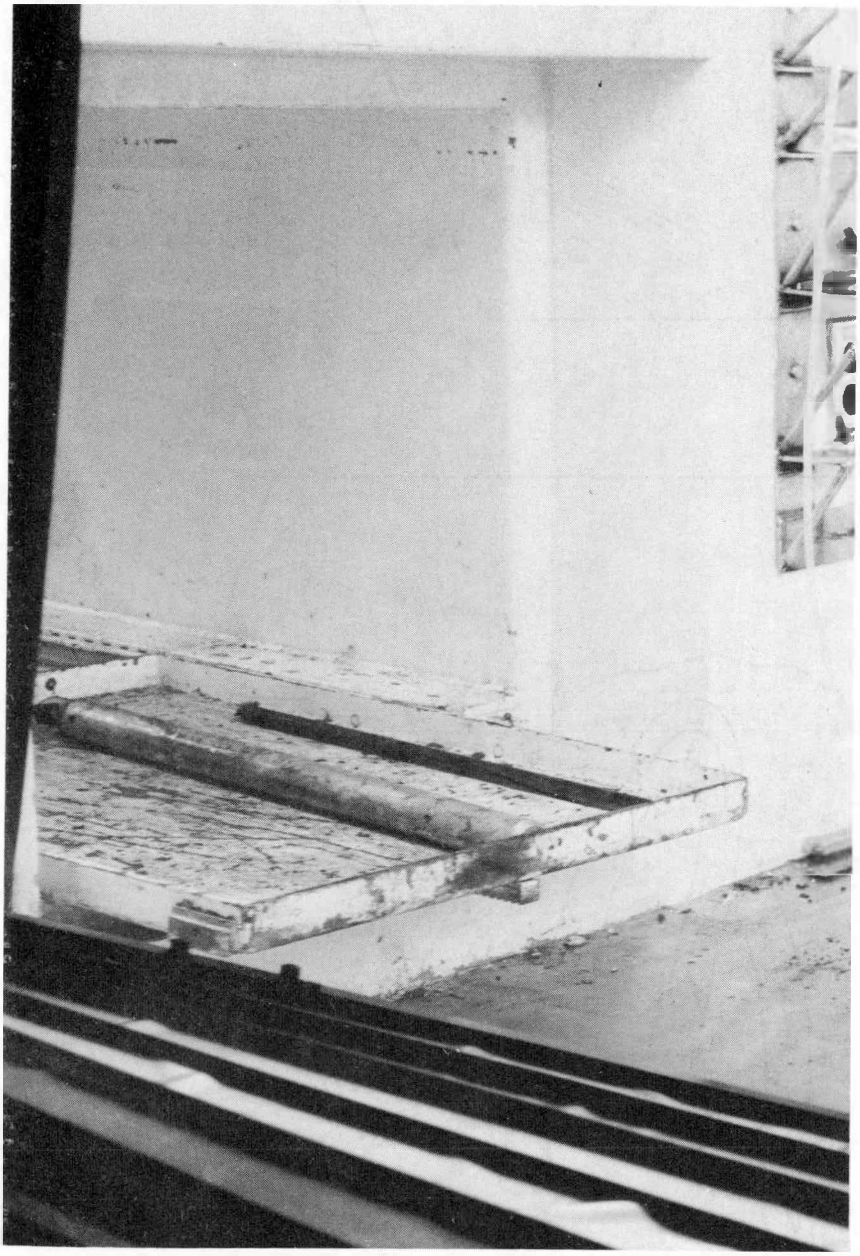


FIGURE 6: Transfer Port Between Cells 1 and 2

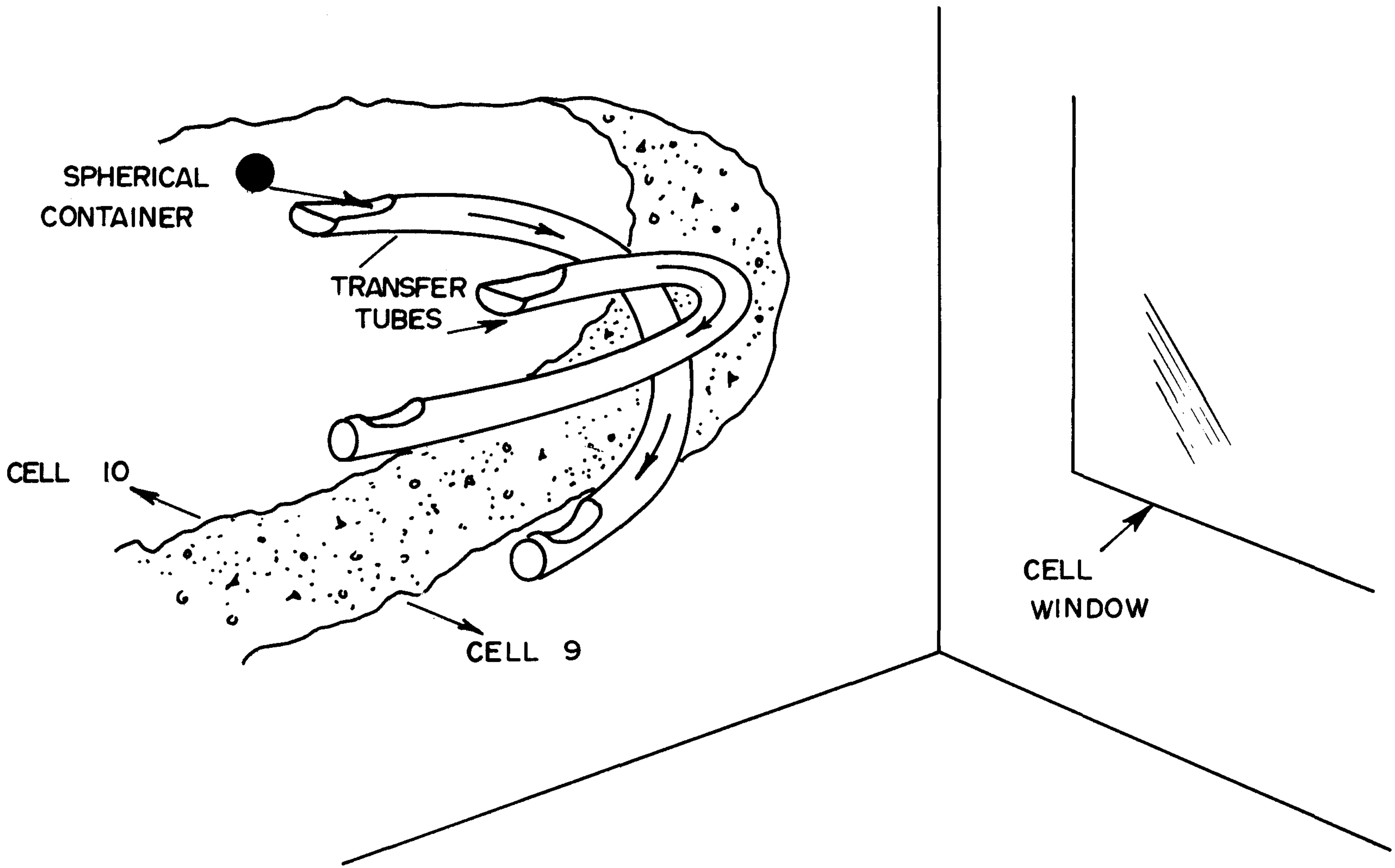


FIGURE 7

DIAGRAMMATIC SKETCH OF TRANSFER TUBES
BETWEEN CELLS 9 & 10

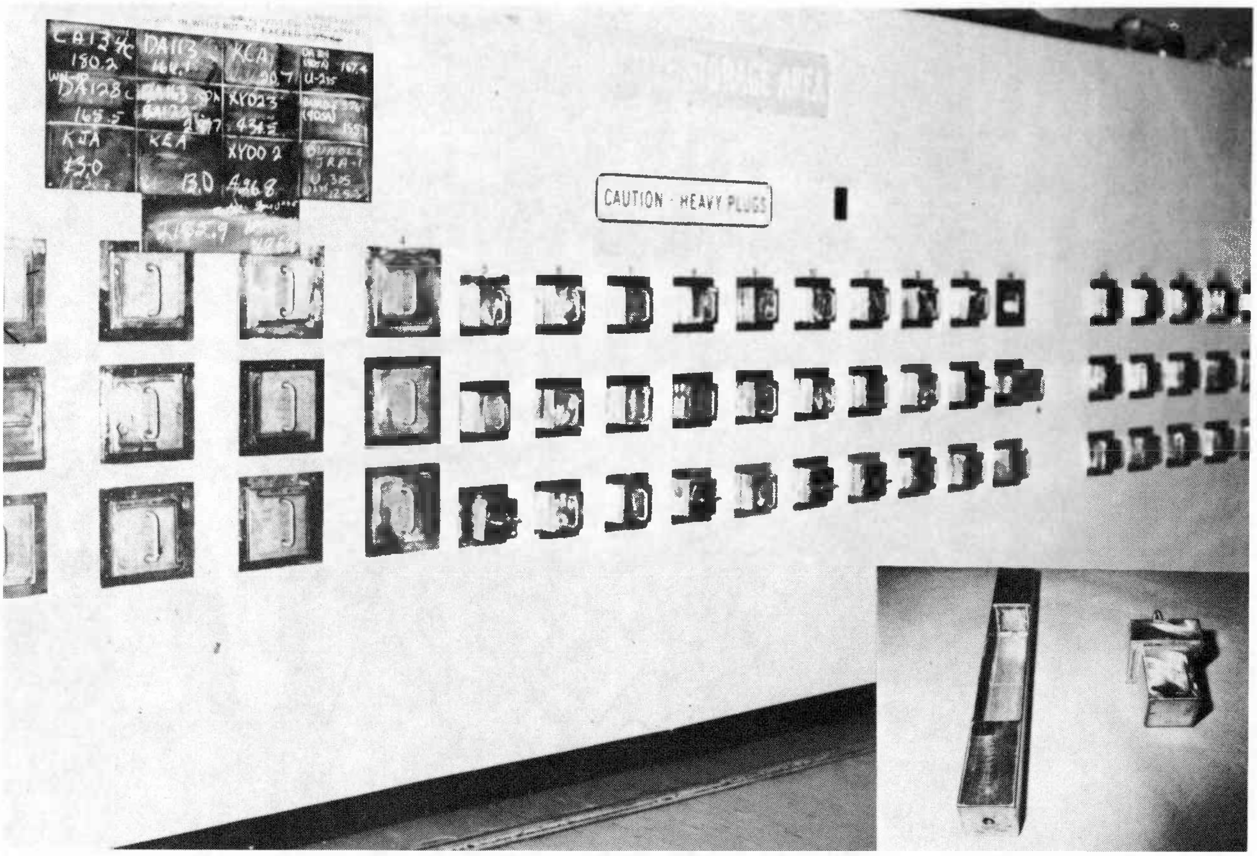


FIGURE 8: Face View of Horizontal Storage with Insert of Shielding Plug and Drawer

FIGURE 9: Standard Transfer Flask positioned in front of Horizontal Storage

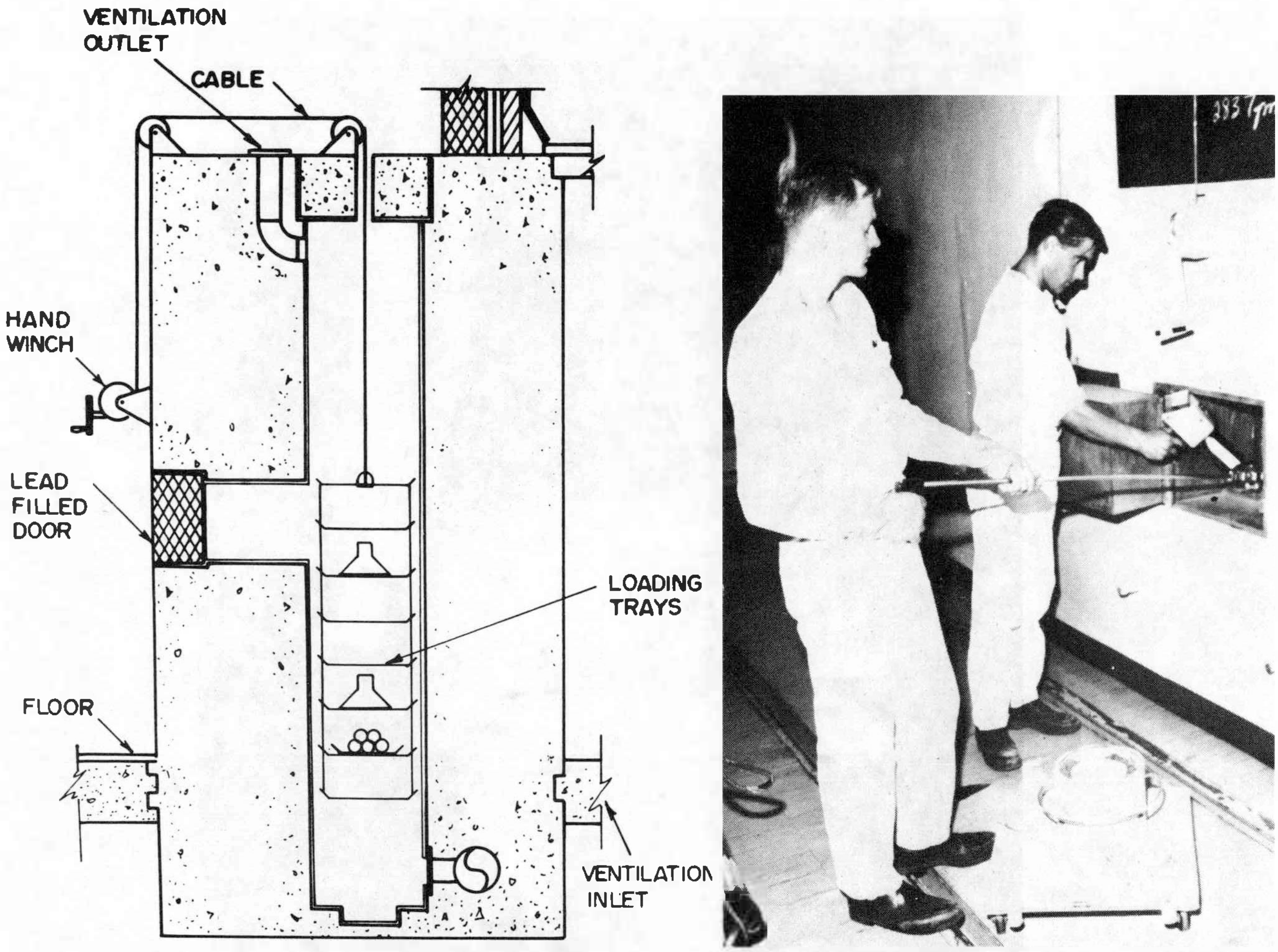


FIGURE 10

LAYOUT OF VERTICAL STORAGE WITH PHOTOGRAPH OF SAMPLE TRANSFER

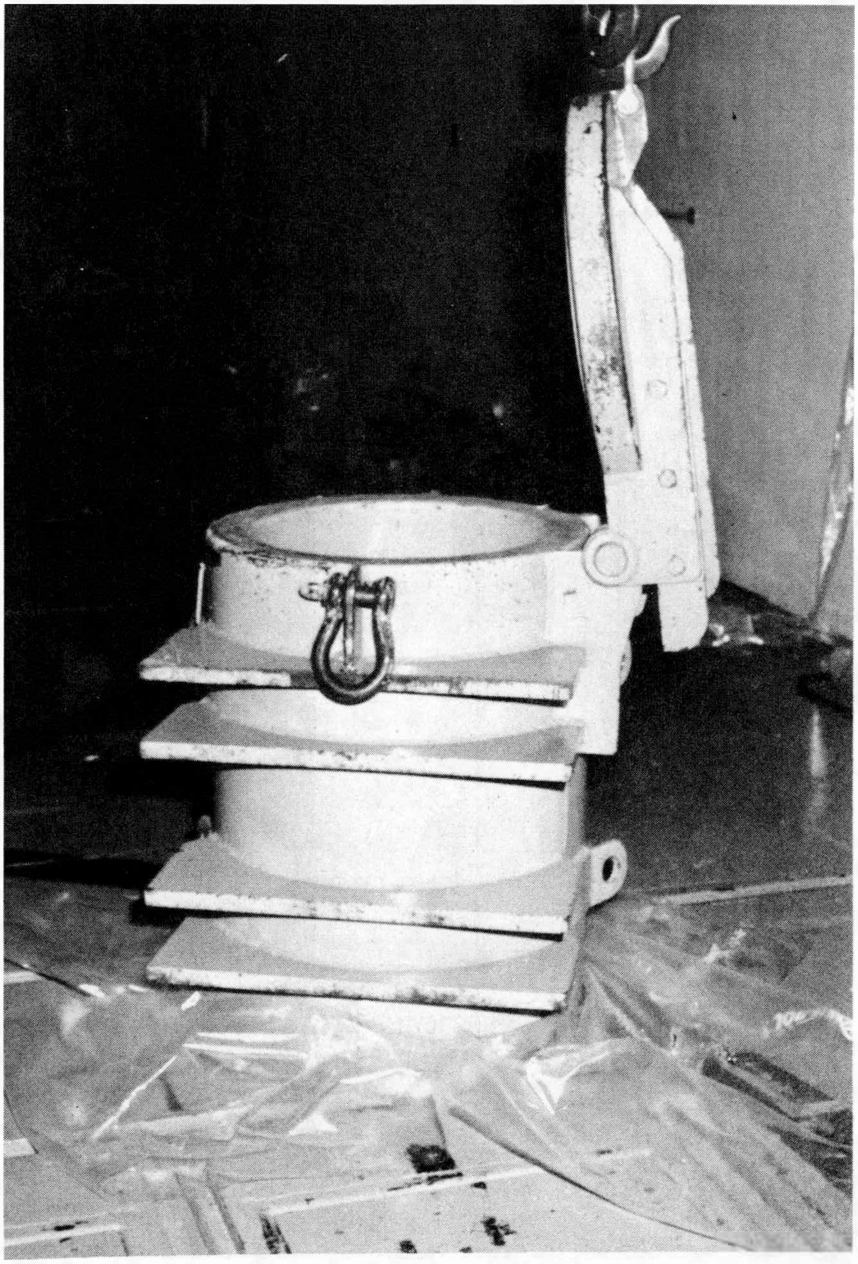


FIGURE 11: Garbage Can Flask in Isolation Room with Lid held open in the Correct Transfer Position

FIGURE 12: Cell Door open with Manipulator picking up Garbage Can

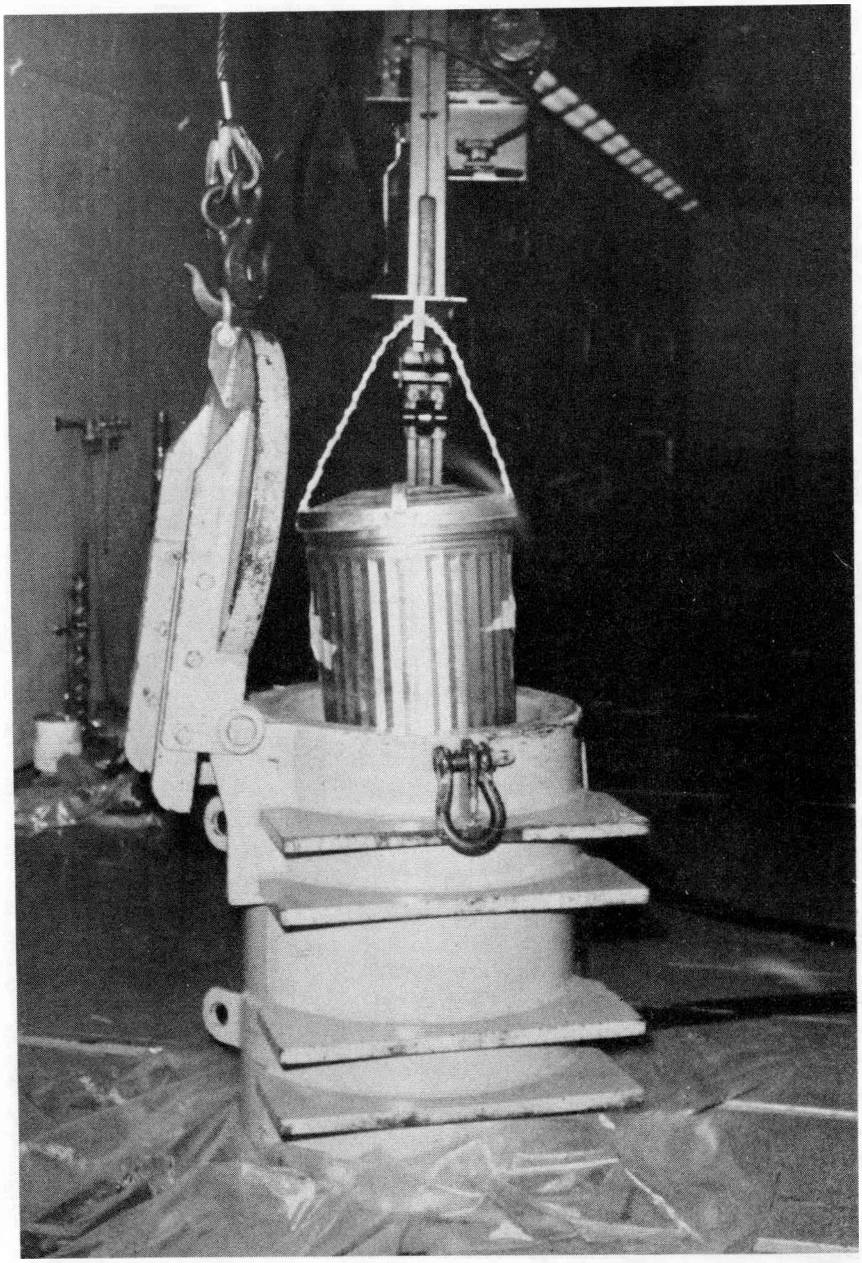


FIGURE 13: Manipulator lowering Garbage Can into Disposal Flask

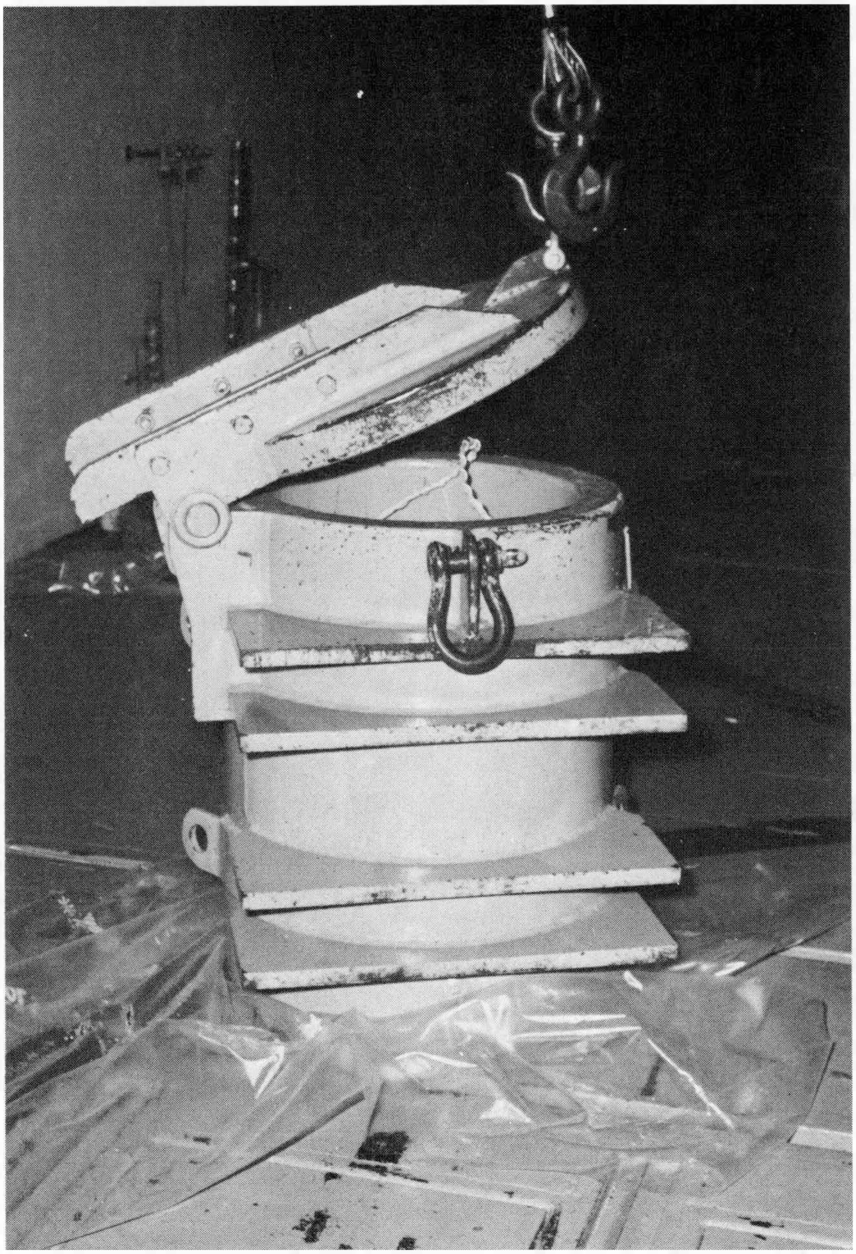


FIGURE 14: Garbage Can Flask with Lid in Partially Closed Position

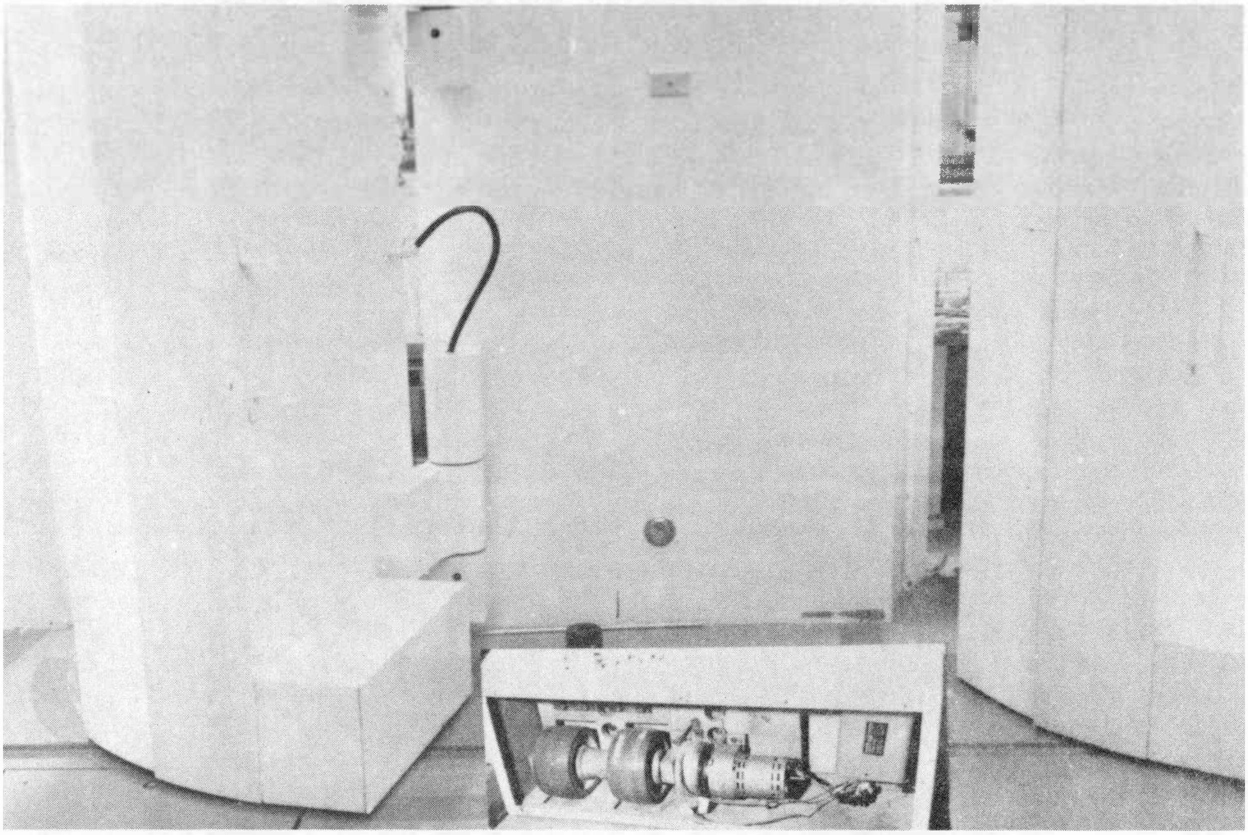


FIGURE 15: Back of Cell Door in Open Position with insert of Drive Wheels

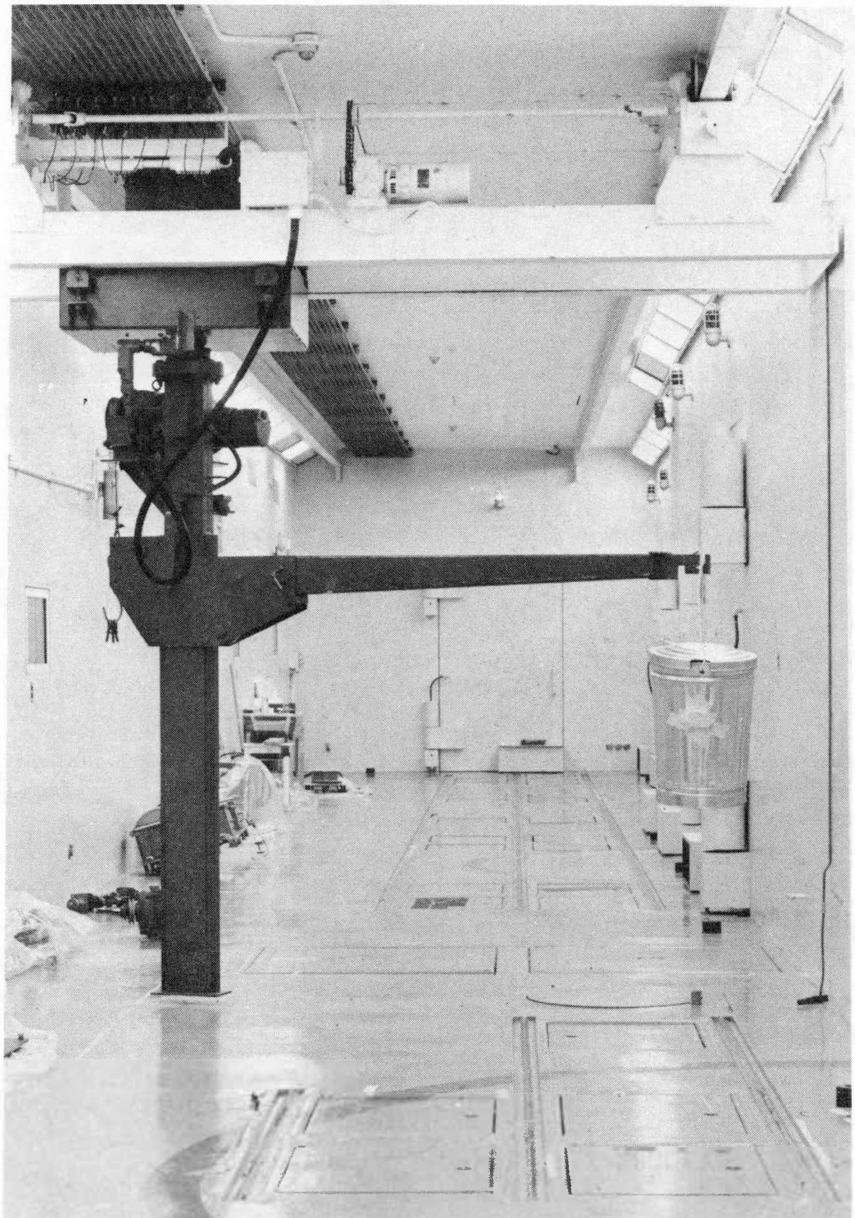


FIGURE 16: Remote Manipulator in Isolation Room

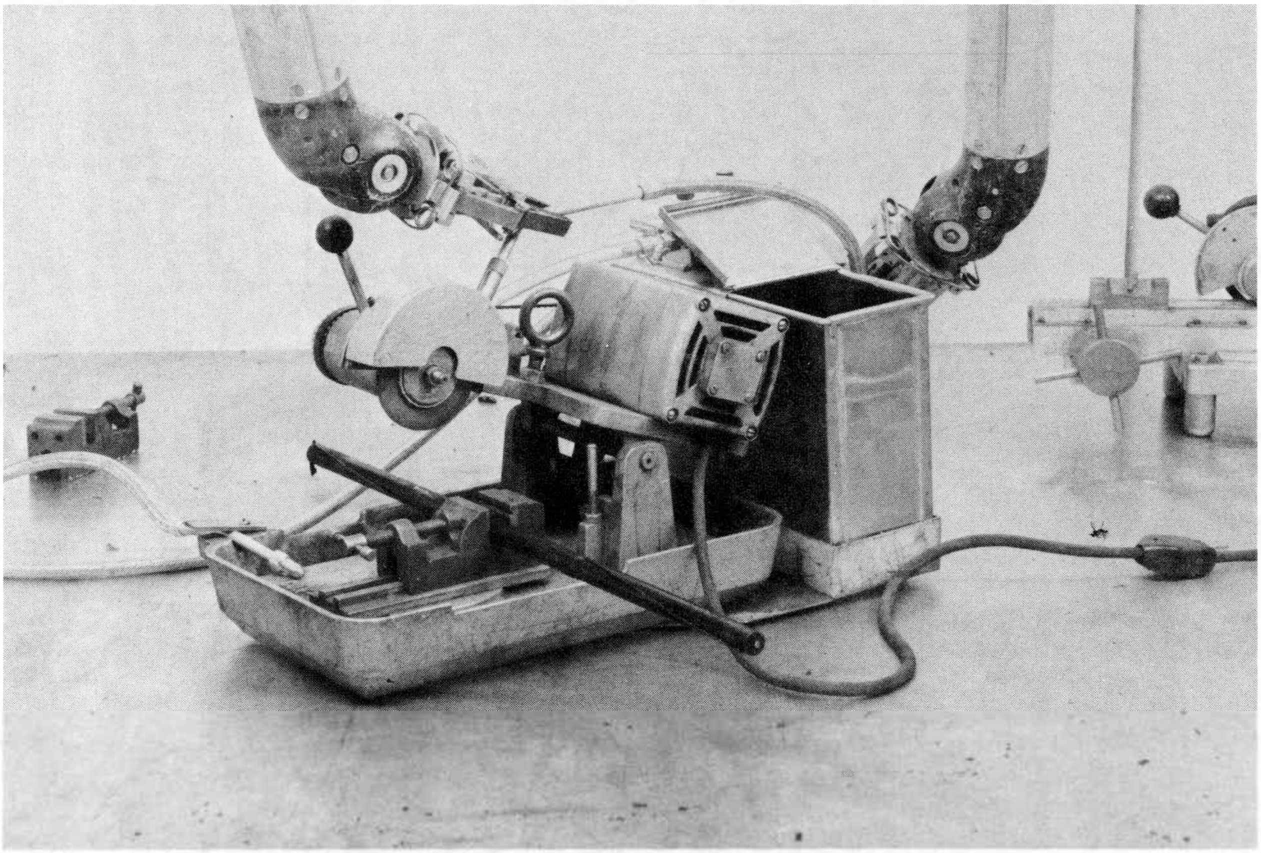


FIGURE 17: Con-O-Saw in Operation

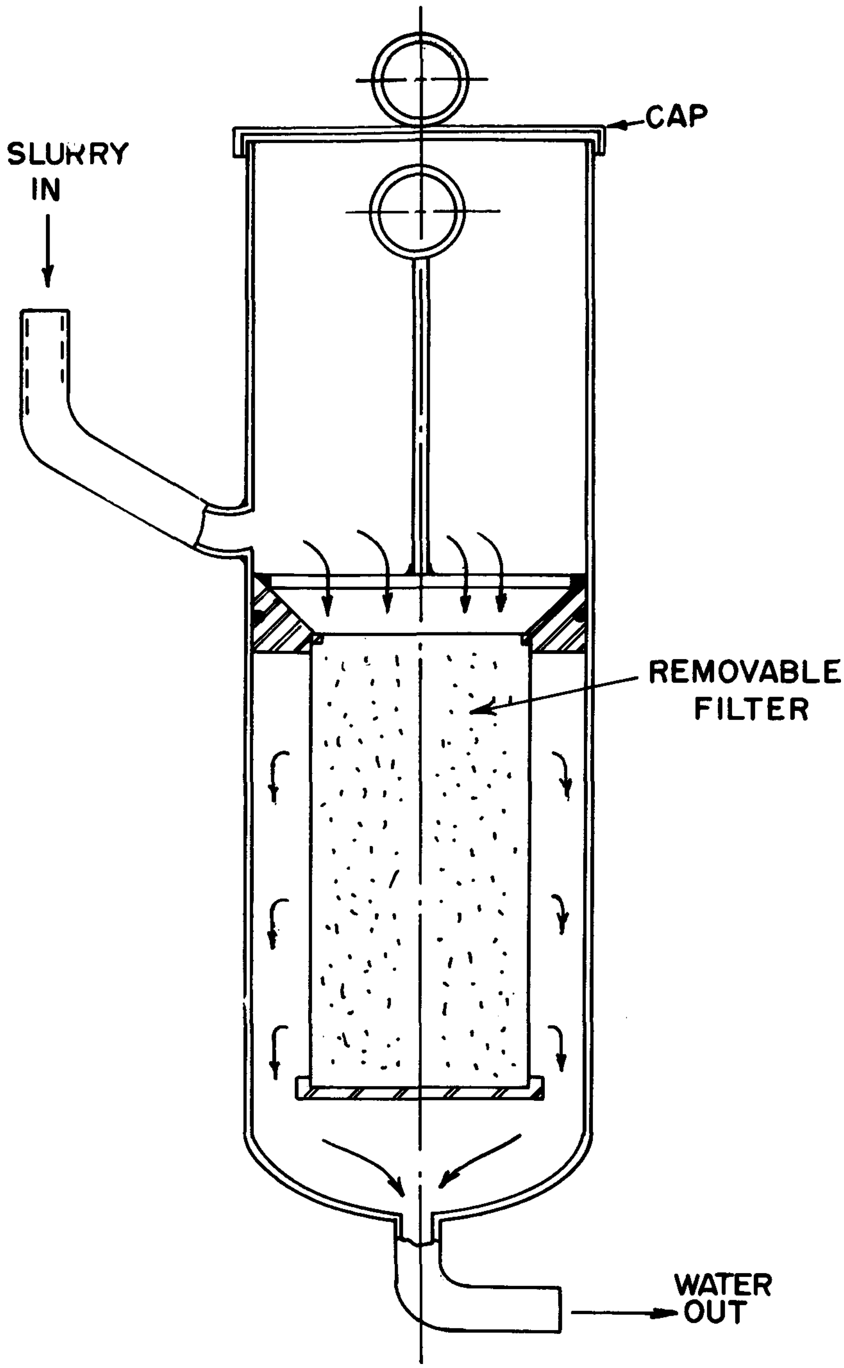


FIGURE 18
SKETCH OF DRAINAGE FILTER ARRANGEMENT

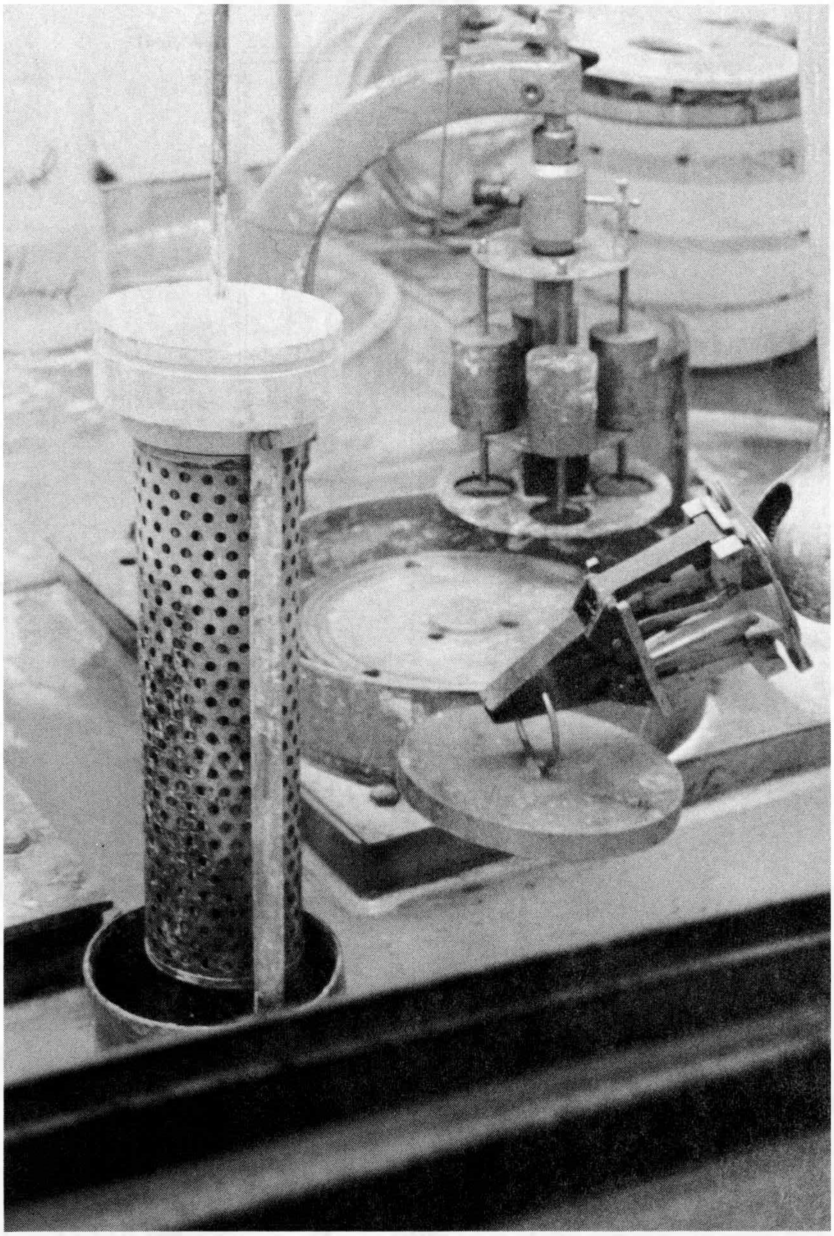


FIGURE 19: Filter Assembly being pulled out of Well with Manipulator

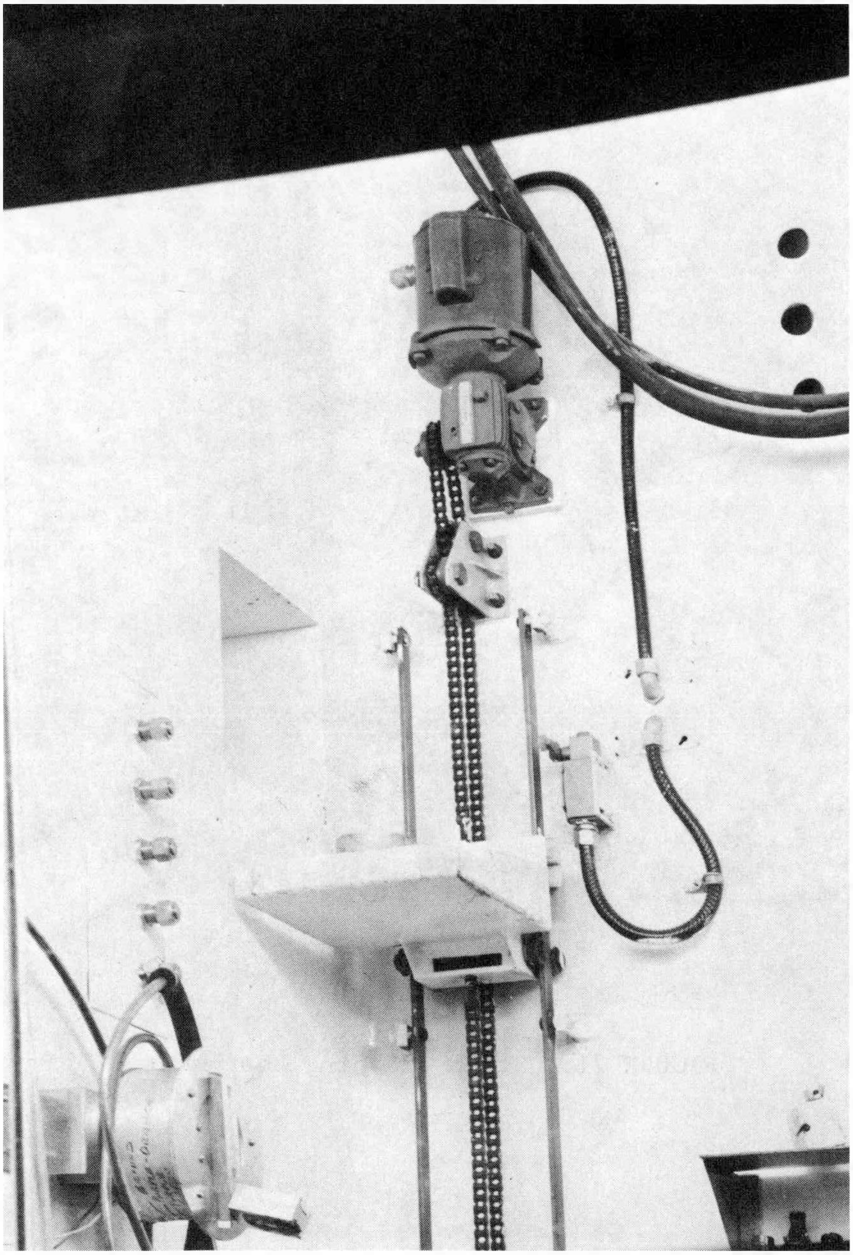


FIGURE 20: Elevator to Access Ports near Ceiling of Cell

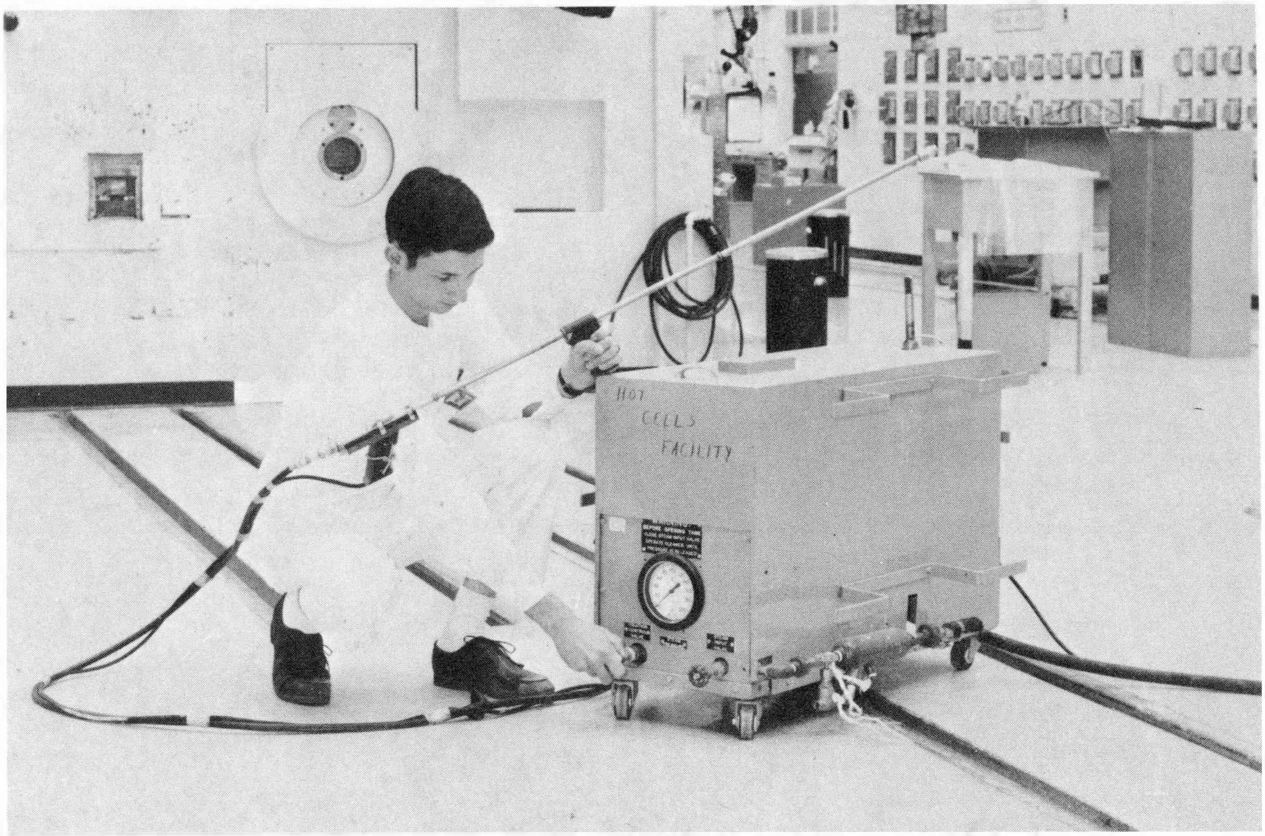


FIGURE 21: Steam Cleaning Equipment

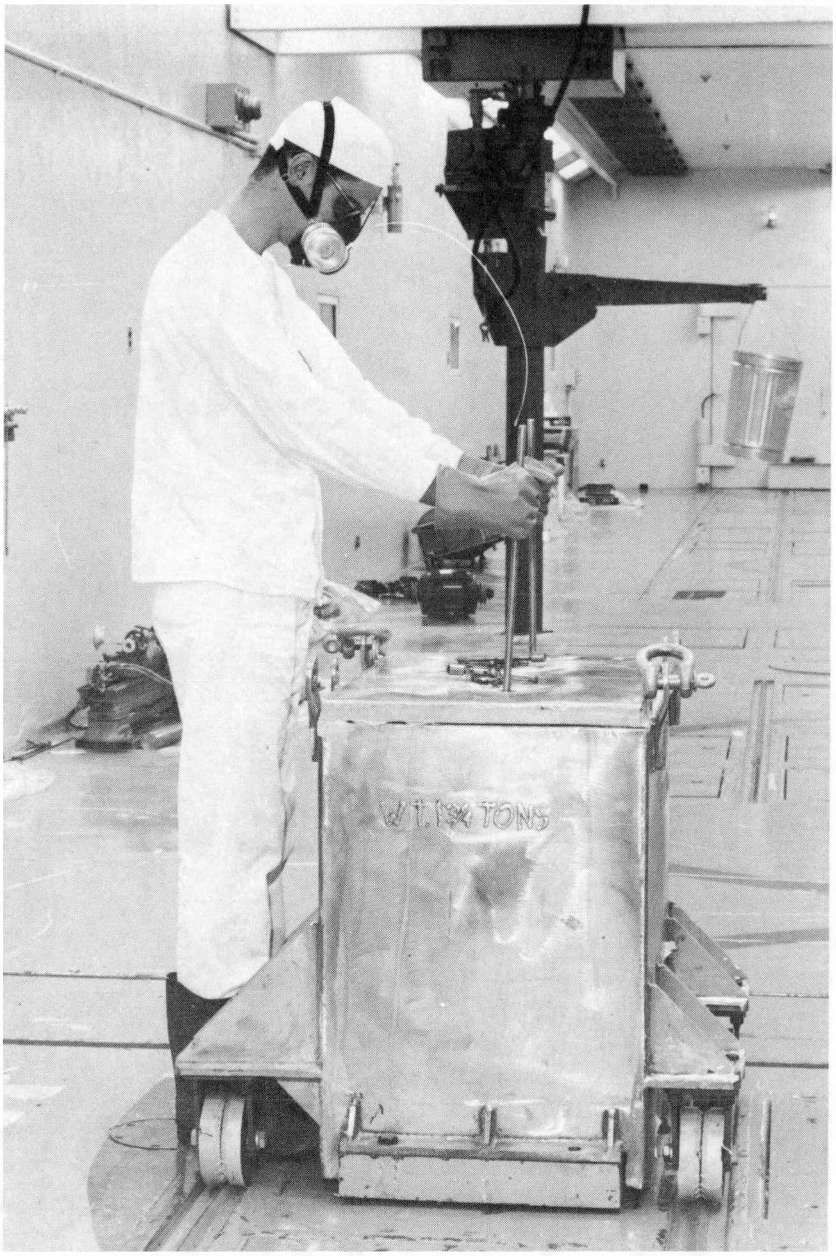


FIGURE 22: Filter Disposal Flask in Position to receive Ventilation Filters