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The Design, Construction, and Equipment of a New High Level Radiation Laboratory at NRL

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ABSTRACT

A new NRL High Level Radiation Laboratory is described, with special emphasis on the design, construction, and collateral equipment. This laboratory provides a means for safely handling and conducting research on gamma-active materials of interest to the Navy. The facility includes: five hot cells, with three designed for 1,000 curies and two designed for 10,000 curies of 1-Mev gamma; isolation cubicles back of cells; a "warm" work area; a decontamination room; x-ray laboratory; radiochemistry laboratory; machine shop; isotope storage facilities; waste disposal system; "cold" laboratories; and offices and utilities area. Design innovations discussed include: steel-lined cells; all-glass windows with exceptional viewing angle and clarity; manually operated hinged steel shielding doors; internal and external transfer drawers; special receptacle panels in cells; cell lighting; underwall U-tubes; underwindow access ports; removable roof plugs; isotope storage; waste disposal system; and gas scrubber. Equipment discussed includes: heavy-duty master-slave manipulators; mechanical arm manipulators and bridge cranes in cells; through-the-wall periscope; through-the-wall stereomicroscope; a remotely controlled shielded metallograph with through-the-wall specimen transporter; and metallographic specimen preparation equipment. Results of tests with a 9,500-curie Co-60 source on the shielding integrity of the facility are presented.

PROBLEM STATUS

This is the report on the facility built under the military construction program funded by the 86th Congress. All work on this project has been completed.

AUTHORIZATION

Military construction program funded by 86th Congress, Appropriation Public Law 86-149 dated 10 August 1959.

Manuscript submitted October 16, 1964.

THE DESIGN, CONSTRUCTION, AND EQUIPMENT OF A NEW HIGH LEVEL RADIATION LABORATORY AT NRL

INTRODUCTION

The Metallurgy Division initiated plans in 1955 for the study of the effects of nuclear radiation on metals in order to fill an important gap in metallurgical knowledge which up to that time had received only cursory attention. The increasing importance of nuclear energy to the Navy made it imperative that exhaustive investigations be made into the effects on the mechanical and other properties of metals operating in a nuclear environment. To implement the early research and to provide means for remote handling and testing of radioactive samples, a shielded two-cell facility with limited work space was assembled under the author's technical guidance during the last half of 1956. An existing experimental one-cell block was expanded to two cells and surrounded with work space, including a change room. This limited interim facility has been in continual use for metallurgical investigations of radiation effects in metals up to the present time.

The subject hot-cell facility was first proposed officially by representatives of the Metallurgy Division and reviewing NRL authorities in March 1956. The initial plan was for eight cells and supporting facilities covering 12,000 sq ft of floor space in an existing warehouse building. After further development of the idea, the Fiscal Year 1959 Shore Station Development Program submitted in Sept. 1956 carried the item of "High Level Radiation Laboratory." In March 1957 the proposal and all subsequent refinements were submitted to ONR. Mr. R. Catey of the Public Works Division of NRL prepared the necessary information. The author assisted Mr. Catey by providing the basic layout requirements.

Advanced planning for the High Level Radiation Laboratory was authorized by BuDocks in April 1957, and Vitro Engineering Company of New York City was selected as the architect-engineer (A&E) to conduct a preliminary engineering study.

In June of 1957, the author was appointed as a Metallurgy Division consultant to the Public Works Division in planning the new facility. Others appointed in an advisory capacity were Mr. J.A. Grand of the Chemistry Division, Dr. V.J. Linnenbom of the Radiation Division, and Mr. L. Garcia of the Nucleonics Division.

The starting concept of a High Level Radiation Laboratory proposed to the A&E was a seven-cell facility that was to include five metallurgical cells, one wet chemistry cell, and one health physics cell, and in addition, a cobalt-60 swimming pool. The cost of this arrangement, including the cost of the necessary collateral equipment, was estimated to be in excess of 2 million dollars. The Director of the Laboratory requested on 19 July 1957 that the scope of the project be reduced so as to be within a 1.5 million dollar level. Based on this recommendation, the size of the facility was reduced to five cells by eliminating the wet chemistry cell and the health physics cell, and replacing one metallurgical mechanical testing cell by a general purpose cell. The cobalt-60 swimming pool was likewise eliminated. With these revisions the estimated cost was reduced to approximately 1.6 million, which included an amount of approximately $460,000 for technical collateral equipment. The revised facility arrangement was covered in the A&E Preliminary Engineering Report dated 1 December 1958. In the final version, the facility was essentially a metallurgical facility.

During the course of the Preliminary Engineering Study, a number of sites were considered for locating the new High Level Radiation Laboratory. The site decided upon by final review of the Director was the north-central section of an existing warehouse. This selection was influenced by several factors, such as eliminating the need for a new building, gaining economy by using an existing crane, services, and utilities, no additional underpinning of existing foundations, no lowering of the existing floor elevation, the building provided space for economical expansion, and desirability of locating the new facility close to the NRL reactor so as to group nuclear research facilities together. The space allocated for the facility contained 14,300 sq ft of floor space.

The project based on the A&E Preliminary Engineering Report was included in the military construction program submitted to the 86th Congress in 1959. The construction of a High Level Radiation Laboratory was funded by the 86th Congress by Appropriation Public Law 86-149 dated 10 August 1959. Included in the appropriation for this project was a provision for the purchase of certain collateral equipment by NRL. The project was funded in Fiscal Year 1960 at $1,591,000.

Vitro Engineering Company of New York City was contracted to prepare the detailed construction plans and specifications for the facility. Since the scope of the High Level Radiation Laboratory had been revised to essentially a metallurgical facility, the author remained as the only active scientific division consultant to the Public Works Division. Some minor changes in arrangement were made in the final plans without changing the basic design requirements.

The construction contract was let on 29 June 1960. Contractor work was completed in November of 1962.

In the capacity of consultant to the Public Works Division during the planning phase, the author specified: the basic design requirements for the hot cells and for supporting work areas, the shielding requirements, the ventilation requirements, the optical and shielding requirements for viewing windows, the requirements for protective coating of all surfaces subject to radioactive contamination, and the type of waste disposal system. In addition, the author specified the requirements for and requisitioned all the collateral equipment.

During the construction phase the author was directed to maintain close technical surveillance over the shielding integrity of the hot-cell structure and in matters which were concerned with fulfilling design requirements, particularly as these related to protection against radioactive contamination.

DESCRIPTION OF THE PROJECT

The High Level Radiation Laboratory and its related adjunct facilities were constructed inside a portion of an existing warehouse, designated as Bldg. 71 on the plan of Fig. 1. The shaded portion shows the space that was allocated for the project. The space limitation made it necessary to give space preference to the hot cells and the work areas surrounding them. The remaining space was divided into offices, conference room, and cold laboratories – these areas are, therefore, somewhat limited.

The plan layout of the High Level Radiation Laboratory is shown in Dwg. 1.* It consists primarily of a bank of five hot cells located, more or less, in the center of the allocated space. These cells are suitable for remotely performing operations on radioactive specimens such as cutting, machining, griding, polishing, analyzing, and mechanical

*The Drawings mentioned in this report are located as a group at the end of the report.

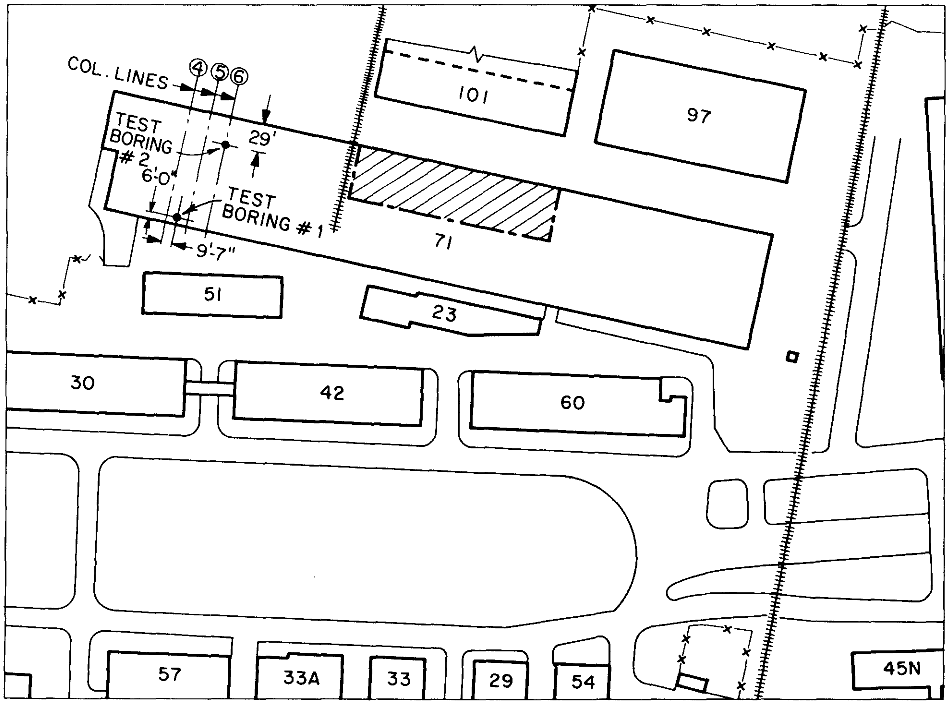


Fig. 1 - Location plan

testing, and for making metallurgical and physical measurements. Table 1 lists the main characteristics and special provisions required for each cell.

The work areas surrounding the bank of hot cells include the following: a radiologically cold work area on the front side where operations may be viewed while being remotely manipulated; isolation cubicles immediately adjacent to the hot cells on the back side which serve as a means of controlling radioactive contamination when equipment and materials are moved in and out of the hot cells; a radiologically warm work area extending along the front side of the isolation cubicles which serves as a staging area for the movement of personnel, equipment, and materials into and out of the hot cells; an isotope storage area for storing radioactive specimens waiting to be tested or being accumulated for eventual disposal; a decontamination room for removing radioactive contamination from equipment and materials prior to repair, maintenance work, storage, or disposal; a machine shop for repair and maintenance of equipment and for preparation of experimental assemblies for irradiation of sample materials; a radioactive waste disposal facility for handling and concentrating liquid radioactive waste originating in radioactive areas; change rooms for both sexes; a radiochemistry laboratory; and an x-ray laboratory.

The work areas included on the second floor consist of the following: exhaust ventilation equipment area, consisting of a scrubber absolute-filter bank and tandem exhaust fans; hatchways located in the floor to permit the movement of heavy equipment with the building crane; roof of the cell block; and a general service and utility area for providing the power and electrical control, ventilation, air conditioning, hot and cold water, and air supplies in the facility.

Table 1
General Characteristics of Hot-Cell Bank

Cell No.	Size (W×D)	Shield Design Requirement (Curies at 1 Mev)	Built-In Storage Facilities (Diam × Depth)	Bridge-Type Manipulative Equip. & Cranes	Remote Sample Transfer Equipment	Access Openings (W×H)	All-Glass Viewing Window Size (W×H)	Intercell Partition	Special Provisions
1	8'×7'	1000	None	None	For samples up to 9"×14"×30" internal transfer drawer	Door 3'×7' and roof plugs	One 48"×30"	Shared with cell No. 2	1. Shielded Remote-Controlled Metallograph mounted against outside wall of cell. 2. Low-power stereographic microscope with remote-controlled stage for fracture studies
2	8'×7'	1000	12"×4'	Shared with cell No. 3	For samples up to 9"×14"×30" internal and external transfer drawers	Door 4'×7' and roof plugs	One 48"×30"	Shared with cell No. 1 and cell No.3	Retractable intercell partition between cell No. 2 and cell No. 3
3	8'×7'	1000	12"×4'	Shared with cell No. 2	For samples up to 9"×14"×30" internal and external transfer drawers	Door 4'×7' and roof plugs	One 48"×30"	Shared with cell No. 2 and cell No.4	Retractable intercell partition between cell No. 3 and cell No. 2
4	24'×7'	10,000	24"×4'	Shared with cell No. 5	Samples up to 9"×14"×30" internal transfer drawers, access plugs in back wall	Double Door 5'×7' and roof plugs	Two 30"×30" One 48"×30"	Shared with cell No. 3 and cell No. 5	Retractable intercell partition between cell No. 4 and cell No. 5 Three under-window access openings–steel shot filled
5	8'×7'	10,000	12"×4'	Shared with cell No. 4	Samples up to 9"×14"×30" internal transfer drawers	Double door 4'×7' and roof plugs	One 48"×30"	Shared with cell No. 4	Retractable intercell partition between cell No. 5 and cell No. 4 One under-window access opening–steel shot filled

DESIGN FEATURES

General Characteristics of Hot Cells

The hot-cell facility was designed to provide a capability for a wide variety of studies and experiments on the effects of radiation on structural metals and other materials. The hot cells, comprising the most important part of the facility, were designed to provide a means of handling and investigating radioactive materials, which emit gamma radiation, in the most efficient, economical, and safe manner. To implement this goal, a great deal of attention was given to the task of incorporating advanced features that would provide substantial gains in research productivity. In as much as the research on radiation effects in materials is relatively new and of long-range scope, it was considered desirable that the new hot-cell facility should have a useful and productive research life of at least 25 years. This life expectancy had an important influence on the design features.

The most important section of the hot-cell facility is the bank of five cells located approximately in the central portion of the available space shown in Dwg. 1. The cells were arranged end to end to permit the economy of using common shielding walls and to utilize certain units of expensive manipulative and crane equipment between cells.

The shielding requirements for the facility had to be considered from both a biological and a background standpoint. Full consideration had to be given to the probable radiation level that would exist at the west or left end of the "warm" work area (see Dwg. 1). It was necessary to insure that sensitive instruments located in the adjoining reactor facility would not be affected by radiation above background from any operations conducted in the new facility. Thus, the shielding walls of the bank of hot cells were designed to limit radiation on the external perimeter of the cells to 0.6 mr/hr. In addition, a concrete shielding wall of normal density and 12 in. thick was provided between the "warm" work area and the "cold" office and laboratory areas to limit the radiation on the "cold" side to 0.6 mr/hr in the event a shipping cask was brought near the wall on the "warm" work area side.

It was assumed that if a cask of approximately 2 ft diameter and designed to comply with ICC regulations (which allow a maximum dosage of 10 mr/hr at a distance of 1 m) was brought as close as 2-1/2 ft from the shielding wall, the radiation level on the cold side of this wall would still be 0.6 mr/hr., while the radiation effect from the cask at the perimeter of the adjoining reactor area would be 0.006 mr/hr. This did not take into account for the additional shielding due to partition walls in the office and laboratory area of the hot-cell facility nor the concrete bearing wall of the adjoining reactor facility. It was assumed that these walls would reduce the radiation dose of 0.006 mr/hr by a factor of one-seventh, making the radiation level at the wall of the adjoining reactor facility completely insignificant. The shield design dose rate of 0.6 mr/hr was considered to be more than adequate to meet the tolerable AEC biological dose rate requirements.

The interior floor dimensions of the cells were primarily dictated by the area that could be covered by a pair of Model 8 heavy-duty master-slave manipulators. Based on this factor a cell floor dimension of 8 ft wide (W) by 7 ft deep (D) per pair of manipulators was selected as an optimum working area. Extra width was necessary in cell No. 1, however, to locate the metallographic specimen transporter to be used in transporting metallographic specimens through the front shielding wall to the stage of the shielded remote-controlled metallograph mounted externally against the front face of the cell. Cell No. 4, to be used as a machine shop, was designed 24 ft long in order to accommodate the necessary remote-controlled machine tools. This cell was equipped with three pairs of manipulators for complete coverage of the internal area.

The interior height (H) of the cells was limited to 14 ft 10-1/2 in. This tight dimension was necessary due to the fixed vertical operating height of the existing 15-ton crane.

Holding the interior height of the cells to the barest minimum made it possible to provide the necessary thickness of shielding in the tops of the cells and to incorporate removable roof plugs into the design to permit transport of large items into the cells with the existing 15-ton crane. There was just enough vertical height available to allow the 15-ton building crane to remove the roof plugs from the top of one cell and to stack them on the tops of adjoining cells.

In considering what shielding capabilities should be incorporated in the hot cells to take care of future research on radiation damage in metals and nonmetals, there was no positive guide as to the maximum source strength that would be encountered in radioactive sources brought in for investigation. In general the sample sizes for metallographic examination are quite small, weighing perhaps only a gram or two, while samples for mechanical testing may weigh upwards of 100 grams or more. The source strength of individual samples could reach 50 curies or perhaps more. In the case of parts of structural and other components of reactors, the part brought in for investigation could be of considerable bulk and weight and could have a source strength upwards of several thousands of curies. Thus, in planning the shielding requirements, it was considered economically wise to incorporate additional shielding above the initial requirements, to take care of future requirements since the expense involved increased the capital investment only slightly. Accordingly, the cells assigned to metallographic examination and preparation of samples and to mechanical testing were designed with walls to attenuate 1,000 curies of 1 Mev at 1 ft, while the cells assigned to machine shop and general purpose were designed with walls to attenuate 10,000 curies of 1 Mev at 1 ft. In order to keep the wall thickness as thin as practicable, high-density concrete (density 220 lb/cu ft) was specified for the shielding. The thinner wall design provided certain advantages for viewing and manipulation because it lessened the remoteness of physical contact. It kept the viewing window thicknesses within practicable dimensions and reduced their cost. It also kept the length of wall plugs and other penetrations within reasonable dimensions.

Normally, in hot-cell construction it is advisable for economic reasons to use regular density concrete in certain sections where its use is advantageous, such as the roof of the cell structure. In the case of the hot-cell facility under discussion here, this was not possible because the head room between the cells and the existing crane was already limited. An additional loss of approximately 1 ft in vertical head room would have occurred had normal density concrete been considered for the roof shielding. This would have prevented the use of the existing 15-ton crane over the cell block. For this reason, high-density concrete, heavily reinforced, was specified for the entire cell structure.

The cells were designed to have the interior walls, interior floor, and exterior walls covered with 3/8-in. thick steel plate. This feature permitted the plates to be used as concrete forms and a means for anchoring reinforcing bars during construction. When properly coated, the steel surfaces can be readily decontaminated and provide an excellent base for the fastening of special equipment onto the walls.

Since the hot-cell facility had to be reduced in size from seven to five cells, it was considered desirable to retain space for future addition of two cells. Space was therefore left at each end of the hot-cell block for this future contingency. The anticipation of the future need for an additional mechanical testing cell prompted the arrangement of cells 2 and 3. A future cell added to the left of cell 1 could be conveniently utilized for metallographic sample preparation, since it would adjoin the metallographic examination cell 1. An opening in the left wall of cell 1 has been provided for transfer of samples between cell 1 and the future cell on the left. Cell 2 could be conveniently utilized for mechanical testing since it is identical to cell 3 and shares heavy manipulative equipment and other features with it. A future cell added to the right of cell 5 would have a transfer access to cell 5 since an opening has been provided in the wall of cell 5 for this purpose.

The plan of Dwg. 2 shows the shielding wall thicknesses of exterior walls and of intercell walls. Between cells 2 and 3, and between cells 4 and 5, there is an intercell gate of steel which is retractable into a structural steel pocket above the roof of the cell block. This feature permits the movement of heavy manipulative equipment and a 3-ton crane between cells. In a lowered position, the steel gate provides in-cell shielding. The thickness of steel shielding access doors for each cell is also shown. The viewing windows were designed to match the thickness of the walls and have comparable shielding capabilities to the walls. A provision was incorporated for transfer of materials between each cell by means of a transfer drawer shielded by a movable door at each end. The internal dimensions of the transfer drawers were designed to accommodate a maximum sample size of 9 in. D $\times$ 14 in. W $\times$ 30 in. length (L). The openings in the left wall of cell 1 and in the right wall of cell 5 were left vacant as it was intended that these would be equipped with transfer drawers at a future time. The space is shielded with lead. Means were provided for transferring radioactive materials in and out of cells 2 and 3 by use of transfer drawers located in the back walls of each cell. Dry isotope storage pits are provided in the floor of cells 2 and 3 and in cells 4 and 5 adjacent to their respective intercell walls. Other features are: the location of underwall U-tubes, shown at the inner and outer edges of the front shielding wall and of the back shielding wall, and the penetrations for master-slave manipulators and for wall access plugs.

The elevation of Dwg. 2 shows the design of the front wall of the hot-cell block. Features of this elevation include: the size and location of the viewing windows and the expansion tanks for excluding moisture and airborne dust from the oil that fills the space between glass plates of the window and to provide for expansion of the sealed atmosphere in the window; the arrangement of the master ends of the Model 8 heavy-duty manipulators; the hydraulic control system for operating the shielding doors on each end of the intercell transfer drawers; the hand wheel cranks for manually operating the transfer drawers; location of various penetrations in the wall provided for access into the cell; access ports below the viewing windows of cells 4 and 5; electrical receptacles for control of traveling manipulators and cranes; and the observation end of the through-the-wall periscope.

The elevations of Dwg. 3 are sections taken across the length of the cell block, with section A-A looking toward the viewing windows on the inside of the cell and section B-B looking toward the shielded entrance doors.

Design features shown in section A-A include: the size and position of the viewing windows as seen from the inner side of the cells; the location of the slave ends of the Model 8 heavy duty master-slave manipulators; the thickness of roof shielding and the cross-sectional view of the removable roof plugs; cross-sectional views of the intercell shielding walls and of the retractable intercell gates; the cross-sectional view of the intercell transfer drawers; end view of one set of cable take-up reels and the lay of the cable alongside the rail on which the traveling manipulators and cranes move; the inside ends of the access ports under the windows of cells 4 and 5; the location of ventilation exhaust outlets from cells; and the arrangement of underwall U-tubes.

The design features in section B-B include the position and size of shielding access doors; end views of the second set of cable take-up reels; end views of the General Mills bridge-type traveling manipulators and of the traveling 3-ton cranes mounted on the track located on a ledge in the recessed wall; the position of ventilation air inlets into the cells; cross-sectional views of the in-cell isotope storage pits in cells 4 and 5 showing the design of lead shielding around the cavity; and cross-sectional views of steel plate shielding placed in walls back of cable take-up reels to compensate for absence of concrete shielding at these points.

The elevations of Dwg. 4 show typical cell end sections taken across the plan of Dwg. 2. Section G-G of cell 3 shows the recessed wall configuration with the rails on which the bridge-type manipulators and cranes travel. Flanged wheels mounted on the trucks of the bridge-type manipulators and cranes provide the means for the travel of these devices across the width of the cells. These devices were shown in their mounted position in section B-B of Dwg. 3. Referring to section G-G, it will be noted that there is a step indicated at the top of the left wall. It was necessary to incorporate removable side blocks in the design of the top of cell walls to gain additional head room between the existing 15-ton crane and the cell structure; this will be discussed later on. The broadside view of the intercell shielding wall and the intercell gate is shown for cell 3. The external transfer drawer is shown, together with the hydraulic lifting mechanisms for operating the shielding doors. The arrangement of the underwall U-tubes is shown. These serve as access facilities between cells and manipulative areas for the introduction of special services and utilities. The operating arrangement for the shielding door of the intercell transfer drawer shows the door in the open position. These doors are interlocked so that when one is opened the other must be closed. The crosses on the intercell wall indicate the location of 1/2-in.-diam studs welded to the 3/8-in. steel-plate wall lining. These are for convenience in attaching fixtures and special devices as needed for experimental work. In the floor is shown the upper section of the dry isotope storage pit with its cover.

Section J-J of cell 4 shows the arrangement of the cable take-up reels mounted in the wall recesses. One reel handles the cable for the bridge-type traveling manipulator, while the other handles the cable for the bridge-type traveling 3-ton crane. Each reel is interlocked with the remote controls of the particular device it serves. Below the take-up reel on the right side is shown the air inlet into the cell. In the left wall is shown the stepped configuration for the glass plates of the shielding windows. Directly below the window is shown the large access port that is filled with steel shot as a means of shielding. The configuration of underwall U-tubes is also shown.

Radiation Shielding Viewing Windows

Considerable attention was given to the type of shielding window that would best suit operational requirements and which would provide maximum shielding with minimum thickness. It was considered essential for the windows to match the radiological shielding of the 36-in.- and 42-in.-thick walls on an inch-for-inch basis. In comparing the variables among the characteristics of different commercially available transparent shielding devices, it became apparent that an all-glass window composed of several lights of glass mounted in a stepped frame design and completely packaged in an oil-filled assembly was the most practical and advantageous. Shielding of such windows is permanent with no maintenance. They neither require periodic renewing or replacement, nor stabilizing or stirring. The all-glass window design was corrosion resistant with no decomposition of the shielding media occurring under exposure to radiation. In addition, with this type window there was no possible chance of losing protection through accident, thus making it completely safe.

Commercially available glasses especially produced for application in transparent shielding purposes consist mainly of three types, the characteristics of which are tabulated in Table 2.

Due to the high indices of refraction of the shielding glasses, as shown in Table 2, high viewing angles were possible. By flaring the window on the side exposed to radiation, it was possible to obtain maximum viewing angles through the window. The operational field of view requirements considered necessary for maximum visible coverage of the interior of the hot cells are listed in Table 3. Based on the above criteria, the shielding window configuration proposed by Corning Glass Works was selected.

Table 2
Comparison of Commercially Available Glasses for Radiation Shielding Purposes

Characteristics	Glass Type		
	Nonbrowning Lead Glass	High-Density Lead Glass	Nonbrowning Lime Glass
Density	3.3	6.2	2.7
Index of refraction	1.59	1.98	1.52
Young's Modulus (lb/in.^{2})	8.5×10^6	7.3×10^6	8.74×10^6
Reflection loss (%) per surface at normal incidence — Air	5.2	5.0	4.3
Reflection loss (%) per surface at normal incidence — Oil	0.13	2.1	0.02
Intrinsic color	Nearly water-white	Straw color	Water-white
Chemical stability	Excellent; unaffected by moisture	Susceptible to moisture attack, protection req'd	Similar to comm'l plate glass
Relative hardness	Hard; resists chipping and scratching	Soft; requires special precautions to avoid mechanical damage	Comparable to comm'l plate glass
Relative cost	1	3-1/2	1

Table 3
Window Dimensions and Viewing Angles Required

Cell No.	Window Dimensions (W×H)		Viewing Angle Required (Degrees)
	Side Toward Observer	Side Exposed to Radiation	
1,2,3	48"×30"	54"×36"	86
4	30"×30"	36"×36"	70
4,5	48"×30"	54"×36"	86

In order for the windows to match the shielding of the 36-in.-thick wall (cells 1, 2, and 3), they were designed to consist of: a core of 3.3 density lead glass, 22-1/8 in. thick, made up of three slabs, each 7-3/8 in. thick; 8 in. of 6.2 density lead glass made up of two slabs, each 4 in. thick; a nonbrowning cover plate, 1 in. thick, of 2.7 density glass facing the radiation side; and a cover plate, 1 in. thick, of 2.5 density plate glass facing the observer. The composition of these windows is illustrated in the upper sketch of Fig. 2.

For matching the shielding of the 42-in.-thick wall (cells 4 and 5), the windows were designed to consist of: a core of 3.3 density lead glass, 27-9/16 in. thick, made up of three slabs, each 9-3/16 in. thick; 8-1/2 in. of 6.2 density lead glass made up of two slabs, each 4-1/4 in. thick; a nonbrowning cover plate, 1 in. thick, of 2.7 density glass facing the radiation side; and a cover plate, 1 in. thick, of 2.5 density plate glass facing the observer. The composition of these windows is illustrated in the lower sketch of Fig. 2.

In order to reduce reflection losses to a negligible amount at the inner glass surfaces and to enhance transmittance of light, the 1/16-in. spaces between the lights of glass are filled with oil.

The transmission of incandescent light through the windows designed for mounting in the 36-in.-thick wall was calculated to be about 23 percent and about 19 percent for the windows in the 42-in. wall.

A rigid control of the optical quality in radiation shielding glasses is essential to limit those factors which interfere with the attainment of maximum visibility. Among these factors it is essential that the central area, comprising at least 80 percent of the maximum usable window dimensions, is relatively free from various defects that interfere with the straightforward transmission of light. Included in these defects are a variety of inclusions, striations, condition of edge surfaces, and condition of viewing surfaces. Inclusions of 0.010 in. or less in mean diameter are not considered detrimental in normal shielding window viewing situations. The maximum mean diameter of inclusions, however, is another matter requiring that their size be held within certain limits. The permissible sizes for different glasses is tabulated in Table 4.

Table 4
Permissible Maximum Mean Diameter of Inclusions for Window Glasses

Window Area	Maximum Mean Diameter (in.)		
	2.7 and 3.3 Density Glass	6.2 Density Glass	
	Throughout Viewing Area	In Central Area	Outside Central Area
1-1/2 to 4 sq ft	0.125	0.125	0.125
Greater than 4 sq ft	0.125	0.187	0.250

The distribution of inclusions must also be restricted within certain limits. Thus, it is essential that the total projected area of all inclusions on a polished surface does not exceed 0.0031 percent of the area per inch of light path (thickness) in glasses of 2.7 and 3.3 density and does not exceed 0.0062 percent in 6.2 density glass. Furthermore, it is essential that not more than one-fourth of this allowable projected area be taken up by inclusions over 0.060 in. in mean diameter. As a further precaution to prevent localized areas of poor quality, it is required to subdivide the total viewing area into nine equal subareas by trisecting the length and width dimensions and applying the above restrictions to each subarea. The total number of all inclusions in any cubic inch (one inch cube) of glass must not exceed three in 2.7 and 3.3 density glasses and must not exceed four in 6.2 density glass.

The requirements for presence of striations in the central area of the radiation shielding glasses followed those of class C optical glass specification JAN-G-174. These requirements permit light striae when viewed in the direction of maximum visibility; however, the striae must be parallel to the face of the glass surface. Outside the central area of the glass, somewhat heavier striation is permissible, but not to an extent that it prevents general observation work.

To prevent internal reflections from being generated from edge surfaces of the radiation shielding glasses and interfering with visiblity, the edge surfaces must be dull and nonreflecting. Several methods by which the required dull surface may be produced include acid etching, sawing, and sand blasting.

To insure maximum visibility the viewing surfaces of the radiation shielding glasses must be plane ground and polished. The finish in the central area must be good and free from short finish. Outside the central area small areas of short finish can be permitted; however, on gasketing surfaces no checks, chips, or deviations from a plane surface can be tolerated. The viewing surfaces of 6.2 density lead glass are required to have all polished surfaces specially leach-treated to produce a uniform nonreflection coating so as to reduce reflection losses to a minimum.

To take advantage of the high indices of refraction of the radiation shielding glasses and to obtain high viewing angles, the windows were designed to be flared on the side exposed to radiation. Thus, for the windows having an observer side dimension of 48 in. W × 30 in. H and a dimension of 54 in. W × 36 in. H on the radiation exposure side, the lateral viewing angle obtained was 86 degrees as shown on the plan view of Dwg. 2 and on the sketches of Fig. 2. This flared design provided an "expanded view characteristic" making it possible to view the full 8-ft width of a cell with a single window and to actually see the entire intercell walls on each end of a cell, to within 2 in. of the inside face of the window wall, without any apparent image distortion. The vertical viewing angle obtained for the windows in the 36-in. wall was 78 degrees, and 70 degrees for the windows in the 42-in. wall. The exceptional viewing capability of these windows provided for maximum utility of a hot cell for remote manipulation.

In order to protect the window assembly, particularly the 6.2 density lead glass, against intrusion of dirt and moisture, each window is connected to an expansion chamber and a desiccant-filled dryer. The expansion chamber is fitted with an elastomer bellows which permits expansion of the self-contained atmosphere within the window, while preventing atmospheric contaminants from entering into the window assembly. The expansion-dryer-bellows device is shown on the elevation of Dwg. 2.

The openings provided in the shielding walls for the shielding windows were designed to be fitted with wall liners, fabricated to match the steps and contour of the frame of the window and to act as a form when the shielding wall was poured. This arrangement provided fixed dimensions for the window openings and facilitated the installation of the packaged window assemblies without a single difficulty. The wall liners for the windows are illustrated in the plan view of Dwg. 2 and in section J-J of Dwg. 4.

Shielding Access Doors to Hot Cells

Among the various ways that shielding doors may be applied to shield the entrances to hot cells, it was decided that a solid steel door swung on hinges attached to a steel door jamb of comparable thickness and manually operated was the simplest. In order to limit the weight of the doors, a single door was used for a 3-ft opening and double doors were used for openings of 4 ft and 5 ft as shown on the plan view of Dwg. 2.

The weight of the doors is supported on steep-angle tapered roller bearings mounted in the bottom hinges, whereas double-row self-aligning ball bearings are mounted in the top hinges for keeping the doors in vertical alignment. The bottom hinge bearings are subjected to both radial and thrust loading, whereas the top hinge bearings are subjected to radial loading only. The capacities of the bearings and sizes of hinge pins are tabulated in Table 5, while the typical hinge design is shown in details C and D of Dwg. 5, and detail F shows the door bottom closure configuration and clearance.

The elevation of Dwg. 6 shows the single access door and door jamb configuration for cell No. 1, while section B-B shows a vertical cross section of the thickness and the closure at top and bottom of the door. Also shown is the door latch and the location of the solenoid interlock for securing the doors.

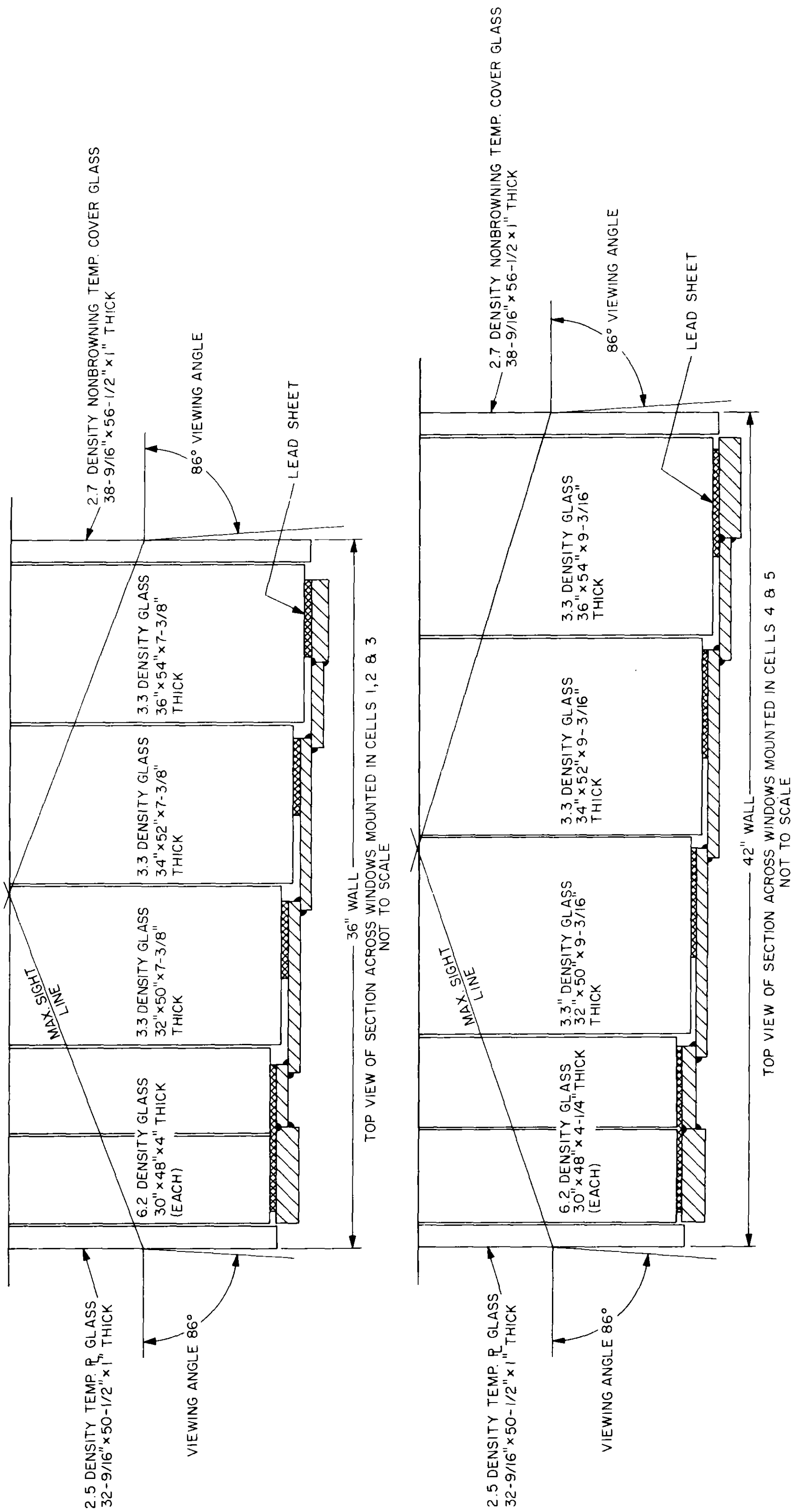


Fig. 2 - Schematic showing composition of glass shielding windows

Table 5
Loading Capacities of Shielding Door Bearings and Sizes of Hinge Pins

Door Opening	Door Thickness	Each Bearing (Bottom Hinge)		Hinge Pin Size (Diam)	Each Bearing (Top Hinge)		Hinge Pin Size (Diam)
		Radial	Thrust		Radial	Thrust	
3 ft (single)	15 in.	7500 lb	16000 lb	2-1/8 in.	7500 lb	0	2-1/8 in.
4 ft (double)	15 in.	3700 lb	10700 lb	1-3/4 in.	3700 lb	0	1-3/4 in.
4 ft (double)	16-3/4 in.	3700 lb	10700 lb	1-3/4 in.	3700 lb	0	1-3/4 in.
5 ft (double)	16-3/4 in.	7500 lb	16000 lb	2-1/8 in.	7500 lb	0	2-1/8 in.

Section A-A of Dwg. 6 is a horizontal cross section of the door showing the stepped configuration of the closure between door and door jamb. The latch bar penetrating the door is threaded full length and rides in threads tapped in the door. This arrangement prevents radiation leakage through the door at this point. An enlarged view of the stepped configuration of the door closure is shown in Fig. 3. This configuration was adopted when it became evident from calculations that radiation leakage would probably occur at the juncture of door and door jamb, or at the juncture between double doors, unless special precautions were taken to prevent such leakage. It will be noted that the steps are laid out on an arc. This concept is intended to prevent any radiation which enters the juncture from following the joint and manifesting itself as radiation leakage. The elevation of Dwg. 7 shows the double access door and door jamb configuration for cells 2, 3, 4, and 5. In the case of the double doors, one of the doors is secured with a cremone bolt as shown. The horizontal cross section of the door is shown in section A-A, while the vertical cross section is shown in section B-B. The enlarged view of the stepped configuration of the double-door closure is shown in Fig. 4. This configuration is very similar to that shown in Fig. 3 for the single door.

The vertical alignment of the doors is critical in view of the need to maintain the gap between the bottom of the door and the floor no greater than 1/8 in. and the need for the doors to hang stationary without any tendency to move by themselves toward an open or closed position due to misalignment. When properly aligned, the doors can be easily opened or closed manually. This feature is made possible by the very low starting friction of the steep-angle tapered roller bearings mounted in the bottom hinges upon which the weight of the doors is supported.

Intercell Gates

In order to utilize bridge-type manipulative and crane equipment between cells, a movable intercell shielding gate was designed which permits the transfer of the equipment from one cell to another and provides the necessary shielding isolation between cells. The locations of the movable intercell shielding gates are shown in Dwgs. 2 and 3. The lower portions of the intercell walls between cells 2 and 3 and between cells 4 and 5 are 8-1/2 ft high and are an integral part of the cell structure, and therefore fixed. The movable gates, however, are of solid steel, 10 in. thick, and cover the depth of the cells from front to back as shown in section G-G of Dwg. 4.

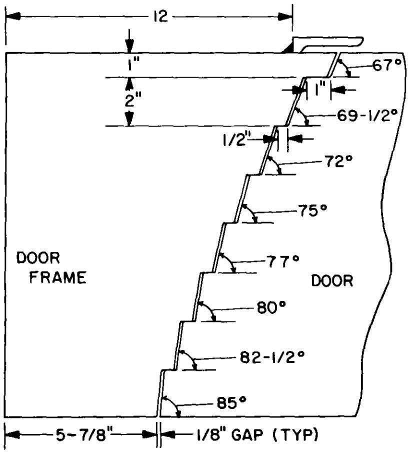
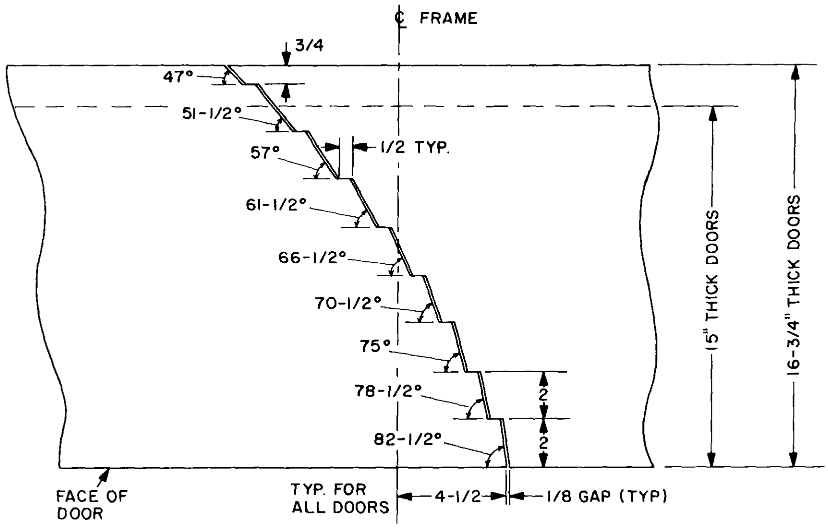


Fig. 3 - Enlarged view of single-door steps



DETAIL "F"

Fig. 4 - Enlarged view of double-door steps

The solid steel gates are of the guillotine type and are raised and lowered by the rotation of rolled screw shafts in ball nuts attached to each edge of the gate, driven through shafting by a single 5-hp motor and a reducer unit. The gates and the drive mechanisms are each supported by a totally enclosed structural steel framework which maintains the relative positions of shafts, bearings, and gate and into which the gate retracts when in the opened position. The enclosed framework extends above the top of the roof of the cell block as shown in Dwgs. 2, 3, and 4.

In view of the importance of the intercell gates to the operation of the facility, it was considered essential that they should operate troublefree for at least 25 years. Moving parts, subject to wear, were therefore given special attention in order to provide a long operating life. Antifriction bearings made of hardened alloy steel are used throughout the drive mechanism to support shafting. Gears are made of heat-treated high-tensile alloy steel. Speed reducers and gear reduction housings are made of close-grain gray iron castings accurately machined to maintain alignment of shafts and bearings and the proper relation between gears. Speed reducer components operate in an oil bath.

The weight of each gate is carried on two Saginaw rolled screw shafts having a 2.230-in. ball circle diameter and a lead of 0.500 in. A ball nut attached to each side of the gate rides on the screw shaft and provides the means for moving the gate. The screw and ball-nut combination was designed to carry a 6-ton load at 140 rpm for a minimum of 25,000 cycles of gate operation. On the basis of raising and lowering a gate once each working day during a full year, the life expectancy for the screw and ball-nut combination is 25 years.

The screw shafts, in turn, are each supported from the top on a ball thrust bearing mounted in a bearing housing attached to the structural framework. Each bearing is rated for a loading of 18,770 lb at 200 rpm with a minimum operating life factor of 20,000 hours. The bearings are of an enclosed type with spherical seat. The balls are made of high-carbon chrome tool steel, hardened, ground, and polished. The races are made of high-grade bearing tool steel, hardened and ground, and utilize the cone principal of four-point contact.

The top end of each screw shaft is connected to a right-angle spiral bevel gear speed reducer located at each end of the top of the enclosed structural framework as shown in section G-G of Dwg. 4. These speed reducers are connected to the 5-hp right-angle gear motor by 1-1/4 in. diam shafting and gear-type flexible couplings. This arrangement drives the screw shafts at 140 rpm.

The lower end of each screw shaft is kept in position by a bronze insert bearing mounted on the ledges of opposite hot-cell walls.

The gates are operated remotely from a control point on the front wall of the hot cells, located between viewing windows so that the gate opening can be seen from either side. The upper and lower extremes of gate travel are controlled by limit switches to prevent the gate from over riding in either direction.

Transfer Drawers

A system of transfer drawers was provided in the hot cells for transferring radioactive materials between cells and for transferring such materials under certain conditions into the cells from outside the cell block. The locations of the intercell transfer drawers with respect to the front wall of the hot cells and the locations of the external transfer drawers providing access to cells 2 and 3 are shown in the plan view of Dwg. 2. The openings in the outer end walls of the cell were not equipped with drawers; however, the openings were fitted with embedded components and with shielding doors.

The transfer drawers consist of complete unit assemblies with drives, shielding doors, hydraulic operators, limit switches, and controls. The drawers, constructed of aluminum, measure 9 in. D by 14 in. W by 35 in. L and are carried on ball bearing slides which permit travel of the drawers in either direction from within their intercell wall position. The intercell transfer drawers are driven manually from outside the front face of the cell walls by means of a hand wheel connected by a shaft in the wall to a chain-driven rack and pinion assembly mounted in the drawer wall opening.

The wall passageway in the walls between cells into which the drawers retract are lined with a liner composed of a 1/4-in. plate steel shell filled with 1-5/8 in. of lead on the vertical sides and 1 in. of lead on the top and bottom sides. The ends of the openings on each side of the intercell walls are provided with shielding doors 22 in. wide by 13-3/8 in. high by 4-1/4 in. thick, constructed of a 1/4-in. plate steel shell filled with lead. These doors move horizontally on rollers and are operated by hydraulic cylinders remotely controlled from the outside face of the cell walls. The shielding doors are interlocked so that only one door may be opened at one time. Extension of the drawer operates a limit switch which closes a solenoid valve that prevents closing of the door until the drawer is fully retracted.

Since the external drawers in the back of cells 2 and 3 opened to the outside of the cells, it was necessary to provide extra shielding on the wall passageways and on shielding doors. The wall passageway liners consisted of a shell of 1/4-in. steel plate provided with a right-angle offset at the outside face of the cell wall. The liner and its offset were filled with cast lead. The vertical walls of the liner were 4-3/8 in. thick, while the top and bottom sides were 3 in. thick. The offset was similar to a flange and extended 2-1/2 in. more than the thickness of the sides of the liner. The offset was 4 in. thick. This arrangement shielded the joint between the steel case of the liner and the concrete of the cell walls. The doors were designed to be 25-3/4 in. wide by 16-1/8 in. high by 8 in. thick, which amply shielded the wall passageway opening of 17 in. wide by 10-1/8 in. high. The doors in this case are lifted to permit extension of the transfer drawer. The lifting mechanism consists of hydraulic cylinders mounted above the doors and interlocked in the same manner as the intercell transfer drawers.

Cell Roof Plugs

Access into the cells from the roof of the cell block was provided by a system of removable stepped roof plugs. This was essential for the introduction and installation of equipment too large or unwieldy for handling through the cell access doors. The utility of this feature was fully demonstrated in the cases of the installation of the bridge-type manipulative and crane equipment and the cable take-up reels within the cells. It would have been exceedingly difficult to install this equipment if it had been necessary to handle it through the access doors and raise it to its operating position.

The stepped design across the ends of the roof plugs is illustrated in sections A-A and B-B of Dwg. 3, while the side view of the plugs is illustrated in sections G-G and J-J of Dwg. 4. It will be noted in Dwg. 3 that none of the plugs can be removed until the keystone plug is removed. The positions of the keystone plugs shown in Dwg. 3 for cells 2 and 4 were reversed during construction when it became obvious that these key plugs should be positioned over the cable take-up reels to avoid uncovering the entire roof of the respective cells to obtain access to the cable take-up reels for maintenance purposes.

The removable roof plugs were designed to not exceed 15 tons each in order to keep within the handling capacity of the building bridge crane. Because of the tight headroom restriction, the plugs were constructed of a 1/4-in. steel plate form into which heavy density concrete (220 lb/cu ft) was poured to the top and steel-trowel finished. Steel lifting rings are embedded in the tops of the plugs for lifting and handling. The plugs are positioned in place by means of aligning keys, which consist of V notches on the bottom side of each end which mesh with a mating triangular key mounted on the recesses in the cell walls which support the plugs. This feature provides positive positioning for every plug each time it is moved and keeps physical contact between plugs to a minimum during handling, thereby preventing scuffing of the protective coatings on plug sides and ends.

Early design study showed that the available distance between the top of the cell block and the lifting limit of the 15-ton crane was approximately 4 ft. This severe height limitation was overcome by incorporating openings for each cell at the top of one shielding wall. These openings measure about 6 ft 9 in. across and 2 ft 6 in. deep, making the clearance between crane hook and the side opening about 6 ft 6 in. The openings are each shielded with removable side plugs constructed similarly to the removable roof plugs. The end view of the side plugs is illustrated at the top of the left wall in sections G-G and J-J of Dwg. 4.

Under-Window Access Openings

Access openings were incorporated under the viewing windows of cells 4 and 5 to provide for a future contingency of having to penetrate the shielding wall to operate or control machine tools or some other devices by direct mechanical linkage, or to house electronic control circuitry for such tools in part of the space, thereby conserving floor space and providing a greater amount of flexibility of action at the viewing windows. These openings are flared, measuring 2 ft 10-1/2 in. high by 5 ft 3-1/2 in. wide on the outside face of the front cell wall, as shown on the elevation of Dwg. 2, and 1 ft 7-1/2 in. high by 5 ft 1-1/2 in. wide on the inside face of the front cell wall as shown in section A-A of Dwg. 3. A side view of the access opening and its position with respect to the viewing window is shown in section J-J of Dwg. 4. The openings are lined with 3/4-in. thick plate steel and filled with copper plated steel shot, approximately 1/8-in. diam, for shielding. A 3/8-in.-thick cover plate closes off the end of the opening facing the inside of the cell, while a 1/2-in.-thick cover plate closes off the end of the opening facing the outside. The outside cover plate is provided with two slots at the top for filling shot and three slots at the bottom for draining shot. Each slot is covered with a cover plate bolted to the main cover plate.

Wall Sleeves, Shielding Plugs, Underwall U-Tubes, and Metallograph Wall Plate

Small diameter access ports were incorporated in the front and back cell walls for purposes of emergency or of convenience under advantageous circumstances. Three ports were provided above each viewing window and one port on each side of the windows of cells 2 and 3 as shown on the elevation of Dwg. 2 and on the section A-A of Dwg. 3. Similar ports were provided in the back wall of cell 4 as shown on section B-B of Dwg. 3.

The access ports were designed with a two-step cylindrical configuration so as to accommodate a shielding plug of similar contour. The ports measure 5 in. inside diameter in the larger bore and 4 in. inside diameter in the smaller bore. The larger bore has a length of 19 in. in the 3-ft-thick wall and 22-1/2 in. in the 3-1/2-ft-thick wall, while the smaller bore length in the 3-ft-thick wall is 17 in. and 19-1/2 in. in the 3-1/2-ft-thick wall. The wall sleeve assemblies were fabricated from steel tubing and positioned in the walls prior to their embedment in shielding concrete.

Two types of shielding plugs were designed. One was a solid plug which consisted of a steel shell with a core of poured heavy density concrete. The second type was intended as a service plug and also consisted of a steel shell, but in this case the core was filled with copper-plated steel shot which can be removed to permit entry into the plug when desired and which can be refilled with shot.

It was necessary to provide penetrations of uniform dimensions in the front cell wall for mounting the master-slave manipulators. The wall sleeves were fabricated of steel tubing, 10-1/2-in. o.d. with 1/4-in. wall, fitted with flanges at each end, and the assembly positioned and fastened in the wall before embedment in the shielding concrete. The locations of these wall sleeves are indicated by the manipulators shown on the plan view of Dwg. 2 and on section A-A of Dwg. 3, while a through-the-wall view is shown on section J-J of Dwg. 4.

For mounting various through-the-wall remote viewing optical instruments, the bore of wall penetrations had to be maintained within very narrow tolerance limits. The requirements included precision on concentricity of bore, maintenance of the bore on a constant level axis, and bore smoothness. To meet these requirements, it was essential to select steel tubing of sufficient strength to withstand distortion under the stresses imposed by embedment in heavy density concrete. The wall sleeves had to be machined to the final bore dimensions, concentricity, axial requirements, and bore finish before positioning and anchoring in the wall structure. Positioning had to be carefully done to maintain a level axis and to prevent shift during embedment of the sleeves in concrete.

The wall sleeve for the through-the-wall periscope mounted on the front wall of cell 4 consisted of a steel tube 9-1/2-in. o.d. by 3 ft 6 in. long with a bore machined to $8.535^{+0.010}_{-0.000}$ in. The end facing the outside cell wall (observer side) was fitted with a mounting plate 1-in.-thick which was welded to the 3/8-in.-thick cell wall liner to permanently position the end in the cell wall. The opposite end of the wall sleeve was permanently attached to the inside cell wall liner by welding.

The wall sleeve for a through-the-wall remote viewing stereographic microscope mounted on the front wall of cell 1, to the right of the viewing window, had to be exceptionally precise in its bore, axial requirement, and surface finish. The bore requirement was $8.974^{+0.004}_{-0.000}$ in. i.d. in order to accommodate the optical instrument tube having a maximum dimension of 8.968-in. o.d. The tight dimensional, axial, and surface finish requirements demanded in the wall sleeve by the requirements of the instrument gave the construction contractor some difficulty.

The wall sleeve to the left of the viewing window of cell 1 was provided for mounting a mechanism for transporting, by remote control, radioactive metallographic specimens from inside cell 1 to the stage of a remotely operated shielded metallograph located on the outside wall of cell 1. The wall sleeve in this case consisted of a steel tube 6-3/4-in. o.d. with a bore of 5.971 in. into which was fitted the tube containing the assembled components of the transporter mechanism. A 3/4-in.-thick steel flange, attached to one end of the wall sleeve, provided a means for anchoring the transporter mechanism for proper alignment. The wall sleeve was positioned and permanently anchored in the cell wall by welding the flanged end to the outer 3/8-in.-thick steel wall and the opposite end to the inner steel wall liner.

A system of underwall U-tubes was incorporated into the hot cells to provide a convenient method for easily introducing various types of services and utilities into the cells from the outside when needed for in-cell experimentation and equipment. The locations of the ends of U-tubes, with respect to the front wall, are shown on the plan view of Dwg. 2. The outside ends of the U-tubes under the front wall are contained in a covered trough below floor level and thus do not show on the elevation of Dwg. 2. There are two 2-in. schedule 40 stainless steel U-tubes located under the front wall of each cell for electrical purposes, except cell 4 which has eight such tubes; the rest of the tubes are 2-1/2-in. schedule 40 stainless steel tubes. A view of the terminal ends of the U-tubes inside the cells is shown on section A-A of Dwg. 3. The U-tubes passing under the back wall of the cells consist of 3-in. schedule 40 stainless steel tubes, as shown on the plan view of Dwg. 2 and the in-cell view on section B-B of Dwg. 3. The sweep of the bend of the U-tube under a 3-ft thick wall is shown on section G-G of Dwg. 4, and that under the 3-1/2-ft-thick wall on section J-J of Dwg. 4.

A steel plate 3 ft wide by 2 ft high by 2-1/2 in. thick was permanently incorporated into the outside wall of cell 1 and flush with it, as shown on the elevation and plan views of Dwg. 2. This plate was placed in the wall structure for the purpose of mounting a steel sealing plate against which the open end of the metallograph shield is tightly drawn to seat the gasketing located in the edges of the open end of the shield. This arrangement thus prevents the escape of radioactive contamination to the outside from the shielded metallograph.

Isotope Storage Facilities

In-Cell Storage – Storage pits were provided in all cells except in cell 1. The purpose of these pits was for temporary isolation of radioactive source materials within the cells as circumstances required. This type of storage was considered to be a valuable asset to the productivity of cell operations.

The pits were designed circular, with the entire cavity lined with stainless steel backed with lead shielding. The pits in cells 2, 3, and 5 were designed 10 in. in diameter and total depth of 5 ft 3 in., of which about 4 ft 3 in. is usable space. The tops of these pits are stepped, into which a mating stepped plug inserts. The plug design consists of a stainless steel shell filled with cast lead to a thickness of 8-1/2 in. The pit in cell 4 was designed 22 in. in diameter and total depth of 5 ft 3 in., of which about 4 ft is usable space. The mating plug is of similar design to that of the 10-in.-diameter pits, except that it is 9-1/2 in. thick. The vertical sections of both pit sizes, shown on section B-B of Dwg. 3 for cells 4 and 5, illustrate the shielding features, while the locations of the in-cell storage pits is shown on the plan view of Dwg. 2.

The shielding plugs are lifted and handled by an in-cell 3-ton bridge crane to be described under the section which discusses collateral equipment.

In-House Isotope Storage Facility – In anticipation of a growing wide spectrum of research activity related to the nuclear effects on materials and their properties, it was considered necessary to provide, for future contingency, an in-house isotope storage facility sufficiently diversified to accommodate a variety of gamma emitters. It was further anticipated that the isotope storage facility would only be used as an interim deposit for radioactive materials awaiting to be investigated and for the collection of radioactive waste as investigative work was completed for eventual off-site disposal.

The arrangement of the in-house isotope storage facility is shown on the plan of Dwg. 8. Referring to this drawing, pits "A" are 2 ft square by 8 ft deep with 5 ft of usable depth. The top 3 ft was designed to flare in a two-step configuration, into which a mating plug fits and acts as a shielding cover. The pits are contained in a block of concrete (180 lb/cu ft) 10 ft 3 in. by 11 ft 0 in. by 10 ft 3 in. deep. The pit cavities are completely lined with stainless steel, while the exterior surfaces of the mating shielding plugs are covered with stainless steel. The cores of these plugs are of concrete (220 lb/cu ft). These plugs are fitted with lifting rings and handled with a chain fall mounted on a traveling bridge. The vertical section 32-32 of Dwg. 8 illustrates the design of the pit. Surrounding each pit, a removable handrail was provided for the safety of operating personnel. Adjoining pits "A" is a bank of 24 tube-type storage wells of three different diameters, all 17 ft deep. Of the 17 ft depth, 12 ft 3 in. is usable space, while 4 ft 9 in. is occupied by the shielding plug at the top. Referring to the plan of Dwg. 8, the eight storage wells labeled A are 8 in. in diameter in the straight bore section, the eight labeled B are 6 in. in diameter, and the eight labeled C are 4-1/4 in. in diameter. The straight sections consist of stainless steel tubing closed off at the bottom by a stainless steel plate. The top 4 ft 9 in. of each well was designed to flare in a three-step configuration, into which a mating plug fits and acts as a shielding cover. The flared top section is lined with stainless steel, making a continuous lining of stainless steel in the well cavity. The shielding plugs are covered with stainless steel, while the cores are of concrete (220 lb/cu ft). The plugs are fitted with lifting rings and handled by the chain fall previously mentioned.

Previous experience at NRL with deep tube-type storage wells showed that considerable condensation of atmospheric moisture occurred in them. This situation promoted and caused severe corrosion of specimens stored in the tube wells which were either waiting to be investigated or were being collected as radioactive waste for disposal. Corrosion of specimens is not only detrimental to the investigative results, but the corrosion products tend to become detached and settle to the bottom of the wells. Accumulations of corrosion products with long half lives in the tubes could eventually produce serious radiation problems and seriously restrict the usefulness of the storage facility. It was therefore considered essential to provide a drainage system at the base of the tubes to continually drain off any condensate that formed. Therefore, each tube storage well is connected at its bottom to a 1-1/2 in. stainless pipeline which leads to a sump, 1 ft square by 1 ft 8 in. deep, at the bottom of pit "B", shown on the plan of Dwg. 8 and in vertical section on section 33-33 of Dwg. 8. Condensate collected in the sump is removed by a pump located in pit "B" and delivered to a radioactive waste disposal system to be described later. Pit "B" measures 1 ft 6 in. square by 19 ft 8 in. deep from the top to its bottom, excluding the sump. The pit cavity is lined with stainless steel. The top 3-ft section of pit "B" is flared in a two-step configuration, into which a mating shielding plug fits and acts as a shielding cover. The plug is covered with stainless steel and its core is of concrete (220 lb/cu ft). It is lifted by a lifting ring embedded in the top and handled by the chain fall previously mentioned. The bank of tubes, together with the bottom drainage system is embedded in a block of concrete (180 lb/cu ft) 10 ft 6 in. by 9 ft 0 in. by 20 ft 0 in. deep.

A third type of isotope storage well that was provided consists of a deep pool filled with deionized water. This type of storage facility was intended primarily for storage of certain isotopes. However, the storage well has shielding features which also permits certain types of experiments with radioisotopes. The location of the pool is shown on the plan of Dwg. 8 and its structural relation to the adjacent storage tube wells is shown on section 32-32 of Dwg. 8. The cavity is 5 ft square by 17 ft deep with a water depth of 15 ft. The concrete surfaces of the cavity were left unlined; however, they are protected with a special heavy protective coating. Water in the pool is treated in a deionizer unit located opposite the pool against the north wall of the area, as shown in the first floor plan of Dwg. 1. The pool is not covered, but is surrounded by a protective hand rail for safety.

Special Receptacle Panels

Since remote operations as conducted in hot cells are always somewhat hampered by the confined space and the inflexible nature of the structure, it is necessary to incorporate certain built-in features in order to provide as much flexibility as possible for experimental operations. One area in this respect was concerned with the matter of providing electrical connections between equipment located in the cells and the control instrumentation on the outside of the cells and of providing power from convenient outlets in the cells which could be switched on or off from outside the cells. To implement the need for this requirement a receptacle panel system was devised which involved two methods of delivering power from the operations area to each cell. The system consists of a two-panel arrangement with one receptacle panel located on an intercell wall and the other panel located on the outside wall of the cells in the operations area. In applications where power to in-cell equipment must first be controlled by an instrument control console located in the operations area, the power from this control unit is transmitted into the cells by plugging in the cable from the control unit into a receptacle on the outside panel and plugging in the cable from the equipment into a companion receptacle on the in-cell panel, the two receptacles serving as a "jumper circuit." In applications where power needs to be fed directly to the in-cell equipment, plug in receptacles are provided in the in-cell receptacle panels for 120 v ac, 208 v ac, and 120 v dc power. The circuit to each of these receptacles is controlled by an individual switch located on the outside receptacle panel. The system is illustrated by a typical case shown in Fig. 5. The in-cell panels are located back to back in the intercell wall between cells 2 and 3 in which the conduit carrying the wiring is embedded. The outside panel is located on the outside wall midway between the viewing windows. The locations of the outside receptacle panels are shown on the elevation of Dwg. 2 and the typical locations of the in-cell receptacle panels are shown on sections G-G and J-J of Dwg. 4.

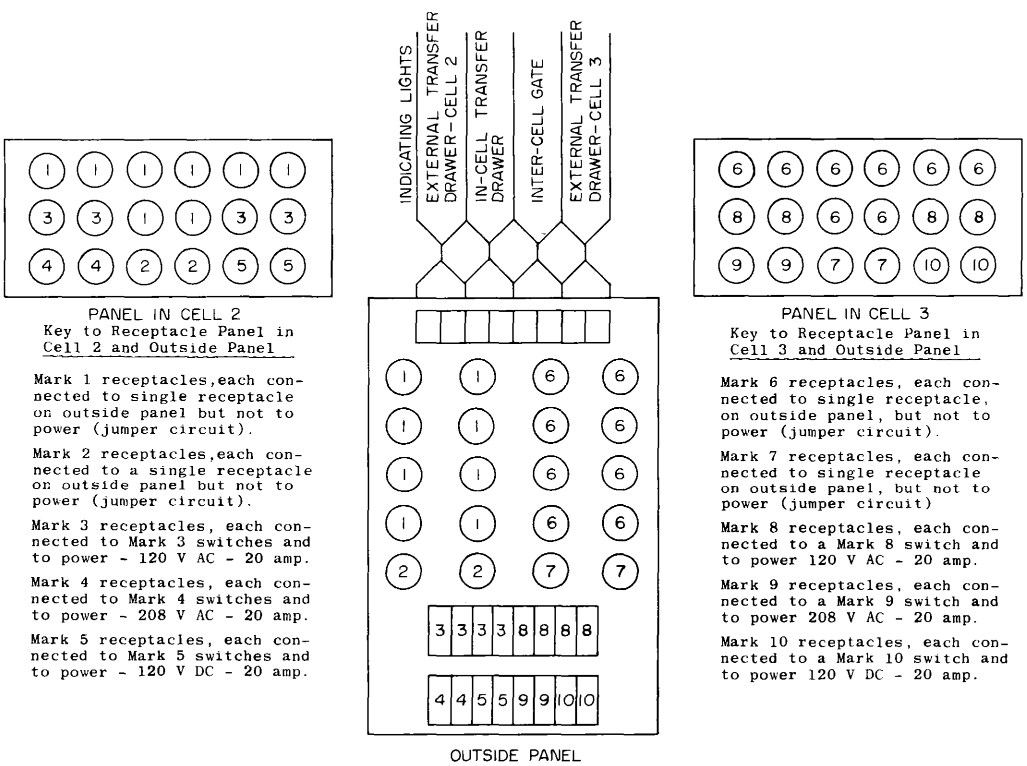


Fig. 5 - Typical example of in-cell and outside interconnected receptacle panels

In-Cell Lighting

Thick radiation shielding windows, because of their relatively low light transmission characteristics, require intense and efficient illumination for maximum visibility. Illumination in the cells was designed so as to yield an illumination level such that the transmitted light on the observer's side of the cell shielding window would measure approximately 50 foot-candles. Color-corrected mercury lamp lighting was selected as it provides the most economical lighting for intense illumination from a small source of light using the minimum amount of space. A mercury lamp fixture was selected which uses a 400-watt

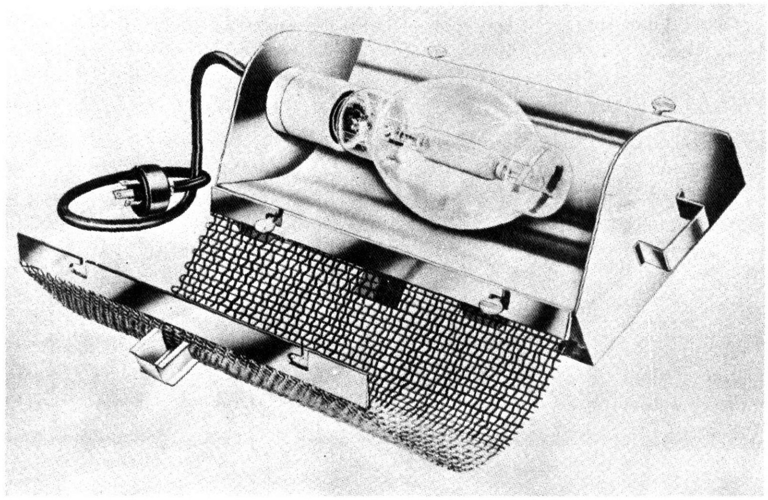


Fig. 6 - Mercury lamp fixture assembly

bulb (approximately 20,000 lumens) screwed into a mogul-base socket. The lamp fixture features a one-piece reflector, designed to get the most illumination from the large area source, mounting brackets providing the means for attaching the fixture on two studs anchored to the hot-cell wall, and a heavy duty wire mesh screen cover over the mercury lamp for protection against breakage due to possible accidental bumping during in-cell manipulative operations. A two-prong twist lock plug on a short length of wire lead which plugs into a wall receptacle provides a positive electrical connection. Another feature of the lamp fixture is that it can be unplugged from the electrical receptacle, demounted from the wall, and the bulb replaced remotely by the master-slave manipulators using special finger grips to remove the screens. All edges of the fixture parts are smooth and constructed of stainless steel for ease in decontamination when necessary. The fixture assembly is shown in Fig. 6.

In order to obtain the necessary illumination in the cells, the mercury lamp fixtures were arranged around the periphery of the inside edge of the viewing windows as illustrated in Fig. 7. The lamp fixtures are mounted at a 45-degree angle from the wall to provide the most intense illumination in the central viewing area of the window. The five lamps, arranged as shown, provide approximately 100,000 lumens of illumination per window.

Electrical Service in Cells

Power service in the cells is mainly 120/208 v, 3 phase, 60 cycle, 3 wire system. All motor driven equipment is constructed to operate on 208 v, 3 phase, 60 cycles. Single receptacles carrying 208 v, 3 phase power are located in each cell. In addition, cell 4 has two single receptacles wired for 440 v, 3 phase power for driving machine tools. Power wiring for the cells is carried in a trough located along the outside of the back wall of the cell block. Control wiring for permanently installed equipment in the cells is carried in a trough along the outside of the front wall of the cell block as shown on section G-G of Dwg. 4. Receptacles for General Mills manipulator consoles and for in-cell crane pendants are located in the front wall of the cell block as shown on the elevation of Dwg. 2. The pushbutton controls for the intercell gates are also located on the front wall of the cell block, one to the right of the window of cell 2 and one to the right of the window of cell 4 that is adjacent to cell 5. To keep the cell walls as free as possible from traps for contamination, the amount of exposed conduit is kept to a minimum.

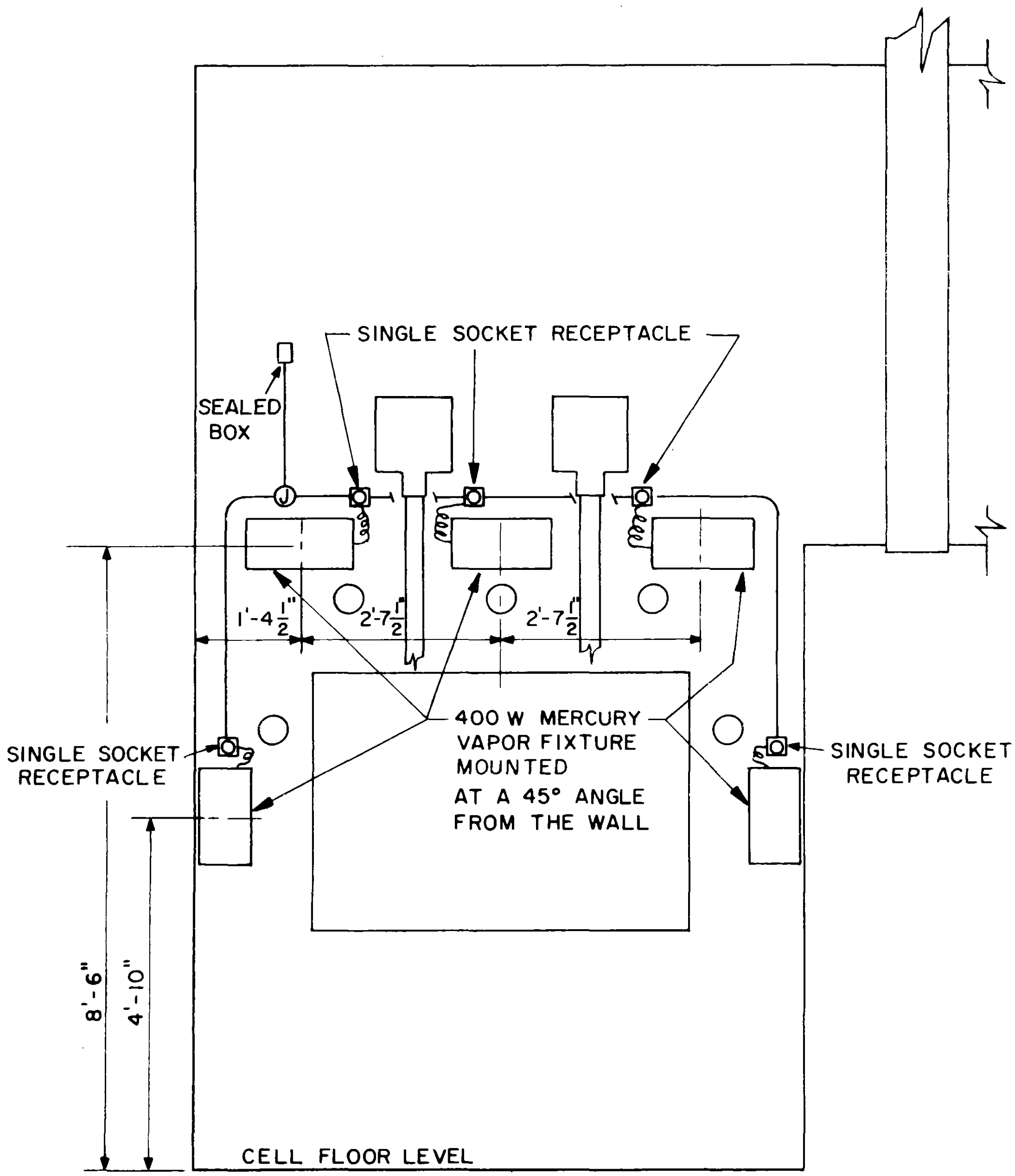


Fig. 7 - Arrangement of mercury lamps around viewing window

Protective Coatings

The problem of radioactive contamination of the surfaces of construction materials is a constant potential hazard in areas where radioactive materials are being investigated and handled. The contaminants may be in the form of liquids, gases, solids, or a combination of any of these. To prevent materials of a structure from accumulating radioactivity and becoming potential radioactive sources, it is mandatory to protect the surfaces with a continuous coating that seals the surface and confines the radioactive contamination at the surface, from which the contamination must be easily removable without having to resort to destruction methods.

The structural design of the walls, floors, ceilings, as well as doors, ductwork, and piping included in the areas of the facility subject to potential radioactive contamination, involved a diversity of construction materials with different characteristics. The surfaces of the entire cell structure, inside and out, and the shielding doors are entirely of steel, with the exception of the tops of the cell roof plugs which are of concrete. The floors and ceilings of the first floor of the facility outside the cell structure are of concrete. Masonry block was used in partition walls of the following areas: isolation cubicles back of cells; x-ray laboratory; decontamination room; radiochemistry laboratory, machine shop, wash rooms; walls at the ends of the cell block, separating the cold and warm work areas; curtain walls at each extremity of the facility; and a large blocked-off doorway at the south end of the waste disposal area. The existing north and south walls of the facility were of structural tile; these walls within the facility were covered with hard plaster. The west wall of the waste disposal area is of glazed brick. Walls and floors of the pits in the waste disposal area as well as the pit covers are of concrete with structural steel angles embedded at exposed edges. Structural framework and some piping in the pits is of carbon steel. The walls and floor of the deionized waterpool isotope storage pit are of concrete. The transition section which conveys cell exhaust air from the 30-in.-diam underground duct to the above ground rectangular duct is of concrete. Ventilation ductwork is of galvanized sheet metal, while exposed piping and conduit are of iron. Doors between rooms are of hollow sheet metal construction.

It was essential that each type of material be protected with a suitable coating that would give maximum protection against radioactive contamination and which could be easily decontaminated when necessary. It was therefore essential that all coating systems considered for use met the following requirements.

1. possess good irradiation resistance, prevent contamination of the base material, and be easily decontaminated

2. provide an even, smooth, pore-free coating on the base material to prevent trapping of radioactive contamination in irregularities and holes

3. possess high chemical resistance to acids, alkali, and solvents as may be used to remove contamination. Coating must form tight bond with base material and resist abrasion.

A search made during the design phase of this facility for coatings having proven reliability under radioactive service conditions revealed that the availability of such coatings was limited. Protective coatings for the hot-cell facility were selected after a review of available data concerning the chemical and physical properties, irradiation resistance, and decontamination characteristics of commercial coating materials. Based on these criteria, modified phenolic resin formulae coatings and systems of application developed by the Carboline Company were selected for application in the hot-cell facility.

The presence of diverse types of construction materials in many areas subject to radioactive contamination made it mandatory, in the interests of economy, to carefully consider the extent of protection required on each material and to select the coating

Table 6
Protective Coating Systems

Coating System	No. Coats	Dry Film Thick. (mils)	Total Thick. (mils)	Coating Material	Legend for Coating Materials
1	1	10	-	A1	Coating materials listed under A, B, and C classification are of the same generic type consisting of modified phenolic resins to which a catalyst (curing agent) is added prior to application. A1: Formula 300 orange primer to which catalyst and special mica filler are added prior to application. A2: Formula 300, finish top coat (gray or white). A3: Formula 300, floor finish, silica filler added with catalyst prior to application (gray), applied with trowel. A4: Formula 300 AE-primer (green) applied with trowel. B1: Formula 305 primer (yellow). B2: Formula 305 finish (white or gray). C1: Formula 302 (black), designed for immersion service. C2: Formula 302 (green). D1: Generic type is modified vinyl, containing rust-inhibitive pigments, formula #6 primer. D2: Generic type is vinyl copolymer, formula 120-1 (decontamination grade). E1: Generic type is epoxy coal-tar to which a catalyst is added prior to application, formula #3 primer (black). E2: Epoxy coal-tar, formula #2 finish (black). X: An acrylic polymer resin, Portland cement slurry-product of Tusco Chemicals, Inc.
	1	8	18	A2	
2	1	10	-	A1	
	1	3/32"	-	A3	
	1	8	112	A2	
3	1	26	-	X	
	1	4	30	B2	
4	1	4	-	B1	
	1	4	8	B2	
5	1	26	-	X	
	1	4	-	B1	
	1	4	34	B2	
6	1	4	-	B1	
	2	8	12	B2	
7	1	26	-	X	
	1	4	-	B1	
	2	8	38	B2	
8	1	14	-	A4	
	1	8	-	C1	
	1	8	-	C2	
	1	8	38	A2	
9	1	2	-	D1	
	1	5	7	D2	
10	1	8	-	E1	
	1	8	16	E2	

system best adapted to protect the base material. This resulted in the selection of nine coating systems for the protection of surfaces against radioactive contamination and of one system mainly for the protection of metal against corrosion inside the gas-scrubber absolute-filter chamber and in ventilation ductwork where necessary. The protective coating systems specified for the facility are summarized in Table 6.

In order for the coatings to provide maximum protection it was mandatory to prepare the surfaces of the base materials in proper condition prior to the application of the coating materials. Thus, carbon steel surfaces were required to be sandblasted to white metal, using sharp abrasive, followed by removal of dust from the blasted surfaces and an immediate application of a prime coat. Cementaceous surfaces were also required to be sandblasted with sharp abrasive, but in this case special attention was required to avoid overblasting which would create deep holes and an excessively roughened surface. The resultant surfaces were required to be hard and strong with surface voids opened. Such voids as well as cracks and expansions were required to be sealed with a special caulking compound prior to the application of the primer coat. In the case of plaster, the surface was required to be cleaned by brushing with water to remove loose cement and dirt followed by thorough drying before application of an acrylic-polymer-resin and cement slurry sealing material that was compatible with the modified phenolic resin formulae coating materials. Masonry block walls were required to be steel brushed with detergent and water, followed by a clear water rinse. When partially dry, the still damp surfaces were required to be sealed with the same sealing material as required for plastered surfaces. The sealing operation was required to cover all surface cavities and pinholes and to provide a smooth surface.

It is desirable to discuss the characteristics of the materials employed in the coating systems listed in Table 6.

The special caulking compound used for sealing expansion joints, cracks, and large voids prior to coating surfaces with modified phenolic resin formulae consisted of an epoxy polysulfide rubber, compounded in two components which were mixed together prior to application. This material satisfactorily sealed joints in concrete masonry, steel, or wood, or any combination of these. Its flexibility was very good, with 20 percent maximum elongation retained after curing. It was compatible with various coating materials and could be coated over with epoxies, phenolics, and vinyls after it was tack-free. It had good chemical resistance to water, salts, solvents, acids, and alkalies and good abrasion resistance. It could be applied to vertical surfaces without sagging.

The special sealing material for porous surfaces, a product of Tusco Chemicals, Inc., consisted of an acrylic polymer resin dispersed in water together with additives such as emulsifiers, pigment dispersants, antifoaming agents, preservatives, pigments, portland cement, etc., all dispersed into a slurry. This product was designed as a surface conditioner and a filler coat for monolithic concrete and masonry block structures as a base surface for the application of special coatings needed to protect construction materials against radioactive contamination common to nuclear installations.

The phenolic coating materials consisted of pigmented, high-solids, modified phenolic resin formulae requiring the use of a catalyst (curing agent) prior to use. These coating materials were designed for the protection of concrete and steel surfaces against contamination in a radioactive environment under severe service conditions of chemical action, corrosion, wear, abrasion, and temperature, where resistance to gamma irradiation and ease of decontamination is required. The applications include: floors subject to heavy traffic and abrasion, walls, ceilings, lining of pools requiring high resistance to demineralized water, structural steel, and equipment. The coatings produced from these materials are nontoxic and do not impart taste or odor to liquids coming in contact with them.

When properly mixed and applied, an 8-mil thick coating is obtainable on a vertical surface without sag. The primer coat for concrete contains a special silica filler, while the primer coat for steel contains a special mica filler. In general, a primer coat followed by a finish coat is considered to provide satisfactory protection for less severe service conditions, whereas, a primer coat followed by an intermediate and by a finish coat are necessary in situations involving heavy traffic or severe abrasion. In special cases, such as a lining for a pool containing demineralized water and subject to gamma irradiation, four coats are necessary to provide the necessary protection to the base material.

To insure good coverage with each coat, the coating materials are pigmented in different colors so that each coat contrasts with the preceding coat. This color system also provides an indication as to how much protection has been removed in heavy wear areas or under severe abrasion.

Test data submitted by the manufacturer of the phenolic coating materials indicated that these have a high resistance to the effects of gamma irradiation and to chemical action. As a measure of resistance to gamma irradiation in demineralized water, the coatings showed no blistering, flaking, cracking, or softening on samples exposed to a cumulative dose of 5×10^8 roentgens from a flux of 1×10^6 roentgens per hour or more in water whose resistance was no less than 0.02 megohm/cm. A measure of the chemical resistance was that the coatings showed no blistering, flaking, cracking, or softening upon immersion of coated samples in such liquids as 50 percent H_2SO_4 at 80°F for 30 days, 50 percent NaOH at 150°F for 30 days, xylol at 80°F for 30 days, methyl ethyl ketone at 80°F for 48 hours, and isopropyl alcohol at 80°F for 30 days.

Data on coated steel samples showed no loss of bond or cracking when subjected to the following conditions: bending of the coated shape through 180 degrees over a 1/2-in. mandrel and back to its original shape; heating of the steel at 180°F for 48 hours, followed by cooling to room temperature and then bending over a 1/2-in. mandrel. Cyclic exposure of coated samples to dry ultraviolet light for 17 minutes, followed by water spray for 3 minutes with black surface temperature between 150 and 180°F for 500 hours, showed no blistering or rust spotting.

The decontamination properties of the phenolic coatings were as follows: the percent of residual contamination did not exceed 18 percent of the initial dose after washing with 75°F tap water for 2 minutes and drying, followed by scrubbing with a soft nylon brush under 75°F tap water for 2 min, then drying.

To avoid sandblasting of surfaces of certain iron base materials prior to coating them, a vinyl base coating system formulated in a decontamination grade was selected for protection of sheet metal ventilation ductwork, iron piping, structural steel framework and housings, and hollow metal doors.

The primer for black iron piping, hollow metal doors, and structural steel surfaces consisted of a single-component modified vinyl, containing rust-inhibitive pigments. The characteristics of this undercoat included: good physical properties (tough and flexible), good immediate bond, good sharp-edge protection, good chemical resistance, and compatibility with vinyl base topcoats.

The vinyl base topcoat for primed iron surfaces and for galvanized sheet metal ductwork consisted of a single-component high vinyl chloride vinyl-acetate copolymer formulated in a special decontamination grade. The characteristics of this topcoat material included: glossy coating resistant to dirt penetration, easy to clean, relatively impermeable, nonoxidizing, and good resistance to acids, alkalies, straight chain hydrocarbons, and water. The dried film does not support combustion. The coated surface can be decontaminated to a safe level with the use of wash water only.

For protection of the interior of the steel gas-scrubber chamber, surfaces of absolute-filter steel framework, and adjacent plenums against attack by moisture, a two-component epoxy-tar coating system was selected, to which a catalyst was added prior to application. The epoxy-tar primer coat contained inhibitive pigments in the formulation, thereby providing excellent resistance to undercutting, making it an excellent primer for steel. The film is glossy, with very good resistance to acids, alkalies, water, salts, and solvents, except ketones. This coating material was designed to give maximum protection from underfilm corrosion. The epoxy-tar topcoat formulation was designed for maximum resistance to penetration by water, brine, and hydrogen sulfide.

To assure that the coatings would be effective, the coated surfaces had to be smooth and free from pores. This required strict adherence to prescribed procedures for preparing surfaces in proper condition, proper mixing of coating ingredients, and considerable skill and attention to the application of the coatings. It was considered necessary to have a skilled representative of the manufacturer of the coating materials to assist in the coating work by providing guidance in the preparation of surfaces, in the mixing of ingredients, and in the application of the coating materials to the various types of construction materials listed in Table 6. The unusual problem of coating diverse types of materials occurring in the various areas of the facility is illustrated by the schedule of Table 7, which lists the protective coating systems employed.

Ventilation

Ventilation Systems – The ventilation of the facility was divided into two separate zones, one zone to ventilate the space occupied by offices, laboratories, and "cold"* work areas, and the second zone to ventilate the hot cells, decontamination, and "warm"* work areas. This was necessary in order not to recirculate air from areas subject to potential radioactive contamination into other areas. Each zone was therefore provided with a separate ventilating system complete with exhaust fans and accessories. Both systems were designed for 80°F dry bulb and 50 percent relative humidity for summer conditions and 73°F dry bulb and 50 percent relative humidity for winter conditions.

Conditioned air for the offices, laboratories, and "cold" work areas was designed for delivery to the area through ducts and grilles and returned through corridors and grilled doors. In wash rooms and some laboratory areas the ventilating air was made to exhaust directly to the atmosphere. The system was designed to provide six complete changes of air per hour, maintaining a positive pressure over the second zone which ventilated the areas subject to potential radioactive contamination.

The ventilation system for the areas subject to potential radioactive contamination was designed for delivery of 100 percent fresh, filtered, conditioned air, either cooled or heated, depending on the season, through fan ducts and grilles. In this area no recirculation of ventilating air could be permitted; it therefore was necessary to arrange the system so that exhaust air was removed continuously from the hot cells and the "warm" work areas. To prevent possible back streaming of airborne radioactive contamination from the hot cells to other areas, it was necessary that the cells be maintained at a negative pressure of at least 1 in. water gauge with respect to the atmospheric pressure in surrounding areas. The air supply system was designed to furnish fresh air through ceiling diffusers to the various areas indicated in Dwg. 9. It will be noted that air supplied to areas 106, 140, 139, 135, 134, and 133 mixes with air supplied to the "warm" work area 121. A part of this air exhausts through ceiling registers located in area 121, close to the isotope storage area 139. The other part of this air passes into the isolation cubicles where it mixes with make-up air supplied to the isolation cubicles through ceiling diffusers. This air enters the cells through ductwork and is exhausted from the cells to the scrubber absolute-filter system. The air supplied to the decontamination room (area 136) exhausts directly through the scrubber absolute-filters to the atmosphere. The air supplied to the "warm" chemistry laboratory, area 132, was designed to exhaust directly through the scrubber absolute-filter system except when either the radioactive fume hood or the perchloric acid hood exhaust fans were operated. In this case, the exhaust from this area passed through a separate filter and exhaust system to the atmosphere. The air supplied to the wash and locker rooms (areas 128, 129, 130, and 131) and janitors closet (area 137) was designed to exhaust directly to the scrubber absolute-filter system.

Fresh air to each room of the offices, laboratories, and "cold" work areas is supplied by fan (item K-40) through ductwork. This fan was designed to furnish 5,350 cfm. Part of this input, amounting to 3,700 cfm, is supplied directly to the "cold" work area (122). The

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*"Cold" or "warm" refers to the absence or possible presence, respectively, of gamma radiation.

Table 7
Protective Coating Schedule

Area (Refer to Fig. 3)	Finish Color	Surface Coated	Protective Coating System No. (Refer to Table 6)
122,133	Gray	Concrete floor and trench	1
	Gray	Plastered and masonry block walls – lower 7 ft	4
	White	Steel-walls and doors	4
	White	Plastered and masonry block walls – above 7 ft	3
Hot Cells (interiors)	Gray	Steel floors	1
	White	Steel walls, steel intercell gates, and transfer drawers	6
	Gray	Steel doors (both sides and tops) and under-window access openings in cells 4 and 5	6
	White	Exposed concrete	7
123,124,125,126 127	Gray	Concrete floors	2
	White	Masonry block walls and concrete ceiling	7
	Gray	Doors (steel)	4
106,121	Gray	Concrete floor, including platform	1
	White	Masonry block, plastered walls, and concrete ceiling	5
	Gray	Doors	4
	White	Concrete walls	4
140	Gray	Concrete floor	1
	White	Masonry block and plastered walls	5
	White	Concrete wall and ceiling	4
139	Gray	Concrete floor	2
	White	Masonry block, plastered walls, and concrete ceiling	5
	White	Deionized water pit	8
	Gray	Doors	4
136	Gray	Concrete floor	2
	White	Masonry block, plaster walls, and concrete ceiling	5
	Gray	Steel gratings, and walls and floor of pits	6
	Gray	Doors	4
134,135	Gray	Concrete floor	1
	Gray	Masonry block and plastered walls – lower 7 ft	5
	White	Masonry block and plastered walls – above 7 ft – and ceiling	3
	Gray	Doors	4
132	Gray	Concrete floor	1
	White	Masonry block walls and ceiling	5
	Gray	Doors	4
128,129,130,131	Gray	Concrete floors	4
	White	Masonry block walls and ceiling	3
	Gray	Doors	4
137,138 Janitor's closet	Gray	Concrete floors	1
	White	Masonry block walls and ceiling	5
	Gray	Doors	4
146 Radioactive waste Disposal area	Gray	Concrete floor and pit covers	4
	Gray	Masonry block and plastered walls – lower 7 ft	3
	White	Masonry block and plastered walls – above 7 ft – and ceiling	2 coats, Formula D-2
	White	Interior walls and floors of pits	6
	Gray	Doors	4
2nd floor area surrounding scrubber-filter chamber	Gray	Concrete floor	4
	Gray	Plastered walls – lower 7 ft	3
	Gray	Plastered walls – above 7 ft	9
2nd floor area: interior of filter chamber, exterior of ductwork	Black	Steel interior of filter chamber and duct plenums adjacent to filters on intake side	10
	Gray	Steel – exterior surfaces of filter chamber and duct plenums	9

other part of the input, amounting to 1,650 cfm, is circulated through the offices and laboratories through individual fan coil units. The air is delivered to the "cold" work area through air diffusing supply outlets mounted on the wall opposite to the cell wall.

Stale air from the office and laboratory areas exhausts to the atmosphere through exhaust fan K-17. Air supplied to the "cold" work area is not recirculated but exhausts directly through absolute filters (item K-101) and an exhaust fan (item K-11) to the outside atmosphere. Not all of the input of 3,700 cfm which enters the "cold" work area (122) exhausts through fan K-11. It was estimated that about 1,400 cfm would enter the cells by leakage through various wall penetrations and be exhausted through the cell exhaust system.

Certain safety precautions were included in the design of the systems. Fan K-40, supplying air to the office, laboratory, and "cold" work areas, is manually started and interlocked with exhaust fan K-17 so that supply fan K-40 cannot be started unless fan K-17 is operating. Upon start up of fan K-40, an outside air damper opens automatically and temperature controls are energized.

Filtered fresh air supply to the "warm" work area is provided by supply fan, item K-21, designed to deliver 18,850 cfm through ductwork and ceiling air diffusing outlets equipped with volume dampers and distributing grids in the necks of the outlets. Air supplied to the "warm" work area is not recirculated but is exhausted through ceiling registers in the "warm" work area (121) in near proximity to the isotope storage area (139). Exhaust air passes through a scrubber (item K-120) absolute-filter (item 100) system and main exhaust fans (items K-14 and K-15) to the outside atmosphere. It was estimated that about 350 cfm of the air input into the "warm" work area would pass into the isolation cubicles and thence into the cells as a result of the suction produced by the negative pressure in the cells. It will be noted in Dwg. 9 that the air supplied to the "warm" records room (106) and "warm" x-ray laboratory (140) passes into the "warm" work area (121), mixing with the air supplied to that area. The air supplied to the corridors (133 and 134) passes into the machine shop (135), joining air delivered to that area. All of the air from areas 106, 140, 121, 133, 134, and 135, together with that supplied to the isotope storage area 139, exhausts through ceiling registers located in the "warm" work area (121) in close proximity to area 139. Air supplied to the decontamination room (136) is exhausted directly from the room to the scrubber absolute-filter exhaust system. Air supplied to personnel washrooms (128 and 131) and locker rooms (129 and 130) and air supplied to the janitor's closet (137) also exhausts directly to the scrubber absolute-filter system.

To insure that the airflow pattern would be maintained in the "warm" work area as planned, certain safeguards had to be incorporated into the system. When fan K-21 was started, the supply air damper was arranged to open and the temperature controls to be energized. In the event any one of the fans K-11, K-14, or K-15 should stop, fan K-21 would automatically stop. Fan K-12 was interlocked with the "warm" chemistry laboratory supply and exhaust dampers so that when K-12 was started manually, the wall dampers opened, admitting an additional 660 cfm to the normal input of 1,840 cfm into the room. At the same time the exhaust duct dampers, which normally exhaust 540 cfm from the room to the scrubber absolute-filter system, were arranged to close. This arrangement provided the "warm" chemistry laboratory with ample air supply to exhaust either through the normal exhaust system or through the separate hood exhaust fans K-12 and K-13 as conditions required.

The air supply to the cells was designed to be largely derived from leakage around gaps in cell wall penetrations and shielding doors. The airflow derived in this manner, however, could not be predetermined accurately during the design stage of the project and only rough estimates were possible. It was estimated that the suction produced in the cells by exhaust fans K-14 and K-15 would require an input airflow of 6,650 cfm to obtain a negative pressure of 1 in. water gauge. The airflow by leakage into the cells was conservatively estimated to be 1,750 cfm, leaving a difference of 4,900 cfm that would have to be supplied to the cells as make-up air. This was provided by the separate air supply system (item K-20) which was designed to deliver the required make-up airflow to the isolation cubicles through ceiling air diffusers. Delivery of the required amount of make-up air to each cell was provided through louvered intakes located on the outside cell wall, conveyed into the cells through ductwork embedded in the shielding walls, and supplied into the cells through outlets such as the one shown in section J-J of Dwg. 4. Fan K-20 was electrically interlocked with main exhaust fans K-14 and K-15 so that it could not be started unless the main exhaust fans were operating. Should either of the exhaust fans stop, fan K-20 also stopped. Motor driven dampers on the suction side of the main exhaust fans operate manually from a remote station. Additional interconnections were provided so that if either exhaust fan K-14 or K-15 should stop, the dampers on the inlet ducts to each cell closed automatically and the discharge damper on the particular fan also closed. For normal operation each discharge damper was required to be adjustable so that it could take a porportional amount of airflow passing through. In case one of the main exhaust fans were to shut down, the damper of the remaining fan was required to open to its maximum position. If both fans were to shut down, both dampers were required to close. If, however, a power failure caused both main exhaust fans to shut down, both dampers were arranged to open to their maximum position, thereby providing some exhaust to occur from the natural updraft in the 61-ft tall exhaust stack.

Exhaust fans, item numbers K-11 through K-17, were specified to be of the backward inclined type with the fan wheels statically and dynamically balanced and with the shafting turned, ground, and polished to dimensions. The fan inlets were required to be streamlined to permit smooth entry of air with a minimum of shock and turbulence so as to provide quiet efficient operation. For fans under 30 brake horsepower (BHP) the bearing requirements specified were for sealed, prelubricated, cartridge-type ball bearings having a rated life of 60,000 hours of operation without further lubrication. For requirements above 30 BHP sleeve bearings were specified having an external lubricant storage reservoir. The fan drives were specified to be infinitely adjustable to plus or minus 10 percent of the required speed. All fans were specified to have a single inlet, except fan item K-16 which was to have a double inlet. Details of motor sizes, speeds, and suction pressures in inches of water for the various fans appear under each item on Dwg. 9.

Gas Scrubber – The purpose of including a gas scrubber (item K-120) in conjunction with absolute filters was twofold. It provided the facility and the surroundings with maximum protection against release of radioactive contamination into the atmosphere by the main exhaust system. It also reduced the dust burden on the absolute filters to a minimum, thereby prolonging their useful life and requiring less frequent replacement. The advantages foreseen in this arrangement were that the radiological hazards involving the maintenance of the filter system would be effectively reduced and a substantial monetary saving would result from fewer replacements of the expensive absolute filters.

The scrubber was designed to utilize the principle of intimate contact between the gas of the air stream and water to remove suspended particulate matter and to absorb soluble matter. The required efficiency was 90 percent at 1 micron size particulate matter and a capability of operating with water up to 60 percent solids in it.

The specified size of the scrubber chamber was 10-1/2 ft wide by 14 ft long by 8-1/2 ft high constructed of 3/16-in.-thick plate steel, reinforced. Design features included a spray washer, impingement baffle stage, entrainment separators, and a level control device with control valve for adding make-up water as needed. The water basin was designed to hold up to 1 ft of water depth with the operating depth of 6 in. The basin bottom was sloped to facilitate drainage of water bearing solids to the waste disposal system for concentration.

Prefilters and Absolute Filters - All supply air was required to be prefiltered through disposable fiber-glass filters, 2 in. thick.

Exhaust air from the cells was required to be prefiltered at cell outlets through 2-in. thick fiber-glass filters, arranged in a V, to have a maximum velocity of less than 300 fpm. This precaution was to prevent coarse dust particles (which could be radioactive) from entering the cell exhaust ductwork.

The type of absolute filter selected for filtration of air from areas subject to radioactive contamination consisted of a pleated filter medium composed of asbestos and fiber glass with aluminum separators assembled in a cadmium-plated steel frame. This type of filter was moisture resistant and fireproof. Each filter must be tested for airflow and pass smoke tests based on the use of dioctylphthalate test smoke of homogeneous particles of 0.3 micron size and optical evaluation of the smoke fraction penetrating the filter in accordance with U.S. Army Chemical Corps and U.S. Atomic Energy standards.

After exhaust air leaves the scrubber it proceeds next through absolute filters held in a chamber adjacent to the scrubber and integral with it. The absolute-filter system for handling the main exhaust through fans K-14 and K-15 was designed to consist of two banks of 16 filters each (item K-100). The size of individual filters was 24 in. by 30 in. by 11-1/2 in. thick with each having a rated flow of 1,500 cfm at 1 in. water gauge (when clean). The filters were stacked four wide and four high in each bank which measured 8 ft high by 10 ft wide with an airflow capacity of 24,000 cfm at 1 in. water gauge. The filter banks were arranged in the plenum chamber in such manner that the side containing an accumulated dust load would be away from the side which an operator would face when removing filters for replacement. Filters were individually gasketed against the frame to prevent air leakage around them and held in place in the frame by quick-disconnect fasteners.

The absolute-filter system (item K-101) designed for the exhaust through fan K-11 consisted of one bank of four filters, stacked two high and two wide, with a total rated flow of 4,400 cfm at 1 in. water gauge. The individual filters measured 24 in. by 24 in. by 11-1/2 in. thick having a rated flow of 1,100 cfm at 1 in. water gauge. The characteristics of these filters and the filtering integrity were the same as that required for the main exhaust system.

Heating and Cooling - Heating and cooling of the office and laboratory areas was designed to be by individual fan coil units located in each room except the stock room (area 111). Delivery of fresh air to each room through ductwork is by fan K-40. Zone temperature was designed to be controlled with a "Heat-Cool" selector switch which was also to position diverting valves in hot or chilled water manifolds to direct water to either a hot-water converter (item K-70) or to a refrigeration machine (item 50). Each room unit was required to be equipped with a three-way valve to control the water flow through the coil. Under a heating regime, less hot water was to flow through the coil as air temperature in the room increased and more water was to flow through the coil as air temperature decreased. Under a cooling regime, more chilled water was to flow through the coil as air temperature increased and less water was to flow as air temperature decreased.

Since air supplied to the "cold" work area was not to be recirculated a separate system (item K-130) was necessary for heating or cooling the supply air to this area. This consisted of a separate "Heat-Cool" selector switch, circulating pump, and the heating/cooling coil. Hot water for heating was provided from the hot-water converter (item K-70), or chilled water was provided from the refrigerating machine (item K-50). Control of the water flow through the heating/cooling coil is by a room thermostat.

Air supply to the "warm" work areas was designed to be heated or cooled at fan K-21 and delivered, conditioned, to the various ceiling air diffusers in the area. The Heat-Cool selector switch when set to Heat energizes steam valves and directs thermostatic control to them. The steam valve on the preheat coil is controlled through a low limit thermostat and switch. As inlet air temperature drops below 35° F, a two-position steam valve on the preheat coil opens to its maximum position. With air temperature above 35° F this valve remains closed. A thermostat in the discharge duct of fan K-21 modulates the reheat coil steam valve so as to maintain a constant preset temperature. With the selector switch set to Cool, chilled water circulates from the refrigerating machine to the cooling coil with thermostats controlling the discharge air temperature from fan K-21, resetting as required to maintain average conditions in the area and to maintain a differential to the outside not greater than 15° F, but not reducing the temperature below 75° F. A humidistat was included to provide dehumidification control by overcooling and reheating.

The refrigeration machine (item K-50) was interlocked with a cooling tower circulator, the circulators to coils at fans K-20, K-21, and K-40 and in the supply duct at K-130, and the Heat-Cool selector switches so that the refrigeration machine could not be started unless at least one selector switch was set to Cool and its corresponding circulator and the cooling tower circulator were operating. Control of cooling tower fans was by ambient air temperature, one fan starting at 70° F and the other fan at 75° F.

Dampers – Dampers placed in the ductwork at various points provided a means of balancing and controlling air distribution. These dampers were of the opposed blade type, operated manually with a locking quadrant.

Fire dampers were located at various points in the ventilation system to interrupt air flow in case of fire. These were designed to close automatically and remain tightly closed. Activation of the fire dampers was by means of a heat-sensing device, located where it would readily respond to an abnormal temperature rise in the duct. The requirement was that it would operate the fire dampers when the temperature reached approximately 50° F above the maximum temperature expected to prevail in the ventilation system when operating or shut down.

Liquid Waste Drainage Systems – The problem of handling liquid waste resulting from hot-cell and laboratory operations and from decontamination work required special consideration. Radioactive liquids cannot be dumped down a drain, but must be handled and disposed of according to prescribed methods. Where relatively large volumes of contaminated liquid waste are involved, such as wash water, handling through a drainage system to a collection point becomes a practical necessity. It is not permissible to empty radioactive contaminated liquid waste directly into the sanitary sewer.

A gravity drainage system was provided to convey liquid waste to a collection point from floor drains, cup drains, sink drains, and pit drains located in the hot cells, isolation cubicles, warm work area, decontamination room, "warm" chemistry laboratory, machine shop, "warm" area wash rooms, and scrubber. A separate drainage system was provided to collect condensate water from drains in the isotope storage area in a sump from which the liquid waste is transferred to the above-mentioned gravity system by a steam jet syphon.

The contaminated liquid waste drainage system was designed with piping and fittings of schedule 10, type 304 stainless steel with all joints and connections welded in accordance with ASME unfired pressure vessel code. One characteristic in the system was the absence of the conventional traps used in sanitary systems.

Floor drains were intended to be used only during scrub-down operations; at all other times the drains were to be blanked off with covers. The drain system was designed to vent through the waste disposal system, to be described in the next section.

Contaminated Waste Disposal System – Since it is not permissible to dispose of radioactive contaminated liquid waste in the sanitary sewer, some means had to be provided to cope with the problem of waste disposal. The original plan was to collect the liquid waste in storage tanks and periodically dispose of it through AEC-licensed commercial sources. In the latter stages of the facility design, however, it became known that this plan could not be used and some other alternative would have to be selected. After an intensive study of possible methods for the collection and treatment of radioactive liquid waste for disposal it was decided that concentration of the liquid waste to a small volume by evaporation would provide the most practical method for coping with the problem. It was assumed that the bulk of the radioactive contamination in the liquid waste could be precipitated as solid matter upon evaporation and that the evaporated water upon condensing would be free of radioactivity.

The system as designed is illustrated by the engineering flow diagram of Dwg. 10 and consists of passing the raw liquid waste through 100-mesh stainless steel strainers (items G-101 and G-101A), thence by pump J-102 through fine filters G-103 and G-103A, and thence by gravity to 1,000-gal holding tank F-104. At this point, if monitoring shows that the filtered water in the tank is free of radioactivity the contents can be emptied into the sanitary sewer. If low-level radioactivity is detected in the tank water and sufficient capacity remains in the tank, contamination-free water can be added to dilute the contents and thus lower the activity. If by the process of dilution the activity of the water is reduced to an acceptable level for disposal into the sanitary sewer, the contents of the tank are disposed of in this manner. If, however, the radioactivity detected in the tank water cannot be reduced to an acceptable level for sewer disposal, the contaminated water is processed through evaporators C-106 and C-106A. As water evaporates, the vapor passes through demisters G-106-1 and G-106-2 and condensers C-106-2 and C-106-2A and the condensed distilled water collects in tanks F-107 and F-107A. As evaporation of the water proceeds in the evaporators, the solids burden of the remaining liquid increases until it reaches the consistency of a sludge. Solids removed from solution and suspension in the water by evaporation are prevented from accumulating on the sides of the evaporators by vibratory action. The concentrated sludge removal is from the hemispherical bottoms of the evaporators through appropriate valving into shielded containers. The final details of sludge removal were not included in the design phase of the waste disposal system but deferred until the system was ready for actual operation.

The waste disposal system was designed with dual components in order to provide means for continuous collection and processing. Thus, two sets of coarse strainers, fine filters, evaporators, and distilled water tanks were included with one of these components to be in use and the other either undergoing maintenance or on standby readiness.

The criteria used in determining the capacity of the waste disposal system was based on the following reasoning. In accordance with recognized statistics the maximum liquid waste anticipated for a typical chemical laboratory is approximately 20 gal per day per person. For a typical metallurgical laboratory, this figure could be safely reduced to about 10 gal per day per person. On this basis and assuming a maximum working staff of 20 people, a maximum of 200 gal of liquid waste would be generated daily. To handle this volume the holding tank F-104 was designed for a capacity of 1,000 gal, sufficient for a 5-day accumulation, the evaporators were designed to each evaporate 20 gal per hour, and each distilled water tank for a capacity of 260 gal.

Circumstances required that the waste disposal system be located at one end of the high-level radiation laboratory facility. This end was also required for the unloading and handling of heavy equipment for the facility from trucks with the 15-ton capacity facility bridge crane. It was therefore necessary to locate the waste disposal system below floor level in individual pits and to cover the pits with 2-ft-thick plugs flush with the floor. This provided the necessary shielding and permitted trucks to be rolled over the area. The arrangement of the pits and the components they contain is indicated on the plan of Dwg. 1.

Essential features included that all piping handling contaminated liquid waste between various components of the waste disposal system was required to be of stainless steel. All piping embedded in concrete between pits was required to be without joints in any run in the concrete. Where fittings were necessary, the joints were required to be welded or silver brazed in the case of copper. Contaminated waste and chemical valves were required to be of a diaphragm type, either lever operated or motor driven. Valve bodies were required to be of "Hypalon." Valve design requirement was that abrasive slurry could be handled with no settlement of particulate matter to interfere with tight cutoff of the line. The installation requirement was that the valve position would permit complete drainage of the valve. Pressure rating requirement for the valves was 100 psi at 125°F.

Coarse filters equipped with 100-mesh stainless screen baskets were designed to screen out coarse particulate matter from the raw waste as an initial step. The baskets were designed removable so they could be readily emptied or replaced as needed. The filter cases were vented to the cell exhaust system and these vents also served to vent the contaminated drainage system.

The fine filters were required to have the following characteristics: continuous flow, post type, disposable cartridge; flow rating 0-18 gpm; differential pressure range 3 psig (filter clean); max. temperature rating 180°F; pressure rating 75 psig; stainless steel body; filter element capable of removing particulate matter 5 micron size or larger; filter element arranged for easy removal.

Raw waste pump (J-102), filtered waste pump (J-105), and distillate pump (J-108) were designed with a magnetic drive and hermetic sealing. The magnetic drive was considered to be an important factor for the prevention of leakage of contaminated liquid waste onto the pit floors by the elimination of the stuffing glands in pump construction.

The 1,000-gal-capacity holding tank F-104 was designed to be of stainless steel construction and equipped internally with a stainless steel integral sparger pipe for agitating the contents with low-pressure compressed air so as to mix the contents with neutralizing chemicals, when necessary, and to homogenize the waste. To maintain the contents of the tank in a neutral condition, acid or alkali of proper concentration was fed into the tank as needed through a line from two mixing tanks located outside the waste disposal system, as shown on Dwg. 10. A continuous pH recording system calibrated to bracket the range of 4 to 10 pH, and complete with immersion-type elements and the necessary instrumentation, was provided to monitor the acidity or alkalinity of the tank contents. To prevent gases from collecting in the tank and spreading to other parts of the system through piping, the tank was vented to the cell exhaust system through a 2-in. line for safety.

The evaporator shells were designed with hemispherical bottoms to provide a contoured shape which would permit efficient withdrawal of sludge from the lowest point and a shape around which steam jackets could be fitted. This design permitted the evaporators to be supported on the steam jackets attached to a structural steel base and provided for easy removal of the evaporator shells for disposal when necessary.

The steam jackets were designed to operate at a pressure of 60 psig, with the inlet steam flow to the jacket controlled by the temperature of the discharge vapor. The control of liquid waste into the evaporators was designed to be by a float control inlet valve. An electrically activated bin-type vibrator, adjustable from 3,600 to 7,200 vibrations per minute, was provided, to be mounted on the outside of the evaporator shells. The function of these vibrators, as mentioned previously, was to prevent solids released from solution or suspension in the liquid from caking on the inside surfaces of the evaporators during operation. Final details of the mechanism involved for removal of sludge were not resolved in the design phase of the waste disposal system.

In order to protect the concrete of the pit walls, floors, plugs, and exposed piping (nonstainless) from becoming radioactively contaminated and to facilitate decontamination, the surfaces were protective coated, as was shown for area 146 in Table 7.

Due to the potential radiological hazards that are likely to prevail in the various parts of the waste disposal system during treatment of contaminated waste, it was considered necessary to exclude personnel from entering the pits except to do maintenance work when necessary. Operation of the waste disposal system was designed to be remotely controlled from a control panel located at one end of the machine shop (area 135) and close to the door between the waste disposal area and the machine shop.

The control system included indicating lights and an audible alarm for liquid level controls in the coarse filters, the holding tank for filtered waste, the evaporators, and the distilled water tanks. Pressure differential indication and alarm was provided for the fine filters. All valves were either solenoid equipped or motor driven and remotely operated by pushbuttons. All motors are started and stopped remotely by pushbutton controls; however, in addition, some of these motors are provided with manual start-stop pushbutton stations within the pits to facilitate maintenance work on them. Radiation monitors were provided in the holding tank and in the evaporators to indicate remotely the radioactive level in each component.

Water Treating System (Deionizer) – A water treating system was designed to provide water of necessary quality for the pool in the isotope storage area. The requirements of the system were that a continuous flow of 10 gpm of deionized water would be produced, having the following quality: specific resistance of 1 megohm-cm (minimum), CO_2 content of 1 ppm (maximum), and silica content, as SiO_2, of 0.2 ppm (maximum). The flow diagram of the system is shown in Fig. 8 and as assembled in Fig. 9. Its location is shown in Dwg. 1 in the isotope storage area (139).

The system included one activated carbon filter with valve nest, one mixed bed-type demineralizer unit with all appurtenances, and one replaceable cartridge-type filter.

The activated carbon filter was designed as a vertical pressure filter case of carbon steel fabricated in accordance with ASME code for unfired pressure vessels. The design working pressure was 75 psi and the flow rate 10 gpm with a maximum filtration rate not to exceed 3 gpm per sq ft of effective filter area. The filter unit was arranged for manual operation and equipped with inlet distributors and underdrains. The head was designed to be easily removable for replacing the filter media.

The mixed bed demineralizer was designed as a vertical vessel of welded steel construction lined with polyvinyl chloride, 30 mils thick, for manual operation at a working pressure of 75 psi and a maximum flow rate of 10 gpm, but not to exceed 6 gpm per sq ft of effective area. The mixed bed unit was required to include polystyrene cation resin and strongly basic anion resin to at least a 20-in. minimum depth bed of each and to include all required operating accessories. These included all piping and valves, a disc-type inlet water meter (reading in gallons) with alarm-type register, inlet and outlet pressure gauges, sample cocks, and an effluent conductivity meter with temperature compensator and conductivity cell for determining effluent and rinse conductivity.

The regenerant equipment included two 18-in. diam separate regenerant tanks for sulfuric acid and caustic soda regeneration, and all regenerant piping, ejectors, rate of flow indicators, and related items made of polyvinylchloride lined steel.

Exchange resins were required of a quality that would not impart color to the treated water and whose capacity would not exceed a loss of 3 percent per year for three years for cation resin and not exceed a loss of 15 percent per year for one year for anion resin. The capacity requirement of the unit was that at least 5000 gal of deionized water would be produced with 6 lb of acid per cu ft of cation resin per regeneration.

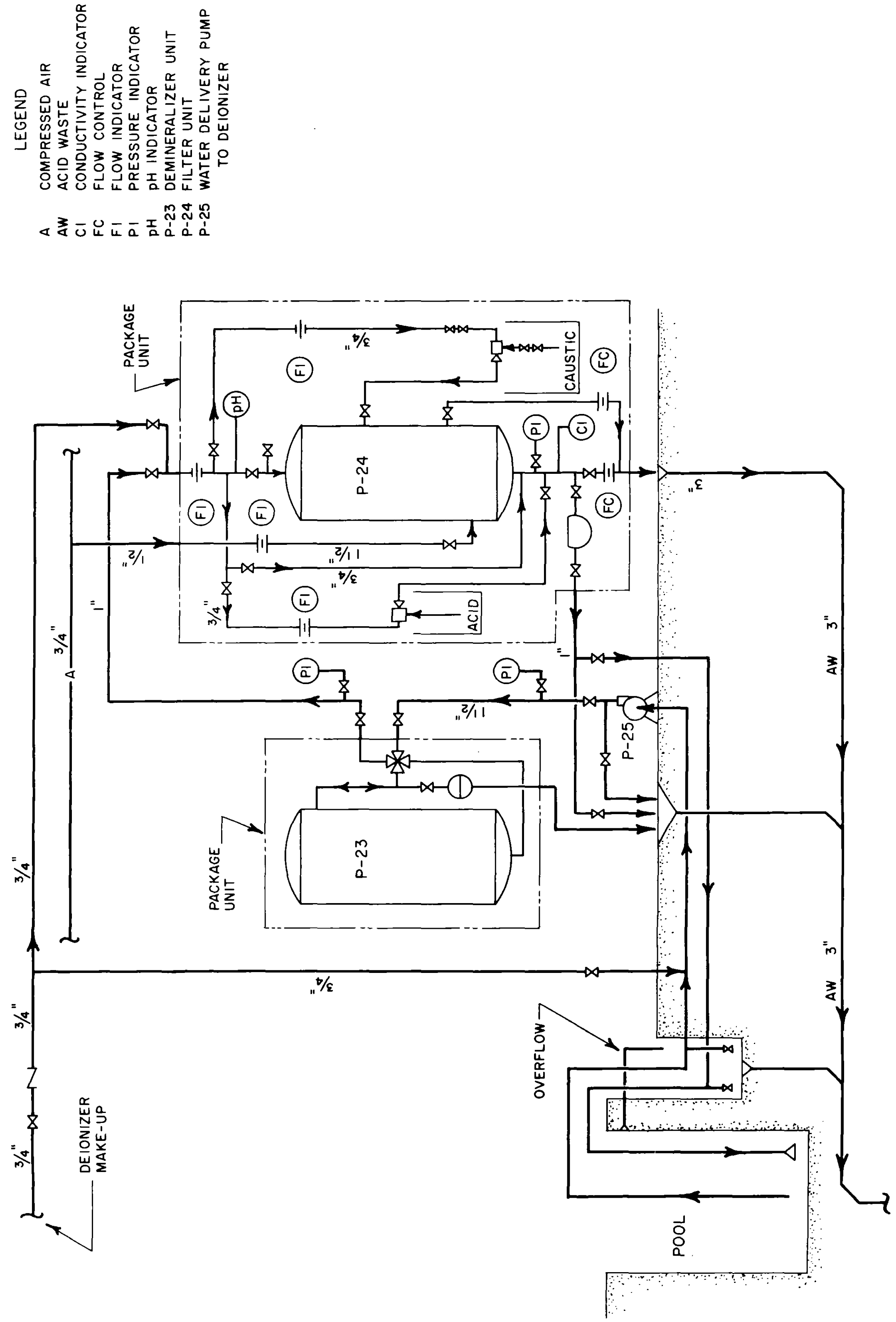


Fig. 8 - Deionizer flow diagram

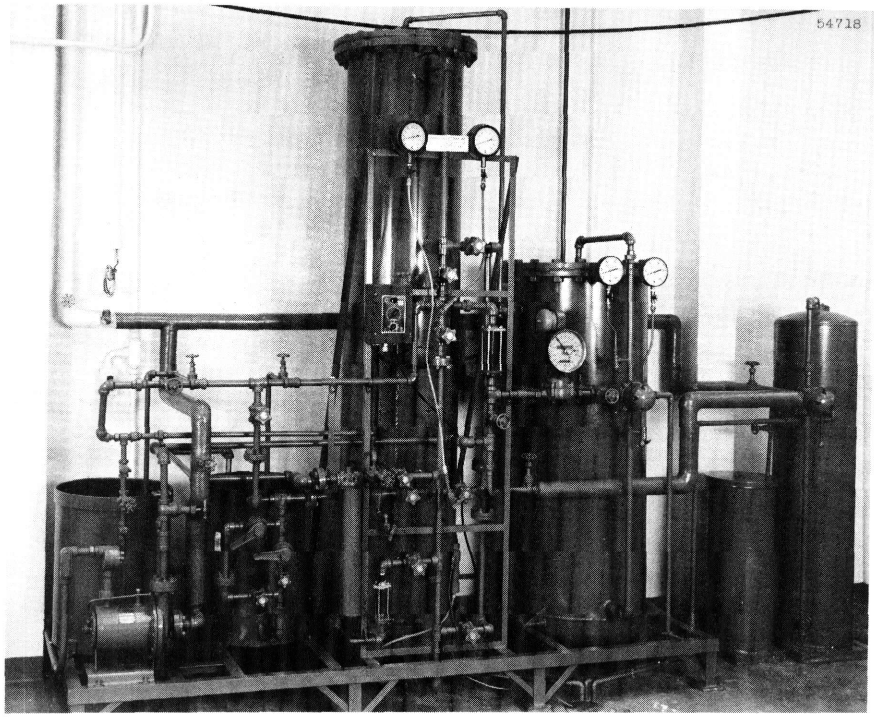


Fig. 9 - Deionizer assembly

The cartridge-type filter for the outlet of the mixed bed demineralizer was required to have the following characteristics: continuous flow type disposable cartridge; flow rate of 10 gpm deionized water of 1.0 specific gravity; differential pressure range of 3 psig (when clean); operating pressure of 75 psig and operating temperature of 110°F; body material of stainless steel; filter element of cellulose; and capability of removing all particulate matter down to 10 micron size. The pressure drop from the inlet of the cartridge filter, through the mixed bed, to the outlet of the cartridge filter (when clean) was not to exceed 18 psig, and not exceed 40 psig at any time.

Lighting – Since the facility was designed to be windowless, artificial lighting had to be provided in all areas. Standard fluorescent fixtures were required in all areas of the facility, except in the isolation cubicles and in the hot cells. Incandescent lights were provided in the isolation cubicles and special mercury lights in the cells. The illumination levels required in the various areas are as follows:

Area	Foot-candles
Offices	40-50
Work areas and machine shop	50
Laboratories	50-60
Wash and locker rooms	30-35
Storage areas	15-20

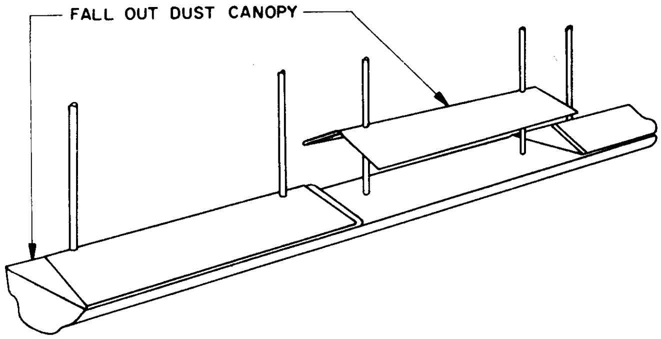


Fig. 10 - Fluorescent fixture canopy design

The fluorescent light fixtures were required to be equipped with a lens made in sections of prismatic clear crystal glass, having low brightness. The light distribution requirement was that not less than 41 percent of the total lamp lumens would be provided in the 0 to 60 percent zone, not more than 11.5 percent in the 60 to 90 percent zone, and an overall efficiency of not less than 56 percent.

In the areas subject to radioactive contamination, the fluorescent fixtures were equipped with dust canopies, as illustrated in Fig. 10. The purpose of the canopies over the top of the fixtures was to keep the tops of the fixtures free from accumulation of dust and to facilitate maintenance and decontamination when necessary. As an additional precaution the canopies were joined together with screw fasteners to make a continuous shield and gasketed at the end covers to seal the fixtures against dust.

The lighting in the "cold" work area (122) was given special consideration in order to provide the necessary intensity of illumination without producing reflections from the shielding windows that would cause difficulties in obtaining a clear view of the cell interior. The light fixtures were required to be mounted at the ceiling, and dimmers were provided to reduce light intensity as may be needed to achieve optimum viewing in the cells. The dimmers were required to provide a smooth flickerless dimming by a continuous change in voltage from full line voltage to zero.

The arrangement of the fluorescent lighting fixtures in the "cold" work area (122) and in the "warm" work area (121) and of the incandescent light fixtures in the isolation cubicles is shown in Dwg. 11.

Utilities – The electrical power service for the facility was designed to operate from 13,200-v primary feeders, with feeder power stepped down through primary transformers rated at 1,000 kva, 3 phase, 60 cycle, 80°C temperature rise, with the 13,200-v primary of the transformer delta-connected and the 480-v secondary also delta-connected. The output of the primary transformers was further stepped down from 480 v to 208/120 v through low-voltage transformers for lighting and general power service in the facility. Primary transformers and switch gear located on the second floor of the facility are illustrated in Fig. 11.

Power requirements for receptacle circuits in laboratories, hot cells, and "warm" work areas were designed to be supplied from distribution panels conveniently located and protected by automatic circuit breakers and independent from lighting and general receptacle circuits. Lighting and general receptacle circuits were also supplied from panels protected by automatic circuit breakers.

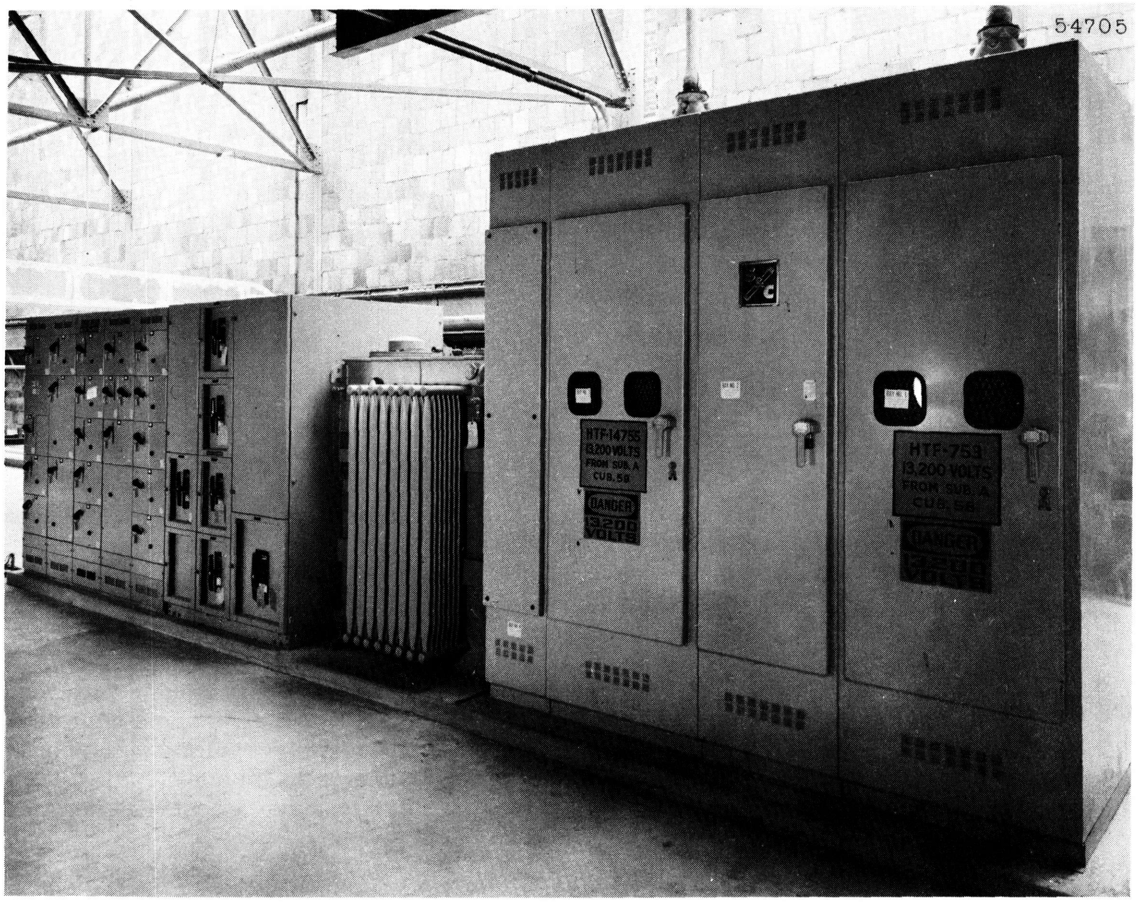


Fig. 11 - Primary power transformers and switch gear

Motor starters and motor control centers for operating permanent in-cell, and other, equipment were located on the second floor of the facility.

A hermetic centrifugal refrigerating machine (item K-50), provided for supplying chilled water to the air-supply cooling coils, is illustrated in Fig. 12. The machine characteristics include the following: cooler – capacity 160 tons, flow 385 gpm, entering water temperature 55°F, leaving water 45°F; two-pass condenser – flow 456 gpm, entering water 85°F, leaving water 95°F; 128-kw input (150 bhp). Compressor design is such that capacity regulating vanes are closed upon start-up, thus assuring start-up without load. Capacity regulating vanes are designed to be hydraulically powered. A sensing element in the leaving chilled water stream initiates operation of the vanes. Operation of the machine is automatic as required by demand of various air supply units and as reflected by return water temperature. Protective features include: protection against starting compressor, unless cooling tower pump, chilled water pumps, and oil pump are first started; chilled water low-temperature cut-out to prevent freezing; low oil pressure cut-out; and high condenser pressure cut-out. In addition to the above controls, the control panel contains a modulating temperature controller, sensitive to the chilled water return temperature, suction discharge, and oil pressure gauges, and an on-off manual switch.

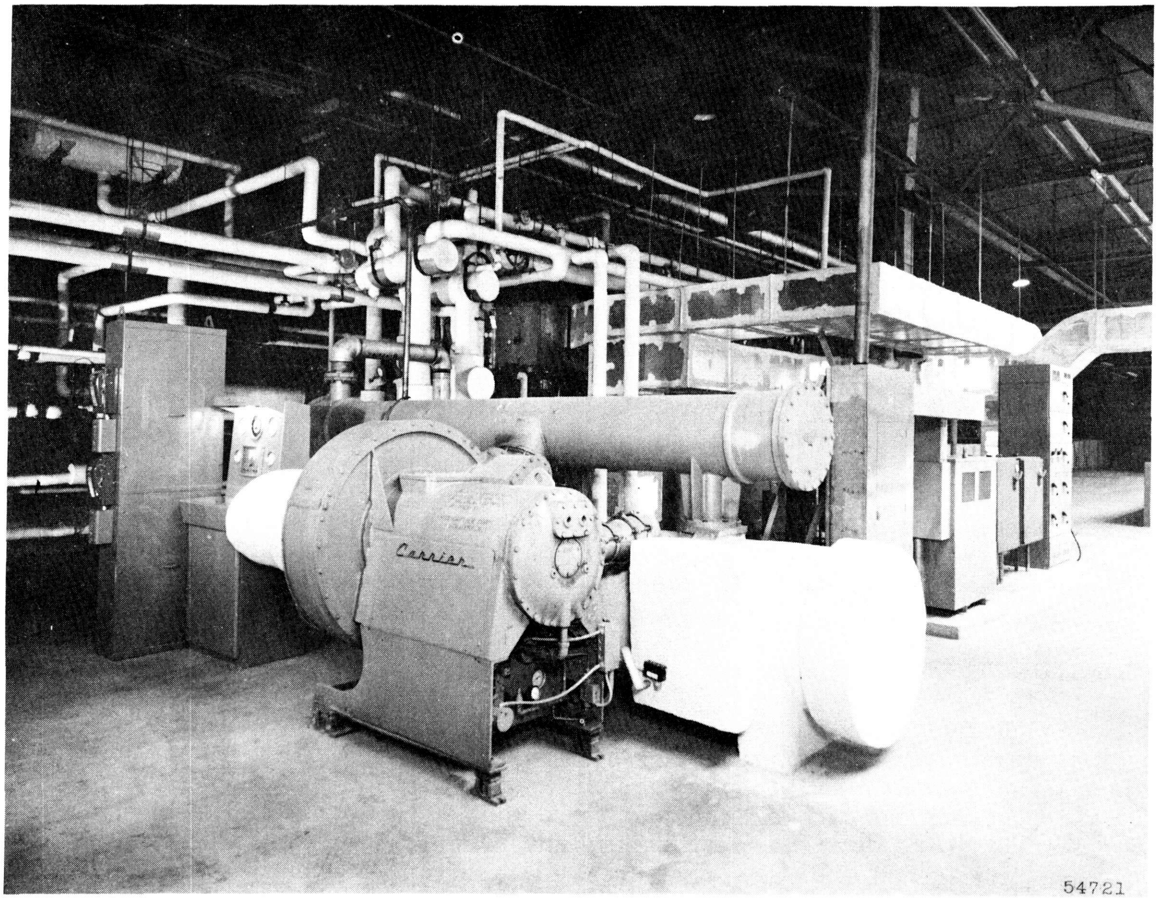


Fig. 12 - Refrigerating machine for supplying chilled water to cooling coils

Heating system design was based on use of steam and included steam supply and return connections and a system of pressure reducing valves, safety relief valves, traps for all steam-heated air heating coils, steam jacketed water heaters, and evaporators.

Process steam was provided in isolation cubicles and in the decontamination room (136), supplied to 1/4-in. diam steam jet nozzles for decontamination and cleaning purposes. Process steam was also provided to steam jet syphons for the transfer of contaminated liquid waste.

Fire Protection - Although the High Level Radiation Laboratory was designed to be structurally fireproof, government regulations required that the entire first floor area of the facility be equipped with an automatic, wet-type, extra hazard sprinkler system, except in the interior of the hot cells. The system was designed to conform to the requirements of the National Board of Fire Underwriters Pamphlet No. 13. Sprinkler heads were of the regular automatic closed spray type, having ordinary degree temperature ratings with nominal 1/2-in. discharge orifices. Where required, sprinkler heads were provided with higher temperature ratings.

For fire protection in the cells it was originally planned to provide a manual, electric, remote control, fixed pipe, double shot, dry powder extinguishing system to protect each cell. The system was to include dry powder extinguishing material using carbon dioxide (CO_2) or nitrogen propellant. This system was abandoned because of uncertainties as to its effectiveness and because the dispersion of dry powder particulate matter into the cells would be detrimental. Another system considered consisted of introducing carbon dioxide or nitrogen into individual cells through nozzles at a sufficiently rapid rate to displace the air in the cell and thus cutoff the supply of oxygen. This system, however, required the release of a large volume of gas in a short time to be effective. To prevent spread of airborne radioactive contamination from the cells to the surroundings requires that a negative pressure is maintained in the cells at all times. To extinguish a fire in a cell by flooding it with enough gas to displace the air would require reducing the negative pressure to almost zero in the cell with the cell exhaust system operating. Since it would be extremely difficult to control the pressure in a cell under such conditions, any reversal of pressure from negative to positive could quickly cause the spread of airborne radioactive contamination to the surroundings. Such a system could not be considered completely reliable.

The problem of fire protection at the site of an experiment in the cells was resolved through the use of dry fire extinguishing agents packaged in cans and conveniently located for quick remote application with master slave manipulators.

CONSTRUCTION FEATURES

In planning the foundation requirements for the hot cells, it was assumed that the soil conditions would be comparable to those existing under the NRL reactor adjacent to the new facility. As a result, no preliminary test borings were made to determine the actual soil conditions underlying the cell block site. Excavation work disclosed, however, that soil conditions were considerably different from that anticipated and were inadequate to support the weight of the cell structure. It was therefore necessary to sink 42 piles about 24 ft deep to provide the necessary foundation for supporting the cell structure.

After the floor slab of the hot-cell block was poured, the cell floor steel liner plates were set and seam welded to 3/8-in.-thick steel wall liners. The steel wall liners were tied together by an intricate welded network of reinforcing bars. The permanent steel wall liners provided the forms for pouring high-density concrete.

The heavy density concrete requirement was that it have a minimum density of 220 lb per cu ft and a minimum compressive strength of 3,000 psi. Aggregate was magnetite having a specific gravity range of from 4.4 to 4.7.

Special precautions had to be exercised in mixing the concrete so as to provide a slump of 3 in. or less to minimize bleeding and segregation. To insure that no cleavage planes or construction joints occurred in the concrete, it was necessary to pour the concrete walls of the cell block without interruption. The mixing, handling, and pouring of the high-density concrete had to be carefully planned and controlled to insure that the radiation shielding requirement of 220 lb per cu ft was obtained at every point and that a uniform distribution of the required density was maintained for each foot of wall height erected. It was mandatory that the shielding walls did not contain voids, pockets, or segregations which would decrease the shielding capability. Since no postcorrection of improperly mixed or placed concrete was possible, it was necessary to control the rate of build-up in height and to carefully vibrate the concrete so as to prevent voids and pockets. Particular attention had to be given to the careful placing of concrete around reinforcing steel, piping, wall sleeves, shielding window frames, access ports, and other embedded items to insure that the embedded items were not displaced during pouring.

In view of the cell structure foundation problem that developed during excavation, it was necessary to make a design change concerning the floor under the swing of the steel shielding doors. Originally the concrete floor slab outside the cell structure was to be laid up to the outside cell wall as a separate construction. Since the floor slab was in no way to be connected to the cell structure, any vertical settling of the cell structure on its foundation would have easily jammed the heavy steel doors against the floor slab, since only a 1/8-in. clearance was available. To prevent this event from occurring, the concrete floor under the swing of the doors was made an integral part of the cell structure. Since the doors are supported on the cell structure and since the floor under the doors was made an integral part of the cell structure, all parts involved would move together and not affect the clearance under the doors, should settling occur.

The cell roof plugs were constructed of heavy density concrete (220 lb/cu ft) cast into 3/8-in.-thick steel forms reinforced with steel bars. The steel forms were permanently retained as outer shells of the roof plugs with the tops of the cast plugs as the only surfaces with exposed concrete. Precautions were necessary regarding the mixing and pouring of the concrete in the roof plug forms; however, the problem in this case was not as critical as in pouring the cell walls.

Where normal density concrete (180 lb/cu ft) was to be protective coated, certain precautions were necessary during concrete pouring work to leave surfaces to be protective coated in a condition and quality that would readily accept the coating system. This required the poured concrete to be vibrated to remove air so as to give a dense concrete with a minimum of holes, porosities, and irregularities on the surfaces in contact with forms. After removal of forms and while the concrete was still green, the concrete surfaces to be coated were required to be inspected for voids. Such areas were required to be opened and filled with portland-cement sand grout, smoothed flush with the wall surface.

The hot-cell shielding doors and frames were constructed of laminated steel with the requirement that there would be no accumulation of voids through any line perpendicular to their faces. The design of the doors involved close-fitting surfaces and bearing points and required accurate fitting and operation. Fabrication required careful assembly and machining to the required dimensions. The hinge axes were required to be truly vertical since the doors were required to remain stationary at any point in their working arc. Installation required very accurate positioning and anchoring of the massive steel frames in the cell structure. The frames were anchored in the concrete structure by embedding reinforcing bars attached to frame angle clips. The juncture between frames and cell steel wall linings were seam welded. The manner in which the doors are hinged makes them remarkably easy to move manually despite their weight, which in the case of the single door in cell No. 1 is nearly 8 tons.

Air exhaust from the hot cells is conveyed under the facility through a horizontal 30-in. diam duct buried 6-1/2 ft below the facility floor line. The end of this duct terminates in a concrete pit located in the waste disposal area (146). The pit serves as a transition for a rectangular 40 in.$\times$20 in. duct which conveys the exhaust air to the filters and exhaust fans located on the second floor. After the 30-in. duct system had been completed, subsurface water began to collect in the duct and rose to a depth of about 15 in. in one instance. The duct in contact with earth had been spirally wrapped with 50-lb felt and given a coat of hot tar. This had not prevented infiltration of the subsurface water and it became necessary to seam weld all duct joints to make them water tight. To keep subsurface water below the 30-in. duct, a well was bored in the machine shop (135) in close proximity to the buried duct and equipped with an automatic pump.

The following series of photographs illustrates graphically typical features of the facility after completion of construction.

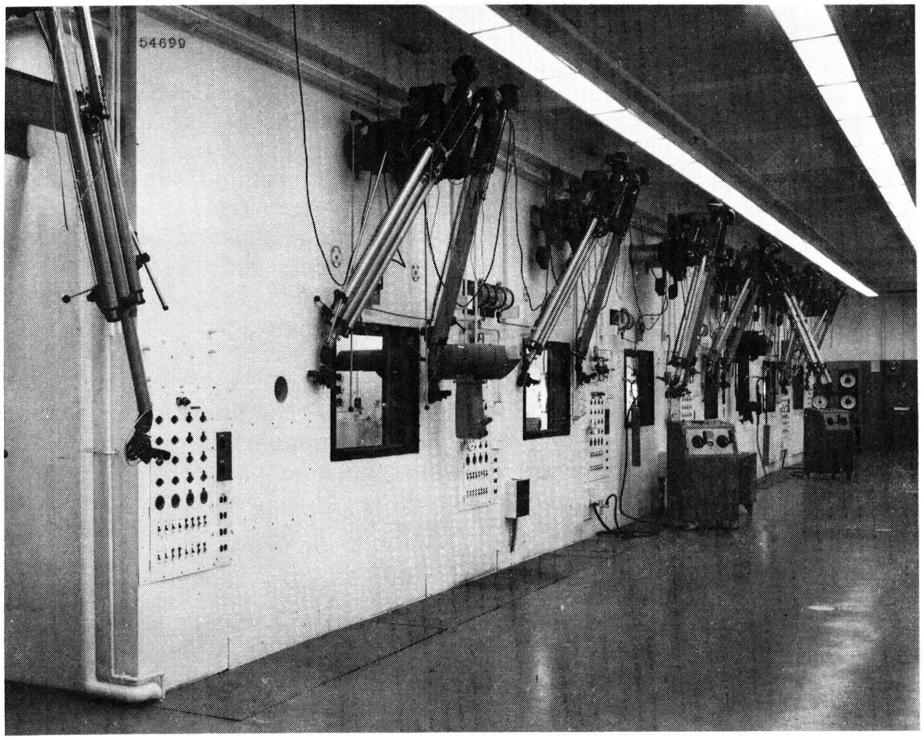


Fig. 13 - Front or observer's side of cell block

The front or observer's side of the cell block is shown in Fig. 13. This view shows the arrangement of shielding windows and the location of window expansion tanks, the outside electrical receptable panels (connected to duplicate panels in the cells), General Mills manipulator control consoles and control pendants for in-cell cranes and their plug-in receptacle connections in the cell wall, hand crank wheels (on edge of electrical receptacle panels) for manually operating transfer drawers between cells, hydraulic controls above electrical receptacle panels for controlling doors shielding transfer drawers, master ends of AMF heavy duty Model 8 master-slave manipulators, arrangement of fluorescent lighting, one run of sprinkler fire protection system above left row of lights, electrical instrumentation wiring trough on cell wall above the manipulators, plugged cell wall convenience ports above cell windows, through-the-wall port to the left of first window on left for locating specimen transporter for remote controlled metallograph (not shown), remote viewing stereographic microscope located on the right of first window, covered utility trough at the base of cell wall, and covered floor drains in middle of floor. Attention is called to the unobstructed headroom in this area. This was planned in this manner to permit the installation and/or removal of through-the-wall master-slave manipulators without difficulty.

A closeup view of the front wall of the cells in front of a shielding window is shown in Fig. 14. This view shows the exceptional quality and viewing characteristics of the shielding windows. Shown in greater detail are the electrical receptacle panels, the hand cranks for operating transfer drawers, the hydraulic controls for operating the doors shielding the transfer drawers, the plugged access holes to left and right and above the window, the instrumentation wiring trough above the manipulators, and window expansion tanks.

A view inside cell 4 looking toward the intercell wall between cells 4 and 3, shown in Fig. 15, is typical of the cell interiors. This shows the unbooted slave ends of the

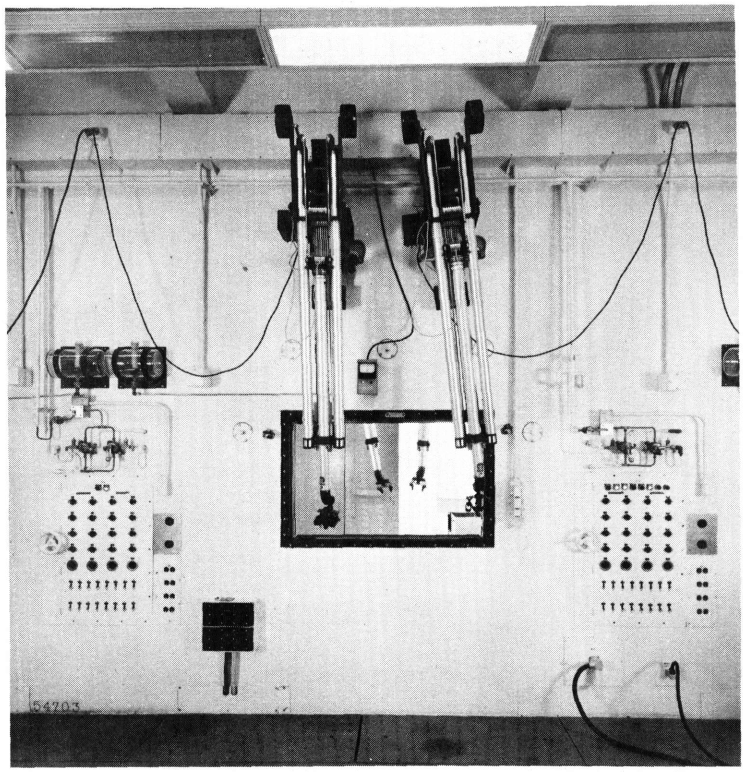


Fig. 14 - Close-up of front of the cells in front of a shielding window

master-slave manipulators, the arrangement of mercury lighting around the 30 in. by 40 in. shielding windows, the location of the cable take-up reels at the top of the intercell walls, the bottoms of the removable roof plugs, the air supply inlet into the cell located in the upper right of the intercell wall and the exhaust outlet located at lower left side of the cell, the capped ends of underwall U-tubes at base of front and back walls, the transfer drawer retracted into cell 4 with its shielding door in open position to the right of the drawer, 3-ton capacity bridge-type crane mounted on rails located on ledges in both walls of the cell, in-cell side of plugged access ports, in-cell end of through-the-wall periscope located in front wall between the windows, the in-cell electrical receptacle panels (connected to duplicate panels outside front cell wall), in-cell ends of covered steel-shot-filled underwindow access ports, floor drain, power receptacles on back cell wall, utility cocks located to right of receptacle panel for introduction of gases as needed, and the entrance doorway.

The view inside cell 4 looking toward the intercell wall between cells 4 and 5 is shown in Fig. 16. This view shows the height of the fixed intercell wall. The space between the top of this wall and the ceiling of the cell is shielded with a movable intercell steel gate, a portion of which is shown resting on top of the fixed intercell wall. An air inlet is located at upper left of the intercell wall and utility cocks for gases below it. Part of the General Mills manipulator equipment appears at the top center. A good view of the shielding door for transfer drawer equipment is shown in the closed position with a limit switch and interlock trip. Also shown, both to the left and above the receptacles, is the arrangement of 1/2-in diam threaded wall studs placed on each end wall of the cells for mounting experimental gear or instrumentation as may be needed. At floor level is shown the location of the in-cell isotope storage pit uncovered, while the ends of underwall U-tubes are at the right.

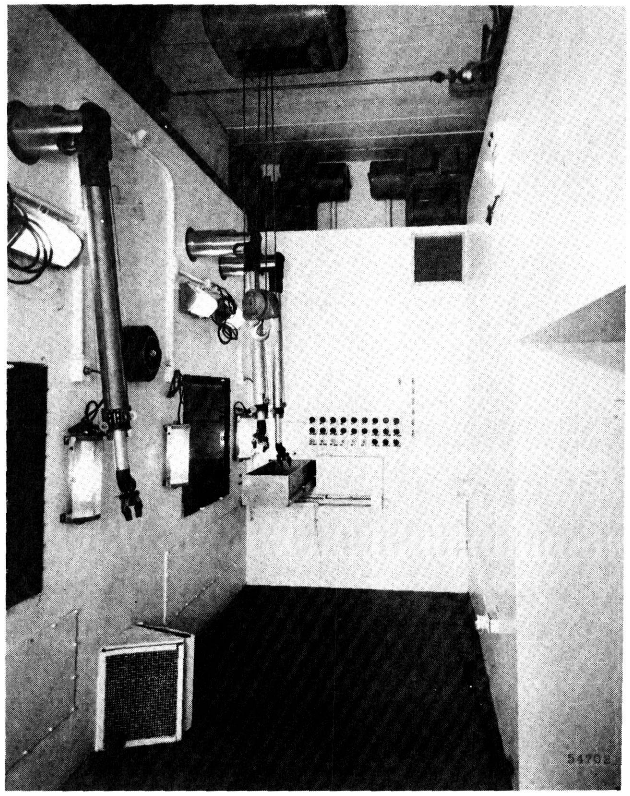


Fig. 15 - View inside of cell 4 looking toward intercell wall between cells 4 and 3

A partially retracted intercell gate is shown in Fig. 17. This view was taken through an opening in the cell roof made by removing three roof plugs. The top of the intercell wall is shown with a recess in the center in which the 10-in.-thick steel gate rests when closed. Slots in the cell walls serve as guides for the gate. On top of the cell roof is shown the steel housing which supports the gate and the driving mechanism. The drive motor is shown in the center of the housing connected to gear reducers at each side of the housing through shafting. The holes in the housing near the cell roof top and the pins located in clips in close proximity are for supporting the gate mechanically when maintenance requires disconnecting the drive mechanism. The triangular keys mounted on the edges of the cell walls fit into mating recesses in the roof plugs. Thus, the roof plugs can be replaced in exactly the same spot each time they are moved. This feature facilitates the handling of the massive roof plugs and prevents jamming and scarring of the protective coated surfaces of the plugs.

The construction features of the cell shielding doors are illustrated by the double door to cell 3 shown in open position in Fig. 18. The salient features include the door hinging and the curved configuration of the steps in the closure joint between the two halves of the door. Also shown is the cremone bolt latch system on the right half of the door for securing it in closed position and the latch on the left half for securing it against the right half in a closed position. The latch on the left half of the door is connected to a trip handle on the cell side of the door by means of a shaft through the door. The shaft is threaded full length, while the door is tapped to receive the threaded shaft. This arrangement provides the capability for opening the cell door from within the cell and also provides

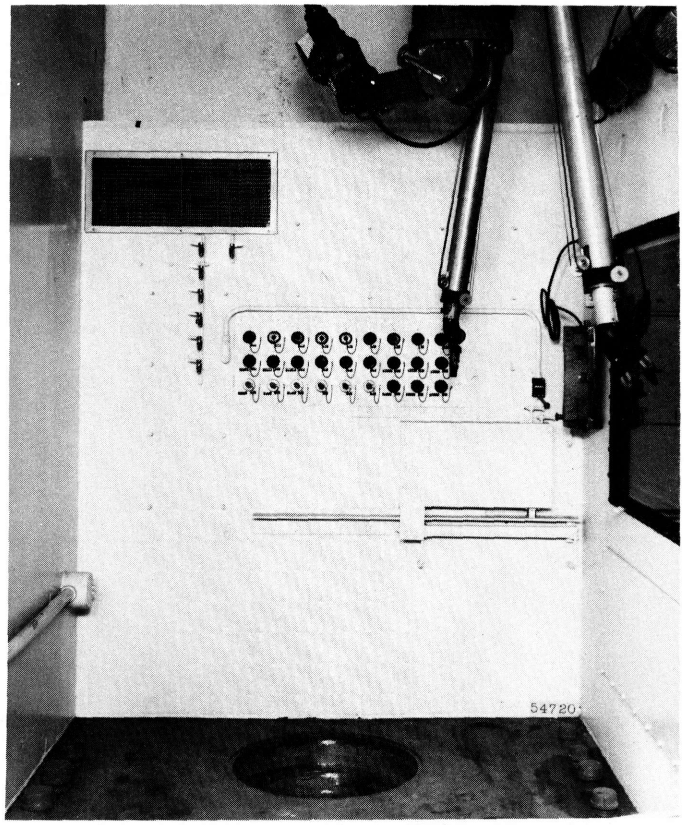


Fig. 16 - View inside cell 4 looking toward intercell wall between cells 4 and 5

the necessary shielding for the penetration of the shaft through the door. The trip shown on the wall to the right of the door is a manual release for a solenoid-actuated latch at the top of the doors. The solenoid was intended to be connected to a radiation monitor in the cells and to secure the doors against accidental opening when the radiation level in the cells was above a preset limit. This feature is shown more clearly in the next figure (Fig. 19) with the doors in the closed position.

A view inside the isolation cubicle adjacent to the access doors to cell 3 is shown in Fig. 19. The shielding doors are shown in closed position with the doors secured by both cremone bolt and the main door latch. The solenoid latch system and the manual trip release are clearly shown. Attention is called to the hinging arrangement of the doors with the doors flush with the cell wall. The doors when opened are prevented from swinging too close to the wall by means of rubber bumpers shown mounted on the cell wall slightly above center on the right and near the floor on the left. These bumpers were designed to stop the door short of any equipment that could be damaged by the door. An example of this is seen on the left side where the transfer drawer extends into the isolation cubicle. The door bumper in this case extends a sufficient distance from the wall and stops the door before reaching the extended drawer. The arrangement of the external transfer drawer system is shown on the left of the closed doors. The shielding doors in this case are attached to hydraulic cylinders which raise and lower the door. The hydraulic controls are on the isolation cubicle wall. The duplicate shielding door located in the cell is interlocked with the external door so that one cannot be raised unless the other is in closed position. The drawer is extended into the isolation cubicle and retracted into the

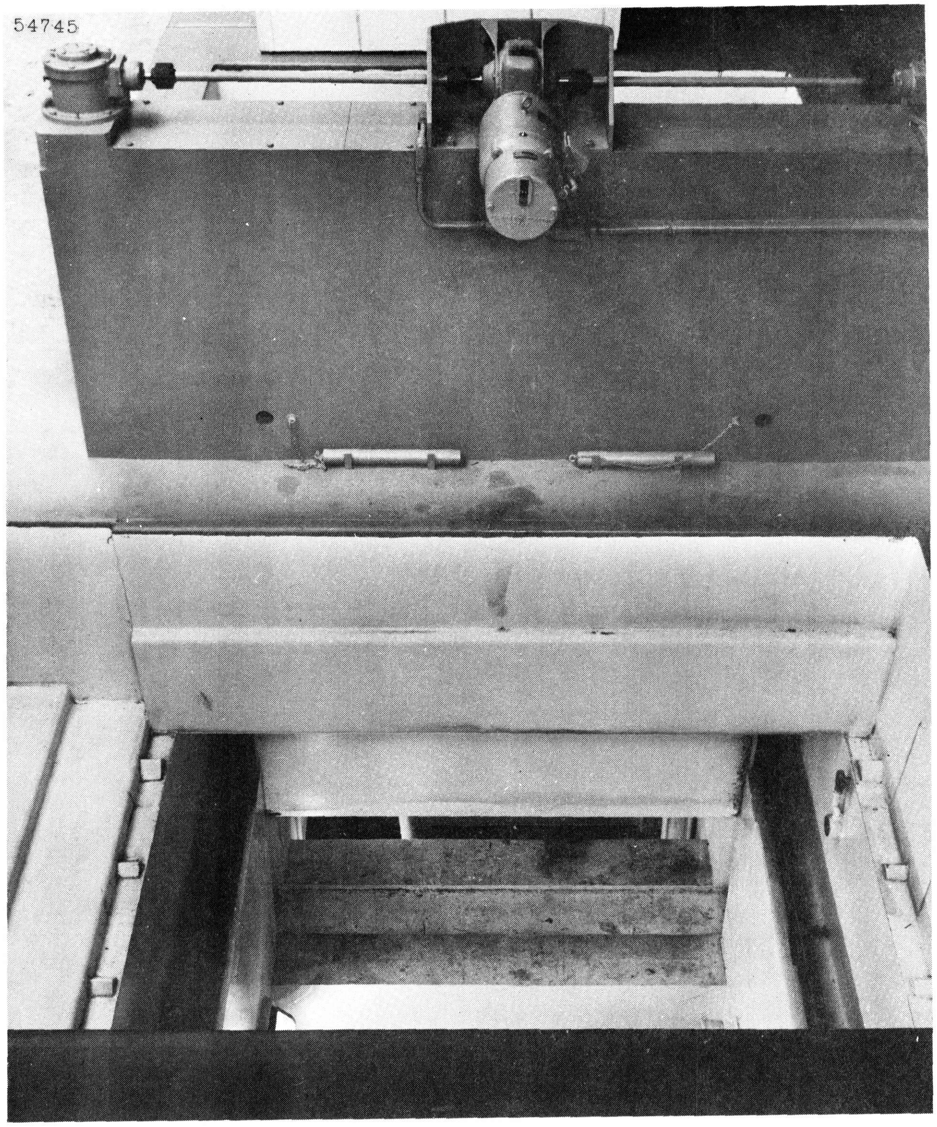


Fig. 17 - View of partially retracted intercell gate taken through cell roof opening

wall opening by means of a push rod. In the cell the drawer is extended and retracted in the same manner but done remotely with the use of master-slave manipulators. The make-up ventilation air inlet to cell 3 from the isolation cubicle is shown near the floor to the right of the closed doors. Plugged through-the-wall access ports are shown above the doors, while the capped ends of under-the-wall U tubes are shown at the base of the cell wall to the left of the doors. A power convenience outlet is shown in the left foreground corner.

Access into the cells from the top side was made possible by a system of removable roof plugs as illustrated in Fig. 20. This view shows cells 2 and 3 completely uncovered, with the roof plugs stacked on top of the uncovered parts of the structure. It will be noted that the access openings include cutaway sections in the front wall as well as those

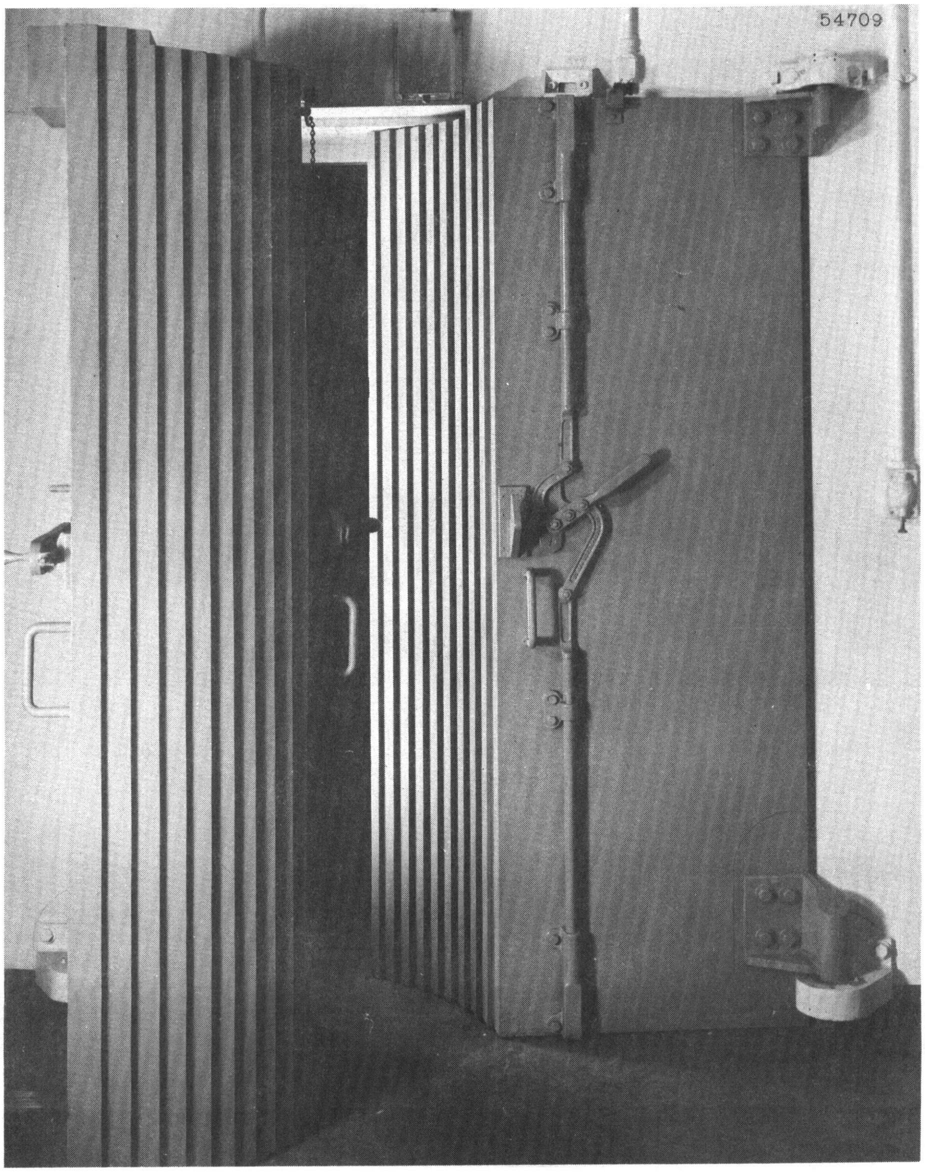


Fig. 18 - Typical construction features of steel cell shielding doors as shown by double door to cell 3

which are shielded by removable side plugs in each case. The side plugs are shown at the right end of the left stack of roof plugs and at the left end of the right stack. The roof and side plugs covering cells 4 and 5 are in place and illustrate the shielding system in the closed position. Lifting rings anchored in the tops of the removable roof plugs provide the means for handling the plugs which weigh about 15 tons each. The lifting rig for handling the plugs is shown in Fig. 21, while Fig. 22 shows the removal and stacking of the plugs in progress. Attention is called to the extremely limited headroom available for crane hook operation. This necessitated holding height dimensions of the cell structure to very close tolerances and made it necessary to provide side openings in the cell structure as well, so as to gain enough headroom to handle and lower such equipment

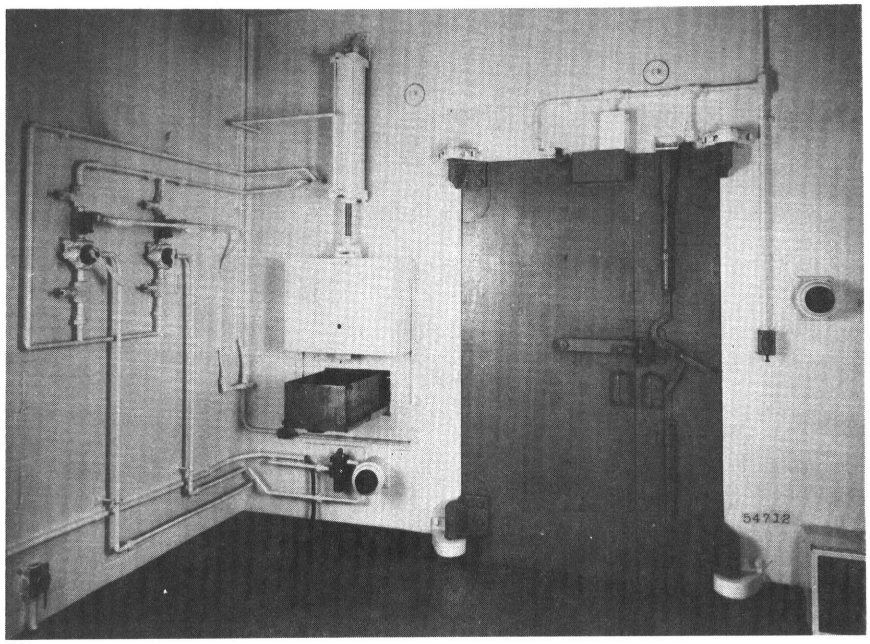


Fig. 19 - View of double shielding doors to cell 3 in closed position and external transfer drawer arrangement in open position

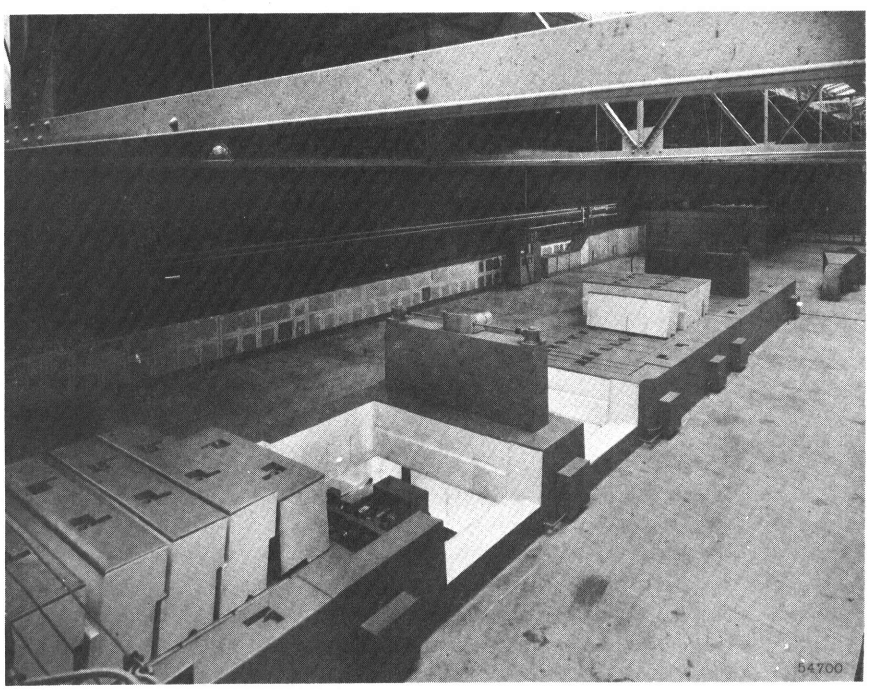


Fig. 20 - View of cell structure roof providing access into cells from top by means of removable shielding roof plug system

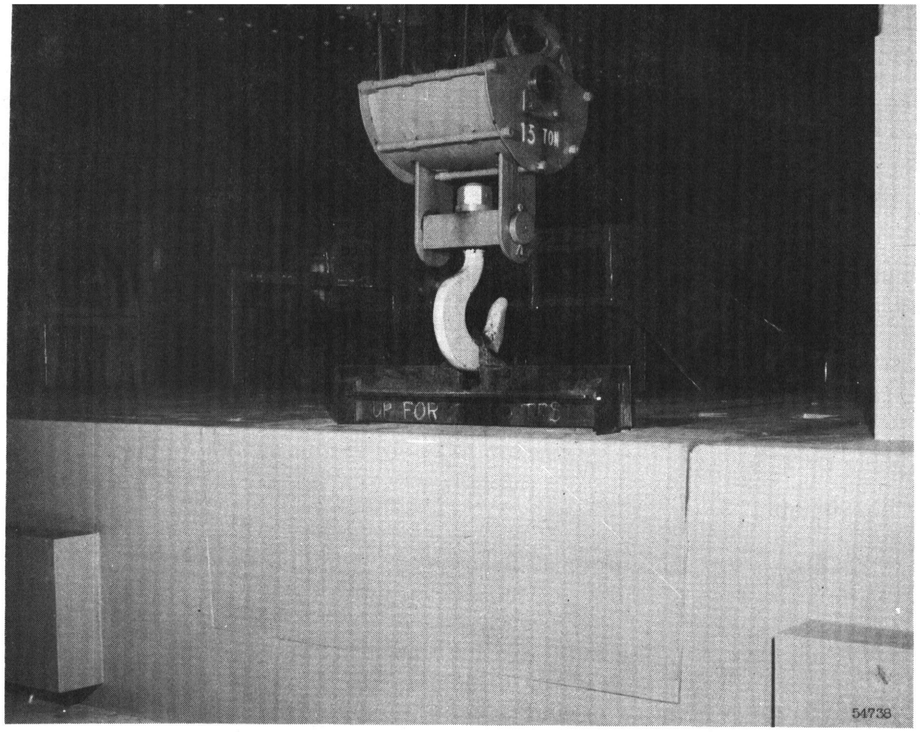


Fig. 21 - Lifting rig for handling removable roof plugs

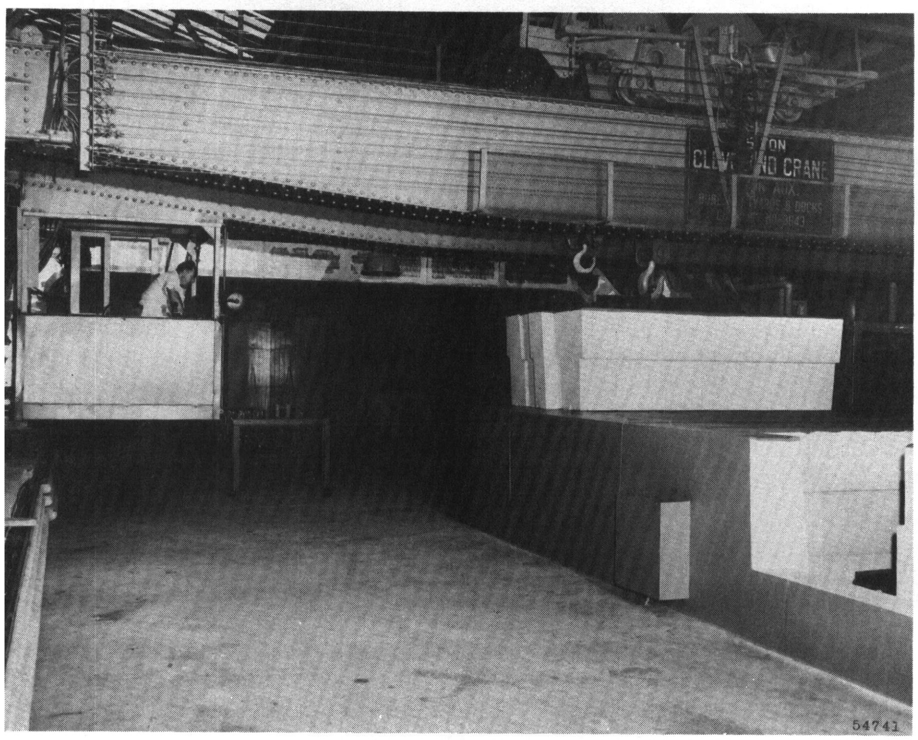


Fig. 22 - View of building crane handling and stacking removable roof plugs

from the top that could not be passed through the cell access doors at floor level. This is illustrated in Fig. 23, which shows the cable take-up reels mounted over the top of the intercell wall and the bridge-type traveling equipment such as the General Mills mechanical arm and the 3-ton in-cell crane. It will be noted that very little room exists between the tops of this equipment and the bottoms of the roof plugs when these are in place, as indicated by the ledge on which the plugs rest. Without access from the top of the cells, it would have been exceedingly difficult to install this equipment and equally difficult to maintain.

The system of removable roof plugs was arranged so that the keystone plug was located advantageously with respect to in-cell equipment and other requirements. A look at Fig. 24 shows that the plugs cannot be removed at random, but must be removed in a certain sequence beginning with the keystone plug. Thus, in cells 2 and 4 the keystone plug was located over the cable take-up reels, as shown in Fig. 24. This arrangement provides access to this equipment by removing the access plug and only as many other plugs as may be necessary without having to uncover the entire cell roof. If, however, this is necessary, Fig. 25 illustrates the convenience afforded by the flexibility of access to in-cell equipment.

The removable roof plugs of cell 2 are shown in place in Fig. 26 with the side plug removed to show the side shielding of the step joints of the roof plugs by the side plug.

The interior of an isolation cubicle illustrated in Fig. 27 shows the entrance to the cell and the entrance to the cubicle from the "warm" work area (121). Salient features are the lighting arrangement of incandescent lights, arrangement of ceiling air supply diffusers for supplying make-up air to cells, air supply inlet to cell at bottom of right corner of room with damper control, capped underwall U-tubes along base of cell wall, power convenience outlets near floor on left and end walls, and process steam outlets on left wall for decontamination when needed.

The arrangement of the "warm" work area is shown in Fig. 28. The five isolation cubicles (areas 123 to 127) adjacent to the cell entrances are shown on the left with individual doorways to each. The x-ray laboratory is on the right in the rear background and the records room on the left. The platform in right center leads to a loading platform outside the facility and is the main entry point for materials. The beginning of the isotope storage area is in the foreground with the water treating equipment (deionizer) shown in the right foreground and the pool containing deionized water in the left foreground (white pit walls surrounded by hand rail). The shielding plug, partly shown in center foreground, covers the sump into which isotope storage tube condensate drains. Other salient features of the area include the lighting, the fire protection sprinkler system, which can be seen running parallel to the light runs, the ceiling air supply diffusers in the center, covered floor drains in the center of the room, and the unobstructed headroom available in the room. The walls of the isolation cubicles and the x-ray laboratory were erected using masonry block, the back wall is of concrete, the right wall between columns is plaster over structural tile, the floors and ceiling are of concrete. The area was protective coated on all sides, including bare and covered piping, and all potential traps for dust are sealed.

A view of the isotope storage area located adjacent to the "warm" work area is shown in Fig. 29. The pool shown in the right foreground was designed to contain a depth of 15 ft of deionized water. The walls and floor of the pool were constructed of concrete and given a heavy protective coating to prevent leakage through the concrete and to preserve the quality of the water. The raised section back of the pool contains 24 stainless steel tubes, each 17 ft long, of 8-in., 6-in., and 4-1/4-in. diam, each capped with a stepped shielding plug 4-1/2 ft long as shown suspended above one hole. The visible opening to the right of the large square shielding plug is a stainless steel lined sump pit 19 ft 8 in. deep. Water, condensing in the storage tubes, is drained from the bottom of the tubes into the sump and

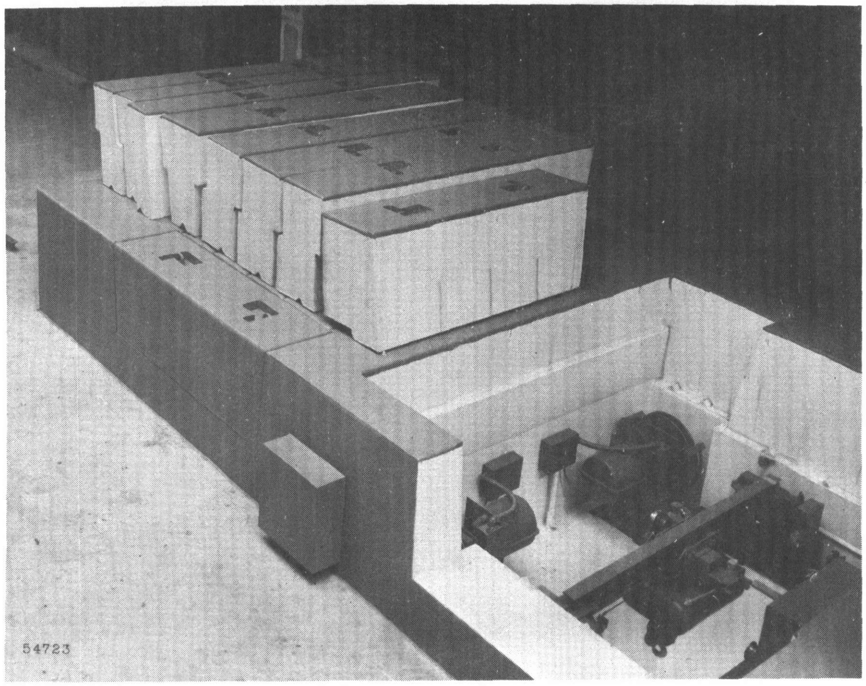


Fig. 23 - View showing accessibility of cells for installation of large items of equipment and for subsequent maintenance

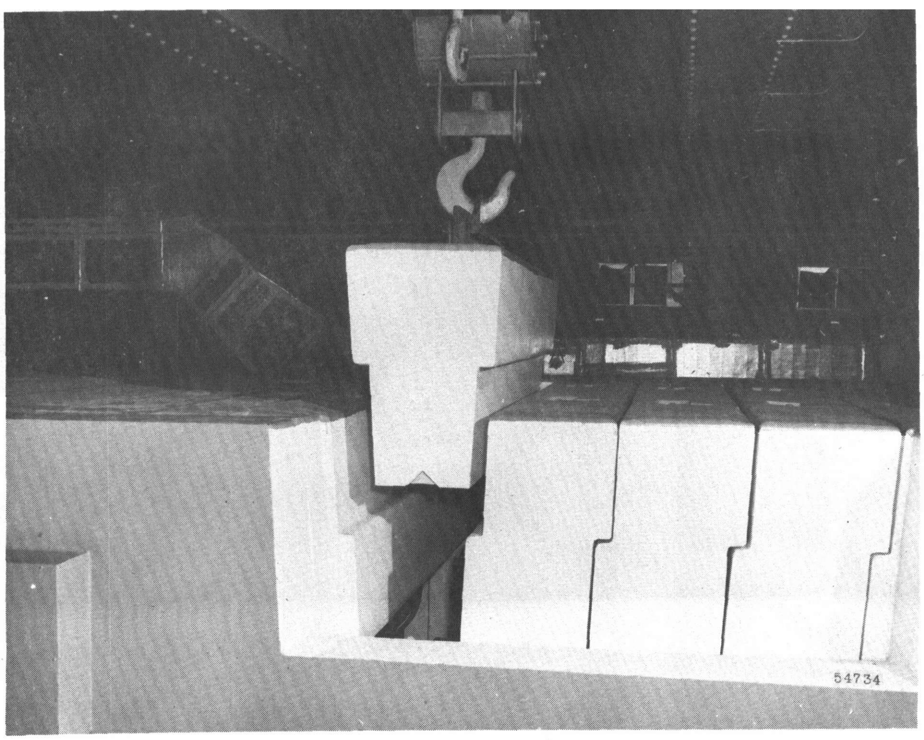


Fig. 24 - View of location of keystone plug over cable take-up reels

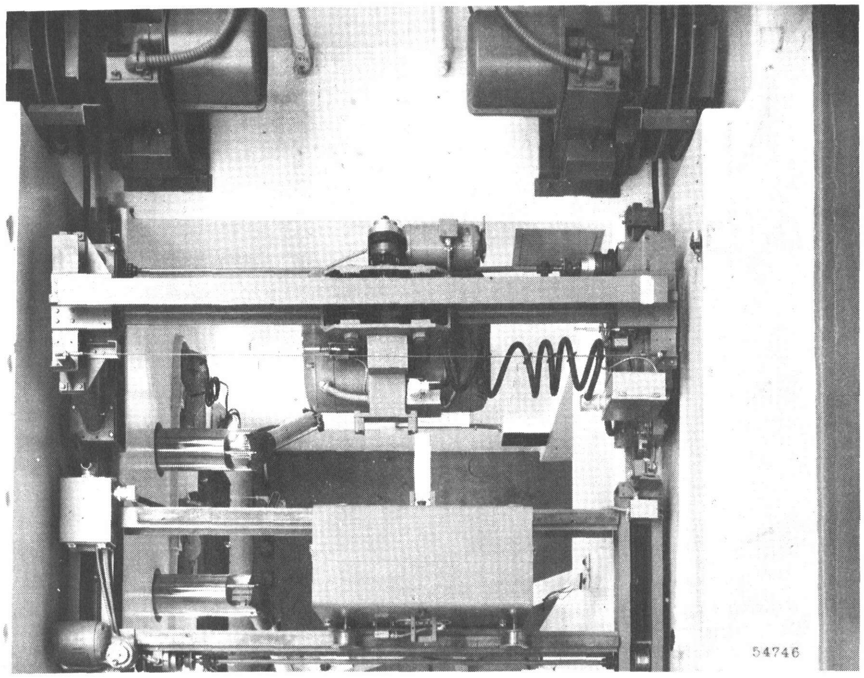


Fig. 25 - View showing accessibility to in-cell equipment from top of cell with roof plugs removed

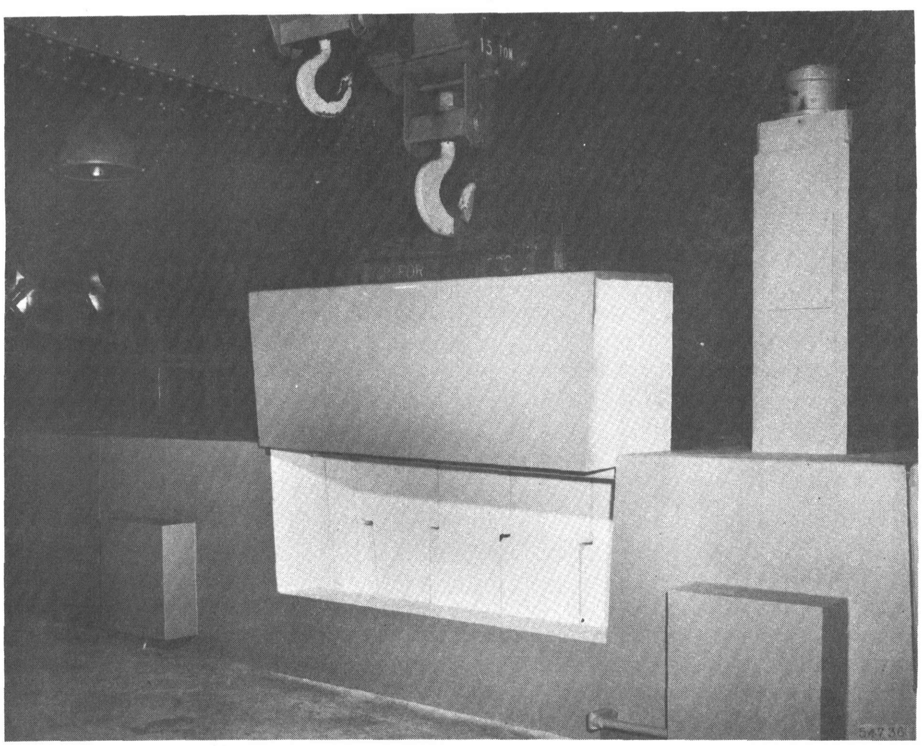


Fig. 26 - Side shielding of step joints of roof plugs

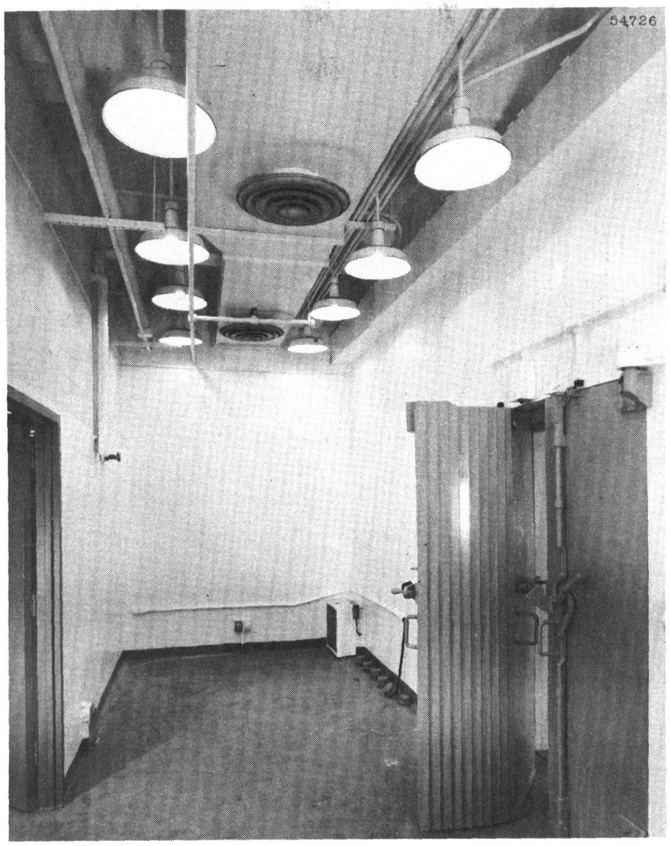


Fig. 27 - Interior view of isolation cubicles showing lighting arrangement and air supply

removed to the contaminated waste disposal system by means of a steam jet syphon located in the pit. The stepped shielding plug, 3 ft high for covering the pit, is shown to the left of the open sump pit. Four stainless steel lined storage pits with shielding covers in place and each surrounded by guard rails are located in the rear of the isotope storage bank. These pits are 2 ft square by 10 ft deep, shielded with stepped plugs similar to that shown for the sump pit. Loads are handled over the isotope storage area by means of a 1-ton hoist mounted on a traveling bridge. A radiation monitor with alarm is shown mounted on the wall to the right of the hoist hook. No overhead lighting was placed above the storage pits but located on the back wall as shown. The fixture was totally enclosed to prevent possible contamination from entering the fixture.

The salient feature of the decontamination room (136) consists of two stainless steel lined pits shown covered with grating in Fig. 30. The pits are 7 ft by 8 ft by 12 in. deep with the bottom sloping from four sides to a drain at the center. The pit in the foreground is for decontamination purposes and the adjoining pit for rinsing and drying. Process steam and cold water lines are mounted on the left wall. A stainless steel sink with valves set at knee level is shown in the background. All piping that did not have at least 1-1/2 in. standoff from the walls was caulked to eliminate trapping of possible contamination. All gaps between ductwork and ceiling were likewise sealed against possible entrapment of contamination. The design of the light fixture canopy is also shown.

The arrangement of the "warm" chemistry laboratory is shown in Fig. 31. A radioactive fume hood is located in the right foreground and a perchloric acid hood in the right

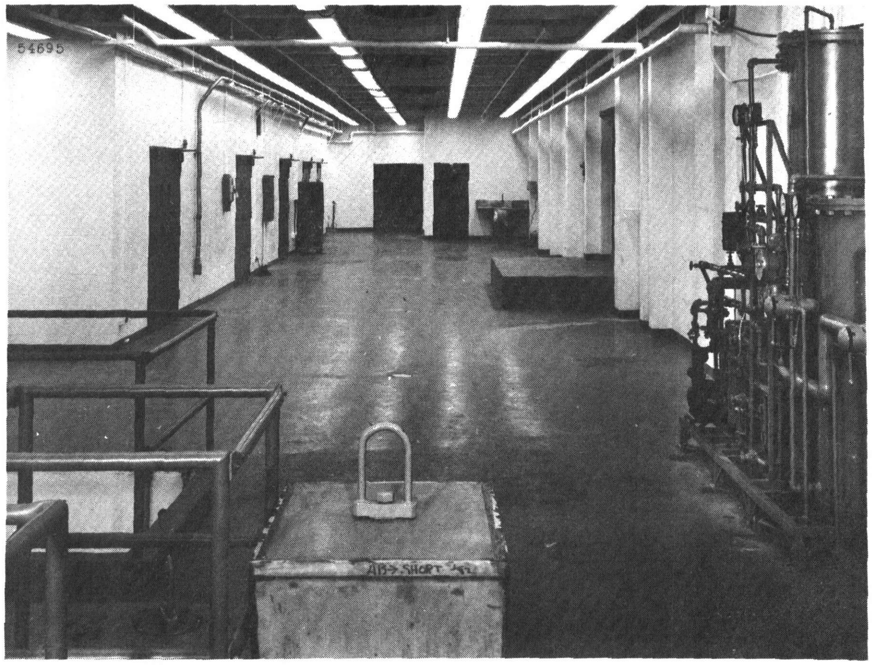


Fig. 28 - Arrangement of "warm" work area (121)

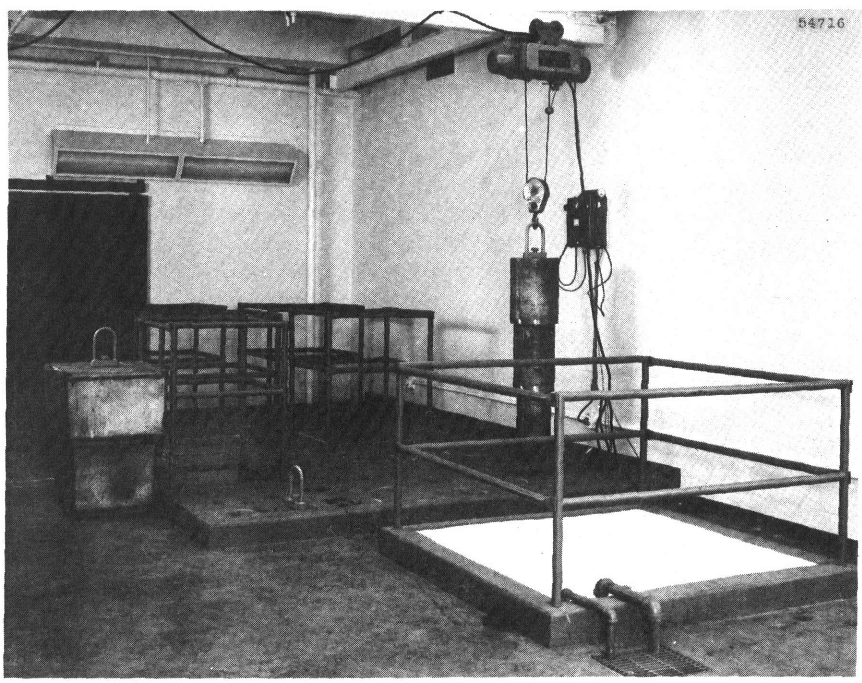


Fig. 29 - Arrangement of isotope storage area

Fig. 30 - Decontamination room showing grating-covered shallow pits

background. On the left side a refrigerator (shown with white door) is located under the counter. The frame at the end of the base cabinets is an emergency shower stall with an eye wash mounted on the right side of the frame. The cylindrical vessel beyond the shower frame is a ceramic crock for neutralizing acid waste. Piping mounted on the walls above base cabinet counters supply hot and cold running water to sinks and drain cups and air and gas to counter top locations. The space between piping and walls is completely filled with caulking to eliminate entrapment of contamination. The arrangement of canopied light fixtures provides virtual shadowless illumination. The air supply diffuser is shown between the center light fixtures. A radiation monitor is shown on the left wall mounted on a shelf.

The layout of the waste disposal system is shown in Fig. 32, as seen from above the pit area. The sequence of individual units of the system are located as follows: the uncovered pit at top of the photograph and the covered pit adjacent to it on the right contain 100-mesh coarse strainers; the pit below the uncovered coarse strainer pit contains a pump which transfers waste from the coarse strainers to the fine filters; the small pit to the right of the pump pit and the covered pit adjacent to it contain fine filters; filtered waste is transferred by gravity to the holding tank shown in the pit at right center; the evaporators, demisters, and condenser are located in the pit to the left of the holding tank pit; and the distilled water tanks are located in the pit below the evaporator pit. Each pit is covered with a stepped shielding cover that meshes with the stepped configuration of the pit openings. The dark outline shown around the stepped opening is a gasket for sealing the pit against ingress of water.

Closeup views of the various individual components of the waste disposal system are shown in the following photographs.

The arrangement of the coarse strainer system is shown in Fig. 33. The raw waste is delivered to the filter through a 3-in. stainless steel drain line shown at the top of the

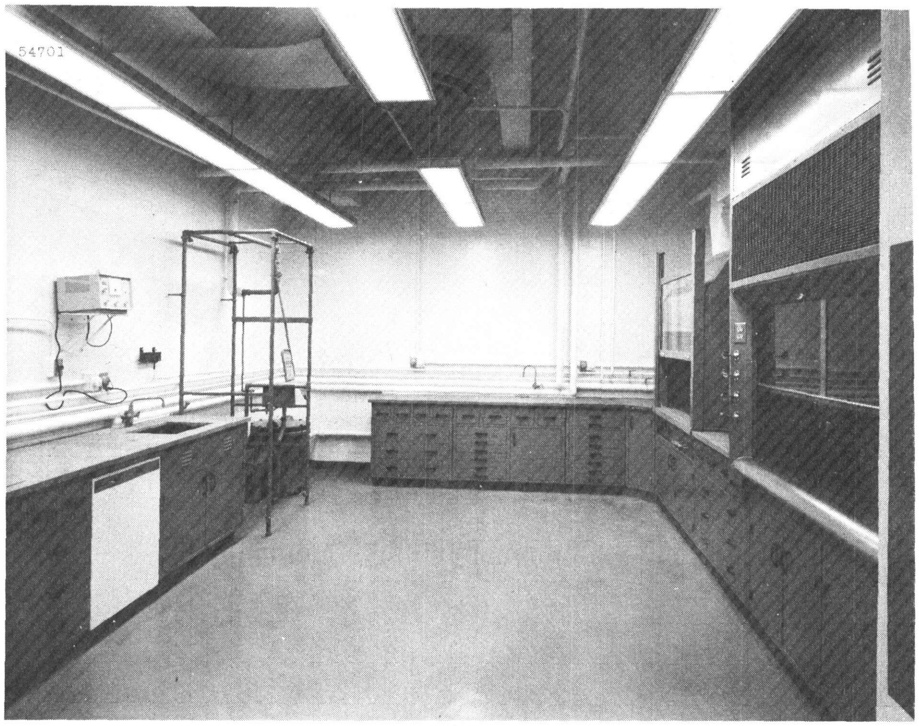


Fig. 31 - Arrangement of "warm" chemistry laboratory

photograph. The filters can be isolated by a pinch valve as shown attached to the drain line. The cover is fastened to the filter case with screws. The discharge line is shown below the inlet to the filter. The filters are vented by vent lines as shown on left side of the filter case. A level indicator connected to an alarm on a remote panel is shown near the top of the case on the right side. The pit drain is connected to a sump in the evaporator pit.

The discharge from the coarse filters is forced through the fine filters by the raw waste pump shown in the right foreground of Fig. 34. The pump features a magnetic drive, hermetically sealed centrifugal type, capable of pumping 10 gpm of waste water against a head of 75 ft containing suspended solids which have passed through the 100-mesh screen of the coarse strainer. The second pump, shown lower down in the pit, transfers filtered waste from the holding tank to the evaporator system. This also features a magnetic drive, hermetically sealed centrifugal type, capable of pumping 5 gpm of filtered waste water against a head of 75 ft. Wetted parts of both pumps are constructed of type 316 stainless steel. The pump pit is equipped with a floor drain connected to a sump in the evaporator pit.

The fine filter system, designed to remove particulate matter from liquid waste down to 5 micron size, is shown in Fig. 35. The filtering elements are disposable cartridge-type units having a flow rate range of from 0 to 18 gpm and a differential pressure range of 3 psig when clean. The filter elements are arranged in a basket with a fixed upright bail for easy removal. The top cover of the filter body is held in place with toggle clamps and has an upright bail for removal using a crane hook. The pit drain is connected to a sump in the evaporator pit.

The discharge from the fine filters flows by gravity to the holding tank shown in Fig. 36. The tank has a capacity of 1000 gal and is 5 ft diam and 7 ft long, constructed

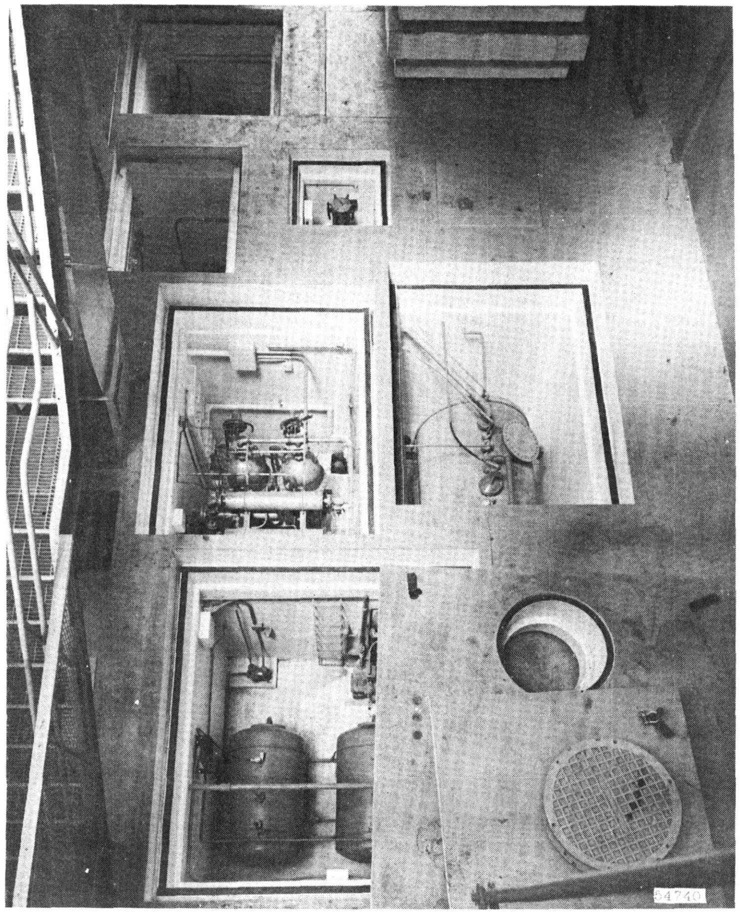


Fig. 32 - Layout of waste disposal system

of type 304 stainless steel. The large covered port on the left side is a manhole. The various pipe inlets into the tank beginning with the lowest in the photograph and proceeding upwards are as follows: waste from fine filters; bypass from pump, transferring waste from holding tank to evaporator system; waste water from deionizer system; a spare port; line to introduce neutralizing acid or alkali for maintaining liquid neutral in tank; vent pipe to cell exhaust system; and a level indicator and pH indicator connected to remote recording system on control panel. An air line connection (not visible) to a sparger pipe in the tank is located near the bottom on one end. Liquid waste is withdrawn from a connection on the underside of the tank (not visible) and transferred to the evaporators by a raw waste pump, previously mentioned.

The evaporative system is illustrated in Fig. 37. The evaporators are shown mounted on a frame base, the body height of each vessel is about 3-1/2 ft and the body diameter about 20 in. Each vessel is constructed of type 316 stainless steel and has a capacity of 20 gph. The bottom of each vessel is hemispherical and rests in a close-fitted steam jacket for heating and evaporating liquid waste fed to the evaporator from the holding tank. Liquid feed enters at the side of the evaporator and the vapor discharges at the top through a diaphragm valve to demisters, which are the two large cylindrical vessels appearing at the top of the photograph. The demisters are constructed of 8-in. diam schedule 40 pipe of type 304 stainless steel. Each demister contains three one-piece demister elements, 7.9-in. o.d. by 12 in. long, centered in the vessel and constructed of

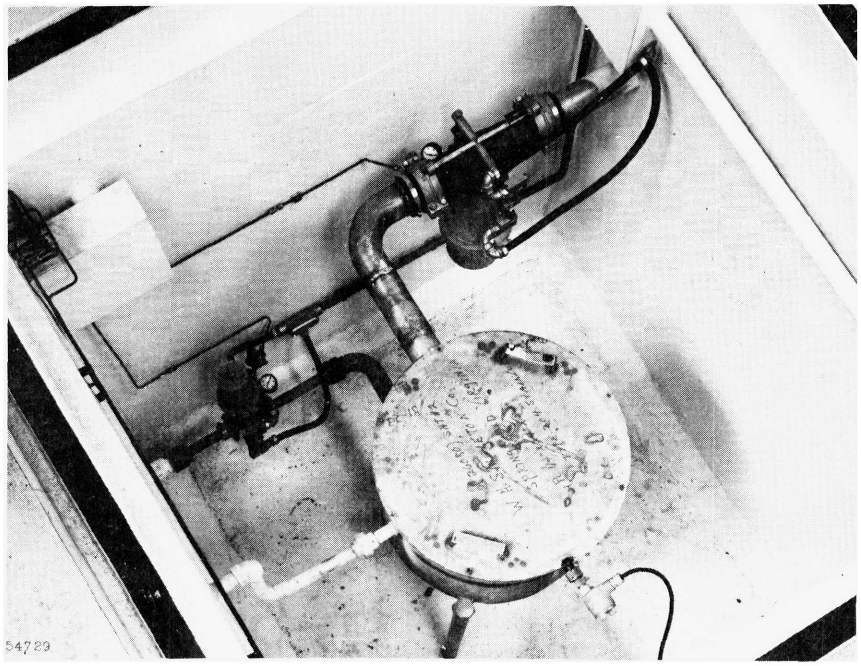
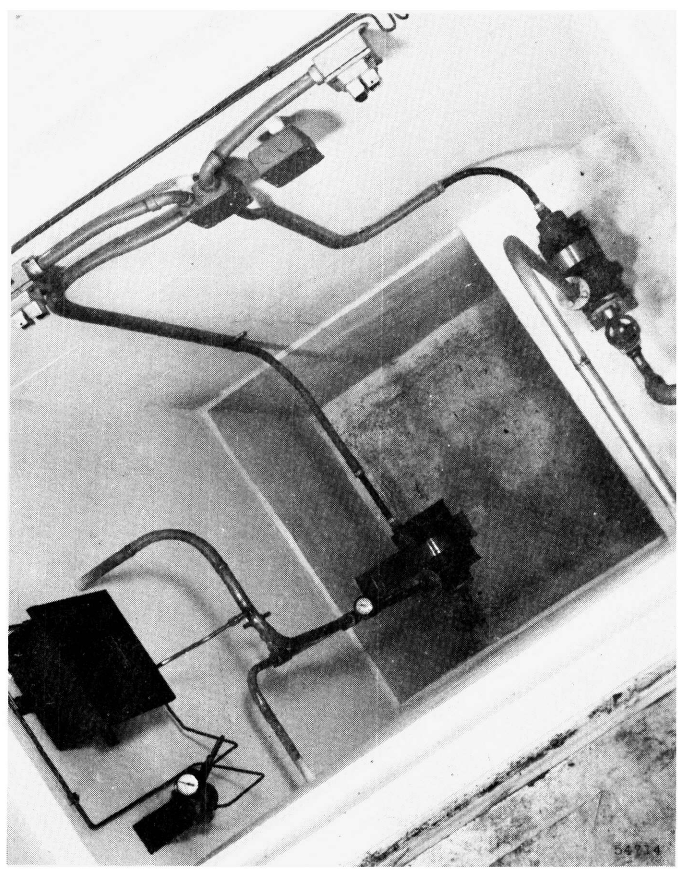


Fig. 33 - Close-up view of coarse strainer arrangement

Fig. 34 - Raw waste pump arrangement



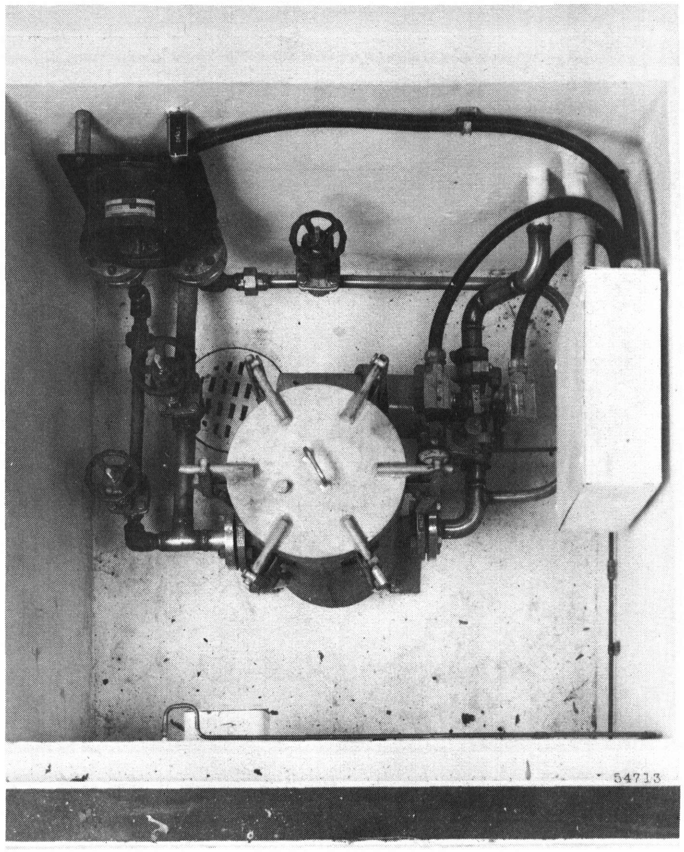


Fig. 35 - Close-up view of fine filter system

type 304 stainless steel wire mesh having a residual entrainment capability of less than 0.35 ppm. Water that collects in the demister is returned to the side of the evaporators through a separate line. Vapor from the demisters passes to the condensers appearing as smaller diameter cylindrical vessels below the demisters. The condenser shell tubes, tube sheet, and head are constructed of type 304 stainless steel with a shell diameter of about 6 in. and an overall length of about 3 ft. Vapor is circulated inside the shell but outside of the 3/4-in. condenser tubes through which cooling water is circulated. The condensers have sufficient surface to condense vapor driven from the evaporator at 5 psi to water at 160°F based on cooling water having an entering temperature of 60°F. The condensed water is collected in tanks (shown in Fig. 38). The fouling factor of the condensers was specified to be 0.001. The solid matter as it precipitates from solution and collects on the bottom of the evaporator will be removed as a sludge. This concentrated waste will be placed in suitably shielded containers and disposed of through approved channels.

The distilled water tanks shown in Fig. 38 have a capacity of 260 gal each. The tanks are vented to the scrubber absolute-filter ventilation system as a precautionary safety measure. The tanks are equipped with level indicators and are interconnected for filling and for discharge. The distillate pump shown in the upper right corner of the pit has a capacity of 10 gpm against a 75-ft head. This pump handles the distribution of the distilled water to either the holding tank or to the scrubber, or the water can also be diverted to the sanitary sewer. The control valves for diverting this water are contained in a valve

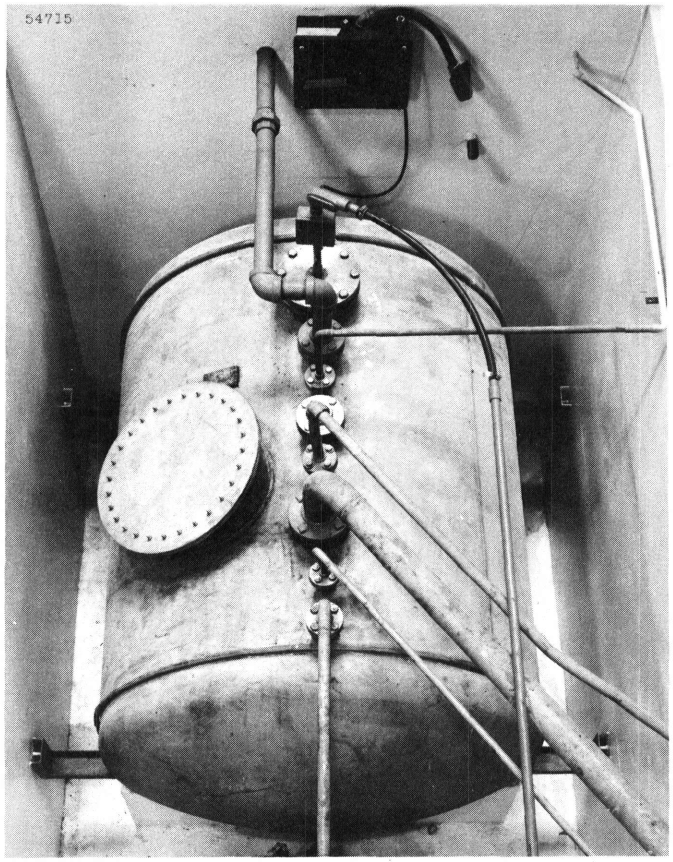


Fig. 36 - Close-up view of holding tank system

pit located to the left of the evaporator pit of Fig. 32. The valves are manually controlled and are kept locked to prevent unauthorized operation.

The duct appearing to the left of the evaporator pit in Fig. 32 is shown more clearly in Fig. 39. This duct conveys the exhaust air from the underground 30-in. duct, connected to the cells, to the scrubber absolute-filter exhaust fan system on the second floor. The view in Fig. 40 shows the continuation of this duct to the plenum at the rear of the gas scrubber chamber. The absolute-filter system is contained in the chamber adjoining the gas scrubber chamber. Air passes from the gas scrubber to the filter chamber at the left end through a vestibule separating both units internally. Exhaust fans (one of which is visible) are connected to the right end of the filter chamber. Exhaust from the fans passes to the stack outside the building through ducts shown to the right of the exhaust fans.

The location of the scrubber absolute-filter exhaust fan system is at the right-hand side of the second floor layout of the facility shown in Fig. 41. The insulated duct which supplies air to the "warm" work areas appears along the right wall of the building. Exhaust from the "warm" work area and from the decontamination room is conveyed to the scrubber by the duct appearing in front of the fresh air supply duct and to the right of the electrical panel in right center. The fresh air supply to the "cold" work area (122) in front of the cells is conveyed by the duct running along the left wall of the building and crossing over to the utilities area in which the supply fan is located. The exhaust from the "cold" work area passes through the absolute-filter system and exhaust fan located on the left foreground nearest to the cell block. The exhausts from the perchloric acid fume hood and the

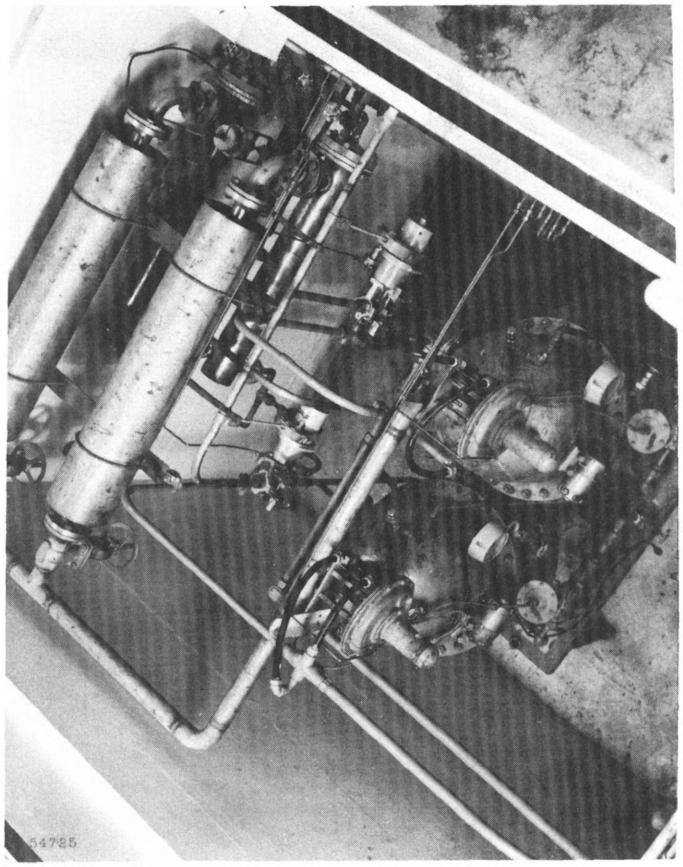


Fig. 37 - Close-up view of evaporative system

radioactive fume hood located in the "warm" chemistry laboratory are located next in line. The projection of the cell block above the second floor level is shown in the center of the floor. The utilities area is located at the rear and contains the power transformers, refrigerating machine, air supply fans with heating and cooling coils, process steam lines for hot-water production and for heating coils, motor control centers, and miscellaneous controls. Access to the "warm" work area and to the machine shop from the second floor was provided through trap doors in the floor. These are located in the floor to the right of the cell block, and the corner of one of such openings is shown in the immediate foreground. The access holes are covered with concrete plugs equipped with lifting rings for handling with the building bridge crane. The purpose of the access holes in the areas below was to obtain the use of the building crane for handling heavy loads in and out of these areas. The building bridge crane straddles the full width of the floor area from wall to wall and rides on rails along the walls.

COLLATERAL EQUIPMENT

AMF Heavy Duty Master-Slave Manipulators

Experience with standard Model 8 master-slave manipulators at NRL and elsewhere indicated that hot-cell experimental work involved at times the necessity of using these manipulators beyond the limits of their design capability, thereby overloading them and introducing equipment difficulties. In view of the increased complexity of hot-cell work

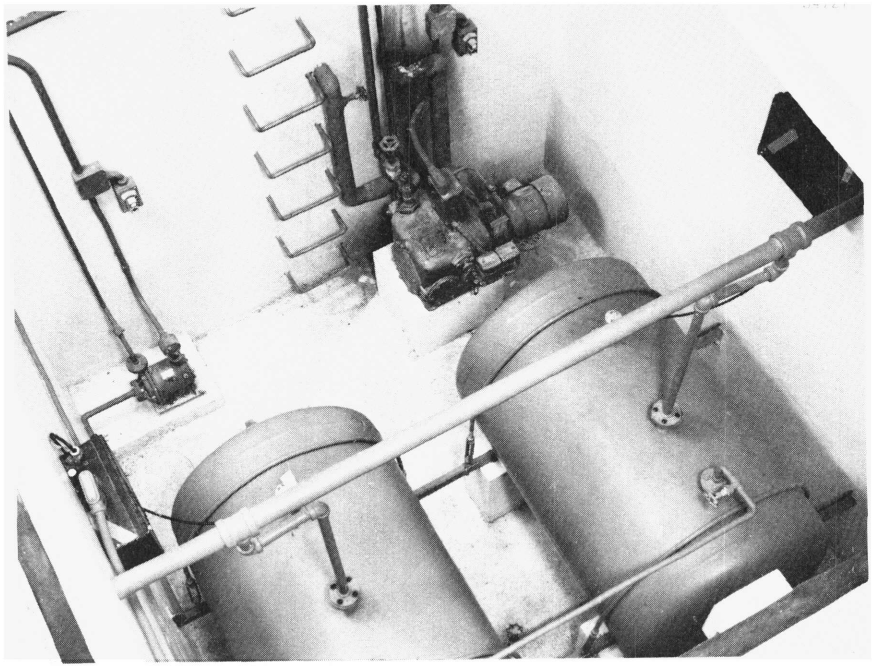


Fig. 38 - View inside pit containing distilled water tanks

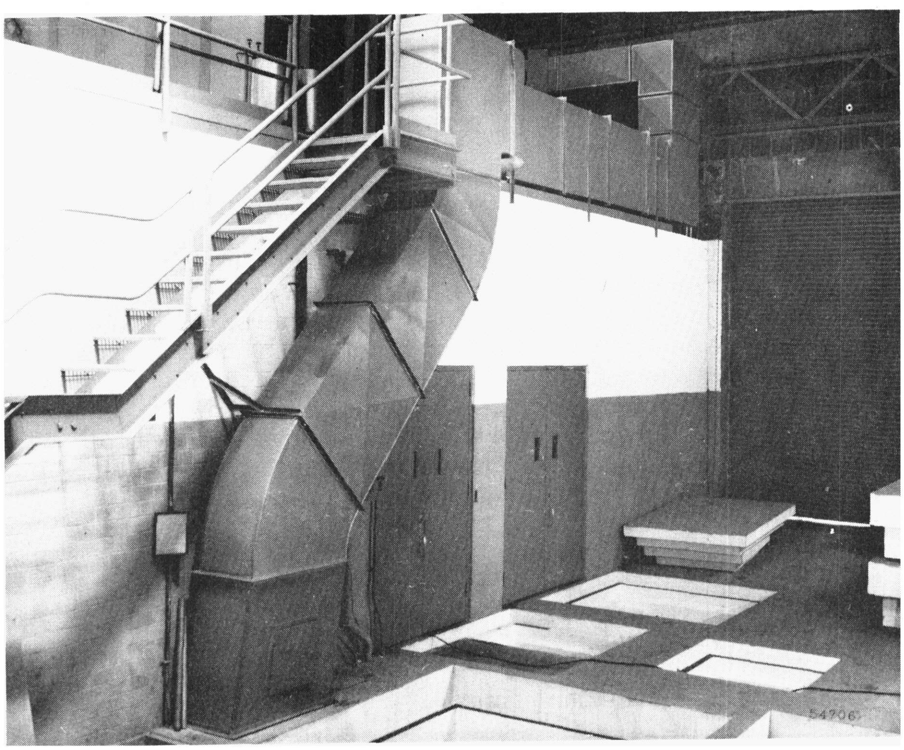


Fig. 39 - Exhaust duct conveying air from 30-in. underground duct from cells to scrubber absolute-filter purifying system

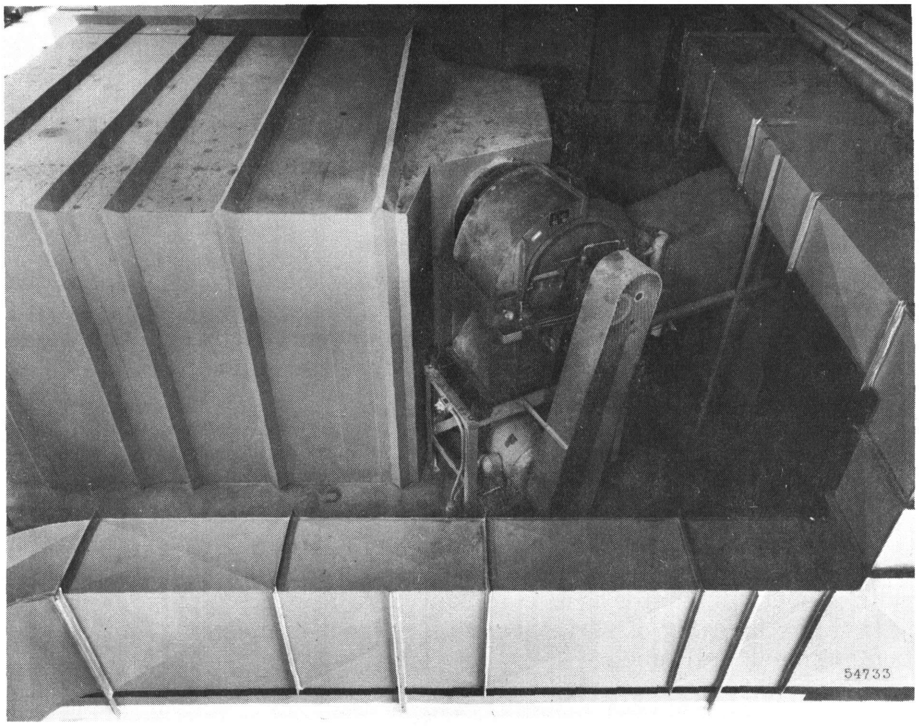


Fig. 40 - Partial view of scrubber absolute-filter exhaust fan system

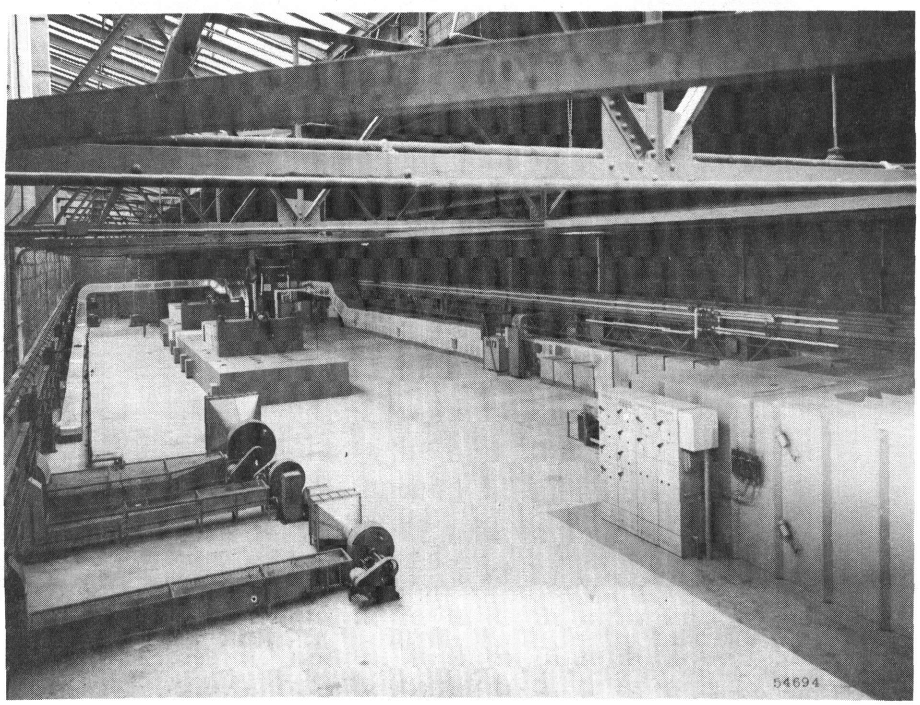


Fig. 41 - Second floor layout of the hot-cell facility

anticipated in the new hot-cell facility, it was considered essential to select a model of manipulator having greater load handling capability in all of the motions. The AMF Heavy Duty Master-Slave Manipulator was selected on the basis that its load handling characteristics best suited the anticipated work requirements of the new hot-cell facility. An added feature in the form of extended reach became available before all of the required manipulators were manufactured. Since extended reach was considered necessary for operations in cells 3 and 4, two pairs of manipulators were manufactured with this added feature.

The principal manipulator dimensions are shown in Fig. 42. The length of the arm in telescoped position is 56 in. from the centerline of the wall tube to the wrist pivot. The length of the arm extended is 97-1/4 in. from the centerline of the wall tube to the wrist pivot. The slave-end pivot extends 18 in. beyond the inside wall of the cell. The master end extends 24 in. beyond the outside wall of the cell. A minimum clearance of 20 in. was required above the centerline of the wall tube. The mounting height from centerline of wall tube to floor is 10 ft.

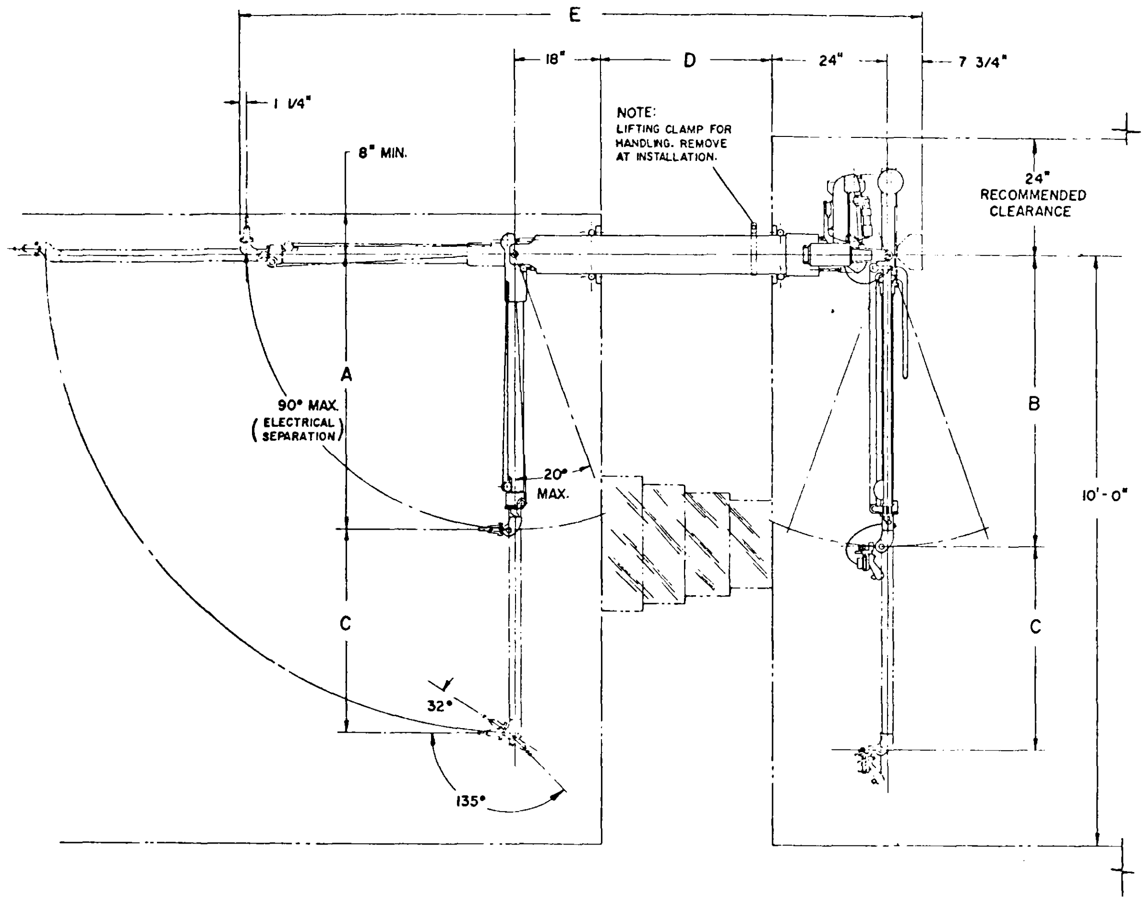
The manipulators have the following degrees of motion: rotation about the wall tube centerline; rotation about the arm centerline; rotation about the wrist joint; bending at the shoulder joint; telescoping of the arm; hand grip; separation (angular indexing of slave arm with respect to master arm in a plane parallel to centerline of wall tube); and side canting (angular indexing of slave arm with respect to master arm in a plane perpendicular to centerline of wall tube).

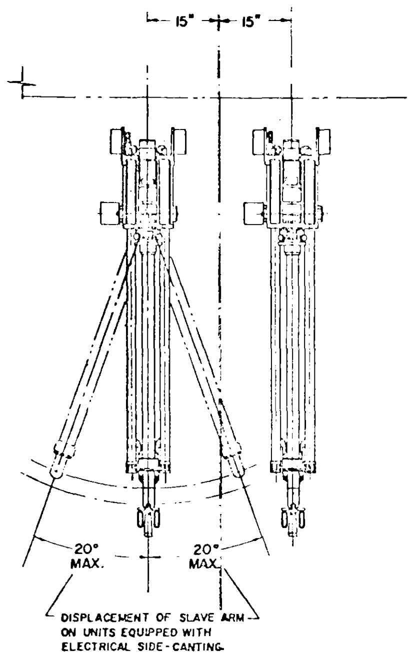
The sensitivity of feel expressed as the force required to initiate and maintain motion in the various directions with boom tubes fully extended is approximately as follows: "X" motion friction force, 2 to 4 oz; "Y" motion force, 2 to 4 oz; and "Z" motion force, 12 to 24 oz.

The manipulator slave arm can exert a 65-lb pushing force against an object with the arm fully extended and a 100-lb force with the arm fully telescoped in either the "X" or "Y" motions. In the vertical direction ("Z" motion) up to 120 lb can be lifted, using a load hook attachment. The heavy duty grip at the operating handle can exert a force at the slave-end tongs to clamp or hold a 30-lb load in any plane or attitude of the hand. The following table lists the capacities of the AMF Heavy Duty Manipulator at the slave end.

Force Capabilities of AMF Heavy Duty Master-Slave Manipulator at Slave End

Function	AMF Heavy Duty
X-motion (side to side)	100 lb, telescopic tube fully retracted
	65 lb, telescopic tube fully extended
Y-motion (back and forth)	100 lb, telescopic tube fully retracted
	65 lb, telescopic tube fully extended
Z-motion (vertical up and down)	120 lb with load hook
Grip	60 lb (direct grip) 30 lb (manipulation)

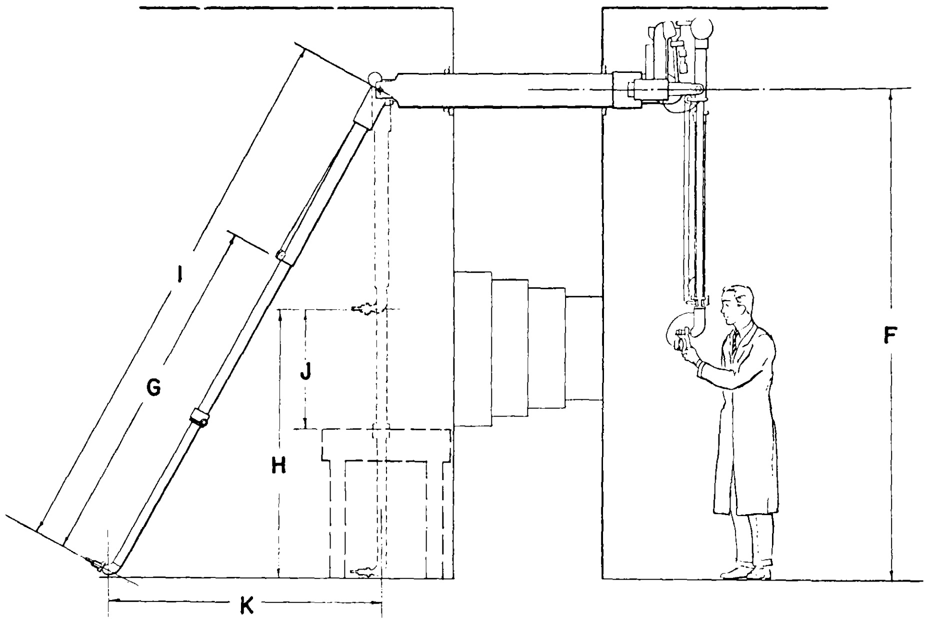




AMF HEAVY DUTY
MASTER-SLAVE MANIPULATOR
STANDARD DIMENSIONS

A	B	C	D	E
56	59	41-3/4	36 42	141-3/4 147-3/4

Fig. 42 - AMF Heavy Duty Master-Slave manipulator dimensions



F	G		H	I		J	K	
MTG. HEIGHT	STROKE		MAX. HEIGHT ABOVE FLOOR	MAX. EXTENSION		HEIGHT ABOVE 40" TABLE	RADIUS OF COVERAGE AT FLOOR LEVEL	HEIGHT ABOVE FLOOR AT MAX. EXTENSION
	NORMAL	TOTAL		NORMAL	TOTAL			
120"	40"	80"	65"	95"	135"	25"	60"	-----
	30"	60"	75"	75"	105"	35"	0"	15"
	20"	40"	85"	55"	75"	45"	0"	45"

Fig. 43 - Extended reach manipulator principal dimensions

The section of the manipulators contained in the wall through-tubes was shielded with 12 in. of lead in the 42-in.-thick cell wall and 10 in. of lead in the 36-in.-thick cell wall.

Side canting or electrical indexing feature was provided on the manipulators in cells 2, 3, and 4. This feature permits a 20 degree side displacement of the slave arm with respect to the master arm in a plane perpendicular to the wall through-tube centerline.

The tong assembly on the slave end is designed to permit remote interchangeability of tong fingers. Tong fingers are cast aluminum and, when contaminated, can be replaced at a low cost.

All manipulators were provided with remotely removable type polyethylene booting to protect the slave end from radioactive contamination.

The extended reach feature incorporated on two pairs of manipulators provides twice the extension of the slave end without having to move the master end. This feature allows manipulation to reach the floor for complete cell coverage as illustrated in Fig. 43. It lets the operator maintain the most convenient working and optimum viewing positions while making floor manipulations and doing below-window level operations. Examples of the extended reach feature are shown in the next two figures. In Fig. 44 the left slave arm grips a radiation monitor on the cell floor at a point 7 ft from the inside front wall

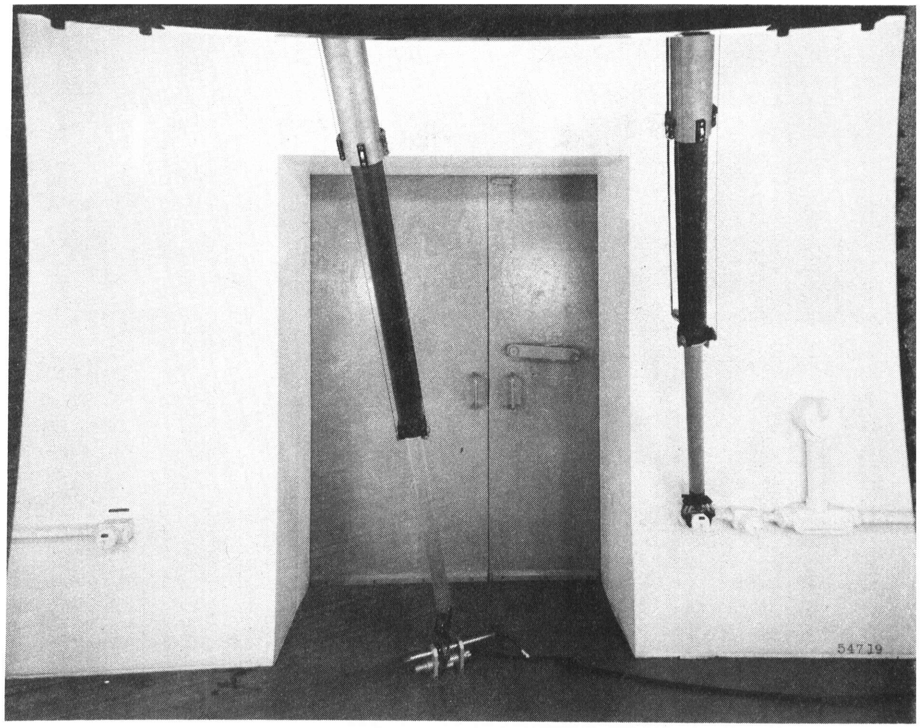


Fig. 44 - Example of the use of extended reach manipulators

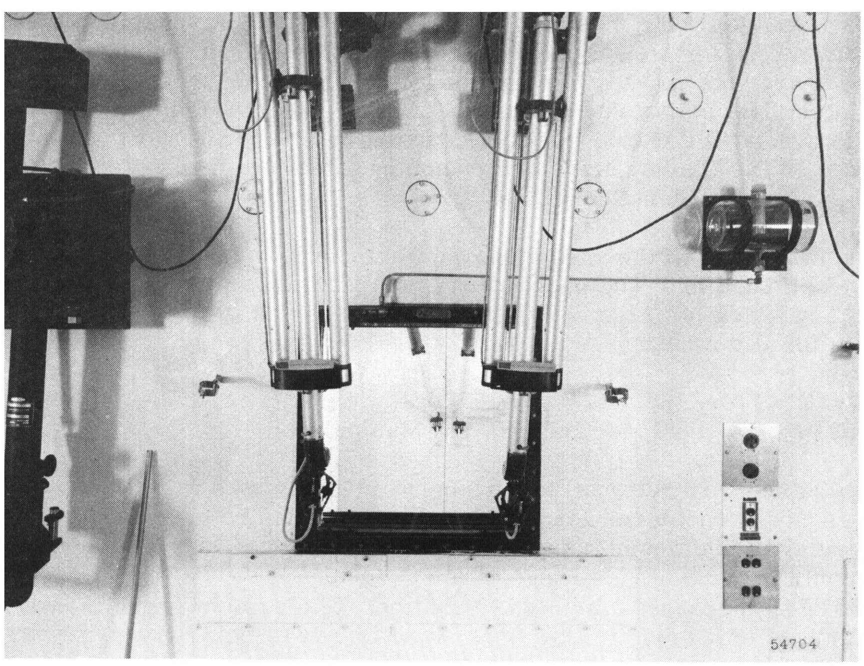


Fig. 45 - Example showing extension of slave arms without comparable extension of master ends

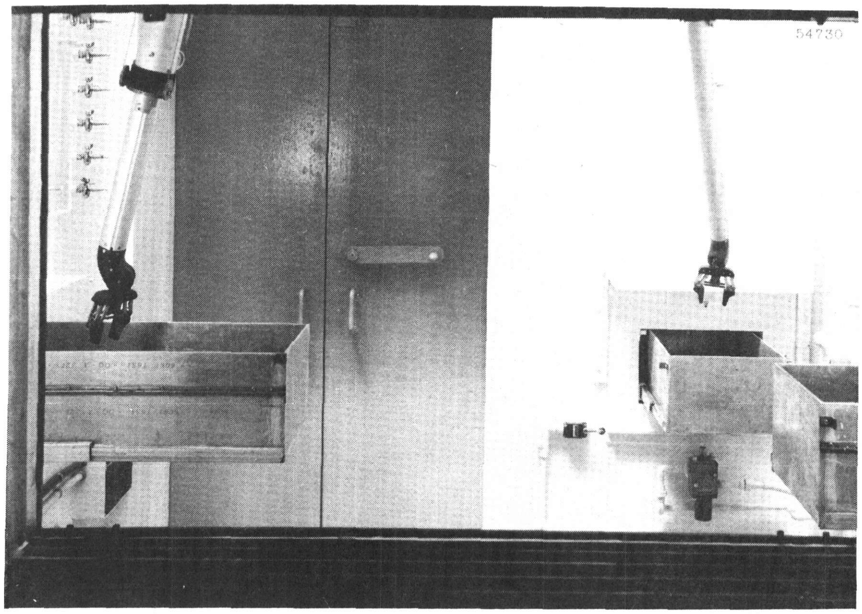


Fig. 46 - Example showing reach capability of heavy duty manipulators without extended reach feature

of the cell while the right-hand slave arm grips the cover to an electrical power receptacle mounted on the inside back wall of the cell. In Fig. 45 the slave arms are shown gripping the door handles on the cell shielding doors, which are 10-1/2 ft from the inside front cell wall, while the master ends remain retracted. The relative extension of the slave end is accomplished by seven movable pulleys on the master end. Motor driven twin screws mounted on the master side extend the slave end, enabling the operator to have both hands free for operation during extension or retraction of the slave ends. The reach of the heavy duty manipulators without extended reach is illustrated in Fig. 46 which shows the interior of cell 3 with cell transfer drawers extended into the cell. The right slave arm is nearly fully extended when reaching into the external transfer drawer in the back cell wall, while the left slave arm reaching into the left transfer drawer is extended less than half of its full length.

Attention is called to the exceptional optical quality of the shielding windows and the excellent in-cell lighting. The photographs just discussed were taken through the windows, which are 42 in. thick for Figs. 44 and 45 and 36 in. thick for Fig. 46, using in-cell mercury lighting for illumination.

General Mills Model 303F Mechanical Arm Manipulator

Certain hot-cell operational requirements involve tasks for which the master-slave manipulators were considered inadequate. It was therefore necessary to include additional manipulative equipment capable of handling items of varying strength and rigidity and which could provide a wide range of mechanical force. To fill this need, the General Mills Model 303F mechanical arm was selected. One complete unit is shared by cells 2 and 3 and another unit is shared by cells 4 and 5 as was depicted in the design stage of Dwg. 3.

The Model 303F mechanical arm is a general purpose electromechanical manipulator utilizing a combination of longitudinal bridge, lateral carriage, and vertical telescoping

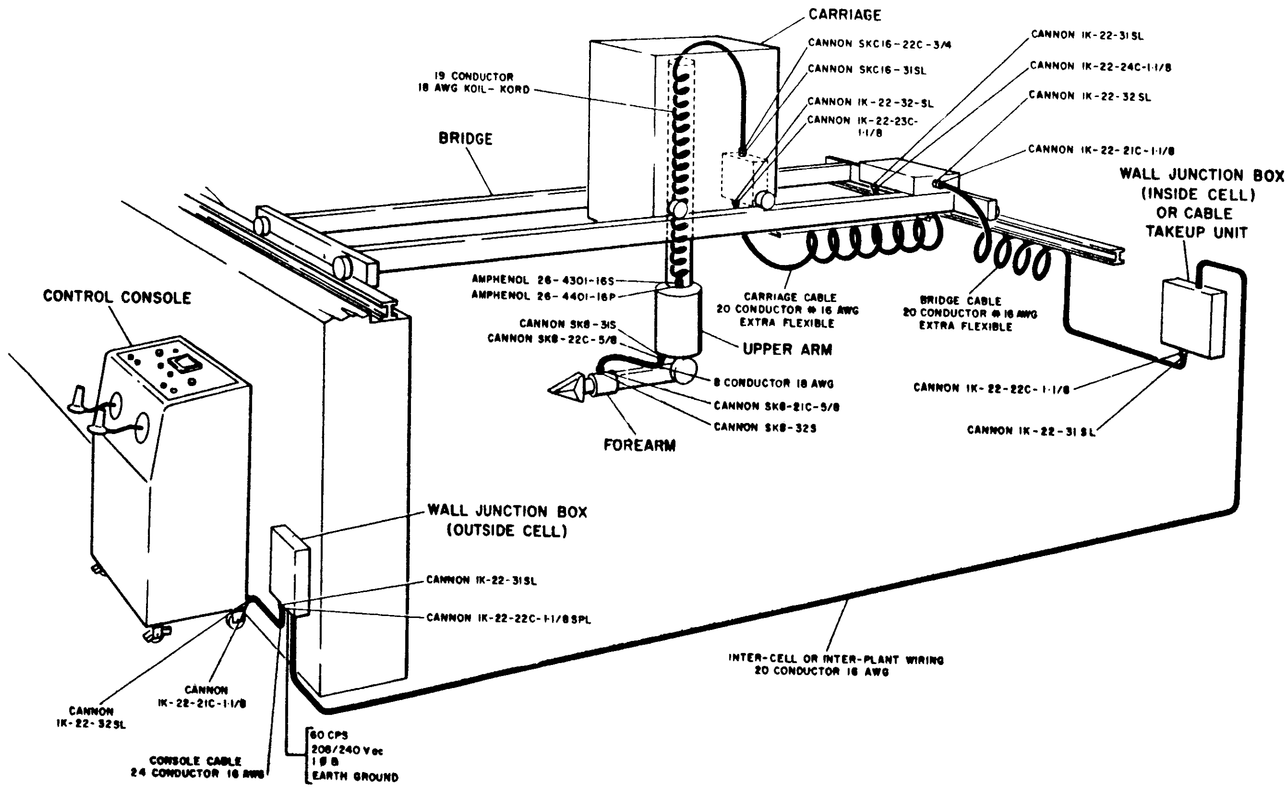


Fig. 47 - Schematic arrangement of General Mills type of mechanical arm manipulator

hoist movements which permit the basic positioning of a mechanical arm within the space of the cell. The arrangement of the manipulator system is shown schematically in Fig. 47 and consists of a bridge which travels on rails set on opposite walls of a cell, an arm carriage which holds the telescoping hoist and mechanical arm and which travels on the length of the bridge, a cable take-up unit, and a remote control unit.

The structural and engineering features of the manipulator bridge are shown in the outline sketches of Fig. 48, while the track mounting pad and cable roller arrangement is shown in Fig. 49. The manipulator bridge features rugged I-beam construction and utilizes narrow end trucks to facilitate application to the limited available space in the hot cells. Bridge movement is produced by a 1/4-hp shunt wound dc motor connected for three-speed armature control. A constant field excitation provides nearly constant torque and permits automatic dynamic braking of the motor. All electrical leads for the manipulator are connected through a bridge junction box which is supplied by a multiconductor cable that originates at a wall mounted junction box adjacent to the cable take-up reel. Limit switches on both sides of one end truck restrict bridge travel over preset limits. Power is transmitted to friction drive wheels at each end truck through an interconnecting drive shaft with the forward wheels driven through a chain and sprocket arrangement. Static braking for bridge motion is provided by self-locking worm gears. An electrically operated drive release permits free wheeling along the track.

The track-mounting cable-roller arrangement is shown in Fig. 49. The track mounting pads consisted of short sections of 5-in., 9-lb channel welded to the base of the rail at intervals from 36 to 48 in. apart. Cable rollers were fastened to the inboard blanked end of the mounting pads. The track was anchored to the 8-in. wide ledges in the cell by passing the bolts anchored in the ledges through holes in the channel web and fastening with nuts. The track was levelled by the use of shims as needed. The center line of the track is 5 in. from the inboard cell wall, which provides just enough space for free rotation of the cable rollers.

The assembly of the telescoping hoist, mechanical arm, and carriage is shown in outline in Fig. 50. A removable sheet metal housing encloses the carriage, which has a steel base structure. The telescoping hoist consists of stainless steel sections featuring a ball spline design which minimizes friction and allows free movement. The telescoping hoist is housed in a steel enclosure. The hoisting cable runs from the hoist motor drum, down the center of the tube, and is connected to the lower end of the tubes. All joints and openings are sealed against dust infiltration. The telescoping hoist is equipped with safety features which include mechanical stops to prevent overextension of the tubes and a sensing switch which detects hoist cable slack and interrupts motor power. Hoist movement is provided by a 3/4-hp, 208-v dc shunt wound motor with a constant 208-v dc field supply. Shaft speed is directly proportional to armature voltage and shaft rotation is dependent on armature polarity. Dynamic motor braking is accomplished by shorting the armature windings upon power cutoff. The hoist motor includes a friction-type brake for holding the load in a static position. Carriage motion is produced by a 1/4-hp 208-v dc shunt wound motor having the same characteristics as the hoist motor mentioned above. The carriage is equipped with an electrically operated disengage mechanism which permits free movement of the carriage across the bridge. In addition to dynamic motor braking, static braking for carriage motion is provided by self-locking worm gears. For safety, limit switches on the carriage restrict its travel over preset limits and detect tilting on the bridge. Hoist and carriage displacements are shown in Fig. 51.

The various parts of the mechanical arm assembly together with pertinent dimensions are shown in Fig. 52, while an actual photograph of the arm as installed is shown in Fig. 53. Mechanical arm motions are depicted in Fig. 54 together with a summary of the operational capability data. A view looking down on the bridge and mechanical arm carriage installation in cell 2 is shown in the foreground of Fig. 55. This view shows the bridge construction and the manner in which the carriage travels across the bridge. Power and control

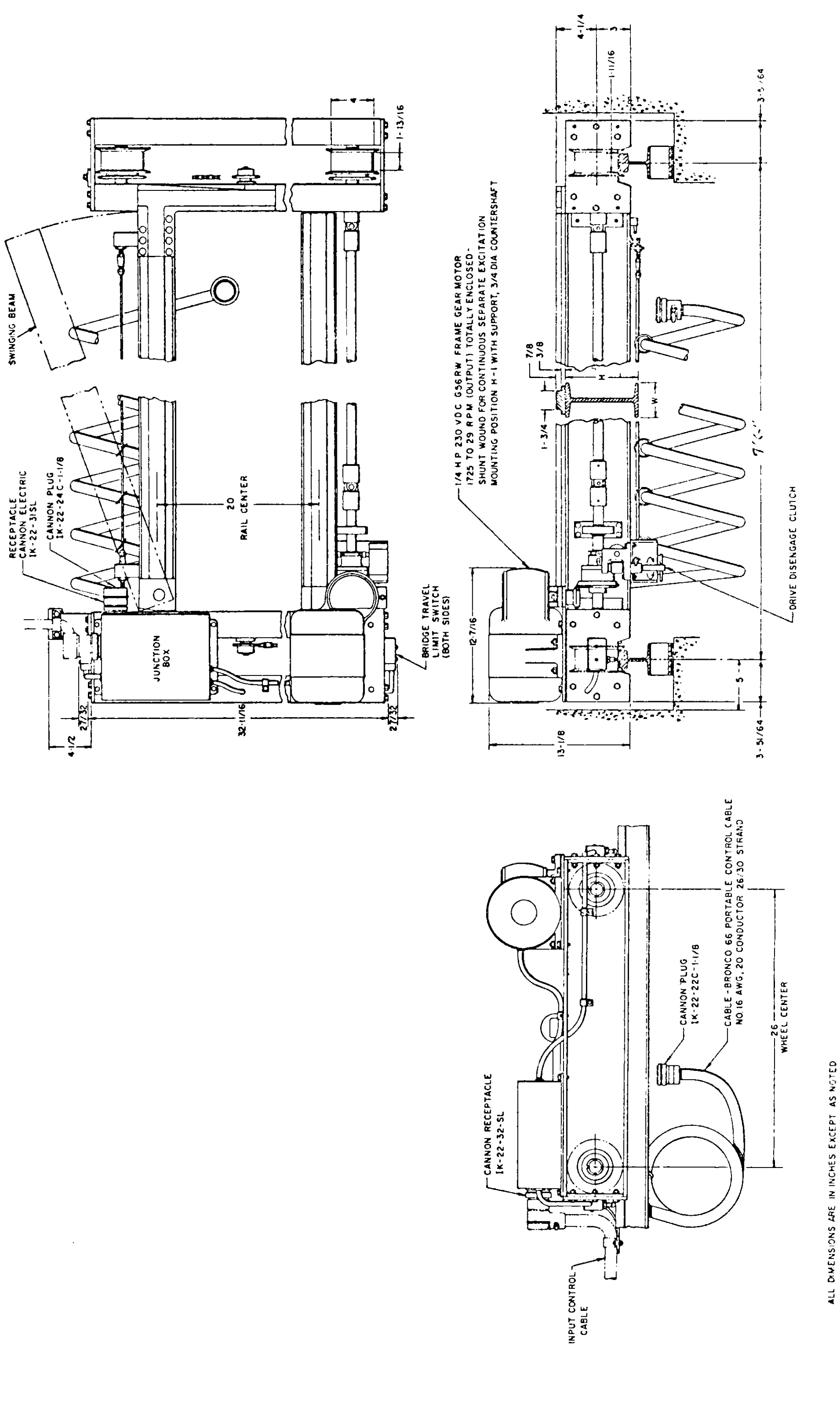


Fig. 48 - Structural and engineering features of manipulator bridge

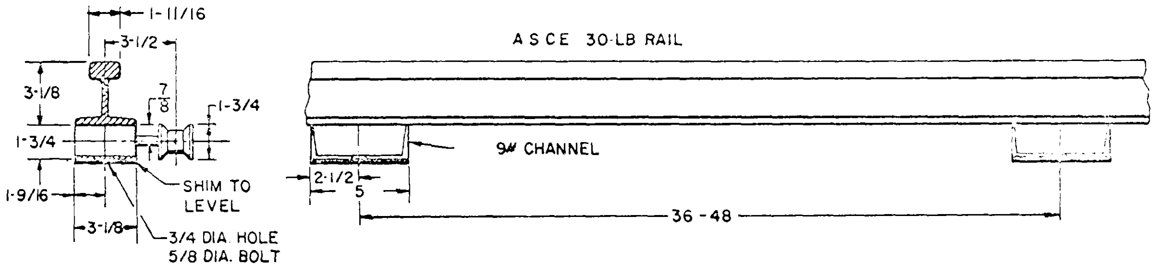
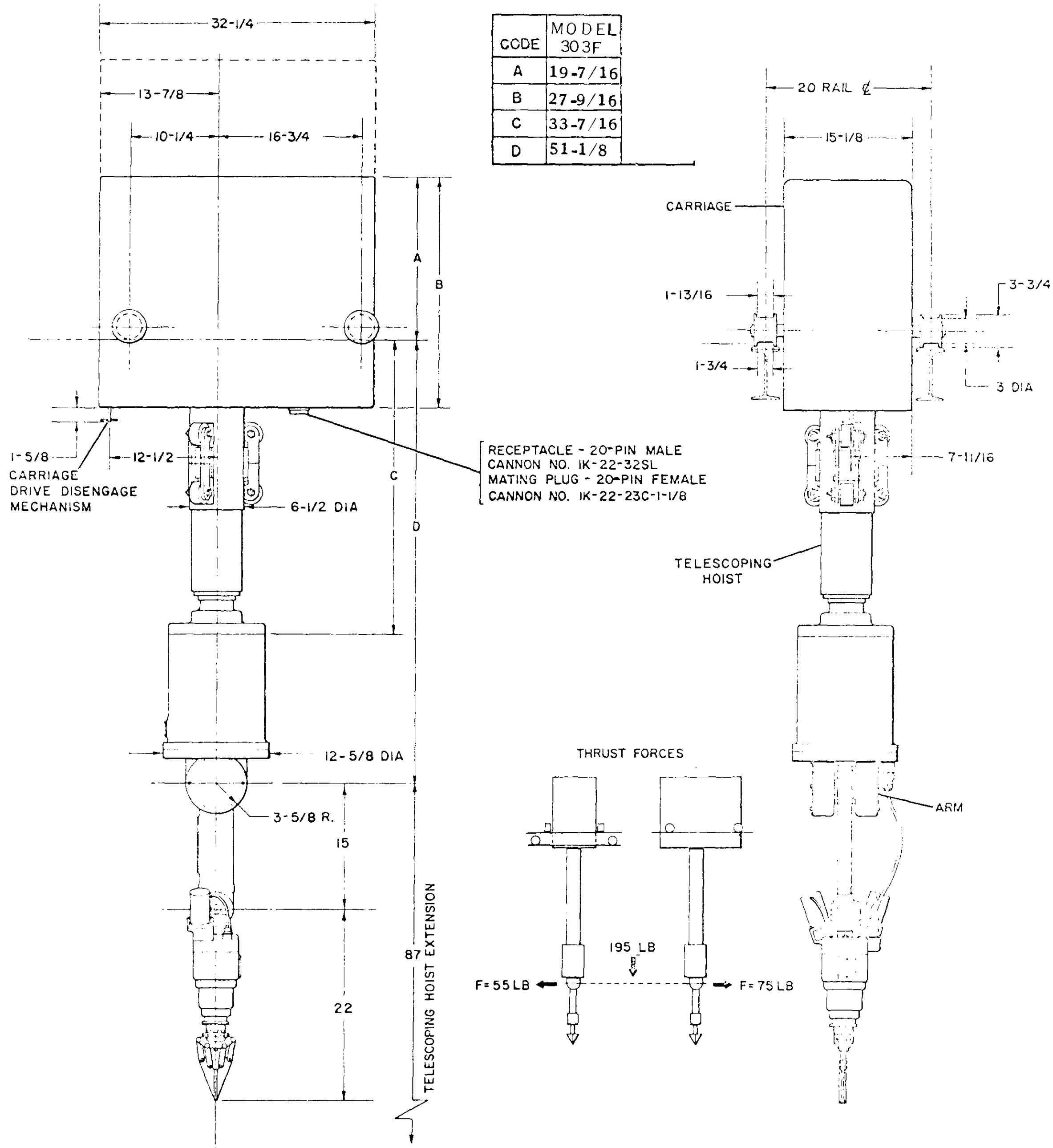
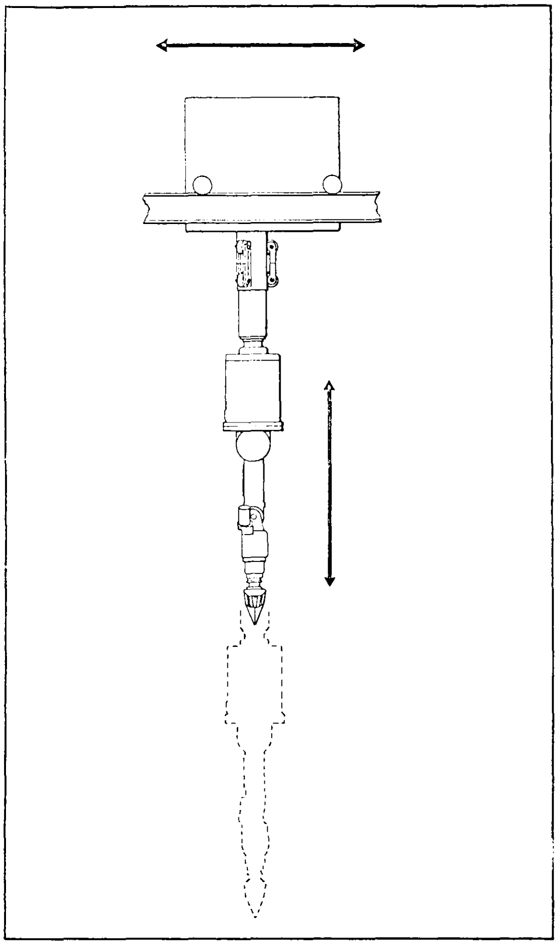


Fig. 49 - Track mounting pad and cable roller arrangement



CODE	MODEL 303F
A	19-7/16
B	27-9/16
C	33-7/16
D	51-1/8

Fig. 50 - Telescoping hoist and carriage dimensions



GENERAL SPECIFICATIONS

SHIPPING WEIGHT (Approximate) . . . . 700 lb
(hoist and carriage only)

TELESCOPING HOIST
Extension-Retraction Speed . . . . 15 fpm
Load Capacity (using arm hook) . . . . 750 lb
Travel Range (standard) . . . . 87 in
(special designs up to 20 ft)

CARRIAGE
Travel Speed . . . . 15 fpm

Travel ranges, load capacities, and speeds are nominal maximum values. All speeds listed are "no load."

Fig. 51 - Hoist and carriage displacements

cable take-off is shown at the left side. The cable passes over cable rollers, mounted on the track mounting pads, to the cable take-up reel on the left. Other equipment appearing on the same track is a bridge-type traveling crane hoist which is to be described in the next section. The mechanical capabilities of the mechanical arm include: maximum lift of 750 lb with telescoping hoist and with arm vertical; a grip force up to 150 lb with fingers of the hand opened 3 in.; load capacity of 65 lb at elbow joint with forearm horizontal and upper arm vertical; load capacity of 39 lb at the shoulder joint with both forearm and upper arm horizontal, and 95 lb with forearm vertical and upper arm horizontal.

All manipulator movements are remotely controlled. Two modes of control were provided, one by means of standard operational controls mounted in a control console, as illustrated in Fig. 56, and the other mode by means of a portable satellite control utilizing power and control equipment of the control console, but with operational controls mounted external to the console in a small, specially designed, finger tip portable controller. Both modes of control are illustrated in the photograph of Fig. 57. When employing the satellite mode of control the control function of the pistol grip handles on the control console is deactivated and replaced by the finger tip controller. These modes of control provide a maximum flexibility around the viewing windows for operating the mechanical arm manipulator.

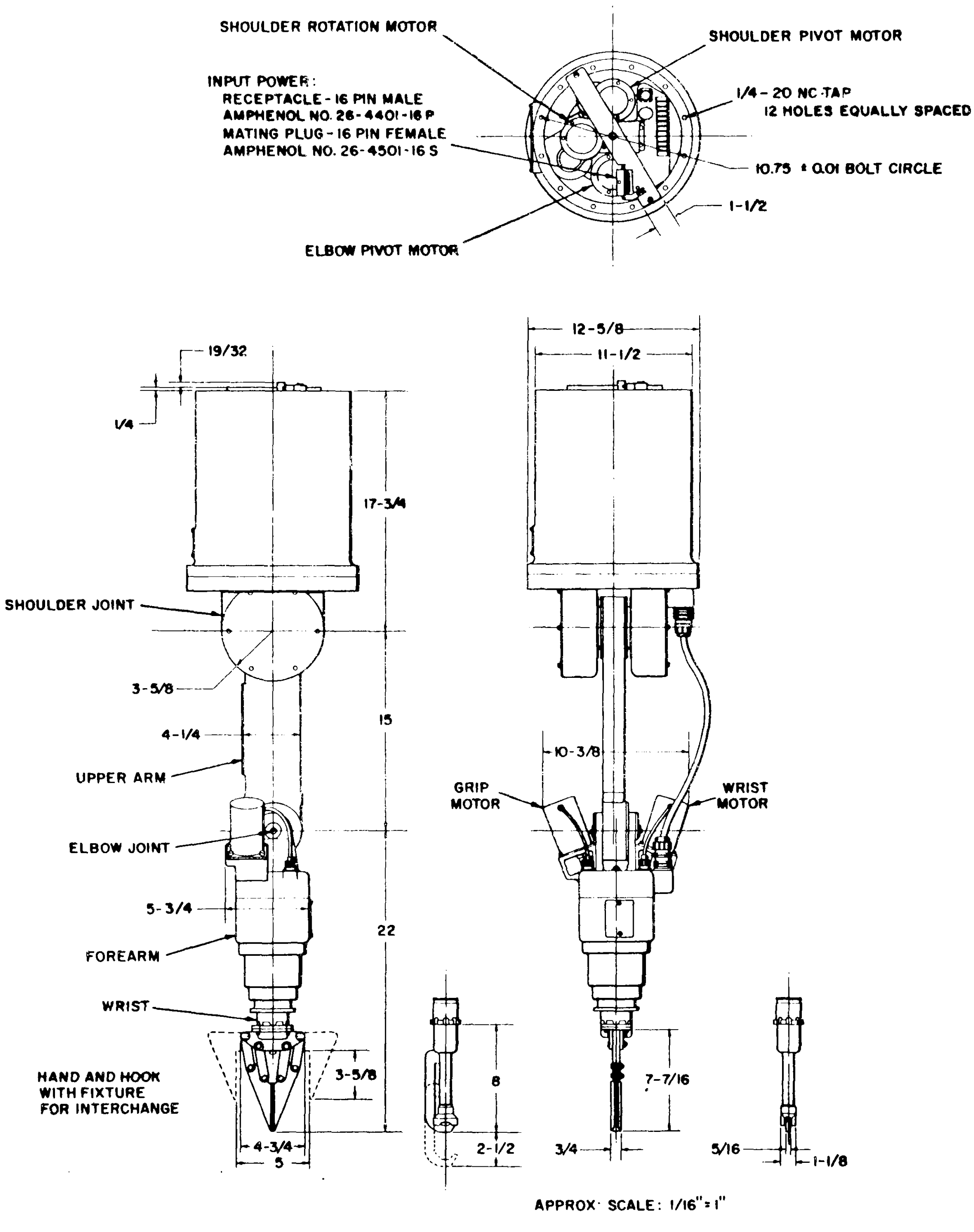


Fig. 52 - Mechanical arm assembly and dimensions

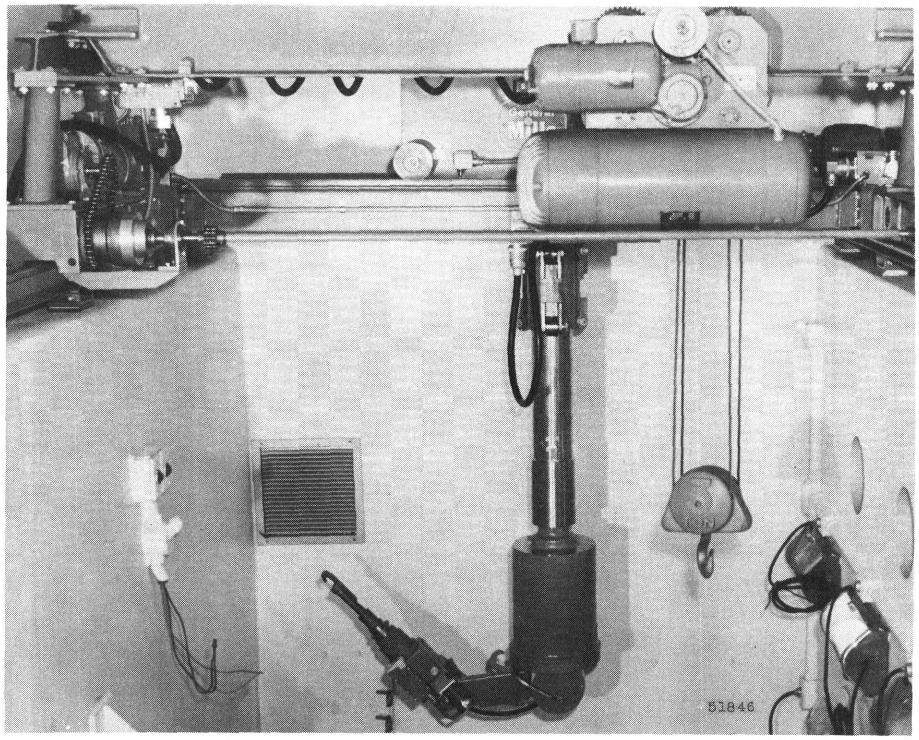
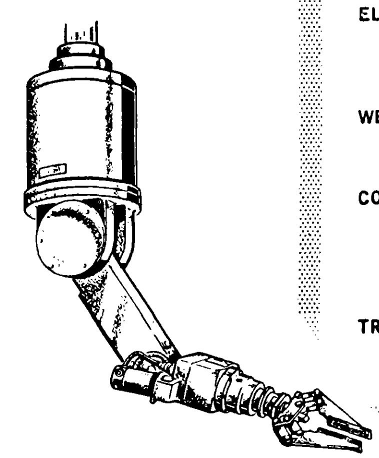


Fig. 53 - View of telescoping hoist and mechanical arm

When the standard mode of control is employed, manipulator movements are controlled independently by two pistol grip handles on the control console in conjunction with visual indicators located in the top panel of the console as shown in Fig. 56. In addition to the standard controls, the grip force indicator controls and tool power controls, shown to the right of the standard control panel, were also included.

Two pistol grip control handles, protruding from the front of the console, govern all manipulator movements when this mode of control is used. Handle movements actuate sector switches in the handle assemblies which in turn energize relays to govern direction and speed of manipulator movements. The control handle action to produce manipulator movement is illustrated in Fig. 58. Both control handles are supported on gimbal-type mountings, permitting coordinated simultaneous motion. Direction of manipulator movement corresponds to the direction of control handle movement and manipulator speed is governed by the amount of control handle displacement from neutral. Each movement has three speed steps in each direction. The handles are spring loaded in all axes to provide automatic return to neutral (or off) position when the handle is released. The type of drive used makes the manipulator maintain any set position or grip force with the control in neutral. Each movement of the manipulator is driven independently by a shunt wound dc motor. The motors and controls are interconnected by a system of cables which use a common ground circuit to minimize the number of conductors required.

Electrical power is supplied to the console at 208 v ac, 60 cycle, single phase. This is converted to direct current, for power and control use, by power supplies in the control console. Power control mechanisms are also contained in the console to remotely govern the manipulator movements in response to commands of operational controls.



ELECTRICAL REQUIREMENTS		
Voltage	208	v ac
Frequency		60 cps
Phase		1
Power		2500 v a
WEIGHTS (Approximate)		
Arm and arm carriage		750 lb
Bridge		400 lb
Control console		250 lb
CONTROL CONSOLE		
Unit controls		2
Type control		Pistol grip handles
Right-hand movements		5
Left-hand movements		3
Speed control (each movement)	Six speed steps in each direction	
TRACK		
Rails		2
Rail section length		16 ft

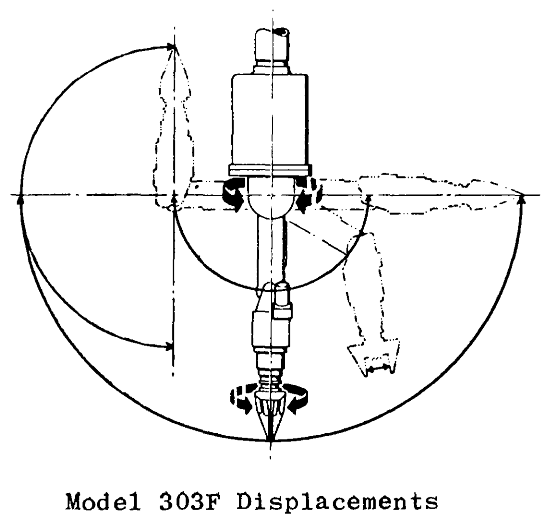
Model 303F Specifications

ARM	
Hand	
Opening	5 in.
Open-Close Speed	20 ipm
Grip Force	150 lb
Hook	
Opening	2½ in.
Open-Close Speed	8 ipm
Wrist	
Torque	30 lb-ft
Rotational Speed	8 rpm
Rotation	Continuous
Elbow	
Forearm Torque	120 lb-ft
Pivot Speed	⅔ rpm
Pivot Arc (total)	180 deg
Load Capacity (forearm horizontal, upper arm vertical)	65 lb
Shoulder	
Upper Arm Torque	120 lb-ft
Pivot Speed	⅔ rpm
Pivot Arc (total)	180 deg
Rotational Torque	35 lb ft
Rotational Speed	3 rpm
Rotation	Continuous
Load Capacity (forearm horizontal, upper arm horizontal)	39 lb
Load Capacity (forearm vertical, upper arm horizontal)	95 lb
TELESCOPING HOIST	
Extension-Retraction Speed	15 fpm
Load Capacity (using arm hook)	750 lb
Travel Range (standard)	87 in.
CARRIAGE	
Travel Speed	15 fpm
Travel Range	41 in. less than rail centers
BRIDGE	
Travel Speed	15 fpm
Span	90 in.

Travel ranges, load capacities, and speeds are nominal maximum values. All speeds listed are "no load."

MODEL 303F

MECHANICAL ARM



Model 303F Displacements

Fig. 54 - Arm displacements and summary of operational capabilities

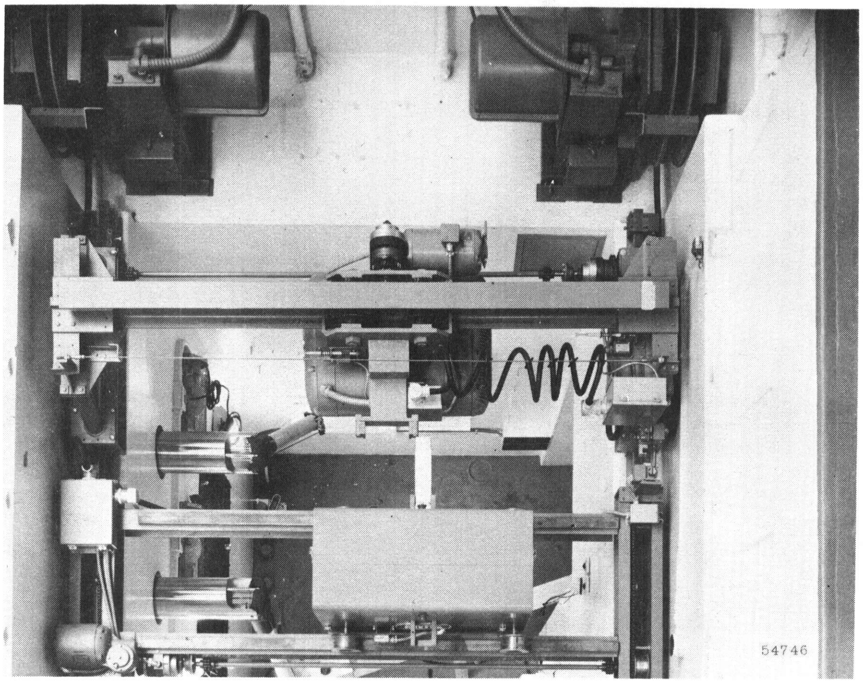


Fig. 55 - View looking down on manipulator bridge (in foreground) and arm carriage

The pistol grip mode of control features a natural movement concept which enables the operator to position the mechanical arm quickly and accurately by introducing displacement in any or all axes simultaneously. The operator has only to visualize his own right arm in place of the manipulator arm. Thus, any movement of his arm and hand causes corresponding movements of the manipulator arm and grasping tool. Characteristic movements of the operator's left arm cause related movements of the bridge for positioning the mechanical arm in the general area of in-cell operation. Direction and rate of each manipulator movement are thus governed by the direction and amount of control handle displacement from a neutral position.

The mechanical arm manipulator was equipped with safety and protective devices to avoid improper operation and prevent damage to itself or other equipment. Both mechanical and electrical protection were provided. Slip clutches are used to prevent excessive overloads and stresses on the arm. Physical stops and limit switches restrict bridge movements over preset limits. All power and control circuits are protected by thermal overload circuit breakers.

To safely handle breakable materials, a visual indicator was provided at the control console as shown in the top panel of Fig. 56. This grip force indicator, in the form of a zero center meter, provides a comparative measurement of grip force applied by the hand or hook attachment. The meter is connected to a grip force transducer in the manipulator forearm through a dual-range wheatstone bridge circuit. The dual-range feature provides two scales of measurement: from 0 to 150 lb and from 0 to approximately 1 lb.

The tool power provision incorporated in the manipulators is a special modification which enables the manipulator to use portable power tools that are remotely interchangeable with the standard hand unit. Thus, certain functions such as driving nuts to fasten or unfasten bolted joints, or other tasks, can be performed remotely in any area of the hot

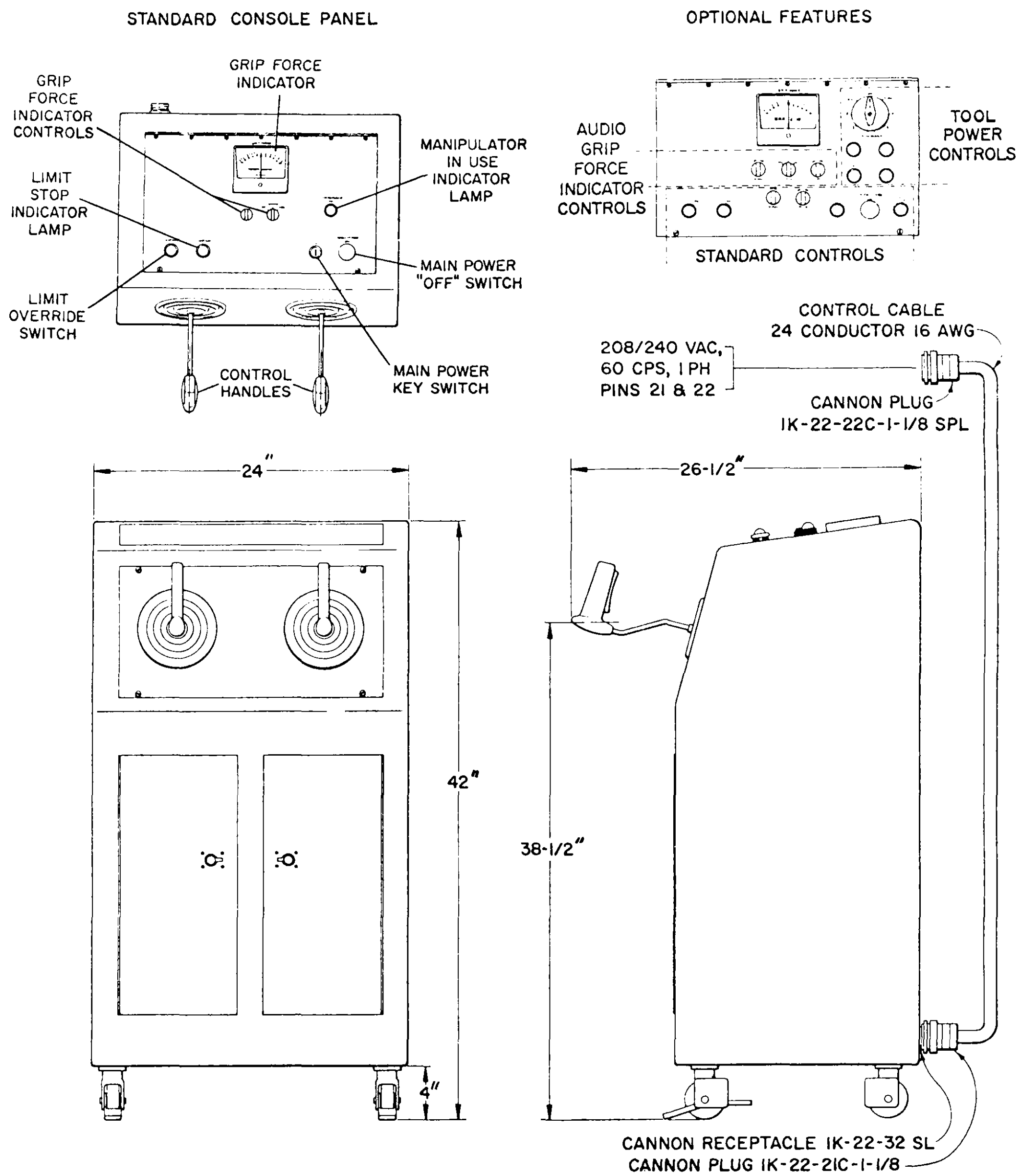


Fig. 56 - Control console dimensions

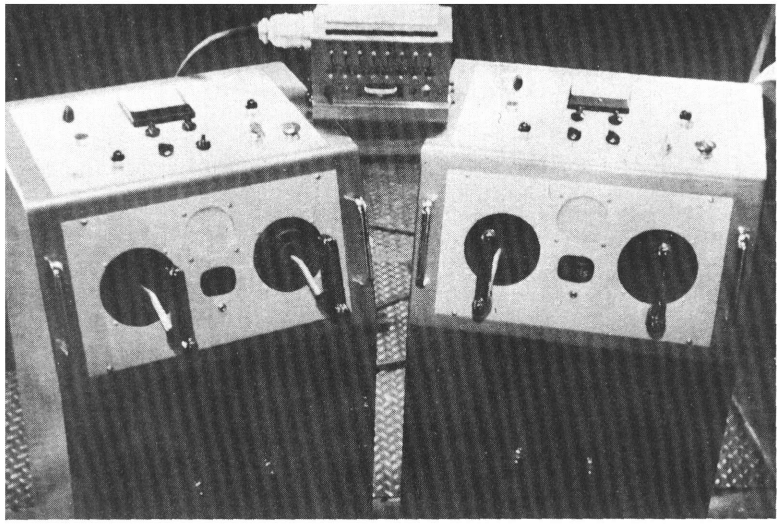


Fig. 57 - View of standard type and satellite controls for mechanical arm manipulator

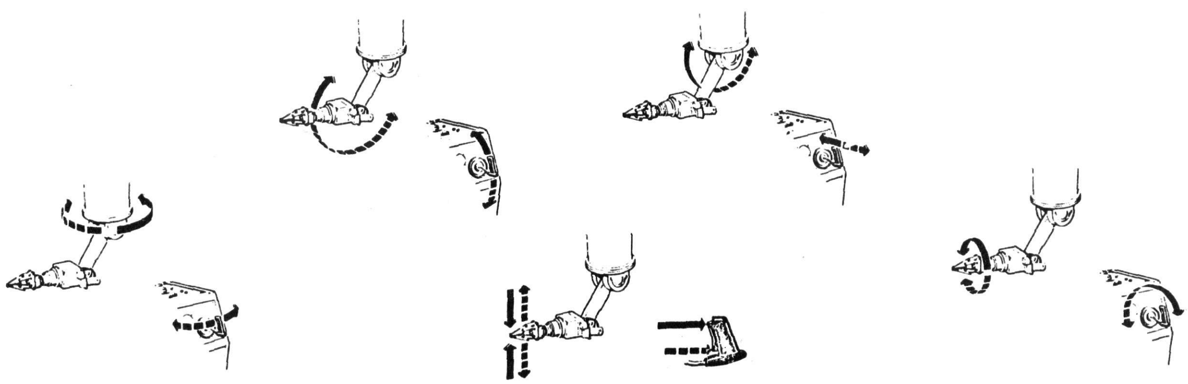


Fig. 58 - Manipulator movements vs control handle displacements

cell. A special receptacle, fastened to the forearm, mates with quick-disconnect plugs fastened to the tools and provides power for driving 115-v ac/dc universal motors up to 1/2 hp. Controls in the console enable the operator to drive the tool in either direction of rotation at one-third, two-thirds, and full speed. The power tool feature is illustrated in Fig. 59.

The cable distribution system for a mechanical arm manipulator was shown schematically in Fig. 47. This system requires 24 conductors for operation and control. The control console cable is connected to a receptacle in the front outside wall of the cell by means of a quick-disconnect plug. Wiring from the wall receptacle is carried in conduit embedded in the cell structure to a junction box located on the intercell wall in back of the respective cable take-up reel. This junction box is connected by cable to a 24-conductor collector ring mounted on end of the hollow shaft of the cable take-up reel spool. The 24-conductor collector rings are connected by cable through the shaft to a junction box on the end of the shaft next to the reel spool. One end of the 24-conductor cable coiled on the reel spool is connected to this junction box, while the other end is connected to

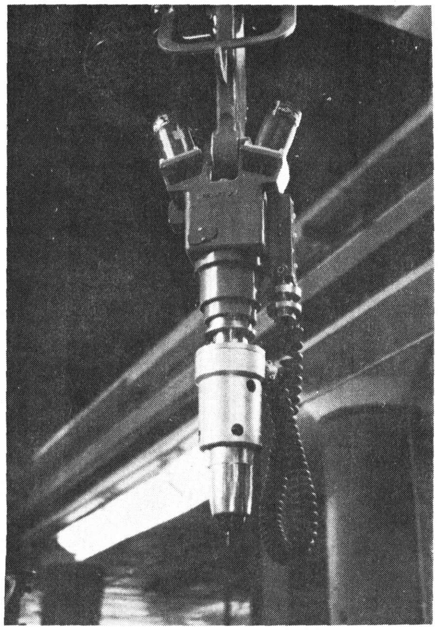


Fig. 59 - View of power tool feature mounted on mechanical arm

the junction box located on the bridge of the manipulator, thus completing the circuit.

General Mills "A" Frame Friction-Type Bridge Equipped With Chisholm-Moore Meteor Hoist

Hot-cell operations often involve a situation where very heavy loads need to be remotely handled and precisely positioned within the cell. This situation requires a means that is not only readily available within the cells but which has the necessary characteristics and reliability. As a solution to this problem the General Mills "A" frame friction-type bridge equipped with Chisholm-Moore Meteor Hoist was selected. The complete assembly is operated by remote control and consists of a hoist and crane bridge traveling on a common track system with the mechanical arm manipulator. The typical in-cell installation is shown schematically in Fig. 60, while the three outline sketches of Fig. 61 show the "A" frame end supports for the I-beam on which the hoist is supported and travels across the bridge. Section "C"-"C" shows a detail of the double-flanged wheels on which the bridge travels. Referring back to Fig. 55, the "A" frame crane bridge hoist assembly is shown in cell 2 as installed. The bridge motion and hoist travel are produced by drives similar to those employed for the mechanical arm bridge and carriage. The hoist unit includes four separate hoisting cables connected to individually braked winding drums mounted on the overhead carriage. The drums are powered by a common drive through four separate clutch mechanisms, enabling any or all cables to be controlled independently or in combination.

From the winding drums to the hook the four cables form an inverted pyramid. With this arrangement, the hook is virtually in rigid suspension and, within certain limitations, features excellent nonswinging, nonrotating characteristics. Selective control of the winding drums enables the hook to work close to cell walls by moving the hook anywhere within the perimeter of the hoist unit. Thus, the unique feature of a twist resisting, nonswinging hook having minimum hook-to-wall clearance provides a stabilized crane hoist.

The hoist specifications are as follows:

Capacity – 6,000 lb

I-beam size – 8 in. at 18.4 lb

Electrical power – 208 v ac, 3 phase, 60 cycle

Trolley driven by 1/4-hp right-angle drive motor with brake and #23 Maxitorq electric clutch (230 v dc). Motor mounted with shaft out of right side facing gear head.

Trolley speed – 16-1/2 fpm

Hoist motor – 4 hp

Two-speed hoist – 6 and 18 fpm, 18-ft lift, four parts of rope.

The hoist equipped with upper and lower screw limit switch.

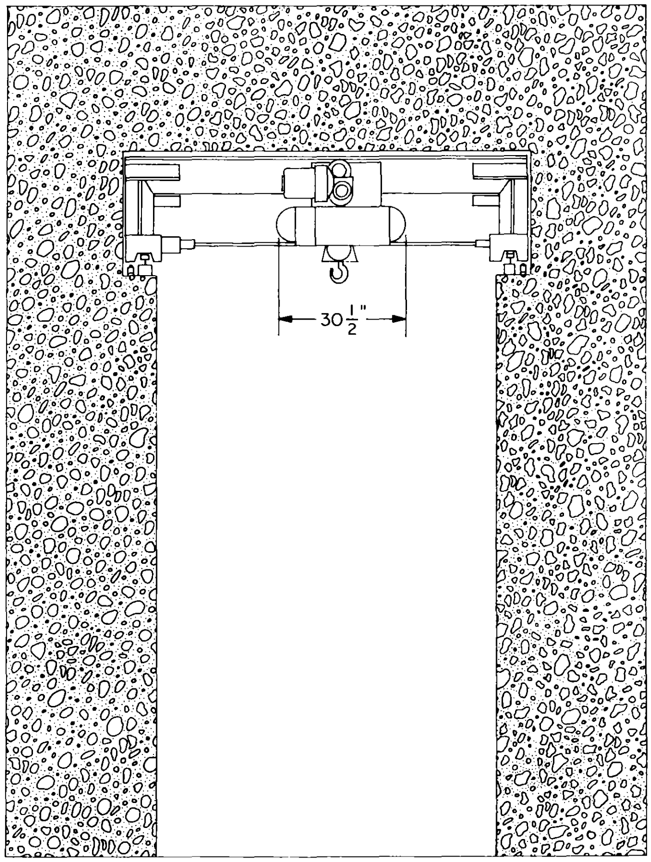


Fig. 60 - Schematic view of in-cell installation of crane hoist

The crane bridge hoist is remotely controlled from a pendant attached to a cable which is plugged into a receptacle in the front outside wall of the cells. The 24-conductor, 16-AWG cable distribution system for the crane bridge hoist is similar to that employed on the mechanical arm manipulator. The cable take-up reel arrangement which spools the 24-conductor cable for the crane bridge hoist is shown on the right side of Fig. 55.

As a safety measure, a provision was included for towing the mechanical arm manipulator bridge by the crane bridge in case the manipulator became disabled for any reason. This feature consists of a remotely operated coupling device, part of which is mounted on the trolley frame of the crane bridge hoist and the other part is shown as a white lever mounted on side of the manipulator carriage. The remote controlled coupling feature is operated from the pendant control of the crane bridge hoist.

Industrial Electrical Works, Inc., Cable Take-Up Reels

The problem of dragging and retracting the 24-conductor cables attached to both the mechanical arm manipulators and the crane bridge hoists during their travel across the width of the cells was resolved by the use of motor driven cable take-up reels. These were mounted in recessed spaces provided in the intercell walls as indicated on the design sections of Dwg. 3 and by the typical installation shown in Fig. 62. Since the distance of travel in cells 2 and 3 was shorter than the distance in cells 4 and 5, the cable take-up reels had to be designed to fit each case. For cells 2 and 3 the cable take-up

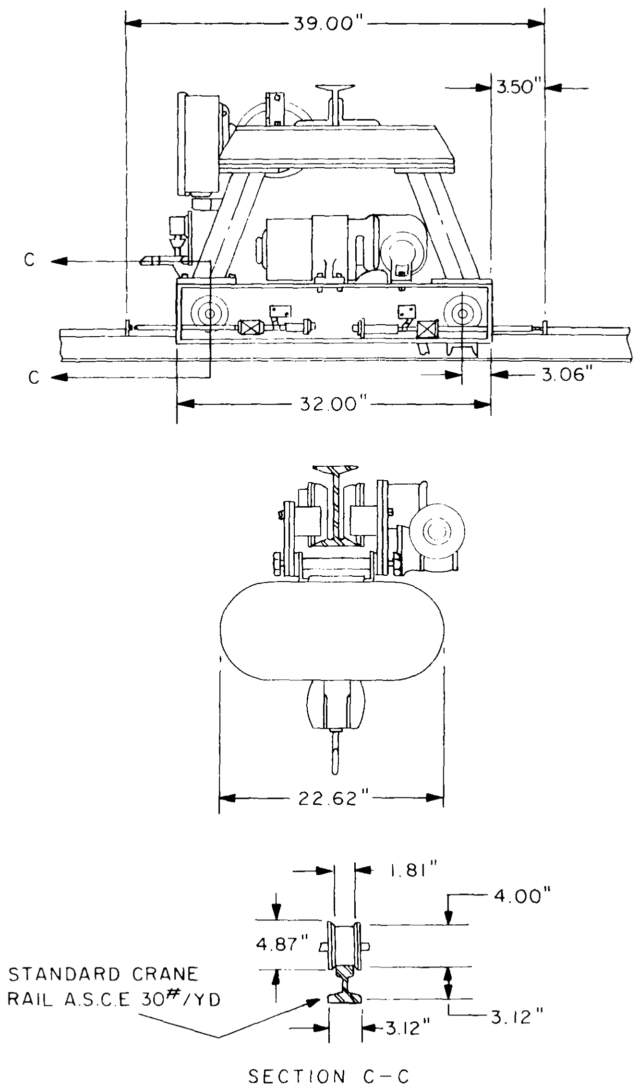


Fig. 61 - Sketches showing "A" frame end supports, bridge I-beam and trolley, and bridge wheel detail

reels were designed to drag and to retract 19 ft of 16-gauge, 24-conductor cable (1.025 in. o.d.), while for cells 4 and 5, the reels were designed to drag and retract 36 ft of the same size cable.

The outline drawing of the reel for dragging and retracting 36 ft of cable shown in Fig. 63 illustrates the design. The reel mechanism is supported on an angle frame with the motor mounted on its base. A hollow shaft mounted on antifriction bearings is attached to the top of the frame. A 35-amp 24-conductor collector ring is mounted on the right end of this shaft and a reel spool and junction box on the left end. A housing attached to the frame encloses the collector ring with the upper half removable for accessibility. The reel mechanism is driven through sprockets and roller chain as shown.

The reels are powered by 100 percent full-stall type torque motors with 3 ft/lb disc-type brake operating at 600 rpm on 208 v, 3 phase, 60 cycles. The motors are totally enclosed, nonventilated construction with a retracting speed of 314 fpm.

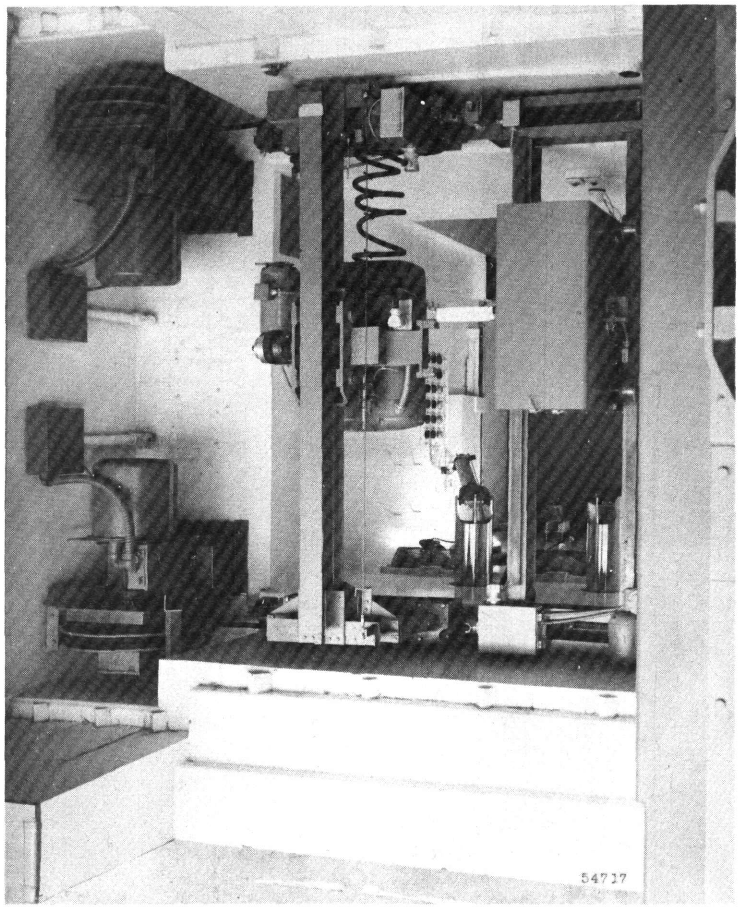


Fig. 62 - View of cable take-up reels and mounting arrangement

The installation shown in Fig. 62 is typical for all the reels and includes one reel constructed with the collector ring located on the right side and the other reel with the collector ring on the left side. This was necessary to permit spooling of the cable adjacent to each cell wall. The installation of Fig. 62 shows the electrical connections to each reel. The cabling from the receptacles on the front outside wall of the cells is brought to each junction box shown mounted in back of each reel. Connections from this junction box are carried to a junction box mounted on the frame of each reel adjacent to the collector ring housing. Connections are carried from this junction box to the collector ring. Connections from the collector ring are carried through the hollow shaft to the junction box at the extreme spool end of the shaft. Connections from this junction box are carried through the trailing cable wound on the spool to the junction box on either the mechanical manipulator or the crane bridge hoist. The reels are interlocked electrically with each piece of equipment they are connected to and operate automatically to drag or to retract the cable, depending on the direction of bridge travel. Cable guides are mounted on the frames at the bottoms of the spools to maintain the cable in a constant attitude for dragging or retracting.

Kollmorgen Wall Periscope–Model 301

The purpose of this instrument was to provide a remote means of viewing and photographing areas inside cell 4, within a solid angle of 180 degrees centered about the objective

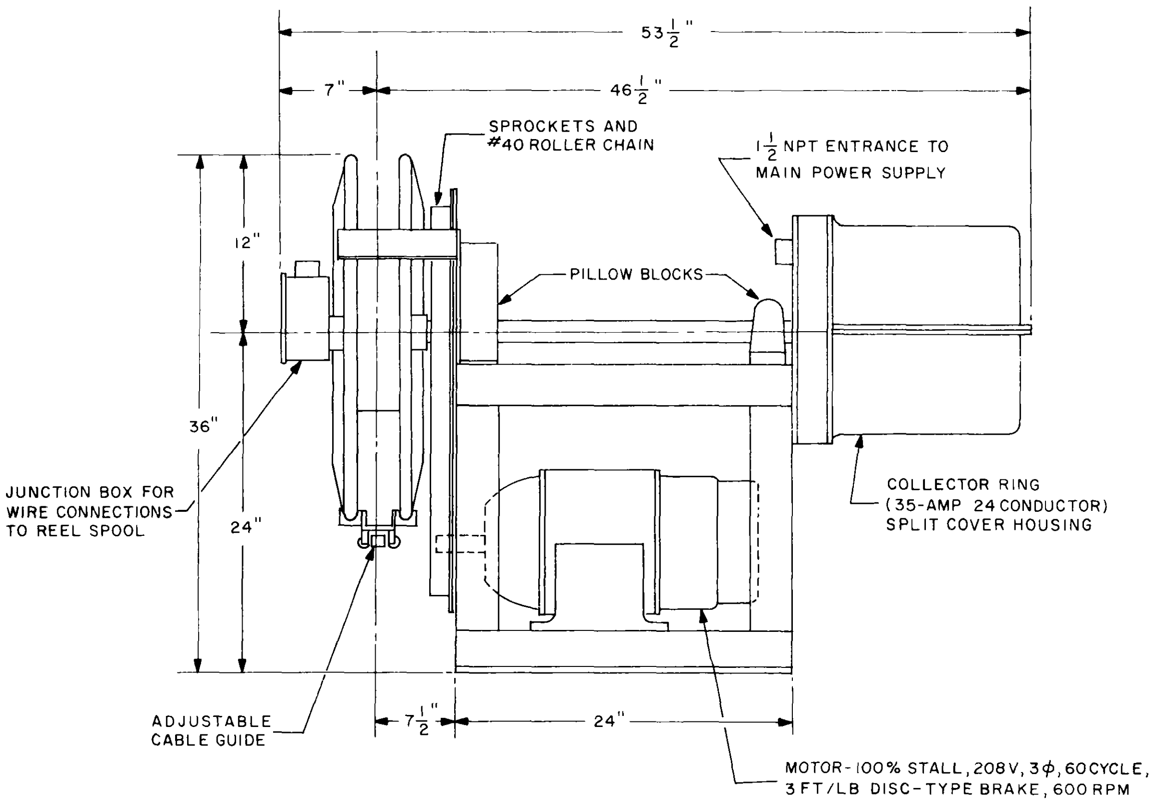


Fig. 63 - Outline of cable take-up reel (designed and mfd by Industrial Electrical Works, Inc.)

end. Since the operations anticipated in cell 4 were to include the preparation of samples by the use of machine tools, it was considered essential to provide an optical instrument that could be used for inspection of such work and to provide a means for examining and macrophotographing radioactive parts of reactor structures. The instrument selected was Kollmorgen Model 301 wall periscope with camera adapter. The installation drawing of Dwg. 12 illustrates the various parts of the instrument and the manner it is mounted in the cell wall. A cell wall sleeve with inside diameter of $8.650\,^{+0.010}_{-0.000}$ in. was provided in the cell structure for mounting the instrument. The instrument is located between two viewing windows on the left side of cell 4, as was indicated on the south wall elevation of Dwg. 2 and in mounted position in Fig. 13 to the right of the closest mechanical arm control console. The objective end inside cell 4 appears in Fig. 15 to the right of the closest manipulator slave arm.

The wall periscope is an L-shaped optical instrument designed for through-the-wall remote viewing inside a hot cell. The optical train of the instrument is contained in a sealed right-angle section composed of a horizontal arm and a vertical arm. The horizontal arm is contained within an outer tube which has a 21-in. square face plate welded to it adjacent to the vertical arm for securing the periscope assembly to the outside face of the cell wall. An externally mounted counterweight and two bearings within the outer periscope tube allow the entire periscope to swing through a 90-degree angle. The objective or "head" end of the periscope is located at the free end of the horizontal arm, while the eyepiece is located at the free end of the vertical arm. The horizontal centerline of the instrument is 7 ft above the floor. All operations of the periscope and its accessories are transmitted by purely mechanical drives.

The hemispheric scan capability of the periscope permits an observer to view and, with the camera adapter and camera, photograph any object in the hot cell within a solid angle of 180 degrees centered about the objective end. Thus, any target within the 180-degree arc from the inside cell wall may be located by a combination of two movements: rotation of the eyepiece assembly which controls the scanning head, and swinging of the eyepiece about its hinges. Rotation of the eyepiece causes the line of sight to describe a cone in the object space, and the angle of tilt of the eyepiece proper determines the angle of the cone. The pointing of the line of sight is controlled by and synchronized with the attitude of the eyepiece barrel, thus providing a true feeling of direction being viewed. All moving parts of the scanning mechanism are counterbalanced and are mounted on antifriction bearings for virtually effortless control. The image stays erect at all times, for any direction of scan. The direction of the eyepiece axis is always parallel to the line of sight so that an observer has a complete sense of orientation at all times.

The periscope is equipped with a standard 50mm visual eyepiece. The angular magnifications of the periscope with this eyepiece are 2X and 10X for an infinite object distance. For closer objects each magnification is somewhat higher. Change in magnifying power from 2X to 10X is accomplished internally through a change of objectives, actuated through a power-shift lever located on the right side of the eyepiece casting. The apparent illumination of the image is the same in both magnifications.

Internal focusing is accomplished by means of a focus knob located on the right side of the vertical tube above the power-shift lever. As measured from the head prism, the focusing range is unlimited from zero to infinity at 2X magnification. At 10X magnification the range is from 38 in. to infinity. Focusing compensates for variations in target distances and, to a lesser extent, for individual differences of observer's eyesight.

The apparent field of view at the eyepiece is 30 degrees. The true field equals the apparent field divided by the overall magnification. Thus the true field is 15 degrees at 2X and 3 degrees at 10X. The exit pupil diameter is 3.4mm at 2X and 10X with the 50mm eyepiece.

The image of the periscope is substantially free of spherical and chromatic aberrations as well as coma, astigmatism, distortion, and curvature of field. The resolution of the instrument is 60 sec of arc divided by the magnification. All light-transmitting optical surfaces are hard coated to minimize reflection losses. All aluminized surfaces are protected by a silicon monoxide coating. All optical elements in the horizontal section of the periscope are made of nonbrowning glass. The optical elements of the head and eyepiece scanning mechanisms are protected by overlapping dust seals. All other optical elements are enclosed in the L-shaped gas-tight main tube of the periscope, which is filled with dry nitrogen to prevent fogging at air-glass interfaces.

The counterweight balances the vertical arm of the periscope so that the eyepiece level can be adjusted to the eye level of the observer. This adjustment includes the extreme vertical eyepiece attitude for looking up and looking down position of an observer.

The periscope was supplied with an outside radiation shield consisting of an 11-in.-diam and 10-in.-thick lead filled drum. This radiation shield was hinged on a yoke which in turn swung about brackets welded to the large faceplate. This shielding arrangement was intended to permit retraction of the periscope from the outer tube, if necessary, after swinging the radiation shield over to one side on a parallelogram linkage. The vacant access hole in the wall was then to be shielded by swinging the radiation shield back until flush against the face plate and locked. The shielding arrangement was found to be inadequate after installation as it permitted radiation leakage to occur, and additional shielding was provided at the cell side to overcome the problem.

In order to use the periscope in conjunction with a camera, the instrument was equipped with a camera adapter which is an integral part of the instrument. It is designed for mounting a standard press camera on its bracket. A reflex-type arrangement permits instantaneous shunting of the image from the eyepiece to the ground glass of the camera by turning a conveniently located selector lever. The field seen through the visual eyepiece corresponds to the one appearing on the ground glass of the camera. The camera can be set to be parfocal with the visual image. The camera is a standard 4 in. × 5 in. Crown Graphic camera with an 8 in. (203mm) f:7.7 Ektar lens. The 8-in. lens yields an image of about 4-1/4 in. diam, resulting in a slight reduction along the width of the 4 in. × 5 in. frame.

The following external accessories were included with the periscope: filar eyepiece and filar eyepiece adapter; and interchangeable eyepieces including 25mm visual eyepiece, 25mm camera eyepiece, and 17mm visual eyepiece.

The filar eyepiece adapter is an integral part of the camera adapter. This permits the insertion of a standard 12.5X filar microscope eyepiece. Turning the camera selector and filar selector levers shunts the periscope image from the scanning eyepiece into the filar eyepiece. After calibration of the scales for a particular setup, the filar eyepiece may be operated to measure linear dimensions of an object on the stage of a microscope located in the hot cell.

The interchangeable eyepieces provide greater magnification. With the 25mm visual and camera eyepieces the field and magnification of the periscope become 7.5 degrees at 4X power and 1.5 degrees at 20X power. Exit pupil diameter is 1.7mm with focus range remaining the same as previously discussed. With the 17mm visual eyepiece the field and magnification of the periscope become 5 degrees at 6X power and 1 degree at 30X power. Exit pupil diameter is 1.5mm with no change in focus range from that discussed previously.

Bausch and Lomb Remote Control Stereomicroscope

The remote control stereomicroscope shown in Fig. 64 was designed specifically for remote visual examination and 35mm stereophotography of radioactive materials. A view of the instrument as installed is shown in Fig. 65.

The instrument consists of three main parts: the stereomicroscope proper, the horizontal instrument-sealing tube, and the external shield. The sealing tube was designed to fit into a 8.974-in. i.d. sleeve anchored in the cell wall located to the right of the viewing window of cell 1. Holes provided in the flange, part 2 of view A in Fig. 64, permit securing the assembly to the flange of the cell wall tube. A gas-tight seal between the inside and outside of the cell is achieved by means of two O-rings fitted into grooves machined in the outer tube of the instrument and by a sealed window through which the specimen is viewed. The gas-tight seal is designed to hold against a negative pressure of 1 in. water gauge. The stereographic microscope proper is designed so that it can be inserted into and removed from the outer sealing tube from the front outside face of the cell wall without disturbing the gas-tight seal between the inside and outside of the cell. The third part consisting of the radiation shield is screwed onto the stereomicroscope proper. This external shield (part 1 of view A in Fig. 64) in conjunction with internal shielding provides protection against radiation equivalent to that of 12 in. of lead, which exceeds the protection of the walls by about 2-1/2 times. The lower sketch of Fig. 64 indicates the instrument mounting in the cell wall and overall dimensions of the complete instrument assembly.

The optical system incorporates a 4X zoom system, which in combination with three sets of wide-field eyepieces and a built-in, remotely controlled, low-power supplementary lens, covers continuously the visual magnification range from 1X to 60X.

Magnifications and field sizes are as follows:

With Eyepiece Indicated	Power	Field Size (in.)
5.5X	4X to 16-1/2X *(1X to 4X)	1.12 to 0.26 4.48 to 1.04
10X	7X to 30X *(1-3/4X to 7-1/2X)	1.12 to 0.26 4.48 to 1.04
20X	14X to 60X *(3-1/2X to 15X)	0.69 to 0.16 2.76 to 0.64

*With supplementary lens attachment.

Visual magnification of the instrument is varied by operating the auxiliary lens control knob 3 and power changes knob (part 4 of view A in Fig. 64).

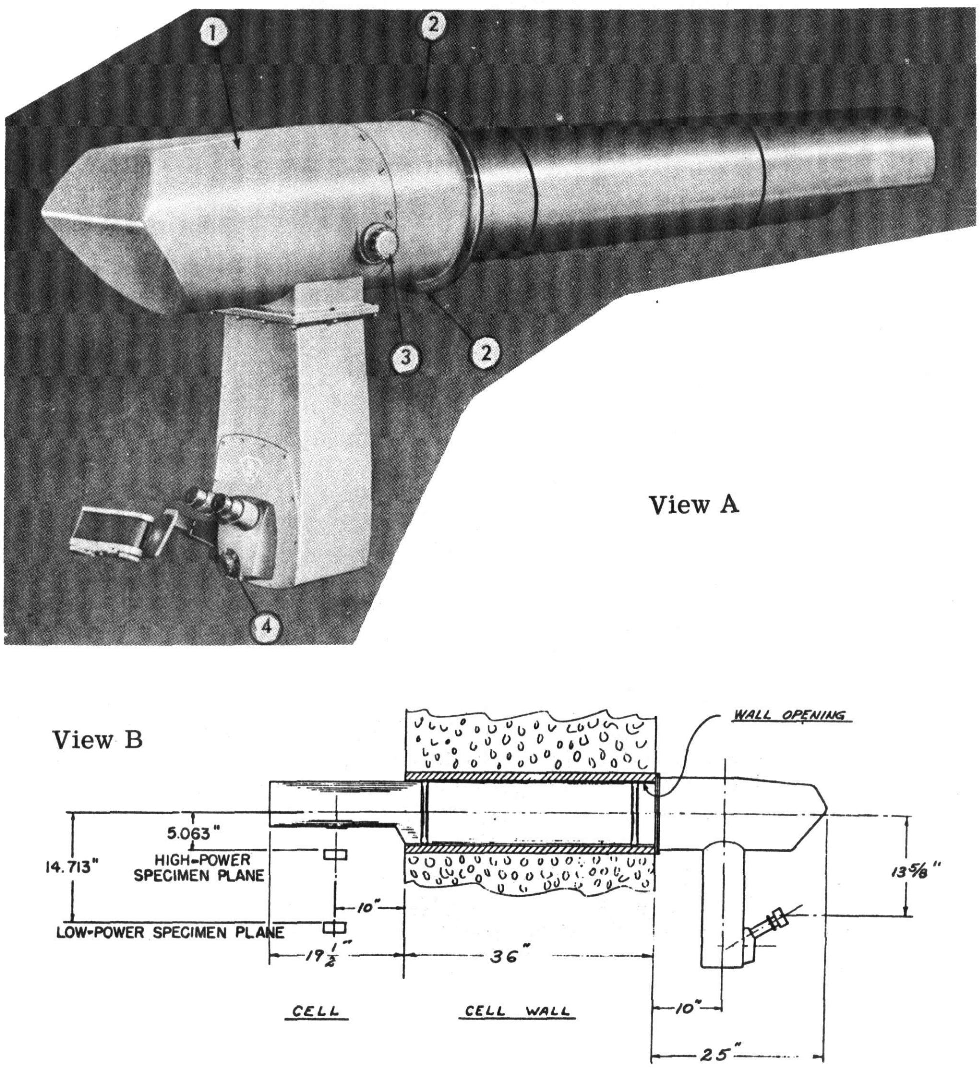


Fig. 64 - Bausch and Lomb remote control stereomicroscope: view A, assembly; view B, wall installation

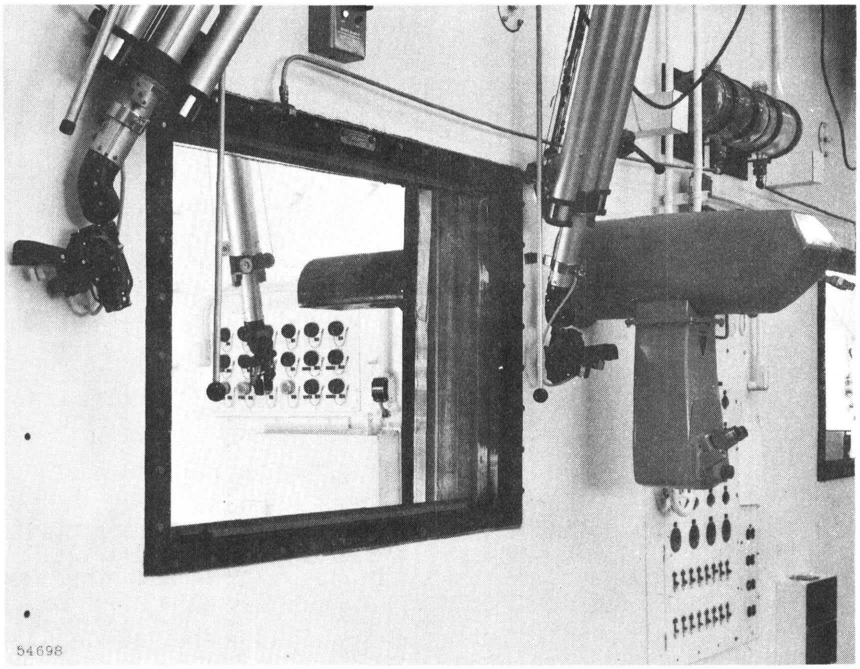


Fig. 65 - View of Bausch and Lomb remote control stereomicroscope as installed

Reichert Remote Control Shielded Metallograph

The system designed for metallographic examination of radioactive specimens included sample preparation in cell 2, transfer of samples to cell 1 via the transfer drawer between cells, transfer of samples from cell 1 through the shielding wall to a shielded metallograph stage via a specimen transporter, and viewing and photographing samples external to the metallograph shield by means of an optical relay system. The nature of the metallograph instrument did not permit locating the stage within the hot cell. The stage was enclosed in a steel shield mounted against the outside front wall of cell 1 to the left of the viewing window. Mechanical controls were brought out through the steel shield by means of linkages appropriately fashioned to prevent radiation leakage. Electrical controls were also brought out through the steel shield through special feed-throughs.

The main steel shield measures 46-1/2 in. W × 47 in. D × 33 in. H and is 8 in. thick on three sides and 6 in. thick on the bottom. The side against the cell wall was left open since this side is mounted against a 1-in.-thick sealing plate mounted on the cell wall. Under this arrangement the cell wall provides the necessary shielding. The top section of the shield consists of a removable cover which measures 46-1/2 in. W × 47 in. D × 13 in. H and is 8 in. thick on all sides except the side that seals against the cell wall sealing plate. The top cover is fitted with a 6-1/2-in. effective diameter circular shielding window, located on the same side as the remote controls on the main shield, and a plugged access port in the top located over the metallograph stage. The main shield mounted against the cell wall sealing plate is shown in Fig. 66 and the top shield is shown in place in Fig. 67. The sealing plate, the main shield, and the top cover are appropriately stepped to prevent radiation leakage at all joints. In addition, all joints are sealed by gasketing to prevent transfer of radioactive contamination from the enclosure to the outside.

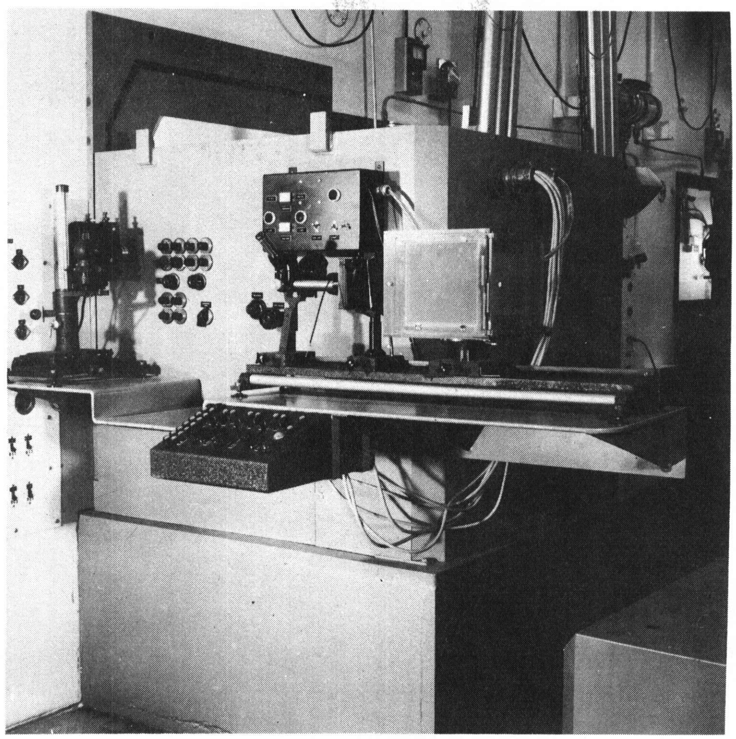


Fig. 66 - View of Reichert remote controlled shielded metallograph mounted against cell wall sealing plate

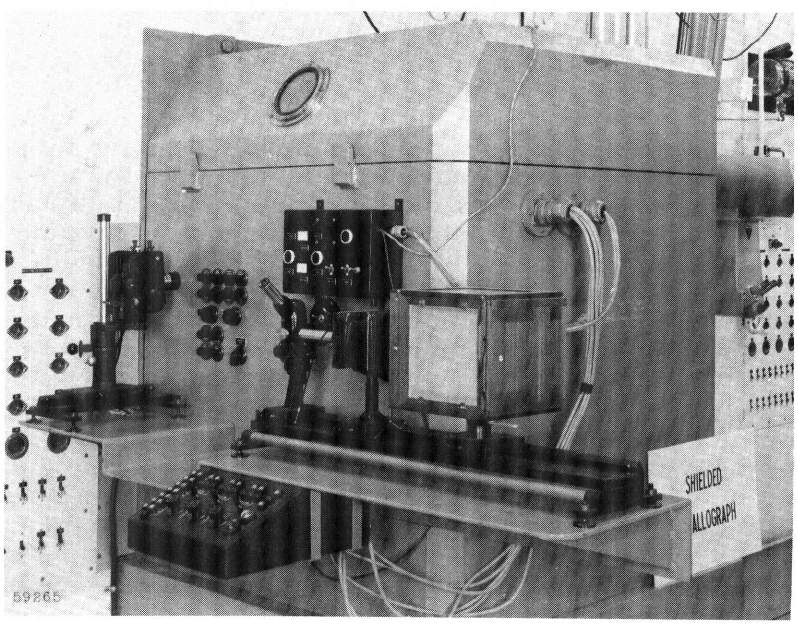


Fig. 67 - View of shielded metallograph shielding assembly with top cover in place

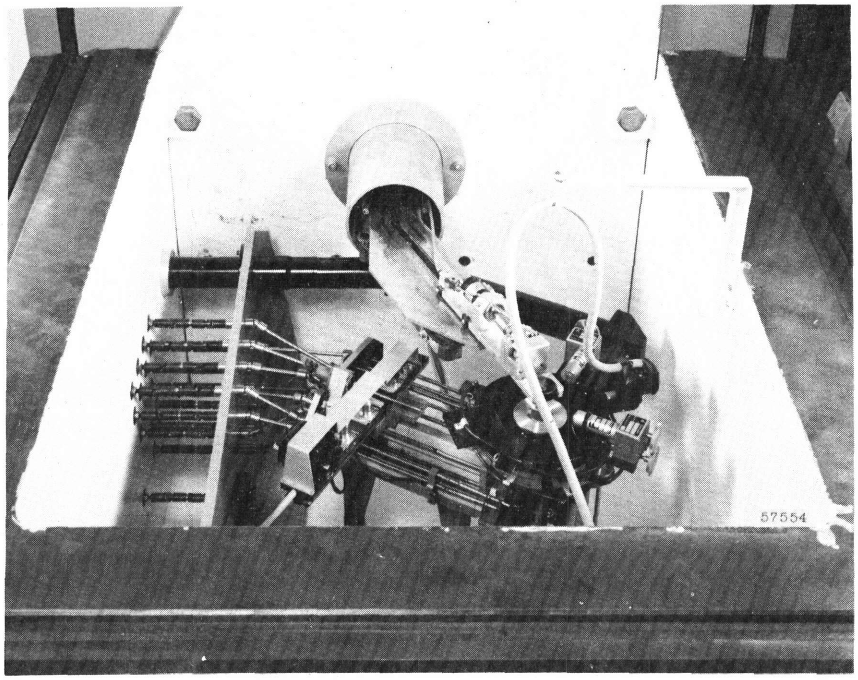


Fig. 68 - View inside shielded enclosure showing specimen transporter and metallograph stage with mechanical linkages

The transporter mechanism consists of a specimen tong assembly that travels in slotted guides mounted in a wall tube. The tong assembly is propelled from inside the cell to the metallograph stage and back again by a motor driven endless chain and sprocket arrangement. The tong assembly is actuated by a motor which upon signal closes the jaws and clasps the mounted specimen holding it firmly. When reaching the metallograph stage the jaws open and release the specimen upon signal. The view of Fig. 68 shows the portion of the transporter mechanism within the steel enclosure and the manner the mounted specimen is delivered to the stage of the metallograph. Controls for operating the transporter are mounted in a control cabinet attached to the side of the main shield above the microscope of Fig. 66.

The Reichert remote control microscope assembly consists of: an inverted-type metallurgical microscope with binocular relay system and microscope stage, an optical relay system, a vertical illuminator with relay system, and camera with relay system.

The microscope stand and microscope stage are mounted within the steel enclosure. The microscope stand is a metallurgical microscope of the inverted type with the following characteristics: extended coarse focusing adjustment, fine focusing adjustment on ball races, electrical contacts for the indication of the position of coarse and fine adjustments on a main control panel, sturdy metal baseplate with three-point leveling arrangement, geared motor for stage rotation, telescope shaft connecting stage, and geared motor. The microscope is mounted to the slide for the micrometer screw of the microscope. It contains, besides the illuminating optic, a deviating system for achieving oblique illumination, a double slide with compensator (gypsum red, first order), an auxiliary analyzer (for centering the rotatable polarizer), and a phase diaphragm slide. The built-in rotatable filter analyzer, with range of rotation of 175 degrees, can be put out of action by means of the two short shaft ends. Three levers serve for the displacement of the aperture field and dark-field diaphragm. They are operated by means of a linkage via the post for the polarizer. Two Bowden cables located close to the dovetail of the objective slide control the changeover of the microhardness tester from indentation to visual observation.

The microscope stage is a permanently centered mechanical stage, rotatable by a geared rim around the stage. The two coordinate stage motions (±7mm) are operated by two geared motors mounted to the stage itself, whereas the rotation (approx. 330 degrees) is operated by a geared motor mounted on a metal base, via the telescope shaft. All movements have electrical contacts indicating various positions and control at the control unit. The electric cables of the rotatable stage portion are joined in a plug box from which a connecting cable leads to two plug plates. A special stage insert receives the specimen (1-1/4 in. diam) which is placed onto the stage insert by means of the specimen transporter.

The post for the polarizer which is attached to the left of the microscope carries the illuminating transport optic as well as the filter polarizer in its dovetail. The polarizer is rotatable as well as disengageable by means of two short shaft ends. Four shafts supported on the post actuate the levers for the diaphragms. Two shafts mounted on the drive stand located to the right of the microscope serve for actuating the coarse and fine focusing motion with their bevelled gears.

The objective changer is located in front of the microscope on a solid cast support rigidly secured to the baseplate. The support carries two dovetail slides. In the one to the left glides a longitudinal slide, which is activated by a male shaft. This longitudinal slide carries a cross-slide which is disengageable by means of a driving shaft. The cross-slide serves as an objective magazine which accepts up to seven objectives and the microhardness tester. In the right-hand dovetail guide glides the transport slide, activated by a male shaft. This transport slide transfers the objectives to the microscope and back to the magazine by means of a coupling shaft. The connection and disconnection of the objectives are made by a special interlocking shaft. All movable slides are fitted with electrical contacts to control lamps located on the main control unit. A bearing plate is attached to the front part of the post where all operating shafts end up in universal joints which lead to the linkage support plate.

The linkage support plate shown in Fig. 68 is fastened to a baseplate. On the side of the support plate facing the steel shield are located 17 bearings for the universal joints, the shafts for coarse and fine focusing, and the microhardness tester shaft, as well as flanges of the two transport optics and six pressure proof plug plates into which all leads are centralized.

Penetrating the 8-in.-thick steel shield are located 17 connecting shafts to the linkage located in the linkage support plate, each having one of the following control knobs:

1. deviating lens for steep oblique illumination
2. compensator and auxiliary analyzer
3. phase annulus
4. rotation of analyzer
5. rotation of polarizer
6. analyzer "in" and "out"
7. polarizer "in" and "out"
8. aperture diaphragm
9. field iris diaphragm
10. dark-field stop
11. fine focusing micrometer screw

12. longitudinal slide
13. objective magazine (cross-slide)
14. transport slide
15. interlocking shaft
16. microhardness tester control
17. coarse focusing drive with locking device.

The interior illuminating transport optic is double angled and supported between the post for the polarizer and the flange on the linkage support plate. The straight exterior illuminating transport optic is inserted into the fitting sleeve of the sealing flange mounted against the inside wall of the main steel shield. The observation transport optic terminates in a ring dovetail onto which the angled phase contrast attachment is fitted. Onto another corresponding ring dovetail, the following interchangeable tubes are attached: inclined binocular tube and trinocular tube with microviewscope attachment, or inclined monocular tube with Ramsden measuring eyepiece for microhardness testing, as shown in Fig. 66. The phase contrast attachment is supported by a support which rests on the 1-m long leveling optical bench, provided with remote control device for the micrometer screw. On the optical bench is also located the 5 in.×7 in. reflex bellows camera shown in Fig. 66.

The main control unit is connected to multiple cables brought out of the end of the steel shield as shown in Fig. 66. The control unit contains the power supply cable, the central switch, switches for the change of rotation, and potentiometer for the change of velocity of the servomotors driving the elevating screw and the rotation of the stage, as well as rectifiers, transformers, and relays for operating these components. Three rows of horizontally arranged pilot lights indicate the middle and end positions, and also in-between positions, of the microscope stage. A vertically arranged row of pilot lights indicate which objective is in place on the microscope and whether it is ready for use on the objective changer, respectively. Another vertically arranged row indicates the position of the objective, that is, the prefocus position of each objective. Three, also vertically arranged, pilot lights indicate the upper, lower, and medium position of the fine focusing (micrometer screw). A warning light indicates the highest position of the microscope stage, necessary for the interchange of objectives. Another light regulates the control of the objective clutch shaft. The instrument primary power is 117 v, 60 cycles ac.

The entire optics of the instrument consists of radiation-resistant optical glass coated with antireflection coating.

Illumination is provided to the microscope through the illuminating relay optics by means of two light sources, a 200-watt mercury vapor arc and a 100-watt zirconium arc lamp, interchangeable, and equipped with separate power supplies.

The instrument as equipped provides a capability for remote metallographic examination and photography of radioactive specimens under bright and dark field and oblique illumination, reflected polarized light, and for microhardness testing.

Miscellaneous Collateral Equipment

<u>Gamma Alarm Detectors</u> – A multistation gamma detection alarm system was planned as a first approach for the control of safety devices related to cell access doors that included indicating lights, solenoids, and annunciator panel. The instrument selected was Model GA-2 detector system of Nuclear Measurements Corporation. This is a compact self-contained instrument which operates on a 115-v circuit. For in-cell use the detector or photomultiplier tube is detached from the power supply and mounted inside the cell

while the power supply is mounted on the outside back wall of the cell. The detector and power supply are connected by a cable passed through a U-tube under the back cell wall. Control wiring from indicator lights, solenoids, and annunciator connects to relays provided in the instrument power supply.

The characteristics of the Model GA-2 detector are as follows: gamma activity detection of 20 kev and up; precision of ±20 percent at all levels; sensitivity: basic range 0.05 to 50 mr/hr logarithmic; time constant of 2 sec; stability ±2 percent full-scale detection; crystal type sodium-iodide thallium activated; temperature sensitivity, 20° to 150°F; Off-On control switch, Alert, and Alarm settings on indicating meter; power requirement, 45 v-amp, 60 cycle, 90-130 v ac; high-voltage supply adjustable 600 to 950 v; power supply enclosed in dust-tight enameled steel cabinet. Special features of the instrument included: power supply totally regulated, alarm and alert points separately adjustable over all scale, and insensitive to line transients.

Under alarm conditions with the radiation field greater than the full-scale indication, the GA-2 instrument continues to operate showing full-scale deflection even in the presence of 1000 roentgens. The instrument does not jam and continues to operate until the radiation field falls to a level equal to a full-scale deflection or less. When the activity has dropped to within indicating range of the instrument, it will continue to read accurately.

The self-contained version of the Model GA-2 instrument wherein the detector is contained in the case with the power supply was also provided for monitoring other areas besides the cells. One of these units was shown in Fig. 29 located on the wall, back of the suspended isotope storage well plug.

Ultrasonic Cleaning Devices – In the preparation of metallographic samples, surfaces to be examined under the microscope must be rendered optically flat. The polishing operation usually requires the use of abrasives of varying grit sizes. When proceeding from coarser to finer grit during polishing it is necessary to remove all vestiges of the coarser grit particles from the sample and its mount, otherwise the sample surface will show the effects of scratches from the coarser grit. Removal of previous grit is generally accomplished by thorough washing of the sample surface and its mount. In the case of radioactive samples, the cleaning operation is not only concerned with the removal of previous grit but also with radioactive contamination generated during the polishing operation.

The machining of radioactive materials generates radioactive contamination in the form of metallic dust and fine particles which lodge in tool marks. To prevent spread of contamination, it is necessary to remove loose contamination not only from the machined sample but also from the turning tools, milling cutters, fasteners, etc.

Cleaning operations to remove radioactive contamination must be performed remotely. The cleaning action of ultrasonic energy was considered to be an efficient method for not only cleaning objects to remove adherent particles but to remove contamination as well. Since the ultrasonic cleaning equipment was required to operate remotely, it was necessary to select equipment whose design did not require manual adjustment of ultrasonic activity in the cleaning tank. To meet this requirement, it was considered necessary that the ultrasonic generator circuitry continually measure the level of ultrasonic energy and automatically tune the generator output to optimum operating condition without operator attention. A further requirement for in-cell operation of ultrasonic cleaning equipment was that the equipment would function at peak efficiency and provide maximum cleaning action even when the load impedance varied because of changes in loading temperature, liquid level, or even carelessness of the operator. The equipment was expected to withstand such oversight as low liquid level or no load operation, and not cause damage to any of the components or impair the efficiency. To provide remote control of the equipment it was necessary for the transducerized tank to be separate from the ultrasonic generator so that the tank could be located in the cell and the generator and its controls located outside the cell.

For in-cell cleaning of metallographic samples, two Powertron Ultrasonic Corporation ultrasonic cleaners were selected, consisting of an ultrasonic generator and a 2-1/2 gal capacity stainless steel transducerized tank connected by 25-ft rf cable. The generator has an average power input of 100 w and a peak power of 400 w at 28 kc, automatically tuned. The tank is rated at 100 w at 28 kc and is 6 in. W × 9 in. L × 10 in. H inside dimensions and 6 in. W × 9 in. L × 14-1/2 in. H overall dimensions with an outlet for recirculating pump and filter system. The tank is equipped with a covered basket which holds the objects in the cleaning bath and which can be removed from the tank for removal of the objects.

The ultrasonic cleaners provided for the cell machine shop were Powertron Ultrasonic Corporation cleaners consisting of a transducerized tank and generator connected by 30-ft rf cable. The generator is rated at 7 amps, 115 v, 60 cycle average power input. Output power is 300 w average, with 1200 w peak, and a frequency of 28 kc automatically tuned. The tank is rated at 5 gal capacity, 300 w at 28 kc with a compartment 9 in. W × 14 in. L and 10 in. deep and 9 in. W × 14 in. L and 14-1/2 in. deep overall and an outlet for recirculating pump and filter. The tank is equipped with basket and cover for holding the objects during cleaning.

For general use in cleaning tools in the warm machine shop, two complete Powertron Ultrasonic Corporation self-tuning cleaners were provided having the following characteristics:

<u>Ultrasonic generator</u> – average power output 700 w, peak 2800 w, 28 kc; operating at 115 v, 60 cycle; 14-amp primary.

<u>Transducerized tank</u> – 700 w, 28 kc; 8-gal capacity compartment, size 14 in., × 14 in. × 10 in. deep; overall dimensions 14 in. × 14 in. × 14-1/2 in. high tank connected to generator with 6-ft rf cable.

For general use in the decontamination room, an immersible transducer model was provided which could be used in any suitable container. This unit was also a Powertron Ultrasonic Corporation self-tuning cleaner composed of an ultrasonic generator with average power output of 700 w, peak power of 2800 w, 28 kc, primary power 115 v, 60 cycle, 14 amp. The immersible transducer was jacketed in stainless steel – 4 in. W × 30 in. L and 4 in. deep – and connected to the generator with 6 ft of waterproof stainless braid cable.

<u>NUMEC Cathodic Vacuum Etcher</u> – The cathodic vacuum etching technique was selected for etching radioactive metallurgical samples for microscopic examination since this method offered many advantages that could not be obtained by conventional methods of chemical and electrolytic etching. These include: grain boundaries and impurity inclusions are not excessively attacked; specimen surfaces are not pitted; the depth of etch is easily controlled by varying the sputtering time; the specimen is free from chemically active etching reagent stains and other surface contaminants; and the technique etches and preserves dissimilar metals and the interface. The method eliminates entirely the need for etching liquids and solutions which present complex operational problems in hot cells, thus making it the most practical method for etching samples remotely in a hot cell.

Cathodic etching or ion bombardment is a method for delineating the microscopic structure of metals, ceramics, and cermets for microscopic examination. The process is essentially a sputtering phenomenon in which selective removal of atoms occurs by positive ion bombardment of the sample surface (made cathodic) in a glow discharge system. The glow discharge is generated by applying a high dc potential between two electrodes (one of which is the specimen) in a partial vacuum. The theory of sputtering has been the subject of considerable interest and has been extensively reported on in the scientific literature. The accepted theory of the sputtering phenomenon is that the impingement of high-velocity gas ions on the cathode (sample) surface dislodges cathode atoms or molecules, resulting in a net removal of material from the surface. Unlike chemical and electrochemical etching, the region of variation in cathodic etching is narrower. The number of variables are fewer since the system does not use combinations of chemicals in solution. The effective variables are time, voltage, current, type of gas and its pressure, and temperature. Experience with cathodic etching has shown that the efficiency in removing material is best with a heavy gas. The logical choice is an inert gas such as argon since it is the heaviest inert gas that is readily available at reasonable cost.

The cathodic etching equipment was obtained from Nuclear Materials and Equipment Corp. (NUMEC) and consists of an etcher console and a control console. The etcher console contains the vacuum system and the vacuum etching chamber as illustrated schematically in Fig. 69. The remote portion of the equipment is located inside the cell while the control console which contains the power supply and control instrumentation is situated outside the hot cell on the viewing window side.

The power supply delivers up to 5 kv and 50 ma rectified dc current with voltage overload protection, current limiting resistance, and positive ground.

The vacuum system is arranged to permit pumping through a diffusion pump and a fore pump with provision for a diffusion pump bypass which permits roughing down with the fore pump. The system consists of a 2.1-cfm two-stage mechanical pump, a 2-in., three-stage fractionating diffusion pump, three motor-operated vacuum valves, flushing valve, controlled inert gas leak regulating valve, and a vacuum interlock for safety.

The etching chamber consists of a glass bell jar and baseplate on which the cathode sample holder is mounted. Solenoid valves control the raising and lowering of the bell jar. The cathode sample holder is water cooled. Gas pressure has a variable range of 25 to 300 microns. Consistent rapid etching is expected at about 150 microns and 3500 v with a resulting current of from 2 to 3 ma per sq cm of sample surface area.

<u>Metallographic Specimen Cutter And Mounting Press</u> – The lack of ready made equipment for the preparation of metallographic specimens in hot cells made it necessary to select certain basic units which could be modified for remote operation.

A metallographic specimen cutter was selected in which the metal specimen is fully submerged during the cutting operation. This produces a cut surface ready for mounting and polishing without intermediate grinding. Through the use of a special slow-speed (2,200 rpm) abrasive wheel on a completely submerged sample held rigidly in position, a perfect cutoff is possible without burning or grain distortion. The cutter is capable of cutting specimens, from thin sheet material to pieces 1-1/2 by 8 in., with cuts parallel within 0.0003 in. The machine is equipped with a calibrated rod and pointer which indicates the depth of cut while cutting speed is positively controlled by means of rack and pinion. The cutter is driven by a 1-1/2-hp motor designed for long life under heavy duty operation and mounted on an adjustable frame to maintain proper belt tension and is controlled by a three-position switch. The machine is self contained and stable, requiring no bolting to the floor.

A semiautomatic mounting press was selected which requires a maximum of about 10 min to produce a good hard mount. A major requirement for the metallographic specimen mounting was for a hard mounting which adhered to the specimen, which did not clog polishing laps, and which polished down at the same rate as the metal specimen to produce a flat surface which was both efficient and practical.

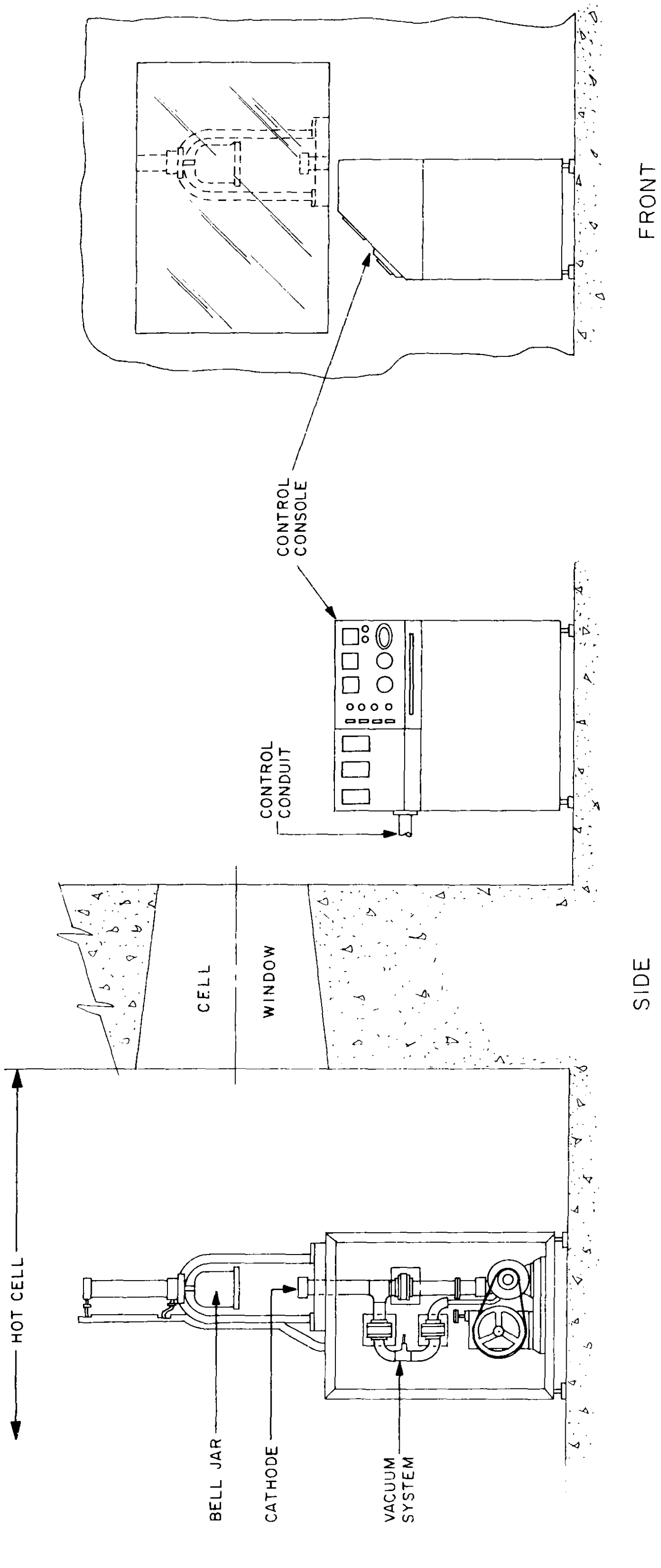


Fig. 69 - Schematic arrangement of NUMEC cathodic etcher in hot cell

The mounting press utilizes air for its operation which insures quality mounting and efficient production. The air cylinder is operated by a simple lever on the side of the cabinet. Raising the lever raises the mold piston for inserting the specimen; then, lowering the lever lowers the piston for loading the molding powder. The bell-type head is locked securely by means of a four-spoked wheel, and air pressure is applied until the timer alarm indicates the end of the curing period. Since the heater, mold, and piston are permanently assembled there are no loose parts to handle. The mold is electrically heated, thermostatically controlled by dual thermostats, and insulated to keep heat loss to a minimum.

Laboratory Furniture and Equipment

The types of laboratory furniture and equipment and the layout in each laboratory area are shown in Dwg. 13. Working surfaces on top of all base cabinets in sinks and hoods are of soapstone. The soapstone is hard, natural silicate rock of massive formation without laminations, stratifications, or cleavage planes and is finely granular in all directions. This grade of soapstone has the following physical properties: minimum modulus of rupture of 3,000 psi in any direction, minimum abrasive hardness of 15 per sq in., maximum water absorption of 0.12 percent by weight in 43 hours. Thickness of soapstone on working surfaces is 1-1/2 in. in fume hoods and in sinks and 1-1/4 in. on counter tops. Exposed edges of working surfaces are rounded and a drip groove is provided on the under front side of counter tops. Joints in slab sections are flush and permanently tight. Working surfaces are of honed finish on all exposed sides.

Built-in service fixtures are especially designed for laboratory use. Faucets and cocks for water, steam, gas, and air are of solid brass with acid resistant plastic coating of color matching base cabinets. Water and steam valves are provided with renewable seats and washers. Gas and air cocks are of ground key construction with each handle equipped with a code color index button. Sinks are equipped with combination hot and cold water swing faucet. A gooseneck faucet with serrated taper is provided at cup drains. Cup sinks are of high-silicon iron, oval shape, 6 in. by 3 in., set flush with counter top. Laboratory sinks are equipped with plug, overflow pipe, drain outlet, and tailpiece of high-silicon iron.

Base and wall cabinets are of steel construction coated with a high-temperature baked-on enamel. The finish is designed to be resistant to the following immersion tests: (a) at room temperature with no effect – cold water for 18 hr, nitric acid solution (1 part acid to 9 parts water) for 18 hr, sodium hydroxide (10% solution) for 6 hr, acetic acid (glacial) for 15 min with very slight softening, acetone for 15 min, ethyl alcohol (95% solution) for 15 min, ethyl ether for 15 min, xylol for 15 min; (b) in boiling solution with no effect – sodium hydroxide (10% solution) for 1 min, water for 2 hr.

Perchloric acid fume hood (FH-1) has superstructure, baffles, condensation troughs, waste water troughs, and working counters all constructed of soapstone. Counter has raised front edge to protect against spillage. Service hose end fittings are provided with remote controls and indexed handles. Water waste trough is equipped with plug, drain outlet, and tailpiece of high-silicon iron. Hood is provided with wash-down facilities for handling of perchloric acid. Wash-down assembly consists of a stainless steel pipe with water nozzles with controllable water consumption limited to a maximum of 4.5 gal per min. Hood is equipped with a vapor proof light mounted integrally in the hood roof. Sliding window sash is 1/4-in. thick safety glass set in stainless steel frame and track. Counterweights are concealed, made of lead, and operated by means of monel and bronze pulleys.

Radioactive fume hood (FH-2) has the entire hood exterior including baffle and counter constructed of 0.05-in.-thick stainless steel, except working surface which is of 1-1/2-in.-

thick soapstone. Service hose fittings are remote controlled with indexed handles. Hood is lighted with a vapor proof fixture mounted integrally with hood roof. Electrical outlets, light switch control, and pilot light for blower operation are mounted at hood front. Hood is equipped with an automatic proportional bypass damper. Sash is of 1/4-in. thick safety glass set in stainless steel frame and track. Counterweights are concealed, made of lead, and operated by means of monel and brass pulleys.

SHIELDING INTEGRITY TESTS

The shielding integrity of the hot cells was tested with Co-60 sources of 20, 800, and 9,500 curies, respectively, by the NRL Health Physics Staff.

A preliminary check of the shielding of all cells was made using a 20-curie source to locate any major shielding weaknesses prior to testing with sources of higher intensity. The source was positioned at various locations in each cell and the resulting radiation intensities reporting outside the cell shielding were measured. Special attention was given to the shielding windows, areas around the windows, shielding doors, and other possible weak spots in the structural shielding. All readings were taken with the source positioned from 12 to 15 in. away from the inside face of the cell wall, except in the case of the cell roof. Readings in this case were taken at the outside surface with the source positioned in the cell from 8 to 10 ft from the top of the roof. The results of the preliminary survey with the 20-curie Co-60 source indicated no major weakness in the structural shielding. The general radiation background outside the cells was less than 0.1 mr/hr.

The structural shielding of all cells was next checked with an 800-curie Co-60 source using the same general survey procedure that was used with the 20-curie source, except that the 800-curie source was frequently positioned to within 1 in. of the inside surfaces of the cell walls, and of the shielding windows and doors. The results of the survey with the 800-curie source indicated no major structural shielding weakness and, in general, the readings on the outside surfaces were less than 0.1 mr/hr. Three local points of radiation leakage, however, were detected by the survey. Radiation leakage was detected through the wall penetration of the periscope in cell 4 when the source was positioned in close proximity to the objective end of the periscope. As a result radiation intensities of up to 2 r/hr were detected in the "cold" work area outside the front cell wall. Radiation leakage was also detected in the "cold" work area at the transfer drawer penetration in the west wall of cell 1 and at the vacant electrical receptacle panel in the outside wall. Readings of 30 mr/hr and 50 mr/hr, respectively, were obtained at these points in the "cold" work area. In order to eliminate these leakages, 4-in. long lead sleeves were added at the objective end and at the outside end of the periscope wall penetration, the transfer drawer cavity was blocked off with a lead barrier 2 in. thick, and the vacant receptacle panel was blocked off with 1 in. of steel, and a 2-in.-thick lead plug was positioned at the point showing the greater amount of leakage. The transfer drawer cavity and the vacant receptacle panel, both in the east wall of cell 5, were shielded in the same manner. A subsequent test of these areas made with the 800-curie source showed a radiation intensity of 20 mr/hr in the "cold" work area at the periscope wall penetration and the source in line with the penetration, while the radiation intensity at the west wall did not exceed 1 mr/hr when the source was positioned to within 1 in. of the cell side transfer drawer cavity and the inside cell wall opposite the vacant receptacle panel.

A final check of the shielding integrity of the hot cells was carried out using a 9,500-curie Co-60 source. Special attention was again given to the shielding windows, shielding doors, roof plugs, intercell gates, and areas around the windows, doors, and other possible points of shielding weakness as disclosed by previous tests. The source was generally maintained at a distance of 1 ft from the inside cell wall except for an occasional spot check of suspected weak areas in the shielding. Readings at the top of the cell roof were taken with the source positioned in the cell at a level of approximately 8 ft from the top of the cell roof. Although the shielding of cells 1 to 3 inclusive was designed to attenuate only 1,000 curies of 1-Mev gamma, these cells were checked out with the 9,500-curie source together with cells 4 and 5 whose shielding was designed to attenuate 10,000 curies of 1-Mev gamma. The results of these tests showed that the structural shielding of the cells attenuated the radiation intensity from the 9,500-curie source to less than 0.1 mr/hr, which bettered the design requirement of 0.6 mr/hr by a considerable margin. Radiation intensities which exceeded 0.1 mr/hr were generally observed to occur: at joints between shielding doors themselves, between shielding doors and door jambs, between the bottom of the shielding doors and the door sill; at stepped joints of roof plugs; and through various penetrations in the cell walls. These readings reflected unusual test circumstances in most cases which would not be expected to prevail during normal manipulation of sources in the cells. Under normal conditions of operating each cell according to its prescribed source strength limits, the "cold" work area at the operating face of the cells and the "warm" work area back of the cells would not exceed the design limit of 0.6 mr/hr. In the event of unusual circumstances regarding source strength and its manipulation, additional shielding could be added to the various areas discussed above. Test results with the 9,500-curie Co-60 source are listed in Table 8. The structural shielding between cells was likewise found to be free from major weaknesses. The areas in which readings greater than 0.1 mr/hr were observed were at the joints: between the bottom of the intercell gate and the fixed intercell wall; at edges of shielding doors for transfer drawers; and at intercell receptacle panels. These areas are amenable to addition of extra shielding as may be needed. It is therefore concluded that the shielding integrity of the hot cells makes it safe to expose and manipulate sources up to 1,000 curies of 1-Mev gamma in cells 1 to 3 inclusive and sources up to 10,000 curies of 1-Mev gamma in cells 4 and 5 without exceeding a radiation intensity of 0.6 mr/hr in the general working areas.

As conceived, this facility provides NRL with an unusual long-range capability for conducting research on radioactive metals and other materials of interest to the Navy. The many features embodied in the design assure that research on radioactively dangerous materials can be efficiently and safely carried out by remote means and that the waste by-products of the research can be properly collected, concentrated, and stored.

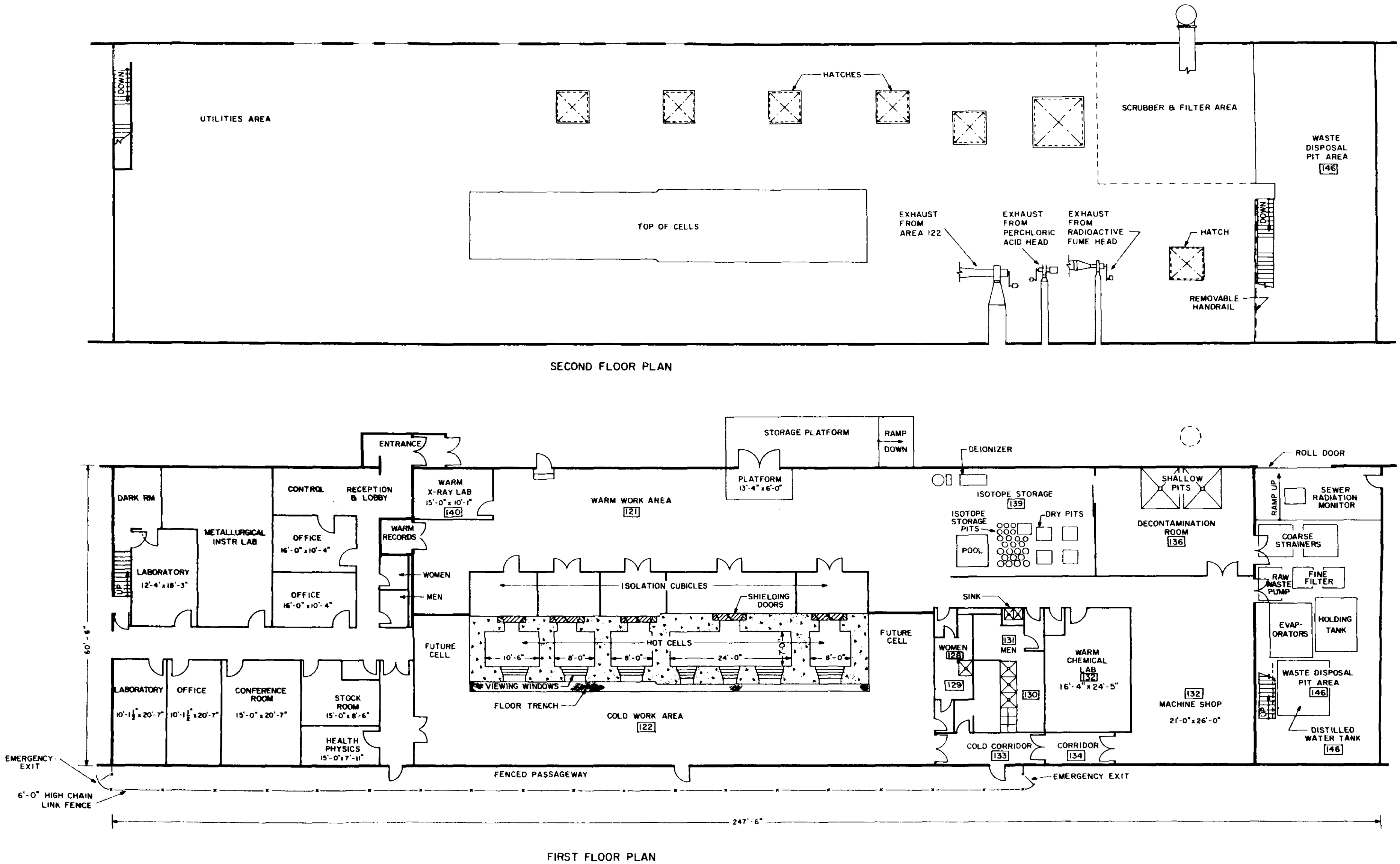
Table 8
Shielding Tests With 9,500 Curie Co-60 Source

Cell	Side of Cell Tested	Radiation Intensity (mr/hr)	Specific Location Where Reading Was Taken
1	West Wall	< 0.1	Structural shield
		1.5	Vacant panel box in outside cell wall
		2	Shielding door in front of transfer drawer cavity
	Front Wall	< 0.1	Structural shield
		40	Center stereomicroscope wall penetration with source in line
		5	18 in. below center of wall penetration with source in line
		4	Center stereomicroscope wall penetration with source 18 in. below center
		1.5	18 in. below center of wall penetration with source 18 in. below center
	Rear Wall	< 0.1	Structural shield
		15	Joint between side of shielding door and door jamb
		50	Joint between bottom of door and door sill
		70	At outer surface of door with source 2 in. from center of door
		4	At 3 ft from door with source 2 in. from center of door
	Roof	< 0.1	Structural shield
		4	At stepped joint, north end, first roof plug from left side of cell 1
		6	At stepped joint, south end, first roof plug from left side cell 1
		15	At stepped joint, south end, third roof plug from left side of cell 1
		10	At stepped joint, east side, fourth roof plug from left side of cell 1
	East Wall (intercell)	< 0.1	Structural shield
		120	Spot in right-bottom corner of in-cell receptacle panel box
2	West Wall (intercell)	< 0.1	Structural shield
	Front Wall	< 0.1	Structural shield
		75	Left manipulator wall penetration with source above window, 3 ft from wall
		100	Right manipulator wall penetration with source above window, 3 ft from wall
		2	Cold work area at front cell wall with source above window, 3 ft from wall
		0.4	Cold work area at front cell wall with source at center of window
	Rear Wall	< 0.1	Structural shield
		400	At clearance gap under door with source 1 ft from door, 2 in. above floor
		30	3 ft from door, 1 ft above floor, with source 1 ft from door, 2 in. above floor
		2	3 ft from door, 3 ft above floor, with source 1 ft from door, 2 in. above floor
		10	6 ft from door, 1 ft above floor, with source 1 ft from door, 2 in. above floor
		40	At clearance gap under door with source 2 ft from center of window
	Roof	< 0.1	Structural shield
		95	Joint, north end, 1st roof plug left of cell 2
		50	Joint, north end, 2nd roof plug left of cell 2
		75	Joint, south end, 2nd roof plug left of cell 2
		20	Joint, north end, 3rd roof plug left of cell 2
		30	Joint, south end, 3rd roof plug left of cell 2
		25	Joint, south end, 4th roof plug left of cell 2
	East Wall (intercell)	< 0.1	Structural shield
		30	Lower left corner of in-cell receptacle panel box
		6	Bottom joint between shield door for transfer drawer and cell wall
		13	Top joint between shield door for transfer drawer and cell wall
		120	Center of cell 3 with source 1 ft from bottom edge intercell gate
		4	Center of cell 3 with source at in-cell receptacle panel box
3	West Wall (intercell)	< 0.1	Structural shield
	Front Wall	< 0.1	Structural shield
	Rear Wall	< 0.1	Structural shield
		10	Joint between top of shield door and door jamb
		14	Stepped closure joint between door halves
		500	At clearance gap under door with source 1 ft from door, 2 in. above floor
		40	3 ft from door, 1 ft above floor, with source 1 ft from door, 2 in. above floor
		25	3 ft from door, 3 ft above floor, with source 1 ft from door, 2 in. above floor
		2	3 ft from door, 6 ft above floor, with source 1 ft from door, 2 in. above floor
		250	At clearance gap under door with source 1 ft from door, 1 in. above floor

Table 8 (Cont'd.)
Shielding Tests With 9,500 Curie Co-60 Source

Cell	Side of Cell Tested	Radiation Intensity (mr/hr)	Specific Location Where Reading Was Taken
3 (cont'd)	Roof	< 0.1	Structural shield
		17	Stepped joint, left side of 1st roof plug, left side of cell 3
		8	Stepped joint, right side of 2nd roof plug, left side of cell 3
		25	Stepped joint, south end of 2nd roof plug, left side of cell 3
		7	Stepped joint, south end of 3rd roof plug, left side of cell 3
		6	Stepped joint, right side of 4th roof plug, left side of cell 3
		2.5 r/hr	At surface intercell gate housing with gate retracted and source being passed between cells 2 and 3
		200	At surface of intercell gate housing with gate in closed position
	East Wall (intercell)	< 0.1	Structural shield
		1	At outside surface of shielding door for transfer drawer
4	West Wall (intercell)	< 0.1	Structural shield
	Front Wall	< 0.1	Structural shield
		40	Center periscope wall penetration, source in-line, 2 ft from wall
		< 1	General area around cell windows under above conditions
		1.5	In proximity of periscope, source at window center, 1 ft away
		< 0.3	General work area around windows under above conditions
	Rear Wall	< 0.1	Structural shield
		1	Joint between top left side of door and door jamb
		4	Joint between bottom left side of door and door jamb
		30	Clearance gap under left half of shield door
		55	Clearance gap under right half of shield door
		5	Closure joint between halves of shield door
		2	Joint between top right side of shield door and door jamb
		3	Highest reading in general area outside back of cell 4 – source 2 in. from floor, 1 ft from door
	Roof	< 0.1	Structural shield
		19	Joint, left side, 1st roof plug from left side cell 4
		10	Joint, north end, 2nd roof plug from left side cell 4
		30	Joint, north end, 3rd roof plug from left side cell 4
		50	Joint, left side of fifth roof plug from left side of cell 4
		40	Joint, lower right corner, 5th roof plug from left side cell 4
		70	Joint, north end, 6th roof plug from left cell 4
		280	Surface of intercell gate housing with gate in closed position and source in cell 4
		2 r/hr	Surface of gate housing, gate retracted – during transfer of source from cell 4 to cell 5
	East Wall (intercell)	< 0.1	Structural shield
		800	Cell 5, left side of gate joint between gate and wall
		300	Cell 5, right side of gate joint between gate and wall
		2	In-cell receptacle panel box
		5	Shield door of transfer drawer
		30	Center cell 5, 6 ft from floor – source at bottom gate edge
		1	Highest reading center cell 5, source at window center cell 4
5	West Wall (intercell)	< 0.1	Structural shield
	Front Wall	< 0.1	Structural shield
	Rear Wall	< 0.1	Structural shield
		15	At clearance gap under left half of shield door with source 2 in. from floor, 1 ft from door
		45	At clearance gap under right half of shield door with source 2 in. from floor, 1 ft from door
	Roof	< 0.1	Structural shield
		10	At stepped joint, left side of 2nd roof plug from left of cell 5
		60	Stepped joint, lower left corner of second roof plug from left of cell 5
		15	Stepped joint, north end of 2nd roof plug from left of cell 5
		9	Stepped joint, north end of 3rd roof plug from left of cell 5
		13	Stepped joint, south end of 4th roof plug from left of cell 5
	East Wall (outside)	< 0.1	Structural shield
		2	At outside vacant receptacle panel box in cell wall

DRAWINGS



Dwg. 1. Floor plan of first and second floors of facility

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Legend for Numbered Items in Dwgs. 2-4 Inclusive

1. Internal transfer drawer through 36-in.-thick wall
2. 30 in. × 48 in. shielding window through 36-in.-thick wall
3. General Mills Model 303F mechanical arm manipulator
4. AMF Heavy Duty Master-Slave Manipulator through 36-in.-thick wall
5. Intercell gate assembly
6. General Mills crane bridge hoist
7. U-tube, 2-1/2-in. schedule 40 stainless pipe beneath 36-in.-thick wall
8. Wall plug through 36-in.-thick wall
9. Internal transfer drawer through 42-in.-thick wall
10. Under-window access opening through 42-in.-thick wall
11. 30-in. × 30-in. shielding window through 42-in.-thick wall
12. Kollmorgen Model 301 through-the-wall periscope – 42-in.-thick wall
13. 30-in. × 48-in. shielding window through 42-in.-thick wall
14. AMF Heavy Duty Master-Slave manipulator through 42-in.-thick wall
15. Wall plug through 42-in.-thick wall
16. U-tube (electrical), 2-in. schedule 40 stainless pipe underneath 42-in.-thick wall
17. Single shielding door, 14-in. thick, cell 1
18. Double shielding door, 14-in. thick, cells 2 and 3
19. Isotope storage well, 10-in. diam by 5 ft 2 in. deep
20. External transfer drawer
21. U-tube, 3-in. schedule 40 stainless pipe beneath 36-in.-thick wall
22. Door bumper
23. Double shield door, 16-in. thick, cell 4
24. Isotope storage well, 22 in. diam by 5 ft 2 in. deep
25. Isotope storage well, 10 in. diam by 5 ft 2 in. deep
26. Double shield door, 16-in. thick, cell 5
27. U-tube, 3-in. schedule 40 stainless pipe beneath 42-in.-thick wall
28. Wall sleeve for metallograph specimen transporter
29. Wall sleeve for AMF Heavy Duty Master-Slave manipulator through 36-in.-thick wall
30. Wall sleeve for Bausch and Lomb stereomicroscope
31. Wall sleeve for Kollmorgen Model 301 wall periscope
32. Wall sleeve for AMF Heavy Duty Master-Slave Manipulator through 42-in.-thick wall
33. U-tube, 2-1/2-in. schedule 40 stainless pipe beneath 42-in.-thick wall
34. U-tube (electrical), 2-in. schedule 40 stainless pipe beneath 36-in.-thick wall
35. Door bumper
36. Door bumper
37. Door bumper
38. Motor driven cable take-up reel for dragging 19-ft cable
39. Motor driven cable take-up reel for dragging 36-ft cable
40. Motor driven cable take-up reel for dragging 19-ft cable
41. Motor driven cable take-up reel for dragging 36-ft cable
42. Metallograph wall sealing plate

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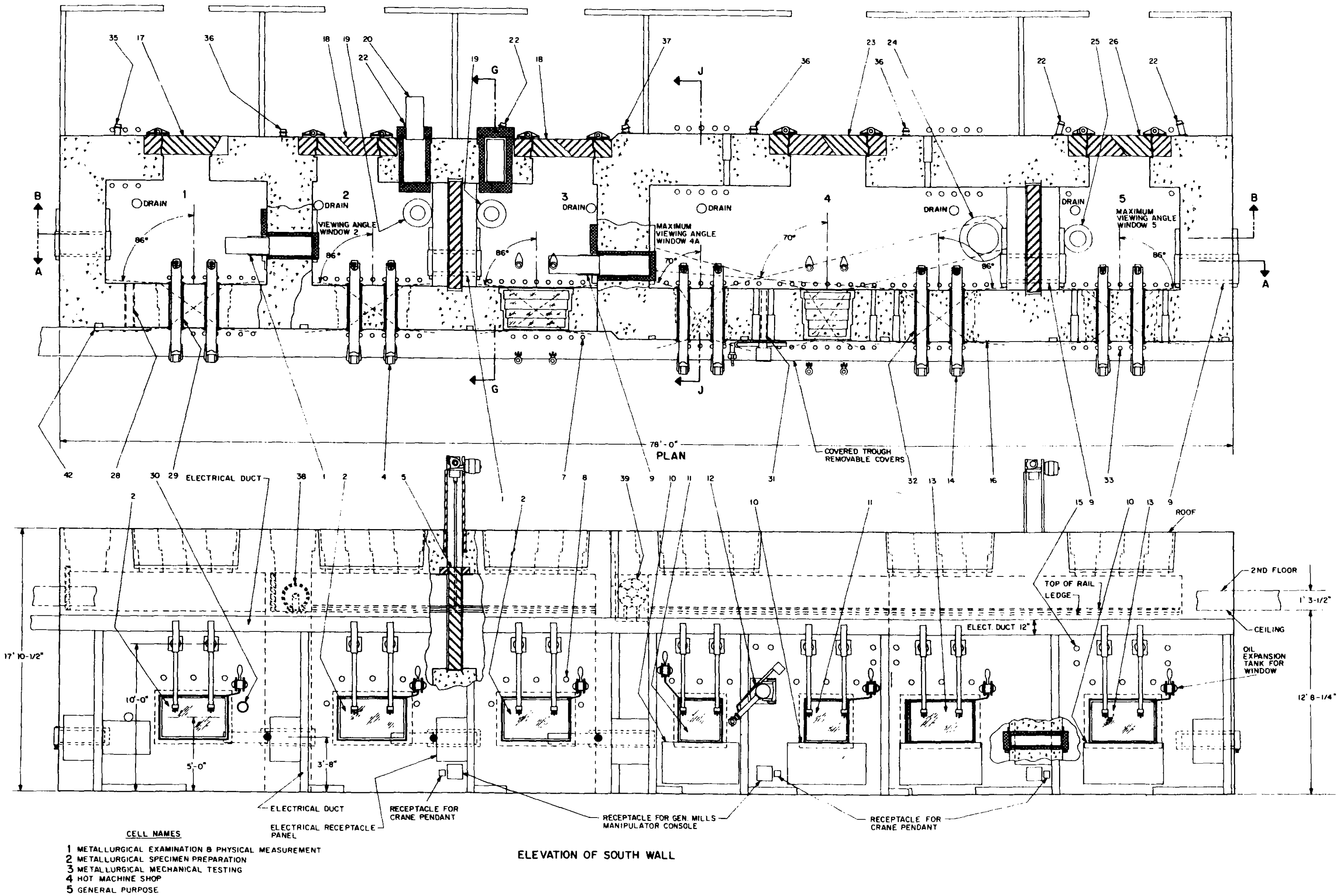

Dwg. 2. Plan and front elevation of hot cells

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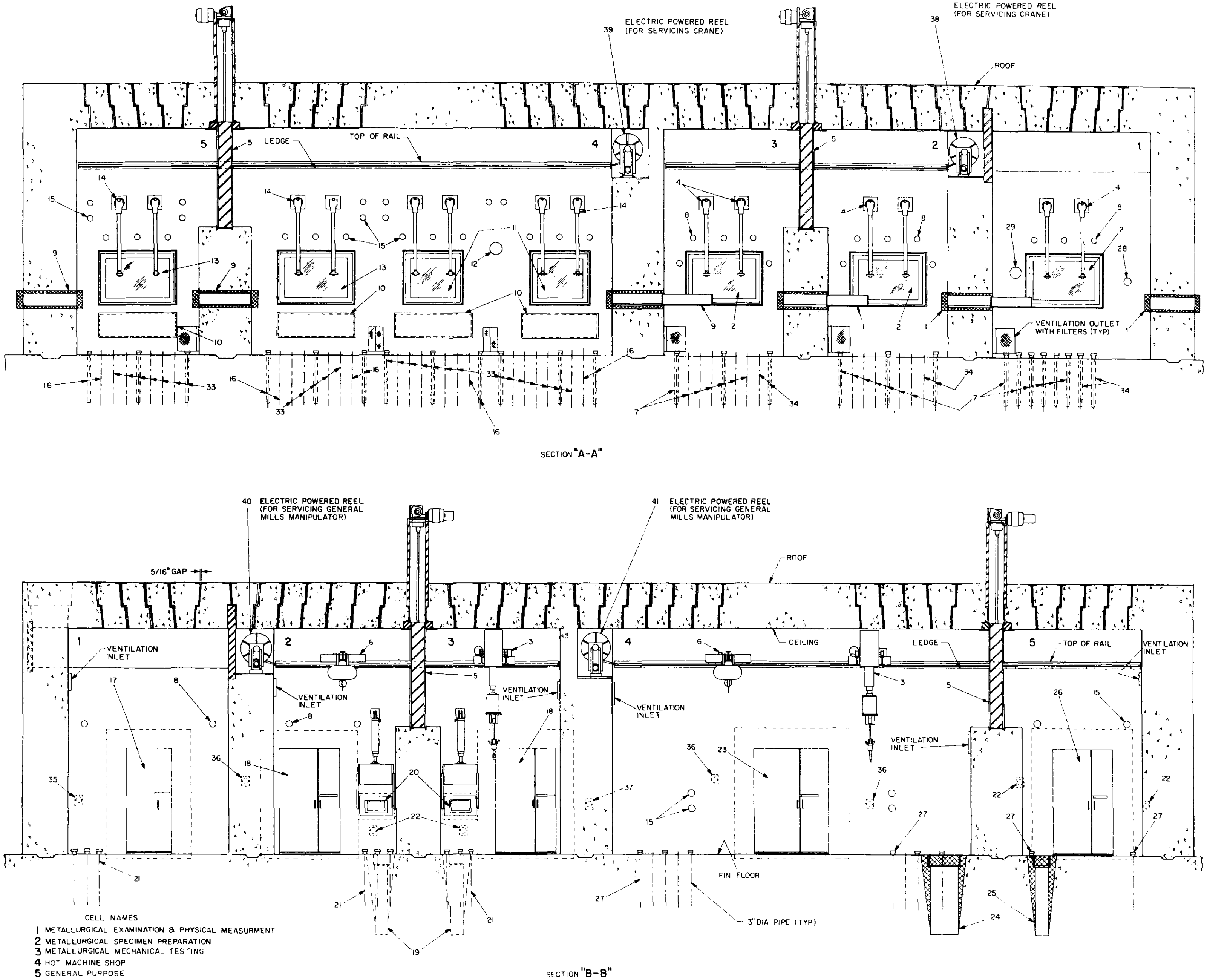

Dwg. 3. Section A-A, elevation looking toward windows; section B-B, elevation looking toward access doors

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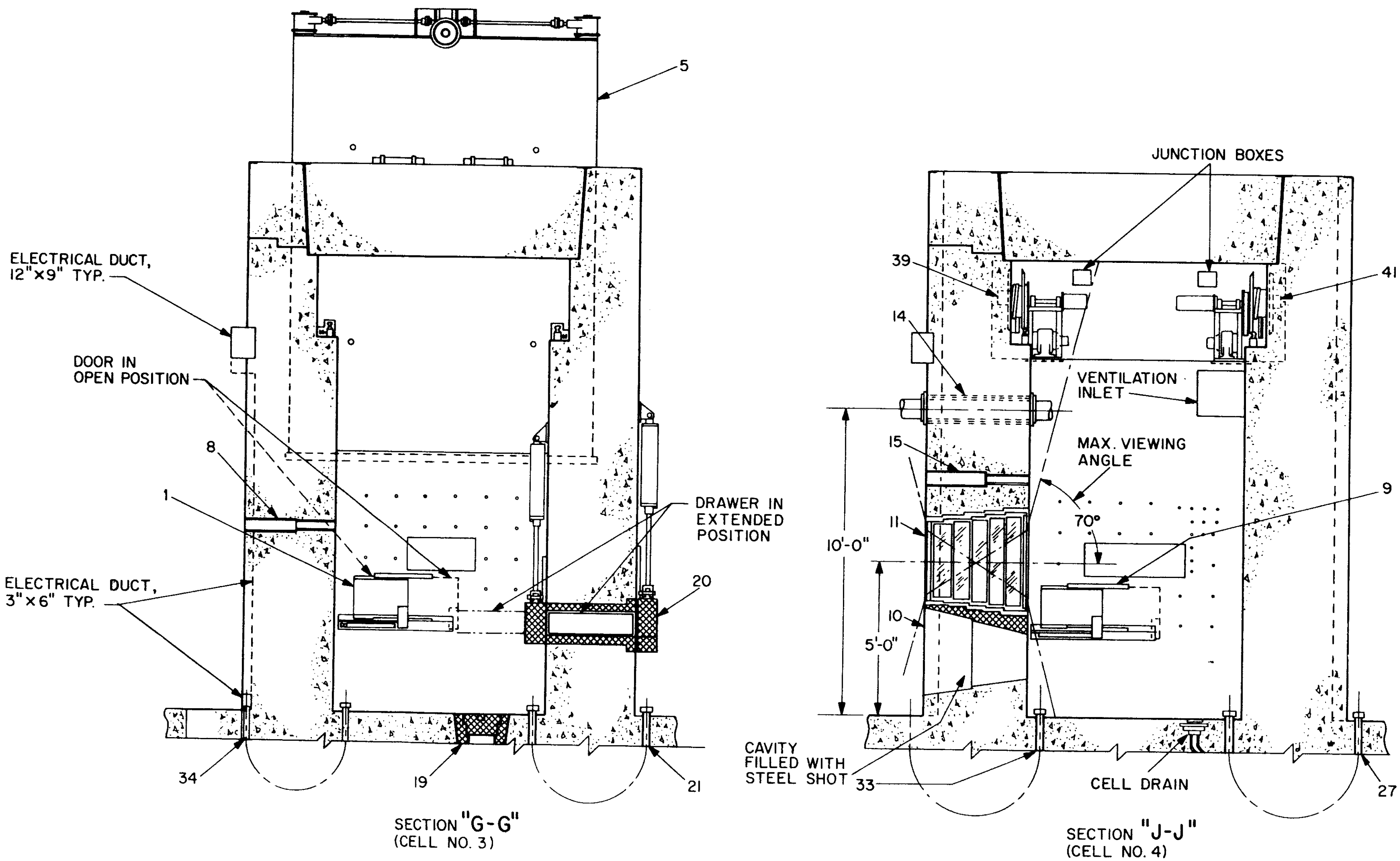

Dwg. 4. Typical elevations of hot-cell ends – sections G-G and J-J (Dwg. 2)

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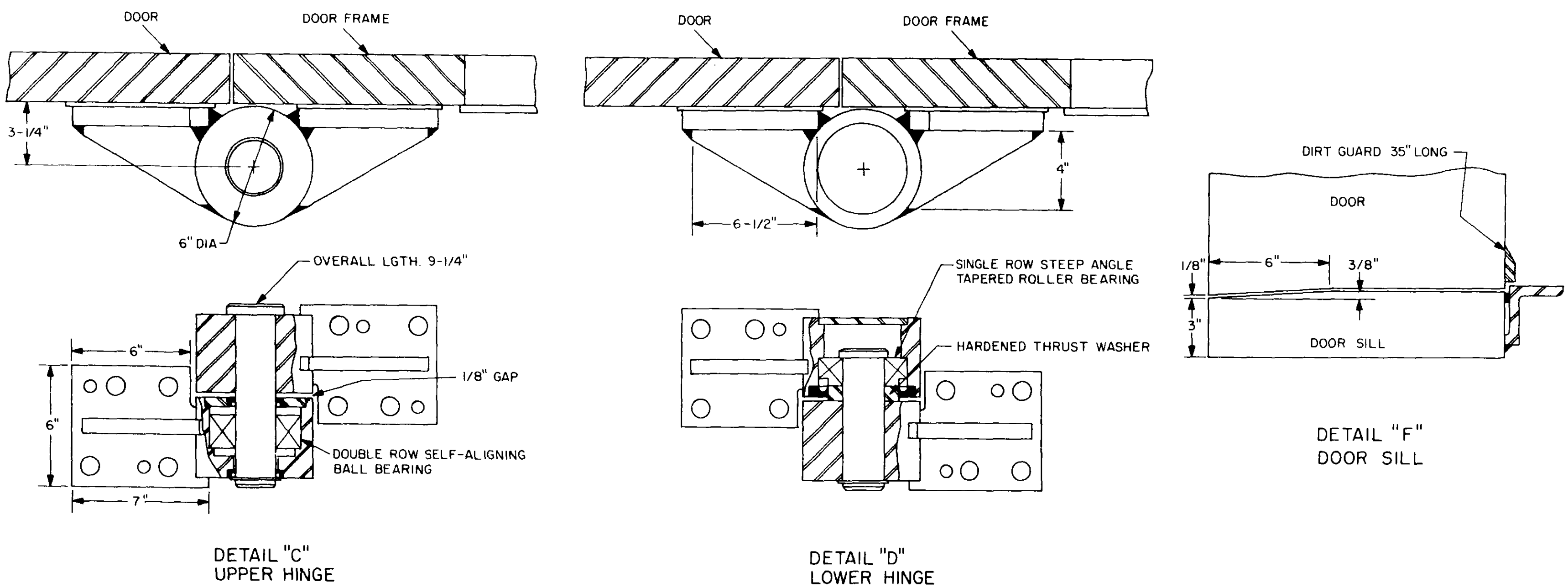

Dwg. 5. Typical upper and lower hinge design for steel shielding doors

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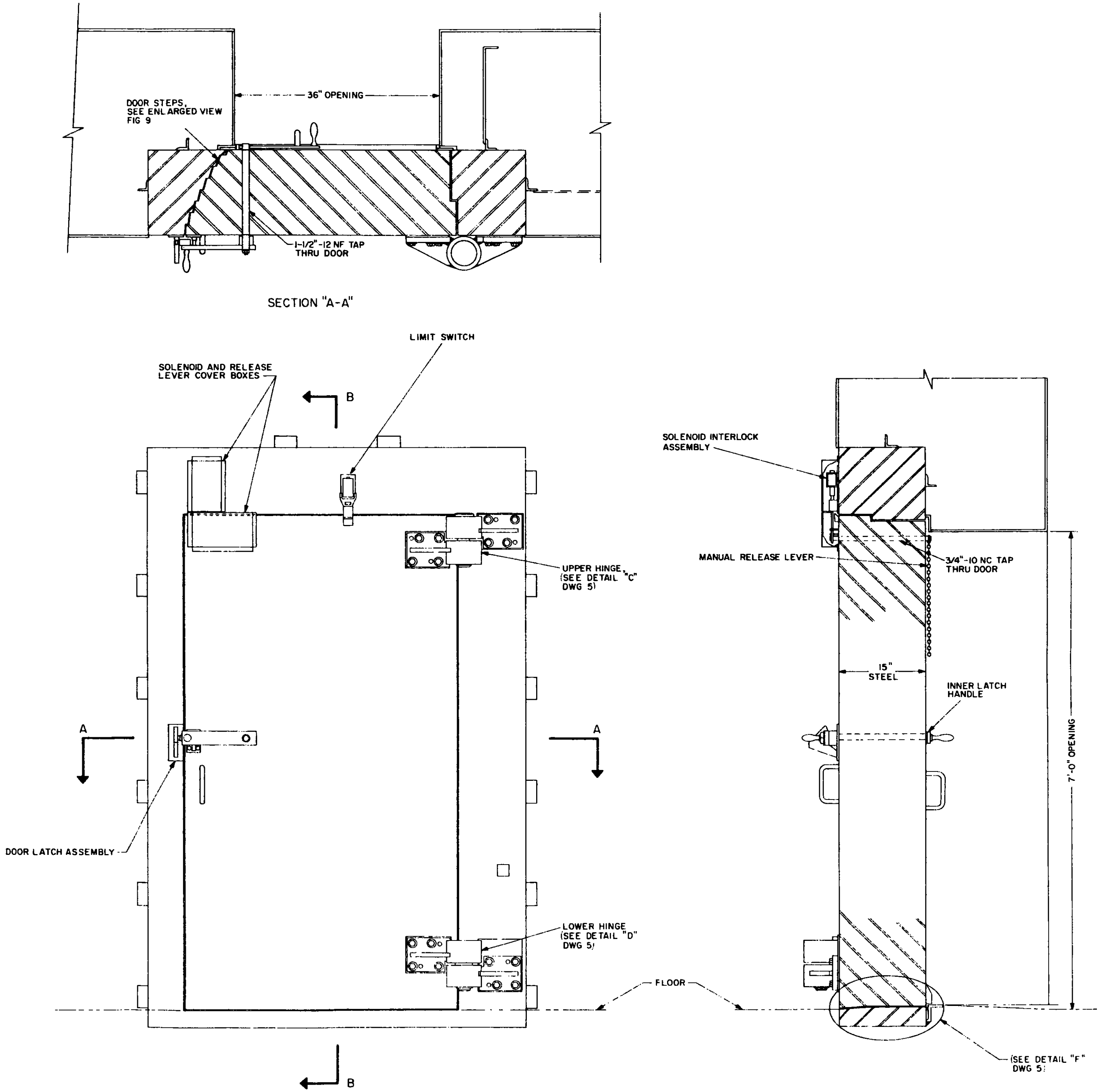

Dwg. 6. Front elevation and sections A-A and B-B of single steel door

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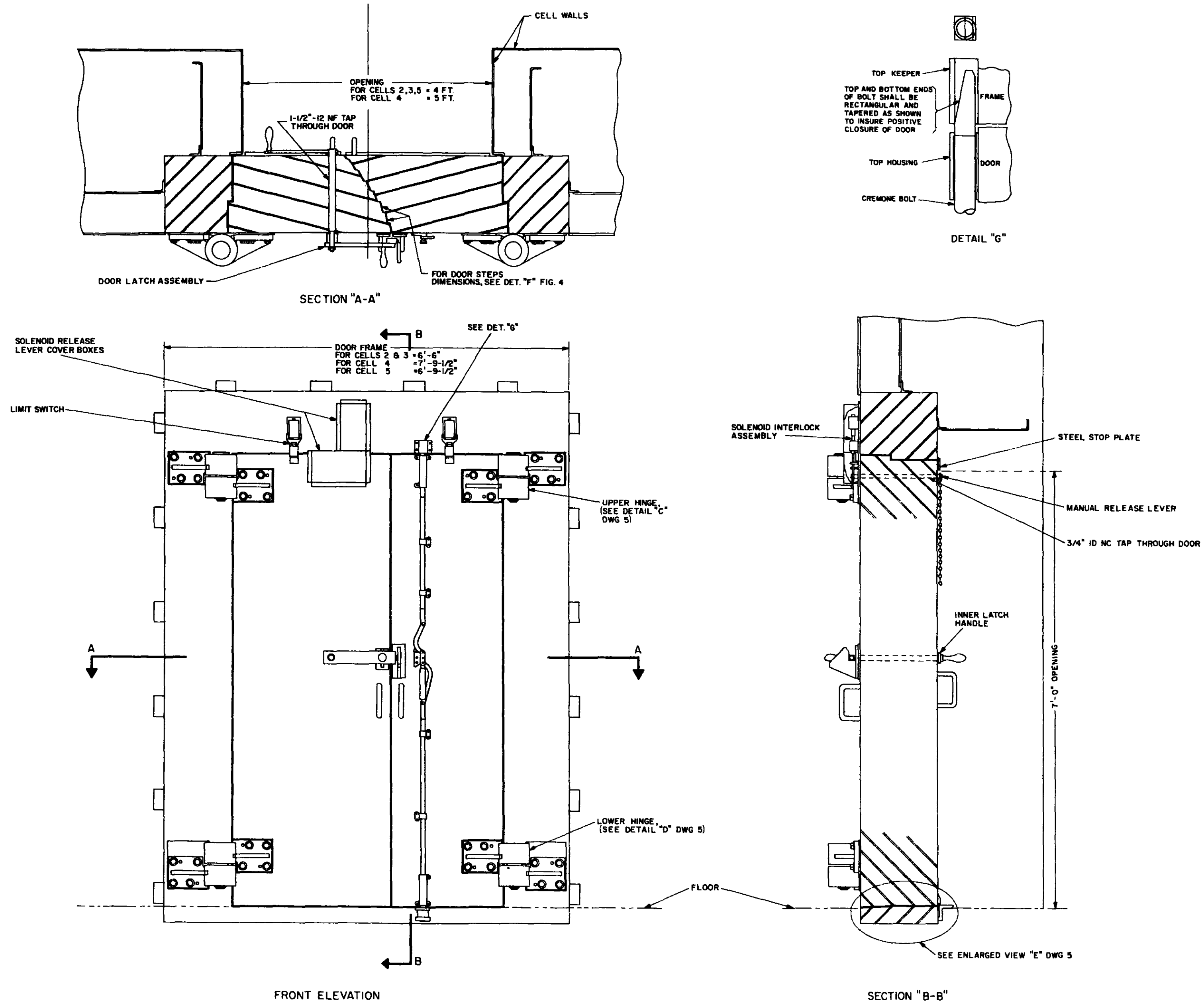

Dwg. 7. Double shielding door design – front elevation, sections A-A and B-B, and detail of cremone bolt

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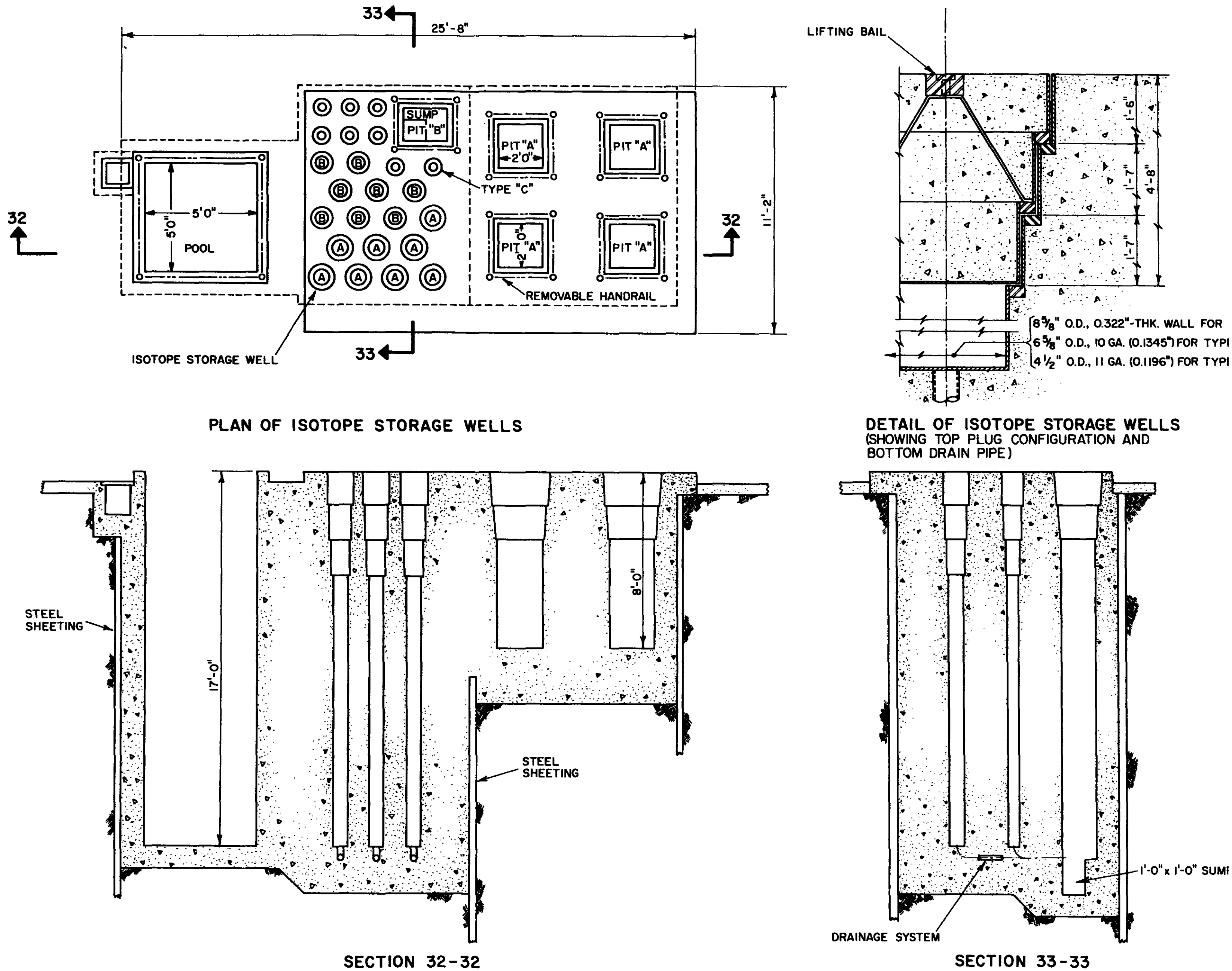

Dwg. 8. Plan of isotope storage wells and detail sections 32-32 and 33-33

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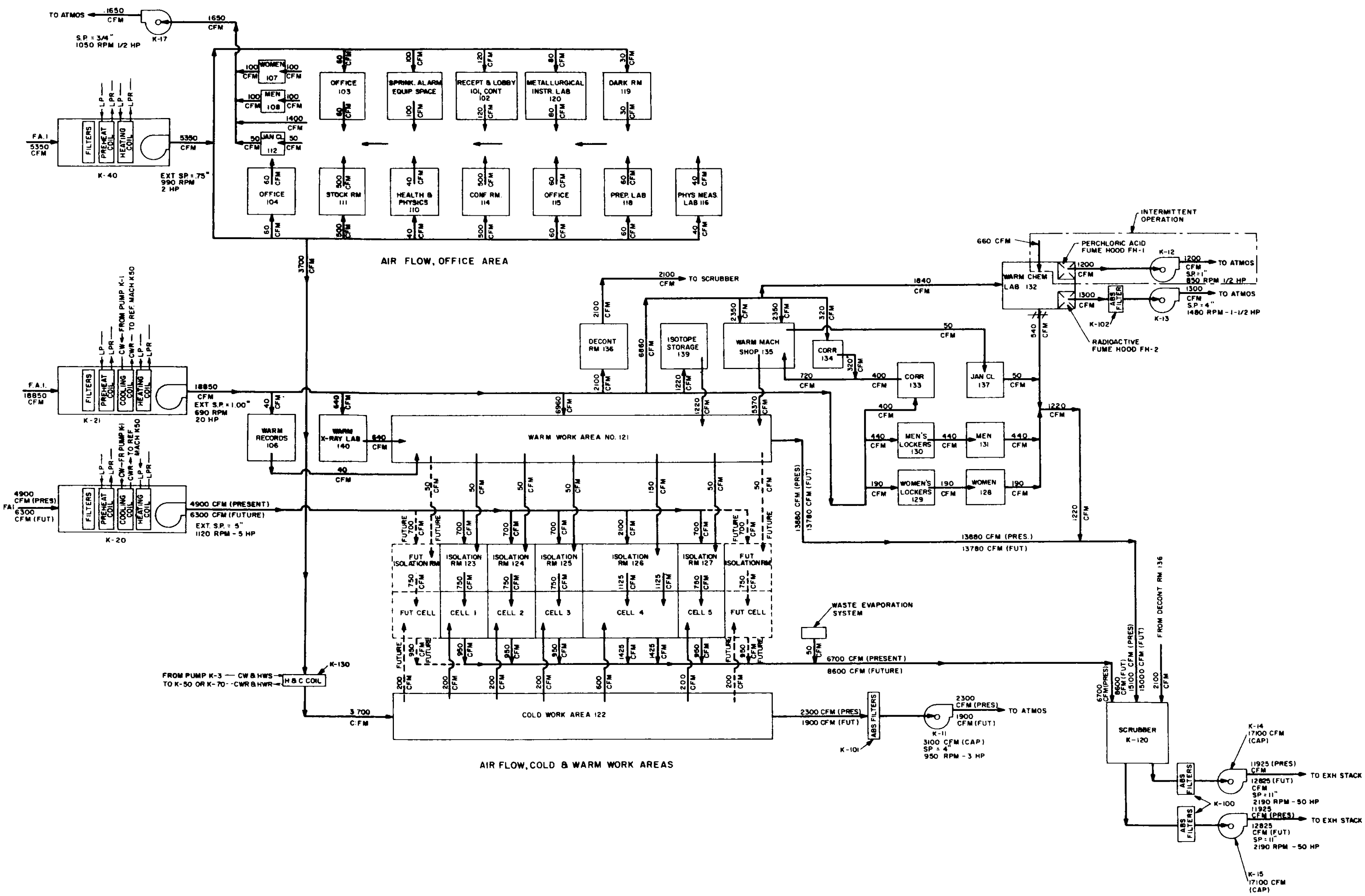

Dwg. 9. Ventilation flow diagram

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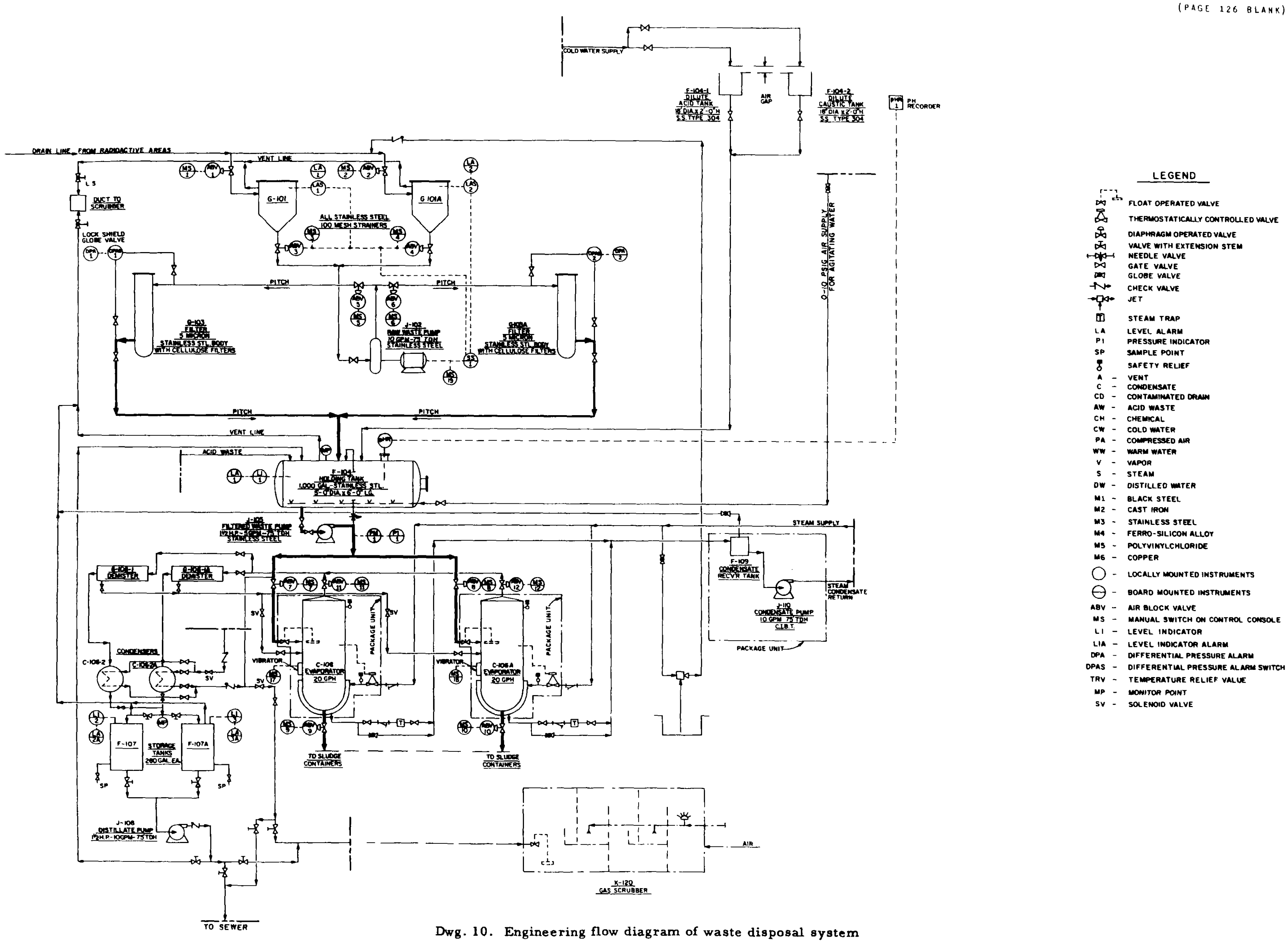

Dwg. 10. Engineering flow diagram of waste disposal system

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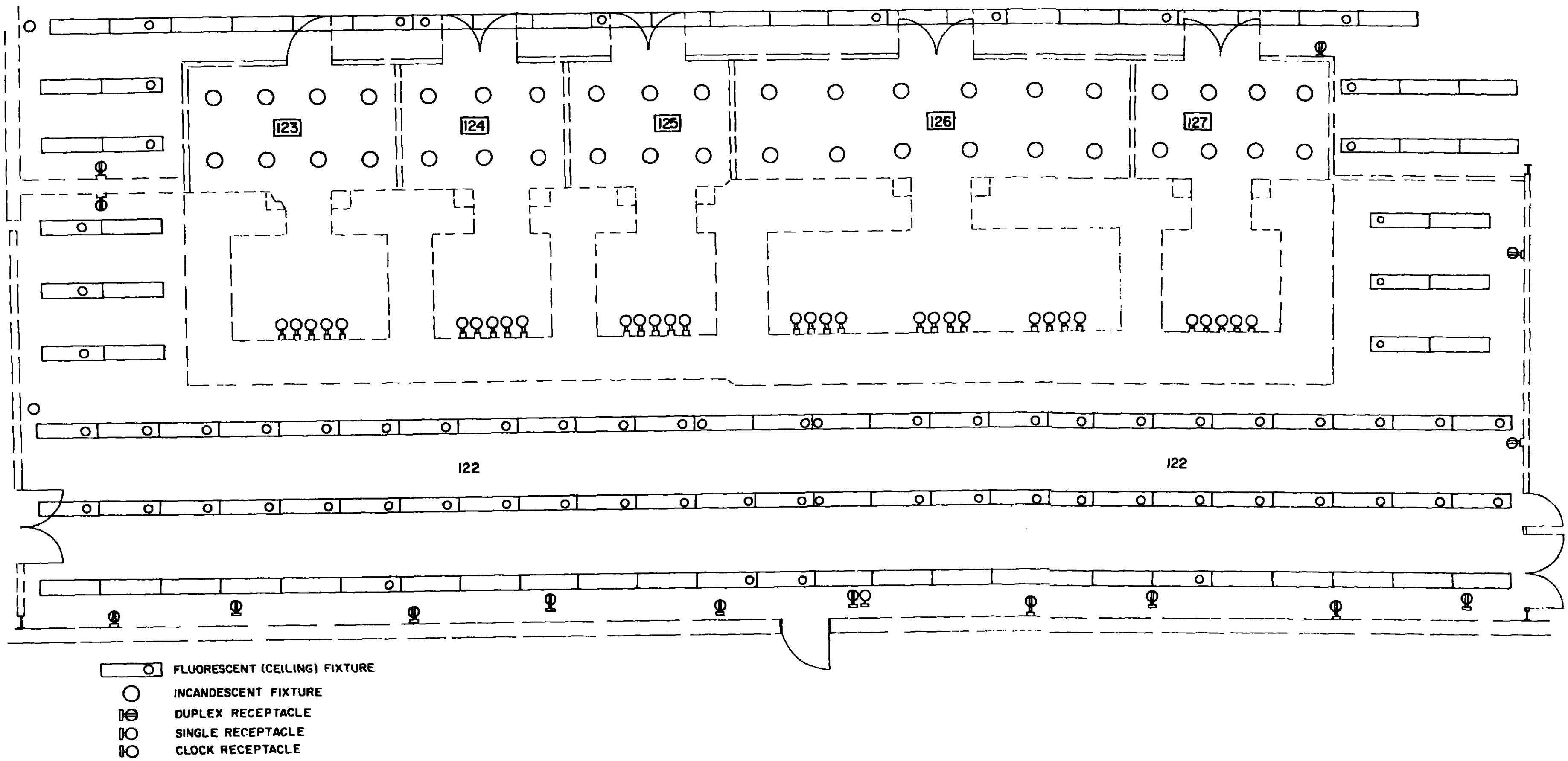

Dwg. 11. Lighting fixture arrangement in "cold" work area (122), hot cells, and isolation cubicles (123-127)

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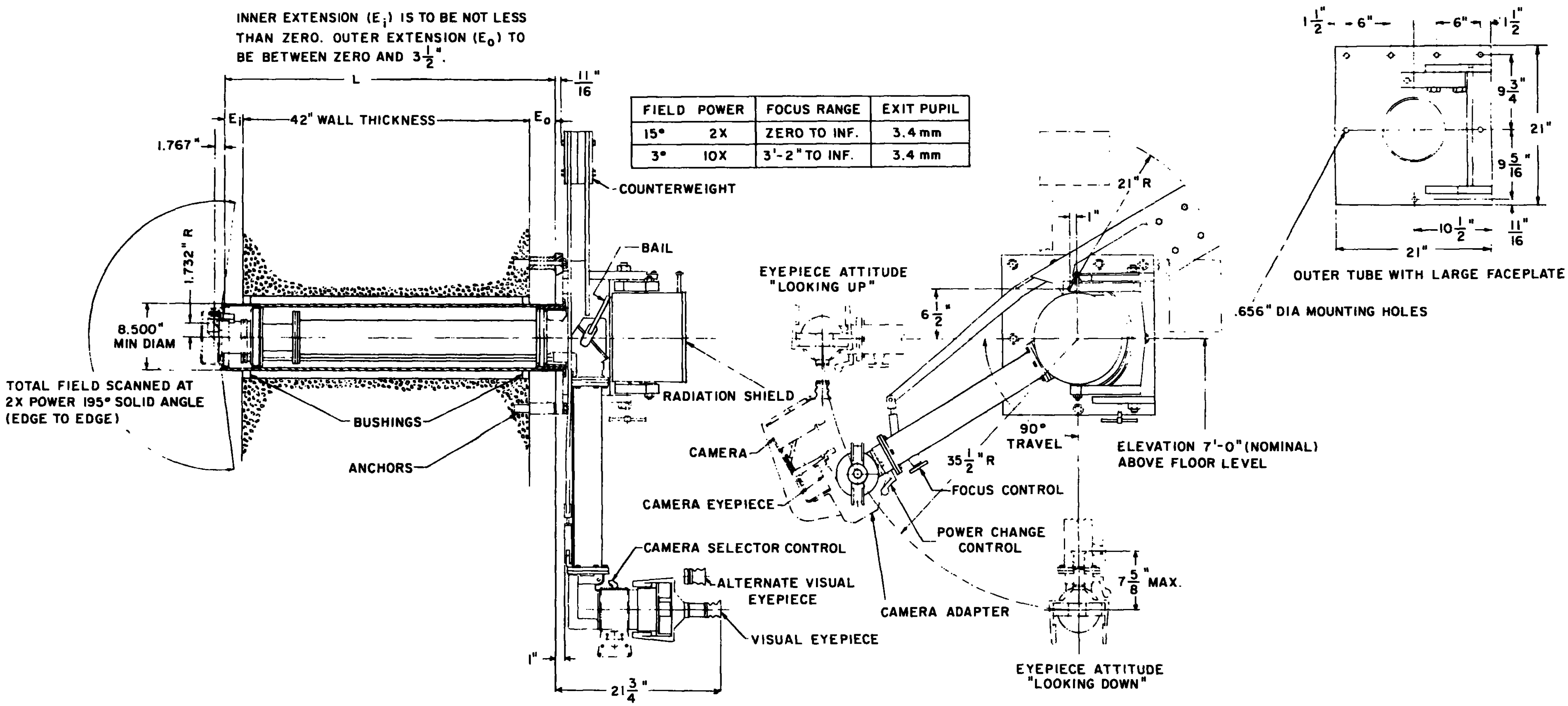

FIELD	POWER	FOCUS RANGE	EXIT PUPIL
15°	2X	ZERO TO INF.	3.4 mm
3°	10X	3'-2" TO INF.	3.4 mm

Dwg. 12. Kollmorgen wall periscope, Model 301

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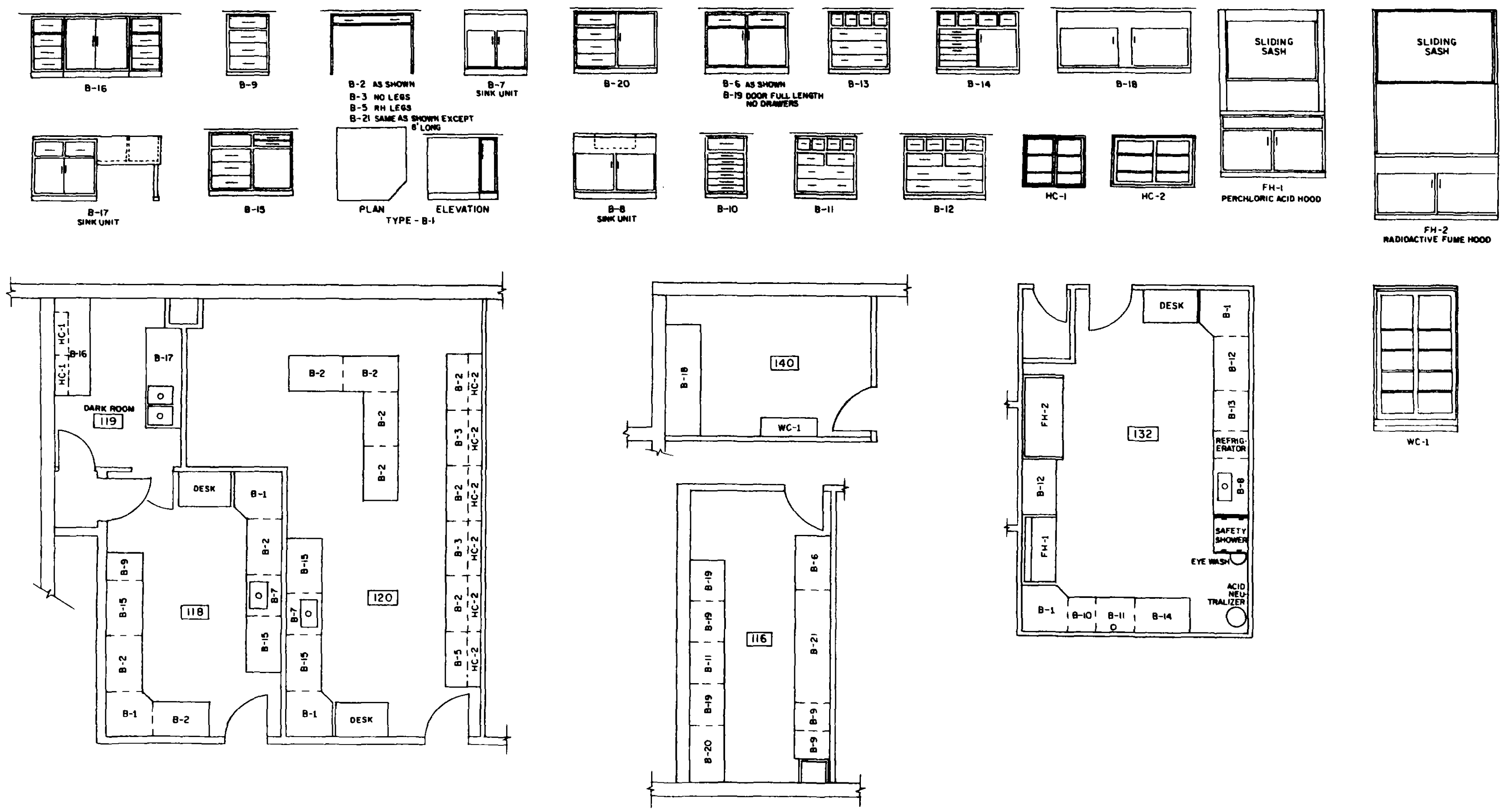

Dwg. 13. Laboratory equipment and layout

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Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (*Corporate author*)
U.S. Naval Research Laboratory
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
THE DESIGN, CONSTRUCTION, AND EQUIPMENT OF A NEW HIGH LEVEL RADIATION LABORATORY AT NRL

4. DESCRIPTIVE NOTES (*Type of report and inclusive dates*)
A final report on this facility built under the military construction program

5. AUTHOR(S) (*Last name, first name, initial*)
Chapin, E.J.

6. REPORT DATE
April 14, 1965

7a. TOTAL NO. OF PAGES
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7b. NO. OF REFS
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8a. CONTRACT OR GRANT NO. APPROPRIATION Public Law 86-149, 10 Aug. 1959,

b. PROJECT NO. 86th Congress

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9a. ORIGINATOR'S REPORT NUMBER(S)
NRL Report 6205

9b. OTHER REPORT NO(S) (*Any other numbers that may be assigned this report*)

10. AVAILABILITY/LIMITATION NOTICES
Unlimited Distribution – Available at CFSTI $2.75

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Military constr. program funded by 86th Congress. Appropriation Public Law 86-149, dtd 10 Aug. 1959.

13. ABSTRACT

A new NRL High Level Radiation Laboratory is described, with special emphasis on the design, construction, and collateral equipment. This laboratory provides a means for safely handling and conducting research on gamma-active materials of interest to the Navy. The facility includes: five hot cells, with three designed for 1,000 curies and two designed for 10,000 curies of 1-Mev gamma; isolation cubicles back of cells; a "warm" work area; a decontamination room; x-ray laboratory; radiochemistry laboratory; machine shop; isotope storage facilities; waste disposal system; "cold" laboratories; and offices and utilities area. Design innovations discussed include: steel-lined cells; all-glass windows with exceptional viewing angle and clarity; manually operated hinged steel shielding doors; internal and external transfer drawers; special receptacle panels in cells; cell lighting; underwall U-tubes; under-window access ports; removable roof plugs; isotope storage; waste disposal system; and gas scrubber. Equipment discussed includes: heavy-duty master-slave manipulators; mechanical arm manipulators and bridge cranes in cells; through-the-wall periscope; through-the-wall stereomicroscope; a remotely controlled shielded metallograph with through-the-wall specimen transporter; and metallographic specimen preparation equipment. Results of tests with a 9,500-curie Co-60 source on the shielding integrity of the facility are presented.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radiation laboratory – Design High-level radiation Radiation laboratory – Construction Radiation laboratory – Equipment						

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