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ORNL-3954
UC-10 – Chemical Separations Processes for Plutonium and Uranium

SAFETY ANALYSIS FOR THE TRANSURANIUM PROCESSING PLANT, BUILDING 7920

Compiled by
L. J. King

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

Printed in the United States of America. Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65

ORNL-3954

Contract No. W-7405-eng-26

CHEMICAL TECHNOLOGY DIVISION

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APRIL 1968

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CONTENTS

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ABSTRACT

This report presents a safety analysis of the Transuranium Processing Plant and the proposed operations and procedures. The topics covered are: (1) a description of the building and building services, with special emphasis on provisions for containment of hazardous materials; (2) processes and equipment; (3) operating safeguards; (4) control of personnel exposure; (5) operations with transuranium elements in the development laboratories, including laboratory hazards and safeguards; (6) radiation and contamination controls; (7) process safeguards; (8) waste disposal; and (9) process hazards and credible accidents.

The purpose of the Transuranium Processing Plant (TRU) is to recover transuranium elements from irradiated targets for distribution to research workers and to refabricate targets from some of the intermediate isotopes, especially americium and curium. After target dissolution, the heavy elements are separated from fission products, and the transcurium elements are separated from curium in two cycles of solvent extraction in 1.5-in.-diam pulsed-column contactors. The transcurium elements are separated from each other and purified, by batch solvent extraction and ion exchange. Most of the americium and curium is refabricated remotely into new targets for reirradiation in the High Flux Isotope Reactor.

The alpha-emitting, spontaneously fissioning actinides present novel problems in radiochemical plant design. The combination of the fast-neutron flux and the penetrating gamma rays from fission products and spontaneous fission requires shielding considerations that are normally associated with reactors. The containment of radionuclides in TRU is complicated because many of the isotopes of the transuranium elements have high specific toxicities and because the plant and equipment must be capable of accommodating extensive changes.

1. INTRODUCTION

The Transuranium Processing Plant (TRU) and the High-Flux Isotope Reactor (HFIR) have been built at Oak Ridge National Laboratory to provide gram quantities of many of the transuranium elements and milligram quantities of some of the transcalifornium isotopes. These radioisotopes will be used in research work by laboratories throughout the country.

Much has already been learned of the general chemistry of the transuranium elements through tracer level and microchemical techniques. Both the similarity between the rare earths and the actinides and the minute individual differences in their chemical behavior are of great interest. Perhaps the most significant chemical implication of transuranium element research arises simply from the fact that these elements have the heaviest nucleii and most complicated electronic structure of the known elements. The role "f electrons" play in chemical bonding is most conveniently studied in the transuranium elements.

The extensive work of recent years on the solid compounds and metals of uranium, neptunium, and plutonium has revealed a research area of unexpected richness and complexity. Indications are that the solid-state physics of the heavier transuranium elements may be equally fruitful, but detailed examination of these elements must await the large-scale productions.

Studies of many nuclear properties of specific isotopes, such as cross sections, alpha decay parameters, and nuclear energy levels have contributed to the development of theories of nuclear structures. These studies will be extended with the availability of larger quantities of the transuranium elements.

Finally, the possibility of synthesizing new elements through further neutron irradiation or heavy-particle bombardment of the heaviest elements produced is always intriguing.

The Transuranium Processing Plant, Building 7920, is to be used for process and development work relative to the separation and recovery of transuranium elements. The building is divided into four functional areas:

1. an office and conference area adjacent to, but isolated from, areas that contain radioactivity;
2. a maintenance shop;
3. a laboratory complex consisting of four alpha laboratories, two cold chemical laboratories, two analytical laboratories, and support areas for conducting process support and development work on transuranium elements and for conducting high-alpha-level work in support of other ORNL projects;
4. an integrated hot-cell complex that contains four cells for the chemical processing of irradiated HFIR targets, three cells for fabrication and inspection of HFIR targets, and two cells for high-level analytical chemistry work.

Targets irradiated in the HFIR are processed in this facility to recover the transuranium isotopes. After target dissolution, the heavy elements are separated from fission products, and the transcurium elements are separated from curium in two cycles of solvent extraction in pulse-column contactors that are 1.5 in. in diameter. The transcurium elements are separated from each other and purified by batch solvent extraction and ion exchange. Most of the americium and curium is refabricated remotely into new targets for reirradiation in the HFIR. This irradiation-fabrication cycling of material will continue for a number of cycles — the number depending on production rates and demands for the various isotopes.

The α-emitting, spontaneously fissioning actinides have created problems that are novel in radiochemical plant design. The combination of the fast-neutron flux and the penetrating gammas from fission products and spontaneous fission requires shielding considerations normally associated with reactors. The high specific toxicity of the α-emitting actinides dictates a refined equipment design philosophy to ensure against the escape of airborne contaminants. The corrosiveness of process chloride solutions makes easy replacement of equipment highly desirable. The uncertainty of the chemical behavior of the relatively rare actinides places the Transuranium Processing Plant in the category of what must be regarded as predominantly a research facility, requiring laboratories and supporting facilities designed for process development, but most important, capable of accommodating rather severe revisions in process flowsheets.

The purpose of this report is to analyze the facility and the proposed operations and procedures to determine that the various programs can be conducted safely. The two major functional areas of the building, the heavy-element processing area and the laboratory area, will sometimes be discussed separately and sometimes together, as is appropriate.

First, the building and building services will be described, with special emphasis on provisions for containment of hazardous materials. This will be followed by a description of the processes to be used for recovering heavy isotopes from irradiated targets and fabricating new targets for further irradiation, including discussions of operating safeguards and control of personnel exposure. Then, operations in the laboratory area will be discussed, including laboratory hazards and safeguards. Radiation and contamination controls for the entire building will be discussed next, followed by descriptions of process safeguards in the heavy-isotope processes and liquid, gaseous, and solid waste disposal. Finally, process hazards and credible accidents will be discussed.

2. PHYSICAL PLANT

The Transuranium Processing Plant is located in the Melton Valley area at Oak Ridge National Laboratory (Fig. 2.1). Nearby facilities, which include the High Flux Isotope Reactor (HFIR) - Building 7900, the HFIR office and maintenance building - Building 7910, and the Thorium-Uranium Recycle Facility (TURF) - Building 7930, are shown in Fig. 2.2.

2.1 Building Description

The two-story processing and laboratory portions of the building and the one-story office and shop areas are of reinforced concrete block construction. Floors are reinforced concrete slabs that are either poured on compacted aggregate or supported on structural steel. The roof is precast concrete-deck, covered with built-up roofing. Total building volume is about 620,000 ft^3, and total floor area is about 29,000 ft^2. These are distributed as follows:

	Usable Area (ft^2)	Service Area (ft^2)	Volume (ft^3)
Pits and Tunnels	1,000	-	17,000
Cells and Transfer Area	1,000	-	60,000
First Floor of Main Building	8,250	3,000	250,000
Second Floor of Main Building	8,250	3,000	250,000
Office and Maintenance	3,000	800	30,000
Shop	1,000	-	12,000
Total	22,500	6,800	619,000

2.1.1 Facilities

The facilities for handling radioactive materials consist of nine heavily shielded cells served by master-slave manipulators, and eight laboratories, four on each of two floors (Figs. 2.3 and 2.4).

One cold laboratory for the preparation of reagents and assembly of equipment is located between two alpha laboratories, and the fourth

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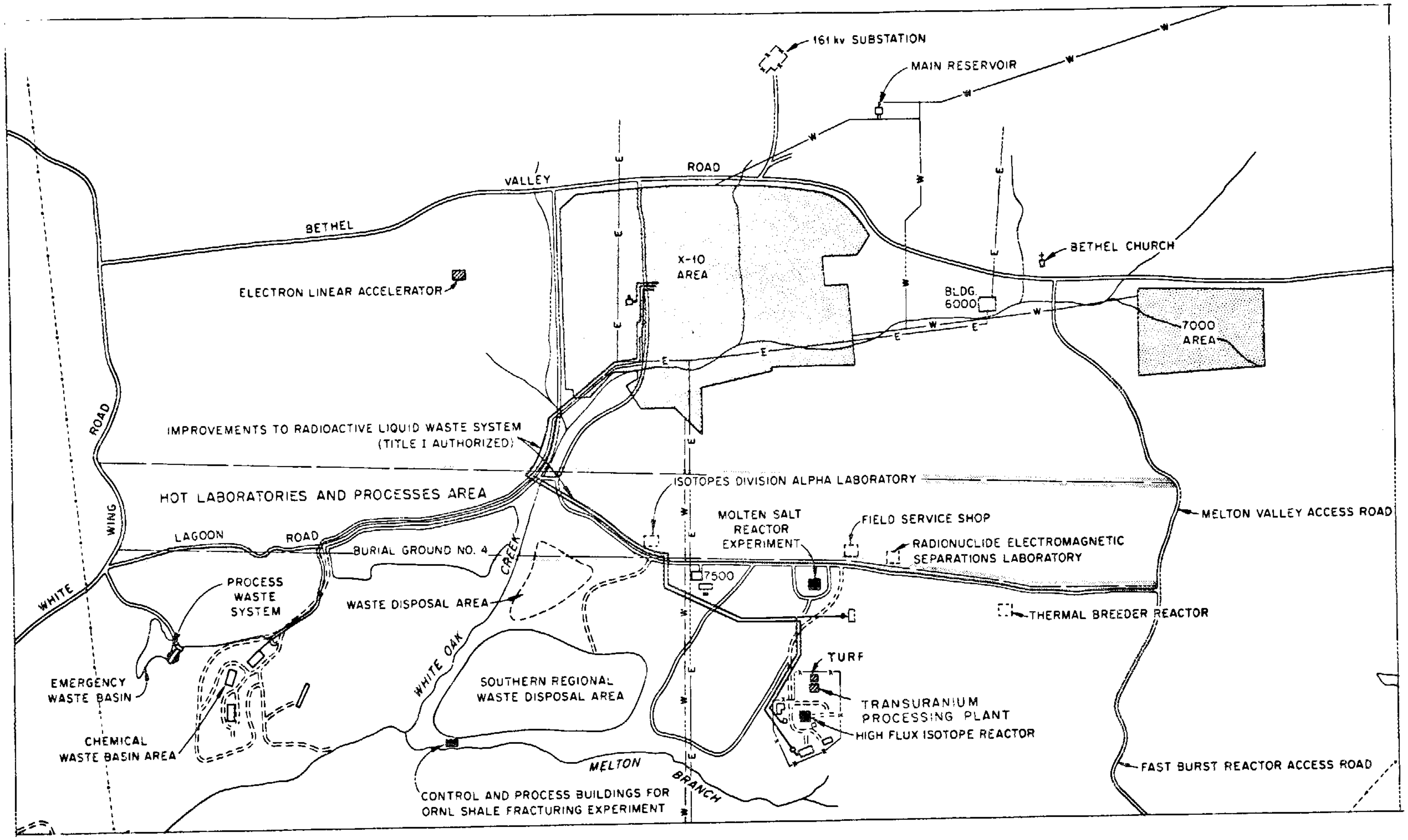

Fig. 2.1. Oak Ridge National Laboratory Area Map, Including Melton Valley Facility.

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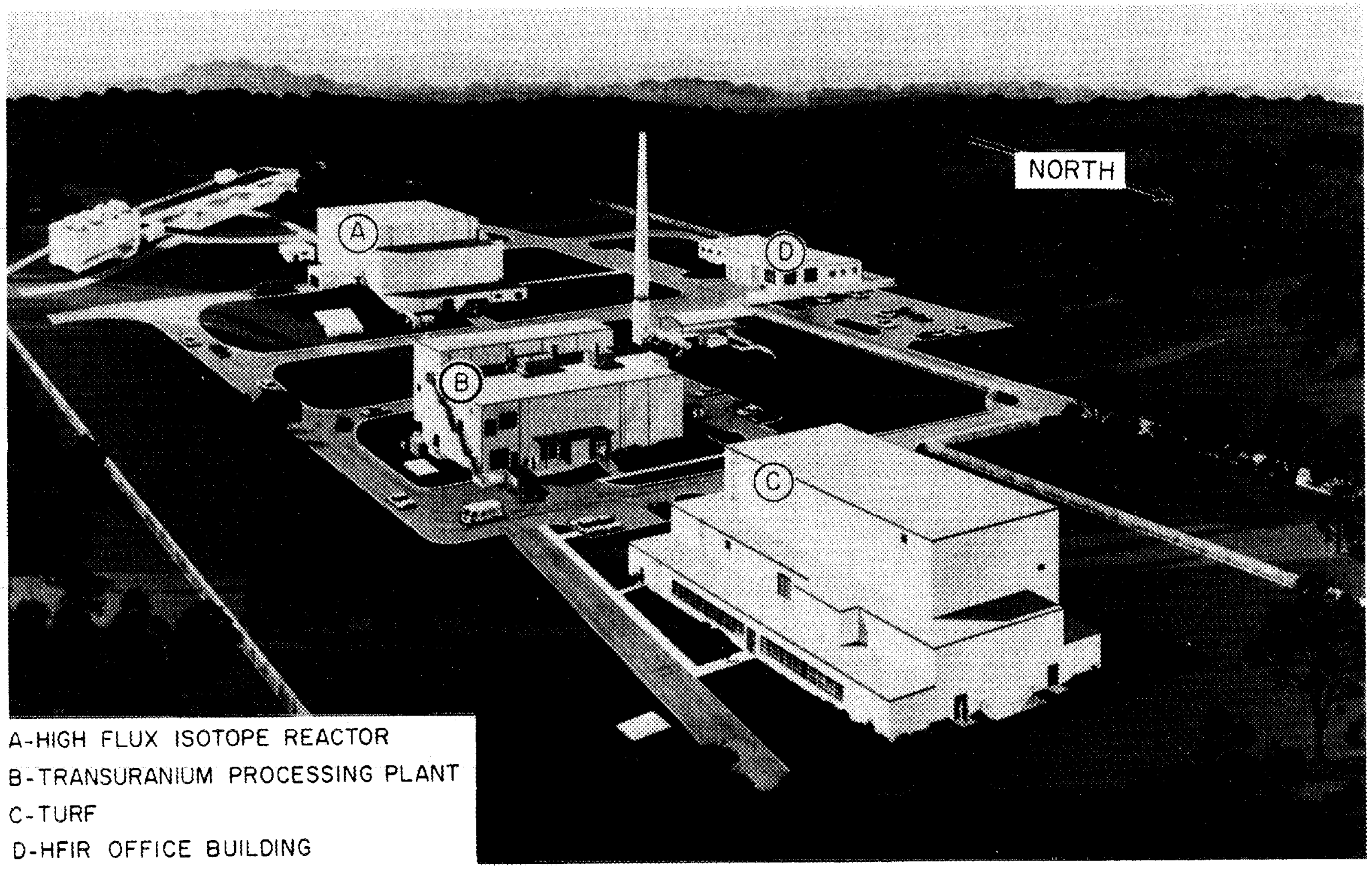

Fig. 2.2. Melton Valley Facilities.

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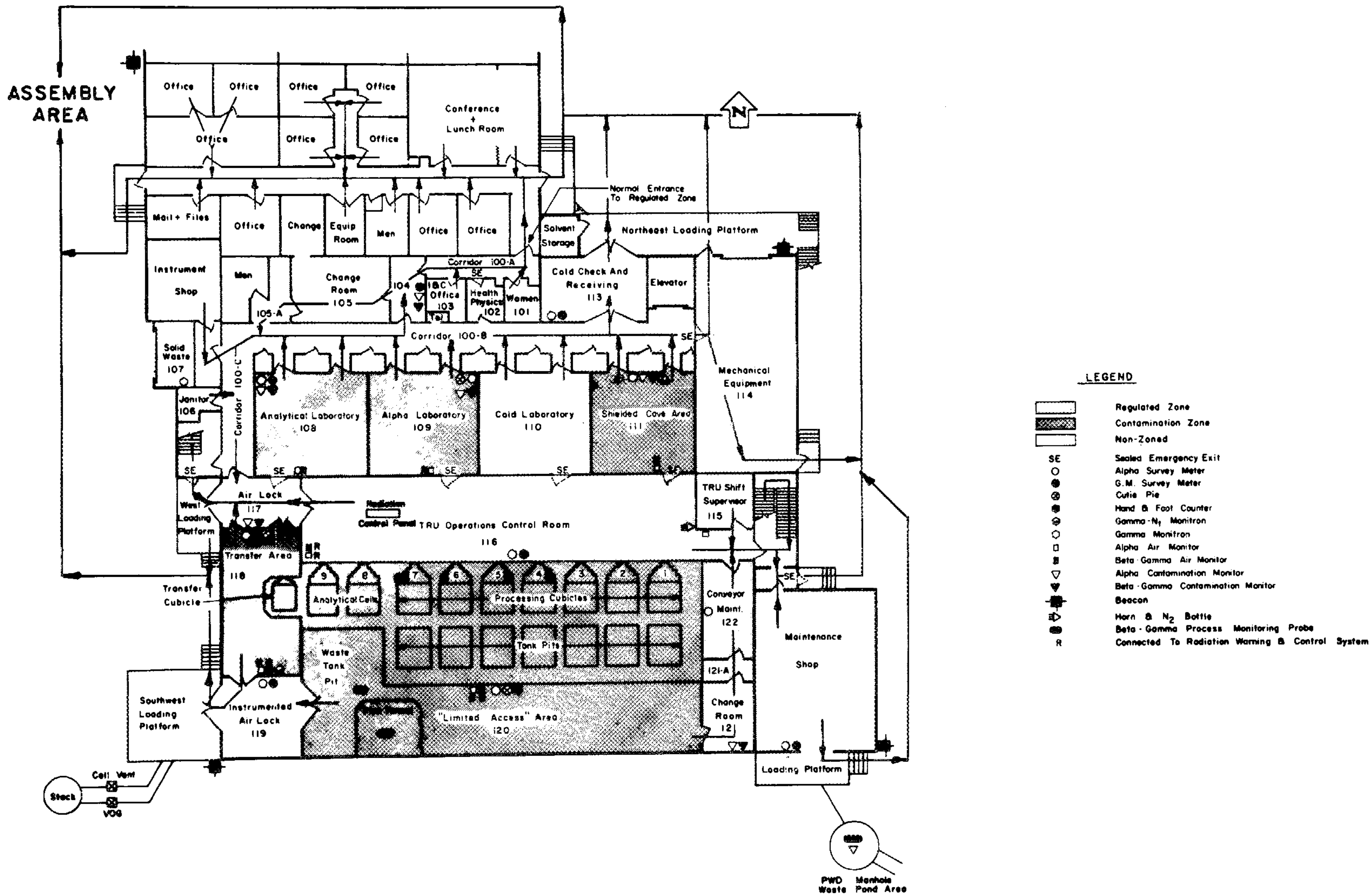

Fig. 2.3. Zoning Plan - First Floor, TRU Facility.

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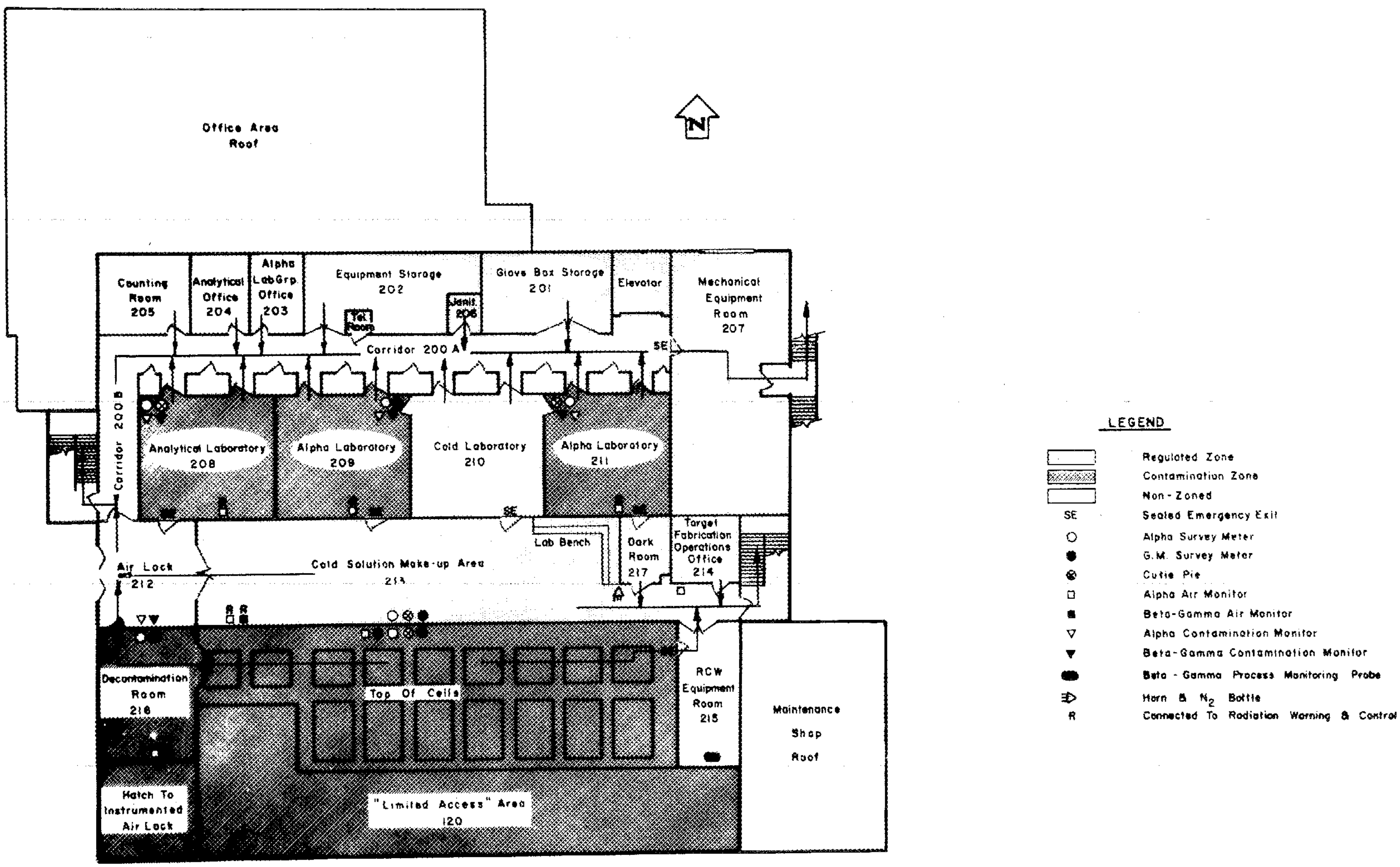

Fig. 2.4. Zoning Plan - Second Floor, TRU Facility.

laboratory on each floor contains analytical equipment. The alpha laboratory in room 111 contains a shielded cave. The laboratory area contains supporting rooms for the handling and storing of process reagents and the storing of glove boxes under off-gas vacuum, and check and holdup areas for maintaining contamination control while things are moved in and out of the building.

The nine shielded process cells (Figs. 2.5 and 2.6) are arranged in line. Removable top plugs provide access to the cells. The top and back of the cell line is served by a bridge crane in a limited-access area of the building not normally occupied by operating personnel. The front face of each cell is provided with a window, master-slave manipulators, and plugged ports for possible future installation of periscopes.

The operating area is considered a nonradioactive zone of low-contamination potential except when manipulators must be withdrawn for repair or replacement. The second floor immediately over the operating area is a chemical makeup area for process reagent head tanks, nonradioactive pumps, and the like.

Of the nine radioactive cells, four contain chemical processing equipment for dissolution, solvent extraction, and precipitation processes. Three contain equipment for the remote preparation and inspection of recycle targets. Two cells are used for remote analytical operations. The cells are shielded by 54 in. of high-density concrete.

Within the shielded cells, process equipment is enclosed in a cubicle formed on the front and sides by the cell walls, and of epoxy resin-coated stainless steel plate on the rear wall and top; the bottom is of Hastelloy C to withstand the corrosion of accidentally spilled chloride solutions. The cubicle is not removable in the sense that a glove box would be but does constitute a containment envelope, the periphery of which is swept by a constant flow of ventilation air. The cubicle atmosphere is recycled at 350 cfm through absolute filters and a cooler, to minimize airborne particulates in the cubicle atmosphere and to remove the heat contributed by process equipment and the mercury vapor illumination lights (see Fig. 2.7). Behind and below

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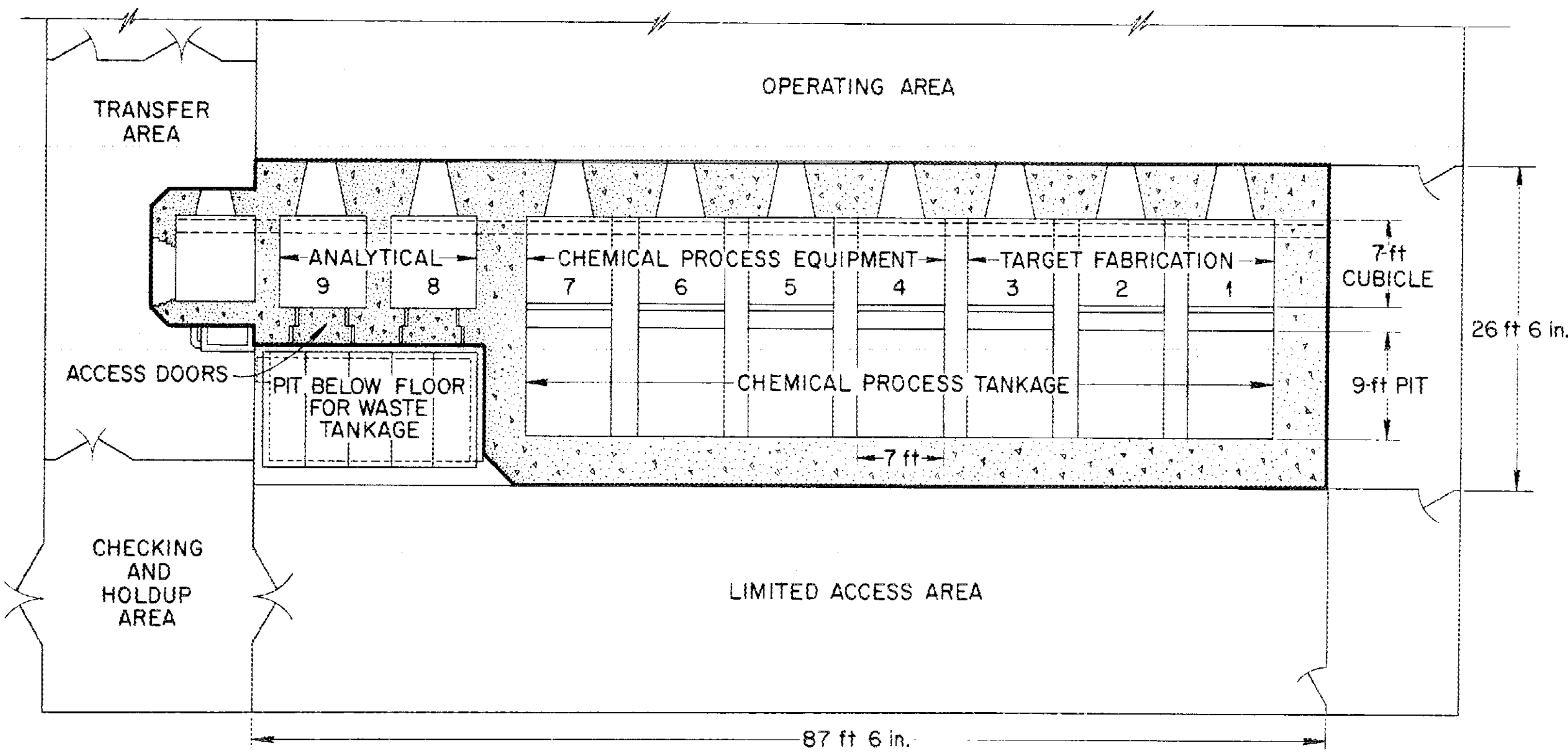

Fig. 2.5. Space Allocation in TRU Cell Bank.

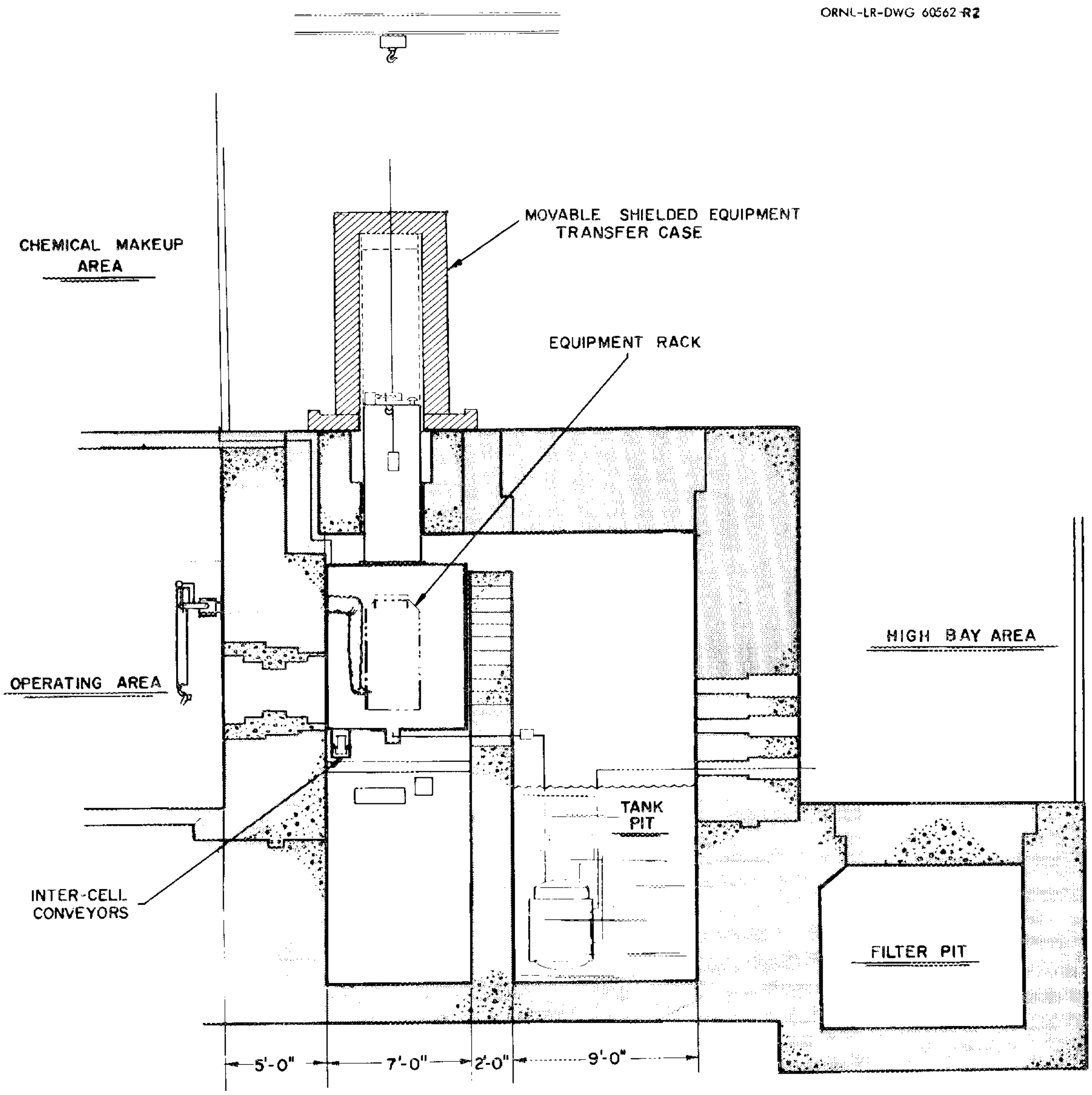

Fig. 2.6. Cross Section of TRU Cell.

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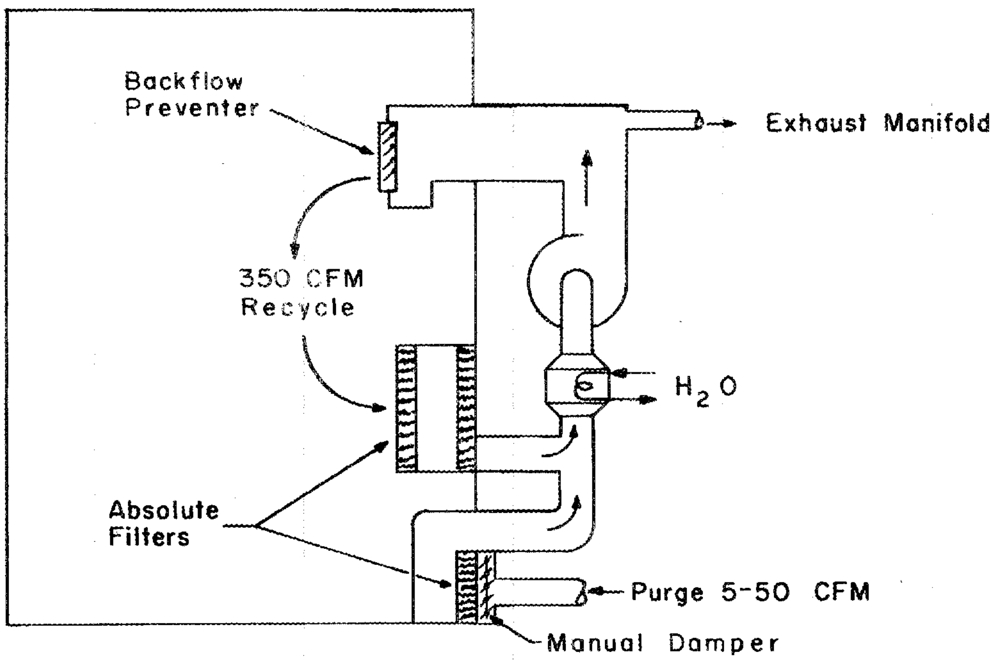

Fig. 2.7. Schematic Diagram of Cubicle Ventilation.

the cell cubicle, and shielded from it by a concrete wall, is a tank pit for housing waste collection equipment and process and storage tanks. The tank pit is floored with a Hastelloy C pan, and the pit walls are of glass-fiber-reinforced resin. The tank pit may be flooded to provide shielding during maintenance.

Service lines enter through removable plugs in the back and top of the cell. Shielded pits behind the cell, in the limited-access-area floor, house off-gas filters and a pipe tunnel for process lines.

Communication between cells is achieved by means of a conveyor consisting of a canister on a dolly drawn by double chains. Differential motion between the chains operates an elevating mechanism on the dolly to raise the canister to seal to a companion covered opening in the cubicle floor (see Fig. 2.8). The design uses the double-cover technique pioneered by Los Alamos.

The canister, whose internal dimensions are 8 in. in diameter by 8 in. high, will be used for small tools, samples, and the like. A 12-in.-square air lock in the walls separating the cells can also be used for transfer. The conveyor communicates with each cell and with the transfer area cubicle, where the canisters can be charged or discharged. The transfer area cubicle is provided with manipulators. A glove box accessible through a rotary transfer port provides for removal of low-activity items. A door in the transfer area cubicle shield accommodates a shielded carrier that uses the double-cover technique for transfer of highly active materials such as analytical samples and solid wastes.

All chemical equipment is mounted on racks to facilitate fabrication and installation. A shielded equipment transfer case (Fig. 2.9), also using the double-cover design, is provided for the introduction of equipment racks into the cubicle. The rectangular transfer case will accommodate equipment 1.5 × 3 × 6 ft (high).

The office annex is isolated from the laboratory portion of the building except for a single doorway, and the shop area is isolated from the processing portion of the building except for a single doorway. The shop area is included in the Regulated Zone, but the office annex is not.

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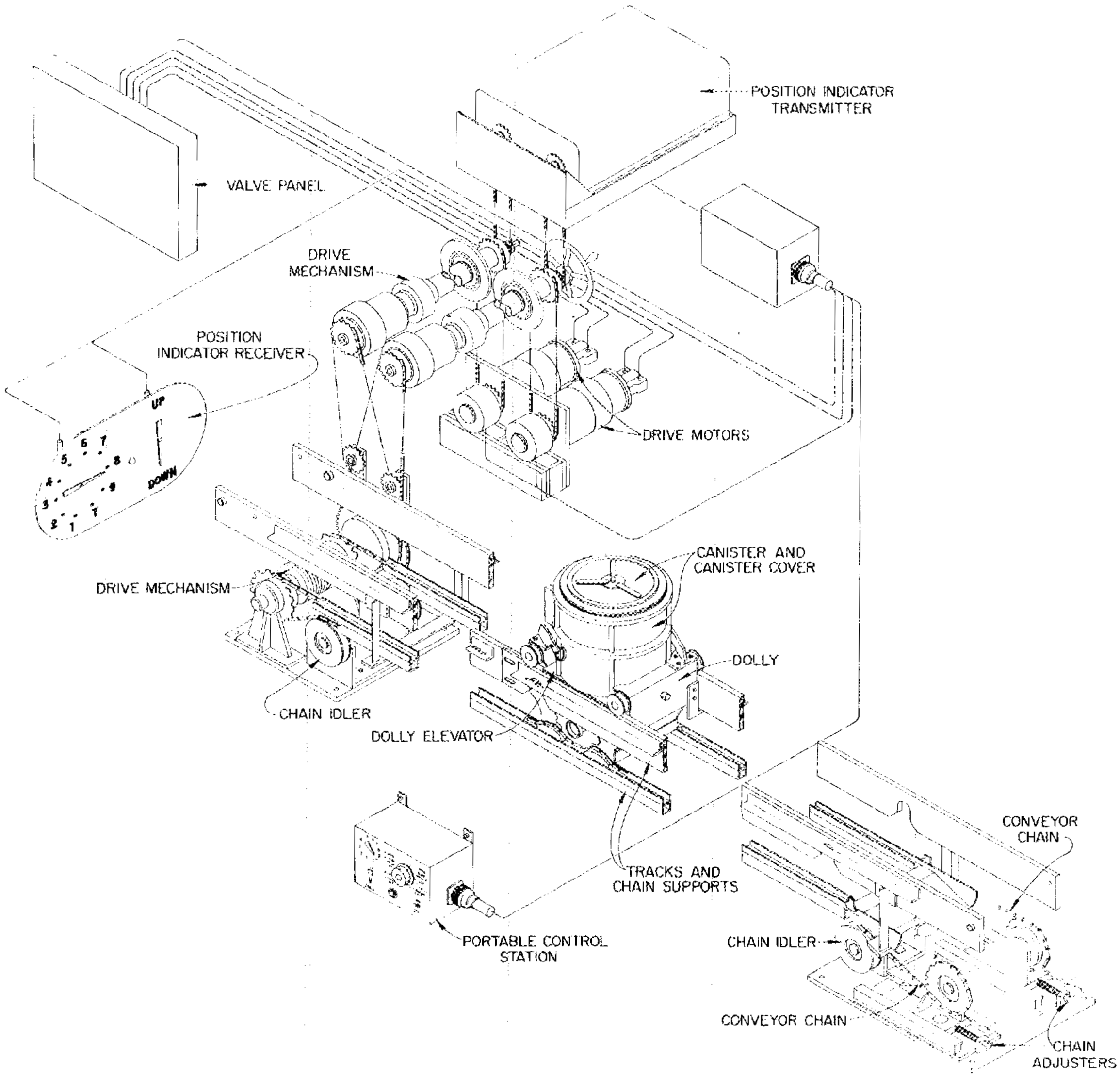

Fig. 2.8. Intercell Conveyor.

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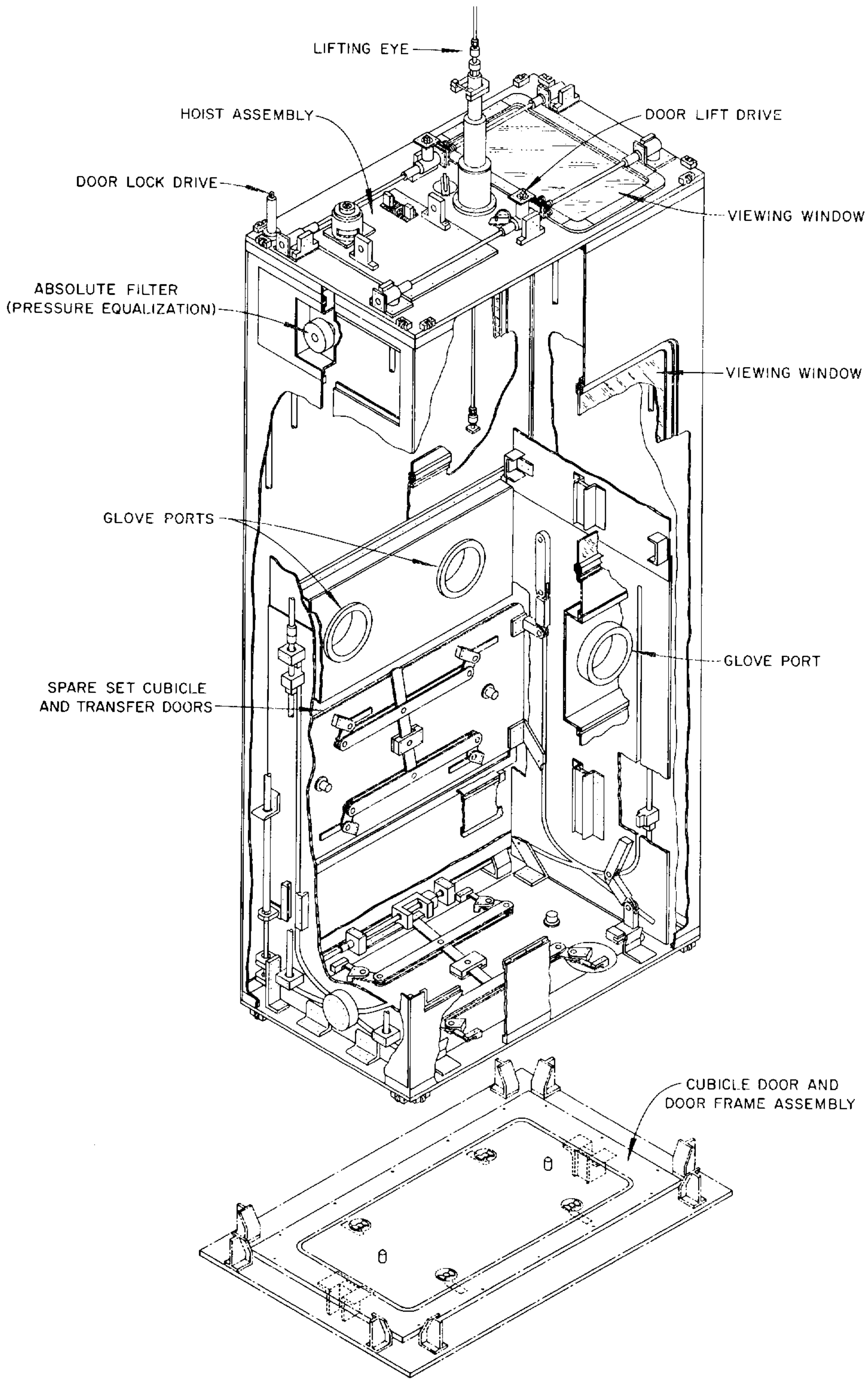

Fig. 2.9. Cutaway View of Equipment Transfer Case. The shield is not shown.

2.2 Penetrating Radiation and Shielding

The fission source design basis for TRU shielding is considered to be the fifth-cycle target (composed of the residual actinides of the successive irradiations beginning with ^{242}Pu). On the average, a fifth-cycle target rod, containing approximately 305 mg of californium and spontaneously fissioning at a rate of 0.78×10^{12} fissions/sec will be processed at the rate of one rod every two years. Special irradiations, such as 1 g of ^{252}Cf fabricated into a target and irradiated for 30 days in the HFIR at a flux of 5×10^{15}, will spontaneously fission at a rate approximately three times that of the fifth-cycle rod; but processing of such a source is unusual and is expected to be very infrequent.

In addition to the neutrons and the gamma radiation that will originate from spontaneous fission of californium isotopes, fission products will constitute a source of gamma radiation. For design purposes, the maximum quantity of fission products was represented by the rare-earth fission products from the fissioning of 10 kg of ^{239}Pu, which will be separated from the associated ^{243}Am – ^{244}Cm in the TRU facility. After a 90-day decay period, the distribution of the rare-earth fission product gamma radiation, on which the gamma shielding requirements are based, was as follows:

500,000 curies of 1-Mev gamma emitters,
80,000 curies of 1.7-Mev gamma emitters, and
2,500 curies of 2.6-Mev gamma emitters.

The shielding of TRU is designed so that, during the processing of the maximum quantity of fission products or a fifth-cycle rod, the penetrating radiation dose rate in normally occupied areas is no greater than 0.75 mrem/hr. The dose rate of permissible hot spots on small areas, such as those opposite wall penetrations, will be no greater than 2.5 mrem/hr. For normal and routine processing, the penetrating radiation level in the operating area will be less than 0.25 mr/hr. In limited-access areas (areas not normally continuously occupied by operating personnel) the maximum dose rate will be, nominally, 2.5 mrem/hr, with limited-area hot spots permitted up to 10 times this value. During the very infrequent operations in which the products of a special californium irradiation are handled in cubicles, the basic dose rate in normally occupied areas will be approximately 2.5 mrem/hr. For short-term nonroutine operations, such as roof plug removal, filter removal, equipment removal, cell entry, and carrier handling, radiation levels as high as 500 mrem/hr will be permitted. The neutron and gamma-ray dose rates at the surface of the 54-in.-thick high-density concrete cell wall, which constitutes the required shield to satisfy the permissible dose rate criteria, are tabulated in Table 2.1. The required shielding thickness assumes a concrete shield containing 1.67 grams of iron and 0.196 grams of H_2O per cc. The increased density contributed by the iron enhances the attenuation of gamma irradiation, but the iron, along with the water retention, is primarily required for the attenuation of the fission neutrons from the spontaneously fissioning californium.

Table 2.1 Neutron and Gamma-Radiation Dose Rates at the Outside Surface of the 54-in.-thick, High-Density Concrete Cell Wall for Various Radiation Sources Located Within the Cell

Source	Dose Rate (mrem/hr)
1. 305 mg of Cf from 5th-cycle rod (0.78×10^{12} fissions/sec, $\nu = 3.8$)	0.75
2. 1 g of Cf after special irradiation at flux of 5×10^{15} (2.7×10^{12} fissions/sec, $\nu = 3.8$)	2.5
3. Gamma radiation from rare-earth fission products resulting from burnup of 10 kg of ^{239}Pu after 90-day decay period	0.05

2.2.1 Design and Construction

Both ordinary concrete and high-density concrete were used for shielding personnel from penetrating radiation. Two kinds of aggregates were used for the high-density concrete: magnetite and a mixture of limonite and ferrophos that has the same shielding properties as magnetite for both gamma rays and neutrons. Limited availability of magnetite ore made it necessary to use the limonite-ferrophos. The high-density concrete has a density of 210 lb/ft^3 with a retained water content of 12.2 lb/ft^3. The shields were designed to be about equally effective for shielding 2.0-Mev neutrons and 2.4-Mev gamma rays.

Walls, Partitions, and Roof. — The exterior cell walls, the intercell and interior cell partitions, and the cell roof will provide gamma-neutron shielding equivalent to the following:

1.	Front wall (all cells)	54 in. of limonite-ferrophos concrete
2.	East end wall	54 in. of limonite-ferrophos concrete
3.	West end wall	24 in. of limonite-ferrophos concrete
4.	Rear wall (cells 1 to 7)	48 in. of limonite-ferrophos concrete
5.	Rear wall (cells 8 and 9)	36 in. of limonite-ferrophos concrete
6.	Roof slabs (removable)	48 in. of limonite-ferrophos concrete
7.	Intercell partitions	24 in. of magnetite concrete
	Except partition between cells 7 and 8	48 in. of magnetite concrete
8.	Interior cell partitions at operating level	18 in. of magnetite concrete

High-density concrete was used above the level of the operating-area floors, and extends far enough below the floor level to give adequate shielding. Below that level, ordinary concrete was used.

The cell roof is made of removable precast slabs of limonite-ferrophos concrete. The entire cell interior and all partition walls are completely exposed when the roof plugs are removed.

Viewing Windows. — Each of the nine cells and the transfer area cubicle have a combination lead glass and oil-filled viewing window. The cell windows are 54 in. thick, and the transfer-area cubicle window is 25 in. thick.

Radiation Shielding Doors. — In the rear wall of each of the two analytical cells (8 and 9) is a high-density door. These doors have a clear opening 4 ft wide and 7 ft high, are stepped over their entire periphery to prevent radiation streaming, and are gasketed to provide a positive seal against air inleakage when closed. The seals leaked 0.3 cfm when tested at a pressure difference of 2 in. water (gage).

2.3 Evacuation Routes

Evacuation routes out of the building are shown in Figs. 2.3 and 2.4, and the assembly point where personnel are to await instructions from the Laboratory (ORNL) Emergency Supervisor is shown in Fig. 2.10. The way in which emergencies are to be handled and the circumstances under which the evacuation routes will be used will be examined in detail in a Building 7920 Emergency Manual.

2.4 Process Equipment

Flexibility is the outstanding feature of the process equipment. Uncertainties in the chemistry of the actinides, as well as the corrosiveness of the chemicals required for the processes that will be used initially, necessitate complete and relatively simple replacement of process equipment. The large amounts of radioactivity involved require that maintenance and equipment replacement be done remotely. An all-metal piping disconnect is used throughout the plant for installing equipment and process piping. Process valves and pumps have been developed for use with the disconnect system in the limited space that is available. All process equipment was fabricated out-of-cell, using jigs that will be used to fabricate replacement equipment. A basic cubicle and cell structure was mocked up and used to test design and maintenance concepts.

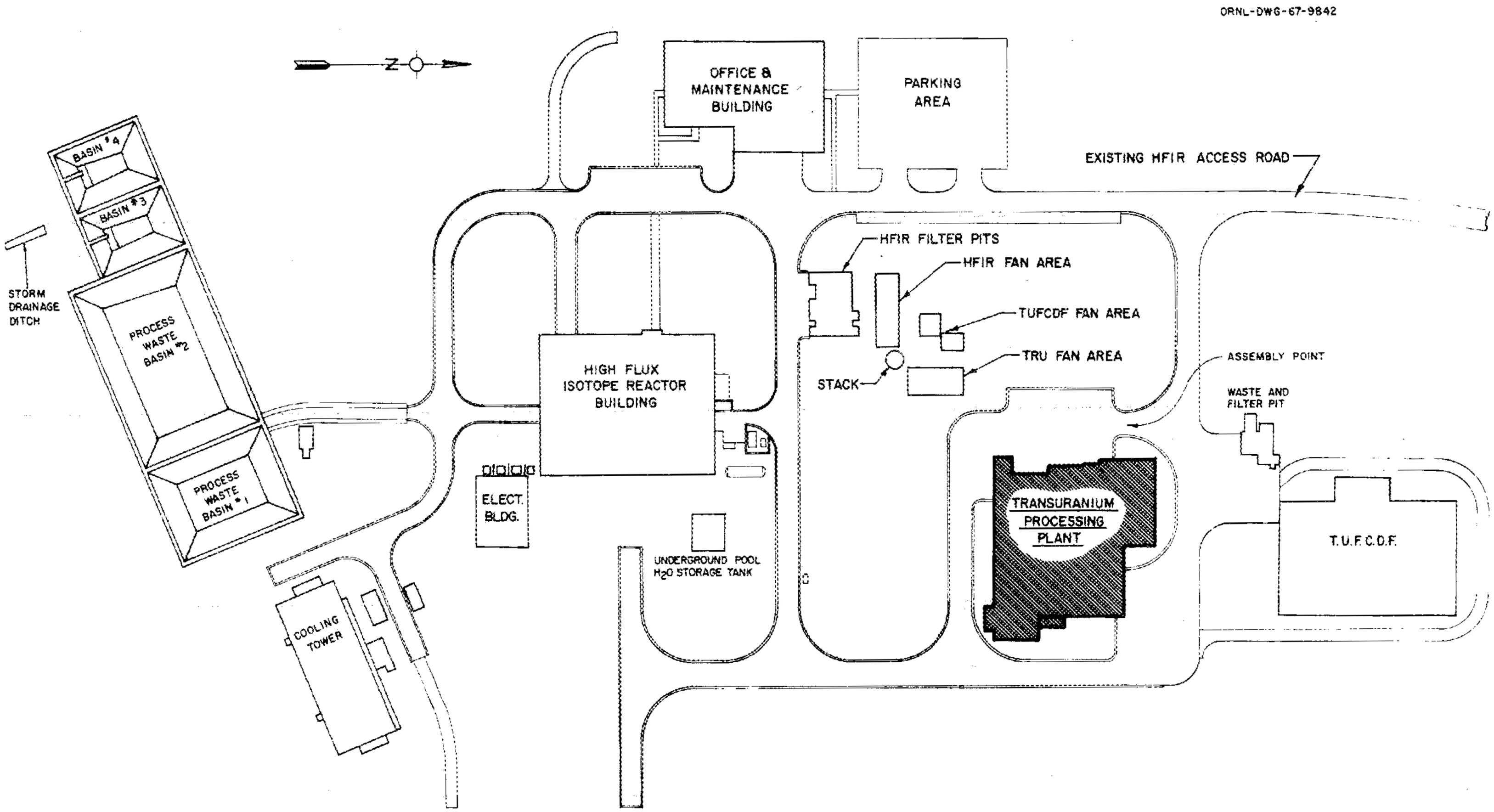

Fig. 2.10. Melton Valley Area.

2.4.1 Cubicle Equipment

All mechanical equipment for chemical processing is located on one of three racks in each of the cubicles in cells 4 through 7. A 12-point sampling station is located in the bottom half of the back racks of the four cubicles for sampling tanks in pits 1 through 9. The side racks and the top half of the back racks contain the process equipment, which is connected to the tanks in the pits by jumper lines that pass through disconnect wells in the cubicle floor and under the floor to a group of disconnects in the pit (Fig. 2.11). The entire bundle of lines beneath each cubicle can be removed and replaced from the pit by working through an opening in the top of the cell. The opening would be made by removing some of the roof plugs.

A typical rack, for solvent extraction equipment, is illustrated in Fig. 2.12. The valves and pumps can be removed from the rack with manipulator-operated tools and replaced with new units transported to the cubicle in the intercell conveyor. Objects up to 8 in. in diameter and 8 in. high can be transported in the conveyor. The pulsed columns and other large pieces of equipment, or entire equipment racks, can be removed and replaced through a removal hatch in the cubicle top into the sealed transfer case. Jumper lines connecting equipment racks to each other and to the disconnect wells are removable by the same techniques. Service line bundles to the cubicles are removable through roof plugs in the cell bank. Use of the disconnects for all connections allows the cubicle to be remotely stripped of all process lines and equipment if necessary.

TRU Disconnects. — Removal of equipment is facilitated by an all-metal piping disconnect developed for tubing sizes from 3/8 to 3/4 in. Two conical surfaces, differing slightly in angle of the mating surfaces (18° male and 20° female), are forced together by a clamp (Fig. 2.13). The single bolt on the disconnect clamp can be operated by a manipulator-held impact wrench or directly by a long-handled socket wrench. Repeated tests of this disconnect under simulated process conditions indicated leakage rates of less than

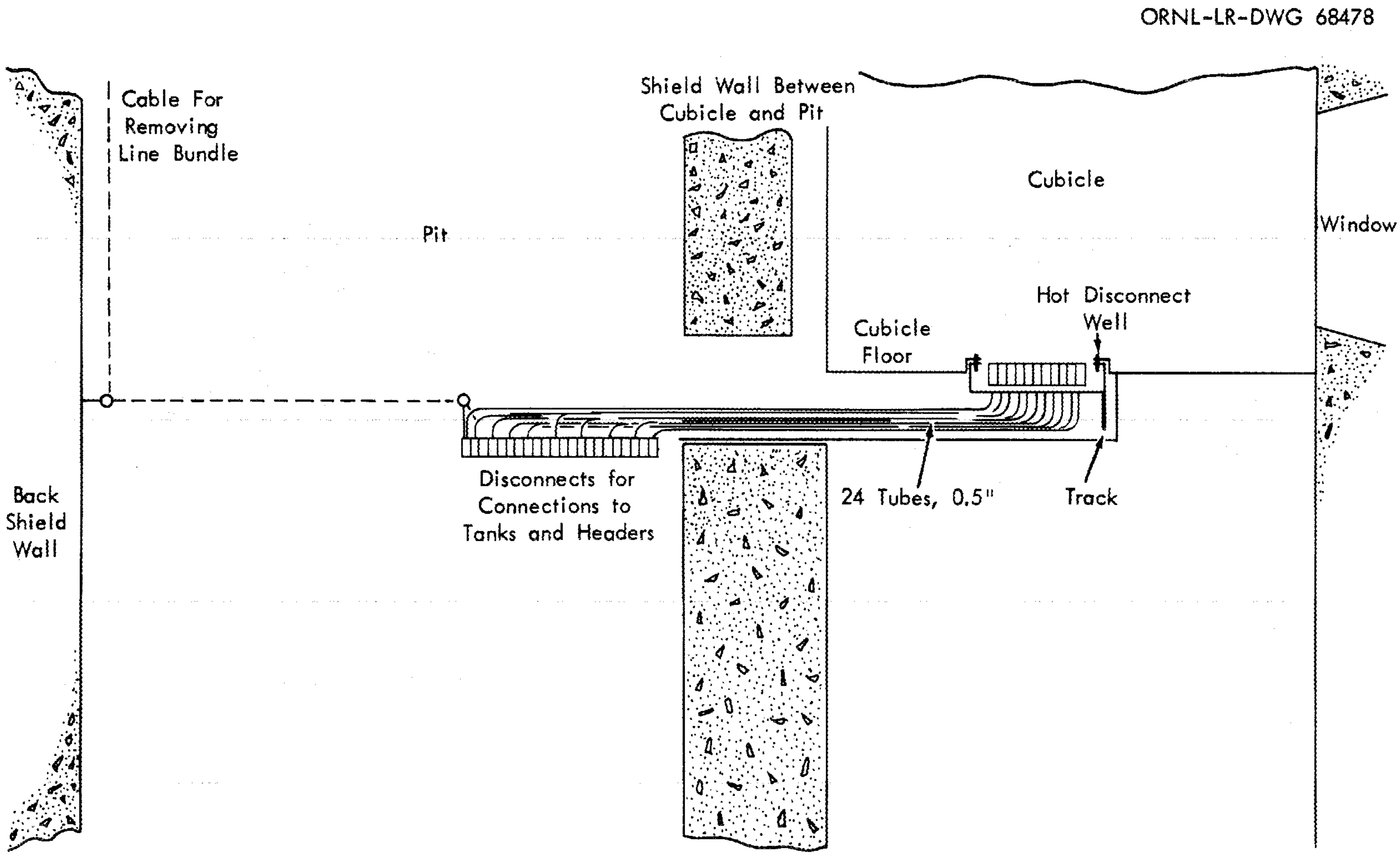

Fig. 2.11. Method of Replacing Disconnect Well.

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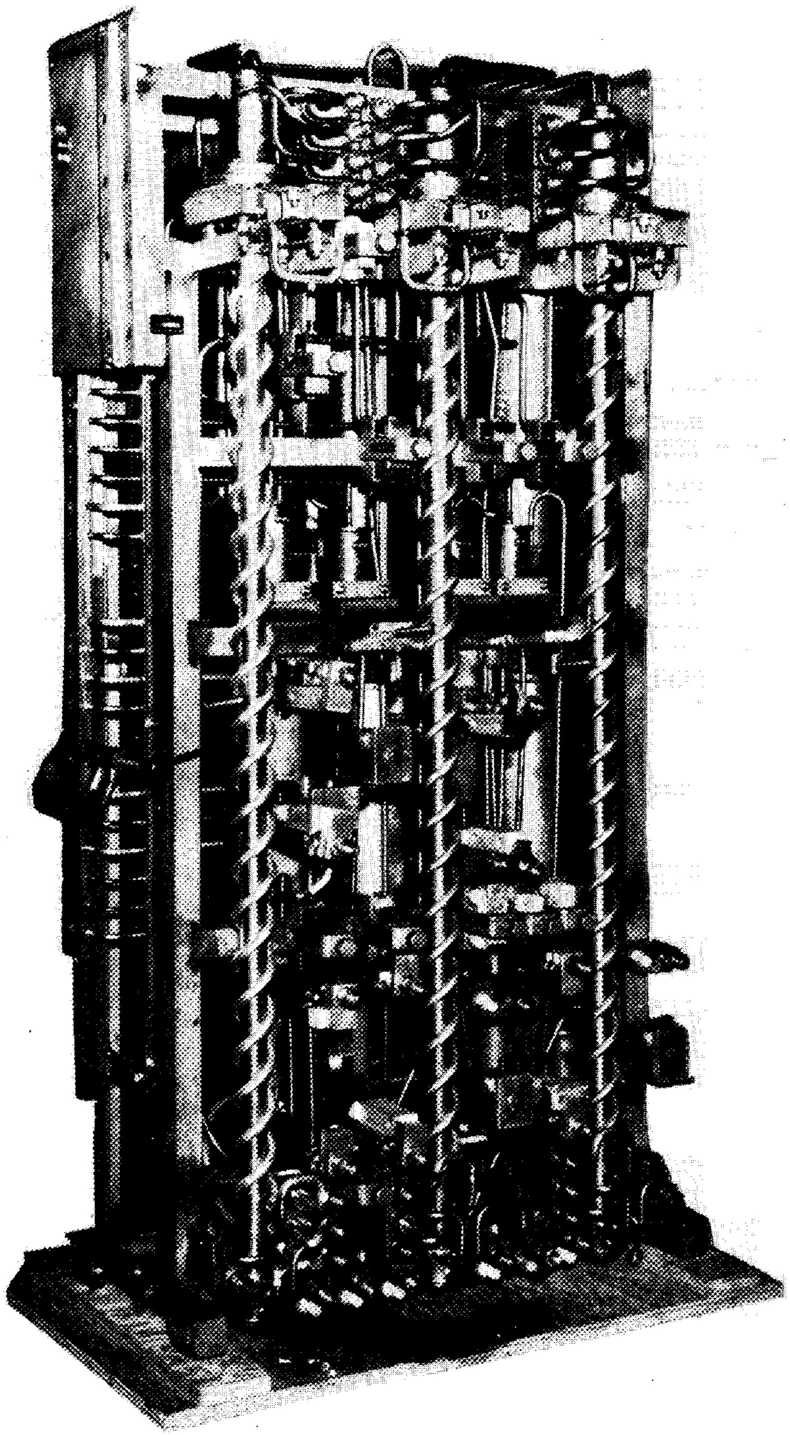

Fig. 2.12. Solvent Extraction Equipment Rack.

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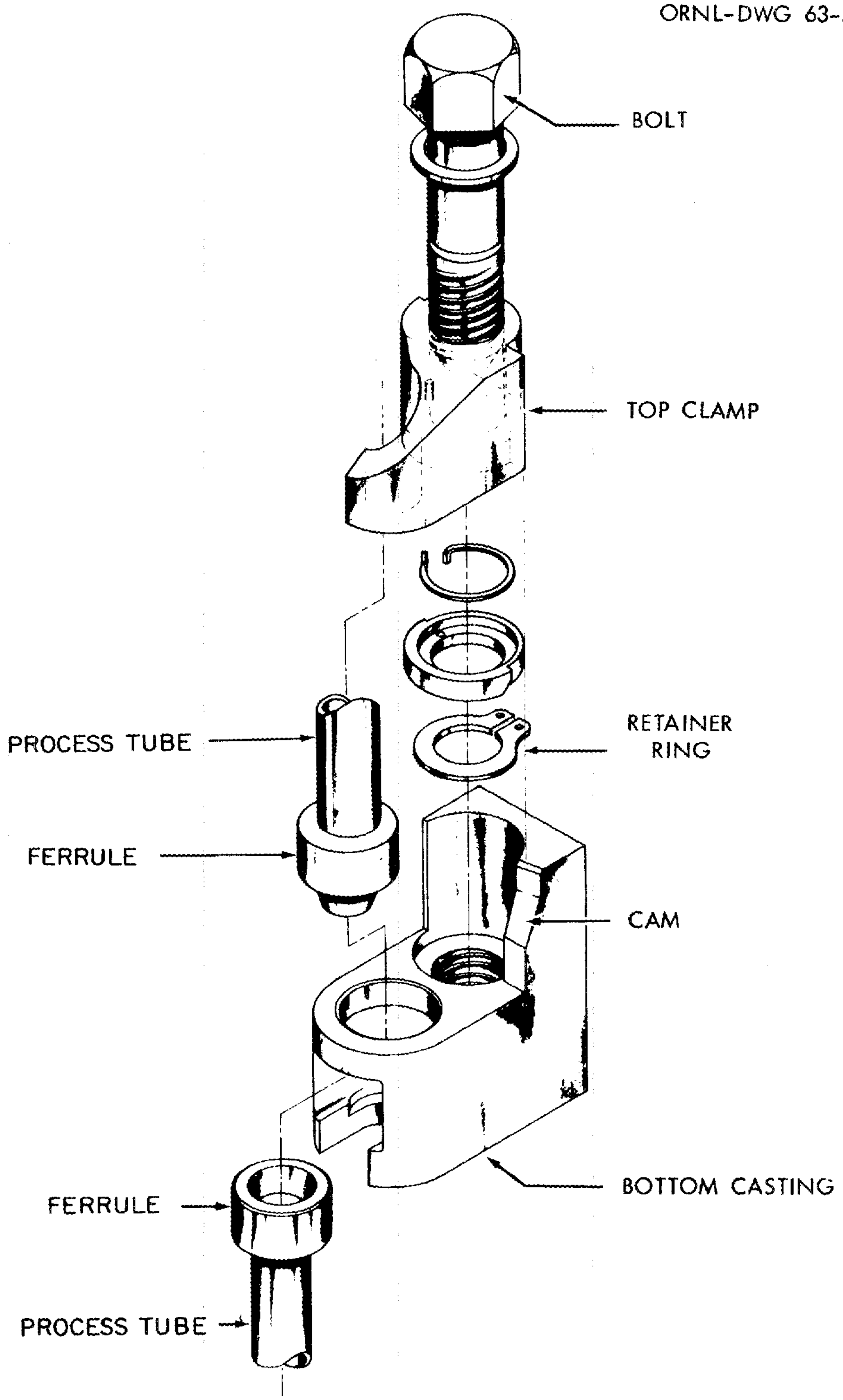

Fig. 2.13. TRU Disconnect.

1×10^{-8} std cc of helium per second, even after several makes and breaks of the disconnect surface. This disconnect is used throughout the plant for installing equipment and process piping.

Process Pumps. — The process pumps (Fig. 2.14) are air-operated diaphragm pumps that are pulsed by alternately applying pressure and vacuum to the drive side of the diaphragm. Each pump is 6 in. in diameter and 1.5 in. thick, with a capacity of 30 to 40 liters/hr at pulsing frequencies of 60 to 80 cpm. The pumps are installed with two bolts, can be handled with the heavy-duty manipulators, and will fit into the intercell conveyor canister. There are about 40 sampler pumps and 15 feed and transfer pumps.

Sampler Station. — A 12-unit sampler is installed on the back rack in each of the four processing cells. The sampler station can be separated as a unit from the rack so that major equipment changes in the rack equipment may be made without replacing the sampler. Each of the 12 units consist of a drive pump, needle block, and bottle-handling mechanism. A conventional two-needle arrangement is used. The needle blocks are in an enclosed housing that is equipped with water spray for simple decontamination after each sampling operation. All pumps in one station are driven from the same external pressure-vacuum supply system; manipulator-operated valves on each pump are used to actuate the desired pumps.

Target Dissolver. — Targets from HFIR and other types of slugs up to 1 in. in diameter and 45 in. long are dissolved in the dissolver, T-70 (Fig. 2.15). The dissolver vessel is located in a well in the floor pan of cubicle 7, and a tantalum condenser and condensate routing system are located on the right-side equipment rack in cubicle 7. The location of the vessel in a well provides enough room within the cubicle, above the dissolver, for loading the targets which are 35 in. long (Fig. 2.16).

The dissolver and associated solution transfer system are made of Zircaloy-2. The vessel is 50 in. high, with a small-diameter lower

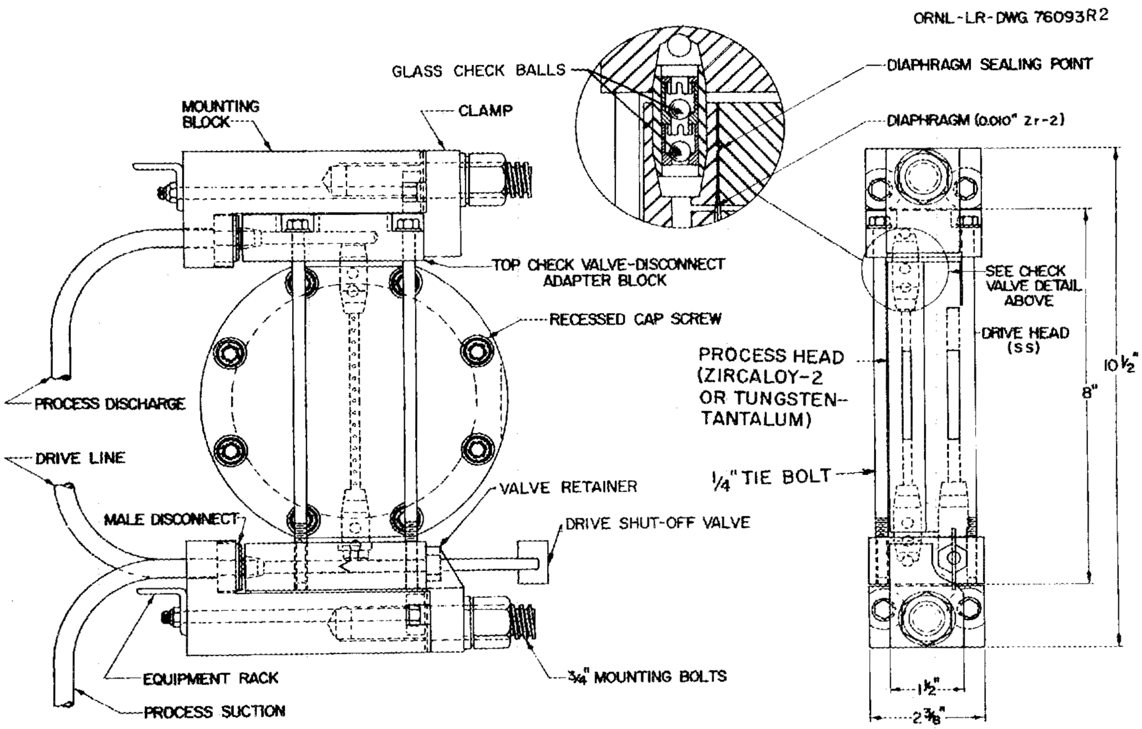

Fig. 2.14. Schematic of TRU Pump.

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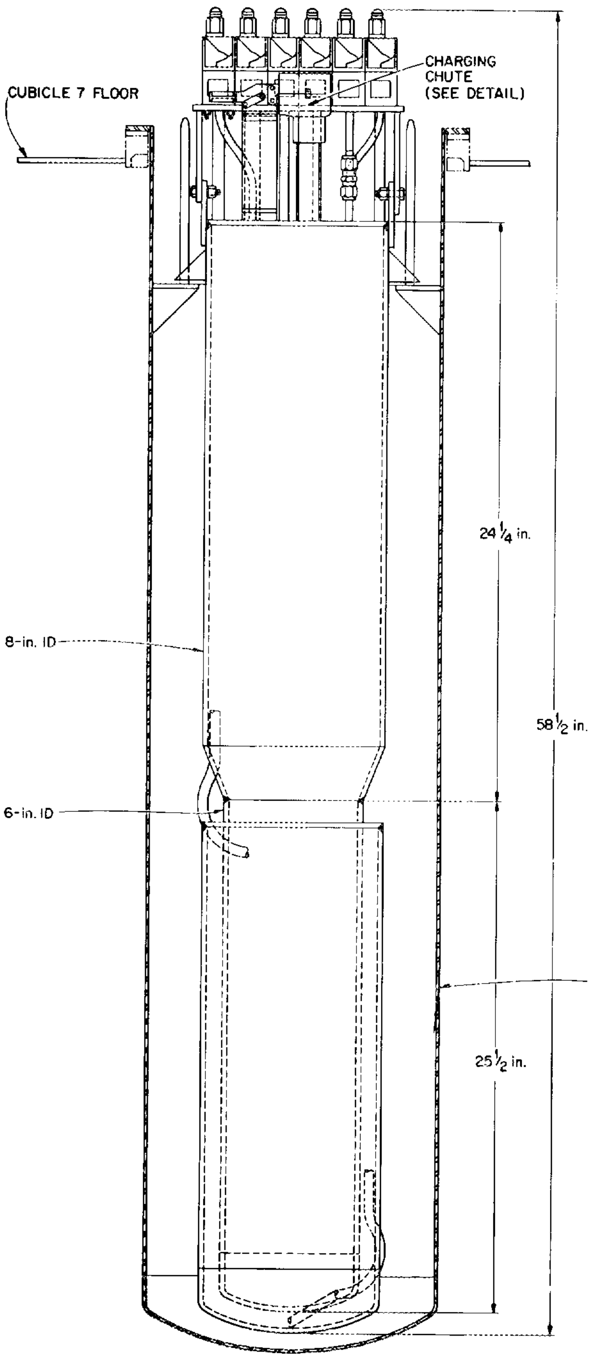

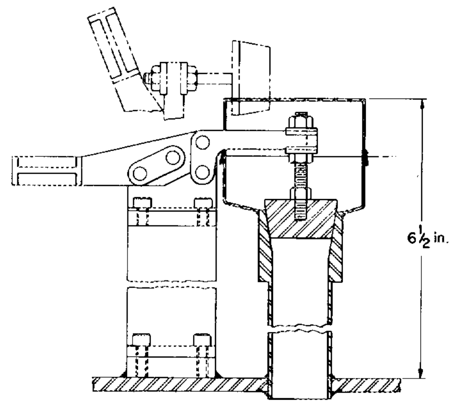

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Fig. 2.15. Zircaloy-2 Dissolver.

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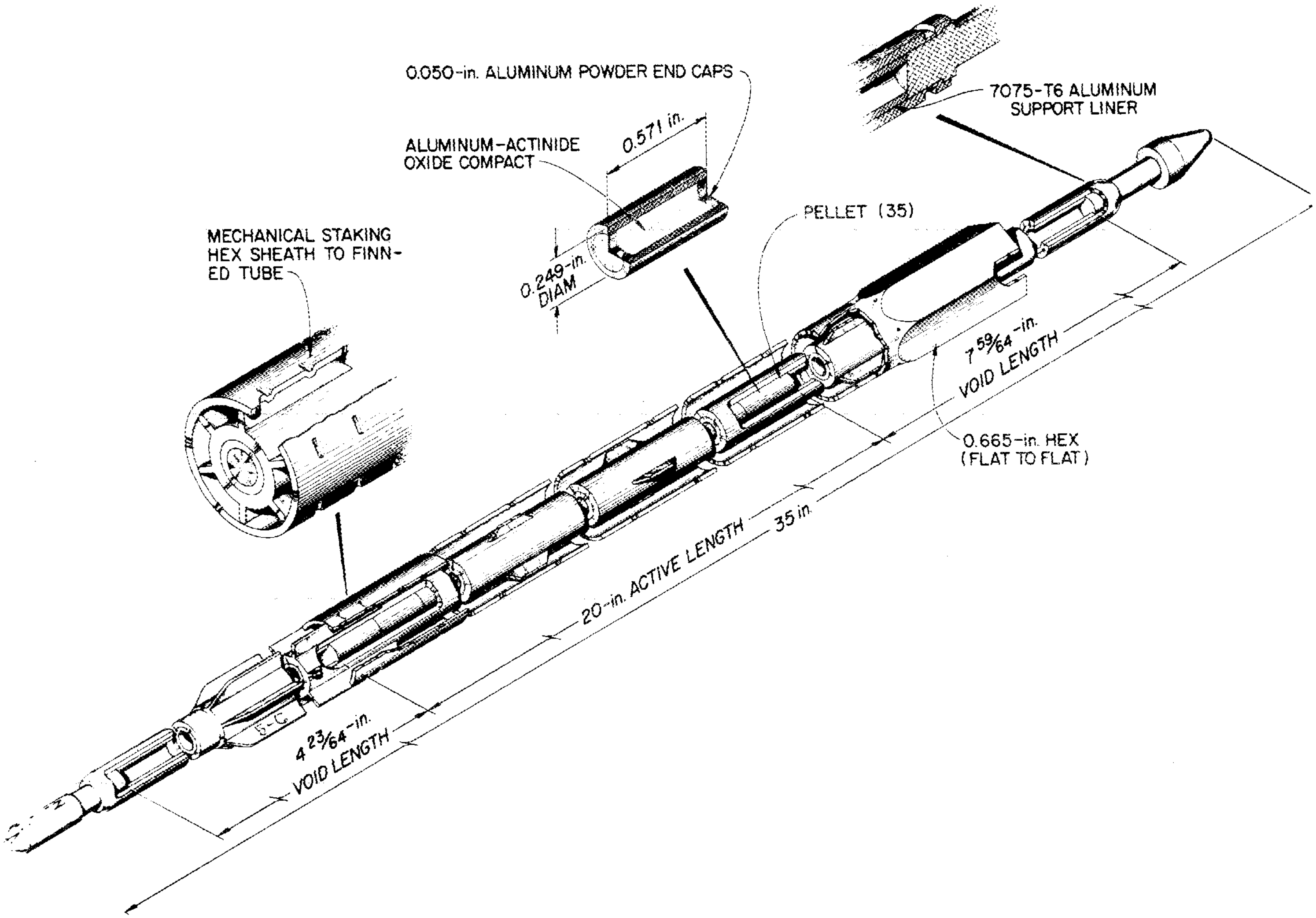

Fig. 2.16. HFIR Target Rod.

section (6-1/8 in. I.D. by 25 in. high) to minimize the amount of solution required to cover a target, and a larger-diameter upper section (8-in. I.D. by 21 in. high) for de-entrainment. The lower section is surrounded by a jacket for temperature control and is equipped with a sampler; level, density, and pressure-recording instrumentation; an air sparger; and a line for purging with air to dilute the hydrogen formed during the dissolution.

All lines that extend outside the cell bank from the interior of the dissolver are protected by radiation block valves which are closed if high activity is detected in any of the lines.

Cubicle 7 Right Rack. — This equipment rack contains an ion exchange column in addition to the dissolver condensate system. The column is to be used primarily for the recovery of plutonium from short-irradiated targets that contain significant quantities of plutonium. It is about 5 ft high, is made of 2-1/2 in.-O.D. Zircaloy-2 tubing, and the bottom portion has a jacket made of 3-1/4 in.-O.D. Zircaloy-2 tubing. Total volume is 2.7 liters.

Cubicle 7 Left Rack. — Equipment for the Tramex process occupies this rack. There are three pulsed columns that are 1-1/2 in. in diameter and have 5-ft-long contacting sections. Total volume of each column is 2 liters. Auxiliaries include the feed-metering system, pulsers, intercolumn pumps, pressure-pot flow control systems, and two solution hold-up pots. The hold-up pots (10 liters each) provide the means for isolating catch tanks during sampling and transfer. The material of construction of most surfaces that contact process solutions is Zircaloy-2. Exceptions are the tantalum-tungsten diaphragms in the pumps and the tantalum strip column C-74.

Cubicle 7 Back Rack. — The back rack contains filter F-70 and pump P-70 for transferring solution from the dissolver. Filter F-70 consists of a fiber-glass-wound filter element in a 2-1/2 in.-O.D. by 5-5/8 in.-long Zircaloy-2 tube. Total volume is about 420 cc. The bottom part of the rack contains a 12-unit sampler station.

Cubicle 6 Right Rack. — The berkelium recovery system is located on the right-side equipment rack in cubicle 6. The major components, the batch contactor C-66, the feed and scrub hold tank T-63, and the berkelium product hold tank T-64, are made of Zircaloy-2. The contactor C-66 is a spray column 1-1/2 in. in diameter by 57-1/2 in. long with a solution outlet at the bottom and two separate spray heads in the top for introducing radioactive and cold feed solutions. Column volume is 1450 cc. Tanks T-63 and T-64 hold 9.1 and 8.6 liters, respectively.

An auxiliary equipment rack containing a dissolver system is temporarily attached to right rack 6. All equipment is of stainless steel for dissolving, in HNO_3 - HF, targets in which plutonium burnup is less than 80%. The dissolver, T-604, is a 3-ft-long, 6-in. schedule-40 pipe that has a 17-liter capacity. Off-gas scrubber C-607 is an 18-in.-long, 4-in. schedule-40 pipe packed with glass Raschig rings. Other equipment includes a condenser H-606, a sintered stainless steel filter F-605, and a pump P-608.

Cubicle 6 Left Rack. — The second-cycle solvent extraction equipment (Pharex flowsheet) is similar to the first-cycle equipment. Either the Tramex or Pharex flowsheet can be run in either set of equipment. However, some minor changes in arrangement of jumper lines would be necessary.

Cubicle 6 Back Rack. — The upper part of the back rack contains filter F-60 and process pumps P-63 and P-64. The bottom part contains a 12-unit sampler station.

Cubicle 5. — Cubicle 5 is free of equipment except for the sampler station and product distribution system on the back rack. It will be used for special separations as needed.

Cubicle 4 Right Rack. — The equipment that is located here for the separation of californium, einsteinium, and fermium is made entirely of tantalum. The process is a chromatagraphic ion exchange separation that is effected in column C-41. Column volume is 500 cc. Other equipment includes a 5-liter, jacketed feed evaporator T-400, a 3-liter-capacity feed tank T-401, a filter F-400, and three 2-liter product tanks T-402, T-403, and T-404.

Cubicle 4 Left Rack. — Equipment for the preparation of actinide oxides for target fabrication will be located here. Design is not complete.

2.4.2 Target Fabrication Equipment

The in-cell equipment for target fabrication is located in cubicles 1, 2, and 3. Components are arranged so that the target fabrication can proceed nearly automatically. The equipment rack-disconnect concept is not used here because of the precision with which equipment must be located. However, all equipment can be repaired or replaced remotely.

The system is designed to minimize the spread of contamination. In general, operations with loose powders will be performed in cell 3, those with pellets open to the cubicle atmosphere in cell 2, and those with sealed target elements in cell 1.

Equipment layouts for cubicles 3, 2, and 1 are shown in Figs. 2.17, 2.18, and 2.19, respectively.

2.4.3 Equipment in Tank Pits

Tank pits that contain waste collection equipment, process equipment, and process and storage tanks are located behind and below the cubicles and are shielded from them by concrete walls. The tank pit floors are covered with Hastelloy C pans, and the walls are covered with glass-fiber-reinforced resin.

The equipment in the tank pits is listed in Table 2.2. The in-cell tanks for the process can be classified in three groups as: (1) feed and product evaporators, (2) product storage tanks, and (3) waste accumulation tanks. The tanks are about 4-1/2 ft high and range in volume from 20 to 600 liters. All nozzles terminate in TRU disconnects located 40 in. above the head of the tank.

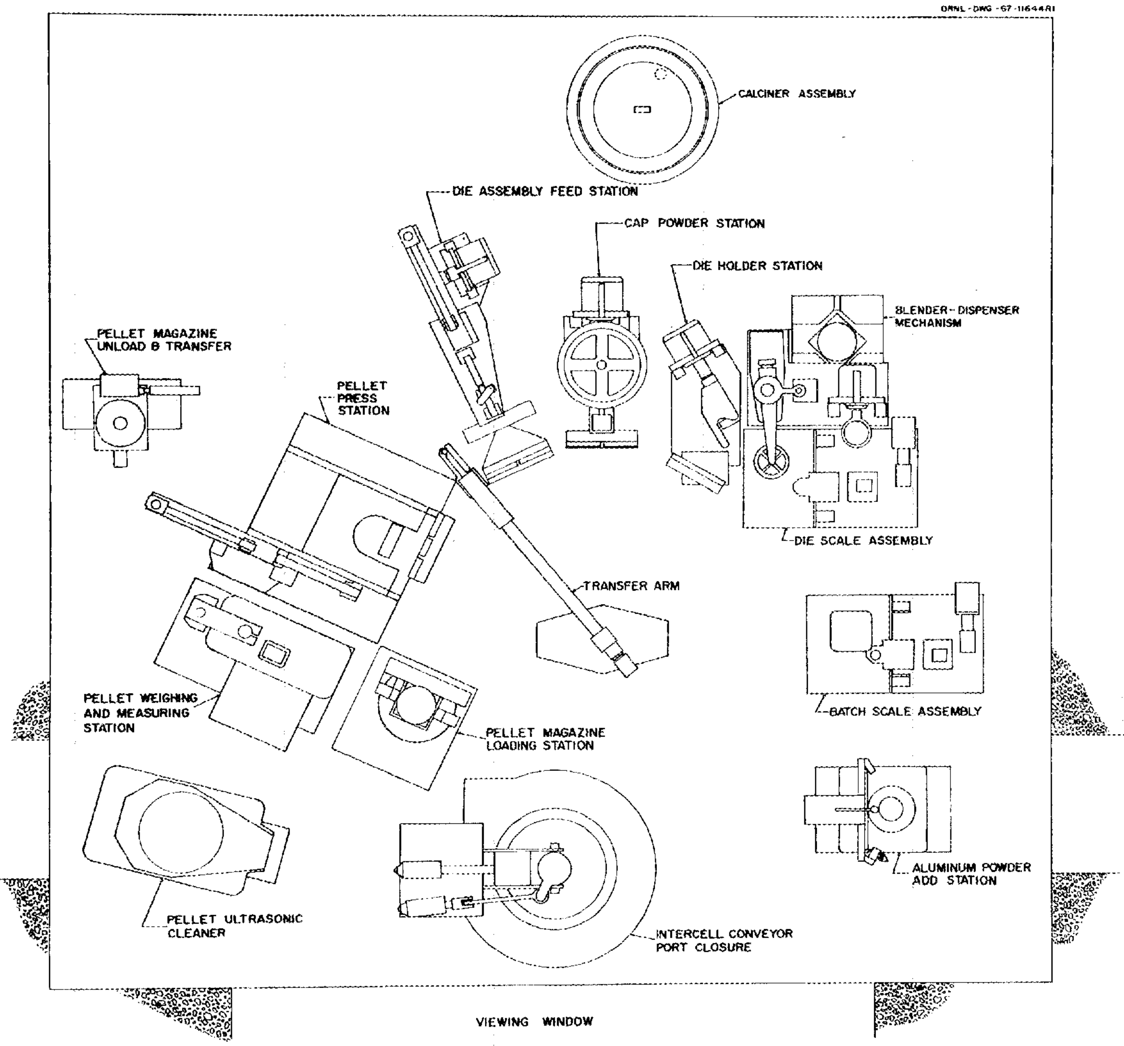

Fig. 2.17. Equipment Layout for Cubicle 3.

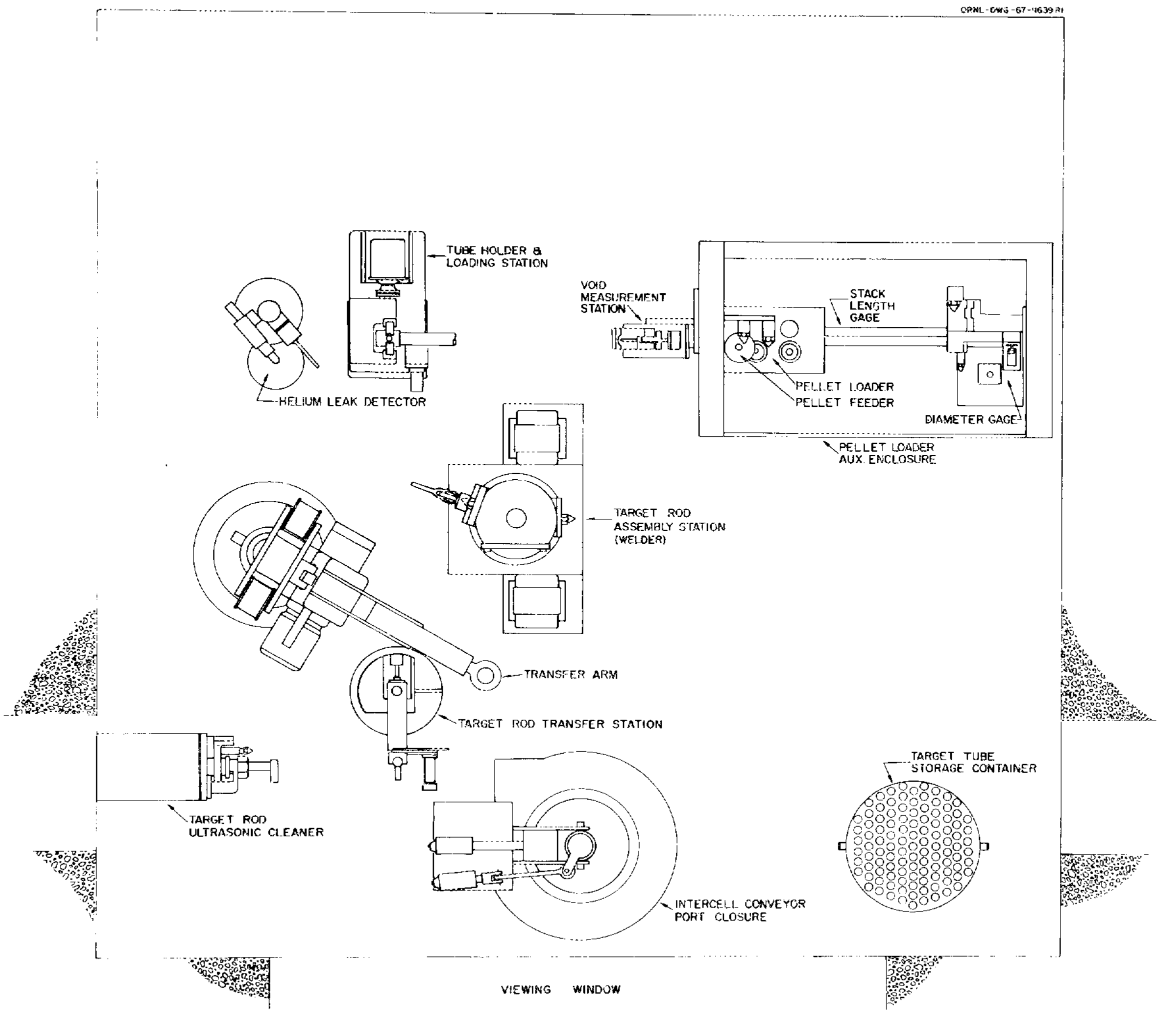

Fig. 2.18. Equipment Layout for Cubicle 2.

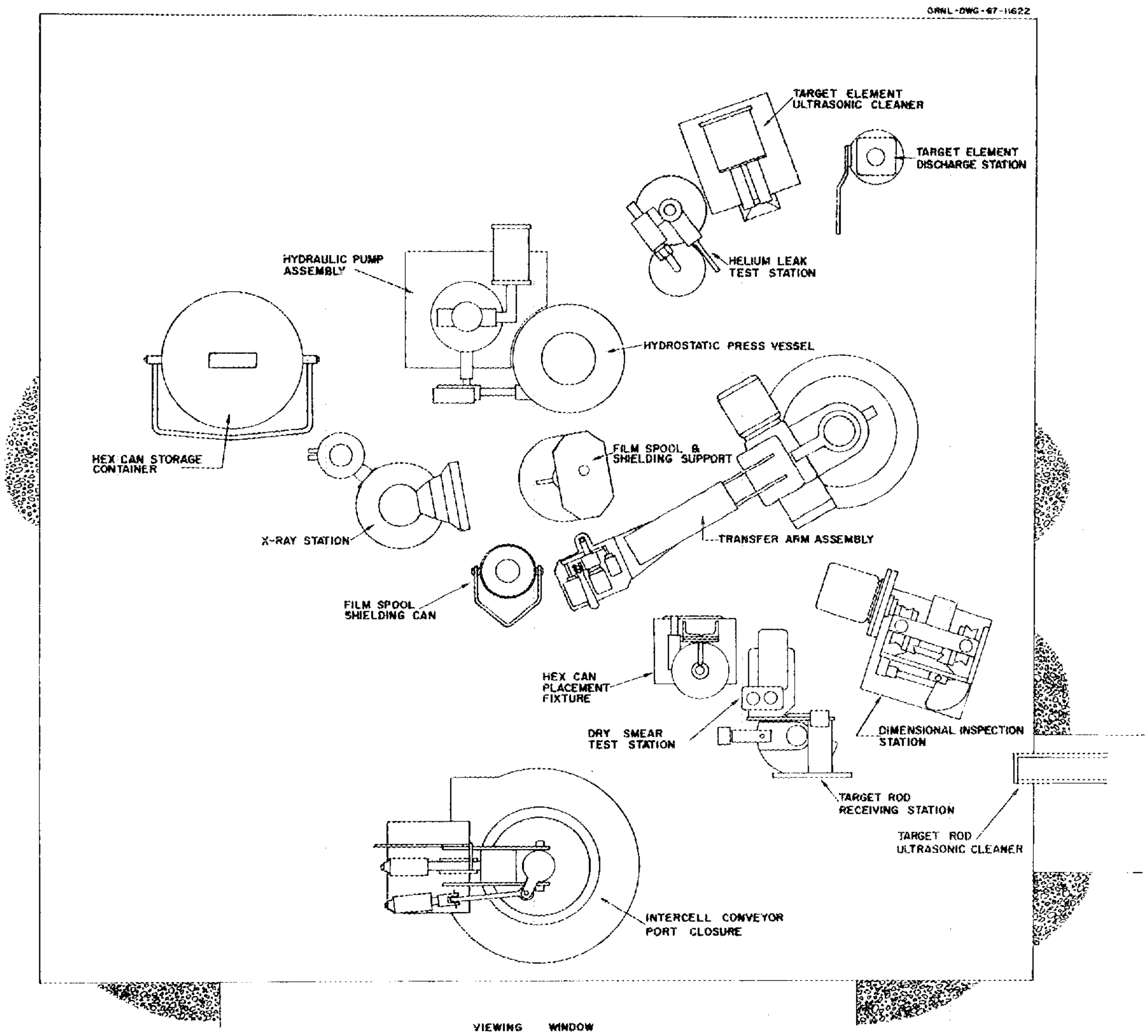

Fig. 2.19. Equipment Layout for Cubicle 1.

Table 2.2. Tanks and Equipment in Cell Tank Pits

Location	Equipment No.	Volume	Material	Description of Process Function
Waste Tank Pit	F-111	125 gal	Stainless Steel	Waste collection from transfer-area drain and conveyor housing drain
	F-115	550 gal	Hastelloy C	Intermediate-level waste collection from building ILW drains or from process
	F-126	1200 gal	Stainless Steel	Waste dilution and neutralization tank
Cell 7 Tank Pit	L-131	130 liters	Hastelloy and stainless	Vessel off-gas caustic scrubber
	T-71	70 liters	Hastelloy C	Plutonium feed adjustment tank
	T-72	83 liters	HC-Ta-Ta[a]	Feed adjustment for first-solvent extraction cycle
	T-73	70 liters	Zircaloy-2	First-cycle feed tank
	T-77	298 liters	Hastelloy C	Aqueous rework
	T-78	157 liters	Hastelloy C	Collection of waste ion exchange resin
	H-72		Ta - stainless steel	Off-gas condenser for T-72
Cell 6 Tank Pit	T-60	67 liters	HC-Ta-Ta[a]	Intercycle evaporator
	T-61	70 liters	Zircaloy-2	Second-cycle feed tank
	T-65	24 liters	HC-Ta-Ta[a]	Berkelium system feed adjustment tank
	T-66	70 liters	Zircaloy-2	Centrifuge overflow collection tank
	T-67	25 liters	Zircaloy-2	Intercycle catch tank (after first cycle)
	T-601	70 liters	Hastelloy C	Second-cycle aqueous waste catch tank
	T-602	20 liters	Zircaloy-2	Centrifuge solids feed tank
	F-61	19 liters	Zircaloy-2	Centrifuge for removing aluminum precipitate from dissolver solutions
	H-60		Ta - stainless steel[b]	Off-gas condenser for T-60
	H-65		Ta - stainless steel[b]	Off-gas condenser for T-65
Cell 5 Tank Pit	T-50	25 liters	Zircaloy-2	Transuranium product storage tank
	T-51	25 liters	Zircaloy-2	Transuranium product storage tank
	T-52	25 liters	Zircaloy-2	Transuranium product storage tank
	T-53	25 liters	Zircaloy-2	Transuranium product storage tank
	T-54	24 liters	HC-Ta-Ta[a]	Product evaporator
	H-54		Ta - stainless steel[b]	Off-gas condenser for T-54
Cell 4 Tank Pit	T-40	67 liters	HC-Ta-Ta[a]	Am-Cm evaporator
	T-41	25 liters	HC-Ta-Zr2[c]	Transuranium product hold tank
	T-42	25 liters	HC-Ta-Zr2[c]	Transuranium product hold tank
	T-43	24 liters	HC-Ta-Ta[a]	Precipitator feed adjustment
	T-45	25 liters	Zircaloy-2	Precipitator waste tank
	T-47	70 liters	Zircaloy-2	Californium storage
	T-48	25 liters	HC-Ta-Zr2[c]	Transuranium product hold tank
	H-40		Ta - stainless steel[b]	Off-gas condenser for T-40
	H-43		Ta - stainless steel[b]	Off-gas condenser for T-43
Cell 3 Tank Pit	T-30	25 liters	Zircaloy-2	Transuranium product storage
	T-31	25 liters	Zircaloy-2	Transuranium product storage
	T-32	70 liters	Zircaloy-2	Transuranium product storage
	T-33	25 liters	Zircaloy-2	Transuranium product storage
	T-34	158 liters	Hastelloy C	Process condensate collection
Cell 2 Tank Pit	T-20	78 liters	Hastelloy C	First-cycle aqueous waste
	T-21	158 liters	Hastelloy C	First-cycle organic waste
	T-22	70 liters	Hastelloy C	Second-cycle organic waste
	T-23	158 liters	Hastelloy C	Organic rework
	T-24	70 liters	Hastelloy C	Target fabrication waste collection
Cell 1 Tank Pit	T-10	634 liters	Hastelloy C	Americium-curium feed storage

[a] Hastelloy C shell, tantalum liner, tantalum head. Mercury between shell and liner for heat transfer.

[b] Condensers are tantalum tubes with stainless steel jackets.

[c] Hastelloy C shell, tantalum liner, Zircaloy-2 head. Mercury between shell and liner for heat transfer.

The evaporators consist of tantalum-lined, Hastelloy C vessels with flanged heads of 3/8-in.-thick tantalum plate. The evaporators and associated condensers are designed for boilup rates of 15 liters/hr.

The product storage and waste accumulation tanks (Fig. 2.20) are of all-welded construction except for the tubing penetrations through the tank heads, where rolled joints are used. The product storage tanks are fabricated from Zircaloy-2, which is sufficiently resistant to corrosion to prevent the buildup of undesirable amounts of corrosion products or contaminants in the stored actinide products. The waste accumulation tanks are made of Hastelloy C, which has acceptable corrosion rates for this application. Nozzles for both types of tanks are of Zircaloy-2.

In-Cell Piping. — Service lines to the tanks cross the top of the cell bank, drop down the back face of the cells, and enter the cells through removable service plugs in the back wall. Piping connections between equipment components in both cubicle and pit are made by individual jumper lines having TRU disconnects at either end. Interconnecting jumper lines between cubicles and pits are grouped in bundles.

Piping between cells is routed through intercell piping plugs (Fig. 2.21) set into 1- by 5-ft openings in the cell partition walls. The plugs are sealed to a metal frame permanently mounted in the opening. Jumper lines run from disconnects mounted on these plugs to other locations in the pits. The waste header is installed in an opening in the removable plug, and the off-gas header is installed in a similar opening in the permanent frame above the piping plug. The waste header in any pit can be remotely replaced without disturbing the piping plugs. Individual sections of the off-gas header can be replaced only after disconnecting and moving sections in other cells.

Maintenance. — Personnel entry into the cell bank will not be required for maintenance. The pits will be flooded approximately 3 ft above the top of the tanks, and work will be done by long-handled

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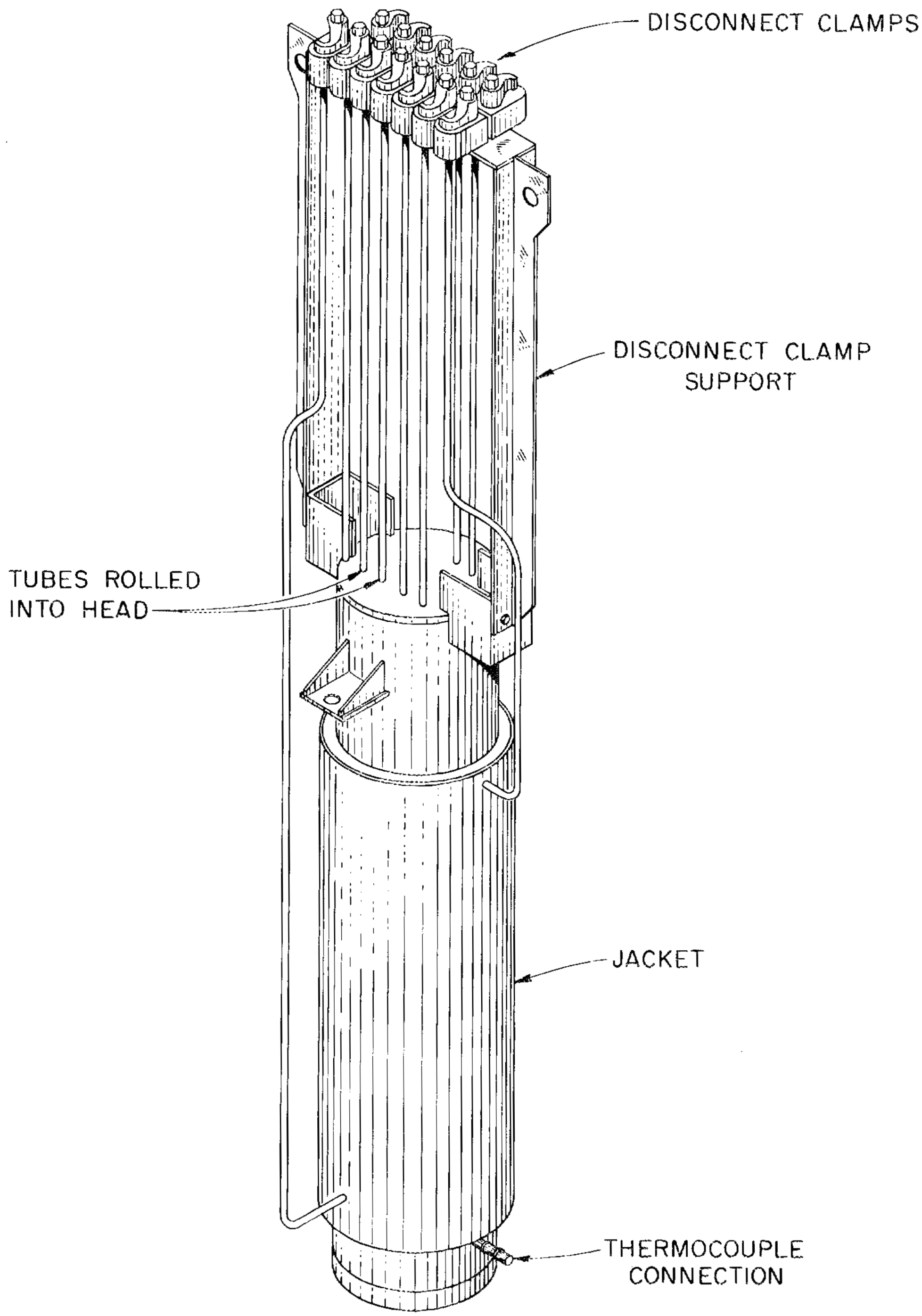

Fig. 2.20. Typical TRU Process Tank.

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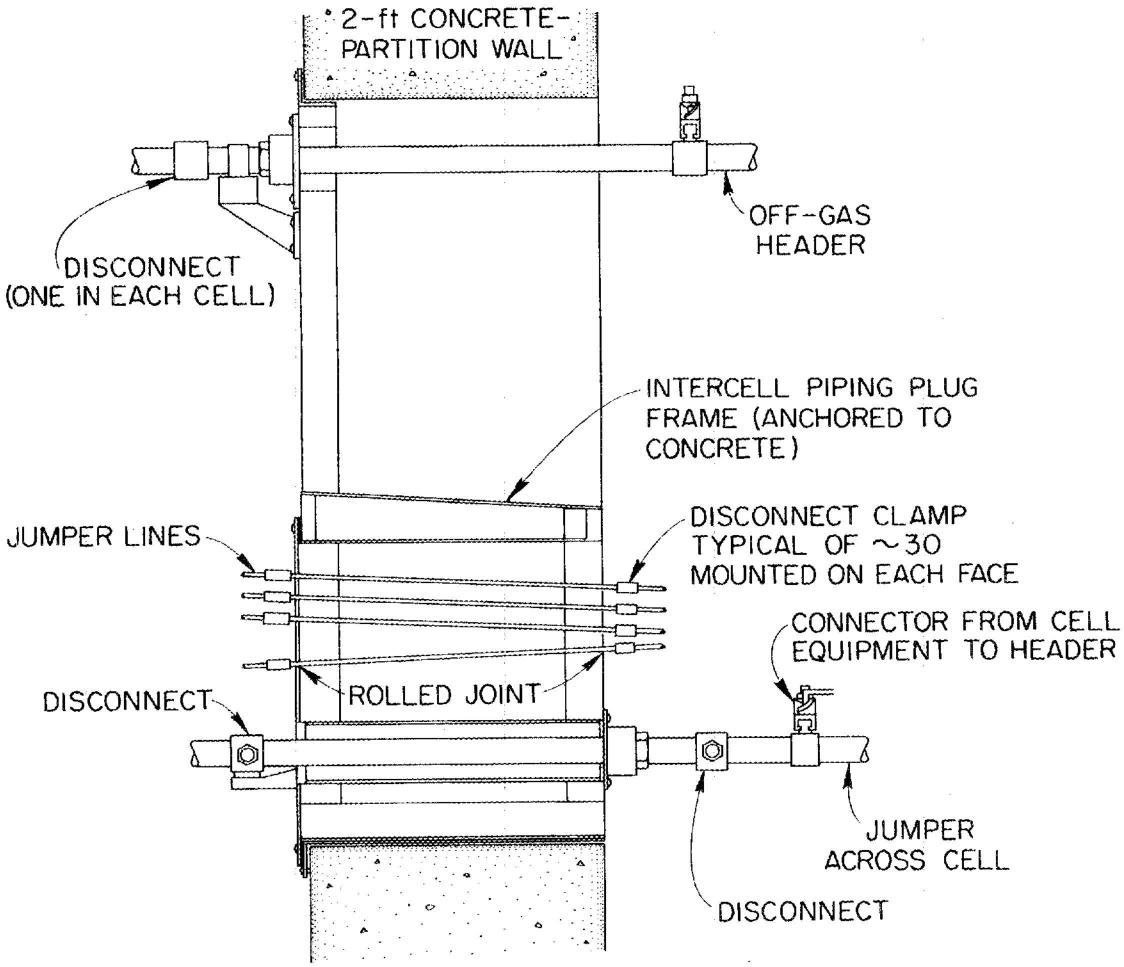

Fig. 2.21. Intercell Piping Plug.

(about 20 ft) tools from the top of the cell bank. All disconnects will be located above the flooding level to prevent water leakage into the system during maintenance operations. Equipment to be removed from the tank pits will be pulled into shielded casks by the building crane, and the casks will be sealed for disposal.

2.4.4 Out-of-Cell Equipment

Solution makeup and process head tanks are located in the chemical makeup area, room 213. These tanks are made of mild steel coated with Penton or are of stainless steel. Process functions, volumes, and materials of construction are listed in Table 2.3.

The tanks are located over shallow pans that are continuously flushed with water. Thus, any solutions that are spilled during filling or sampling, or that drip from the tanks will not accumulate or get on the floor of the room.

Solutions are transferred from process head tanks to process equipment in the cubicles or to tanks in the tank pits by pressurizing the head tanks to 5, 10, or 25 psig. Flow to the process tanks is through flow controllers or valves, plus check valves. Head tank pressures are limited by regulators and pressure relief valves (pop-off type) to prevent excessive pressures in the tanks.

2.4.5 Transfers into or out of Cubicles

Everything that enters a cubicle from outside the cell bank or that leaves a cubicle to be removed from the cell bank must be handled either with the equipment transfer case or with the intercell conveyor. Size is the factor that determines which path is used.

Articles that will fit in the 8-in.-diameter by 8-in.-high canister are transferred using the conveyor. Both paths provide for maintaining the cubicle alpha seal.

The double-door technique is used; the door on the cubicle is locked to the door on the transfer device when the device is sealed

Table 2.3 Tanks and Equipment at Tank Pans in Makeup Area

Location	Equipment No.	Volume (liters)	Material	Process Function
Cell 4 pan	M 41	6	Stainless steel	Resin addition
4	M 43	6	Penton[a]	HNO_3 addition
4	M 50	20	Penton	Feed adjustment solution addition
4	M 610	17	Stainless steel	Addition and head tank for stainless steel dissolver
4	H 44			Heater for C41
4	H 77			Heater for C71
Cell 5 pan	M 4	75	Penton	Second-cycle organic makeup
5	M 5	156	Stainless steel	Caustic makeup
5	M 40	50	Penton	Caustic addition
5	M 51	6	Stainless steel	Product distribution flush tank
5	M 60	75	Penton	Second-cycle extractant head tank
5	M 66	5	Penton	Organic extractant head tank
5	M 67	5	Penton	Scrub and strip solution head tank
Cell 6 pan	M 1	53	Penton	HCl makeup
6	M 2	53	Penton	LiCl makeup
6	M 63	75	Penton	Second-cycle organic scrub head tank
6	M 71	53	Penton	LiCl addition
6	M 72	20	Penton	Elutriant head tank
6	M 76	53	Penton	First-cycle scrub head tank
6	M 77	53	Penton	First-cycle strip head tank
6	H 66			Heater for second-cycle columns
Cell 7 pan	M 3	75	Penton	First-cycle organic makeup
7	M 61	53	Penton	Second-cycle scrub head tank
7	M 62	53	Penton	Second-cycle strip head tank
7	M 70	20	Penton	HCl addition
7	M 73	6	Stainless steel	Resin addition
7	M 74		Stainless steel	Pressurization-surge tank for T 70 heating-cooling
7	M 75	75	Penton	First-cycle extractant head tank
7	M 78		Stainless steel	C71 pressurization tank
7	M 750	75	Penton	First-cycle organic scrub head tank
7	H 76			Heater for first-cycle columns
7	H 78			Cooler in T-70 jacket heating-cooling loop
7	H 79			Heater in T-70 jacket heating-cooling loop

[a]Carbon steel coated with Penton.

to the cubicle. Thus, the interiors of the device and cubicle are joined, while each of the doors prevents the exterior surface of the other door from becoming contaminated.

Conveyor System for Intercell Transfers. — The function of the intercell conveyor system for TRU is to furnish communication between nine cell cubicles in the cell bank and a transfer cubicle. The conveyor and accessories consist of tracks and chain supports, drive mechanism, chain adjusters, chain idlers, dolly, canister, position indicator transmitter and receiver, and control box.

The conveyor drive mechanism, tracks and chain supports, chain adjusters, chain idlers, dolly, and canister are enclosed in an alpha-tight housing approximately 95-1/2 ft long. Openings in the top of the housing coincide with transfer ports in the nine cell cubicles and the transfer cubicle. The dolly is driven by two endless chains which extend the length of the housing. The chains are attached to the dolly mechanism and are separately powered by two reversible air motors with sealed drive shafts penetrating the housing wall. The direction of rotation of the motor that is energized determines the resultant direction of the dolly or dolly elevator: right, up or down, and left, up or down. Sensor rollers located on the dolly elevator and underneath the tracks enter accurately located vertical slots in the tracks, positioning the canister at the preselected transfer port. Any transfer port or ports can be bypassed by selecting either of the "down" modes. The canister is elevated by the dolly mechanism and is sealed to the bottom of the cubicle at the transfer port. An air-actuated port closure mechanism (located inside the cell) unlocks the canister cover from the canister and locks and seals it to the port closure. Materials to be transferred are inserted or removed from the canister with the cell master-slave manipulator.

The position indicator transmitter and receiver and control box are located in the operating area. Interlocks prevent incorrect sequencing of the normal operations and resultant break of containment.

Equipment Transfer Case for Equipment Removal System. — The equipment transfer case functions with all cell cubicles and other components that are located in the limited-access area and are concerned with the decontamination, maintenance, bagging, or burial of the large process equipment which is removed from the cell cubicles. The doors of the nine cubicles, decontamination glove box, and burial cask are all interchangeable.

Guides are located on top of the cell cubicle to give initial alignment between the transfer case and the cubicle door (see Fig. 2.9). The guide pins located in the top of the cubicle door provide final alignment of the transfer case. When the case is rested on top of this door, it compresses the gasket located on the bottom of the transfer case and effects a seal to the top of the cubicle. A manual drive simultaneously unlocks the cubicle and transfer case doors and locks and seals the two doors to each other. A mechanical indicator ensures proper position of the door lock actuator when the door is being replaced or removed from the ports. A second manual drive is used to elevate the two interlocked doors into the transfer case while equipment is being removed from the cubicle. A 1000-lb-capacity electric hoist equipped with limit switches and located inside the case is used to raise the equipment from its position in the cell cubicle.

In case of mechanical failure the doors may be replaced by means of a duplicate door combination (spare) which is stored in the transfer case on the opposite side.

The interior of the transfer case, which is of stainless steel, may be decontaminated with acid spray nozzles inserted through the top of the case. Provisions have been made to drain the case at the decontamination glove box which is located in room 216 off the limited-access area of the cell bank complex. Glove ports and viewing windows are also provided in the front and back of the transfer case to give access to the front and back of all equipment which will be lifted within the case.

Inspection ports are provided in the ends of the transfer case to allow adjustment of the door drive mechanisms. Under normal operating conditions, no adjustment will be necessary; however, since no lubrication will be used, some adjustment may be required to compensate for wear.

A one-foot-thick concrete shield, with a lead glass window in the top, can be put around the transfer case if required. There are no penetrations in the shield through which operations can be performed.

Decontamination Glove Box. — A decontamination glove box (Fig. 2.22) is located in room 216. This device can be wheeled onto the top of the cell bank, where large equipment is introduced into it from the equipment transfer case. The transfer is made through a door in the top of the glove box that is like a door in the top of a cubicle. There is also a side-loading port, where smaller items are introduced into the glove box from the carrier from the transfer area. The provisions for maintaining containment during transfer are similar to the provisions at the transfer cubicle in room 118.

The glove box will be connected to the vessel off-gas system and intermediate-level-waste system by flexible hoses.

2.5 Building Services

2.5.1 Normal and Emergency Power Supply*

Power is normally supplied to the TRU facility from TVA feeder No. 294. All emergency power was to be provided from the HFIR normal-emergency feeders. However, the demands for HFIR emergency power exceeded the supply, and it is necessary for TRU to supplement that

*The permanent supply system for normal and emergency power is in service; it was installed after this report was written, but prior to publication.

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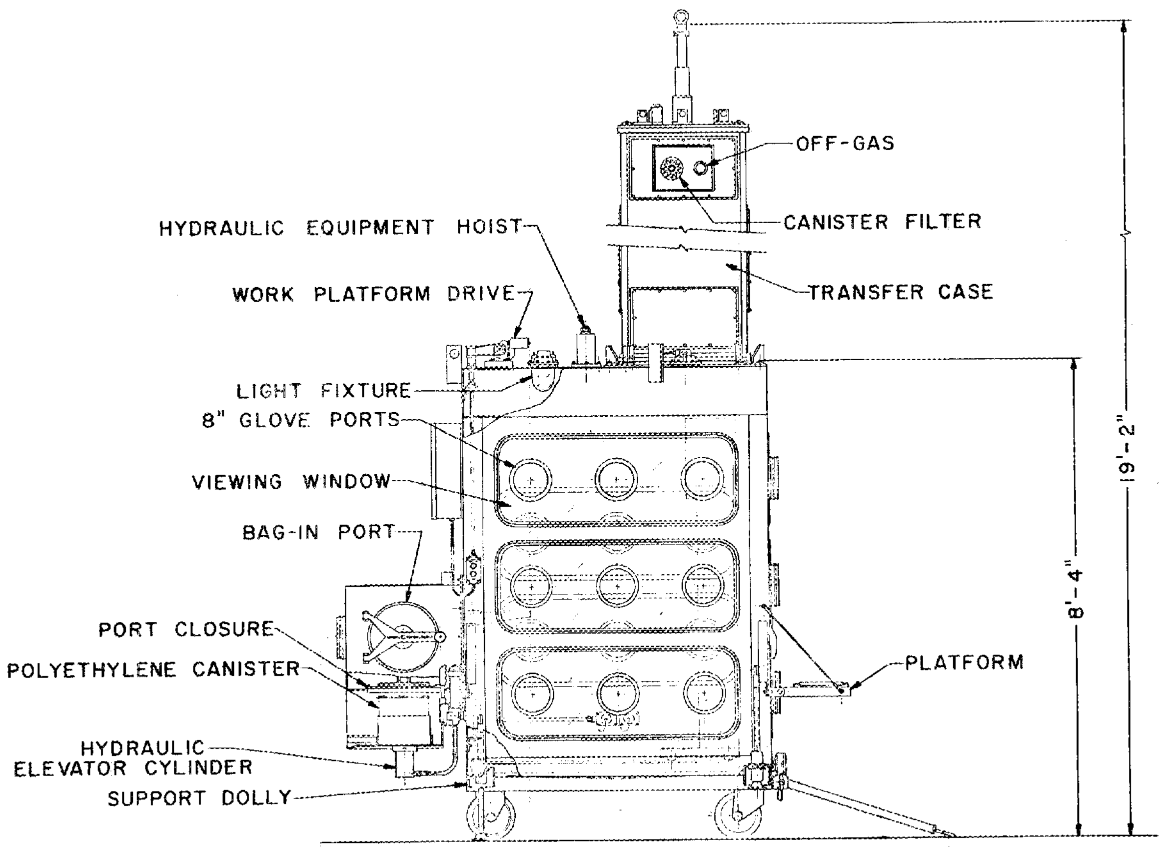

Fig. 2.22. Decontamination Glove Box.

supply by installing a new diesel motor-generator. Until the new generator is installed, emergency power will be supplied from HFIR power that is reserved for the future needs of experiments but is not yet being used.

When the new generator is in service, primary equipment for the instrument air compressor, recirculating cooling water pump, vessel off-gas exhaust fan, cell exhaust fan, and the pump for recirculating caustic in the off-gas scrubber will be connected to one of the HFIR normal-emergency feeders; all spares will be connected to the other normal-emergency feeder. Both HFIR normal-emergency systems provide power from either of two separate feeders (TVA 294 and TVA 234), and each HFIR system is backed up by a diesel generator.

Building air supply fans, cell cubicle lighting, radiation detection and monitoring instruments, process instruments, and the two primary and two spare building exhaust fans will be supplied emergency power from the new diesel generator.

The present and future normal and emergency power arrangements are summarized in Table 2.4.

The present system is a safe system, but under some circumstances it might be necessary to evacuate the building if both HFIR diesel generators did not operate during a power failure.

Effects of Power Failure Before November 1966. — In the past three years, simultaneous failure of feeders 294 and 234 has occurred four times. In addition, in the past five years, feeder 294 has failed five times and feeder 234 has failed seven times.

Failure of 234 only has no effect on operations since all power is normally supplied by feeder 294. Failure of only feeder 294 would result in loss of all power to TRU except that coming from the HFIR normal-emergency systems. If either feeder 234 was in service or both HFIR diesel generators operated properly, the effect would be the same. Cell containment would be maintained, building exhaust fans would operate, radiation detection and monitoring instruments would operate, and cubicle lighting would stay on. Since the building supply fans

Table 2.4 Present and Planned Emergency Power for the TRU Facility

(Normally all power is supplied from TVA Feeder 294)

		Service Required for		Emergency Power	
Description of Service	Equipment Nos.[a]	Cell Containment	Controlled Shutdown	Now	Future
Instrument Air Compressor	L-133 and L-137	X	X	HFIR No. 1 and No. 2[b]	HFIR No. 1 and No. 2[b]
Recirculating Cooling Water Pump	J-113A and J-113B	X	X	HFIR No. 1 and No. 2[b]	HFIR No. 1 and No. 2[b]
VOG Exhaust Fan	AJ-112 and AJ-113	X	X	HFIR No. 1 and No. 2[b]	HFIR No. 1 and No. 2[b]
Cell Exhaust Fan	AJ-103 and AJ-104	X	X	HFIR No. 1 and No. 2[b]	HFIR No. 1 and No. 2[b]
Caustic Recirculating Pump	J-131A and J-131B	X	X	HFIR No. 1 and No. 2[b]	HFIR No. 1 and No. 2[b]
Cell Cubicle Lighting	LP-7		X	HFIR No. 2	New generator
Building Supply Air No. 1	AJ-102		X		New generator
Building Supply Air No. 2	AJ-111		X		New generator
Building Supply Air No. 3	AJ-124		X		New generator
Lab Area Exhaust Fan	AJ-120 and AJ-121		X	Both on HFIR No. 2	New generator
Processing Area Exhaust Fan	AJ-122 and AJ-123		X	Both on HFIR No. 1	New generator
Radiation Detection Instruments			X	HFIR No. 1	New generator
Process Instruments			X		New generator

[a] Two numbers indicate duplicate equipment items.

[b] One unit is on HFIR No. 1; the other unit is on HFIR No. 2.

would be without power, the building vacuum would become greater than normal. When this was tested in January 1966 by turning off the supply fans, the pressure of the entire building decreased to −0.75 in. water (gage). The glove-box vent system reacted smoothly to maintain −0.3 in. water (gage) with respect to the building. When the supply fans were turned on, the pressure of the building returned to normal, and the glove-box vent system followed smoothly.

If feeder 234 should fail and if only HFIR diesel No. 1 should operate, there would be no cubicle lighting and no exhaust from the TRU processing area except in the limited-access area. The building would not have to be evacuated unless one of the automatic evacuation systems alarmed. If only HFIR diesel No. 2 came on, the building would have to be evacuated because there would be no exhaust from the laboratory portion of the building and the radiation detection instruments would be without power.

2.5.2 Water

Water systems for TRU include potable water, process water, demineralized water, recirculating cooling water, cooling tower water, and fire protection water.

Potable Water. — Potable water from the ORNL system is distributed at ambient temperature to drinking fountains, safety showers, lavatories, toilets, janitors' closets, and the change-room sinks. A steam-heated water heater, located in No. 2 Mechanical Equipment Room (room 207), heats the potable water for use in sinks and lavatories.

Process Water. — Process water is obtained from the potable water system via a surge tank and process water pump, both of which are located in No. 2 Mechanical Equipment Room (room 207). The surge tank provides an air break to prevent backflow of process water to the potable system. Hot process water for the laboratories, limited-access area, and the cold checking and receiving area is provided by the process water heater (130-gal capacity, steam heated - 15 psig - normal temperature, 140°F).

Cold process water is supplied to the laboratories, chemical makeup area, glove-box storage area, cold checking and receiving area, and transfer cubicle area. Hose bibs are provided in the checking and holdup area, laboratory reagent and equipment storage area, limited-access area, decontamination area, conveyor maintenance area, operating area, cold checking and receiving dock, and checking and holdup loading dock.

Demineralized Water. — Demineralized water is obtained from the HFIR demineralizers for distribution to the laboratories, cells (via chemical makeup area), decontamination area, transfer cubicle area, operating area, and the limited-access area.

Recirculating Cooling Water. — Process water is recirculated in a closed loop for use in cooling process equipment in the cells, for the vacuum system circulation cooler, and as makeup to the vacuum separator F-118. The equipment for this system, surge tank F-113 (575 gallons capacity), recycle pumps, and heat exchanger, is located in room 215.

Cooling Tower Water. — Water from the HFIR cooling tower basin is received at the TRU facility at 85°F and returned at about 95°F. A booster pump is used to increase the water pressure to 43 psi and to supply 960 gpm for the TRU facility and 890 gpm for the TURF facility. The water is used in TRU to cool the recirculating cooling water heat exchanger, the air compressors, and the chiller for building air conditioning.

Fire Protection Water. — The fire protection system is supplied from the fire protection loop encircling the building, with shut-off valves located east of the building.

2.5.3 Vacuum System*

The present vacuum system is adequate for our needs. However, there is no spare equipment, and the present vacuum pump is a mechanically sealed unit that is susceptible to leakage of radioactive liquids, with resultant maintenance and operational problems. This unit will be replaced with a water-jet vacuum pump that is designed especially to handle acidic radioactive gases. The new unit is a dual unit incorporating a multi-jet venturi through which water is circulated by a vertical centrifugal pump. It will eliminate seal or packing leakage, minimize shielding problems, and provide a spare. It is felt that the present system will be satisfactory in the interim.

Vacuum Distribution. — Vacuum lines from the laboratories, transfer area cubicle, chemical makeup area, and cells 8 and 9 tie into a common header. Vacuum is maintained at 22 in. Hg at a design flow rate of 40 cfm. The vacuum pump discharges into the vessel off-gas system.

2.5.4 Steam

Steam is supplied at 250 psig from the X-10 area. The 250-psig steam enters the building in the No. 1 Mechanical Equipment Room (room 114) where it is reduced to 100-psig and 15-psig superheated steam. The 100-psig steam is used primarily for heating process equipment and operating eductors in the cells, pipe tunnel, and cell ventilation and vessel off-gas filter pits. The 15-psig steam is used in the potable water heater, process water heater, and the building heating system. It is also used for decontamination purposes in the decontamination room and limited-access area.

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*The new vacuum system was installed after this report was written but prior to publication.

Low-pressure condensate from the water heaters and building heating system, plus 250-psig line condensate, discharges into a ditch located east of the building.

2.5.5 Compressed Air

Air is compressed to 100 psig and dried to a dew point of −40°F in equipment located in the No. 1 Mechanical Equipment Room (room 114). This equipment includes two compressors, two after-coolers and air separators, an air receiver, and an air dryer. After the dryer, the distribution header splits into a utility air header and an instrument air header. Controls are provided to automatically shut off the utility header when the system pressure drops to 75 psig. In the event of a compressor failure, the net output (76 scfm) of a single compressor is adequate for the operation of all instrumentation in the facility. Emergency power is provided for both compressors.

The 100-psig instrument air header supplies instruments and controls in the operating area, chemical makeup area, conveyor maintenance area, transfer cubicle area, mechanical equipment rooms 114 and 107, and all heating and ventilating instruments throughout the building. Instrument air is also used to purge steam supply lines to all process eductors and sump eductors for cubicle pits and tank pits 1 through 7. A pressure-reducing station located in mechanical equipment room 114 provides 25-psig filtered utility air for operating air-vacuum process pumps, for sparging tanks, and for use in the laboratories. Pressure-reducing stations located in the chemical makeup area supply 5-psig and 10-psig air to the chemical makeup and feed tanks.

The 100-psig utility air is used to purge sump eductors in cells 8 and 9, the pipe tunnel, and the filter pits. Air monitors in the conveyor maintenance area, the checking and holdup area, the limited-access area, and the decontamination area are operated by using utility air.

2.5.6 Cylinder Gas

Helium. — Helium is supplied to cubicle 2 from one cylinder in the chemical makeup area. It is used both as a cover gas for welding target elements and as an internal gas within the elements.

Argon. — Argon is supplied from one cylinder in the chemical makeup area to the automatic welder, which is in the makeup area, as cover gas for the high-frequency starter.

Nitrogen. — Nitrogen, which is used as a buffer seal on two leak-test chambers in cubicles 1 and 2 and is used to purge the chambers and associated piping, is supplied from one cylinder in the chemical makeup area.

Propane. — Propane is supplied to hoods and benches located in the "cold" chemical and analytical laboratories from cylinders located on the northeast dock.

Counter Gas. — Counter gas (90% argon, 10% methane) is supplied from cylinders located on the northeast dock to instruments in the counting room and in the first-floor analytical laboratory.

2.5.7 Fire Protection

The special fire hazards involved in TRU operations are as follows: (1) use of solvents and other flammable chemicals, (2) use of nitric acid, (3) electric-furnace calcination of americium and curium oxide powder, and (4) concentration of process liquids by steam evaporation at approximately 300°F. Most of the building interior is protected by an automatic wet-type sprinkler system. Exceptions to this general plan are laboratories 108 through 111 and 208 through 211 and the cells and cubicles. These areas are protected by an automatic pre-action system and an automatic heat-responsive system working together.

The most likely origins of fire in the laboratories are the hoods and glove boxes; the boxes that will be used to handle quantities of solvents will have independent fire-protection systems of limited-volume water spray.

The cubicles are the most likely source of fire in the cell bank, and these are provided with independent fire-protection systems, which are backed up by the automatic pre-action systems in the cell proper.

Laboratory Pre-Action System. — The laboratories are protected by an automatic pre-action system which opens the main header valve when a temperature rise of 15 to 20°F/min is detected. Fusible spray heads initiate the sprinkler when a temperature of 165°F is reached.

Cell Pre-Action System. — The detection and actuation system for each cell consists of thermopneumatic rate-of-rise devices arranged to open the main header valve, deliver a fire signal at the annunciator panel, and transmit a fire alarm over the plant Gamewell. When a temperature of 175°F is exceeded, detection elements trip the deluge valve and spray the cells through nozzles located at the top of the cell, the 10-ft level, and underneath the cubicle. Individual systems are provided for each cell so that a heat release in one cell does not cause any other cell to be deluged with water.

Cubicle Pre-Action System. — Each cell cubicle is equipped with a rate-of-temperature-rise device arranged to deliver a local fire signal and open the main header valve when the rate of rise exceeds 15 to 20°F/min. Each cubicle is equipped with a deluge valve actuated by a pushbutton on the cell face in the operating area. Each cubicle has a separate system.

Location of Supply and Main Control Valves. — The TRU facility is connected to the ORNL fire-protection water system at the northeast corner of the building, and the supply line enters the building at the northeast corner of the first-floor mechanical equipment room (room 114). The main manual and control valves are located at this point. The fire-department siamese pumper connection is located on the east end of the north loading dock.

Fire Alarm System. — The TRU fire alarm system is connected to the ORNL fire alarm system through master box 835, located northwest of the building.

Signals into the master alarm are fed by the TRU alarm system, which is divided into 40 local zones. Twenty zones are for the general building and laboratory areas, with the red annunciator panels located on the south wall of room 104; and twenty are for the cells and cubicles, with the panel located on the control board in room 116.

Fire alarm signals originate from the following: (1) water flows into either the first- or second-floor wet sprinkler system, (2) tripping of preaction valve for the first- or second-floor laboratories by the rate-of-rise devices, (3) tripping of the preaction valve of the cell and cubicle system by the rate-of-rise devices in the cells or cubicles, and (4) 12 manually operated local fire alarm pull stations.

The fire alarm system is equipped with a standby 24-volt, heavy-duty wet-cell battery unit and battery charger to ensure operation in case of electrical power failure.

Local Fire-Fighting Devices. — A system of standpipes and hose cabinets or racks is provided throughout the building. Water supply is from the sprinkler system. Squeeze-grip-type, 15-lb CO_2 fire extinguishers are available at many building locations.

2.6 Description of Laboratory Rooms

2.6.1 Size and Layout

On each floor there are two alpha laboratories, an analytical laboratory, and a "cold" laboratory arranged as shown in Figs. 2.3 and 2.4. Alpha laboratory 111 contains a shielded alpha cave for performing development work involving alpha activity plus gamma or neutron activity. All of the laboratories are about 23-1/2 ft wide by 23 ft deep by 10-1/2 ft high. The concrete block walls are built on curbs that are poured into the floor.

Each of the laboratories is connected to a corridor through two doors and to the TRU processing area through an emergency exit door that has a crash bar on the laboratory side and no hardware on the processing area side. Each of these doorways has a 1/2-in.-high threshold that is built into the floor. Laboratory floors are covered with vinyl sheet, which is curved up the walls to the tops of the curbs. Thus, any liquids that are spilled on a laboratory floor will not run out of the room.

The emergency exit doors are gasketed and will be sealed with wire seals that will break if the doors are opened. The doors to the corridors are solid doors with glass panels, but they do not have gaskets. All doors open out from the laboratories.

The ceilings are of gypsum board with cemented, perforated-taped joints on a metal suspension system and contain sheet-metal hatches that are sealed with tape. The space above the suspended ceilings of the four laboratories on each floor is connected. Concrete block partitions between the laboratories extend 4 in. above the suspended ceiling.

On each floor the "cold" laboratory is connected to each of the two adjoining alpha laboratories by a small pass-through door that is above the level of the back counter of the laboratory benches.

2.6.2 Equipment

The alpha laboratories contain no installed laboratory furniture, except for one 24-in.-wide by 18-in.-deep stainless steel sink in each laboratory. Normally, only glove boxes and auxiliary equipment, plus a few tables and chairs, will be in the rooms. The shielded cave is discussed below in Section 2.7.

The cold laboratories and the analytical laboratories are equipped with the usual types of laboratory furniture. Working surfaces in the cold laboratories are Johns Mansville "Colorith" composition bench tops, and surfaces in the analytical laboratories are of 304L stainless steel.

2.6.3 Services

Services to the laboratories will normally include vessel off-gas, glove-box ventilation, plant vacuum (22 in. Hg), plant air (25 psig), process water, demineralized water, process drains, intermediate-level-waste drains, and propane.

Alpha Laboratories (109, 111, 209, 211). — Each alpha laboratory has a sink to which hot and cold process water, demineralized water, and a process drain are connected. There are 14 "glove-box sets" of service connections (4 sets along each side and 6 sets across the center) that enter each laboratory from the bottom of sealed service-pipe racks. There are 10 extra glove-box ventilation connections in each laboratory, two on each side and six in the center. Each "glove-box set" is composed of one 208-volt and three 120-volt electrical power receptacles, and connections for glove-box ventilation, vessel off-gas, plant vacuum, plant air, process water, and demineralized water. Glove-box ventilation connections are plugged. Lines for the other services are terminated at valves.

There are two capped process drains in the floor of each laboratory and one intermediate-level-waste and three process drain connections in the form of standpipes that stand about 3 in. above the floor and are plugged or capped. In preparation for construction of the shielded cave, all services in laboratory 111 except those on the west wall have been removed.

Cold Laboratories (110 and 210). — Both cold laboratories are equipped with ordinary laboratory benches and chemical fume hoods that are supplied with hot and cold process water, demineralized water, plant air, plant vacuum, propane, process drains, and intermediate-level-waste cup drains.

Hood ventilation is provided by exhausting room air through the hoods to the building ventilation exhaust filters.

There are capped process drains in the floors.

Analytical Laboratories (108 and 208). — The analytical laboratories are slightly different from each other. Both are equipped with ordinary laboratory benches to which hot and cold process water, demineralized water, plant air, plant vacuum, propane, and process and intermediate-level-waste drains are connected. Laboratory 208 contains two chemical fume hoods that are provided with the same services as the benches, and a perchloric acid fume hood that is supplied with plant air, propane, process water, and glove-box ventilation. The chemical fume hoods are ventilated by drawing room air through them to the building ventilation exhaust filters. There are six "glove-box sets" of services from the center pipe rack in laboratory 208, and there are nine "glove-box sets" of services from the pipe racks in laboratory 108, four on each side of the lab and one near the back wall. There are eight additional connections to the glove-box ventilation in this laboratory for open-faced glove boxes.

There are capped intermediate-level-waste standpipes and plugged process floor drains in each analytical laboratory.

2.7 Shielded Cave in Room 111

An arrangement of two shielded caves has been designed for laboratory 111 to provide space for laboratory development work, where a small amount of shielding is required and somewhat better containment is needed than is obtained from a glove box. At present only one cave is under construction; it is scheduled to be ready for operation in the late summer of 1966.* The facility has many features identical to those of the cave presently installed in Building 3508.

2.7.1 General Arrangement

The plan view depicting the arrangement of the two caves in laboratory 111 is shown in Fig. 2.23. Cave A is under construction

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*The shielded cave is in service; it was finished after this report was written but prior to publication.

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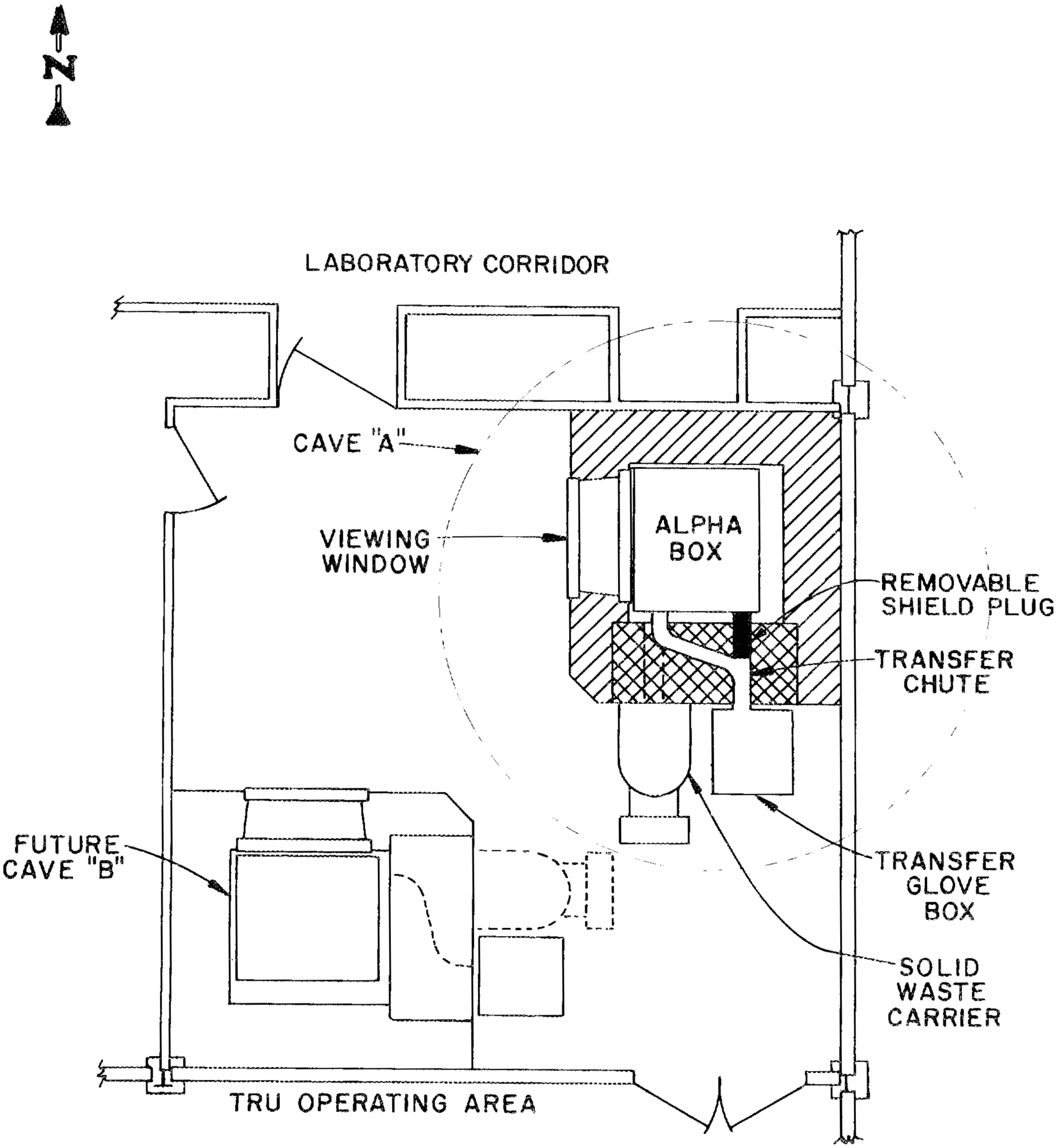

Fig. 2.23. Plan View of Shielded Caves, Room 111.

now. Two feet of normal concrete shielding surrounds a disposable alpha box, 54 × 60 × 42 in. high. The alpha box is installed and removed after unstacking the south concrete block wall and at the same time disassembling the transfer chute. This exposes a seal plate, which can be dismantled, exposing the box. All connections to the box can then be broken and sealed, and the box can be removed. Although this operation can be done in a rather short time, it is not anticipated that the box will be replaced more than once per year. A 2-ft-thick zinc bromide shielding window provides shielding for viewing through the 1/4-in.-thick Plexiglas alpha window. Operations are done with master-slave manipulators.

Transfers in and out of the alpha box can be made by the following three methods:

1. Normal routine transfers of materials requiring little shielding are made through a standard glove box attached at the end of an S-shaped labyrinth transfer chute. The south wall is 3 ft thick, and the shielding is equivalent to the 2-ft shielding on the other walls even in the vicinity of the transfer chute. The glove box, the transfer chute, and the alpha box are connected by flanges and/or bagged connections, making all three a single containment volume. Transfers are made using a hand-powered, cable-driven cart.
2. Objects too long for passage through the chute can be inserted through an alternate port from the glove box to the rear section of the alpha box.
3. High-level radioactive materials can be loaded into or removed from a sealed port in the floor of the alpha box at the southwest corner. This operation is similar to that of removing material at the transfer cubicle in room 118. The same carrier is used, and the double-door port-closure and heat-seal mechanisms work similarly to those in the transfer cubicle.

2.7.2 Ventilation Systems

Ventilation to the cave-alpha box system is provided from the building vessel-off-gas system, a source normally maintained at −10 in. water (gage). A flow of 75 cfm is admitted to the cave space surrounding the alpha box through absolute filters in the front concrete wall. This flow is then directed into the alpha box through one set of absolute filters and out through a second set to the vessel off-gas system. The pressure in the box is controlled automatically at −0.9 in. water (gage) by a control valve in the exit line, and the exact flow rate and the pressure in the cave are set by manual dampers. This pressure is set at −0.6 in. water (gage), about midway between the pressure in the laboratory (−0.3 in. water) and that in the alpha box. A vacuum breaker capable of handling the entire 75 cfm, set at −1.3 in. water (gage), is provided on the vessel off-gas header to ensure that the box does not collapse because of a control system failure.

An auxiliary connection of the cave ventilation system to the room exhaust provides 500 cfm exhaust while the alpha box is being installed and removed. This flow is filtered through the absolute filters on the roof.

2.7.3 Other Services

An automatically actuated, limited-water-volume fire-protection system is provided for the interior of the alpha box. A water tank is partially filled and overpressured with air. On release of the water, a float valve seals off, preventing the air from bleeding into the alpha box. This arrangement is identical to the one presently installed on the similar cave in Building 3508. The float valve will be thoroughly checked prior to installation.

A drain connection is provided to the intermediate-level waste collection tank via a 2-in. connection into the existing below-floor radioactive drain system. The drain line in the box extends 6 in. above floor level, is normally plugged, and is disconnected below the floor level of the box when the box is removed.

Low-pressure air (25 psi), demineralized water, process water, and 110-volt electrical service are provided in the alpha box.

3. CONTAINMENT

TRU has special containment provisions to ensure against the escape of process materials to the environment. Containment in the laboratories is similar to that in existing high-alpha-level laboratories. However, containment in the processing area is unusual.

The building is divided into six distinct areas: (1) cold areas such as that housing mechanical equipment, offices, change rooms, and the like; (2) laboratories; (3) operating areas; (4) limited-access areas surrounding the cell banks; (5) cells; and (6) the alpha-sealed cubicles. The distribution of the ventilating air is designed to maintain a positive flow of air from cold areas toward those of a potentially increasing contamination level. The building will be maintained at a pressure of −0.3 in. water (gage) at all times; this will prevent the escape of airborne contaminants to the environment except via the normal, filtered discharge system.

Cell process equipment is enclosed in process cubicles, which, in turn, are enclosed in the primary cell. The primary cell is enclosed by the building shell. Each enclosure is separately ventilated with differential pressures, maintained automatically, so that each enclosure is at a lower pressure than its immediate envelope. Thus the process equipment is operated at −10 in. water (gage), the processing cubicle at −1.7 in. water (gage), the cell at −1.4 in. water (gage), the limited-access area at −0.4 in. water (gage), the laboratory sections at −0.35 in. water (gage), and the building at −0.3 in. water (gage). All purge air flowing from one containment envelope to the next is introduced through filters or backflow preventers. The purge from the offices in the processing part of the building, the operating area, and the laboratories is exhausted through a set of roughing and absolute filters. The purge air exhausted from the limited-access area, the cells, and the glove boxes is filtered through one set of roughing filters and two sets of absolute filters before discharge to the environment. Air from the vessel off-gas and cubicle exhaust system is treated in a caustic scrubber both to remove noxious chemical fumes and to absorb fission product iodine; it is then filtered through three sets of filters, two of which are absolute. After filtration, the exhaust air from vessels, cubicles, cells, and the limited-access area is discharged to the atmosphere through a 60,000-scfm, 250-ft-tall stack.

Chemical laboratory work involving the actinide elements is conducted in glove boxes, which are maintained at −0.3 in. water (gage) with respect to the laboratory and exhausted to the cell ventilation exhaust system. Purge air is introduced to the glove boxes from the laboratories through absolute filters.

3.1 Primary Containment

3.1.1 Processing Area

The containment envelope that meets the ORNL criteria for primary containment is the heavily shielded bank of process cells. As an added precaution against the release of any of the transuranic actinides, those process operations that are likely to result in release of radioactivity from process lines and vessels are performed in alpha-tight process cubicles. The cubicles contain all sampling stations and all process equipment that might require maintenance frequently or might be expected to require replacement. Except for the centrifuge for removing aluminum precipitates from the target dissolver solution and the caustic scrubber, tanks and piping are the only process equipment located in the cell bank outside of process cubicles.

Each process cubicle is located inside a separate processing cell. The cubicles are isolated from each other and from their respective cells; the cells are isolated from each other except for interconnection via the cell ventilation duct.

Cubicle Ventilation. — In each cubicle, air is circulated from the cubicle through absolute filters, past cooling coils, and then back into the cubicle at a rate high enough to remove heat produced by the process or by cell lighting. From 5 to 50 cfm of purge air from the cell in which the cubicle is contained enters each cubicle through an absolute filter. The purge rate is set from inside the cubicle by using a manipulator to adjust a manual damper. Thus the entire exhaust capacity of 50 cfm is always available in the event the cubicle pressure starts to increase. The purge capacity of 50 cfm is more than one-tenth of a cubicle volume per minute. The cell cubicle exhaust system consists of single lines (one from each cubicle) tied into a main header. A pressure control station maintains a pressure of −0.3 in. water (gage) with respect to the cell ventilation system. Cubicle vent gases are discharged into the main off-gas system header located in the pipe tunnel, treated in a caustic scrubber, and discharged through a pipe heater, one roughing filter, and two absolute filters to the HFIR stack. This system has duplicate fans which receive emergency electrical power from different emergency systems.

Cell Ventilation. — Air for ventilating each cell is drawn from the limited-access area through a roughing filter and backflow preventer located in a duct at the rear of each cell. A manually set damper and a connection for measuring air flow rate are provided in the inlet duct to each cell to regulate air flow. Air flow patterns are shown schematically in Fig. 3.1. All inlet ducts and filters are large enough to provide each cell with 1000 cfm of ventilating air, the volume necessary for removing the 6-kw process heat load from each of cells 4 through 7. The remaining cells are supplied 370 cfm of ventilating air, which is more than the required one-tenth of a cell volume per minute.

The air is exhausted to the cell ventilation filter pit through a header that interconnects all cells and is located within the cell. Alternate exhaust blowers are connected to separate emergency power supplies. Air is passed through one roughing filter and two absolute filters before being discharged to the HFIR stack.

Transfer Case Seal. — The transfer case will be used to remove large items from a cubicle or to introduce them into a cubicle when no processing operations are being performed in the cubicle. The weight of the transfer case pressing on a gasket seals the case to the

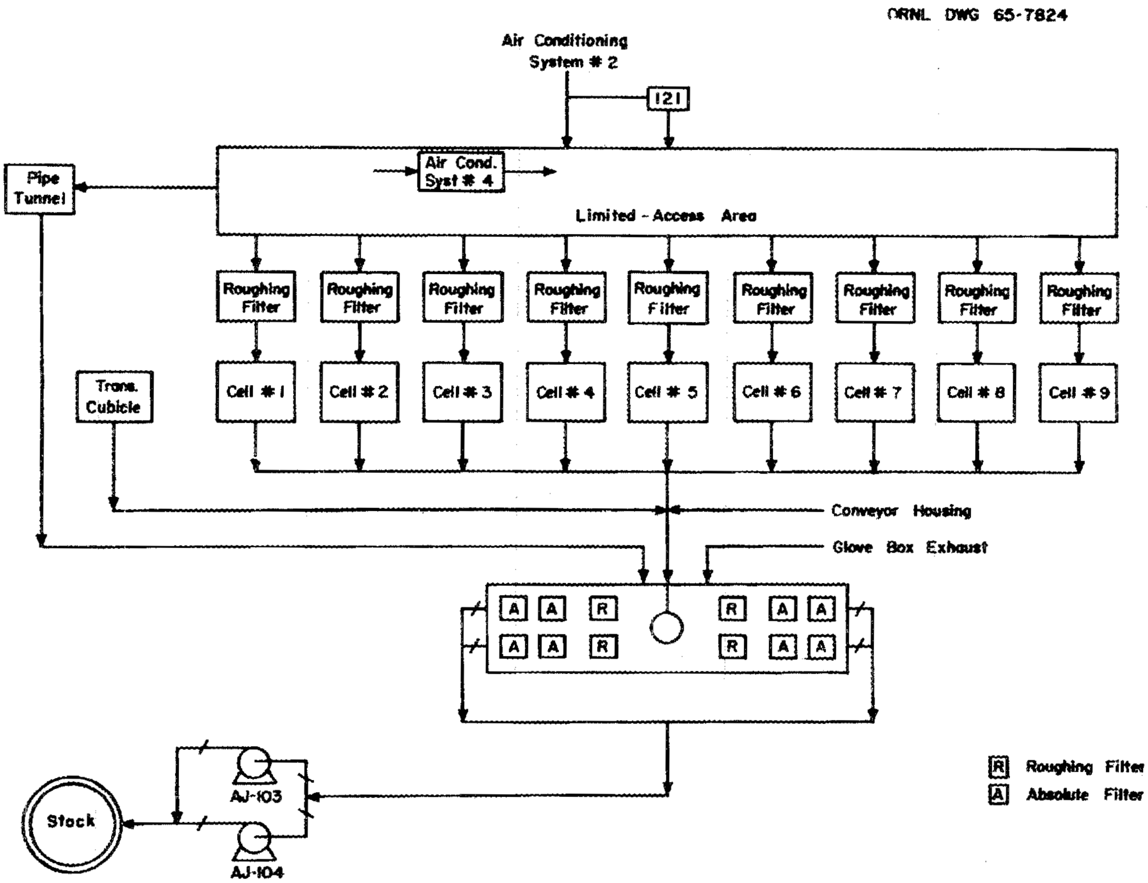

Fig. 3.1. Schematic Diagram of the Flow of Ventilating Air Through TRU Cells.

top of the cubicle during transfer operations. There is no holddown device or automatic mechanism for preventing removal of the transfer case when the doors to the transfer case and the cubicle are open.

Intercell Conveyor Seal. — The intercell conveyor will be used to transfer small items into or out of the cubicles during operating periods as well as during maintenance periods. A locking device seals the conveyor canister to the bottom of the cubicle at the same time that the cubicle door and canister door are locked together. The same air system that actuates the canister dolly locks and unlocks the seals, and a system of interlocks prevents movement of the conveyor dolly when the cubicle and canister doors are not properly closed.

Window Seals. — The alpha-seal windows are designed to withstand a pressure of 900 lb/ft^2 without losing the seal. A prototype window was tested by mounting the assembly in a container and testing the seal with a pressure of −10 in. water (gage) on the cubicle side. The vacuum was maintained for 2 hr with no leakage. The seal window was then replaced, using the replacement equipment. Leakage did not exceed 5 cfm with a pressure of −1 in. water (gage) on the cubicle side. The alpha window assembly can be replaced from the operating area and can be removed into the cubicle so that the atmosphere of the latter is never in communication with that of the operating area.

3.1.2 Alpha Laboratories

Primary containment for handling alpha-active materials in the laboratories is provided by multicurie glove boxes (Fig. 3.2). These boxes are fabricated of mild steel and painted with Liquid Tile. The windows are safety plate glass held in place with a neoprene zipper gasket. Each box is provided with both a 6-in.- and a 12-in.-I.D. access port. Interior metal shields cover these ports when they are not in use. In addition, exterior metal access port covers are used whenever a box is left unattended for any length of time.

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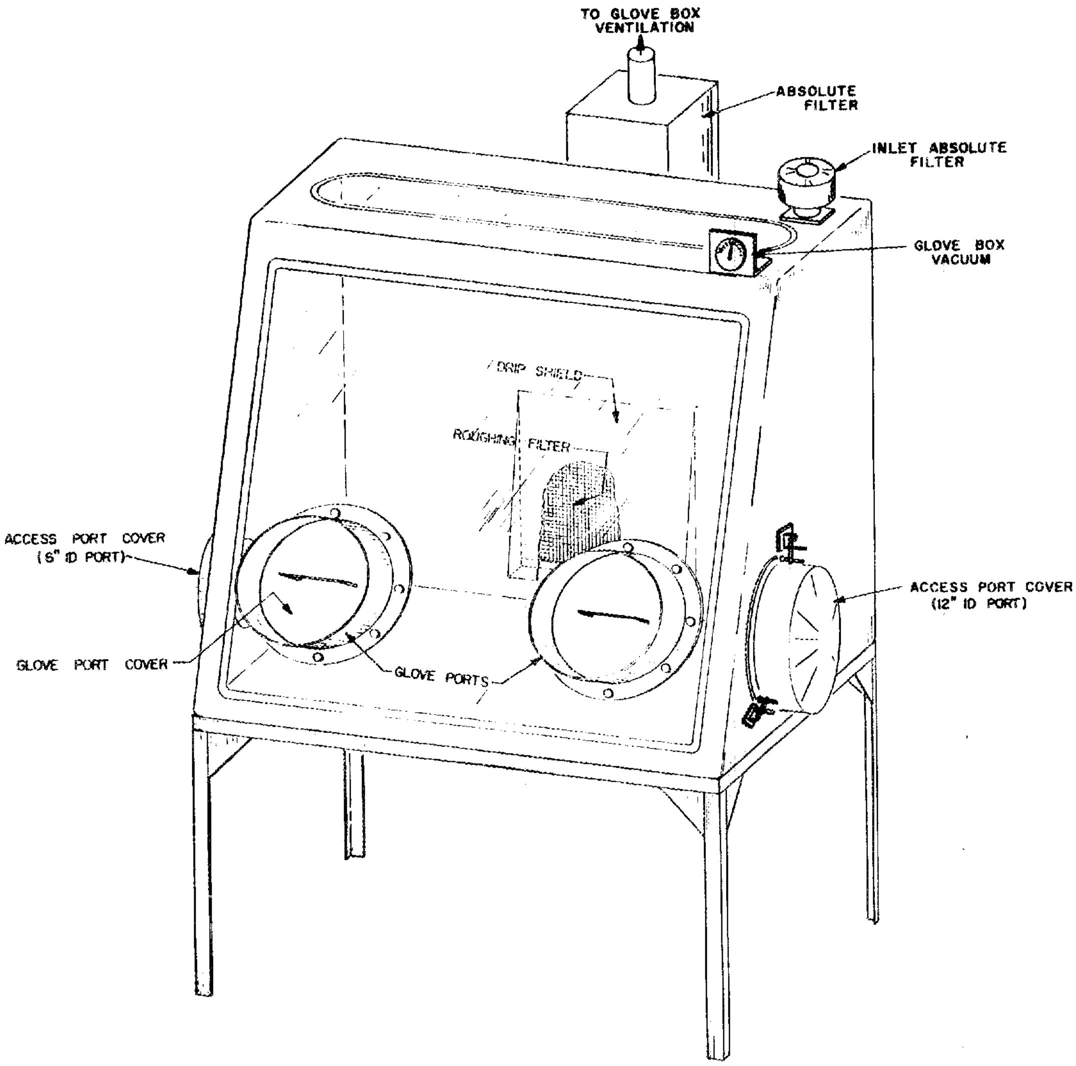

Fig. 3.2. Multicurie-Level Alpha Glove Box.

The glove boxes are operated under a −0.30 in. water (gage) pressure with respect to the room ventilation system. This ensures that any leakage will be into the box and aids in preventing contamination from escaping from the box. Air flow through the glove box is about 0.5 cfm unless larger quantities are required for heat dissipation. All inflow air is prefiltered into the box through one or more absolute filters. Air leaving the box is filtered through a FG-50 prefilter (inside the box) plus a 12-in.-thick 99.97% absolute filter at the exit from each box.

Transfers into and out of glove boxes are made through the transfer ports. The plastic-bag transfer technique is used. This provides heat-sealed plastic containment of alpha material transferred out of the box and results in positive alpha containment during all transfer operations.

Operations within the glove box are carried out with neoprene gloves, which are held in place on the glove port ring by either rubber O-rings or metal clamps. The procedure for replacing gloves is as follows:

1. Slip old glove to front part of glove ring, but do not remove from ring.
2. Turn new glove inside out and slip over old glove on the glove ring.
3. After new glove is firmly in place, pull old glove off into the alpha box, making certain that the new glove does not slip off the glove ring. (Double grooves in the glove port ring facilitate this operation and virtually eliminate the possibility of an uncovered port, assuming normal operational skill.) Treat old glove as contaminated solid waste.
4. Monitor around edge of glove ring and decontaminate, if necessary.

Services to the boxes are provided by totally enclosed laboratory racks.

Since relatively short-term operations and programs make it desirable to incorporate flexibility and mobility as part of the operating philosophy, all service tie-ins to the box are made with nonrigid connectors. While the service racks will contain vacuum, electricity, air, gas, and water, only electricity and water are required for normal operations. Water from the service rack is used only as cooling water during reflux and distillation operations. Various cylinder gases (Ar, N_2, etc.) are routinely required. Traps are used between gas lines and reaction vessels to prevent back-siphoning of contaminated solutions into external lines. Water and gas box connections are made through valves that are opened only when required.

3.1.3 Shielded Cave

The primary containment of the shielded cave in laboratory 111 is provided by the internal alpha box, which has many features identical to the alpha glove boxes. However, it is surrounded by a 2-ft concrete shield, and operations are performed with manipulators. A glove box attached through a labyrinth transfer chute provides a means of transferring materials in and out of the alpha box by bagging techniques; and high-level activity can be removed via a sealed container and the side-loading carrier, which is also used at the transfer area.

Ventilation for this primary containment is provided by a 4-in. header, through suitable pressure controls, from the VOG system. Approximately 75 cfm of air flows from the laboratory, through absolute filters, to the cave in the space around the box, and then through a second set of absolute filters. Pressure within the alpha box is controlled at −0.7 in. water (gage) (with respect to the room) by an automatic control valve system in the exit-air flow line. The pressure in the cave itself will be approximately midway between that of the alpha box and the laboratory and will be determined by the setting of manual dampers.

During the infrequent replacement of the alpha box, the entire south wall of the cave will have to be removed. Extra ventilation is provided for this operation by a bypass into the normal room exhaust to the absolute filter-fan system on the roof. Up to 500 cfm can be exhausted during this operation.

3.2 Secondary Containment

The shell of the laboratory and processing parts of the building constitutes the secondary container for TRU. The office annex is operated at atmospheric pressure and is heated and ventilated by its own system. Thus, it is not included in this discussion.

The processing and laboratory parts of the building contain a number of air conditioning, heating, and exhaust systems that are combined to provide the pressure differences required for secondary containment. The normal ventilation for this area is designed to maintain a pressure of ~0.3 in. water (gage) with respect to outdoors – the required pressure for containment under emergency conditions, as given in the ORNL Radiation Safety and Control Manual.

Details of the building ventilation systems are given in the following sections.

3.2.1 Air Conditioning and Heating System

The heating, ventilating, and air conditioning system for all building areas, except the limited-access area, is of the once-through type. The limited-access area is provided with a once-through ventilation system, plus a recirculation system which further conditions the air within the space. The chilled water from a centrifugal water chiller cools the air, and hot water generated within the building is used for reheat coils and perimeter radiation.

The equipment rooms are provided with exhaust fans for constant ventilation.

The air conditioning and heating systems filter, cool (or heat), and dehumidify air taken from outside the building. The conditioned air is then discharged to the duct systems by centrifugal fans for distribution to the various areas. There are a total of 27 zones of temperature control. Each zone has its own hot-water reheat coil, thermostat, control valve, ductwork, and diffusers or registers. The reheat coils control the temperature of the air entering a zone, as required by the varying conditions in the space. The primary air conditioning system (No. 1) delivers conditioned air to all areas in the building, except those noted below for the other systems.

Air conditioning system No. 2 delivers conditioned air to the limited-access area and limited-access change room No. 2. Air conditioning system No. 3 delivers conditioned air to the transfer area, decontamination room, and checking and holdup area. Air conditioning system No. 4 recirculates and further conditions the air within the limited-access area.

3.2.2 Heating and Air Conditioning Controls

A pneumatic two-pipe, nonbleed type of system of automatic temperature control is provided. Steam valves in the lines to the preheat coils are controlled by an outdoor thermostat. The steam valve is full open when the outside temperature is 35°F or below. Face and bypass dampers are used to maintain the temperature of the air leaving the preheat coils at 50°F. To prevent freezing of the steam preheat coils, an alarm is sounded at a fan discharge temperature of 45°F and the fan is shut down automatically when the temperature falls to 40°F. The air temperature of the chilled-water coil is controlled by an averaging bulb in the airstream and a three-way chilled-water mixing valve at the coil. The individual temperatures of the respective spaces are maintained by means of a room type of thermostat and a three-way hot-water mixing valve at the reheat coils serving the respective areas.

The recirculation unit serving the limited-access area has a chilled-water coil with a three-way mixing valve controlled by a remote bulb thermostat set for 80°F and located in the return air, and a steam heating coil with a steam valve controlled by a remote bulb thermostat set for 76°F and located in the return air.

3.2.3 Air Flow Pattern for the Building

A schematic diagram of air flow through the building is presented in Fig. 3.3. System No. 1 supplies air to the laboratory portion of the building and to most of the rooms in the TRU processing area. Systems 2 and 3 supply air to parts of the TRU processing area, and system 4 recirculates air within the limited-access area. The air in the laboratory portion of the building is exhausted through one of two filtered exhaust systems that are located on the roof, and the air in the TRU processing area outside of the limited-access area is exhausted through the second system on the roof.

The two systems will be referred to as systems AJ-120 and AJ-122. These are the equipment numbers for the primary blowers for the laboratory and TRU processing portions of the building.

The air in the limited-access area is exhausted through the processing cells to the HFIR stack.

The office annex is heated and ventilated separately except for the instrument shop (room 18), the air from which is exhausted through blower AJ-122.

Mechanical equipment rooms 114 and 207, waste room 107, and solvent storage room 112 are special cases (see below).

Sources of air and paths for exhaust are given below for various rooms or groups of rooms.

Laboratories. — The laboratories are supplied air partly from system No. 1 and partly from the corridors through wall louvers that have backflow restrictors. The air in all laboratories is exhausted through a filtered exhaust system (AJ-120) on the roof. Air from laboratories 109, 209, 211, 111, and 108 is exhausted at the ceilings; that from laboratories 210, 110, and 208 is exhausted through laboratory hoods to the filtered exhaust system on the roof (see description of laboratory 208 below).

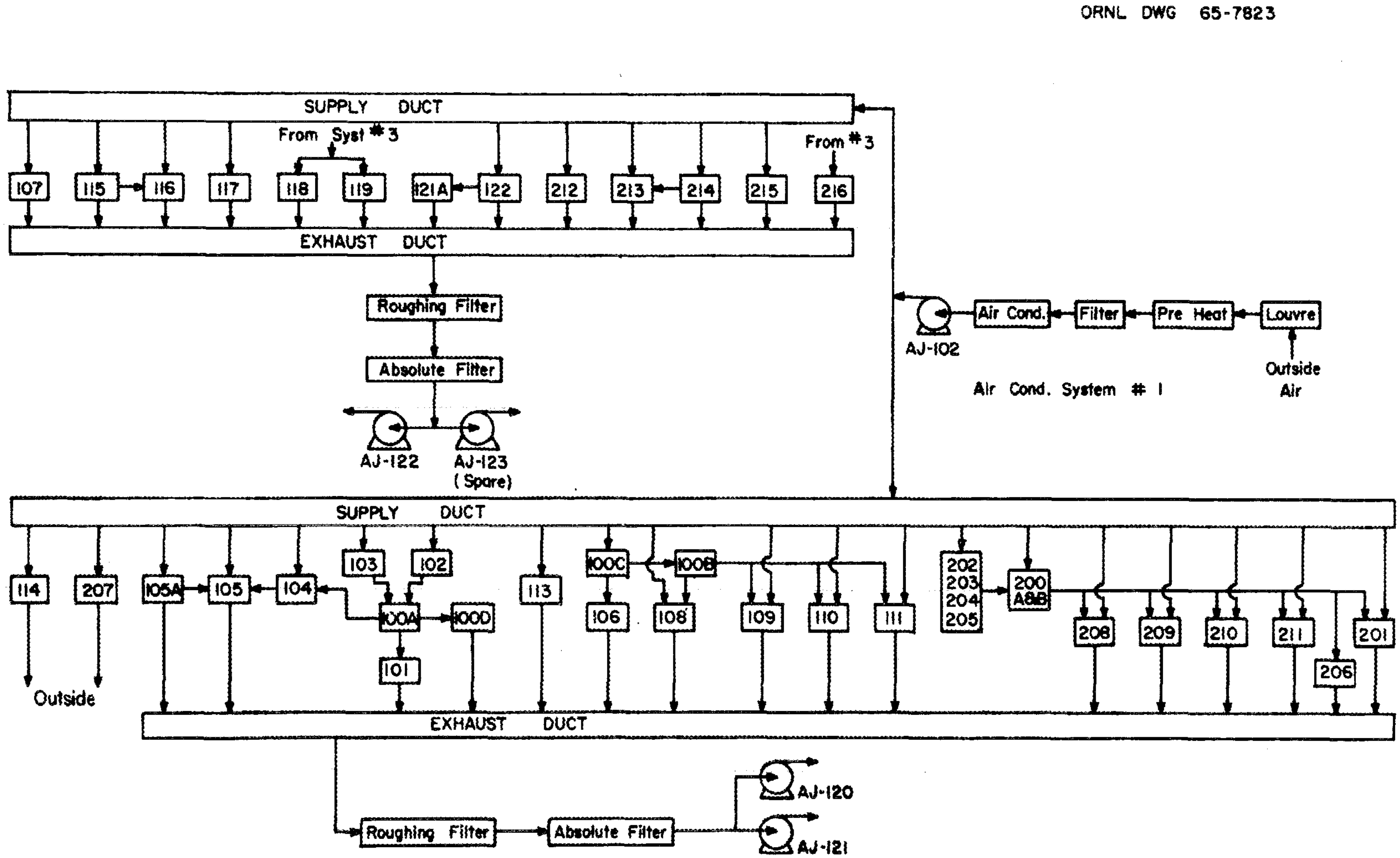

Fig. 3.3. Schematic Diagram of the Flow of Ventilating Air Through the TRU Facility.

Analytical Laboratory 208. — There are three laboratory fume hoods, which exhaust a total of 2100 cfm. An additional 1200-cfm capacity is available for open-face glove-box and/or room ventilation.

Women's Room 101. — Air is supplied from control corridor 100A through a wall louver and is exhausted to the filtered exhaust system (AJ-120) located on the roof.

Health Physics Office 102. — Conditioned air is supplied from system No. 1 and is exhausted through wall louvers to corridor 100B.

Calculating Room 103. — Conditioned air is supplied from system No. 1 and is exhausted through wall louvers to control corridor 100A. The air in control corridor 100A is exhausted partly through wall louvers to the women's room 101 and partly through room 105.

Corridors 100C and 200B. — Conditioned air is supplied to the corridors by system No. 1 and from rooms adjoining the corridor. The air is exhausted to the various laboratories, janitors' closets, and glove-box storage room.

Mechanical Equipment Rooms 114 and 207. — Air is supplied to the equipment rooms from system No. 1 for ventilation, and the areas are heated by unit heaters. These rooms operate at atmospheric pressure, and the air is exhausted, unfiltered, through wall exhaust fans.

Laboratory Waste Room 107. — Ventilation air is provided to the laboratory waste room through inleakage around the door, and is exhausted to a filtered exhaust system (AJ-122) located on the roof.

Solvent Storage Room 112. — Outside air is supplied through louvers and is exhausted by a separate sparkproof exhaust fan (AJ-109) located on the roof of the room.

Office 115. — Conditioned air is supplied to the room from system No. 1 and is exhausted through a soundproof return duct into the operating area, room 116.

Operating Area 116. — Conditioned air is supplied partly from system No. 1 and partly from the louvered exhaust from room 115. The air from this area is exhausted through the filtered exhaust system (AJ-122) located on the roof.

Conveyor Maintenance Area 122. — Conditioned air is supplied to the area from system No. 1 and is exhausted through a ceiling register and ductwork. This exhaust, along with the exhaust from the operating area (room 116), is discharged to the filtered exhaust system (AJ-122) located on the roof.

Chemical Makeup Area 213. — Conditioned air is supplied to the area from system No. 1. Air is also supplied through louvers from office 214. The air from this area is exhausted to the filtered exhaust system (AJ-122) located on the roof.

Control Office 104. — Conditioned air is supplied to the area from system No. 1 and is exhausted through louvers to change room No. 1.

Men's Change Room 105 and Men's Room 105A. — Air is supplied to the men's change room No. 1 (room 105) partly from system No. 1 and partly by louver supply from corridors 100A, 100B, and 100C, and is exhausted through the filtered exhaust system (AJ-120) located on the roof. Air is supplied to the men's room 105A partly from system No. 1 and partly through wall louvers from corridor 100B and men's change room No. 1, and is exhausted to the filtered exhaust system (AJ-120) on the roof.

Janitors' Closet 106. — Ventilation air is supplied to this room through a wall louver from corridor 100C, and is exhausted to the filtered exhaust system (AJ-120) located on the roof.

Cold Checking and Receiving 113. — Conditioned air is supplied to the room from system No. 1 and is exhausted to the filtered exhaust system (AJ-120) located on the roof.

Glove-Box Storage 201. — Conditioned air is supplied partly from system No. 1 and partly through wall louvers from laboratory corridor 200A. It is exhausted to the filtered exhaust system (AJ-120) located on the roof.

Laboratory Reagent and Equipment Storage No. 202. — Conditioned air is supplied to the area from system No. 1 and is exhausted through wall louvers to laboratory corridor 200A.

Calculating Rooms 203 and 204 and Counting Room 205. — Conditioned air is supplied to these rooms from system No. 1 and is exhausted through wall louvers to laboratory corridor 200A.

Janitors' Closet 206. — Ventilation air is supplied to this room through a wall louver from laboratory corridor 200A and is exhausted to the filtered exhaust system (AJ-120) located on the roof.

Darkroom 217. — Conditioned air is supplied from system No. 1 and is exhausted through a lighttight louver to the chemical makeup area 213.

Office 214. — Conditioned air is supplied to the room from system No. 1 and is exhausted through a wall louver into the chemical makeup area 213.

Recirculated Cooling Water Equipment Room 215. — Conditioned air is supplied from system No. 1 and is exhausted to the filtered exhaust system (AJ-122) located on the roof.

Change Rooms 3 and 4. — Conditioned air is furnished to each of the change rooms (rooms 117 and 212) by system No. 1. The air from each change room is exhausted through the filtered exhaust system (AJ-122) located on the roof.

Cell Transfer Area 118. — The cell transfer area is supplied with fresh air from system No. 3. The air from the area is exhausted through the filtered roof exhaust system (AJ-122).

Checking and Holdup Area 119. — Conditioned supply air is furnished by system No. 3. The air is exhausted through the filtered exhaust system on the roof (AJ-122). This room is provided with instrumented doors to form a positive air lock.

Decontamination Room 216. — Conditioned air is supplied to the room by system No. 3 and is exhausted to the filtered exhaust system (AJ-122) located on the roof.

Limited-Access-Area Room 120 and Change Room 2 (Room 121). — Air flow patterns for this area are shown schematically in Fig. 3.1. This area is supplied from system Nos. 2 and 4. System No. 2 provides outside air to the limited-access area, room 120, and change room No. 2 (room 121). The air from room 121 is exhausted through wall louvers to room 120. System No. 4 provides recirculated, conditioned, and filtered air in the limited-access area.

The air from the limited-access area is exhausted partly via the cell ventilation system, through 90% roughing filters, to each cell and partly by two filtered exhaust openings to the pipe tunnel for pipe tunnel ventilation. During maintenance operations, which require the roof plugs of a cell to be removed, additional air is supplied through system No. 2 and is exhausted through the open cell. All air that is exhausted from the cells and pipe tunnel will pass through the cell ventilation filters, and from there will go to the exhaust fans and stack.

3.2.4 Building Pressure Control

The building area outside the cells is divided into six zones that are provided with differential-pressure controls and differential-pressure dampers in the air streams from the supply systems. The differential-pressure controllers (static pressure-sensing pickups) act in conjunction with the constant-volume filtered exhaust systems to maintain the required negative pressure. The six zones that are independently controlled are: (1) first-floor laboratories, offices, and corridors; (2) second-floor laboratories, offices, and corridors; (3) TRU operating area; (4) TRU makeup area; (5) TRU decontamination and transfer areas; and (6) TRU limited-access area.

3.2.5 Alpha Laboratories

The laboratory portion of the building constitutes the secondary container for the experiments done in the glove boxes and the shielded cave. The normal ventilation for this area is designed to maintain a pressure of −0.3 in. of water (gage) with respect to outdoors – the required vacuum for containment under emergency conditions, as given in the ORNL Radiation Safety and Control Manual.

The laboratory rooms provide an effective intermediate barrier to the release of radioactive materials to the environment even though the rooms are not sealed. Ventilating air for the building normally flows into the laboratories from the corridors through backflow preventers and from there to the building exhaust system. Thus, radioactive materials released to the laboratory room from a glove box would probably be retained within the room or be collected on the building exhaust system filters.

3.2.6 Portals

There are a number of kinds of portals through which parts of the building are connected and through which the building is connected to the outdoors. These are discussed further in Section 12, which deals with radiation and contamination controls.

Normal passage to and from the building is through corridor 100A, which forms a vestibule air lock connecting the monitored-exit zone checking station and the one-story office annex. The cold checking and receiving station, room 113, is a vestibule air lock through which the building is connected to the northeast loading dock. Miscellaneous materials will be delivered here, and various items leaving the building will be held here for monitoring prior to shipment. The two air locks in the processing area, rooms 117 and 212, will be used for transferring large process-related items such as manipulators or drums and carboys of chemicals. The contamination zones that are located in the transfer area and decontamination room are isolated from other operating areas and from outdoors by these two air locks which also serve as monitoring and change stations for the areas.

The stairwells on the east and west sides of the building serve as vestibule air locks between floors. The outside doors will be sealed and used only as emergency exits.

There are doors from the east end of the corridors on both floors to the mechanical equipment rooms, rooms 114 and 207, which contain doors to outside and exhaust fans that provide unfiltered discharge of air from the equipment rooms. The doors from the corridors will be sealed and are to be used only as emergency exits. The equipment rooms will normally be entered from outdoors. The maintenance shop is located outside the east stairwell air lock.

The doors in the instrumented air lock, room 119, are equipped with interlocks that prevent the outside door from being opened unless the door to the transfer area and the door and the hatch to the limited-access area are closed. Similarly, these three openings cannot be opened unless the outside door is closed. This air lock is instrumented as an added precaution against opening the contamination zones to outdoors.

Each alpha laboratory, as well as each cold laboratory, has an emergency exit door that opens into either the TRU operating room on the first floor or the TRU "cold"-solution-makeup area on the second floor. The analytical laboratories have emergency exit doors that open into the TRU air locks on each floor. These emergency exit doors will be sealed with tape and will be used only in emergencies. This prevents the laboratory contamination zones from being connected directly to the processing-area regulated zones.

A yellow dumpster is located in room 107. The outside door is normally closed and cannot be opened from outside. Thus, it is permissible to freely use the door that connects the corridor to room 107; this is the only way to get in and out of the instrument shop. When the dumpster needs to be moved, the instrument shop door and corridor door will be sealed temporarily until this operation is completed.

4. CHEMICAL PROCESSES

4.1 General Process Description

The principal function of the Transuranium Processing Plant is to prepare targets for neutron irradiation in the HFIR and to reprocess irradiated targets to recover the heavy isotopes. In general, ^{242}Pu, ^{243}Am, and curium isotopes will be recycled to the HFIR, and the transcurium elements (berkelium, californium, einsteinium, and fermium) will be purified and held for distribution to other investigators. However, small amounts of the former group will be available for distribution, and occasional irradiation of the heavier elements will be made. The equipment available in TRU, plus the versatility of the flowsheets, enables this facility to handle other jobs. For example, it is planned to process hectogram amounts of ^{243}Am and ^{244}Cm, which are available as raffinates from the production at Savannah River of the original ^{242}Pu charge for the HFIR. The facility also has the ability to process ^{241}Am targets for recovery of decagram amounts of highly active ^{242}Cm, if further requirements for this isotope arise.

4.2 Plant Feed

TRU is designed to handle a variety of feeds. The usual feed will be HFIR-irradiated targets containing varying amounts of the heavy-element oxides dispersed in aluminum. Table 4.1 shows the expected composition of HFIR targets after each of several cycles of irradiation. A fifth-cycle target has more alpha and neutron radioactivity than any of the other materials processed, but early targets have greater amounts of gamma radioactivity.

There is a backlog of actinide materials from several sources which will supply feed to TRU until the irradiations in the HFIR become routine. These sources include the following:

1. Four "prototype" targets whose active regions are the same size as those of HFIR targets but whose external

Table 4.1. Approximate Composition of HFIR Targets at Discharge

	Cycle No.		
	1	2	5
Al, g/target	200	200	200
^{242}Pu, g/target	0.02	–	–
^{244}Cm, g/target	1	1.5	0.8
^{248}Cm, g/target	0.3	1.5	13
^{249}Bk, mg/target	0.2	2.5	23
^{252}Cf, mg/target	3	17	230
^{254}Cf, mg/target	0.015	0.08	1
Mixed fission products, g/target	8	3	1.5

configuration is different to make irradiation in one of the SRP reactors more convenient.

2. Eight slugs (fabricated at SRP) which contained all available ^{242}Pu not already committed to HFIR targets.
3. About 250 gallons of nitric acid solution containing about 260 g of ^{244}Cm and 220 g of ^{243}Am. This material was recovered from the wastes from the ^{242}Pu processing.

Table 4.2 lists the expected heavy-element compositions of these special feeds.

4.3 Flowsheet

Detailed chemical flowsheets are available as ORNL drawings (series F-12175-CD-002 through -010, plus -016). These flowsheets represent current thinking about the best means to perform the various operations but will undergo evolution as operating experience is gathered and the availability of larger amounts of the transuranium elements permits more elaborate investigation of chemical properties. It may be that even the order of the operations will change, particularly if radically different processes are developed. Figure 4.1 is a block diagram showing the interrelationship of the various operations that are discussed below.

4.3.1 Target Dissolution

All curium targets, and targets of ^{242}Pu that have been irradiated to greater than 80% burnup, will be dissolved in a Zircaloy-2 dissolver using hydrochloric acid. The dissolution will be monitored by heat evolution and controlled by regulating the temperature and acid concentration. Hydrogen produced in the dissolution reaction will be diluted immediately to 2 vol % by an air purge.

Targets that have less than 80% burnup of ^{242}Pu will be dissolved in $NaOH-NaNO_3$ solution in a stainless steel dissolver. The oxide

Table 4.2. Expected Compositions of Special Feeds to TRU

	Number and Type		
	Four TRU-SRP Prototypes	Eight SRP Slugs	250 gal of Nitric Acid Solution
Al, g	1000	2000	–
^{242}Pu, g	12	92	0
^{243}Am, g	6	37	220
^{244}Cm, g	14	93	260
^{248}Cm, g	0.002	0.05	–
^{249}Bk, mg	0.04	0.7	–
^{252}Cf, mg	0.2	1.7	0.2
Mixed fission products, g	8	50	5000[a]

[a]Almost all γ-emitters have decayed or been separated except ^{154}Eu and ^{144}Ce.

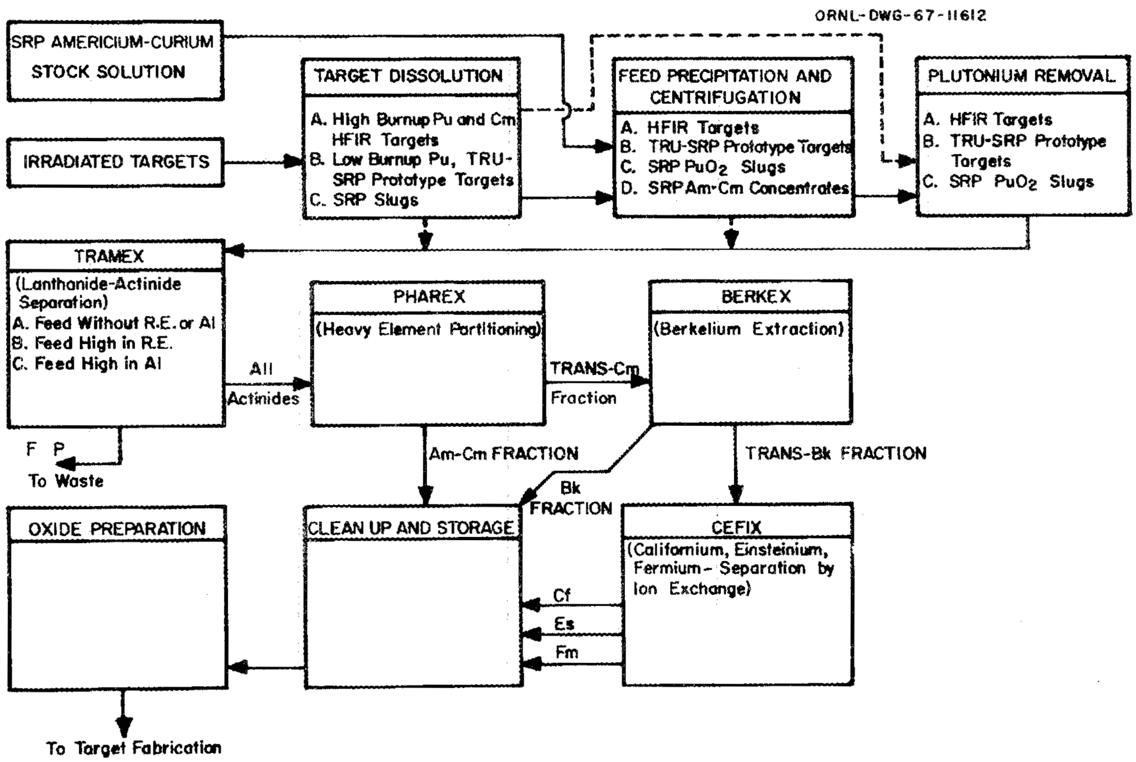

Fig. 4.1. Block Diagram of Chemical Operations in TRU.

residues will then be dissolved in refluxing 15 M HNO_3 — 0.1 M HF. Fluoride will be removed by successive hydroxide precipitations, followed by redissolution in dilute nitric acid, until a final concentration of less than 10 ppm is reached.

4.3.2 Feed Precipitation and Centrifugation

This step is used to remove aluminum from the process solution, or, in the case of nitric acid feeds, to convert to a chloride solution for Tramex processing. The feed stock is precipitated by slow addition to excess NaOH; the solids are then collected in a semicontinuous centrifuge and, after washing, are recovered by dissolution in dilute HCl.

4.3.3 Plutonium Removal

Plutonium will be recovered prior to solvent extraction because of difficulties in adjusting its valence and the possibility of hydrolysis during Tramex processing. The plan is to sorb Pu^{4+} onto an anion exchange resin from 6 to 8 M HCl. Under these conditions, curium and californium, the major sources of α-radiation, do not sorb, and the column effluent goes directly to Tramex feed adjustment. The plutonium will be eluted with dilute HCl and saved for later decontamination from fission products.

4.3.4 Tramex (Tertiary Amine Extraction) Process

The Tramex process is a solvent-extraction process that is designed to make a complete group separation between all the rare-earth elements (or lanthanides), which include some of the major fission products, and all the transuranium elements or actinides (see Fig. 4.2). The process is an adaptation of well-known anion exchange processes and makes use of a "liquid ion exchanger," a trialkyl amine dissolved in diethylbenzene. The feed is a solution of 11 M LiCl that is 0.2 M in acid. The transuranium elements are extracted from this feed, and small amounts of rare earths which extract or have been

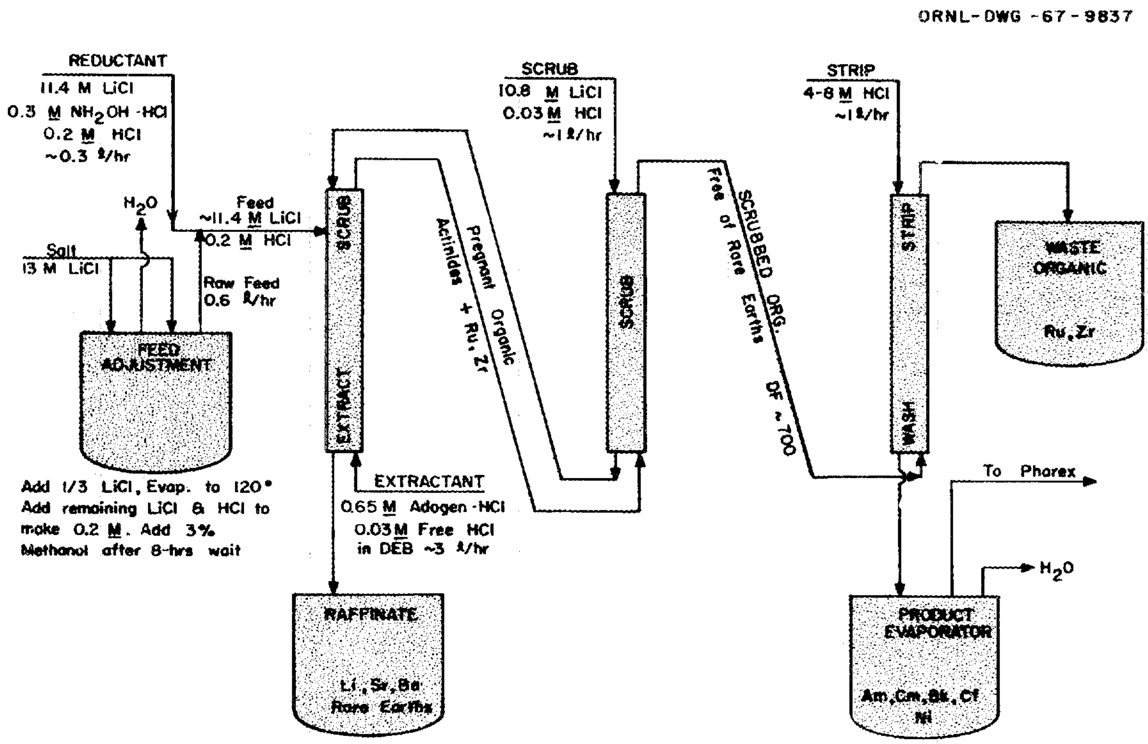

Fig. 4.2. Tramex Flowsheet.

entrained are scrubbed out with a similar 11 M LiCl solution. The pregnant organic is stripped (or back-extracted) with 8 M HCl. It is important that the feed be free of nitrate, as this ion promotes the extraction of rare earths and destroys the group separation. Most other fission products are also removed in the Tramex process to some extent, either in the raffinate or in the waste organic. The curium and/or americium in the product are suitable for recycle to the HFIR without further decontamination from fission products because remote refabrication methods will be used.

4.3.5 Pharex (Phosphonic Acid Reagent Extraction) Process

The Pharex process is designed to provide a rough separation of the transplutonium elements into two groups. The first group contains curium and americium, if these elements happen to be present. This fraction is refabricated into HFIR targets. The second group contains the elements of special interest to the Transuranium Program: berkelium, californium, einsteinium, and fermium.

The flowsheet for this process is presented in Fig. 4.3. The Tramex product is concentrated and then diluted to make a feed of 1 M HCl. The transcurium elements are extracted from this feed by a solution of 2-ethylhexyl phenylphosphonic acid in kerosene diluent. Decontamination from curium is achieved with a 1.5 M HCl scrub, and the product is stripped (back-extracted) with 6 M HNO_3. Stripping with nitric acid is a convenient way of preparing feed for the next step in the process, berkelium extraction.

4.3.6 Berkex (Berkelium Extraction) Process

The berkelium extraction (Fig. 4.4) is carried out in a batch-differential contactor since the amount of material to be handled is small and the separation factor obtainable in this chemical system is quite large. The Pharex product is concentrated at least 10-fold and converted to 8.5 M HNO_3, 0.1 M $KBrO_3$.

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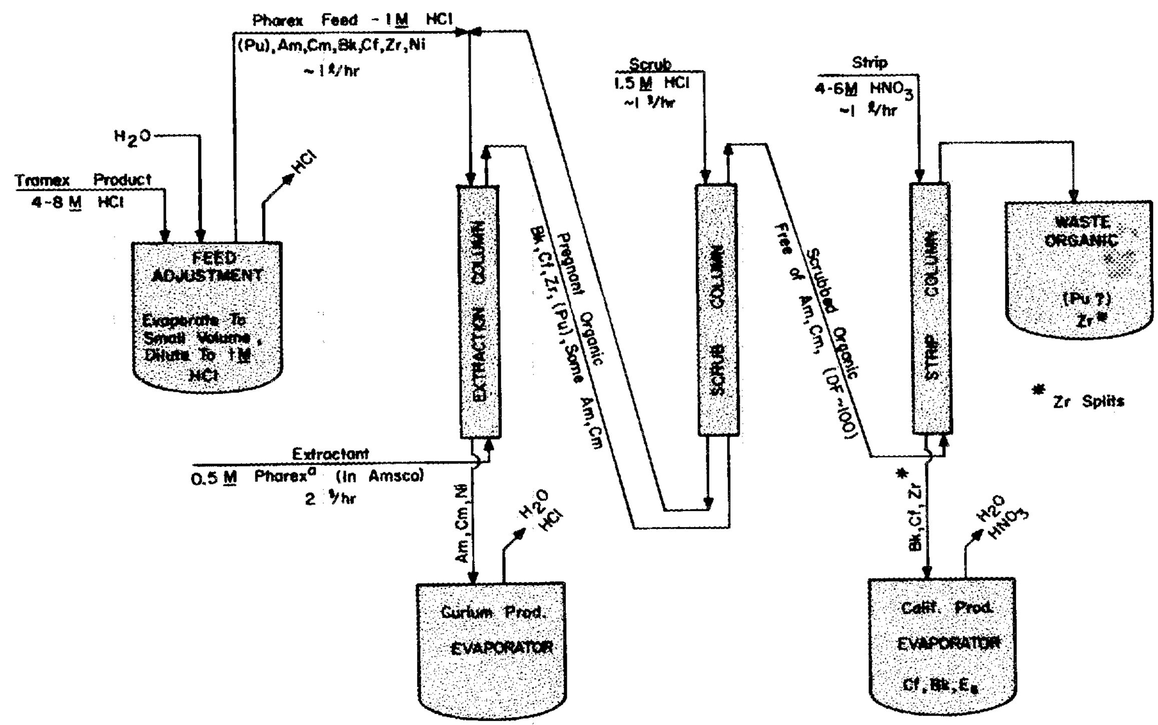

a Pharex = 2 ethyl hexyl hydrogen phenyl phosphonate

Fig. 4.3. Pharex Flowsheet.

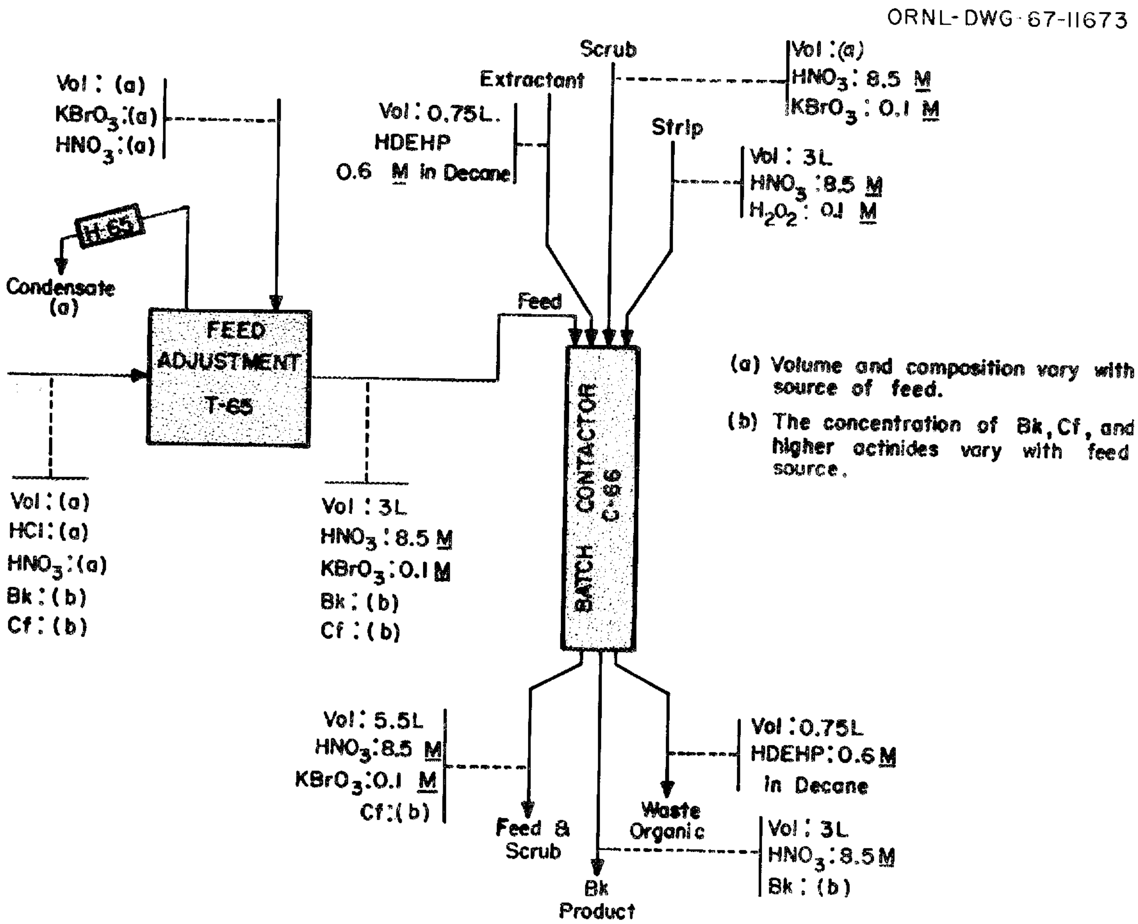

Fig. 4.4. Berkex Flowsheet.

The $KBrO_3$ in the feed oxidizes the berkelium to the (IV) valence state so that it can be quantitatively extracted by 0.6 M di(2-ethylhexyl) phosphoric acid (HDEHP) in decane. Residual amounts of californium and other trivalent actinides are scrubbed out of the system with more 8.5 M HNO_3 - 0.1 M $KBrO_3$. The berkelium product is then recovered by stripping with 8.5 M HNO_3 containing 0.1 M H_2O_2 to reduce the berkelium back to the (III) valence state.

4.3.7 Cefix (Californium, Einsteinium, Fermium Ion Exchange) Process

The Cefix process makes a first cut between the last three elements to be recovered from HFIR targets (see Fig. 4.5). The solvent extraction product solution is treated by cation exchange and then anion exchange to separate various salts and corrosion products from the actinides. This cleanup processing must be thorough because the volume of feed to the Cefix process represents a considerable concentration of the solvent extraction product solution.

The final feed is taken up in a small volume of 0.05 M HCl and loaded in a tight band on the top of the cation chromatographic column. The bands are separated by careful elution with 0.4 M ammonium α-hydroxyisobutyrate (hence the name "but" column for the chromatographic exchanger). In-line alpha and neutron monitors help determine the proper time to make cuts in the effluent stream. Since the isobutyrate is quite radiation sensitive, the product isotopes must be recovered from the effluent streams within a few hours. The three separate product fractions are processed successively through a small cation column for this purpose.

4.3.8 Cleanup and Storage

As in the case of the Cefix process above, the various products from the separation steps will have to be concentrated many-fold before they can be stored or converted to oxides for reirradiation or shipment. It is therefore necessary to remove accumulated salts and corrosion products. The basic procedures for doing this are precipitation in caustic to remove aluminum and chromium, precipitation in

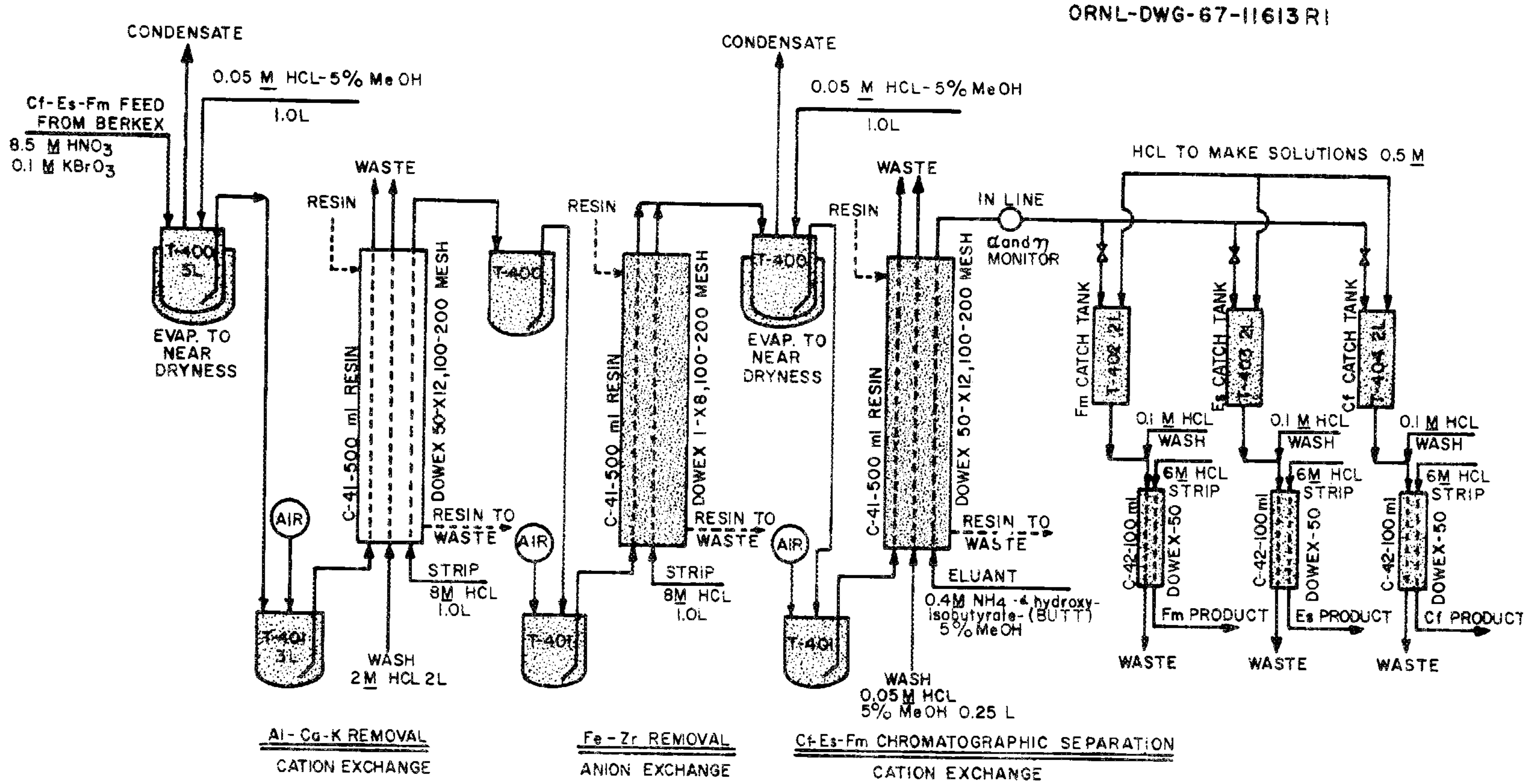

Fig. 4.5. Cefix Flowsheet.

ammonia to remove nickel and copper, and anion exchange from 8 M HCl to remove iron and zirconium. TRU has nine tanks for holding various transuranium element products, either for decay to other isotopes or for storage until requested by experimenters. Small amounts of special mixtures will be stored in solid form.

4.3.9 Oxide Preparation

Transuranium element oxides, whether for reirradiation, shipment, or storage, will be prepared by a sol-gel process (Fig. 4.6) from a highly concentrated stock solution. Again, a preliminary cleanup procedure will be necessary. The final precipitation of "clean" actinide will be made by adding the element at concentrations up to 10-20 g/liter in dilute nitric acid to an excess of 8 M NH_4OH. The resulting hydroxide precipitate will be collected in a laboratory-scale continuous centrifuge. After four washes with demineralized water, the cake will be compressed to its minimum volume and as much free water removed as possible; it will then be converted to a sol by gentle heating and the addition of a small amount of HNO_3. The sol will be dried to a gel and simultaneously formed into microspheres by spraying into a drying solvent. The dried gel microspheres will be transferred to the target fabrication section of TRU for calcination and incorporation into recycle targets.

4.3.10 Other Processes

The procedures described above are "main-line" processes. From time to time there will be special separation jobs that are performed in one of the cells reserved for this purpose. These special separations, such as milking ^{249}Cf from decaying ^{249}Bk, or purifying a sample for shipment to another site, will be performed in laboratory-type equipment especially installed in the cell for each job. These procedures will generally involve a small fraction of the amount of material handled in the main line. They will vary greatly to meet the specific requirements at hand, and no flowsheet can be presented at this time.

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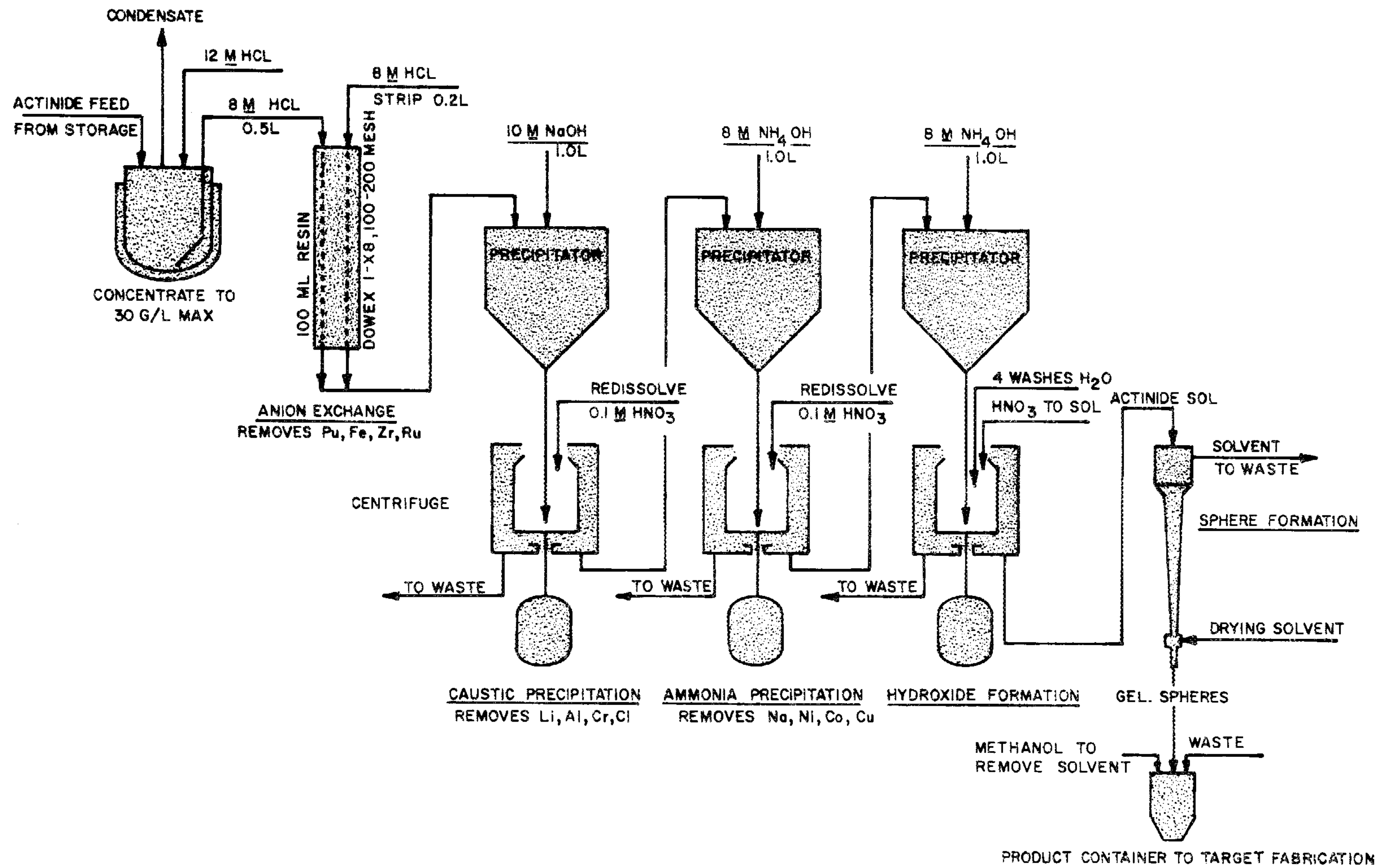

Fig. 4.6. Sol-Gel Process for Actinides.

4.4 Process Flexibility

The basic flowsheet presented above will undoubtedly be modified from time to time as more experience is gained with the chemistry of the heavy elements. This is especially true as you move from the front end of the process toward the tail end. Relatively little development work has been done to date on the Pharex, Berkex, Cefix, and sol-gel processes for actinide elements, partly because of lack of adequate facilities up until now for handling the transplutonium elements and partly because of a lack of adequate supplies of these elements for testing equipment and processes on an engineering scale. In this sense, production of the transplutonium elements will be a bootstrapping operation; as larger amounts are separated in TRU, they will serve as test materials for process development.

In addition to the above considerations, there will be some changes made for operating convenience. For example, the dissolution of aluminum in various media has been thoroughly studied. However, it is still necessary to try the different possible procedures to see which one works most efficiently in our equipment and fits in most conveniently with subsequent operations.

Examples of possible modifications which we expect to study are given in the following sections.

Target Dissolution. — Dissolution in caustic, planned for ^{242}Pu targets of low burnup, may prove to be useful for main-line targets also.

Feed Precipitation and Centrifugation. — This step could be eliminated as a means of removing the aluminum from the system either by a caustic dissolution or by a precycle of solvent extraction, using di(2-ethylhexyl) phosphoric acid, to separate actinides and rare earths from aluminum and concentrate them prior to the Tramex procedure.

Plutonium Removal. — Plutonium could be removed by anion exchange either from a chloride feed, as presently planned, or from a nitrate feed in the conventional plutonium anion-exchange process. Plutonium might even be removed in a simultaneous plutonium-berkelium recovery extraction. At this point, we do not know whether to try to effect fission product decontamination while recovering the plutonium or to combine several plutonium batches and recycle for fission product removal.

Tramex. — This process has been studied extensively in the Curium Recovery Facility and at the Savannah River Laboratory, but much optimization remains to be done before best combinations of recovery and purification can be achieved. We may even study other diluents such as diisopropylbenzene or decalin.

Pharex. — This flowsheet definitely needs to be optimized for best californium (and berkelium) recovery while still maintaining effective decontamination from curium.

Berkelium Extraction. — Further work on this procedure awaits the availability of multimilligram amounts of berkelium. It may prove to be desirable to move the berkelium recovery to the head end of the process, in which case plutonium and cerium will also be recovered with the berkelium and an additional separation step will be required.

Cefix Process. — From this point on, process flowsheets are so dependent on future developments that it would be impossible to list possible process variations.

4.5 Reagents Used in Process

Tables 4.3 - 4.11 show the various reagents used in current TRU processes, their purposes, and the approximate rate of consumption, on a monthly basis. The last column indicates the approximate amount stored in the makeup area at any time.

Table 4.3 Acid Reagents

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
12.2 M HCl	Target dissolution	16 liters	
	Plutonium removal (anion-exchange)	50 liters	
	Tramex strip	100 liters	
	Pharex scrub	20 liters	
	All others	14 liters	
	Total	200 liters (∿16 cases)	300 liters
15.8 M HNO_3	Pharex strip	55 liters	
	Berkex scrub and strip	24 liters	
	All others	11 liters	
	Total	90 liters (∿7 cases)	50 liters

Table 4.4 Basic Reagents

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
50% NaOH	Caustic scrubber makeup	1400 liters	
	Neutralizing acid wastes	300 liters	
	Aluminum removal	20 liters	
	Product cleanup	10 liters	
	All others	5 liters	
	Total	1735 liters	400 liters

Table 4.5 Salts

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
13 M LiCl	Tramex feed adjustment	75 liters	
	Tramex reductant	40 liters	
	Tramex scrub	120 liters	
	Total	235 liters	500 liters
Ammonium α-hydroxy-isobutyrate	Cefix	1 lb	6 lbs
Pentasodium diethylene-triamine pentaacetate	Decontamination solution	10 lbs	30 lbs

Table 4.6 Sorbents

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
Silica Gel	Purifying DEB and Amsco	10 lbs	20 lbs
Alumina	Purifying DEB and Amsco	10 lbs	20 lbs
Dowex 1	Plutonium recovery	20 lbs	
	Product cleanup	4 lbs	
	Total	24 lbs	15 lbs
Dowex 50	Cefix	4 lbs	5 lbs

Table 4.7 Reductants

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
$SnCl_2 \cdot H_2O$	Tramex; holding reductant for Ce	3 lbs	20 lbs
30% H_2O_2	Berkex; reductant for Bk extraction	<1 lb	10 lbs
Methanol	Tramex feed; holds acid	5 liters	Limited to 5 liters

Table 4.8 Oxidant

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
$KBrO_3$	Berkex; Bk oxidation in feed and scrub	2 lbs	2 lbs

Table 4.9 Organic Extractive Reagents

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
Tert-amine (2 M)	Tramex extractant	100 liters	200 liters
2-ethylhexyl phenylphosphonic acid	Pharex extractant	50 liters	200 liters
di(2-ethylhexyl) phosphoric acid	Berkex extractant	1 liter	100 liters

Table 4.10 Organic Diluents

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand
Diethylbenzene	Tramex diluent	200 liters	200 liters
Amsco 125-82	Pharex diluent	150 liters	200 liters
Decane	Berkex diluent	4 liters	5 liters

Table 4.11 Organic Cleaning Agents (Degreasers)

Reagent	Purpose	Amount Used per Month	Approximate Amount on Hand[a]
Alcohol (formula 3A)	Cleanout of Tramex equipment	40 liters	Limited to 5 gal
Acetone	Cleanout of Pharex and Berkex equipment	40 liters	Limited to 5 gal

[a]See also methanol, Table 4.7.

4.6 Dangerous Chemical Reactions

Most chemical reactions in the Transuranium Processing Flowsheet do not involve significant amounts of energy, either because the number of moles of reactants is vanishingly small, or because the energy released per mole is quite small. Examples of this type of reaction are the complexing of curium to make it extractable in the Tramex process:

$$Cm^{3+} + 5\ Cl^- \rightleftarrows CmCl_5^{2-} ,$$

and the oxidation of berkelium, also to make it extractable, in the Berkex process:

$$6\ Bk^{3+} + 6\ H^{+} + BrO_3^{-} \rightleftarrows 6\ Bk^{4+} + Br^{-} + 3\ H_2O\ .$$

(The latter reaction involves a large amount of energy per mole but few moles.)

The few reactions which do involve release of significant amounts of energy are discussed below.

4.6.1 Aluminum Dissolution in HCl

Dissolution of aluminum occurs quite readily in hydrochloric acid of almost any strength. In fact, the rate is so rapid that means for its control must be provided to avoid overheating or generating of explosive mixtures in the equipment. The aluminum dissolution rate has been defined by the following equation:

$$k = M^{2.42}\ e^{(16.74 - 5,260/T)}\ ,$$

where

k = dissolution rate, $mg/(cm^2)(min)$,

M = HCl concentration, M,

T = temperature of metal surface, °K, generally 2 to 5 degrees higher than the solution.

In the region of interest, a temperature rise of 12°C or an increase in acid concentration of 33% will double the reaction rate. Since the reaction releases 125 kcal/mole, this heat, unless removed, will rather quickly increase the temperature of the system and accelerate the reaction. Fortunately, as the metal surface gets still hotter, a blanket of steam and hydrogen forms, which drastically limits the actual contact between acid and metal and thereby prevents the dissolution rate from rising much above 50 $mg/(cm^2)(min)$. In the TRU dissolution the rate is controlled by adding the proper amounts of acid and adjusting the temperature to achieve a dissolution rate of 1 g/min. The dissolution rate is monitored by measuring the temperature rise of the cooling water. If the temperature in the dissolver becomes excessive, all heat is removed from the recirculating cooling water, thus causing the dissolver to cool. The hydrogen evolved during the dissolution step is immediately diluted to 2% by a purge of 2 cfm of air.

4.6.2 Aluminum Dissolution in $NaOH-NaNO_3$

This dissolution procedure will be applied to plutonium targets in which the ^{242}Pu burnup is less than 80%. If it performs satisfactorily for these targets, it may be used for the high-burnup targets also. The basic reaction, $Al + NaOH + 3\ H_2O \rightarrow NaAl(OH)_4 + 3/2H_2$, produces hydrogen and heat similar to that produced in an acid dissolution. However, the presence of NO_3^- causes most of the hydrogen to be converted to ammonia by an approximate overall reaction:

$$Al + 2\ H_2O + 0.85\ NaOH + 1.05\ NaNO_3 \rightarrow NaAl(OH)_4 + 0.9\ NaNO_2 + 0.15\ NH_3 + 0.2\ H_2O + 0.008\ H_2$$

This reduced amount of hydrogen will permit a faster dissolution rate and still maintain the same percentage hydrogen in the off-gas. The dissolution rate will be controlled by restricting the amount of aluminum added. This is done very simply by putting the target into a tall, thin vessel. The bottom 6 in. is filled with the caustic solution, and the vessel is heated to start the reaction. As the dissolution proceeds, the bottom of the target corrodes away and the rod begins to slide down into the broth, exposing fresh surface. The temperature will rise to the boiling point and remain there as the heat of reaction is removed by refluxing. The off-gas will pass through a dilute acid scrubber to remove the ammonia.

4.6.3 Preparation of Highly Oxidizing Berkex Feed

The feed (and scrub) for Berkex (8.5 $\underline{M}$ HNO_3 – 0.1 $\underline{M}$ $KBrO_3$) is a highly oxidizing medium which reacts vigorously with reducing agents.

The extraction equipment is periodically cleaned out with acetone to remove organic films. Great care is exercised to make sure that the acetone is completely flushed out of the column and the catch tank before the highly oxidizing feed is added.

4.7 Forbidden Reagents

Most of the main processing equipment in TRU is made of Zircaloy-2. This alloy is highly resistant to nearly every conceivable combination of acids and bases except those containing fluoride. Even small (10-25 ppm) concentrations increase the corrosion rate detectably. Fluoride contamination is believed to account for the marked corrosion observed in Zircaloy-2 mixer-settlers used by the Savannah River Laboratory and by the Curium Recovery Facility. An upper limit of 5 ppm has been placed on the fluoride content of all reagents ordered in bulk for TRU.

In spite of the importance of barring fluoride from the system, it has been found necessary to include HF as a reagent for the dissolution of high-fired, low-burnup plutonium. Therefore, a small subsystem built entirely of stainless steel has been added to one of the cubicles to perform this dissolution. All streams leaving this subsystem will either be neutralized by caustic or be decontaminated from fluoride. Hydrochloric acid must be barred from this subsystem because it corrodes stainless steel excessively.

A few parts of the system are fabricated of tantalum. Caustic solutions must be barred from these tantalum lines and vessels.

5. TARGET FABRICATION

Cell cubicles 1, 2, and 3 contain equipment that is used to process the sol-gel products from the chemical processing steps and fabricate them into target elements for irradiation in the HFIR. The elements may contain any combination of the transuranium isotopes, depending on availability and production schedules.

5.1 Process Description

Targets are fabricated by a series of simple operations. The system is designed to minimize the spread of contamination and to facilitate repair or replacement of components. Transfer arms and other special devices, operated semiautomatically, are used to move target element components between steps in the process. Master-slave manipulators are used principally for maintenance and for transfer of materials to and from the intercell conveyor. Auxiliary enclosures are used within the cubicles to minimize the spread of contamination. Whenever it was possible, sensitive parts were made small enough to fit into the intercell conveyor. All equipment may be demounted, using a manipulator-held impact wrench and an in-cubicle overhead crane, and may be removed and replaced by means of the equipment transfer case.

The process steps have been grouped in the three cubicles, according to the potential they have for releasing radioactive nuclides to the cubicle. Generally, operations with loose powders will be performed in cubicle 3, those with pellets in unsealed tubes in cubicle 2, and those with sealed target elements in cubicle 1.

5.1.1 Pellet Forming and Cleaning

Figure 5.1 is a schematic flowsheet for the pellet forming and cleaning steps that are performed in cubicle 3.

Actinide hydroxide powder in a special container is moved from cubicle 4 to cubicle 3 via the intercell conveyor and is moved to the calciner by means of the manipulator. The container with calcined

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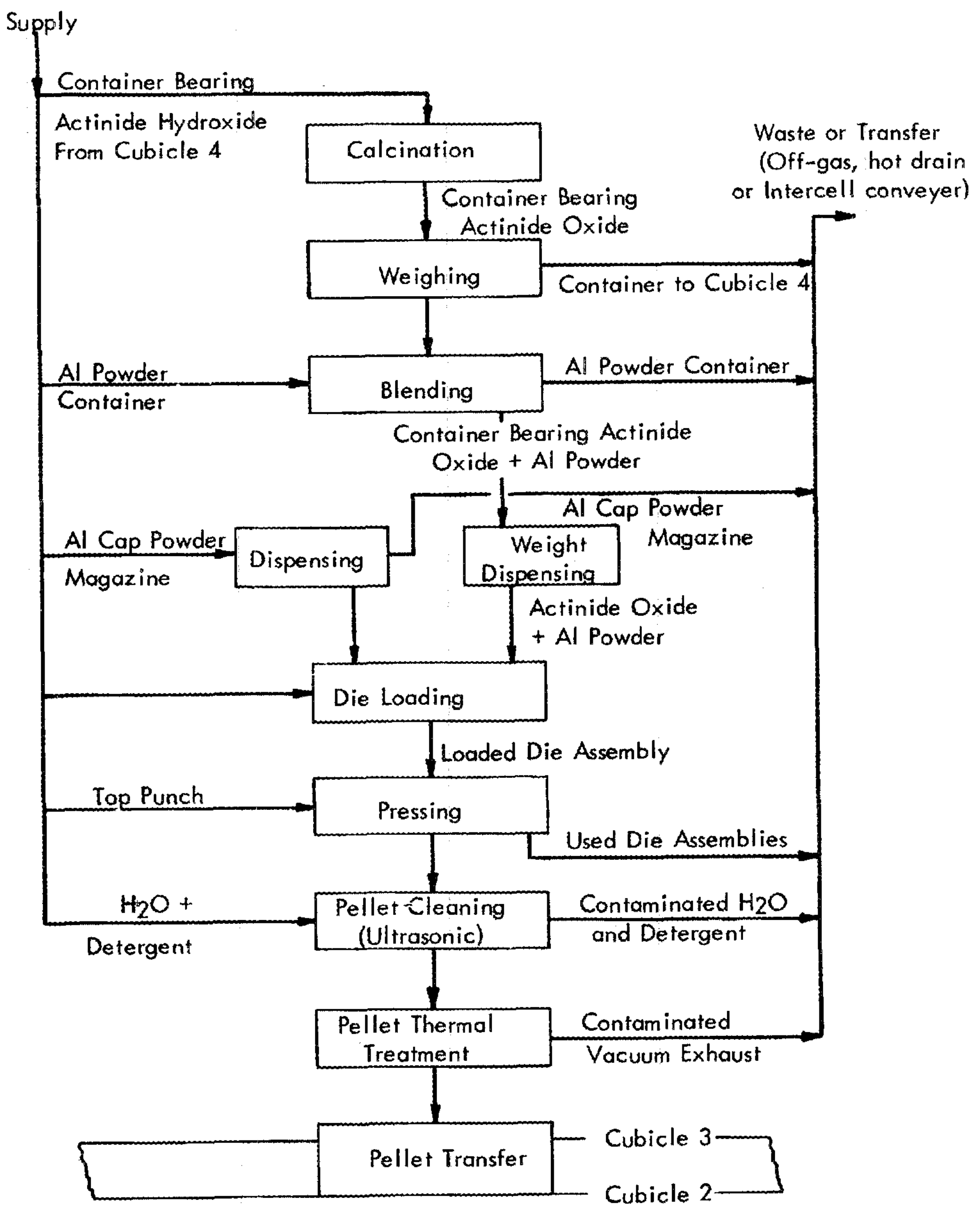

Fig. 5.1. Flowsheet for Pellet Fabrication, Cubicle 3.

oxide is transferred by manipulator to the batch scale, where the oxide is weighed to determine the amount of aluminum powder to be added. The proper quantity of aluminum powder (weighed outside the cell bank) is put into the cubicle via the intercell conveyor and added to the actinide oxide at the powder add station. The mixture of powders is blended and dispensed to dies. Each of the dies, which are prepared outside, contains an aluminum tube and a bottom powder cap. One die at a time is placed on a scale that is interlocked with the blender-dispenser to automatically stop dispensing when the desired weight is reached. The loaded die is transferred by the transfer arm to the cap powder station, where a top punch is loaded and the pellet is pressed at about 22 tsi. The pellet is ejected from the die, and the die components are discarded.

The length of the pellets is checked, and each pellet is weighed to be sure that the actinide oxide:aluminum ratio is correct. Rejected pellets are stored for chemical reprocessing, and acceptable pellets are loaded into a magazine for subsequent fabrication steps.

The magazine containing the pellets is transferred by manipulator to the ultrasonic cleaner, where the pellets are cleaned and rinsed. It is then transferred to the pellet drier, where the pellets are dried at 500°C in a resistance-heated vacuum furnace until outgassing ceases and furnace pressure is reduced to 100 microns. The vacuum pump in the chemical makeup area induces a vacuum through an absolute filter in the cell and discharges into the VOG line in the makeup area. The dry pellets are fed through the wall to the pellet checking and loading station in cubicle 2.

5.1.2 Target Tube Assembly

Figure 5.2 is a schematic flowsheet for operations in cubicle 2.

Pellet diameters are checked automatically by passing the pellets through a diameter gage. Oversize pellets are rejected and held for chemical reprocessing. Acceptable pellets are stacked in a trough until the number required for one target have been stacked. Total length is checked to satisfy the specification that the active target length is 20 ± 0.5 in. This length may require 34, 35, or 36 pellets.

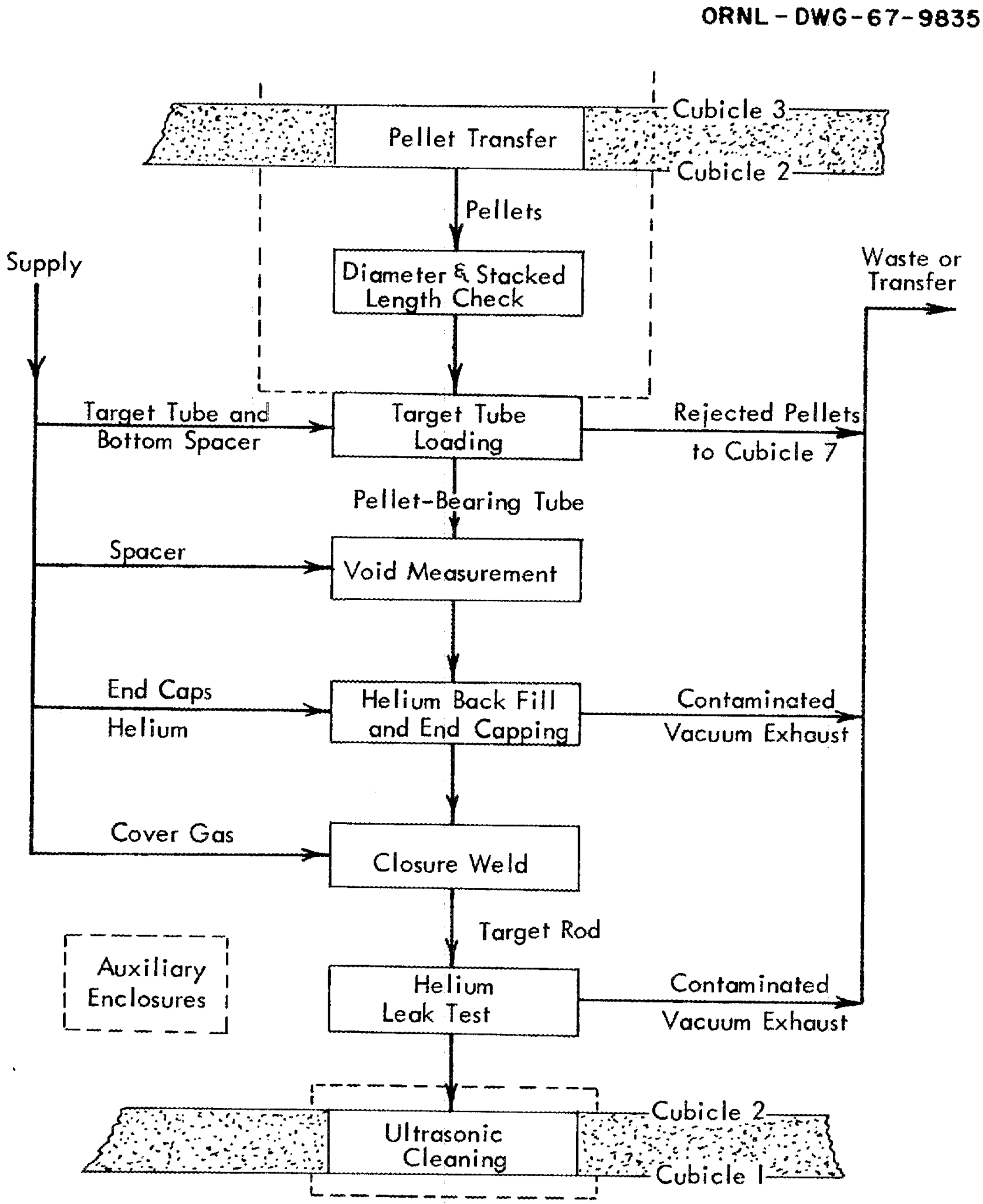

Fig. 5.2. Flowsheet for Fabrication of Target Tubes, Cubicle 2.

A target tube with one closure weld completed and containing a bottom support sleeve is held in loading position by the tube holder and loading station. Pellets are loaded into the target tube one at a time, using a stuffing rod, and then the loaded target tube is rotated vertically 45°. The top support liner is measured and inserted; then the rod is raised upright.

The transfer arm moves the target tube to the assembly machine, the end cap is inserted into the chamber, and the welding chamber is evacuated and backfilled with helium. The end cap is pushed into the target tube to form a mechanical joint, and the closure weld is made. The transfer arm moves the closed tube (now the target rod) to the helium leak chamber, which is evacuated to the helium leak detector in the chemical makeup area. A vacuum is induced through two absolute filters in the cell and is discharged to the vessel off-gas line in the makeup area. The target rod is moved by the transfer arm to the target rod transfer station, where it is cleaned and rinsed in an ultrasonic cleaner and then inserted into cubicle 1.

5.1.3 Target Rod Assembly and Testing

The target rod is transferred by the transfer arm for all operations in cubicle 1 (Fig. 5.3). The rod is dried with a stream of heated air and is smeared for contamination. The smear pad holder contains two pads, of which only one is used to smear the tube. Both pads are removed from the cubicle and counted; the difference in counting rates is attributed to contamination on the target rod.

The transfer arm moves the rod to the x-ray station where six x-ray exposures are made (two at the end that was welded in the cubicle and one at each of four other elevations) to cover the entire pellet area of the rod.

The dimensions of the rod are checked, and the rod is moved to the hydrostatic pressure chamber where the tube is collapsed onto the pellets. The rod is again helium leak tested, and the dimensions are remeasured. If necessary, the rod is straightened and another check is made of the dimensions.

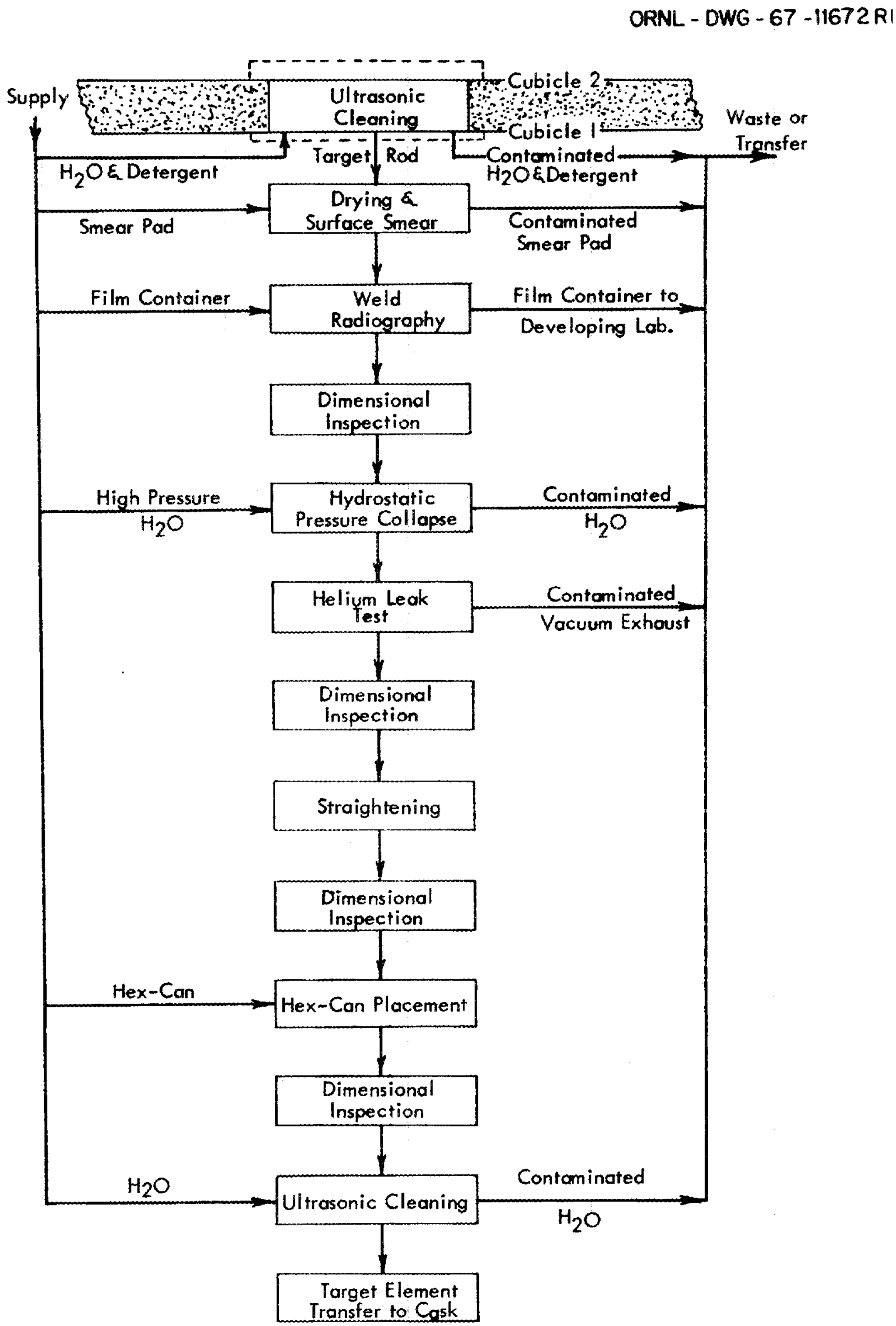

Fig. 5.3. Flowsheet for Target Assembly, Cubicle 1.

The hexagonal can is positioned over the rod, and staking pins are driven into the can to fasten it to the rod.

The target assembly is checked for correct dimensions, ultrasonically cleaned, and moved to the discharge elevator, which raises the assembly to the carrier on top of the cell bank.

5.1.4 Disposition of Reject Rods

Rods may be rejected at several places. Their disposition will be determined by whether the reject occurred before or after the hydrostatic collapse step. If a rod is rejected before collapse, it is opened and the pellets are removed and recycled through cubicle 3. If the rod is rejected after collapse, it will be moved to cubicle 7 for dissolution and reprocessing.

5.2 Inspection of 18 HFIR Targets

About 100 to 200 μg of californium is contained in 18 target rods that were irradiated at the Savannah River Plant and then stored in the HFIR pool. There is no incentive to process these targets to recover the transuranic actinides. However, the rods have the equivalent of three months of full-power irradiation in the HFIR and will be included in the first HFIR target loading if their integrity can be ensured.

The targets will be brought from the HFIR pool to the TRU facility in the CAST cask, lowered into cubicle 1, inspected, and returned to the HFIR in the CAST cask. Movement of the targets in and out of cubicle 1 is achieved by following a written procedure that has been tested, using a dummy target rod. Ten separate inspections or operations will be performed on each rod following a detailed check sheet. The entire inspection involves 42 separate steps.

5.3 Chemical Reagents

The only reagent used in the fabrication cubicles is an aqueous solution of detergent. Acetone, used for cleaning rod components outside the cubicles, will be included in the total inventory of Class A chemicals permitted in the chemical makeup area.

6. CRITICALITY IN PROCESSING AREA

The amount of transplutonic fissile nuclides planned for production is about 2 orders of magnitude less than a minimum critical mass; thus, no criticality hazard exists.

7. OPERATING SAFEGUARDS IN PROCESSING AREA

7.1 Operating Organization

One of the primary factors in the safe operation of any facility such as TRU is an adequately staffed and highly trained operating group. The responsibility for the safe operation of the entire facility rests with the pilot-plant group, which also operates the cell bank and all related equipment. Building service equipment, including all ventilation systems, is operated and routinely checked by the pilot-plant group. It is their responsibility to see that the required services are operating normally for the supporting groups in the laboratories and other areas of the building.

The staff consists of 11 engineers and 21 technicians, as shown in Table 7.1. The operation continues on a 7-day week, 24-hour day schedule with a shift organization, composed of an engineering supervisor and four technicians on each shift, that is supported by technical and engineering groups (including a building safety officer).

7.1.1 Responsibilities

Chief of Operations. — The shift operating group reports to the Chief of Operations. In addition to supervising the shift groups, he has the primary responsibility for administrative control and supervision, with the assistance of a Maintenance Engineer, of all maintenance activities in the building.

Shift Supervisor. — The shift supervisor on duty is responsible for all current operations in the process area, including the determination that any maintenance to be started can be done safely and will not interfere with any operation in progress. He must be aware of all cell bank and building service equipment operations that are under way, and he has the authority and responsibility to stop or change any of these operations.

Table 7.1 TRU Organization

- W. D. Burch, Building Supervisor
  - Janet Mason, Secretary
  - Nancy Wexler, Secretary
- O. O. Yarbro, Chief of Operations
  - J. M. Turley, Maintenance Engineer
    - H. C. Thompson
  - F. R. Chattin, A-Shift Supervisor
    - C. W. Boatman
    - A. V. Wilder
    - J. B. Overton
    - C. L. Johnson[a]
  - E. D. Collins, B-Shift Supervisor
    - T. L. Douglass
    - B. J. Strader[a]
    - W. J. Bryan
    - H. S. Caldwell
  - W. W. Evans, C-Shift Supervisor
    - J. H. Brock
    - R. R. Laxson
    - K. P. Bayne[a]
    - R. C. Shipwash
  - J. E. Van Cleve,[a] D-Shift Supervisor
    - J. H. Groover
    - D. B. Owsley
    - C. L. Shepherd
    - J. T. East[a]
    - C. H. Jones
- L. J. King, Technical Group
  - J. E. Bigelow, Flowsheet Studies and Data Analysis
    - M. C. Hill
    - W. M. Sproule
  - J. L. Matherne,[d] Engineering
  - M. K. Preston,[a] Target Fabrication Engineer
    - J. Eve[a]
  - E. M. Shuford,[b] Field Engineer
  - H. E. Cochran,[c] Instrument Engineer

[a] Assigned from Metals and Ceramics Division.
[b] Assigned from Plant and Equipment Division.
[c] Assigned from Instrumentation and Controls Division.
[d] Building Safety Officer.

Building Safety Officer. — The Building Safety Officer is responsible for all safety matters in the building, including zoning regulations, emergency manuals and procedures, safety training, and other similar functions. In addition, he is responsible for reviewing and approving all non-routine maintenance requests and procedures, and radioactive material transfer procedures.

Technical and Engineering Groups. — These groups review and analyze all data generated in the process operations and determine process conditions for all runs.

Target Fabrication Engineer. — All target fabrication work is planned under the direction of an engineer who is fully acquainted with this equipment. He is responsible for preparing the procedures for executing the work, seeing that the assigned personnel are adequately trained, and providing day-to-day instructions for the operation. He will also analyze the results of these operations.

Building Supervisor. — The above groups report to the Building Supervisor, who has overall responsibility for the operation of the entire facility.

7.1.2 Training Programs

A full-time three-week training session was held at the beginning of the operations to fully acquaint all personnel with the facility, standard procedures, processes, and safety matters. This was followed by a six-month period of check-out operations in which all personnel were trained in their responsibilities. Future training is the responsibility of each shift supervisor, with process matters being coordinated by the Chief of Operations and safety training being organized by the Building Safety Officer.

7.2 Standard Operating Procedures

Although all personnel have been trained so that they are completely familiar with the operations they will be performing, all operations will be done by following a detailed procedure and check list.

7.2.1 Operating Manual, Check Lists, and Run Sheets

An operating manual has been prepared which describes in detail all building and process equipment and the general operating procedures to be followed, and provides all other information required for the safe operation of the building, such as process chemical information, maintenance procedures, radiation safety information, and general building safety rules. It is supplemented by an Emergency Manual which is devoted to the procedures for handling abnormal conditions and emergencies.

Detailed step-by-step check lists are provided which list every operation (such as each valve to be operated) in sequence, and provide some supplementary information.

Detailed run sheets are also provided which specify the exact conditions, flows, chemical compositions, etc. to be followed in a specific run.

7.2.2 Building Log

All building service equipment, including all ventilation systems, air compressors, water systems, the caustic scrubber, etc., are routinely inspected at the beginning of each shift. Operating conditions are logged and compared with the normal. This log is checked by the shift supervisor, and any abnormal condition is immediately investigated.

7.2.3 Transfer of Information Between Shifts

The shift supervisor is responsible for maintaining an accurate and concise record of operations in the shift log. This continuing log is the primary means of transmitting information between shifts. An overlap period of 12 minutes by the non-technical people provides an opportunity for smooth switch-over even for a continuous operation. Operations are not normally shut down at the end of a shift. The supervisors normally discuss the operation for about 30 minutes at the shift switch-overs.

7.2.4 Procedure Changes

As the processes change, procedures must be constantly revised to bring them up to date, to refine the operations and to correct errors as they are noted. The Chief of Operations is responsible, with the concurrence of the Building Supervisor, for all changes in the operating manual and check lists. Certain changes are appropriately reviewed by the Safety Officer and the area Health Physics representative.

7.3 Maintenance Procedures

All maintenance procedures throughout the building are done under a system designed to ensure complete safety at all times. Appropriate people must approve each step and closely supervise the actual maintenance operations.

7.3.1 Work Request System

A work request form (see Fig. 7.1) has been devised to provide (1) a means of requesting maintenance to be done; (2) spaces for the appropriate people to approve the work, along with all procedures required; (3) assurance of the proper safety reviews; and (4) a permanent record of the work performed. Maintenance work may be requested by many people in the building. These requests are first acted upon by the Maintenance Engineer, who reviews the request and prepares the preliminary information on the work request form for the Plant and Equipment Division craft forces, who do the work. At this stage the job is reviewed by the Chief of Operations, who determines whether the job should be done, and, if so, what priority it should have, what

WORK REQUEST NO. ____________

TRU WORK REQUEST, BLDG. 7920

	DATE
TO	WORK ORDER NO.
FROM	WORK REQUEST NO.
	PRIORITY

HAZARDS WORK PERMIT, FORM UCN-326, REQUIRED ☐ YES ☐ NO

RADIATION WORK PERMIT (RWP) FORM UCN-2779, REQUIRED ☐ YES ☐ NO

BUILDING SAFETY OFFICER APPROVAL REQUIRED ☐ YES ☐ NO

EQUIPMENT OR WORK LOCATION

REFERENCE PRINTS OR OTHER

PRECAUTIONS TO BE TAKEN

TRU SAFETY OFFICER APPROVAL	DATE	CHIEF OF OPERATIONS APPROVAL	DATE

SHIFT SUPERVISOR'S APPROVAL TO PROCEED

STARTING TIME	TIME APPROVAL ENDS	SIGNED	DATE

REQUESTED COMPLETION DATE

WORK DESCRIPTION AND OTHER

REMARKS

DATE JOB COMPLETED	BY	ACTUAL TIME CHARGED

UCN-7037
(3 7-66)

RETURN ORIGINAL COPY TO CHEM. TECH. BLDG. 7920.

Fig. 7.1. Work Request Form.

safety reviews, if any, are required, and when the job should appropriately be started. The approved request is then transmitted to the Plant and Equipment Division field engineering forces, who complete preparations to do the job. When the preparations are finished, the foremen review the job with the shift supervisor on duty, who ascertains that the job can be done safely at that time. He makes sure that valves and electrical breakers are appropriately tagged out and that any other preparations are completed, such as Health Physics survey, before signing the form, thus giving approval for the job to proceed. Similar approval is made at the beginning of each new shift in the event that a job carries over to the next shift.

When the work has been completed, the foreman signs the form, returns it to the shift supervisor, and informs him of anything incidental to the work request which might affect the operations. The forms are then filed permanently.

While some minor variation of the above described sequence may occur, the key steps--review and approval by the Chief of Operations and final endorsement by the shift supervisor--are mandatory.

7.3.2 Detailed Procedures

The majority of maintenance jobs are done from instructions written on the work request form, plus auxiliary sketches and drawings. However, more detailed procedures are required for in-cell maintenance work. Maintenance work performed with manipulators in the cubicles by the technicians is not done by work request form since the latter is designed only for support work by the Plant and Equipment Division. A separate form is used for in-cell work. This work will be done according to general instructions in the Operations Manual; however, each specific job must be reviewed and approved either by the Chief of Operations or by the Building Supervisor prior to starting the job.

Maintenance involving removal of equipment from the cell bank, and other in-cell maintenance where the cell is to be opened, will be done according to detailed step-by-step procedures. For semiroutine operations, these instructions will be prepared as part of the Operations Manual. For nonroutine jobs, a special procedure will be prepared at the time the job is to be performed.

8. PERSONNEL EXPOSURE IN PROCESSING AREA

8.1 Curie Load

The largest source of β-γ radiation is the ^{144}Ce - ^{144}Pr fission product associated with the fissioning of the initial 10 kg of ^{239}Pu used to produce the ^{242}Pu target material. The cell design was based on processing 200,000 curies of this material, but most of it has now decayed; less than 10,000 curies remain.

The maximum amount of α activity stored in any cell at one time will be the 260 g of ^{244}Cm from Savannah River, equivalent to 21,000 curies.

The cubicle design is based on the shielding requirements for a fifth-cycle HFIR target, which is expected to contain 305 mg of Cf and spontaneously emit 3×10^{12} fission neutrons per second from all heavy isotopes. This is the equivalent of 80 "curies" of neutron activity. Maximum inventory in the entire cell bank is expected to be less than 5 g of Cf or about 300 "curies" of neutrons.

8.2 Personnel Exposure

The TRU shielding design will attenuate the sources listed above to a penetrating radiation dose rate of <0.75 mrem/hr in normally occupied areas, with "hot" spots of radiation no greater than 2.5 mrem/hr opposite wall penetrations. The dose rates in normally unoccupied areas will be no greater than 10 times these values.

8.3 Exposure in Radiation Zones

As indicated above, exposure in the normal operating area will be <0.75 mrem/hr or <30 mrem per 40-hr week. However, there will be a number of operations such as target charging, sample removal, waste removal, or equipment removal and decontamination that will entail part-time exposure to higher levels of radiation. These operations will be performed with the knowledge of Health Physics personnel, and the working times will be carefully checked to make sure no individual receives an exposure in excess of that provided for in the Health Physics Manual, Section 3.2. Records of accumulated exposures will be kept for pilot-plant personnel and for craft personnel that are regularly assigned to the building.

8.4 Exposure Possibilities

The table below lists the approximate number of people that normally work in the TRU building. Visitors who may be present from time to time will be escorted through the building. They will wear film badges and either electroscope dosimeters or pocket meters.

Table 8.1 Number of Personnel Working in the TRU Facility

	Working Days	Nights and Weekends
Main Processing Area	15	5
Laboratory Area	12	3
Office Area	12	0

9. ANALYTICAL CHEMISTRY DIVISION

The work being done by the Analytical Chemistry Division will be supervised by John Cooper, a member of that division.

Cubicles 8 and 9 will be used to collect and store samples from the cell bank, to perform analyses that must be made without dilution on highly radioactive samples, and to make dilutions for analyses that will be made in laboratories 108 and 208. All operations in the cell bank area must be coordinated with and approved by the TRU Shift Supervisor.

Operations in laboratories 108 and 208 will be those that have previously been reviewed and approved for similar facilities. New procedures will be presented for review if they appear to represent a significant departure from approved practice.

10. LABORATORY GLOVE-BOX OPERATIONS

The laboratory facilities will be used for fundamental studies and process development of alpha-active materials. Much of the work will be concerned with the development of sol-gel processes and with process development for the isolation and purification of various alpha-active materials. For this, emphasis is placed on solvent extraction and ion exchange techniques. However, any operation normally conducted in an inorganic chemistry laboratory might be adapted for use. Work will be carried out in unshielded glove boxes when only alpha containment is essential; when protection from beta-gamma or neutron radiation is necessary, the work will be done in glove boxes shielded by lead or other material and in the large shielded cave. The amount of material handled will vary from trace quantities up to 100 curies. Various isotopes of all elements from thorium through fermium, plus their daughters, will be handled. On occasion, after a special hazards review, a production-type program may be carried out.

The work will be done by experienced personnel under the supervision of M. H. Lloyd and R. E. Leuze. New personnel will probably become involved eventually. People who are not experienced in handling highly radioactive materials in glove-box operations would, of course, be fully trained before being allowed to work without close supervision.

10.1 Radiation Hazards

Alpha radiation is the predominant radiation that will be encountered, and alpha contamination will be contained by use of glove-box techniques. When gamma and neutron radiation is associated with the alpha radiation, the work will be performed in the shielded glove boxes. These boxes might have lead shadow shielding, or be fully lead-lined, and might be equipped with lead-impregnated gloves. The total dose received by personnel will be limited to that allowed by current ORNL standards.

The quantity of alpha emitters that can be handled in the laboratory facility without a formal Radiation Safety analysis (except for fissionable material - see below) is either 100 curies in a glove box or 500 curies in a shielded cave. Five hundred curies is about 150 mg of ^{242}Cm, 6 g of ^{244}Cm, or 150 g of ^{241}Am.

10.2 Criticality Hazard

Laboratory studies may be concerned with programs other than the transuranium-element production program. Therefore, although a critical mass will not be assembled during the transuranium-element program, a potential criticality hazard will exist in the laboratories in the Transuranium Processing Plant.

The assembly of a critical mass of fissionable isotopes is prevented by limiting the total inventory of those isotopes to 350 g.

To ensure that the maximum limit of 350 g of fissionable isotopes is not exceeded in the facility, an inventory will be posted on each laboratory. Transfer of quantities in excess of 5 g into or out of a laboratory must have the prior approval of the laboratory group supervisors, who will be required to keep an accurate inventory of fissionable material within the laboratory complex.

A special review will be requested for programs that require the building inventory of fissionable isotopes to be more than 350 g.

10.3 Chemical Hazards

The types of chemicals and the quantities consumed vary from program to program; however, with certain exceptions, most of the common chemicals will be in general use. Low flash-point solvents such as ether or acetone are not normally used, and chemicals or chemical combinations which could result in violent or explosive reactions are avoided. It is our general practice to investigate any reaction which is suspect prior to experiments with radioactive material in a glove box. High-flash-point solvents (>100°F) are required in solvent extraction processes; however, large quantities of such chemicals are used only in specially protected boxes (see below).

Corrosive chemicals such as acids are required routinely. The glove boxes, as designed, are not adversely affected by such reagents.

Most of the corrosive fumes which might adversely affect glove-box off-gas filters are approximately scrubbed within the box prior to release to the box off-gas.

10.4 Fire and Explosion Hazards

As in any chemical laboratory, the danger of an accidental fire and/or explosion always exists; however, extreme care is taken to minimize the likelihood of such events.

All flammable solvents, except small amounts sufficient for daily operations, are stored outside the building in an approved metal storage cabinet or in metal drums, and portable CO_2 extinguishers are available in each laboratory.

The probability of a fire is low since open flames and low-flash-point organic solvents are normally prohibited in glove-box operations. When more than 500 ml of high-flash-point solvents are required, special equipment is installed on the box. Such boxes are equipped with a water spray that is activated by a temperature-sensitive sprinkler head. The shielded-cave alpha box is equipped with a special fire protection system (see Section 2.7.3).

The possibility of an explosion inside a glove box is minimized by careful selection of reagents and proper design of experiments. In operations where combustible gases or vapors are generated, appropriate purge rates are used to keep the concentration in the off-gas below the explosive limit. When large quantities of heat are generated, such as in a furnace operation, localized cooling of the equipment is provided to prevent heat buildup and temperature rise in the box.

10.5 Maximum Credible Accident

The maximum credible accident in a laboratory is conceived to be a relatively large release of activity from an alpha glove box; however, such a release would not be expected to involve more than a fraction of the total activity within the box. Since the kind of chemical operations performed in glove boxes (primarily wet-chemistry operations) are not conducive to formation of airborne activity, virtually all escaping activity would settle within a short distance of the glove box and would be adequately contained within the alpha laboratory.

The possible consequences of this kind of release of activity are discussed in Section 17.5.

11. OPERATING SAFEGUARDS IN ALPHA LABORATORIES

11.1 Standard Laboratory Procedures

In order to properly contain alpha-active materials and to eliminate accidental contamination of large areas, the alpha laboratories are designated as contamination zones; and special rules and procedures are required.

Since these areas may accidentally become contaminated, contamination clothing is required; and special requirements are posted at entrances. Minimum clothing requirements are:

a. contamination coveralls or contamination lab coat (buttoned)
b. shoe covers

For personnel working in or on alpha glove boxes, the minimum clothing requirements are:

a. contamination coveralls with sleeves taped
b. rubber gloves
c. yellow shoes plus shoe covers or personal shoes plus plastic boots
d. safety glasses

Upon leaving the contamination zone, personnel must do the following:

a. remove shoe covers or plastic boots
b. monitor clothing, hands, and shoes for contamination
c. remove rubber gloves

Entrance to each laboratory is provided by two doors from the access corridor. Either door may be used to enter the laboratory; however, only one of these doors will be used as a laboratory exit, and this door will be provided with an alpha monitor.

All material leaving the contamination zone must be monitored for surface contamination, and such material must be appropriately tagged by a Health Physics representative before it is removed from the adjacent regulated zone. The tag must show the approximate amount of nuclide(s) in the package and must state that the package is free from external contamination. Contaminated materials may be removed only if they are properly packaged and there is no smearable activity on external surfaces.

Each alpha laboratory contains a pass-through door which connects to an adjoining "cold" laboratory. Before material can be passed through this door from the alpha laboratory to the "cold" laboratory, it must be appropriately monitored. The alpha monitor is conveniently located near both the pass-through door and the laboratory exit.

Standard laboratory procedure requires frequent equipment and personnel (especially gloves and shoe covers) monitoring during operations. The exact frequency depends on the nature of the work and is left to the discretion of the operator.

All detectable alpha activity outside of glove boxes or sealed containers is contamination and must be cleaned up immediately.

Two or more persons are required for any laboratory operations except those during the normal day shift. Glove-box equipment is not allowed to operate unattended.

12. RADIATION SAFETY

Only authorized ORNL personnel and official visitors will be permitted in the laboratory and processing portions of the building. The TRU operations shift supervisor is in charge of the processing areas, and the laboratory group supervisors are in charge in their areas. A sign on the door to room 104 indicates this and includes instructions on how to contact the supervisors by using the building intercom phone that is located outside the door.

There are no doors to the processing cells. The cells can be entered only while the roof plugs are removed and, even then, personnel entry is not anticipated. Personnel entry is not required for operations or maintenance. There should be no likelihood that anyone could get confused and enter a cell "by mistake."

12.1 Zoning

The building contains three kinds of Regulated Zones, as shown in Figs. 2.3 and 2.4. These areas have been marked with appropriate signs, and all personnel will observe and obey these signs. There are no unzoned areas except the office annex and rooms 101 and 103. Contamination clothing is prohibited in those areas.

12.1.1 Contamination Zones

Analytical laboratories 108 and 208, alpha laboratories 109, 111, 209, and 211, the transfer area (118), the decontamination room (216), the limited-access area (120), and the pipe tunnel are Contamination Zones.

12.1.2 Monitored-Exit Regulated Zone

The rest of the building, except the loading platforms and mechanical equipment rooms, is a Monitored-Exit Zone. This is identical to an ordinary Regulated Zone except that personnel and materials leaving the zone must be monitored for radioactive contamination.

12.1.3 Regulated Zones

The loading platforms and mechanical equipment rooms are ordinary Regulated Zones.

12.1.4 General Regulations

The following general regulations apply to the various zones:

1. Entry to and exit from the TRU facility will be only through room No. 104. The other passage ways are to be used by personnel only for emergency exit. Operational use under controlled conditions will be permitted.
2. All personnel leaving the facility will check themselves for contamination with instruments provided in room No. 104.
3. No contamination clothing is to be worn in the unzoned areas.
4. Film badges and pencil meters must be worn by all ORNL personnel in regulated zones. Pocket dosimeters may be worn by visitors.
5. Either street or Contamination Zone clothing that is not contaminated may be worn in the Regulated Zone.
6. No eating or drinking, except from approved fountains, is permitted in the Regulated Zone. Smoking is permitted in the Regulated Zone except in the chemical makeup area (room 213), the "cold" chemical laboratories (rooms 110 and 210), the laboratory equipment storage room (room 202), and the solvent storage room (room 112).
7. No eating, smoking, or drinking is permitted in the Contamination Zones.
8. The minimum clothing requirement in the Contamination Zone consists of one pair of shoe covers and a buttoned Contamination Zone lab coat. The nature of the particular job being done will determine the degree of additional clothing protection required.

9. All personnel entering the Monitored-Exit Regulated Zone from a Contamination Zone must survey themselves for alpha and beta-gamma radioactivity.

10. All articles taken from a Contamination Zone must be checked for alpha and beta-gamma radioactivity. If the article is found to be contaminated, it should be either cleaned or properly bagged and tagged to permit its subsequent safe handling outside of the Contamination Zone.

11. Personnel entering the loading platform from the "cold" checking and receiving room (room 113) must survey themselves for alpha and beta-gamma radioactivity.

12.2 Radiation Instruments

Constant air monitors and fixed and portable radiation detection equipment are located throughout the building as shown in Figs. 2.3 and 2.4. These instruments and their normal locations are listed in Table 12.1. Certain alpha air monitors and beta-gamma air monitors (those marked with an asterisk in the table) comprise the Facility Contamination Alarm System. A group of four beta-gamma air monitors, a group of six alpha air monitors, and a group of four alpha air monitors comprise three subsystems of the Facility Contamination Alarm System. Coincident high-level alarms from two monitors that are connected to the same subsystem actuate the building evacuation horn and transmit a signal to the ORNL Emergency Control Center.

Installed process and service line monitors prevent the inadvertent discharge of radioactive materials from the building. Other instruments prevent the inadvertent release of radioactive materials from the processing cells to operating areas.

12.2.1 Personnel Monitoring Instruments

All the types of instruments listed in Table 12.1 and shown in Figs. 2.3 and 2.4 have been reviewed by the ORNL Radiation Control

Table 12.1 Non-Process Radiation Detection Devices in the Transuranium Processing Plant

Room No.	Area Description	Instruments
104	Portal to Regulated Areas	1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Hand and Foot Counter
102	Health Physics Office (includes all spares)	1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Smear Alpha Counter
		1 Smear Beta-Gamma Counter
		7 Alpha Survey Meters
		5 G-M Survey Meters
		6 Cutie Pies
		2 Thermal-Neutron Detectors
		2 Fast-Neutron Survey Meters
		1 High-Range Cutie Pie (1000 r/hr)
113	"Cold" Receiving Area	1 Alpha Survey Meter
		1 G-M Survey Meter
107	Yellow Dumpster Room	1 Gamma Monitron
108	Analytical Laboratory	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie
109	Alpha Laboratory	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie

*These instruments comprise the Facility Contamination Alarm System.

111	Shielded-Cave Area	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie
117	Air Lock	1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
116	TRU Control Room	1 Alpha Air Monitor*
		1 Alpha Air Monitor
		1 Beta-Gamma Air Monitor*
		1 Alpha Survey Meter
		1 G-M Survey Meter
118	Transfer Area	1 Alpha Air Monitor*
		1 Beta-Gamma Air Monitor*
		1 Gamma-Neutron Monitor
		1 Alpha Survey Meter
		1 G-M Survey Meter
		1 Cutie Pie
119	Instrumented Air Lock	1 Alpha Survey Meter
		1 G-M Survey Meter
120	Limited-Access Area	1 Alpha Air Monitor*
	(Lower Level)	1 Beta-Gamma Air Monitor*
		1 Alpha Survey Meter
		1 G-M Survey Meter
		1 Cutie Pie
121	Change Room	1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
122	Conveyor Maintenance Room	1 Alpha Survey Meter
	Maintenance Shop	1 Alpha Survey Meter
		1 G-M Survey Meter

208	Analytical Laboratory	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie
209	Alpha Laboratory	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie
211	Alpha Laboratory	1 Alpha Air Monitor*
		1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
		1 Alpha Survey Meter
		1 Cutie Pie
212	Air Lock	1 Alpha Contamination Monitor
		1 Beta-Gamma Contamination Monitor
213	Solution Makeup Area	1 Alpha Air Monitor*
		1 Alpha Air Monitor
		1 Beta-Gamma Air Monitor*
		1 Alpha Survey Meter
		1 G-M Survey Meter
		1 Cutie Pie
216	Decontamination Room	1 Alpha Air Monitor
		1 Beta-Gamma Air Monitor
		1 Alpha Survey Meter
		1 G-M Survey Meter
120	Limited-Access Area (Upper Level)	1 Alpha Air Monitor
		1 Beta-Gamma Air Monitor
		1 Alpha Survey Meter
		1 G-M Survey Meter
		1 Cutie Pie

Instruments Advisory Group as required according to Section 2.2 of the ORNL Health Physics Manual. Brief descriptions are given below.

Constant Air Monitor (CAM) Model Q2118-1. — CAM monitors the quantity of particulate beta-gamma radiation in the surrounding air. A vacuum pump draws air through a filter over a G-M tube mounted in a stainless steel shield. The tube is connected to a count-rate meter, which is, in turn, connected to a strip-chart recorder which continuously records the radiation level. An associated relay-alarm system permits visible and audible alarms to be activated at predetermined levels. Alarm signals can be transmitted to distant locations.

Constant Alpha Air Monitor (CAAM) Model 2218. — This instrument is similar to the CAM. The only difference is that an alpha detector is used in the CAAM.

Monitron (Model Q1154B-1). — The monitron employs a large ionization chamber which is coated on the inside with enriched boron if it is used for the detection of gamma plus thermal-neutron radiation and is left uncoated if detection of only gamma radiation is required. The ionization chamber is connected with an amplifier circuit and a count-rate meter which reads directly in milliroentgens per hour. A relay circuit may be set to actuate an alarm at any predetermined gamma-radiation level. Alarm signals may be transmitted to distant locations.

Stationary Contamination Monitor (Model Q2277-1). — This monitor consists of a versatile counting-rate meter, ac powered, and either a zinc sulfide scintillation probe for detection of alpha radiation or a G-M counter probe for detection of beta-gamma radiation. An associated alarm circuit permits a local alarm to be actuated at predetermined levels.

Hand and Foot Counter (Model Q1939B-1). — This is a semiautomatic device for detecting beta-gamma radioactivity on shoes and hands simultaneously. Counts obtained by G-M tubes during an automatically timed interval are indicated by lights and registers. There is an auxiliary probe for monitoring other areas of the body or clothing.

Alpha Survey Meter (Model Q1975B-1). — This portable scintillation counter is a battery-powered, transistorized, amplifier with a high-voltage supply especially designed for use with an alpha scintillation probe. The device registers accumulated counts, thus obviating the difficulty of reading low counting rates on a meter. An output for earphone operation is also provided. The power is supplied by nickel-cadmium cells which are kept charged by a plug-in trickle charger operated from 110-v, 60-cps current. The probe employs a 2-in. photomultiplier, a zinc sulfide phosphor, and a lighttight window. It is relatively free of microphonics and is relatively insensitive to beta and gamma radiation.

G-M Survey Meter (Model Q2092B-1). — This survey meter is a medium-weight, portable, beta-gamma-radiation-indicating survey instrument. It was designed to work in gamma-ray intensities up to 500 mr/hr. Audible or visible indication of radiation is afforded by means of earphones and a count-rate meter.

Standard Cutie Pie (Model Q2299-2). — This is a relatively small, lightweight, portable survey instrument used for the measurement of gamma-radiation dose rates up to 10 r/hr. It is used also to indicate beta radiation.

Hi-Range Cutie Pie (Model Q2299-2). — The Hi-Range Cutie Pie is similar to the Standard Cutie Pie except that the chamber volume and the electrometer input resistors are adjusted to provide full-scale ranges of 10, 100, and 1000 rads/hr.

Fast-Neutron Survey Meter (Model 02047A-1). — This survey meter is an all-transistorized count-rate meter calibrated in terms of millirems per hour. The detector is a tissue-equivalent proportional counter. A register is provided for very low dose-rate measurements. Special circuitry provides excellent discrimination against gamma radiation.

Thermal-Neutron Counter (Model 02004A-1). — The portable thermal-neutron counter is a lightweight instrument for measuring thermal-neutron flux rates. All circuitry is transistorized, and power is provided by rechargeable nickel-cadmium cells. The detector is relatively insensitive to gamma radiation.

12.2.2 Radiation Warning and Control System

The radiation warning and control panel (Fig. 12.1) is the collection center for radiation monitoring information (including high-level alarms) from various parts of the building. A fire locator panel and all of the instruments and alarms for monitoring building services are located on adjacent panelboards. Thus, all instrumentation for monitoring building safety (radiation, fire and containment) and locating abnormal conditions is centrally located.

The major components of the radiation warning system are: (1) a beta-gamma contamination alarm system, (2) an alpha contamination alarm system, and (3) a process radiation monitor alarm system.

Beta-Gamma Contamination Alarm System. — Six constant air monitors provide radiation detection for this system. In addition to the alarms that sound at each instrument, "caution," "high-level," or "instrument inoperative" warnings for each instrument are relayed to the control panel in the operating room where alarms are actuated. Further, if two of the four instruments that are located in the limited-access area, the transfer area, the chemical makeup area, and the operating area transmit "high-level" signals simultaneously, a beta-gamma contamination evacuation alarm occurs at the panelboard, building evacuation

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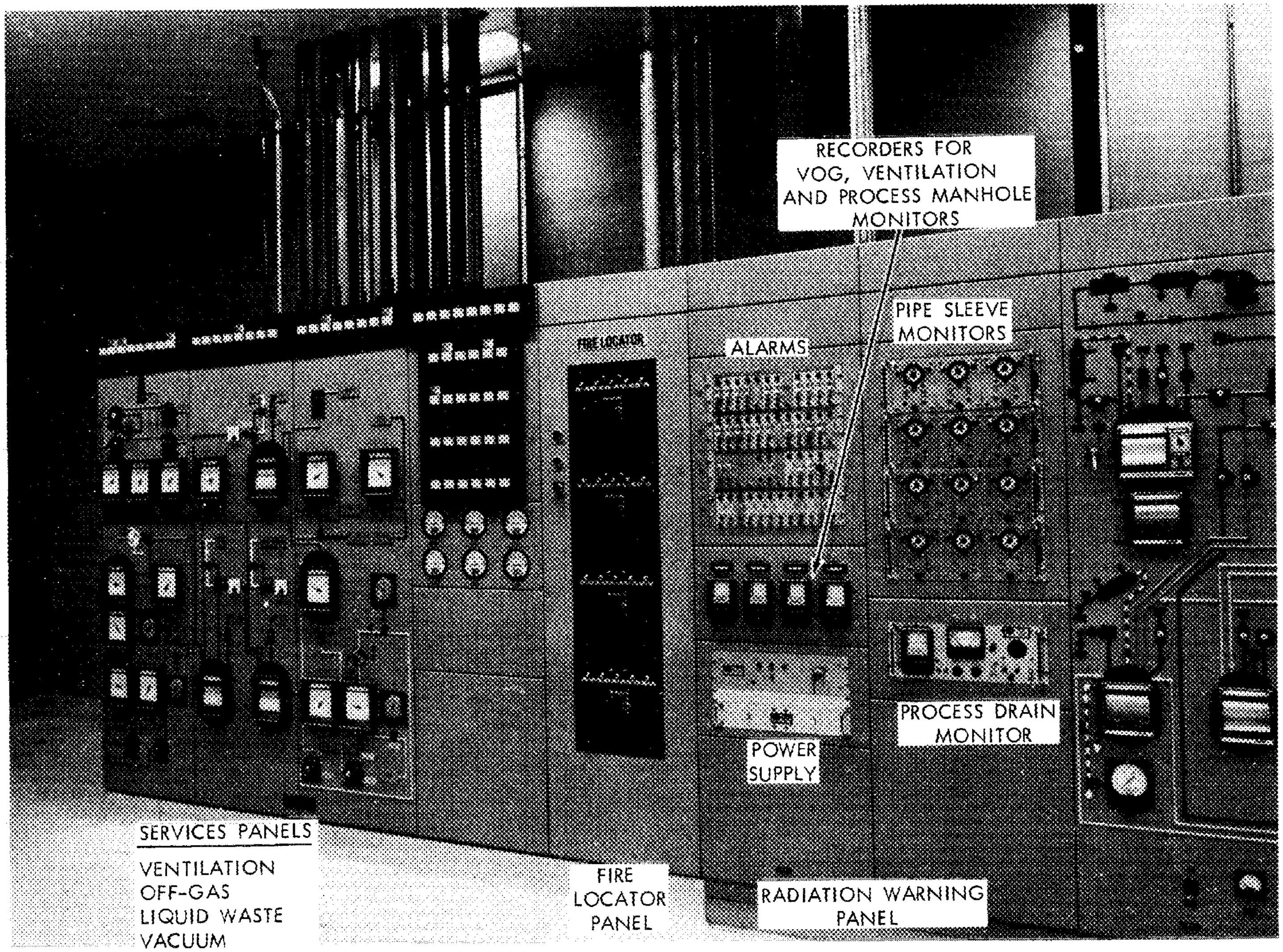

Fig. 12.1. Service, Fire, and Radiation Control Panels.

horns are actuated, and a signal is transmitted to actuate an alarm at the ORNL Emergency Control Center. A CAM located on top of the cells and one in the decontamination room are not included in the evacuation system but do transmit signals to the control panel.

Alpha Contamination Alarm System. — Fourteen constant alpha air monitors (CAAM) are included in this system. All transmit "caution," "high-level," and "instrument inoperative" signals to the control panel in addition to displaying these conditions at each instrument. Six of these instruments form the first-floor alpha contamination evacuation alarm system, and four of them form the second-floor system. Both systems actuate building evacuation horns, alarm at the panelboard, and transmit signals to the ORNL Emergency Control Center if any two instruments in either system (that is, two instruments in the same system) simultaneously transmit "high-level" signals.

The first-floor evacuation system is made up of CAAM's in the limited-access area, the transfer area, the west end of the operating area, analytical laboratory 108, and alpha laboratories 109 and 111. The second-floor evacuation system includes CAAM's in the west end of the makeup area, analytical laboratory 208, and alpha laboratories 209 and 211. Four CAAM's that are monitored at the control panel but are not included in one of the evacuation alarm systems are located at the top of the processing cells, in the east ends of the operating area and chemical makeup area, and in the decontamination room.

Monitrons. — A beta-gamma remote monitron in the yellow dumpster room (107), and a beta-gamma-thermal-neutron remote monitron in the transfer area, transmit "caution" signals to the radiation control panel and cause the radiation warning alarm to sound at the panel.

Process Radiation System. — Signals that indicate abnormal conditions at radiation detectors that monitor various process and service piping systems are transmitted to the radiation warning panel. The function of the process radiation section is described in Section 13.

Evacuation Alarm. — A manual pushbutton is located on the radiation warning panel for actuating the building evacuation horns, which are powered by compressed nitrogen. Warning beacons on the four corners of the building flash, and a signal is transmitted to the ORNL Emergency Control Center when the evacuation alarms sound, whether the evacuation is effected by the coincidence air monitor systems or by the manual pushbutton.

12.3 Connection to the ORNL Emergency Control Center

Signals from the building evacuation alarm, the fire alarm system, and the waste tank F-126 liquid-level transmitter are automatically transmitted to the ORNL Emergency Control Center.

12.4 Radiation Surveys

Radiation surveys will be made at the discretion of the building Health Physics surveyor. As a minimum, the entire facility will be smeared once every four weeks, and the entire building will be "spot-smeared" every week.

The building will be divided into eight areas as follows:

1. Operating area
2. First floor of laboratory part of building
3. Limited-access area
4. Second floor of laboratory part of building
5. Chemical makeup area
6. Decontamination room
7. Office annex
8. Equipment rooms

A check list will be used, and a record will be maintained. Each week two of the areas will be checked thoroughly and the other six will be "spot-checked." If required, supplementary Health Physics personnel will be used to ensure the minimum check of all areas. High-traffic areas such as the main portal in room 104 will be checked at least once daily. Whenever some operation is performed that has a high probability of spreading contamination - such as transferring waste to the solids waste station, or transferring carriers within the building or to and from the building - the area involved will be monitored, using survey instruments and smears. Any area that is suspected of being contaminated will be immediately isolated and checked. The detection of contaminated articles (including gloves and shoe covers) at a monitoring station will require a thorough survey to determine the source of the radioactivity and the extent to which contamination has been spread.

13. PROCESS SAFEGUARDS

While careful operation and good administrative controls are important in the operation of a facility such as TRU, inherent process safeguards built into the system, including adequate instrumentation, greatly enhance the probability of achieving a completely safe operation.

13.1 Instrumentation System

Although the TRU process equipment is in cells equipped with master-slave manipulators, the equipment is operated primarily from panelboards by completely remote means. Valves are air operated by panel switches; solutions are transferred by jets or pumps operated from the panelboard. Remote target fabrication equipment is highly automated, with many operations automatically sequenced from panel controls.

Every effort has been made to prevent the process solutions from getting to the panelboard in the operating area by use of remote transmitters located in the chemical makeup area, which transmit signals to the panelboard. No process lines connect directly from the cell to the operating area, and the transmitter rack is at least eight feet above all process lines.

Chemical process instrumentation is of the conventional type used elsewhere in radioactive processing plants. Tank levels are sensed by bubbler arrangements, transfers are made by steam jet or remote-head diaphragm pump, and valves are remotely operated by air pressure. Alarms are provided to warn of abnormal operating conditions, and safety interlocks are provided to automatically correct an unsafe condition.

13.2 Transfer of Process Solutions

13.2.1 Steam Jets

Solution transfers to the intermediate-level-waste collection system are made by steam jet. Steam supplies to the jets are actuated either by a manual valve or by a panel-mounted switch which opens the valve on the steam line. These valves are located in the chemical makeup area. Protection is provided against backup of the solution into the steam line by using a continuous air purge at about 250 cc/min. This air is supplied from the building 100-psig air header and is routed through a rotameter, a small holdup tank (500 cc), and a check valve into the steam line. The air pressure and flow are maintained even during jetting operations. Air is accumulated in the holdup tank until the pressure reaches 60 psi; the air at the steam header then bleeds into the jet supply line downstream of the steam valve. When the valve is shut off, the accumulated air bleeds rapidly into the line, purging all steam and ensuring that condensation cannot pull active solutions back up the line. Tests showed the system to be completely effective.

13.2.2 Diaphragm Pumps

Most process solutions are transferred by means of remote-head diaphragm pumps. The sealed construction of the diaphragm pumps helps ensure that there is no leakage of process fluids, and the pump heads are located in the cell to ensure containment. Since the process vessels are several feet below them, these pumps must be able to induce a vacuum. This requires the pump to be driven by an alternating air-vacuum source instead of the conventional hydraulic drive system, which intensifies the problem of ensuring that no process solutions leave the cell via the drive line in the event that a diaphragm should fail. However, special process radiation monitors on the drive lines just outside the cell will detect any radioactivity in the lines and automatically switch the pump drive system to the pressure stroke to force any solution back down the line.

13.3 Process Vessel Controls

The entire process system is operated essentially at atmospheric pressure so that problems of applying pressure to the solutions outside the cell, via instrument or other lines, are not severe. To further minimize this risk, all instrument lines are continuously purged and all lines for adding solution are equipped with spring-loaded check valves just outside the shielding walls.

13.3.1 Dissolver Control System - Method of Limiting the Hydrogen Concentration in the Off-Gas

The dissolver is the only vessel in the facility equipped with a temperature control system. This system is used in connection with an air purge to limit the hydrogen concentration in the off-gas to acceptable levels. Since the dissolution is done in the temperature range of 40 to 60°C, the dissolver is heated or cooled by pressurized hot water that is circulated through the jacket. The circulating water is cooled at a constant rate by a water-cooled heat exchanger and heated at a variable rate by an electric heater. Both the heat exchanger and electric heater are external to the jacket. The rate at which heat is added is varied by a pneumatically operated rheostat which is controlled by the dissolver temperature (sensed by a thermocouple inside the dissolver) and the controller set point.

Dissolution rates and the air purge rates are set so that hydrogen is limited to 2 ± 1% in the dissolver off-gas. The design dissolution rate of one gram of aluminum per minute is achieved by establishing the proper acid concentration and dissolver temperature. The actual rate is calculated during dissolution by a heat balance on the water loop, and recent tests have shown that this method is accurate to better than ± 50% at the design dissolution rate. Thus, the hydrogen concentration can be determined and maintained well below the explosive limit. During the dissolution, temperatures are increased in 10°C increments; the actual dissolution rate is determined at each temperature before the temperature is raised to the next level.

As added precautions, the instrument lines are equipped with automatic block valves (just outside the cell) that close on detection of radiation and with a high-temperature interlock (set at 10° above the dissolver control point) that switches the heat off, and switches the cooling water onto, the dissolver.

13.3.2 Evaporators

Steam to the six process evaporator jackets is controlled automatically at pressures established by a panelboard setting. No other controls have been incorporated into the systems because the steam is condensed without any pressurization, even with full steam on the jacket.

13.3.3 Ion Exchange Column

Radioactive solutions are pumped to the ion exchange column C-71 by a pump which is capable of developing 25 psig. Protection has been provided to ensure that the radioactive solutions are not pressured back up the wash-elutriant line to the chemical makeup area. An interlock prevents the pump from being operated unless an in-cell valve in the wash-elutriant line is closed and a pressure of 40 psi has been applied to this line above the valve.

13.4 Protection of Utilities from Process Solutions

Adequate protection has been incorporated into the equipment to ensure that process solutions do not accidentally back up into the various utility systems. In many cases, this protection is achieved by means of process radiation detectors, which control safety interlocks as described below in Section 13.5. Other methods are employed as described here.

13.4.1 Vacuum System

The vacuum system for the building is designed to handle small amounts of radioactive solution and is located remotely in the pipe tunnel. Any contaminated solutions which might get into this system from the glove-box laboratories could be handled without difficulty. The primary place where this might occur is in the air-vacuum drive system for process pumps, in the event of pump diaphragm failures.

Protection is provided by automatic interlocks off process radiation detectors as described in Section 13.5 below.

13.4.2 Water and Steam Systems

All cooling water within the cell bank is supplied by a special closed circulating water loop which, in turn, is cooled by HFIR cooling tower water in a secondary heat exchanger. The surge tank and pump are located above the cell bank so that all lines inside the cell are pressurized at all times.

Steam jackets always constitute a possible means of getting radioactive material into steam and condensate headers and any interconnecting water systems, if corrosion of a vessel should release this material into the jacket immediately after steam pressure is turned off. Process monitors on the recirculating cooling water system and steam condensate collection tank act to minimize the effects of such an incident, as described below in Section 13.5.

The TRU facility is equipped with a process water system with a complete air break, according to ORNL standards. The in-cell fire protection lines are equipped with the special backflow preventer required by ORNL standard procedures.

13.4.3 Off-Gas System

Off-gas from all process vessels and from the cubicle vent system is scrubbed in a caustic scrubber to remove chemical fumes and radioactive iodine before it is passed through absolute filters and on up the stack.

13.4.4 Electrical and Instrument Conduits

All in-cell conduits are isolated from conduits outside the cell by either sealed bulkhead fittings or by potted sections, to ensure that the conduit does not provide a path by which radioactive material can get outside the cell.

13.4.5 Compressed Air

Compressed air is used inside the cell to operate valves; it is also used in instrument-line purge systems. In all instances, the air header is at higher pressures than the in-cell process line, thus ensuring that no active solutions can get back into the air headers.

13.5 Process Radiation Monitors and Control Functions

Process radiation monitors, equipped with alarms and, in some cases, automatic interlocks, act to provide protection against the release of radioactive materials from the cell bank. While these monitors act, primarily, to warn of and correct equipment problems, they also constitute an important supplement to the over-all personnel radiation monitoring system. These detectors serve in the following ways:

1. The vessel off-gas duct and cell ventilation duct are sampled at the stack pad by automatic gas samplers, and counting rates are recorded on strip charts at the radiation panel. "High-level" alarms are transmitted to the radiation control panel and ORNL Emergency Center. Signals also warn of operating difficulty with the filter tape drive unit in the samplers. No automatic process changes are effected.
2. A beta-gamma radiation detector strapped to the process waste line in the pipe tunnel transmits a "high-level" alarm to the control panel. A strip-chart recorder, an audible count-rate monitor, and an indicator with provisions for setting the alarm set point are located on the control panel. No automatic process changes are effected.
3. An alpha radiation detector and a beta-gamma radiation detector are located in the process waste drain manhole. Data are recorded on strip-chart recorders on the control

panel. "High-level" signals actuate alarms on the panel board and cause valves in the waste system to be actuated to divert process waste to the 500,000-gal holding basin. Valves reset automatically when the alarm condition clears. Instrument failure causes the flow to be diverted.

4. A probe is strapped on the lines for air and vacuum that drive the pumps in each of cells 4 through 7. Count rate is displayed on indicators on the panelboard. In the event that a high count rate is detected, an alarm is sounded at the control panel and 25-psig air is automatically impressed on the drive lines by simply removing electrical power from the solenoid valves that control air and vacuum.

5. The lines from outside the cell to dissolver T-70 are monitored and are provided with radiation block valves. If radiation is detected, the block valves close to prevent radioactivity from leaving the cell and an alarm on the control panel is actuated. Radiation count rate is displayed on an indicator on the control panel.

6. The return line for the recirculating cooling water is monitored for beta-gamma radioactivity. Count rate is indicated on the panel, and the alarm is actuated on "high-level." At "high-level," the circulating pump is automatically stopped.

7. Steam condensate from the cells is monitored at a collection tank in the limited-access area. Count rate is indicated on the panel, and an alarm is actuated on "high-level," which simultaneously de-energizes the condensate pump, preventing activity from being pumped to the retention basin.

8. A monitor is located on the suction line to the pump that recirculates caustic through the vessel off-gas scrubber. Count rate is recorded on the panel, and an alarm is sounded by a "high-level" signal. No automatic action occurs.

14. LIQUID WASTE

Liquid wastes, including rain runoff, sanitary wastes, process waste, and intermediate-level radioactive wastes that are generated in the TRU facility are discharged into installed waste-handling systems. High-level radioactive wastes are not usually generated. Liquids that contain enough radioactive nuclides to be considered high-level wastes probably contain valuable material that would require recovery and reprocessing. Highly radioactive liquids that need to be discarded will be diluted to intermediate-level waste and handled in that system.

14.1 Storm Sewer and Foundation Drains

Perforated vitrified clay pipe is used for subsurface drainage around the cell foundation, and discharge is by free outlet to a ditch across the road east of the building. Thus, ground water will not get into the cells.

A storm sewer system with free outlets to ditches across the roads north and east of the building carries away water collected by the roof drainage system, gutter inlets, and catch basin. A number of items of service equipment drain into the storm sewer. These are building service steam traps, air conditioning intake plenums, water heaters, chilled-water expansion tank, etc. -- essentially all the equipment in the two mechanical equipment rooms. Both the pit for the HFIR tower-cooling water pump and the elevator pit drain to the storm sewer.

14.2 Sanitary Waste System

The sanitary waste system collects biological wastes from the entire processing facility and office annex, all liquid waste from the office annex, and the shower and lavatory wastes from the main change room (105), and the women's room (101). All water fountains drain to this system. The waste flows to a septic tank that is used jointly by TRU and HFIR.

14.3 Process Waste System

Liquid wastes that are susceptible to slight contamination are collected continuously in two 50,000-gallon capacity earth retention basins. The basins are periodically sampled and, depending on analytical results, are released to Melton Creek or pumped to the main ORNL waste treatment facility in Bethel Valley for disposal. One basin collects waste while the second is being sampled and emptied.

The following wastes are collected in a common header and monitored for beta-gamma radioactivity: process wastes from the laboratories, decontamination area, chemical makeup area, glove-box storage area, transfer area, limited-access area, operating area, recirculated cooling water system, process condensate receiver, the floor drains of limited-access change room No. 2, pipe heater C-114 in the off-gas system, checking and holdup area, the floor drains of change rooms Nos. 3 and 4, corridor floor drains, sink drains in the janitor's closet, cold checking and receiving area, and the men's change room No. 1. Activity above a predetermined value activates an alarm on the radiation panel board.

Process waste from the shower and sink drains in change rooms Nos. 2, 3, and 4 enters the same waste drain header downstream of the first monitor, and the combined flow is monitored a second time. This monitoring is for both alpha and beta-gamma radioactivity and is done in the process waste drain manhole. In the event that significant radioactivity is detected, the flow will be automatically diverted to the 500,000-gallon HFIR surge basin; otherwise, it will be discharged as usual to one of the 50,000-gallon TRU basins.

Operation of the retention basins is the responsibility of the Operations Division.

The locations of process and intermediate-level waste drains are shown in Figs. 14.1 and 14.2. Figure 14.3 presents a schematic diagram of these systems.

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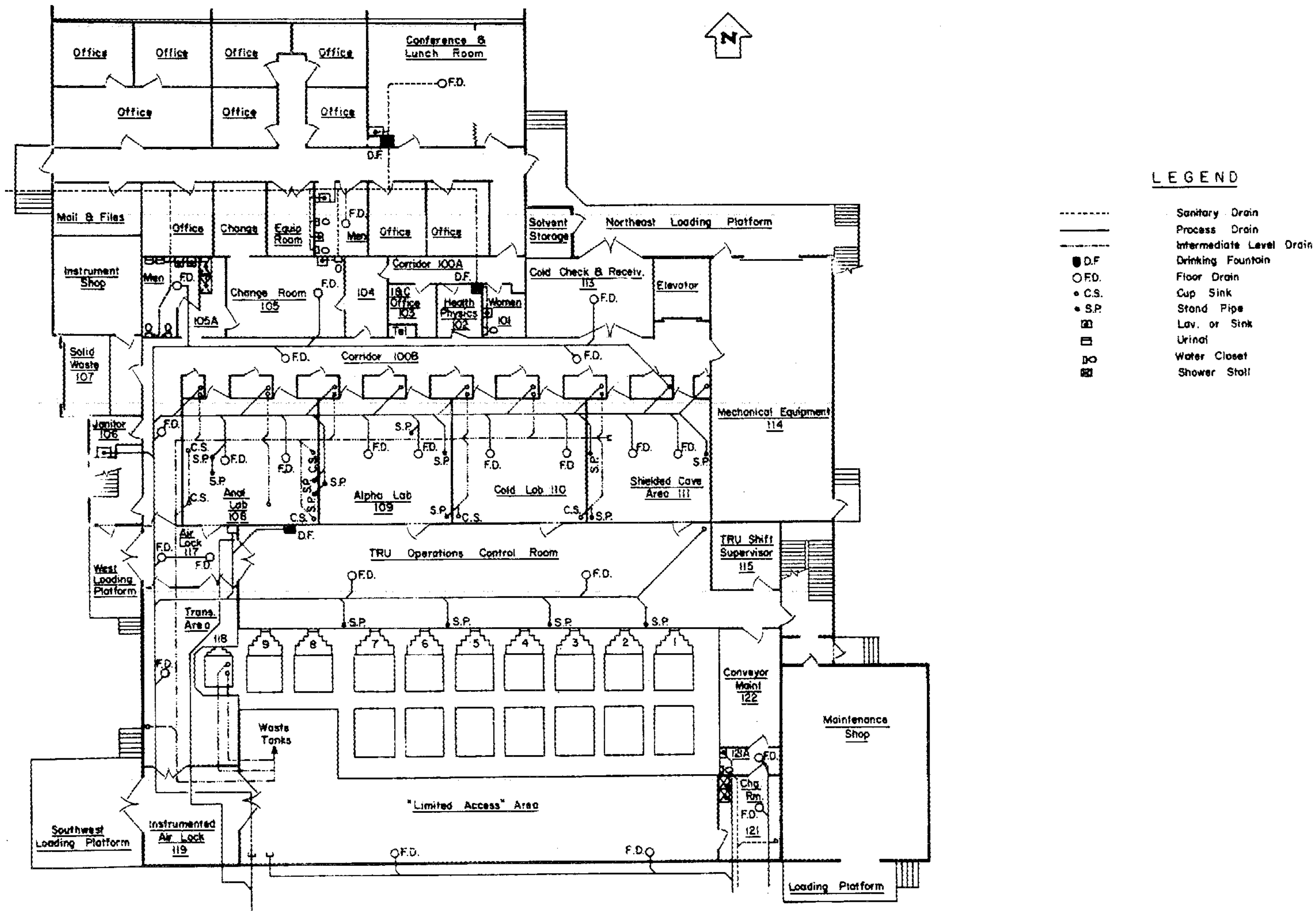

Fig. 14.1. Drain Systems - First Floor.

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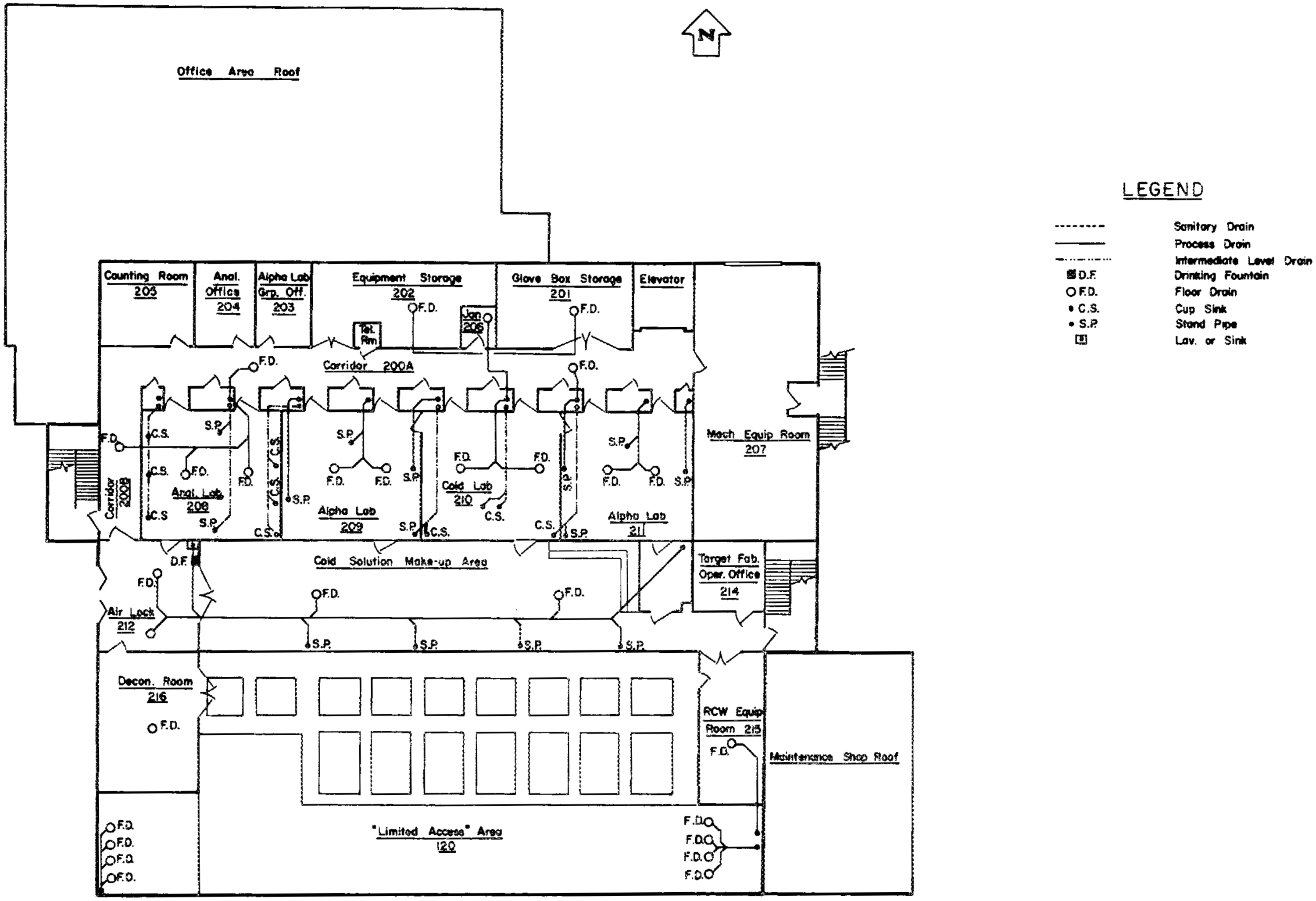

Fig. 14.2. Drain Systems - Second Floor.

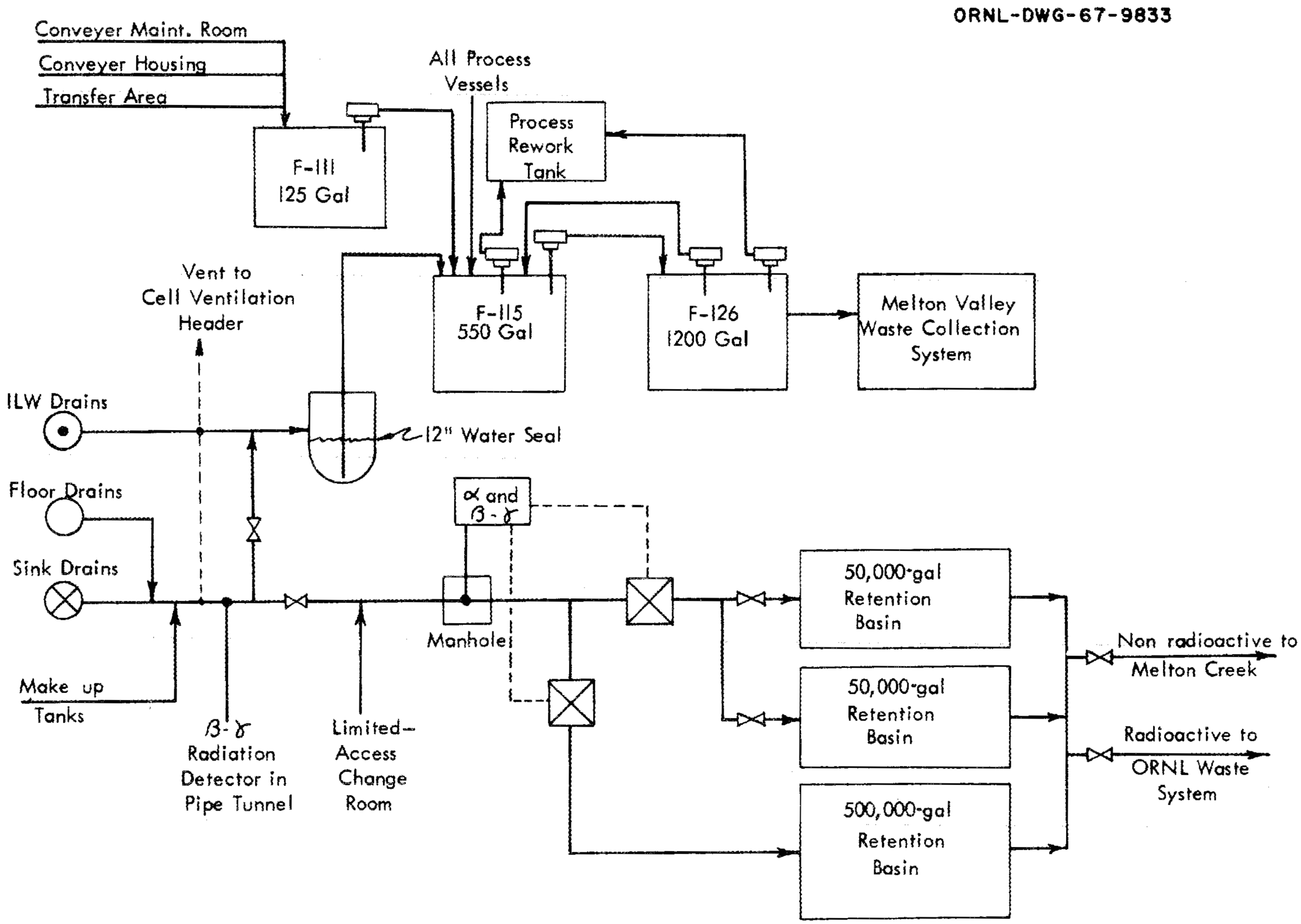

Fig. 14.3. Intermediate-Level and Process Waste Systems, Building 7920.

14.4 System for Intermediate-Level Radiochemical Waste

Intermediate-level radiochemical waste (ILW) from the laboratories, decontamination area, off-gas header drain, vacuum system separator F-118, caustic scrubber L-131, pipe tunnel sump, vessel off-gas filter pit sump, cell-ventilation filter pit sump, cell and tank pit sumps, and the cell process waste drain header is discharged directly to collection tank F-115, which is sampled and discharged to the process waste neutralization tank F-126 or to the rework tank in cell pit 7. Following neutralization in F-126, the waste is transferred to either the rework tank in cell 7 or to the Melton Valley intermediate-level waste collection system. Neutralized waste from F-126 can also be recycled back to tank F-115.

Liquid waste from the cell transfer area and the cell conveyor housing is collected in tank F-111. After being sampled, this waste is transferred to tank F-115.

The radiochemical waste tanks are in the waste tank pit that is located behind cells 8 and 9. Tank F-111 is a 125-gal-capacity stainless steel tank that collects liquid waste from the transfer cubicle drain and the conveyor housing overflow. F-115 is a 550-gal-capacity Hastelloy C tank that is used to collect all other liquid waste that is likely to be radioactive. This includes all intermediate-level waste from building drains and all process wastes. Hastelloy C was used because of its resistance to corrosion by chlorides. F-126 is a 1200-gal stainless steel tank in which waste is neutralized and/or diluted to 5 curies/gal before it is jetted to the Melton Valley intermediate-level-waste collection station. A heel of caustic will be kept in the tank.

All three of these tanks are equipped with cooling-water jackets, liquid-level recorders, air spargers, and sampling lines.

14.5 Disposal of Organic Chemicals

Organic waste materials are added to appropriate waste systems, depending on their radioactivity levels. Since an average of only 300 gal of organic waste will be generated per month, special disposal arrangements will not be required.

15. SOLID WASTE

Provisions have been made for routinely handling a large variety of contaminated waste solids, including wastes generated in glove boxes, small items from the cell bank such as sample bottles, and entire equipment racks.

15.1 Solid High-Level Radioactive Waste

All solid waste that is taken from the cell cubicles will be heat sealed, either in a 10-inch plastic canister or in a large plastic bag, and then put into a 4-in.-thick reinforced-concrete container. A 4-in.-thick concrete cover will be put on the container, the cover joint will be caulked, and the container will be transported to the burial ground for disposal.

Figure 15.1 is a sketch of the solid-waste disposal station as it will be when the small plastic canisters of solid waste are being loaded. The plastic canisters are filled at the transfer cubicle, sealed, and loaded into a shielded carrier for transport to the solid-waste disposal station. An alternate top plug, equipped with a door identical to the cubicle doors, permits the disposal of an equipment rack, with complete containment being assured in all steps by use of the transfer case.

The waste disposal station provides an additional 8 inches of concrete shielding and encloses the 4-in.-thick concrete disposal container that is resting on a motor-driven turntable. A plastic bag is inserted in the disposal container and connected to a large bag ring on the bottom of the station cover. One of the plugs in the cover is removed, and the shielded carrier with the plastic canister in it is placed on top of the station. By removing the proper cover plug and by rotating the turntable to the appropriate indexing point for each transfer, it is possible to stack about 40 of the plastic containers in the disposal container. After a loading operation is completed, the carrier is removed and the plug is replaced.

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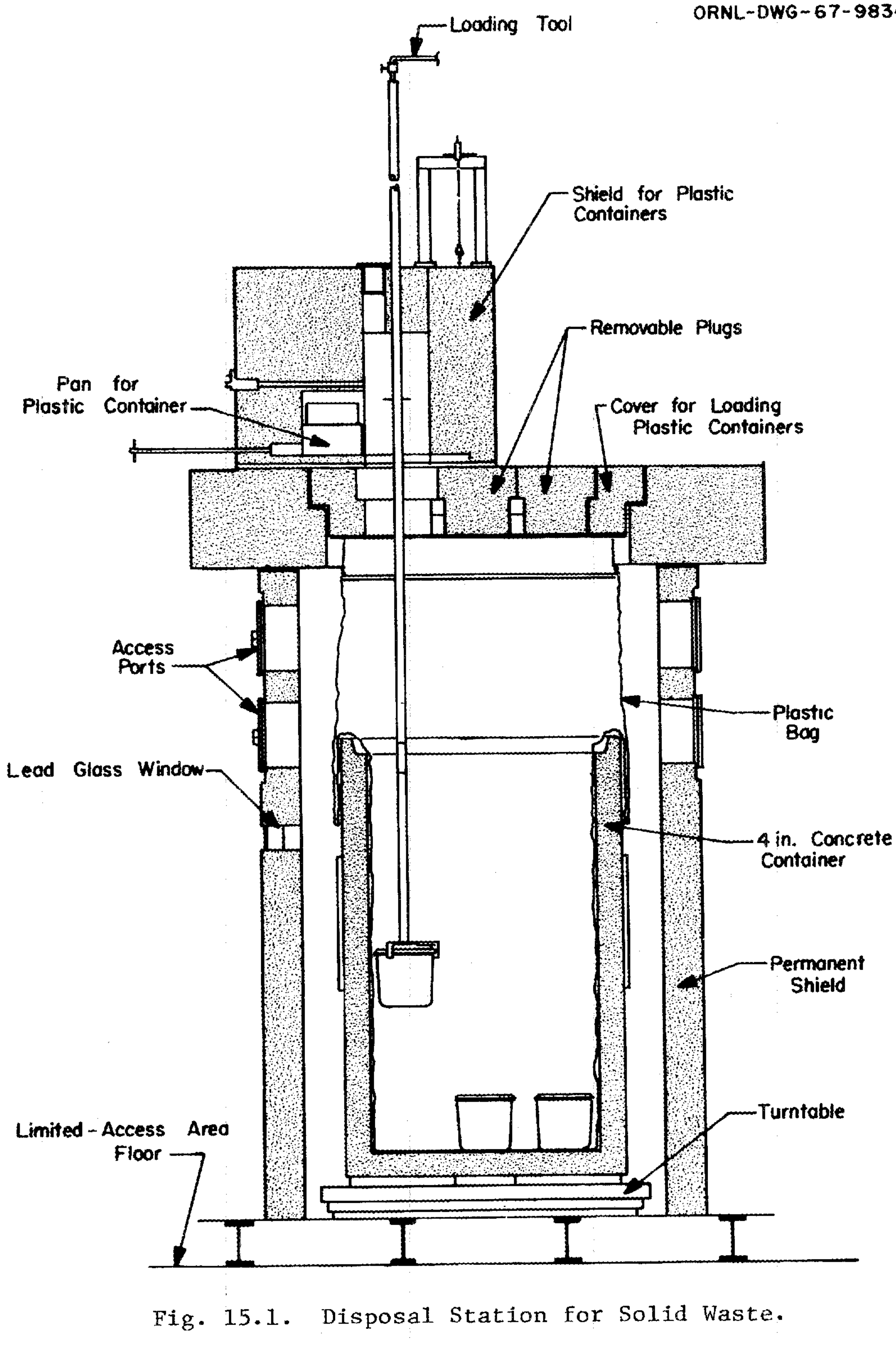

Fig. 15.1. Disposal Station for Solid Waste.

When a concrete disposal container becomes full, or when an empty container is required for the disposal of a large piece of equipment (an equipment rack will completely fill a concrete container), the plastic bag is sealed, a concrete cover is installed, and the cover joint is caulked. The container is then removed from the station, using metal-web slings, checked for contamination, and transported to the burial ground.

The plastic bag is sealed by rotating the turntable to twist the bag into a shape that can be heat-sealed by injection molding of a plastic plug at the small point of the twisted bag. The bag is severed at this point and the upper portion of the bag seals the bottom of the top plug. After a new bag is installed, this upper portion of the old bag is dropped into it.

Both the interior of the station, outside the concrete container, and the interior of the plastic bag are continuously vented to the cell ventilation system. Proper adjustment of vacuum on both sides of the plastic bag by means of hand throttling valves will assist in the manipulation of the bag and, at the same time, ensure that proper containment is maintained.

The alternate disposal station cover, used for loading waste from the transfer case, is also concrete; however, instead of removable plugs, it has a hatch similar to that of a cell cubicle. The method of loading an equipment rack into the disposal station is the same as that of loading a rack into a process cubicle.

Loading and sealing a plastic canister are accomplished by putting the canister (with cover) into the shielded transfer-area carrier. A rod that penetrates the carrier shield is used to position the canister (in a pan connected to the rod) under the disposal port in the transfer area. This port is similar to the cubicle-intercell conveyor access door. The plastic canister is pressed against the bottom of the transfer-area disposal port, the canister cover and disposal port door are locked together, and the door is opened. After waste or other material is put into the canister, the door is closed, the canister cover is unlocked from the door, and the canister is dropped away from the bottom of the transfer area. The heat sealer is inserted between the transfer area and the canister, and the canister is pressed against the heat sealer. Heat is applied to the plastic canister and cover until the plastic is melted enough to allow the canister elevator to move up about an inch, at which point the seal is complete. The canister is then withdrawn into the carrier for disposal.

For transferring items between the transfer area, shielded cave, or decontamination glove box, the sealing step may be omitted.

15.2 Solid Low-Level Radioactive Waste

A yellow dumpster is provided in room 107 for disposal of solid low-level radioactive waste. The dumpster will be used, primarily, for waste from the laboratories and from the analytical chemistry cells. Waste from the processing cells will normally be handled as high-level waste.

A Health Physics survey is required before any material is placed in the dumpster. An area monitron in the dumpster room will alarm if the radiation level becomes excessive.

16. GASEOUS WASTE

A vessel off-gas system discharges gaseous waste from process vessels, cell cubicles, and the plant vacuum system through a caustic scrubber and filters to the HFIR stack. Cell ventilation and glove-box ventilation systems discharge gaseous waste from alpha glove boxes and purge air from the processing cells through filters to the HFIR stack. These systems are shown schematically in Fig. 16.1. The 250-ft-tall HFIR stack has a capacity of 60,000 cfm of air.

16.1 Vessel Off-Gas and Cubicle Ventilation

16.1.1 Vessel Off-Gas

Vessels in the cell and waste tank pits are connected to a 1-1/2-in.-diam Zircaloy-2 header that runs through the cell bank to the caustic scrubber. An off-gas header from the laboratories (2-in.-diam fiber-glass reinforced epoxy resin) and the recirculated-cooling-water surge tank header have separate pressure control stations to permit maintaining these areas at different pressures from the rest of the system. Off-gas headers in the chemical makeup area and decontamination room (both 2-in.-diam epoxy resin) tie directly to a 10-in.-diam Hastelloy C line to the scrubber. The cubicle ventilation header also ties to the 10-in.-diam Hastelloy line. Pressure at the scrubber inlet is automatically controlled at −10 in. water (gage) by adjustment of a valve in the suction line to the off-gas fans. The valve fails open to cause a vacuum of about −14 in. water (gage) in the system. The recirculating cooling water surge tank is controlled at −2 in. water (gage) with respect to the operating area, and the pressure in the header to the laboratories is kept at about −9.7 in. water (gage) with respect to the laboratories. The control valves for both of these systems will fail open to allow a full vacuum to be applied to the systems.

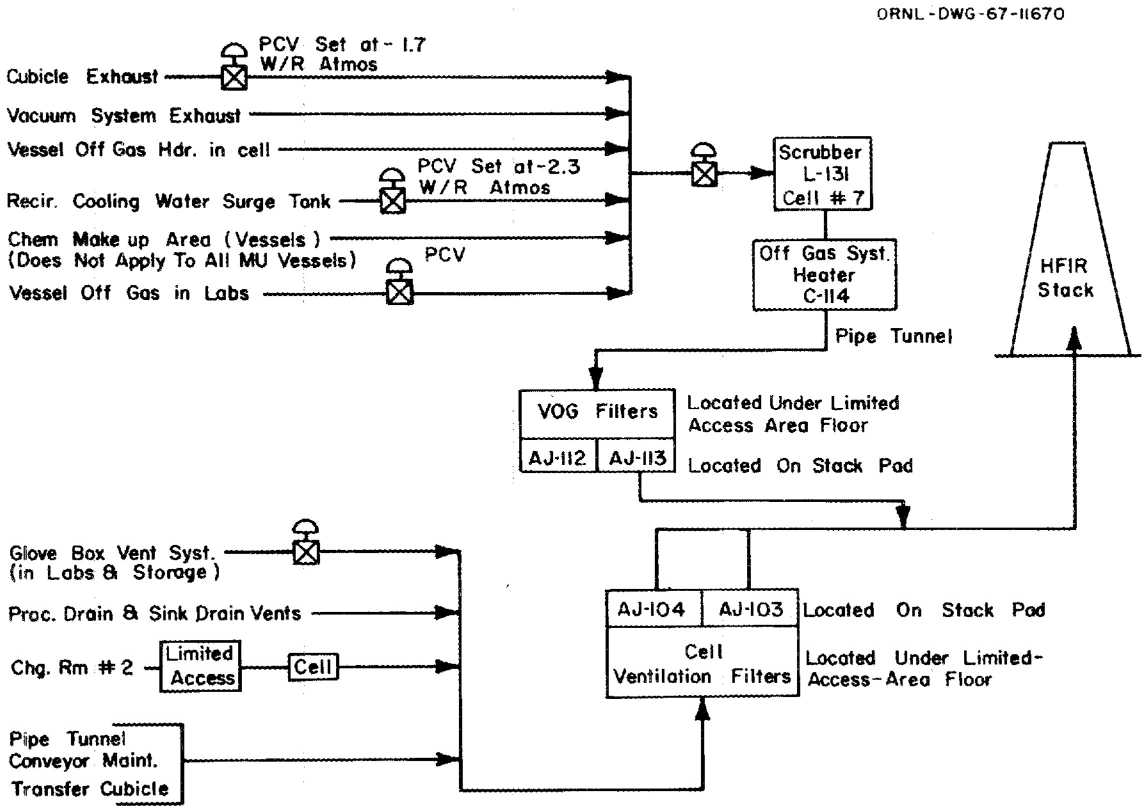

Fig. 16.1. Schematic Diagram of Off-Gas and Ventilation Systems.

16.1.2 Cell Cubicle Ventilation

Each cubicle has a system (Fig. 2.7) that circulates air at 350 cfm from the cubicle, through absolute filters, past cooling coils (cooled by recirculating cooling water), and back into the cubicle through a backflow preventer. This system removes cubicle heat that is generated by process equipment and cubicle lights. Each cubicle is purged with from 5 to 50 cfm of air from the cell in which the cubicle is located. This air enters the recirculation duct through an absolute filter. The purge rate is adjusted, using a manual damper in the intake duct -- thus, the purge capacity of 50 cfm is constantly available in case it is needed to prevent a pressure rise in the cubicle. A single exhaust line from each cubicle is tied into an 8-in.-diam fiber-glass-reinforced epoxy resin header that runs through the cells to the caustic scrubber. A pressure controller actuates a valve in the cell cubicle ventilation header to maintain the header at a pressure of −0.3 in. water (gage) with respect to the cell ventilation system. The valve will fail open to cause a vacuum of more than 0.3 in. water (gage) in the cubicles. The cubicles have been evacuated to 10 in. water (gage) without damage.

16.1.3 Caustic Scrubber

The scrubber, located in cell pit No. 7, is a packed tower 2 ft in inside diameter and about 10 ft high. The packed section, 5 ft high, is filled with 1-inch stainless steel Pall rings. Above the liquid distributor is a 4-in.-thick Yorkmesh demister, also of stainless steel. The upper portion of the tower is stainless steel, while the lower portion, including the support plate, is Hastelloy C. The bottom portion of the tower is a reservoir for the caustic, which is recirculated to the tower by either of two recirculating pumps. Makeup caustic and water are added through nozzles either above or below the demister.

A recent study of the scrubber, made to determine optimum operating conditions, indicated that iodine and HCl will be removed from up to 650 cfm of air with a decontamination factor of from 150 to 500. Normal flow rate is 500 cfm.

16.1.4 Filters

The filters in the exhaust of the vessel off-gas system are located in two removable filter enclosures in a filter pit under the floor of the limited-access area. Each of the steel enclosures holds one roughing and two absolute filters arranged in series. One of the enclosures will be in service, and the other will be an installed spare.

Pressure drop across the roughing filters and across the absolute filters is indicated on magnehelic gages in the limited-access area. Taps for making tests of filter efficiency using dioctylphthalate (DOP) are located in the ducts upstream and downstream of the filter pit.

The enclosures are airtight and are provided at the entrance flange with metal sliding plates to contain contaminated material when the enclosures are removed. Used enclosures are withdrawn into a shielded carrier for transportation to the burial ground, where the entire enclosure is discarded.

16.1.5 Pressure Control Instruments

The pressure at the scrubber inlet is maintained at −10 in. water (gage) by a normally-open air-operated control valve located on the stack pad. A flow switch in the fan discharge line senses loss of flow and energizes the motor on the alternate fan.

16.1.6 Off-Gas Fans

Each of two fans has a capacity of 750 cfm at a suction pressure of 34 in. water (gage). They are to be used alternately and are connected to separate emergency power supplies (HFIR normal-emergency No. 1 and No. 2).

16.2 Cell and Glove-Box Ventilation

16.2.1 Glove-Box Ventilation

Purge air is introduced into the glove boxes in the alpha laboratories through absolute filters. An exhaust duct system in laboratories 108, 109, 111, 208, 209, and 211, and in the glove-box storage area 201, is discharged into the cell ventilation filter facility upstream of the filters. The pressure in the duct is maintained at −0.3 in. water (gage) with respect to the static pressure in the first-floor laboratory corridor by an automatic control valve in the duct. A vacuum relief device that is operated by a solenoid valve and an air-operated valve limits glove-box pressure to −2 in. water (gage) to prevent glove-box collapse. The relief valve will open full if there is an air failure. The solenoid valve receives its power from the power supply for the radiation detection system, which is connected to the HFIR No. 1 normal-emergency power system.

16.2.2 Cell Ventilation System

Normal Operation. — Purge air is drawn through a roughing filter and backflow preventer into each cell and the pipe tunnel from the limited-access area. The inlet duct will handle 100 cfm at the expected operating pressures; however, manual dampers and flow measuring devices are provided at each cell for setting the purge rate to a lower value. Air is supplied to the limited-access area at a maximum rate of 6750 cfm by building supply system No. 2.

Maintenance Operations. — During maintenance operations, with a cell roof plug (maximum opening, 7 x 9 ft) removed, additional air is made available to maintain a minimum face velocity of 100 fpm across the roof plug opening.

16.2.3 Cell Ventilation Filters

Cell ventilation filters are enclosed in four steel enclosures that are similar to the off-gas filter enclosures. In each enclosure, there are three roughing and six absolute filters that are arranged to give three parallel paths through one roughing and two absolute filters. However, two enclosures are required to handle normal ventilation flows, and all four must be onstream when a cell roof plug is off. The same carrier will be used to handle these enclosures, and the ducts and enclosures have the same kind of sealing plates as the VOG enclosures. The entire enclosure will be discarded with the used filters. Pressure taps and DOP test taps are provided, and pressure drops are indicated by magnehelic gages in the limited-access area.

16.2.4 Process Drain Vent

All vent stacks in the process drain system discharge into the ventilation filter plenum.

16.2.5 Cell Ventilation Fans

There are two 13,750-cfm-capacity ventilation fans. Either fan will provide the required ventilation. Both are connected to separate emergency power supplies (HFIR normal-emergency No. 1 and No. 2).

16.2.6 Pressure Control Instruments

The pressure in the ventilation duct is maintained by an automatic damper. A flow switch in the blower discharge line senses loss of flow and energizes the motor on the alternate blower.

17. PROCESS HAZARDS

17.1 Containment and Shielding

The Transuranium Processing Plant was designed and evaluated for safety with the use of containment criteria and calculational methods that have become standard at ORNL. The cells and the building constitute primary and secondary containment, respectively, for radioactive materials in vessels and cubicles within the cells. The glove boxes and the building constitute primary and secondary containment, respectively, for α-active materials in glove boxes. The laboratory rooms provide an additional containment barrier within the building. Filtered air flow is from normally nonradioactive areas to progressively more radioactive areas. Air from the glove boxes, cell cubicles, cell vessels, and the building area around the cells is discharged through separate ventilation systems, which contain double "absolute" filters, to a 250-ft stack. The air from the laboratories and the building area around the laboratories exhausts through absolute filters to the roof of the building.

A more complete discussion of the shielding of penetrating radiation and of containment and ventilation features will be found elsewhere in this report.

17.2 Operational Release of Radioactivity

17.2.1 Airborne Activity

Rare gases and halogens (from dissolution of irradiated targets and spontaneous fission of californium) and miscellaneous aerosols containing actinide elements and fission products will be released in small quantities through the vessel, cubicle, and glove-box ventilation systems to the 250-ft stack during routine operation. The effects of the maximum anticipated rates of release of these materials (Table 17.1) were calculated, using standard techniques and a deposition velocity of

Table 17.1 Effects of Operational Release of Radioactive Gases and Aerosols from TRU

		Activity Release Rates		Ground Dose Rate or Concentration Downwind			Ground Deposition (dis/min·100 cm^2)	
Source and Type of Release	Type of Activity	Maximum Release Rate (curies/sec)	Average Annual Release Rate (curies/day)	Max. Avg.[a]	Peak[b]	Max. Avg.[c] Annual	Maximum	Max. Avg.[c] Annual
Batch dissolution of HFIR target (averages once every week) releases 40 curies of ^{133}Xe and 1 curie of ^{131}I over several minutes.	^{133}Xe ^{131}I	0.1 0.0025	5.4 0.14	0.25 mr/hr 250% $(MPC)_a$	25 mr/hr	10^{-6} mr/hr 10^{-2}% $(MPC)_a$	- 4400	- 100
Continuous release of rare-gas fission products by 100 watts of spontaneous fission in Cf (removal rate before filtration, $1.67 \times 10^{-4} sec^{-1}$).	Xe and Kr	0.0025	220	0.05 mr/hr	5 mr/hr	0.001 mr/hr	5000 Predominantly ^{138}Cs	8 73% ^{137}Cs 20% ^{89}Sr 1.1% ^{90}Sr 2.0% ^{91}Y 3.6% ^{141}Ce
Continuous production of actinide and fission product aerosols by handling operations.	Alpha-emitting actinides. Traced with ^{242}Pu, ^{244}Cm, or ^{252}Cf.	10^{-10}	10^{-5}	0.2% $(MPC)_a$	--	0.005% $(MPC)_a$	--	4.9
	Nonvolatile FP's, 10d < $T_{1/2}$ < 1 yr	10^{-8}	10^{-3}	4×10^{-5} mr/hr	0.004 mr/hr	--	270	80

[a]Maximum value over several minutes to several hours of unchanging weather conditions.

[b]Maximum value of very short duration peaks of statistical fluctuations.

[c]Maximum value averaged over yearly weather conditions.

0.02 m/sec for particles sufficiently small to pass through absolute filters. The calculated concentrations and depositions are considered to be within the present permissible levels for the confines of ORNL.

17.2.2 Activity Discharged in Liquids

The liquid waste system is discussed in another section of this report.

17.3 Accidental Release of Radioactive Materials

There are three prominent types of accidents that could conceivably occur in the Transuranium facility and that would result in the release of radioactive materials to the environment or subject operating personnel to excessive radiation exposure. The nuclear excursion is not a possible hazard because the total quantities of fissile material that are processed, or will be accumulated, cannot approach a critical mass.

17.3.1 Glove-Box Rupture

Loss of containment by fire or explosion is discussed in the sections dealing with glove-box operations.

17.3.2 Fires

The entire building and all the laboratories are equipped with sprinkler systems in keeping with the Atomic Energy Commission's existing policy. In addition, the cells and cell cubicles are provided with sprinklers designed to serve also as decontamination sprays. All ventilation exhaust ducts and filters are of the accepted fire-resistant high-temperature type.

The structure is designed and constructed to conform with NFPA Code requirements insofar as it conforms with specific requirements to provide radiological safeguards in accordance with ORNL radiation and safety criteria.

Fires within the cell bank provide the potential for dispersing large amounts of α- and neutron-active materials. The organic diluents used for processing active materials were selected for their relatively high flash point, and the equipment and cubicles will be operated at a temperature below this flash point. The possibility of vapors accumulating to form an explosive mixture is eliminated by the large cubicle and cell ventilation exhaust system, which will dilute organic vapors and hydrogen well below the explosive limits.

From time to time it will be necessary to clean accumulated solids and films out of the solvent extraction equipment. For this purpose it is necessary to use ethanol in the Tramex equipment, and acetone in the Pharex and Berkex equipment. The equipment, including catch tanks, will be well flushed of active material and cooled to cubicle temperature before beginning the cleanout, and again well flushed of these volatile solvents before returning it to normal service. There is no hazard to the waste system, as these solvents will be diluted many-fold with various aqueous solutions before they arrive at the tank farm.

17.3.3 Chemical Explosions

The credible types of chemical explosions are radiolytic gas and nitrated organic explosions inside a process vessel within a cell. It is not credible that an explosive mixture could occur in the cell air since the ventilation rate is sufficient to dilute the organic vapor content below the explosive limit. Further, the cell air temperature will be controlled below the flash point of the organic materials used in processing.

Gas Formation by Radiolytic Decomposition. — Radiolysis of solutions containing HCl causes a destruction of acid and a release of hydrogen gas. The volume of gas thus released is always very small and is of no concern in itself. The difficulty lies in the possibility of its forming an explosive mixture (see below). Radiolysis of the HCl has been repeatedly determined to be about 0.00067 eq/whr (G_{HCl} value = 1.9). If the missing H^+ ions are all converted to gaseous H_2 (and this is believed to be the case), the release rate would correspond to 0.35 ml of H_2 per minute per gram of ^{244}Cm (or an equivalent amount of another α-emitter). Since every storage vessel is equipped with at least three instrument lines that are purged at a rate of 0.2 cfh each, such a vessel can contain up to 32 g of ^{244}Cm or 2.3 g of ^{252}Cf without the off-gas composition exceeding 4% hydrogen. In the event that it is necessary to store larger amounts in one vessel, the purge rates will be increased proportionately.

Decomposition of HNO_3 solutions follows a completely different mechanism. In this solution, loss of acid is almost undetectable and hydrogen evolution is reduced about sevenfold to 0.05 ml per minute per gram of ^{244}Cm. Thus, 224 g of ^{244}Cm can be stored in one vessel in nitric acid solution without the vapor space exceeding 4% H_2 at regular instrument purge rates.

Gas Formation During Aluminum Dissolution. — Dissolution of aluminum in either base or acid produces hydrogen. The normal dissolution in HCl is controlled at a rate of 1 g/min, and the resulting hydrogen is diluted to 2% by a special 2.0-cfm air purge, in addition to instrument purges. The establishment of this air purge depends upon administrative control, that is, it is included on the dissolution checksheet. If for some reason the purge is omitted, the normal instrument purges would mix with the evolved H_2 and generate a mixture of 81% H_2--4% O_2--15% N_2. Also, by maloperation, an excessively high acid concentration could be added to the dissolver, or a runaway temperature could be caused by a failure of the recirculating water pump. In either case the maximum dissolution rate expected is about 50 mg/cm^2-min, as indicated in Section 4.6.1. HFIR targets have a surface area of about 1000 cm^2, so that the maximum dissolution rate would be about 50 g/min.

Hydrogen evolution would be about 1.5 cfm (not enough to pressurize the dissolver, but it could form a mixture of 50% H_2 with the purge air (see below for a discussion of explosion).

Dissolution in NaOH--$NaNO_3$ also produces hydrogen, but at a much lower rate (see Section 4.6.2). The design conditions should result in a dissolution rate of about 7 g/min. At this rate the hydrogen evolution will match that in the normal HCl dissolution and will be diluted to 3% H_2 by a 1.5-cfm air flow.

Abnormally high dissolution rates could result from adding stronger caustic than called for (5.2 M) or adding a larger volume and hence immersing the target more than the intended six inches. These possibilities will be guarded against by the usual check sheets. If this precaution fails, the gas release will still not be great enough to pressurize the vessel, but will increase the explosion hazard.

Hydrogen Explosions. — Several sources of hydrogen were discussed above, and the statement was made that under normal operating conditions the hydrogen produced would be diluted to less than 4%, the lower explosive limit. However, abnormal conditions that result in concentrations greater than 4% would not necessarily result in an explosion. A spark or an open flame is necessary to set off the mixture, and neither of these will normally be present in the piping. The explosive mixture could cause rupture of only the dissolver and the condensate receiver.

In either of the above vessels, the reaction of the stoichiometric mixture of air and hydrogen will result in a constant-volume pressure rise to 150 psig. If the dissolver should rupture, the escaping gas will raise the pressure in the cubicle by 12 in. H_2O, or to 10.6 in. H_2O greater than that of the operating area. If the condensate receiver (which is located in the cell pit) should rupture, the cell will be pressurized by 14 in. H_2O. Neither of these occurrences will result in a breach of containment, although considerable damage to equipment will result.

In any other vessels it is very unlikely that enough hydrogen can collect to cause an explosion. The off-gas manifold in the cells is a 1.75-in.-diam Zircaloy-2 tube which has a bursting pressure in excess of 9000 psi. The gases are diluted by 50-500 cfm of air in the caustic scrubber. This will reduce the hydrogen concentration to below the explosive limit.

Nitration Explosions. — In the process of adjusting feed for the Berkex and Cefix processes, the feed is evaporated to a very small volume. The nitric acid concentration increases to that of the constant boiling mixture, which is a very powerful nitrating and oxidizing agent. Organic materials are inevitably entrained in these solutions, and the possibility of nitrate explosions is very real. The diluent (Amsco 125-82) tends to steam distill in the earlier part of the evaporation, leaving the extractant residues behind. The situation is not unlike that in the product evaporator in the uranium reprocessing cycle. However, there are several ameliorating factors. No amines or phenol will be present, as was the case with the decontaminating agent that caused the violent reaction in Building 3019. The steam pressure will be reduced to the minimum necessary to accomplish the evaporation (about 20 psig). And finally, if there is a nitration reaction of the di(2-ethylhexyl) phosphoric acid or 2-ethylhexyl phenylphosphonic residues, the severity will be considerably moderated by the longer chain length of the alkyl groups (as compared with TBP). It is to be noted that an explosion of 0.22 lb of nitroethane would be the equivalent of the hydrogen explosion described on the preceding page, and significantly larger amounts of nitrooctane would be required for the same energy release. The vessels used here are quite small, and it is very unlikely that enough nitrated residue could accumulate to cause trouble.

The product of the Tramex cycle, which might contain residues of amines and aromatic diluents, will be boiled only with HCl, a procedure that has been repeatedly demonstrated to be safe.

17.4 Decontamination Hazards

Experience in the Curium Recovery Facility has shown that small equipment of the size used there and in TRU can usually be flushed sufficiently free of activity to permit extracting the equipment into a contained but unshielded transfer case. Within the transfer case, further decontamination and/or repair can be accomplished by standard glove-box techniques. The access time will be based on surveys of both beta-gamma radiation and neutron radiation.

In the event of accidental release of alpha contamination into an operating area, the cleanup squad will wear assault masks and double coveralls, with taped gloves and boots, until the area can be adequately surveyed and the actual extent of contamination ascertained. Each cleanup will be carried out under the supervision of skilled, experienced personnel.

17.5 Maximum Credible Accident

The worst accidents that may credibly occur in TRU would result from dispersal of the maximum quantity of radioactive material in a cell or glove box by a fire or explosion.

Our studies have shown that, in the event of credible (contained) accidents, the activity released from successive leaks through the primary and secondary containment walls is insignificant as compared to the credible release through the ventilation filters. In a credible accident, the blast effects of an explosion are confined to the region of primary containment (glove box, laboratory, or cell). Although a radioactive aerosol may leak through the primary containment wall and become mixed with the air in the secondary containment zone (building) during the period when the primary containment zone is pressurized, the leaked air is ordinarily not sufficient to raise the secondary containment pressure above atmospheric.

The so-called "AEC absolute" filters that are widely used in radiochemical plants are the weakest link in the containment of credible accidents. The susceptibility of the filters to both physical and chemical degradation necessitates that their integrity and efficiency be assured by routine in-situ testing or by preplacement testing plus careful installation and operation. The filters must be protected from excessive corrosion and excessive loadings of dust or water and must be located so that they can withstand the blast wave from credible explosions without rupture. In typical facilities the tortuous path and expansions and contractions of the ventilation duct are sufficient to reduce the blast wave from credible explosions to a tolerable level at the filters.

In the evaluation of the credible accidents in TRU, it is assumed that no more than 20% of the radioactive aerosol that is dispersed in the primary containment zone passes to the filters and that the remainder is deposited on the walls and ventilation ducts. The fraction of aerosol penetrating the filters is estimated from the assumed particle size distribution in the aerosol and the efficiency of the filters as a function of particle size.

Experience with AEC absolute filters operating at the rated flow indicates that they have greater than 99.95% efficiency for removing particles of size greater than 0.3 micron, that the efficiency decreases to a minimum of approximately 87% for particles of 0.05 to 0.1-μ size, and that the efficiency is greater than 87% for particles of smaller size. These filters are approximately 99.5% efficient in removing smoke from a plutonium metal fire, varying in size from 0.004 to 0.03 μ, and the addition of one to six backup filters in series does not significantly improve the efficiency.

In these studies it is assumed that filters have removal efficiencies of 99% for particles smaller than 0.05 μ, 87% for particles 0.05 to 0.1 μ, 95% for particles 0.1 to 0.3 μ, 99.95% for particles 0.3 to 5 μ, and 100% for particles larger than 5 μ. Smokes from fires of metal, solid carbonaceous materials, or organic liquids which would be predominantly 0.01 to 0.1 μ in size are assumed to be 99% removed in filters. This slightly enhanced efficiency, as compared to 87%, partially compensates for the effects of agglomeration in the duct and improved efficiency because of filter loading in moderately large fires involving carbonaceous solids or organic liquids.

The maximum credible accident in the glove-box laboratories of TRU would result from an explosion and fire in a glove box that contains 1 g of ^{244}Cm, the maximum quantity anticipated to be used in glove boxes. Such an accident could result in the dispersal of <1 g ^{244}Cm into the laboratory, requiring that glove-box operators evacuate immediately to prevent ingestion of a lethal dose. Allowing for 80% deposition of the smoke in the glove box and laboratory, and assuming that the filters are only 99% efficient in removing the smoke, approximately 2 mg of ^{244}Cm would be released from the roof of the building through the filtered ventilation systems. This release could cause maximum downwind ingestion doses (accumulated over a lifetime) of approximately 2 rem and contamination of approximately 8.5 square miles downwind to levels greater than 30 dis $min^{-1} dm^{-2}$ of alpha.

While absolute prevention of such glove box ruptures is impractical, the probability of such accidents will be maintained at an acceptably low value by inclusion of the multiple safeguards which were described in Sections 10.3 and 10.4.

The maximum credible accident in the cell area would be an explosion (of Al-air, H_2-air, or organic-air) in a cell cubicle containing 1 g of californium as fine powder. The explosion could have sufficient violence to shatter the vessel or cubicle and scatter its contents within the cell but would not rupture the cell wall or ventilation filters. The californium released through broken "alpha" seals in the cell wall into the building might cause lifetime doses to operating personnel of approximately 1 rem. Assuming a conservative particle size distribution (98.8% = 0.3 μ, 1.1% between 0.1 and 0.3 μ, and 0.1% less than 0.1 μ) and assuming 80% removal by deposition before the filters, 0.2 mg of Cf could be released through the cell ventilation system to the 250-ft stack. This could cause maximum downwind doses (accumulated over a lifetime) of approximately 0.2 rem and contamination of approximately 6.5 square miles downwind to levels greater than 30 dis $min^{-1} dm^{-2}$ of alpha.

The possibility of such dispersive accidents is minimized through inclusion of multiple safeguards. Organic vapor explosions in vessels will be prevented practically by maintaining the organic material below its flash point and omitting possible sources of ignition. Hydrogen generated in radiolytic gas and dissolution operations will be diluted with air to ensure that the concentration is not in the explosive range.

It is not credible that an explosive mixture could occur in a significant portion of an entire cell since the ventilation rate is sufficient to effectively dilute, below the explosive limit, any organic vapor or hydrogen that is produced at the maximum credible formation rates.

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