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BUILDING 4507, HIGH LEVEL CHEMICAL DEVELOPMENT FACILITY - HAZARDS EVALUATION, VOL. 10

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ABSTRACT

The facilities and operations of Bldg. 4507 (High Level Chemical Development Facility) were reviewed from the standpoint of associated hazards (radiation, criticality, chemical, fire, and explosion) and were found to be adequate according to Laboratory containment policy pending the completion of planned changes.

Standards of construction and containment, assumptions made to evaluate the potential hazards of release of radioactive material, and methods of calculation used for development of this hazards analysis are given in ORNL-2956, Summary Report - Hazards Analyses of Radiochemical Processing and Waste Disposal at Oak Ridge National Laboratory, Sects. 4.0, 5.0, and 6.0.

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BUILDING 4507, HIGH LEVEL CHEMICAL DEVELOPMENT FACILITY

1.0 INTRODUCTION

1.1 Purpose and Uses

The High Level Chemical Development Facility, Bldg. 4507, was constructed in 1957 and is used for radiochemical separation process studies with very highly irradiated fuel for such programs as Power Reactor Fuel Processing, Waste Disposal, and Fused Salt Fluoride Volatility. Small sections of irradiated fuel or prototype fuel elements or irradiated fuel pins containing comparatively small amounts of fission products and heavy elements are dissolved for laboratory-scale process development. It has a high degree of versatility for work in the field of flowsheet development. One cycle of solvent extraction, a complete fused salt fluoride volatility plant, and two general purpose cells used for dissolution and high level waste disposal contain radioactive materials. These occur in solution, as solids, or as gaseous fission products or volatile chemical compounds of fission products and heavy elements. Very high activity level chemical experiments will be done in the future.

1.2 Location and Distance from Other Facilities

Figure 1, part of the Oak Ridge National Laboratory Permanent Facilities Plan, shows the location of the High Level Chemical Development Facility in the plant complex. The distances of the various buildings from Bldg. 4507 are:

Bldg. No.	Name	Distance		Activity Inventory	
		ft	Direction	Equiv. Pu, g	β-γ, curies
4507	High Level Chemical Development Facility	-	-	< 1 now; no limit with containment	<40,000
4505	Unit Operations	Abuts	North	~1	<1,000
4501 (abuts 4505)	High Level Radiochemical Lab	60	North	No limit	1,000 or more
4508	Metals and Ceramics	100	South	Unknown	<350
4500	Central Research and Administration (wing 1)	48	East	Unknown	<350
3587	South Field Service Shops	None	West	None	None

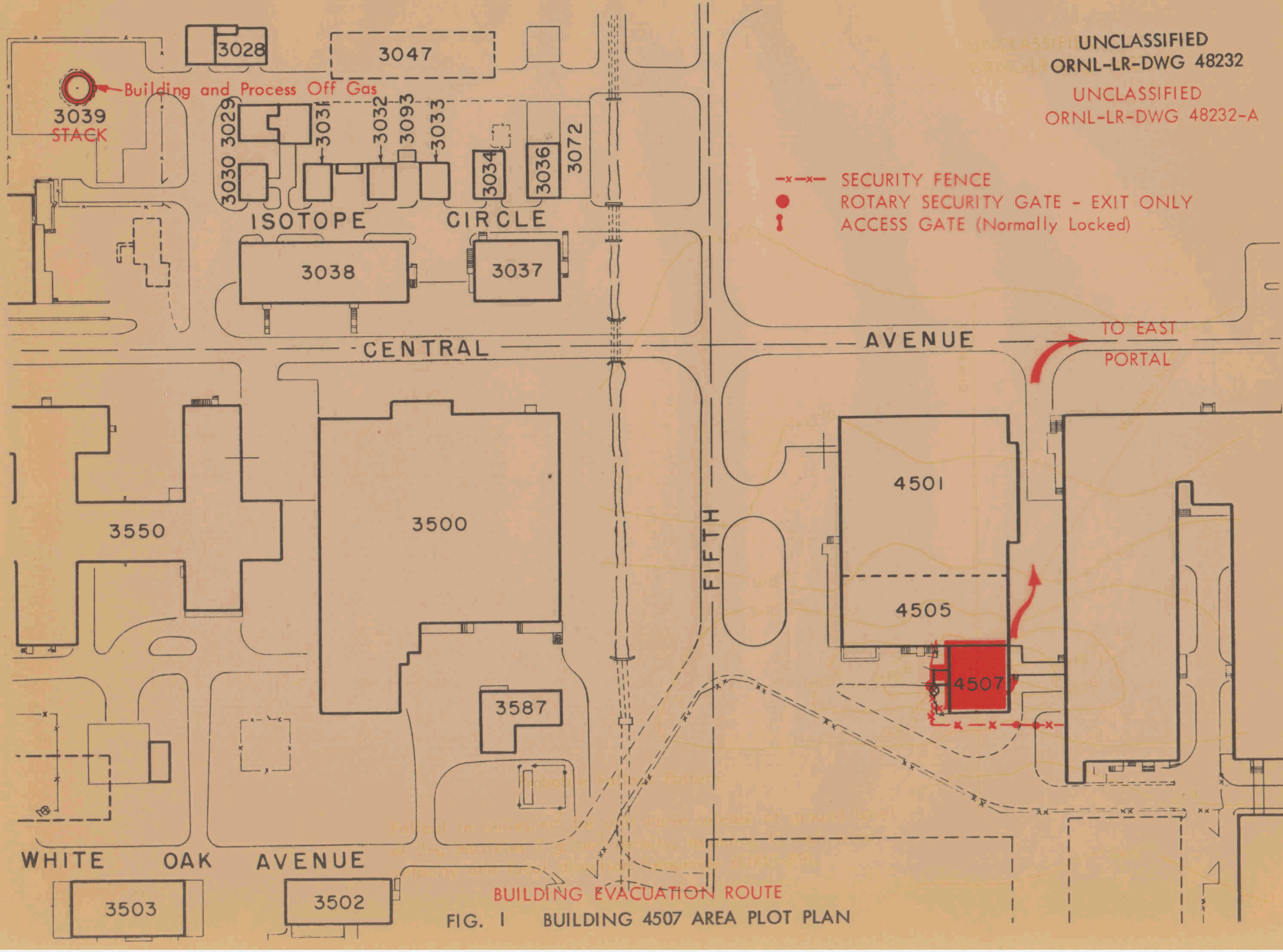

FIG. 1 BUILDING 4507 AREA PLOT PLAN

1.3 Building Description

Building 4507 (Figs. 2 and 3) was constructed as a brick building, but the new penthouse structure will be constructed from insulated sheet metal panels sealed into one continuous shell. Vestibule entrances for personnel are being provided and the building is to be sealed against leaks so as to be able to maintain -0.3 in. H_2O pressure with respect to atmosphere. The building and penthouse provide secondary containment for the facility. Primary containment is provided by the cell block, which is 44 ft long, 19 ft 6 in. wide, and 22 ft 3 in. high, and contains four cells. Each cell has a usable volume that is 10 ft long, 6 ft wide, and 11 ft high, separated from one another by 4-ft-thick concrete walls. The rear wall of the cell block is 5 ft 6 in. thick and the front wall, which has four dense lead-glass windows (one for each cell), is 4-ft-thick special barytes concrete. All openings into the cell are sealed against extraneous leaks, allowing air access to the cell only as planned via the filtered air inlet duct in the rear door.

1.4 Personnel Control

The numbers of people normally in Bldg. 4507 and in other buildings in the area are:

Bldg. No.	No. of People	
	Weekdays	Nights and Weekends per Shift
4507	3-6	1-2
4505	65	3-5
4501	68	3-5
4508	200	Unknown
4500, wing 1	100	1-5
Field shops	30	0

The change room shown is a check point for personnel entering the potentially contaminated charging area. An auxiliary check point in the corridor between Bldgs. 4507 and 4500 will be established by Health Physics in an emergency. The planned evacuation route from the building in an emergency is shown in Fig. 1.

1.5 Process Description

Building 4507 is used for flowsheet development in the Power Reactor Fuel Processing Program and associated development work. The IMMI* Facility in cell 1 is permanently installed and designed for experimental work in processes that use sulfuric acid or caustic decladding agents and a nitric acid core dissolvent. Cell 2 contains 2-liter scale glass equipment for Darex feed preparation and a miniature mixer-settler solvent extractor. Cell 3 contains 2-liter scale glass experimental equipment for either Sulfex or Darex decladding and feed preparation studies. Cell 4 is equipped for experiments on the Fused-Salt Fluoride Volatility process now being investigated for uranium-zirconium alloy fuels. Nickel, Inconel, and stainless steel are the principal materials of construction. Figures 4 and 5 are an equipment flowsheet and layout, respectively, of the IMMI Facility.

*Intermediate-scale mixer-settler.

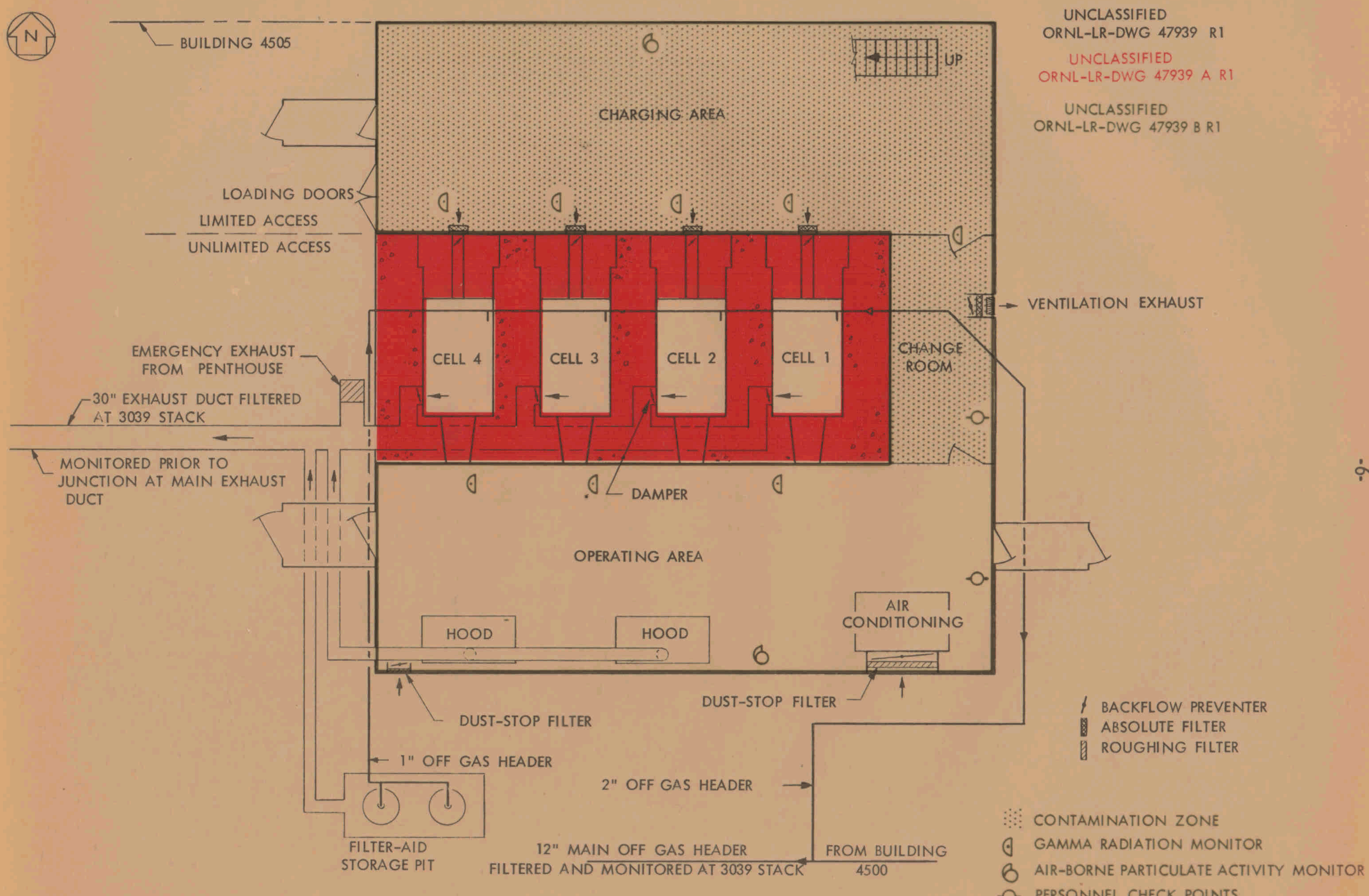

FIG. 2 BUILDING 4507 FIRST FLOOR PLAN VENTILATION SCHEMATIC
LIMITS OF PRIMARY CONTAINMENT
LIMITS OF SECONDARY CONTAINMENT

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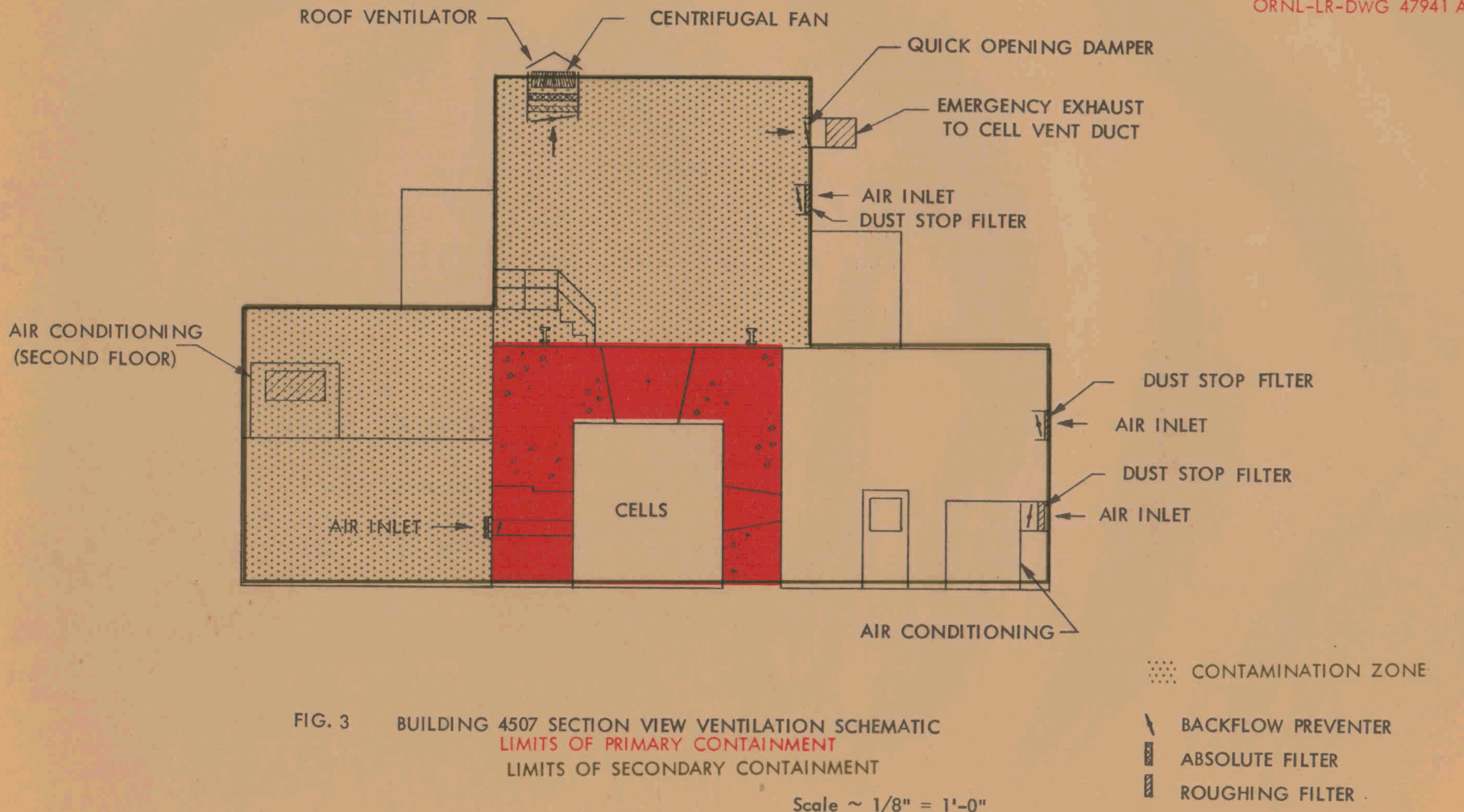

FIG. 3 BUILDING 4507 SECTION VIEW VENTILATION SCHEMATIC
LIMITS OF PRIMARY CONTAINMENT
LIMITS OF SECONDARY CONTAINMENT

Scale ~ 1/8" = 1'-0"

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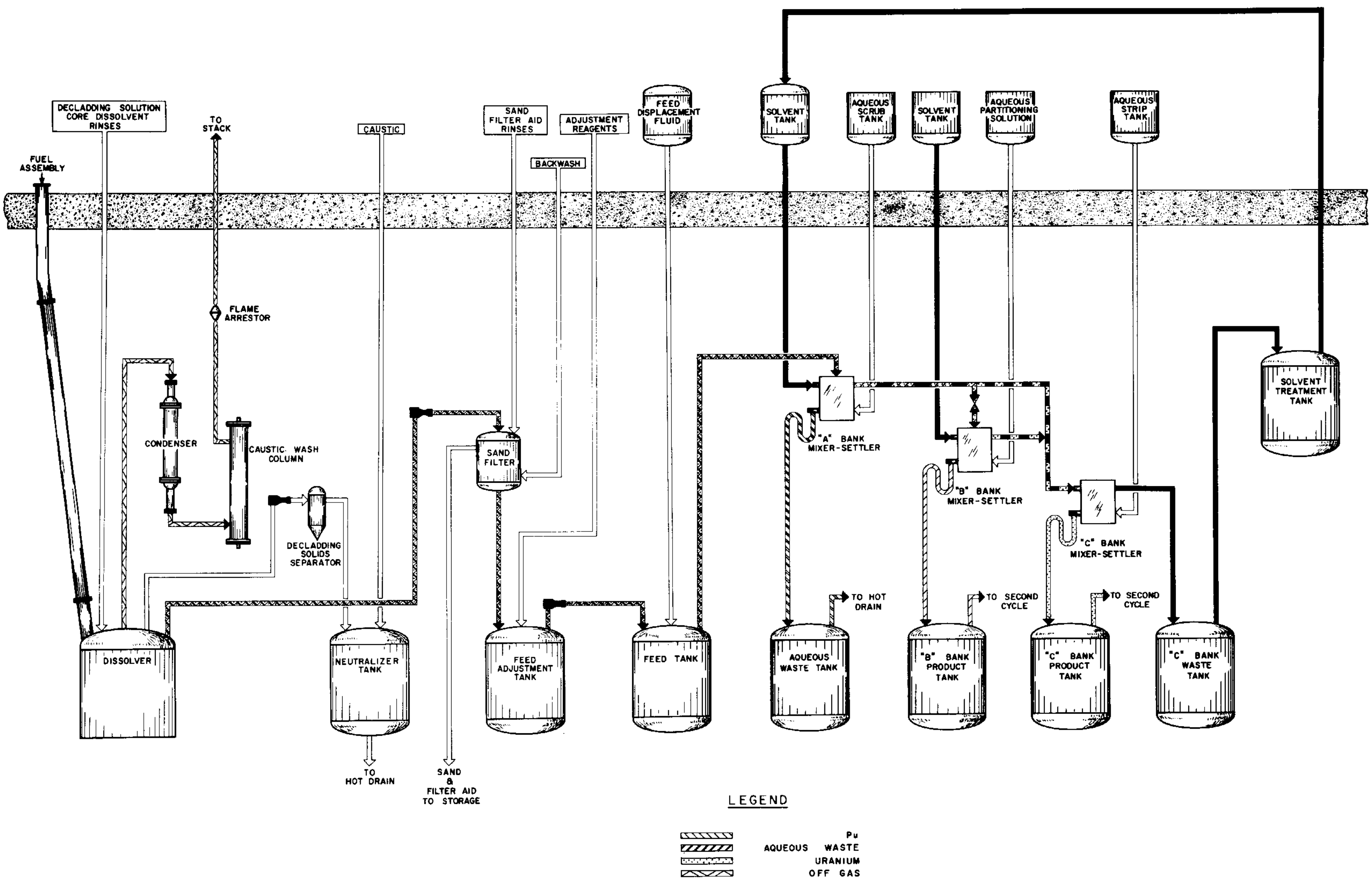

FIG 4 SCHEMATIC FLOWSHEET FOR INTERMEDIATE SCALE HEADEND-SOLVENT EXTRACTION FACILITY

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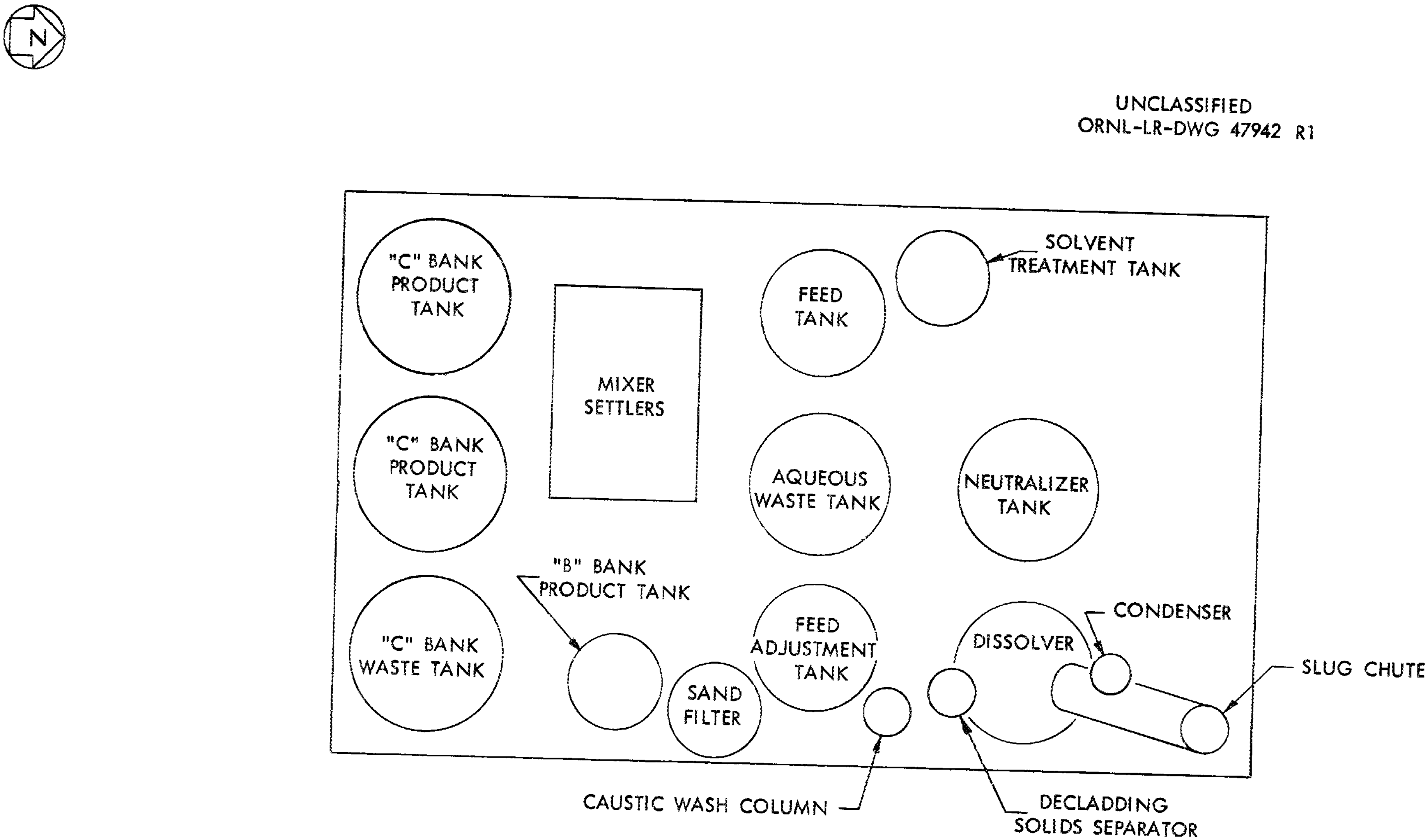

Scale ~ 3/4" = 1'-0"

FIG. 5 PLAN - CELL 1 BUILDING 4507 EQUIPMENT LAYOUT SCHEMATIC

1.6 Criticality

Criticality in Bldg. 4507 is controlled by mass limitation. Equipment sizes, which in turn regulate batch sizes, are so small that minimum natural-water moderated and reflected critical masses of 510 g for Pu^{239}, 588 g for U^{233}, and 800 g of U^{235} are never reached. An experimental run of high burnup (20,000 Mwd/ton) Yankee Atomic Power Reactor fuel will have 36 g of Pu^{239}, and an experimental run with Consolidated Edison fuel will have 138 g of U^{235} and 56 g of U^{233} for a total of 194 g. More than one batch of material will not be permitted in the IMMI Facility at one time. Future experiments with new and different fuels of now unknown composition will also be made, using mass limitation for safety against criticality.

1.7 Liquid Waste Systems

There are three liquid waste systems serving Bldg. 4507 (Fig. 6): (a) the high level radioactive waste system, (b) the filter-aid slurry collection and storage system, and (c) the process cooling water waste system. Liquid radioactive wastes are collected by a 2-in. header which leaves the east side of Bldg. 4507, and then turns south to connect with the 4-in. header that ties Bldg. 4500 directly to the Liquid Radioactive Waste Tank Farm. Slurry wastes, arising from filter operations in Cell 1 that use filter-aid, are sent to a special storage pit south of the building where the solids are permitted to settle. Clear supernatants are permitted to overflow to a second tank and are then jetted to the high-level radioactive waste header. The tank containing the settled solids is replaced periodically with one that is empty. Process cooling water waste, arising from the operation of aspirators, heating jackets, coils, etc. (expected to contain only limited amounts of radioactive materials), leaves each cell via a 2-in. nonradioactive drain which ties to a common header exiting from the north side of the building. It continues into Bldg. 4505, passes through a radiation monitoring station, and then connects to a 4-in. process water waste header.

1.8 Gaseous Waste Systems

Building 4507 has a vessel off-gas system, a cell ventilation system, and two forced air exhausters, one in the change room and one in the new penthouse (Figs. 2, 3, and 7). Any vacuum requirements in the experiments are met by water-operated aspirators where possible. Also available for use are small, locally installed vacuum pumps or a central one for the whole building, both of which are provided with liquid-entrainment traps and filters for removing particulates. Small vacuum pumps used in cell 1 discharge into the vessel off-gas system; the central vacuum pump is being designed to discharge into the cell ventilation system.

Locally scrubbed vessel off-gas from each of the four cells goes to a 2-in. header that emerges from the east side of Bldg. 4507 to connect with a main 12-in. header from Bldg. 4500. This line goes to the 3039 stack area, where the vessel off-gas goes through a Cottrell precipitator (soon to be bypassed for the new caustic scrubber installation), is filtered and monitored, and is then discharged up the stack.

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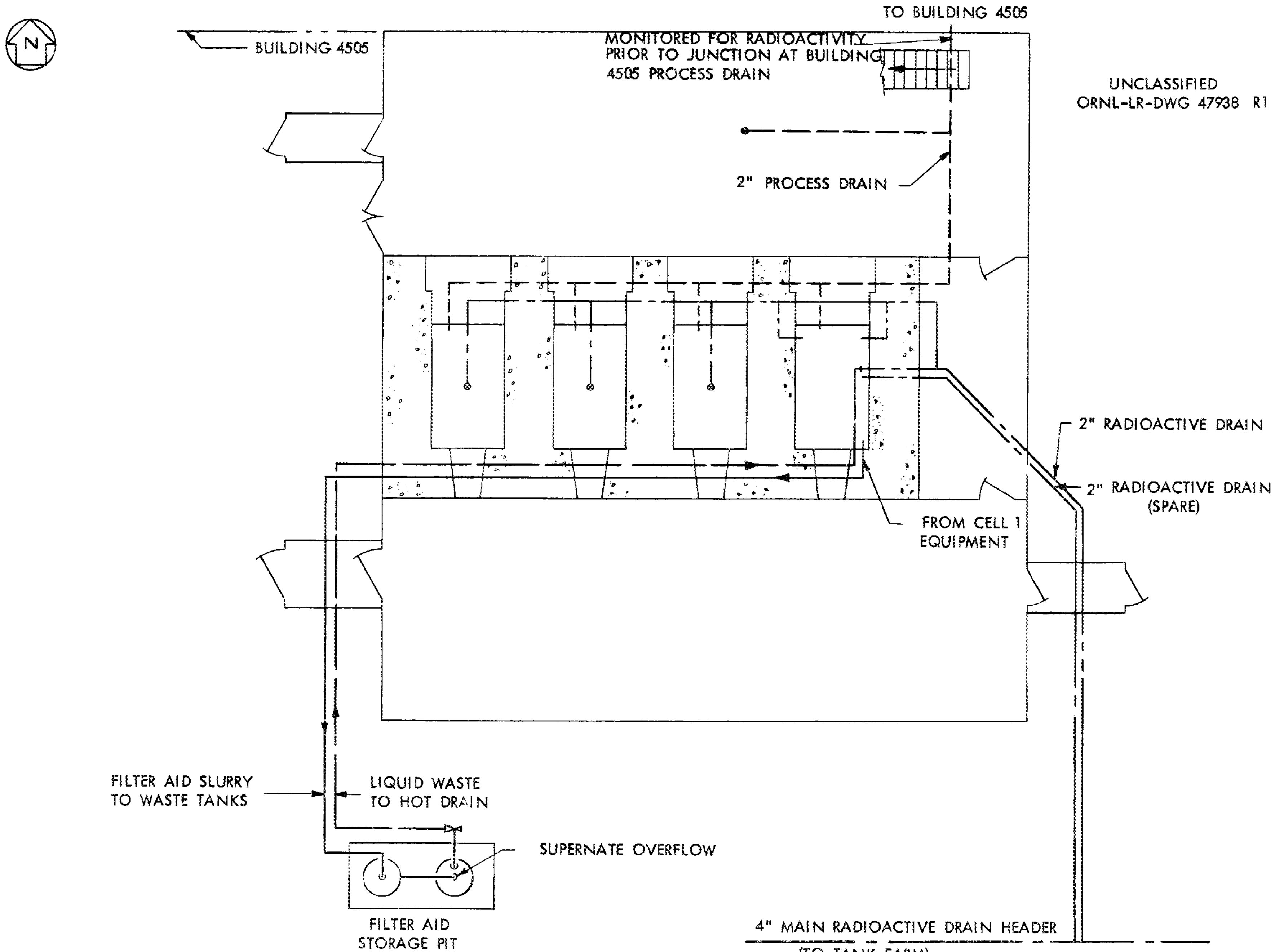

FIG. 6 BUILDING 4507 FIRST FLOOR PLAN DRAIN SYSTEMS SCHEMATIC

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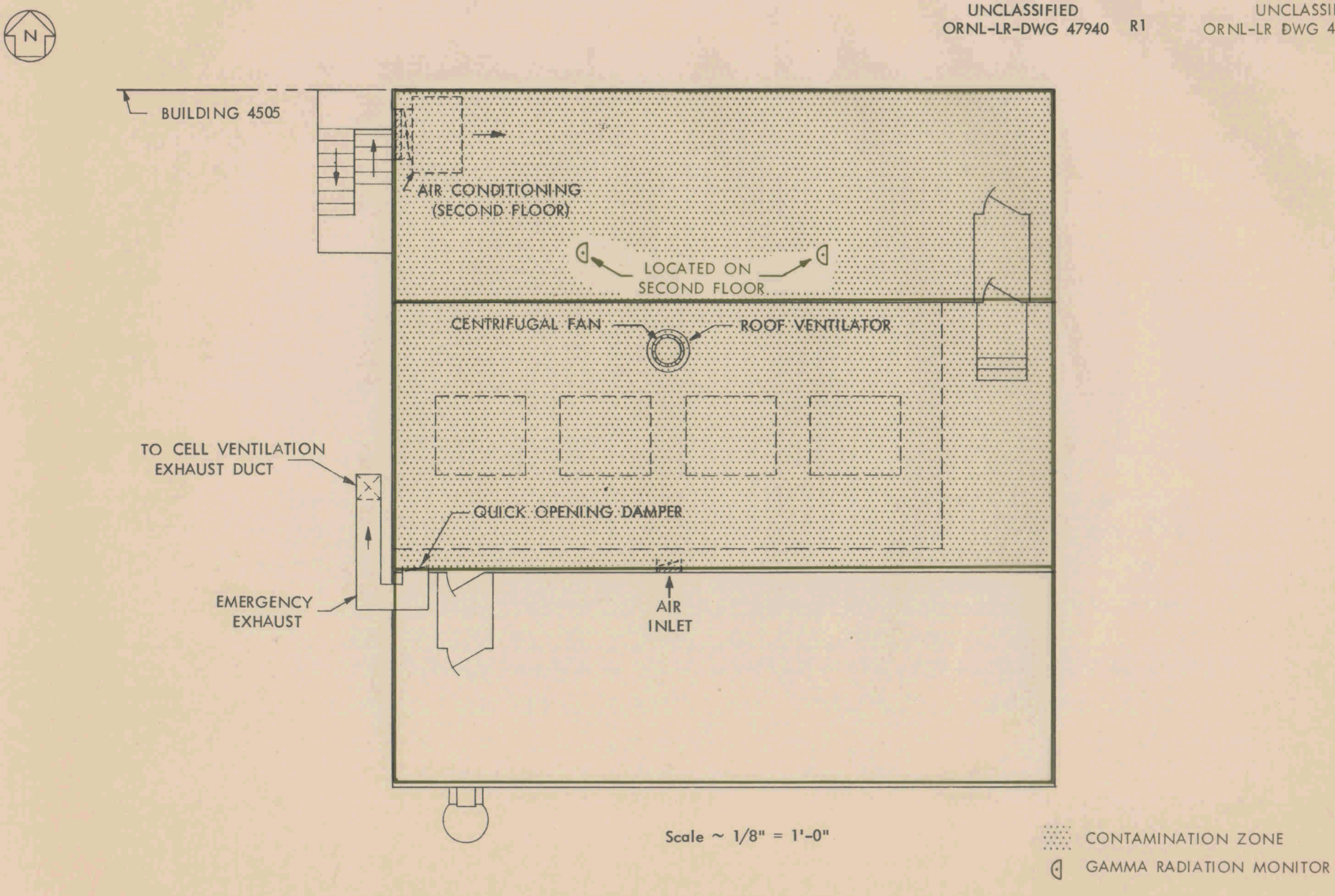

FIG. 7 BUILDING 4507 ROOF PLAN VENTILATION SCHEMATIC
LIMITS OF SECONDARY CONTAINMENT

The cell ventilation system permits a maximum of 1000 scfm of air to be withdrawn from each cell through a 16 x 24 in. vent at its base which connects to a 30-in. header leading to the 3039 stack. This air now discharges directly to the stack, but a filtering (roughing plus absolute) and monitoring station is being designed for the combined cell ventilation air for Bldgs. 4501, 4505, and 4507. Air enters each of the four shielded cells in 4507 from the charging area through a duct equipped with an absolute filter located in the rear door. The two hoods in the operation area also connect to the cell ventilation duct.

Exhausters in the change room and the new penthouse discharge to the atmosphere through absolute filters. All air makeup must pass through dust-stop filters and enter the building through two openings in the operation area, one near the hoods and one near the air conditioner, one opening in the makeup area at the air conditioner, and one opening into the new penthouse. In an emergency, all air inlets to the building and the two exhaust exits from the building will be closed and the fans stopped, either automatically or by manually operated switches. The cell ventilation system will then evacuate the building to -0.3 in. water, relative, via the cell ducts and a new normally closed duct between the penthouse and the cell ventilation duct.

1.9 Monitoring Provided

Monitoring for radiation is provided using alarm type instruments in the cell ventilation system, and in the process cooling water waste system downstream from the building. Work areas in the building are also monitored for particulate radioactive material and for direct radiation by three direct radiation gamma monitrons, two constant air monitors, a hand and foot counter, a 5-probe quintector, and three portable survey instruments. Five additional direct radiation gamma monitrons will be added to provide a total of three in the operating area, three in the charging area, and two in the makeup area. The constant air monitors will remain as located, one in the operating area and one in the charging area. A direct reading alpha air monitor is planned for the building when alpha-active materials are in process. The hand and foot counter will remain near the east personnel exit, and the quintector will remain at the entrance to the charging area from the change room. An alpha survey meter will also be added to the change room instrumentation. The cell air pressure will be measured with alarm type instruments to assure that the cell ΔP is -1.0 in. water with respect to the operating area. All remote detecting instruments will be channeled into one central annunciator located in the operating area, and provisions will be made to install duplicate recording instruments for cell pressure and radiation, vessel off-gas radiation, building monitrons, etc., in the corridor between 4500 and 4507 at a later date.

2.0 SUMMARY*

The maximum credible accident is assumed to be a fire in the 8 liters of TBP-Amsco solvent contained in the mixer-settlers or the attainment of critical mass in a product catch tank. Either incident would be contained in the primary containment (shielded cells) area; the effect on the environment of material released via the ventilation systems is given in tables below.

2.1 Nuclear Safety Hazards

2.1.1 Maximum Radioactive Material Content of Facility

Material	Design Capacity per Batch	Inventory: In Plant	Inventory: In Largest Vessel
Iodine-131, curies	<0.1		
Krypton-85, curies	53		
Mixed nonvolatile fp's, curies	36,400		
Heavy elements		These entries the same as design capacity.	
Pu^{239}, kg	0.036		
U^{235}, kg	0.192		
U^{238}, kg	7.07		
U^{233}, kg	0.056		
Th^{232} (irrad), kg	5.04		
Am^{241}, kg	~ 0.0001		
Others	Negligible		

The above data are composited from data on Yankee Atomic and Consolidated Edison fuel, which may be processed in the Intermediate Scale Mixer-Settler (IMMI) facility in the future. The Yankee Atomic fuel was assumed to have a burnup of 8200 Mwd/ton and a decay time of 180 days, and the Consolidated Edison fuel a burnup of 23,200 Mwd/ton and a decay time of 180 days. Operations in the IMMI facility are on a per batch basis; the size of the batch is limited by the limiting capacity for dissolving 2 kg of stainless steel in the dissolver. Processing of Consolidated Edison fuel is based on a Sulfex head-end step followed by Thorex solvent extraction; Yankee Atomic fuel processing is based on a Sulfex head-end step followed by a standard Purex flowsheet.

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*Calculations and assumptions are given in Volume 1 of this report.

2.1.2 Criticality Incident Potential

Fissionable Isotope	Enrichment	Design Capacity, kg/day	Shield	Type of Controls
Pu		0.036*	4 ft of barytes or 5 ft 6 in. of ordinary concrete	Mass limitation
U^{235}	**	0.138**	Same	Same
U^{233}	**	0.062**	Same	Same

*One batch of Yankee Atomic fuel contains 36 g of plutonium. Each batch stays in the plant for 72 hr of processing: 24 hr for dissolution, 24 hr for feed adjustment, and 24 hr for solvent extraction. Only one batch of Yankee Atomic fuel will be permitted in the building at any time.

**In each experiment performed in IMMI on Consolidated Edison fuel, a total of 245 g of uranium will be present, of the following isotopic composition:

U^{235}	138 g
U^{233} + Pa (56 + 6)	62
U^{238}	18
U^{234}	4
U^{236}	23
Total	245

2.1.3 Effects of Nuclear Reaction of 10^{18} Fissions Followed by Rupture of Vessel Bldg. 4507***

	Aerosol Release	Gaseous fp Release
Maximum downwind integrated dose from VOG release, rem	<0.001	0.61
Maximum downwind integrated dose from COG release, rem	<0.001	0.17
2-min dose from secondary containment shell, rem	<0.001	10.7
Maximum downwind integrated dose from building release, rem	<0.001	< 0.001
Neutron + prompt gamma dose, rem	0.04****	

***Feed adjustment tank.
****Through concrete shield.

2.2 Explosion and Fire Hazards

2.2.1 Description of Combustible or Explosive Material and Probable Reactions That Can Occur

Amsco 125-82 and hydrogen gas are present in various phases of IMMI operation. Either of these substances is capable of explosive gas phase combination with oxygen if mixed in certain proportions.

2.2.2 Specification of Closed-cup Flash Point for Organics

The closed cup flash point for Amsco 125-82 is 128°F.

2.2.3 Specification of Lower Explosive Limits in Air

The lower explosive limits in air are:

For H_2 = 4.1 vol %

Amsco 125-82 = 0.7 vol %

2.2.4 Inventory

a. The total amount of Amsco in the plant is 225 liters.
b. The total amount of Amsco in the largest single vessel is 150 liters.

2.2.5 Energy Release

a. Energy release for Amsco 125-82 = 19,000 Btu/lb
for hydrogen = 57.78 kcal/mole H_2 (10.24 Btu/liter)
b. Total potential energy release in plant for Amsco 125-82 = 7.11×10^6 Btu

A Sulfex dissolution will generate hydrogen gas at a rate of 0.16 ft^3/min under a blanket of N_2 gas. This gas will not be permitted to collect but will pass into the VOG header where it will be mixed with 10 ft^3/min of air to a concentration of less than 2 volume % H_2 which is well below the 4.1 volume % lower explosive limit of hydrogen. If the VOG should fail and all the hydrogen escape into the cell ventilating air, the residual hydrogen concentration would be less than 0.2 volume %, assuming perfect mixing.

c. Total potential energy release from the largest tank, the CW waste solvent catch tank, containing 150 liters of Amsco = 4.7×10^6 Btu.

2.2.6 Means of Preventing Explosion

a. Equipment to prevent explosions is the flame arrestor in the VOG line downstream from the caustic scrubber.

b. Nitrogen blanketing gas is present in the IMMI dissolver and slug chute during a dissolution.

c. The maximum explosive release of energy is estimated as 147.5 Btu from hydrogen in the dissolver.

d. The probability of an explosion from hydrogen is very small since the dissolver is first purged with nitrogen before a dissolution is started and a blanket of nitrogen is kept in the dissolver during a dissolution.

As it is formed and diluted by an average nitrogen purge rate of 4 scfm, hydrogen is swept into the VOG system where it is further diluted with air. A hot-wire hydrogen detector is being considered for installation in the dissolver off-gas line as part of the containment modifications. Actual measurement of the hydrogen concentration in the VOG would then be possible.

The probability of an Amsco explosion in the cell is not considered very likely since the low vapor pressure of Amsco at room temperature and the small quantity of Amsco contained in the mixer-settlers does not permit an explosive concentration to develop in the 100 scfm COG. A combustible gas analyzer is being considered for installation in the COG as part of the containment modification.

A hydrogen explosion in the IMMI dissolver is estimated to be equivalent to a 0.1-lb TNT explosion. Because of the dissolver location in the cell 1 pit, it is estimated that a pressure less than 800 psf would be exerted on the primary containment cell wall and the wall would thus withstand the pressure.

2.2.7 Fire Prevention

A fire eye in each cell, four in the operations area, six in the charging area, and one in the change house are installed to detect fires. The usual fire-fighting equipment is on hand: one fire hose in the operating area and one in the charging area; three portable fire extinguishers in the operations area, two in the charging area, two in the makeup area; a 50-lb CO_2 extinguisher is proposed for the makeup area and a water fog nozzle for cell 1.

The maximum energy release in a fire would be 7.11×10^6 Btu, from 25 liters of Amsco.

The probability of fire is deemed slight since there is no spark-producing electrical equipment in the cell and the process is run at room temperature. The probability of containing the results of a fire without serious spread of radioactive material is deemed excellent.

2.3 Evaluation of Noncriticality Event Leading to Release of Radioactive Material

2.3.1 Description of Cell and Vessel Involved in Credible Accident, Bldg. 4507

Vessel name	Feed adjustment tank
Vessel volume	100 liters
VOG purge flow rate	10 scfm
Cell No.	1
Cell volume	660 ft^3
Cell ventilation purge flow rate	100 scfm

	Analysis of Contents* of Vessel	Total Amount Vaporized or Suspended after Accident
Solution density, g/cc	2.0	
Pu^{239}, curies	2.2	7.7×10^{-5} (4.0×10^{-6} curie/m^3)
U^{235}, curies	2.76×10^{-3}	
Th^{232}, curies	6×10^{-4}	
Mixed fp's, curies	36,400	0.570 (0.030 curie/m^3)
I^{131}, curies	0.1	
Kr^{85}, curies	53	

*Based on Consolidated Edison fuel except for plutonium, which is based on Yankee Atomic fuel.

2.3.2 Effects of Accidental Release of Radioactive Material from Maximum Credible Accident

	Mixed fp's	Pu
Vessel Off-gas Release		
Total amount, curies	0.00720	9.7×10^{-7}
Max downwind integrated dose, rem	<0.001	<0.001
Distance downwind of dose, m	1760	1760
Cell Off-gas Release		
Total amount, curies	0.00780	1.1×10^{-6}
Max downwind integrated dose, rem	<0.001	<0.001
Distance downwind of dose, m	1760	1760

	Mixed fp's	Pu
Release into Secondary Containment Zone		
Total amount, curies	3.6×10^{-4}	4.9×10^{-8}
Concentration, curies/m^3	6.9×10^{-7}	9.3×10^{-11}
2-min dose to building personnel, rem	0.012	0.011
Release from Secondary Containment Zone (assuming ventilation system works)		
Total amount, curies	5.7×10^{-6}	7.7×10^{-10}
Max downwind integrated dose, rem	<0.001	<0.001
Distance downwind of max dose, m	150	150
Ground fallout at 20 m, curies/m^2	2.1×10^{-11}	2.8×10^{-15}
Release from Secondary Containment Zone (assuming ventilation system fails)		
Total amount, curies	1.5×10^{-4}	2.0×10^{-8}
Max downwind integrated dose, rem	<0.001	<0.001
Distance downwind of max dose, m	150	150
Ground fallout at 20 m, curies/m^2	5.1×10^{-10}	6.9×10^{-14}

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3.0 PLANT AND PROCESS DESCRIPTION

3.1 Description of Bldg. 4507

Building 4507 is a brick building; the new penthouse structure will be constructed from insulated sheet metal. Vestibule personnel entrances are being provided, and the building is to be sealed against leaks so as to be able to maintain -0.3 in. H_2O pressure with respect to atmosphere. The building and penthouse provide secondary containment for radioactive materials handled. Primary containment is provided by the cell block, which is 44 ft long, 19 ft 6 in. wide, and 22 ft 3 in. high and contains four cells. Each cell has a usable volume that is 10 ft long, 6 ft wide, and 11 ft high, separated from one another by 4-ft-thick concrete walls. The rear wall of the cell block is 5 ft 6 in. thick and the front wall, which has four dense lead-glass windows (one for each cell), is 4-ft-thick special barytes concrete. All openings into the cell are sealed against extraneous leaks, allowing air access to the cell only as planned via the air inlet duct in the rear door (Figs. 2 and 3).

A 6 x 6-ft opening in the rear of each cell is closed by a concrete door that rolls on wheels and track. Access is available to the top of each cell through a 4 x 6-ft opening by removing concrete plugs.

Each cell has two 12-in.-dia sleeves in the operating face for a pair of Model 8 manipulators. Various other openings, ranging in size from the 12-in.-dia opening required for the manipulator to 2 in., are provided to accommodate pipe, tubing, electrical conduit, etc. Specially designed openings are used to admit fuel to and withdraw samples from the cells.

3.2 Process Description

Building 4507 is used for flowsheet development in the Power Reactor Fuel Processing program. Cells 1, 2, and 3 are assigned to work in aqueous processing systems, and cell 4 is assigned to fluoride volatility work. Cell 1 is of primary interest because of probable hazards arising from chemical processing of fissionable and radioactive isotopes.

The IMMI (Intermediate-scale mixer-settler) facility in cell 1 is permanently installed and designed for experimental work in processes that use sulfuric acid or caustic decladding agents and a nitric acid core dissolvent. It is designed for semicontinuous processing at throughput rates that vary from 50 to 200 liters per 24 hr. Type 347 stainless steel and Carpenter-20 were the principal materials of construction employed; unit shielding was used in the design to permit limited direct maintenance, and extensive use of instrumentation facilitates remote operation of the equipment. Figure 4 is an equipment flowsheet and Fig. 5 an equipment layout of the IMMI facility.

The nonpermanent equipment used in cells 2 and 3 is smaller than that of cell 1, which correspondingly limits the degree of radiation and criticality hazard. Cell 2 contains "2-liter scale" glass equipment for Darex feed preparation and miniature mixer-settler solvent extraction. In the Darex head-end treatment, uranium dioxide-stainless steel fuels of the types developed for the

Army Package Power and Yankee Atomic reactors are dissolved in boiling dilute aqua regia (5 M HNO_3-2 M HCl). The chloride is subsequently removed from the dissolved fuel solution by distillation, and the residual nitric acid solution, which contains uranyl nitrate and nitrates of stainless steel, is adjusted for solvent extraction. The uranium and other fissionable material are recovered in purified form in two or more cycles of solvent extraction with tributyl phosphate.

Cell 3 contains "2-liter scale" glass experimental equipment designed for either Sulfex or Darex decladding and feed preparation studies on Consolidated Edison fuel. Other fuel types, such as UO_2 clad in either stainless steel or Zircaloy, may also be accommodated. There are no facilities for solvent extraction in this cell.

Cell 4 is equipped for experiments on the Fused Salt Fluoride Volatility Process now being investigated for uranium-zirconium alloy fuels. Nickel, Inconel, and stainless steel are the principal materials of construction.

3.3 Waste System Description

3.3.1 Cell Ventilation System

A maximum of 1000 scfm may be withdrawn from each cell through a 16 x 24-in. vent at its base which connects to a 30-in.-dia header leading to the 3026 stack. Each vent is equipped with a damper which may be manually adjusted to provide 1 in. H_2O negative pressure inside the sealed cell. Air in the cell will be continuously replaced by air from the secondary containment area through special ducts fitted with absolute filters and backflow preventers located in the rear plug.

The cell exhaust vents and header will not be equipped with filters; rather, the combined cell ventilation air from Bldgs. 4501, 4505, and 4507 will be filtered for radioactive particulate removal before release to the stack. The pressure drop across the filter is to be measured, and the exhaust air monitored for radioactivity.

Alarm instruments for measuring air pressure in each cell are planned. All indicating instruments and alarms associated with the measurement of pressure and radioactivity in the cell ventilating system will be located in the operating area with provision for installing duplicate recording instruments in the corridor connecting Bldgs. 4507 and 4500 at a future date.

3.3.2 Vessel Off-gas System

A 2-in. stainless steel header provides vessel off-gas service for all four cells. Each cell has its own scrubber through which the vessel off-gas must pass before entering the header. The vessel off-gas system is instrumented to sound an alarm when the relative pressure in the header increases over the desired 5 in. of water, negative, or when radioactivity in the header exceeds a pre-established value. Normal gas flow in the header is estimated as less than 10 scfm.

3.3.3 Vacuum System

Vacuum is provided in the smaller experimental installations by water aspirators equipped with surge tanks and de-entrainment vessels. Trapped vacuum pumps are also used, and a central vacuum system for the building is being designed.

3.3.4 Liquid Waste Disposal

There are three liquid waste systems serving Bldg. 4507 (Fig. 6): (a) high-level radioactive waste system, (b) filter-aid slurry collection and storage system, and (c) process cooling water waste system. Liquid radioactive wastes are collected by a 2-in. header, which leaves the east side of Bldg. 4507 and then turns south to connect with the 4-in. header that ties Bldg. 4500 directly to the Liquid Radioactive Waste Tank Farm. Slurry wastes, arising from filter operations in cell 1 that use filter-aid, are sent to a special storage pit south of the building where the solids are permitted to settle. Clear supernatants are permitted to overflow to a second tank and are then jetted to the high-level radioactive waste header. The tank containing the settled solids is replaced periodically with one that is empty. Process cooling water waste, arising from the operation of aspirators, heating jackets, coils, etc. (expected to contain only limited amounts of radioactive materials) leaves each cell via a 2-in. cold drain which ties to a common header exiting from the north side of the building. It continues into Bldg. 4505, passes through a radiation monitoring station, and then connects to a 4-in. process water waste header.

4.0 HAZARD DESCRIPTION

4.1 Amounts of Radiation

Each cell in the IMMI facility, cell 1, will work with 345 to 1190 curies of radioactive material. This is the minimum amount of radioactive materials compatible with the scale of operation and experimental technique contemplated. Larger amounts of radioactive materials may be involved in the fluoride volatility experiments planned for cell 4, but the hazard is judged not to be as great because radioactivity (except for minute quantities of rare gases present) will be locked in the frozen salt. The maximum amounts of fissionable, fertile, and radioactive materials contemplated for use in Bldg. 4507 in the immediate future are:

	Grams	Curies
U^{235}	159	
U^{238}	7070	
U^{233}	18	
Pu	36	
Th	5400	
Gross β, γ fission products		36,400
Sr^{90}		55
Kr^{85}		53
I		<0.1

4.1.1 Radiation Control, General

All radioactive processing is carried on in vessels inside the shielded cell, which is the primary containment enclosure. The surrounding building is the second line of defense, which ensures that any airborne radioactivity that may escape the primary containment will not be scattered to the environment.

All openings into the cell block will be gasketed and sealed to withstand 10 in. H_2O pressure.

Differential air pressures from cell to building to atmosphere are being arranged so that air flow will always be from the clean region to one of potentially greater contamination.

Personnel doors in the secondary containment shell will be of the vestibule type; the monorail door in the charging area and the roll-up door for the gantry crane in the new penthouse are designed to close automatically in an emergency.

A local and a remote manual switch will also be provided to close these doors. All three switch stations also seal off the normal air entry and exhaust ports and open the emergency exhaust to the cell ventilation system.

As a further control over radiation, all incoming air will be filtered through conventional, expendable dust-stop filters. Air passages into the hot cells from the charging area will be provided with absolute filters and backflow preventers. Exhaust air will first pass through absolute filters which will be provided on the change room exhauster and the new penthouse exhauster.

Processing cooling water will be monitored for radioactivity downstream from Bldg. 4507 before it connects with the main discharge header in Bldg. 4505.

The existing waste collection pit on the south side of Bldg. 4507 will be sealed against air leakage and vented to the cell ventilation system.

4.1.2 Personnel Exposure Control

Personnel radiation exposures and radioactive contamination are kept under control by zoning* practices as carried out by Health Physics.

*A "radiation zone" is an area where control measures involve external radiation exposure to personnel. A "contamination zone" is an area where control measures involve contamination of employees, environs, and/or equipment and where there is a possibility that radioactive material may be deposited inside the body leading to internal radiation exposure. A "regulated zone" is an area where operations are restricted for the purpose of radioactive contamination control. This zone may contain radiation zones, contamination zones, or both, ranging in size from a small spot to a large area.

The insides of cells 1, 2, 3, and 4 are designated "contamination zones" all the time and the cell top area and charging area are designated "contamination zones" when conditions warrant. Cells 1, 2, 3, and 4 and the sample storage area are "radiation zones."

Zones are posted with relevant instructions regarding entry, occupancy, and departure. Necessary coveralls, laboratory coats, caps, gloves, shoe covers, masks, etc. are provided for contamination zone operations. Personnel from the Health Physics Division provide necessary radiation monitoring, surface contamination surveys, personnel checks, consultation, etc. required during "hot" operations.

Various radiation monitoring instruments are found in Bldg. 4507, including three direct-radiation gamma detectors (monitrons) of which two are located in the charging area and one in the operating area. Two indirect-radiation beta-gamma, delayed alpha detectors (constant air monitors) are in use, one in the operating area and one in the charging area. Two contamination detectors are in use, a hand and foot counter near the east door and an "octopus" quintector in the change room. Three portable survey instruments (cutie pies and GM survey meters) are also available.

When the current revisions to make Bldg. 4507 safer are completed, there will be three additional monitrons in the operating area, two more in the charging area, and two new ones in the solution makeup area. An a-c powered alpha survey meter is planned for the change room, and an alpha air monitor will be needed if high alpha operations are undertaken in the building.

4.1.3 Emergency Airflow Procedures

In an emergency, all air inlets to the building and the two exhaust exits from the building will be closed and the fans stopped, either automatically or by manually operated switches. The building will then be pulled down to -0.3 in. H_2O, relative to atmospheric, via the cell ventilation system through the ports in the rear cell plugs and via a new normally closed duct that connects the new third level enclosure with the cell ventilation duct.

4.2 Criticality

4.2.1 Quantity of Fissionable Material

The experiments to be conducted in the "hot" cells of Bldg. 4507 will use less than minimum critical mass of fissionable material. The largest amount handled at any one time will be during the processing of Elk River fuel, in which one-fourth an assembly with the following amounts of nuclear materials will be processed:

U^{235}	159 g
U^{238}	12 g
U^{233}	1 g
Th	5,400 g

Each experiment will include fuel dissolution with acid and uranium recovery by solvent extraction. Two such experiments are planned.

There is no criticality hazard in loading the dissolver preparatory to an experiment. Approximately 3.5 kg of U^{235} would be required in the most favorable case to achieve critical mass by stacking together fuel elements of the nondomestic research reactors. After dissolution of this fuel, 1.4 kg of U^{235} in fully reflected solution is considered safe if "mass limitation" techniques are used, according to data in TID-7016, "Nuclear Safety Guide." Experimental batches of nondomestic research reactor fuel will contain only 84 g of U^{235} which is safely below the amount needed to attain criticality.

Though not contemplated at present, experiments in the IMMI facility, cell 1, could be run on high-burnup fuels of the Yankee Atomic type. These will contain 10-20 g of plutonium per kilogram of uranium, which could collect in the plutonium product catch tank until criticality is reached. This will be prevented, however, by strictly limiting the plutonium inventory in cell 1.

4.3 Chemicals

4.3.1 Quantity

The chemical reagents used in Bldg. 4507 are those found in any chemical development laboratory. Table 1 gives the inventory of reagents needed to sustain peak operation of the IMMI facility over a 4-week period.

Table 1. Chemical Inventory for 4-week IMMI Facility Operation

Reagent	Container Size	Normal Inventory
Common mineral acids		
Nitric acid (70%)	7-lb bottle	12 bottles
Sulfuric acid (95%)	9-lb bottle	2 bottles
Oxidizing agents		
Potassium permanganate	1-lb bottle	1 bottle
Sodium dichromate	1-lb bottle	1 bottle
Sodium nitrite	1-lb bottle	1 bottle
Reducing agent		
Ferrous sulfamate	4-liter bottle	1 bottle
Other reagents		
Aluminum nitrate	100-lb drum	1 drum
Sodium hydroxide	5-lb bottle	1 bottle
Sodium carbonate	1-lb bottle	5 bottles
Sodium oxalate	1-lb bottle	1 bottle
Sodium tartrate	1-lb bottle	1 bottle
Gelatin	1-lb bottle	1 bottle
Mercuric nitrate	1/4-lb bottle	1 bottle
Organic solvents		
Tributyl phosphate	5-gal safety can	1 can
Amsco 125-82	55-gal drum	1 drum
Industrial gases		
Nitrogen	2200-ft^3 cylinder	3 cylinders

4.3.2 Control

By restricting the inventory reagents in the building, a degree of control is exercised over the common hazards associated with the storage and handling of these materials. Laboratory quantities of miscellaneous chemical reagents are stored in metal cabinets in the front operating area. Bulk chemicals such as acids and caustic are stored in metal cabinets in the rear operating area. Gas cylinders are restricted to those actually in use in the operating areas; extra cylinders and empties are stored in racks outside the building. Fluorine is piped to cell 4 from a storage tank outside Bldg. 4507.

4.4 Fire and Explosion

4.4.1 Quantity of Flammable and Explosive Material

A number of the experiments proposed for Bldg. 4507 will produce small amounts of hydrogen. Vessels in which it is produced, however, are connected to an off-gas line, where it is immediately diluted with air, far below the explosive limits.

Solvent extraction experiments at ambient temperature are also conducted in two of the cells. Since there are 20 to 60 air changes per hour in these cells, it would be impossible to form an explosive mixture. If a fire should occur in the various mixer-settlers that contain 1.5-8 liters of TBP-Amsco, a fire detection and fog system would be actuated.

4.5 Maximum Credible Accident

The maximum credible accident is conceived to be a fire in the 8 liters of TBP-Amsco-125-82, which may be in the mixer-settlers of cell 1, though it is hard to visualize how such a fire would start considering the cell ventilation and the fact that there are no open flames or spark-producing devices used in the cell. However, if there should be a fire, about 2 liters of aqueous feed solution would be involved out of a total of 80 prepared for the experiment. The maximum β, γ activity contained in the 2 liters, which could become vaporized from the heat, is estimated to be 30 curies in the case of experiments with Elk River fuel. The airborne activity would follow the cell ventilation air where it would be harmlessly collected on filters. A fire detection and fog system will be relied on to control the fire.

The cell 4 volatility system was also investigated from the standpoint of the maximum credible accident, and it was concluded that the most probable occurrence would be a leak in a fused salt vessel (either fluorinator or hydrofluorinator), in which case the escaping fluoride would cause immediate burnout of the Nichrome furnace elements causing the charge to freeze up. Some minor quantities of volatile fission products would escape to the cell ventilation system. The job of cleaning cell 4 itself would be formidable, but no great hazard would be extended to the environment.

Failure to purge the hydrofluorinator of air before introducing hydrogen may result in an explosive mixture and will be guarded against by careful preparation of and adherence to safe operating procedures. However, it is believed that if such an explosion should occur, any resulting damage will be small and confined within the cell.

5.0 GENERAL DESCRIPTION OF OPERATING PROCEDURES

5.1 Routine

5.1.1 Process Operations

Although the "hot" cell operations conducted at Bldg. 4507 are basically experimental in nature, certain routine procedures are followed to ensure safe, efficient operations and reliable experimental results. Normally, a limited number of runs are planned, which will consume a small quantity of fuel specimens of a specific type and known irradiation history. Operating instructions are written by the scientist supervising the operation to enable the operator (technician) to perform the work in a safe, competent manner. These instructions also provide a detailed record of the experimental procedure as originally conceived. As the work progresses, all the experimental manipulations, observations, and unusual happenings are logged in a bound notebook. Usually, unforeseen incidents or deviations from the planned procedures are dealt with by the scientist-technician team. Under normal circumstances, the group leader, building supervisor, and other responsible persons are consulted before the planned procedure is altered.

5.1.2 Methods of Handling Fuel Specimens

Irradiated fuel specimens from various power and test reactors at ORNL and other sites are procured for use in the experimental programs. In addition, special prototype fuels are fabricated, tested for structural stability, and irradiated under closely controlled conditions in various high-flux test reactors such as the ORR, MTR, and NRX. After discharge from the reactor and sufficient aging to permit decay of short-lived radioelements, the fuel specimens are transferred to the Chemical Development canal and storage garden in sealed watertight metal containers inside lead-shielded carriers. The containers may be stored for indefinite periods in the canal with 10 ft of water shielding or in dry capped wells 12 ft deep. Fuel specimens that have been sectioned, resulting in exposed core material, are placed in polyethylene bottles, which are stored in the watertight containers to provide double containment. The precaution is not necessary with specimens whose cladding is known to be intact.

As the need arises, fuel containers are transported individually from the storage area in a lead-shielded carrier specially designed for either top or bottom loading and unloading of the container. At Bldg. 4507 the carrier is moved to the top of the cell block and positioned over a 7-in.-dia access hole leading vertically through the roof plug into the cell. (All access holes into the cells are to be sealed except during loading and unloading of radioactive materials.) The bottom plug is removed from the carrier and the fuel container is lowered into the cell by a stainless steel cable and reel. The container is detached from the cable which is then withdrawn from the cell. Manipulators are used to open the container with a special wrench, and the contents are removed.

Generally, the same equipment and procedure are used to remove and transport highly radioactive liquid samples from the "hot" cell to the High Level Analytical Facility in Bldg. 3019. Nominal 5- to 10-ml samples from the process are sealed in polyethylene bottles, placed in an enclosed container having racks to accommodate from 8 to 16 bottles, and withdrawn from the cell into the shielded carrier. This same procedure is used for transfer of radioactive material from one cell to another.

5.1.3 Housekeeping

It is generally recognized that good housekeeping is a first line of defense against the hazards of contamination and radiation. During day-to-day operations, good housekeeping affords protection to operating and maintenance personnel against accidental exposure. If an incident does occur that releases large amounts of radioactive material to the nonradioactive operating areas, the task of confinement and decontamination is substantially reduced if the building and environs have been maintained in a clean, orderly state.

Listed below are good housekeeping practices observed in Bldg. 4507 during normal operation. During periods of extensive construction or accidental contamination, these procedures cannot, of necessity, be rigidly followed.

5.1.4 Nonradioactive Operating Areas and Change Area

At three-month intervals, walls, beams, cabinets, lighting fixtures, piping, etc. are vacuumed and washed to remove accumulated dust and stains. Floors are swept, washed, and waxed weekly. On special occasions extra manpower is obtained to clean large floor areas when these areas become more than ordinarily soiled.

5.1.5 Front Operating Area

The operating groups keep all equipment associated with their individual cell in a clean and orderly fashion. They are also responsible for the auxiliary area occupied by their operation, including hoods and sink and bench space. Specifically, the floor is kept uncluttered from electrical wiring, piping, glassware, sample carriers, etc. to facilitate cleaning. Bench tops and hood floors are covered with blotting paper, which is changed weekly. Extra gas cylinders are stored in racks provided outside the building. Only a minimum, necessary supply is carried, and empties are returned promptly. Inventories of chemicals, beyond that needed for the day's work, are stored in the rear operating area, second floor. No contaminated equipment or material of any kind is stored in the front operating area. Any contamination which occurs in this area is removed as soon as possible; contaminated equipment that cannot be moved is immediately masked with polyethylene film.

5.1.6 Rear Operating Areas

The same practices recommended for the front operating area also apply to the rear operating areas, first and second floors, with some modifications. Small items of lightly contaminated equipment, properly bagged in polyethylene, may be stored in the rear operating area until they can be decontaminated. After gas masks are used in a contaminated area, they are washed with soap, water, and brush, checked by Health Physics, and returned to storage. Several 20-gal yellow cans with lids are provided in the rear operating area. These are intended as receptacles for dry contaminated material which accumulates during entry of a "hot" cell. These cans are fitted with polyethylene bag liners. When cell entry is completed, the bag liners are sealed before the cans are carried to the dumpster. After disposal of the bagged contents in the dumpster, the cans are returned to the building and fitted with clean liners. In the rear operating areas, metal cabinets are provided for storage of miscellaneous supplies.

5.1.7 Roof Area

Plugs that seal the access holes in the roof are assumed to be contaminated. When these plugs must be removed, they are bagged and sealed in polyethylene film before storage. The same procedure is followed when any structural members, tools, materials, etc. are withdrawn from the cells. All carriers that arrive at Bldg. 4507 have previously been checked for surface contamination at the pick-up point by Health Physics. Nevertheless, the carrier or any part thereof is placed on disposable blotting paper wherever it is set down at Bldg. 4507. After being emptied, carriers are monitored for beta and gamma radiation before they are removed from the building. All tools, equipment, materials, and protective clothing used in roof operations are removed from this area after completion of the operation. Surfaces that become accidentally contaminated are washed and surveyed by Health Physics. Particular care is exercised during transfer of radioactive liquids via the roof area. Batch transfers and analytical samples are handled only in plastic, screw-cap bottles. Special transfers of radioactive material are sometimes accomplished by vacuum, steam jetting, or gravity after careful review and approval by supervision of the proposed transfer.

5.2 Nonroutine

5.2.1 New Chemical Flowsheets

During tests with new chemical flowsheets, the procedures outlined in Sect. 5.1.1 are followed; however, certain extra precautions are taken since operating personnel are usually unfamiliar with the new system. Operators first become acquainted with the mechanical features of the system when they assemble the various components on a portable steel rack located in a nonradioactive area. After assembly, the equipment is checked for mechanical operability with manipulators in a special "hot" cell mockup. Next, the system is transported and installed in a "hot" cell, previously decontaminated to allow direct maintenance. This installation is directly supervised by the operating personnel.

When the installation is completed, a series of shakedown runs with unirradiated, prototype fuel are performed which serve to: (a) establish the mechanical operability of the remotely manipulated equipment in the hot cell,

(b) determine the chemical operability of the new flowsheet under "hot" cell conditions, (c) provide further opportunity to detect unforeseen hazards in time to eliminate them, and (d) further familiarize the operators with all aspects of the system. When the series of test runs is completed with satisfactory results, the "hot" cell is sealed and charged with a batch of radioactive fuel specimens (Sect. 5.1.2).

5.2.2 Procedure for Entry to "Hot" Cells

The interiors of "hot" cells 1, 2, 3, and 4 have been designated "contamination and radiation zones" according to the rules and regulations contained in Sect. 4.0 of the ORNL Health Physics Manual, ORNL CF-59-4-46.

Prior to entry into the cells all sources of radiation must be decreased to the lowest practical limit. The cell interior must be surveyed by Health Physics and exposure time limits established prior to entry. Radiation exposure of personnel entering the cells is controlled by the Health Physics surveyor in attendance during the operation.

Personnel entering the cells wear direct-reading radiation monitoring instruments and protective clothing, including "C" zone coveralls, shoes, shoe covers, gloves, hats, and gas masks or respirators. Suitable aids, such as blotting paper, plastic film and bags, "hot" cans, etc. are provided to prevent the spread of contamination outside the cell. All tools, apparatus, and other material removed from the cell are checked for radiation and surface contamination before re-use or disposal.

Individuals leaving the cell are monitored by Health Physics in the controlled area behind the cell. Here, contaminated clothing is removed and deposited in "hot" cans. Upon completion of the operation, the area is surveyed by Health Physics for contamination and radiation.

5.2.3 Decontamination of Equipment

Occasions arise when a "hot" cell must be entered for a brief period to perform minor maintenance on the equipment. Before attempting this, the radiation and contamination levels inside the cell are drastically reduced. Waste solutions are discarded via the hot drains, and certain solutions are salvaged for future use by withdrawal into shielded containers. Unused fuel specimens may be either stored temporarily in the shielded transfer drawer or withdrawn into a shielded carrier atop the cell block. Using a manipulator-operated radiation monitor, the equipment components and cell interior are checked for isolated spots of high activity. Where possible, highly radioactive pieces of equipment are detached and removed from the cell. Hot spots are frequently found in the stainless steel tray underneath the equipment. This contamination is eliminated by scrubbing the tray with dilute nitric acid and water, the wash solutions being discharged to the "hot" drain. Glass or stainless steel equipment that cannot be readily detached and removed from the cell is treated with a series of decontaminating reagents to remove residual activity.

5.2.4 Equipment Removal and Cell Decontamination

At the end of an experimental program when the cell equipment must be dismantled and removed to provide space for a new experimental system, the procedure outlined in Sect. 5.2.3 is used. Cell entry is made and the system is rapidly disconnected from all services and outside lines. The system may then be removed from the cell via the rear plug door or through the roof. Before removal, it is sheathed in polyethylene film to contain any particulate contamination which might be lost during transport. After removal, it may be partially salvaged to recover special equipment, the rest being sent to the burial ground.

With all equipment removed, the cell interior is ready for complete decontamination and the walls and floor are scrubbed with detergent solution, which is carefully flushed into the "hot" floor drain with water. Three or more such treatments are sometimes needed to reduce residual activity to 30 d/min α and/or 1000 d/min β, γ over a 100-cm^2 area as determined by Health Physics smear counting. When this specification is met, the cell is ready for maintenance operations.

6.0 EMERGENCY PROCEDURES

The features designed into the ventilation system to prevent radioactive contamination of the environment outside 4507 were discussed in Sect. 4.1.1. If significant radioactive material released should be in the secondary containment shell, standard personnel evacuation procedures go into effect coincident with turning in an emergency alarm to fire headquarters. One person is assigned to check the building during such emergency to ensure that all persons have left.

DISTRIBUTION

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