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

OAK RIDGE NATIONAL LABORATORY LIBRARY
3 4456 0024523 2

ORNL-TM-753, Rev.

48

ISOTOPES DEVELOPMENT CENTER

HAZARDS REPORT FOR BUILDING 3517

FISSION PRODUCTS DEVELOPMENT LABORATORY

C.L. Ottinger
R.W. Schaich

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report. The information is not to be abstracted, reprinted or otherwise given public dissemination without the approval of the ORNL patent branch, Legal and Information Control Department.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

ORNL-TM-753
Revised

Contract No. W-7405-eng-26

ISOTOPES DEVELOPMENT CENTER

HAZARDS REPORT FOR BUILDING 3517

FISSION PRODUCTS DEVELOPMENT LABORATORY

C. L. Ottinger
R. W. Schaich

Isotopes Division

FEBRUARY 1965

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

OAK RIDGE NATIONAL LABORATORY LIBRARY
3 4456 0024523 2

CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and Uses	1
Location of Facility	1
Building Description	3
Personnel Control	3
Process Description	6
Criticality	6
Liquid Waste System	6
Gaseous Waste Systems	6
Monitoring System	7
Instrumentation	7
Sampling	10
Summary	10
Radioactive Material Capacity	10
Criticality Incident Potential	10
Explosion and Fire Potential	10
Maximum Credible Accident	11
Pilot Plant Operations	12
Radiation and Contamination Control	12
Physical Plant Description	12
Building Description	12
Cell Descriptions	12
Process Services to Cells	14
Process Equipment	14
Auxiliary Equipment	14
Containment	16
Cell Containment	16
Building Containment	16
Chemical Processes	17
Precipitations	18
Crystallization	18
Solvent Extraction	19
Evaporation	19
Decantation	19
Manipulator Cells	19
Process Operations	20
Operating Safeguards	20

Page

Personnel Protection 21

Personnel Exposure 21
Exposure Possibilities 22
Radiation and Contamination Controls 22

Waste Disposal 26

Liquid Waste 26
Gaseous Waste 27
Solid Waste 29

Process Hazards Review 30

Radioactive Gas Release 30
Gas Formation and Pressurization 31
Decontamination Hazards 33
Explosion 34
Fire 36
Maximum Credible Accident 37

Appendix No. 1, FPDL Process Equipment 41

Appendix No. 2, FPDL Chemical Processes 43

Cesium-137 43
Strontium-90 44
Cerium-144 45
Waste Processing 46
Americium-241 46

Appendix No. 3, Hazards Report for STT, Model II 51

Introduction 51
Summary 51
Discussion 52

HAZARDS REPORT FOR BUILDING 3517
FISSION PRODUCTS DEVELOPMENT LABORATORY

C. L. Ottinger
R. W. Schaich

ABSTRACT

A review of the hazards associated with the operation of the Fission Products Development Laboratory (Building 3517) is presented. The physical facilities, chemical operations, and operating procedures for the plant are described. Analysis is made of the maximum credible accident involving fire in radioisotope processing. It is shown that the primary and secondary containment features of the facility are adequate to reduce radioisotope contamination external to the building to permissible levels in the event of the maximum credible accident.

INTRODUCTION

Purpose and Uses

The Fission Products Development Laboratory (FPDL) is used to recover long-lived fission products from aqueous waste, to purify and pelletize feed materials which have been previously separated into chemical groups at other AEC production sites, and to test new procedures for fission product source fabrication.

The FPDL facilities are unique in their ability to process or test a wide range of radiochemical processes and to produce beta or gamma sources in the multikilocurie range. The cell arrangement and piping design permit the operation of at least three processes at the same time without cross contamination. The facility is also unique in its ability to receive feed materials as solutions, solids, or absorbed on ion exchange beds and to process these materials to any form of product the consumer may desire.

Location of Facility

The FPDL is located at Oak Ridge National Laboratory near the corner of Third Street and White Oak Avenue (Fig. 1). It is centrally located with respect to the ORNL liquid waste disposal system, gaseous waste disposal system and radiochemical analytical facilities. The location is also isolated from the reactor areas and main research buildings in the event of a reactor incident or an incident involving the FPDL plant. Its

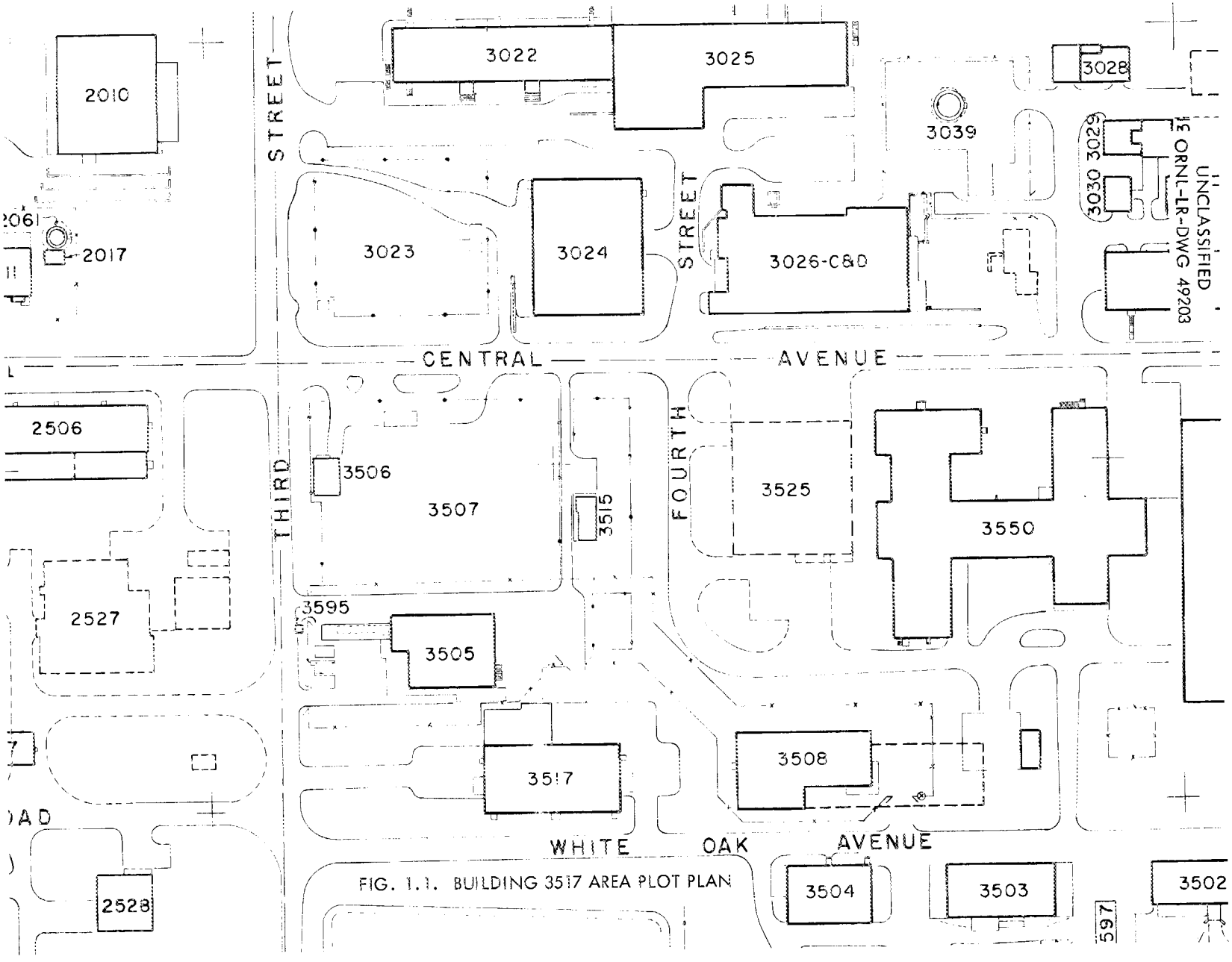

FIG. 1.1. BUILDING 3517 AREA PLOT PLAN

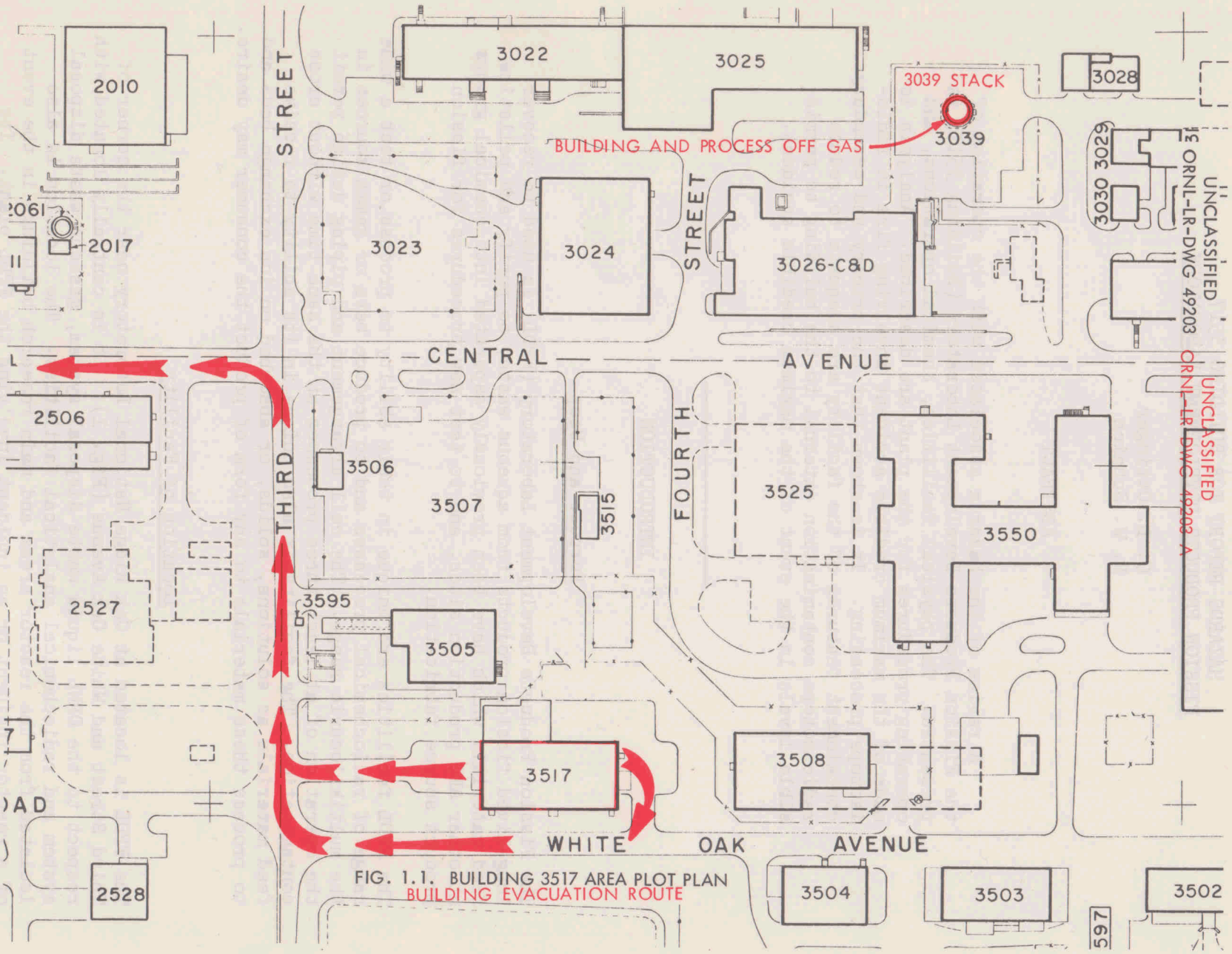

FIG. 1.1. BUILDING 3517 AREA PLOT PLAN
BUILDING EVACUATION ROUTE

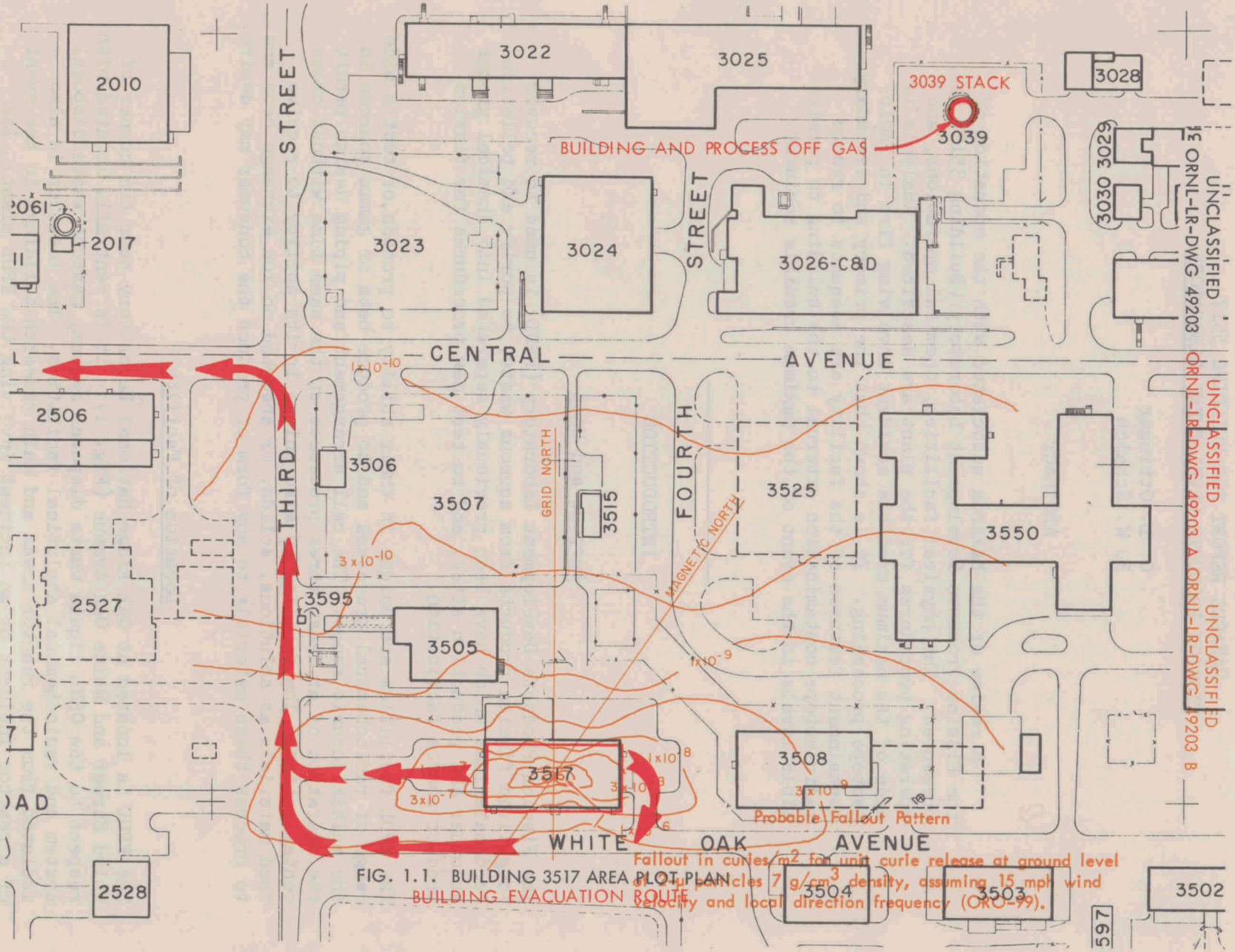

FIG. 1.1. BUILDING 3517 AREA PLOT PLAN

relation to nearby facilities in terms of distance and amounts of radioactivity normally processed is given in Table 1.

Table 1. Relation of Building 3517 to Nearby Facilities

Bldg. No.	Name	Distance		Activity inventory, curies	Type of activity
		Feet	Direction		
3517	Fission Product Development Laboratory	--	--	10.6×10^6	Fission products
3508	Isolation Laboratory	125	East	Gram amounts	Transuranic elements
3505	Metal Recovery Plant	20	North	$<10^3$	^{95}Zr-^{95}Nb, ^{106}Ru
2528	Thorium Oxide Plant	260	West	Negligible	ThO_2
	Tank Farm	175	North	3×10^8	Fission products
2519	Steam Plant	575	West	None	None
3504	Waste Disposal Lab.	140	East	10^{-3}	Fission products

Building Description

The FPDL building, a concrete block and corrugated aluminum sided structure, covers 7,700 ft^2 of area and contains 376,000 ft^3 of free space.

The main cell block consists of ten chemical process cells and six manipulator cells constructed of massive concrete walls (Fig. 2). Three additional manipulator cells are connected to the cell blocks (Figs. 2 and 3), and four concrete cells are located underground on the north side of the building (Fig. 2). Additional low-level cells are available for off-gas scrubbers, services, and decontamination (Fig. 2). As indicated on Figs. 2 and 3, the cells form the primary containment and the building walls are sealed to form the secondary containment barrier. All entrances to the building are by way of air locks.

Personnel Control

The number of people normally occupying Building 3517 and adjacent facilities are:

UNCLASSIFIED
ORNL-LR-Dwg. 49136

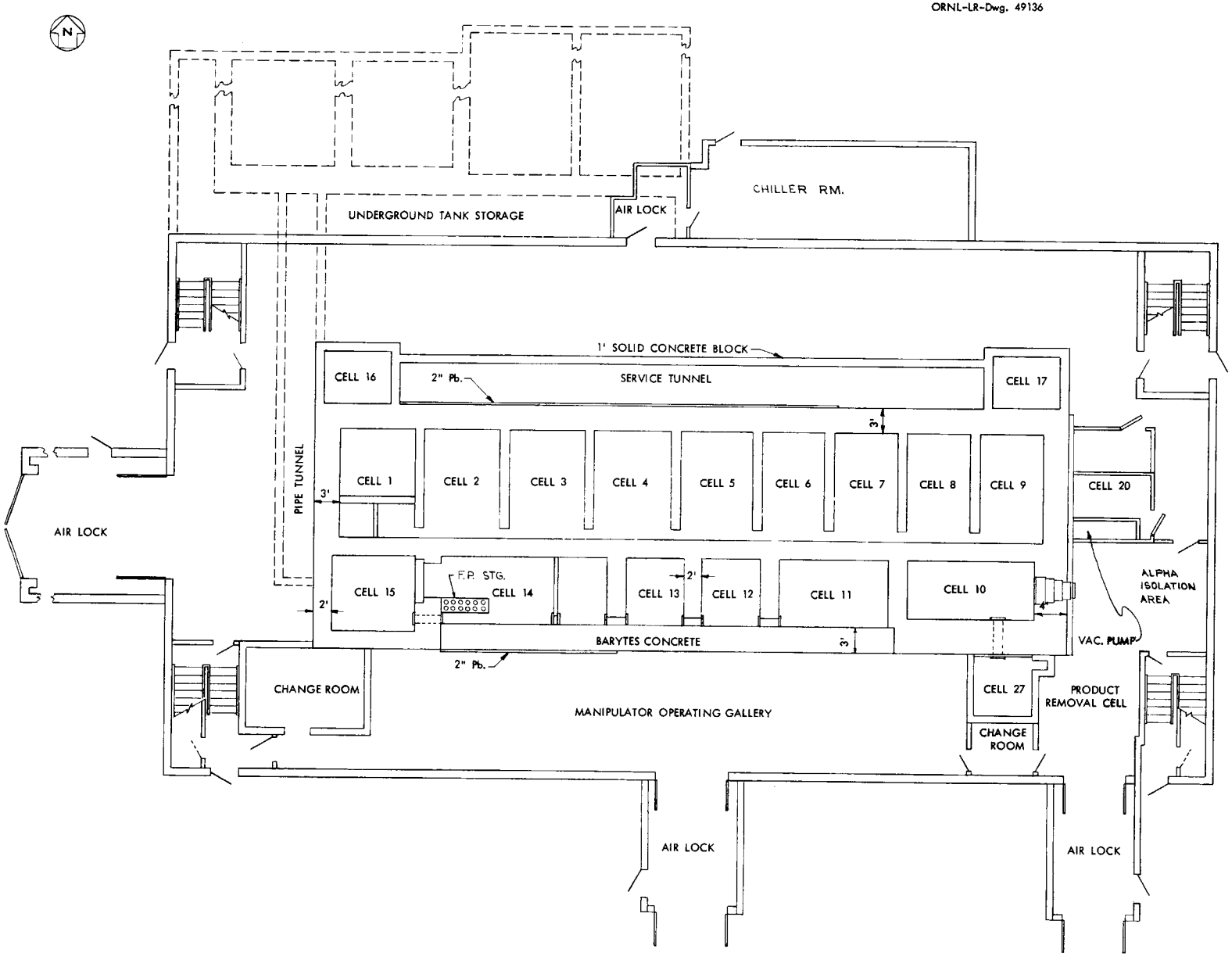

FIG. 1.2. BUILDING 3517 FIRST FLOOR PLAN

UNCLASSIFIED
ORNL-LR-Dwg. 49136

UNCLASSIFIED
ORNL-LR-Dwg. 49136 B

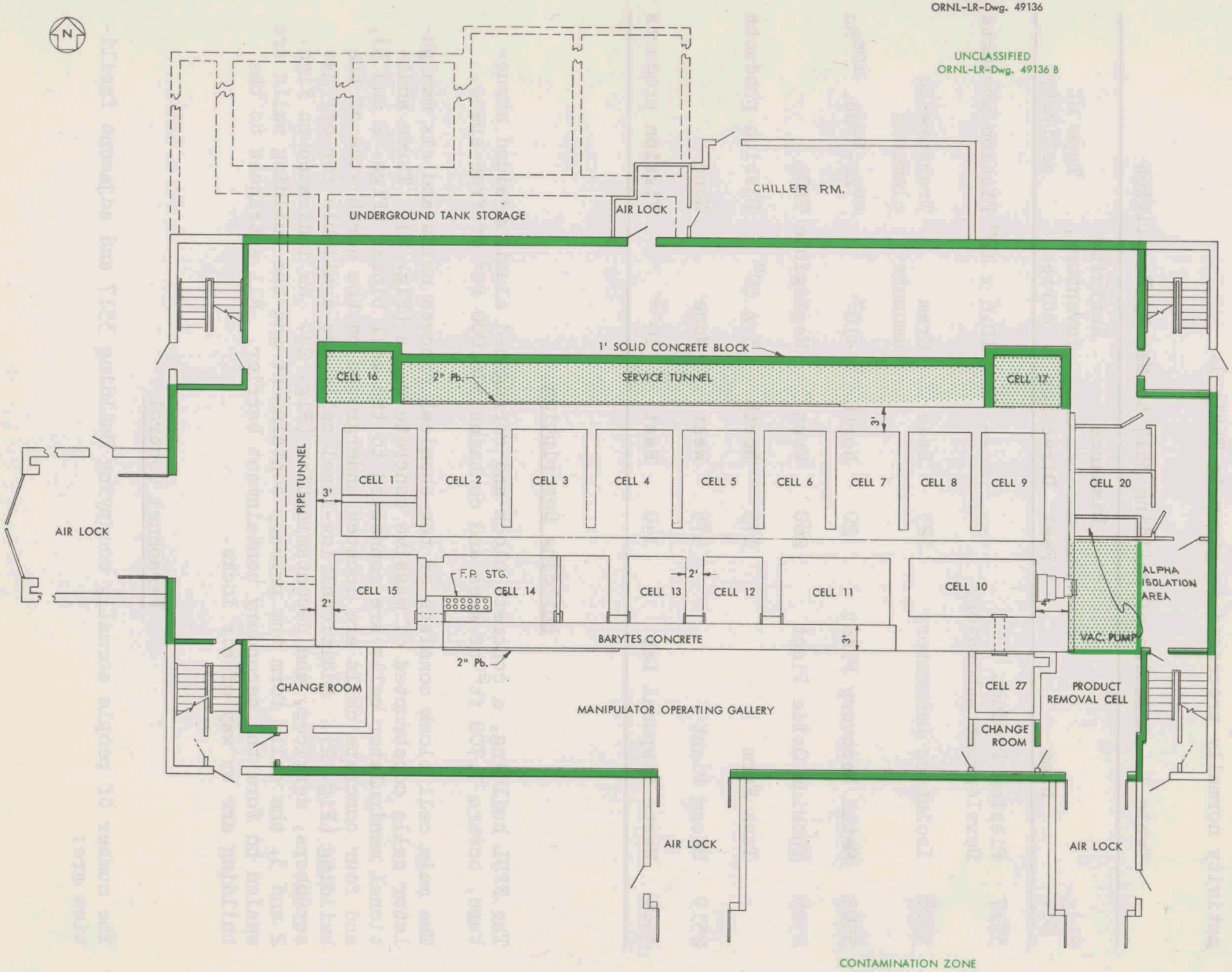

FIG. 1.2. BUILDING 3517 FIRST FLOOR PLAN

LIMITS OF SECONDARY CONTAINMENT

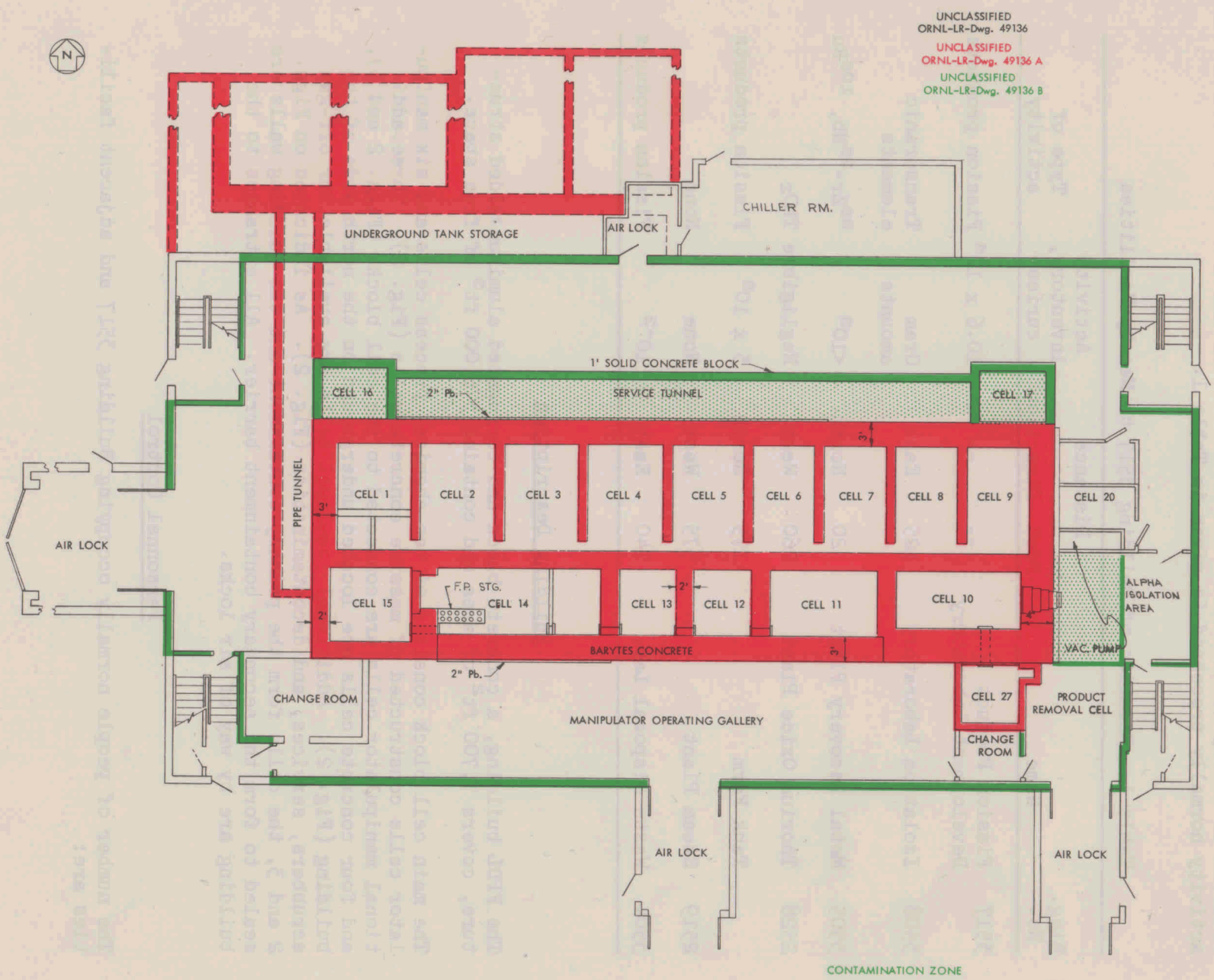

FIG. 1.2. BUILDING 3517 FIRST FLOOR PLAN

LIMITS OF PRIMARY CONTAINMENT

LIMITS OF SECONDARY CONTAINMENT

UNCLASSIFIED
ORNL-LR-Dwg. 49137

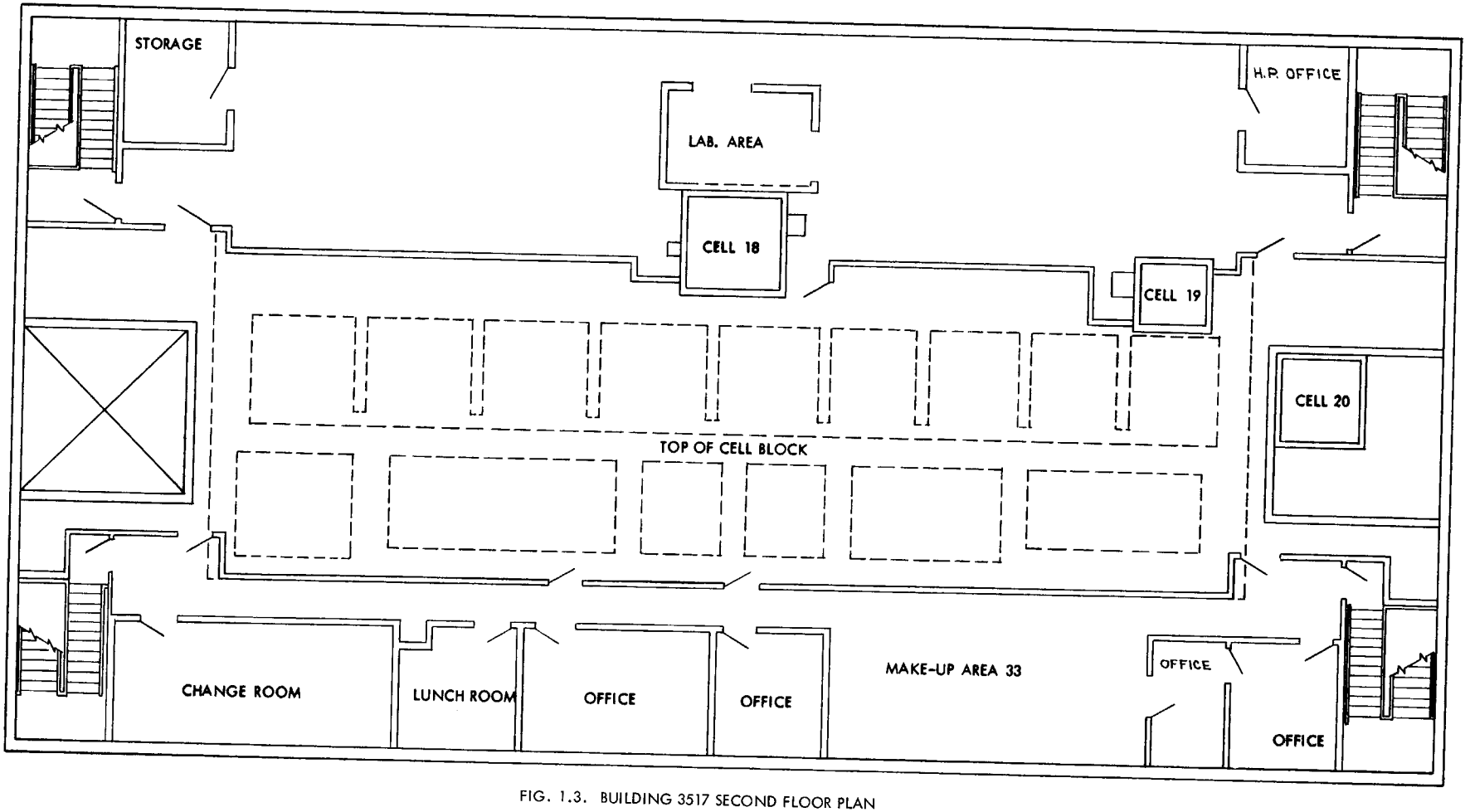

FIG. 1.3. BUILDING 3517 SECOND FLOOR PLAN

UNCLASSIFIED
ORNL-LR-Dwg. 49137
UNCLASSIFIED
ORNL-LR-Dwg. 49137 A

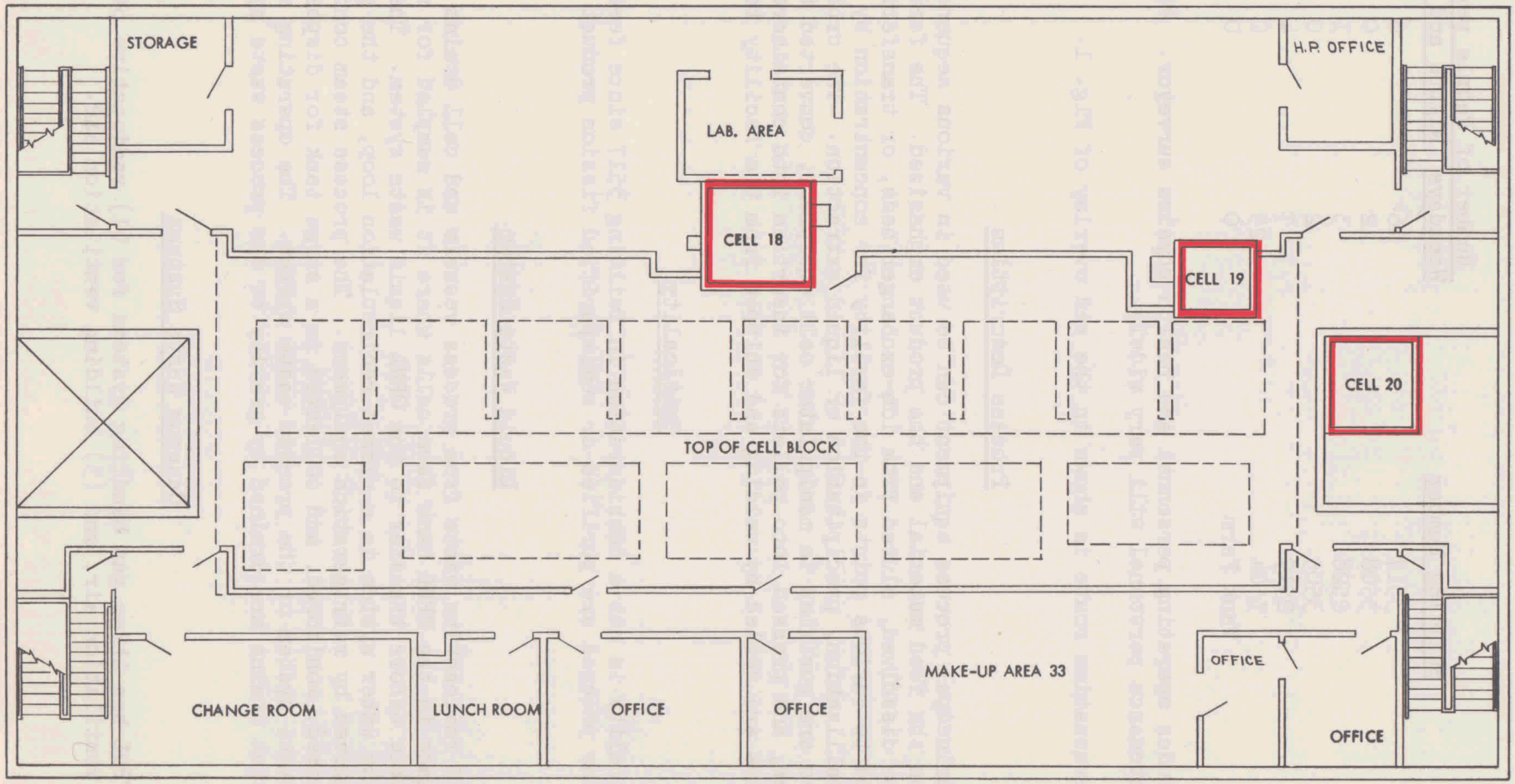

FIG. 1.3. BUILDING 3517 SECOND FLOOR PLAN

LIMITS OF PRIMARY CONTAINMENT

UNCLASSIFIED
ORNL-LR-Dwg. 49137
UNCLASSIFIED
ORNL-LR-Dwg. 49137 A
UNCLASSIFIED
ORNL-LR-Dwg. 49137 B

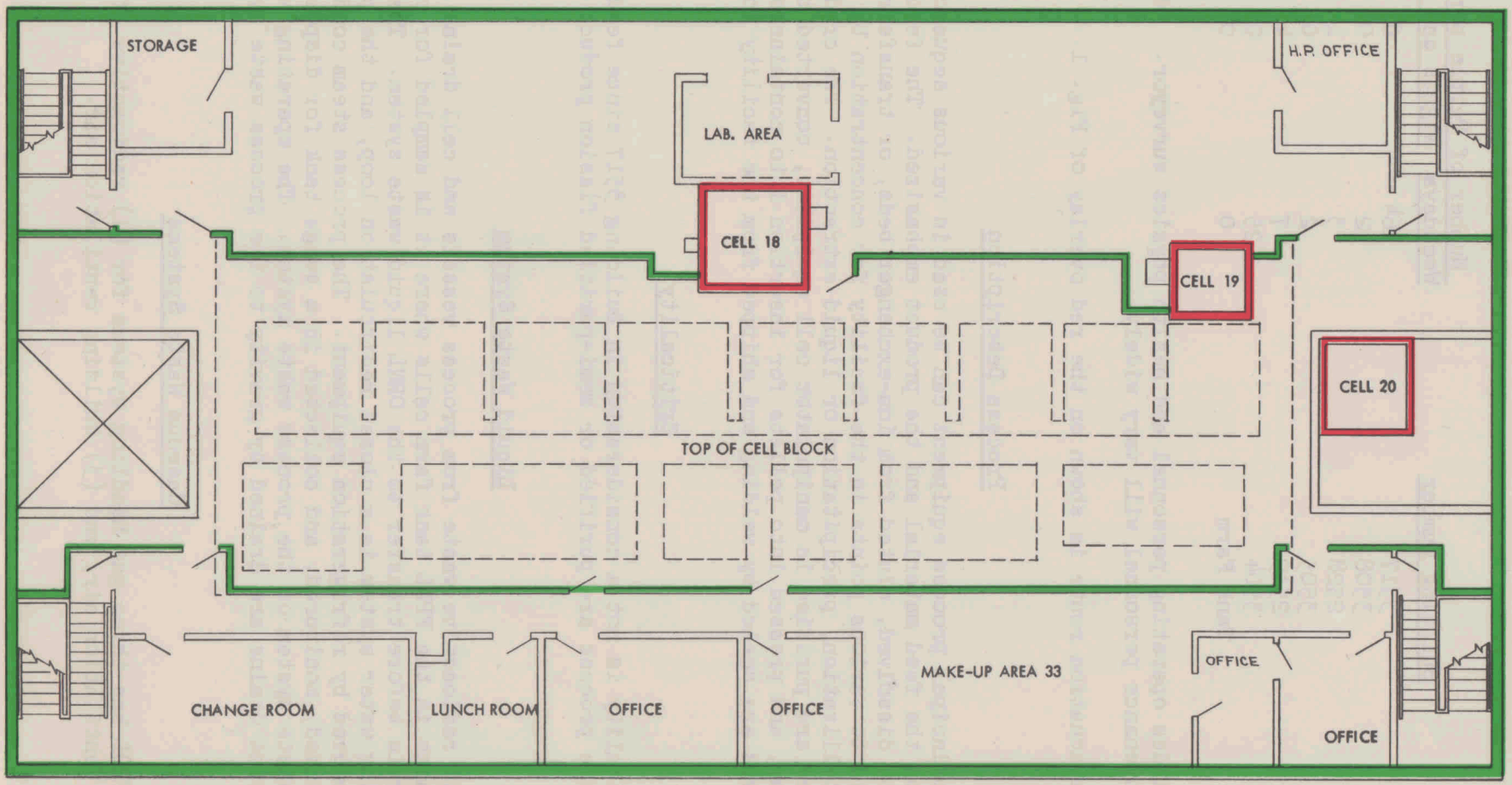

FIG. 1.3. BUILDING 3517 SECOND FLOOR PLAN

LIMITS OF SECONDARY CONTAINMENT

LIMITS OF PRIMARY CONTAINMENT

Building Number	Number of People per Shift	
	Weekdays	Nights and Weekends
3517	16*	6
3508	12	0
2528	3	1
3505	2	0
2519	7	4
3504	25	0
Tank Farm	0	0

*Includes operating personnel and health physics surveyor. Additional maintenance personnel will vary widely.

The evacuation route is shown on the red overlay of Fig. 1.

Process Description

The principal process equipment can be used in various sequences depending on the feed material and the product emphasized. The feed material can be dissolved, eluted from ion-exchanger beds, or transferred as a liquid to various points in the facility for concentration by evaporation, crystallization, precipitation or liquid extraction. The crude concentrates are purified in manipulator cell equipment, converted to a dried powder, and pressed into pellets for insertion into containers. The containers are sealed by welding and shipped from the facility to the customer.

Criticality

Criticality is not a consideration in Building 3517 since feed materials for the process are purified or semi-purified fission product fractions.

Liquid Waste System

Liquid radioactive waste from process vessels and cell drains is collected in tanks in the FPDL tank farm cells where it is sampled for radiochemical analysis before transfer to the ORNL liquid waste system. The process cooling water system is a closed recirculation loop, and the process heat is removed by refrigeration equipment. The process steam condensate is condensed, monitored, and collected in a surge tank for disposal to the hot waste system or the process waste system. The operating area floor and sink drains are drained by gravity to the process waste system.

Gaseous Waste Systems

The FPDL has three gas handling systems for (1) radioactive off-gas, (2) cell ventilation air, and (3) building ventilation air.

The radioactive off-gas system handles the gases and vapors from each process vessel and maintains the vessels at a negative pressure with respect to the cells. The individual lines are manifolded to form a single header which discharges through a scrubber system consisting of two packed column type scrubbers operated in series. The usual scrubber sequence is chilled 2 N H_3PO_4 followed by chilled 4 N NaOH. Other combinations of scrubber solutions can be used if necessary to control the gases produced by certain reactions. The scrubber solutions are recirculated through the scrubbers and are changed routinely; the used scrubber solutions are discharged to the hot waste system. The gases pass from the second scrubber through a heater, a stainless steel roughing filter and an absolute filter; they are monitored as they are discharged to the ORNL gaseous waste system. This system has a maximum capacity of 1,000 cfm and operates normally at 400 cfm.

The cell ventilation system maintains the cells at a negative pressure with respect to the building. Individual ducts from each cell are manifolded and combined at the underground filter pit. The gas passes through stainless steel roughing filters and absolute filters and is monitored as it is discharged into the ORNL gaseous waste system. The capacity of this system is 12,000 cfm and the normal throughput is 6,000 cfm.

The building ventilation system provides air for personnel and the air to the cell ventilation system. Air is pulled into the building through roughing filters and absolute filters. The quantity of air is regulated to equal the air being removed by the cell ventilation system. If the building air becomes contaminated, a supplementary inlet connecting the building to the cell ventilation system opens automatically and rapidly exhausts the building air to the ORNL gaseous waste system. Figs. 4 and 5 show the paths of building air during normal and emergency conditions.

Monitoring System

The continuous air monitors and radiation monitors for the facility are indicated on Figs. 4 and 5. Continuous activity samplers are located on the off-gas discharge, cell ventilation discharge, and steam condensate drain systems.

Instrumentation

Process vessels are operated from graphic panelboards. The panelboard controls send pneumatic or electrical signals to secondary pneumatic relays located in the service tunnel or in service cubicles. The secondary relay system operates the in-cell devices. Temperatures, pressures, liquid levels, specific gravities, noise monitors, and motor speeds are indicated on the panelboards. Low cell ventilation, low off-gas, low steam pressure, and low water pressure are indicated by an air horn alarm as are high building radiation, high radiation in the cell ventilation system, and high process waste activities.

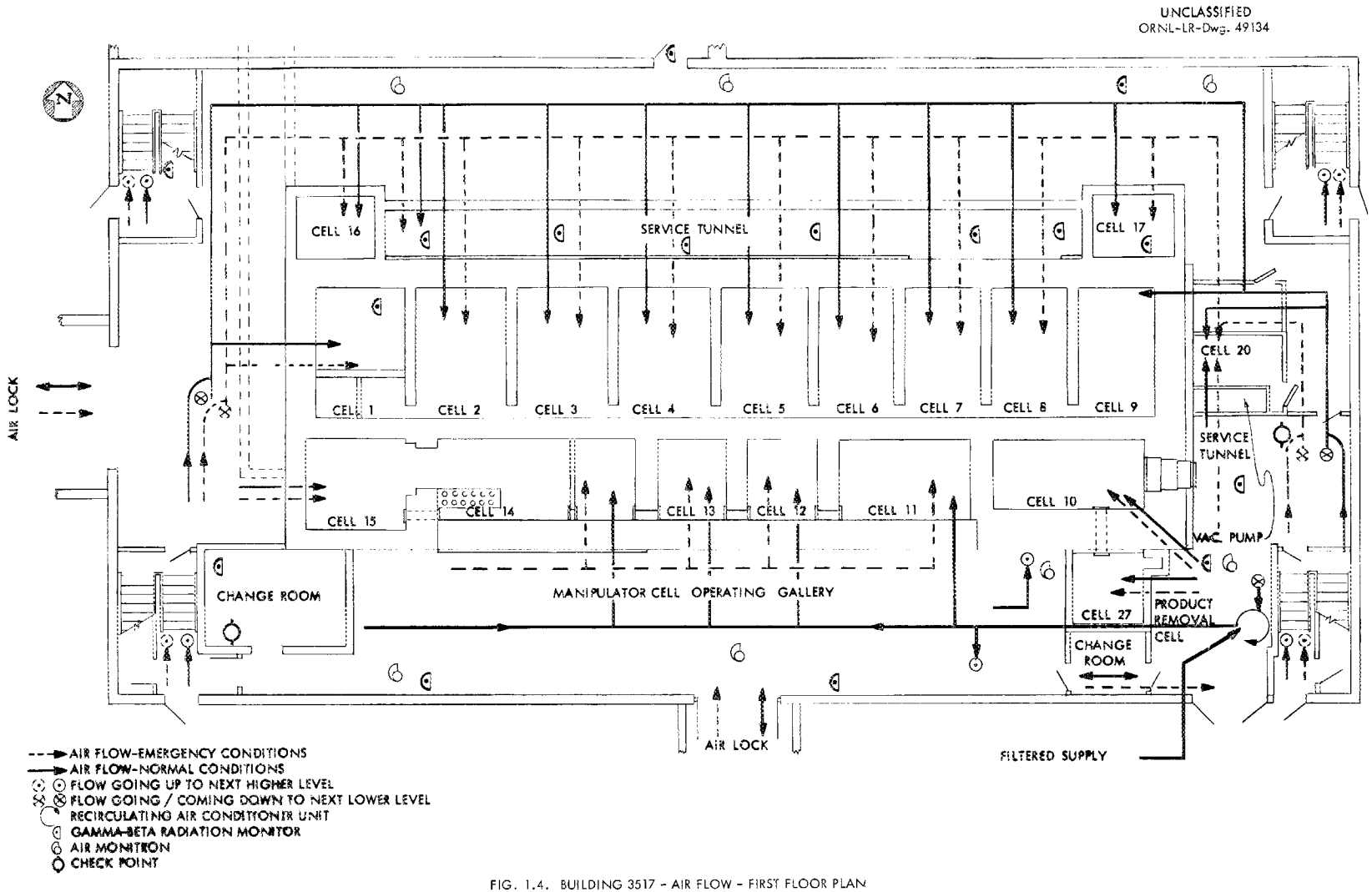

FIG. 1.4. BUILDING 3517 - AIR FLOW - FIRST FLOOR PLAN

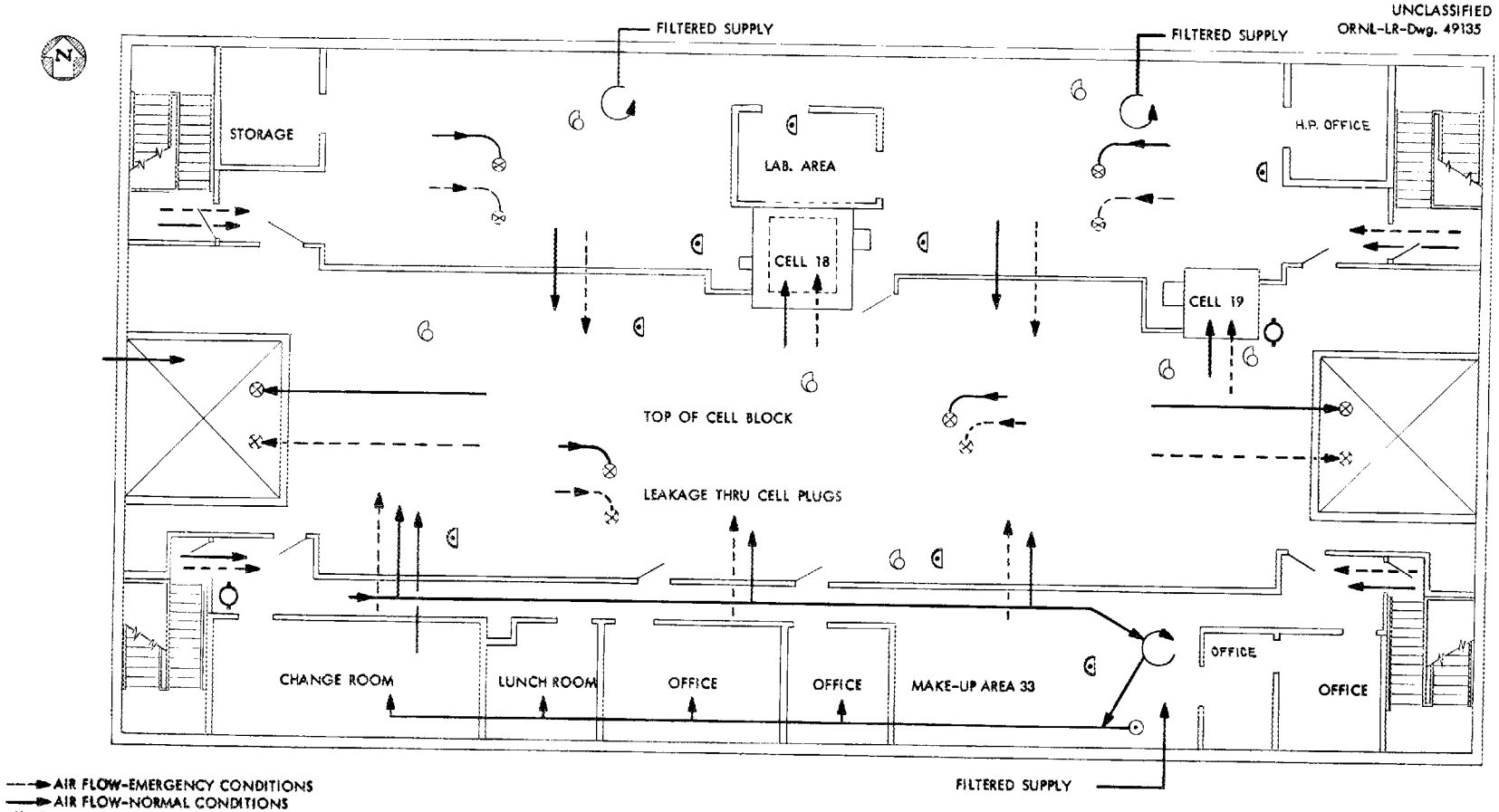

FIG. 1.5. BUILDING 3517 - AIR FLOW - SECOND FLOOR PLAN

Sampling

The various fission product samples removed from process vessels or manipulator equipment are obtained by steam jets for solutions and by manipulator operations for powders. All sampling is accomplished in manipulator cells, with the exception of samples taken from the FPDL tank farm cells which are pulled into a special shielded sample station. Samples that require analysis at other locations are removed from the cells in bottom-loading shielded sample carriers which minimize personnel exposures.

SUMMARY

Radioactive Material Capacity

The plant capacity for the radioactive materials which are processed is shown in Table 2.

Table 2. Plant Capacity for Radioactive Materials

Material	Design capacity, curies/year	Maximum plant inventory, curies	Maximum vessel inventory, curies
Total fission products	5.5×10^6	10.6×10^6	5.0×10^5
Cerium-144	2.0×10^6	1.5×10^6	5.0×10^5
Strontium-90*	2.0×10^6	6.0×10^6	5.0×10^5
Promethium-147	5.0×10^5	1.5×10^5	1.5×10^5
Cesium-137	1.0×10^6	3.0×10^6	2.5×10^5
Americium-241	300 g	150 g	50 g

*$^{89}Sr/^{90}Sr$ ratio could be as high as 5/1.

Criticality Incident Potential

Criticality is not considered a credible event in the FPDL under present operating conditions since the feed materials being processed are semi-purified fractions of ^{137}Cs, ^{90}Sr, and rare earths.

Explosion and Fire Potential

The combustible or explosive materials used in the FPDL are Amsco, di(2-ethylhexyl)phosphoric acid (D2EHPA), hydrazine, ammonia, and hydrogen.

Possible reactions are: (1) ignition of a mixture of Amsco and D2EHPA; (2) reaction of 42.5% hydrazine with 12 N HNO_3 to form hydrazine nitrate followed by drying and heating of the product beyond its decomposition point; or (3) combusion of ammonia or hydrogen in air.

The maximum inventory of organics in the plant will be 450 lb of 1 M D2EHPA in Amsco, with a maximum of 150 lb of this mixture in a single vessel. The most volatile component, Amsco, has a potential energy release of 19,000 btu/lb and a flash-point of 132°F (open cup). Preventive measures against fire or explosion in cells containing organics include the use of explosion-proof equipment and an automatic water spray system supplied by the Gamewell system and actuated by rate-of-temperature-rise detection instruments.

Hydrogen occurs as a result of radiolytic decomposition of aqueous mixtures and is diluted well below its lower explosion limit of 4% by the vessel off-gas. Air-borne ammonia gas is sparged into acid solutions at a flow rate of 0.5 cfm, and ~95% of the gas is absorbed. Even if the entire flow should not be absorbed, the normal vessel off-gas would dilute the ammonia concentration to below the explosive limit of 16%.

The hydrazine-nitric acid reaction would involve the accidental addition of 12 liters of 42.5% hydrazine to 36 liters of 12 N HNO_3 to form 15,150 g of hydrazine nitrate. The potential energy release from hydrazine nitrate is 1,090 cal/g by thermodynamic calculation.

A comparison of some of the potential energy releases discussed above is given below; the potential energy release of 3 lb of TNT is included. The explosion of 3 lb of TNT will release ~100 ft^3 of gas or the equivalent of a 1 min exhaust from an individual cell.

Substance	Specific potential energy release, btu/lb	Maximum weight involved, lb	Total potential energy release, btu
TNT	6,520	3	19,500
Amsco	19,000	150	2.9×10^6
Hydrazine nitrate	1,960	33.5	65,600

Maximum Credible Accident

The maximum credible operational accident at the FPDL is considered to be the accidental release, ignition, and burning of a flammable solvent containing ^{144}Ce. A discussion of an accident of this type and its results is given in the section "Process Hazards Review".

Pilot Plant Operations

The FPDL is a development laboratory and must adjust its procedures and equipment to handle the varying types of feed that are received as well as to demonstrate different processes for final purification of separated materials. A committee has been set up in the Isotopes Division to review all chemical process changes in the production of radioisotopes and to issue hazards reports when appropriate.

Radiation and Contamination Control

The FPDL equipment for controlling the release of radioactive materials to the environment is designed for an absolute minimum discharge under normal operating conditions. In the event of an uncontrolled release of either gaseous or liquid activity, the facility is designed to contain the activity within the building.

The shielding and operating procedures provide protection for the operating personnel at a level of <50% of the allowable tolerances. The shielding permits the processing of fission products that have been aged as little as six months.

PHYSICAL PLANT DESCRIPTION

Building Description

The Fission Products Development Laboratory (FPDL) is located on White Oak Avenue between Third and Fourth Streets and is bounded on the northwest by Building 3505 (Metal Recovery), on the south by the waste disposal equalization pond, and on the east by Building 3508 (Transuranium Lab).

The building structure is two-story, standard concrete-block siding with an aluminum sided crane bay forming the third level. The building encloses 7,700 ft^2 of floor space and contains a total of 376,000 ft^3 of free space.

Cell Descriptions

The cells at the FPDL are divided into several categories and their characteristics are shown in Table 3.

Nine cells have personnel access doors which are entered via the cell door interlock system described under the section "Personnel Protection". All other cells are entered through sealed blocks or manholes. Of the ten access doors only those located on process control cells 18, 19, and 27 enter into normal high-level radiation fields. These doors are locked and sealed as soon as operations begin and are not entered until

Table 3. Fission Products Development Laboratory Cell Descriptions

Cell number	Cell type	Liner	Minimum equivalent standard concrete shielding, ft	Maximum external radiation, mr/hr	Process
1	Process	S.S.	3	<1	Feed unloading
2	Process	S.S.	4.5	<1	Solution transfer
3	Process	S.S.	4.5	<1	^{90}Sr evaporation and storage
4	Process	S.S.	4.5	<1	^{90}Sr evaporation and storage
5	Process	S.S.	4.5	<1	^{137}Cs processing
6	Process	S.S.	4.5	<1	^{137}Cs processing
7	Process	S.S.	4	<1	^{137}Cs crystallization
8	Process	S.S.	4	<1	^{137}Cs crystallization
9	Process	S.S.	4.5	<1	R.E. solvent extraction
10	Process	S.S.	4	<1	None
20	Process	S.S.	1	<1	Off-gas scrubbing
11	Manipulator	S.S.	4	<5	^{90}Sr or ^{144}Ce processing
12	Manipulator	S.S.	4	<5	^{90}Sr or ^{144}Ce processing
13	Manipulator	S.S.	4	<5	^{137}Cs purification
14E	Manipulator	S.S.	4.5	<1	^{137}Cs or ^{144}Ce processing
14W	Manipulator	S.S.	4.5	<1	^{137}Cs or ^{144}Ce processing
18	Manipulator	S.S.	1.5	<1	Process control
19	Manipulator	S.S.	2	<1	Process control
27	Manipulator	Epoxy	0.5	<1	Source fabrication
15	Loading	S.S.	2	<1	Feed and product loading
16	Decontamination	Amercoat	1	<1	Small equipment decontamination
17	Service	Amercoat	1	<1	Cell 9 services
Tunnel	Service	Amercoat	1	<1	Process cell services
21	Tank Farm	Amercoat	4	<1	Fission product storage
22	Tank Farm	Amercoat	4	<1	^{137}Cs feed storage
23	Tank Farm	Amercoat	2	<1	Waste storage
24	Tank Farm	Amercoat	2.5	<1	Waste storage
25	Tank Farm	Amercoat	2.5	<1	Hot pipe tunnel
26	Tank Farm	Amercoat	2.5	<1	Hot pipe tunnel
Filter Pit --		Amercoat	1.5	<10	Cell ventilation filters

decontamination proceedings have started. The entry to these cells is controlled by the Procedure for Personnel Entry to FPDL Cells.[1]

Process Services to Cells

The services to the various cells are listed in Table 4.

Table 4. Fission Products Development Laboratory Cell Services

Cell number	Steam, 30 and 65 psi	Chilled water	Vacuum	Distilled water	NH_3, 25 psi	Air	440 v, AC	30 v, DC	110 v, AC
1	X	X			X				X
2, 3, 4, and 5	X	X			X		X	X	X
6	X	X							
7 and 8	X	X							X
9	X	X			X		X	X	
10	X	X			X		X		X
11	X	X	X	X	X	X	X		X
12, 13, 14E, 14W, and 27	X	X	X	X		X	X		X
18 and 19	X	X	X	X					X
21 and 22	X	X							
23 and 24	X	X					X		

Process Equipment

See Appendix No. 1

Auxiliary Equipment

The chilled water system consists of two chiller units with a combined capacity of 130 tons and a pumped chilled water recirculation system to all vessels and condensers. The compressor system is cooled by a water recirculation system through a forced air cooling tower.

The building vacuum system is supplied by a two-stage Hy-Tor vacuum pump which has a recirculating water cooling system that drains to hot waste. A caustic scrubber and surge tank are located inside the manipulator cells to prevent the accidental entrainment of radioactive solutions from the ^{137}Cs purification equipment into the vacuum system.

Six 500-gal shielded transfer tanks (see Appendix 2) lined with stainless steel are used for the shipment of ^{137}Cs feed from other sites to ORNL and for the transfer of low-level product solutions within ORNL. These tanks, weighing ~20 tons, are equipped with valved Snaptite connections and thermal liquid-level probes. Five of these vessels are loaded with one ton (~400 gal wet volume) each of "Decalso", an inorganic ion exchange material.

Four stainless steel shielded filter casks[2,3] are used for the shipment of dry $^{90}SrCO_3$ or mixed rare earth double sulfates from other sites to ORNL.

An open-air solvent storage shed is located ~60 ft from the northeast corner of the FPDL building. The normal storage capacity is ten 55-gal drums of di(2-ethylhexyl)phosphoric acid and three 55-gal drums of Amsco. All solvent is transferred in safety cans directly to the process solution addition funnel. No solvent is stored in the FPDL building.

A caustic make-up and nitric storage area located in an open area on the north side of the building is used for transfer and storage of 400 gal of concentrated nitric acid and the makeup and storage of 1500 gal of 19 M caustic. The acid and caustic are pumped through separate systems to the second level storage tanks for process addition.

Three chemical makeup and storage areas are located on the second level of the FPDL building; all process chemicals are added to the cell equipment from these tanks. No makeup or storage tank is connected directly to a process solution addition line. Each tank drains through a separate hose system which is connected to a solution addition funnel at the time of the transfer. The total maximum storage capacity is 210 gal of 60% HNO_3, 55 gal of fuming HNO_3, and 400 gal of 19 M caustic.

A 2000-gal stainless steel tank trailer is used for delivery of 8 M NH_4NO_3 solution from Y-12. This solution is pumped to the makeup area for dilution and the diluted solution is used for elution of ^{137}Cs from STT's. A 1200-gal storage tank adjacent to the solvent storage shed is used for storage of 8 M NH_4NO_3.

A phosphoric acid station is located at the east of the building for pumping and storage of phosphoric acid for the off-gas scrubber.

A nitrogen gas storage system installed outside the northwest corner of the building has a capacity of 12,000 ft^3 at 1000 psi. The system will be used for forming inert blankets during fission product source fabrication operations needing this protection. The nitrogen supply is piped directly to Cell 14 and is connected remotely to the equipment.

All radioactive process solutions are transferred by steam jets or air lifts with the exception of the solvent waste pump located in area 27. Lapp pulsafeeder pumps can be used to pump feed from the storage tanks to E-16 evaporator or solutions for dissolving ^{90}Sr or ^{144}Ce from filter slurry casks.

A bank of six 6-volt standard wet cell batteries is located on the outside north wall of the service tunnel to supply an emergency source of DC voltage to the braking circuit of the centrifuges in case of a power failure. An automatic charging system keeps the batteries at full charge. The batteries also supply power to the emergency evacuation siren.

CONTAINMENT

Cell Containment

The containment of radioactivity in the FPDL cells is accomplished by sealing all roof plugs with oakum and G-K compound and the access doors with a sealing compound. In order to prevent their blowing out in the event of an explosion, all access plug holes are welded on the inside of the cells and the plugs are locked in position on the outside face of the cells. The cell ventilation air intake ducts are filtered by FG-25 roughing filters and have a backflow preventer installed to prevent a blowback of activity.

In those cells requiring manipulator operations, the arms are sealed on the inside of the cell with a vinyl-impregnated nylon bagging which protects the arm from contamination and effectively seals the manipulator arm opening into the cell. The master end of the arm is sealed on the inside by wipers which makes a double seal on the manipulator opening into a cell.

All spare lines into the cells are capped on the inside and the outside of the cell walls.

Building Containment

The FPDL structure satisfies the requirements for containment of a radioactive release as specified by the ORNL Radiation Safety and Control Department.

All personnel entrances have air locks provided by enclosing the stairwells and requiring a separate entrance to the first and second floor operating area. The loading areas, which are air locked on the outside of the building, are of sufficient size to allow the largest piece of equipment used to enter the structure. The west air lock permits a 44-ft tractor-trailer to enter the building to unload carriers and equipment. The doors are operated by a controller system that allows only one entrance door to be open at a time. The south air locks permit manipulators,

fork lifts, and other small equipment to enter the manipulator cell area and are operated on the same principle as the west air lock. An air lock has been constructed over the north personnel entrance and encloses the tank farm sampling station.

To minimize air leakage into the building, all doors are gasketed, and the building structure has been treated with polyvinyl chloride and silicone membrane.

Interior partitions are provided to enclose all operating areas, and mechanical cooling is installed for personnel comfort. The crane bay area which houses the top of the cells is partitioned from the operating areas and is ventilated by a filtered air supply system.

All air is exhausted from the building by the cell ventilation system during normal and emergency conditions. The building air supply is limited to the cell ventilation exhaust capacity. The building air supply to the three normally occupied areas enters through a pre-filter and absolute filter bank located on the south side of the west air lock and furnishes the makeup air to the packaged type air conditioners. The supply air then passes from these areas into the cells and out through the cell ventilation exhaust system.

In the event of an accidental release of activity into the building interior from the cells, all building openings are closed automatically. The exhaust duct in Cell 20, which is partially open at all times, is thrown to the full-open position and the interior of the building is exhausted to a vacuum of 0.5 in. w.g. The signal that actuates the automatic devices comes from a Hi-Vol constant air monitoring system in the building or from manual switches located in various areas of the building.

The exhaust duct in Cell 20 is equipped with pneumatically regulated dampers which will maintain the building vacuum at least 0.5 in. w.g. above the vacuum in the cells. Building collapse by an excessive vacuum is prevented by a gravity balanced damper which is set to admit filtered air into the contained building space before the danger point is reached.

The makeup area tanks are exhausted by the hot off-gas system, and the fumes from this source are scrubbed by the off-gas scrubber system.

CHEMICAL PROCESSES

The unit chemical processes which can be carried out in the process cells of the FPDL are precipitation, crystallization, and solvent extraction. Operations such as evaporation, decantation, filtration, centrifugation and dissolution can be done in various cells. In the manipulator cells, almost any chemical process can be set up in relatively small equipment.

Precipitations

Precipitation-Centrifugation

In four of the process cells, precipitations can be made and the precipitate separated from the supernate by centrifugation at 1100G force and a maximum hold-up time of 13 min. Equipment in the cells permits controlled heating and cooling, reflux digestions, and control of the centrifugation rate.

The precipitation cells can be operated either in series, with the supernate from one precipitation being transferred to the next cell for further processing, or as independent units, permitting repeated precipitation, dissolution, and reprecipitation within the same cell. Tanks are available for storage of various fractions during the process.

Precipitation-Filtration

Three precipitators in the plant are equipped with stainless steel filter vessels. In the Cell 9 precipitator, precipitations and filtrations are made and the filter cake is dissolved for transfer to other tankage or to transfer casks for removal from the building. This filter vessel is equipped with a coil for heating or cooling and has a capacity of 1 gal of solids. The 54-gal precipitator can handle activity levels up to 50,000 curies.

The other filter vessels and precipitators are installed in manipulator cells (Cells 11 and 14E). The filters can be disconnected remotely for visual inspection of the precipitate, controlled dissolution, or mechanical removal as desired. These precipitators have a volume of 32 gal and the filter vessels have capacities of ~1 gal of solids.

Crystallization

Two 450-gal and two 125-gal crystallizers are installed in Cells 7 and 8. These vessels are provided with heating and cooling coils, solids addition funnels, and sampling devices for determination of crystal volume. Crystallization temperatures as low as 5°C can be reached. Separation of the crystals from the supernate is performed by decantation and filtration. The crystallizers are interconnected so that repeated crystallizations can be made to achieve crystal volume reduction or concentration. After reduction of a crystal bed to a low volume, the crystals are dissolved and transferred to the manipulator cells for final purification.

Certain types of crystallizations can be done in the precipitator vessels. Strontium nitrate has been crystallized from concentrated nitric acid by the addition of fuming nitric acid. The crystals were separated by centrifugation, washed with fuming nitric acid, and dissolved in water. The existing equipment could be adapted to perform many different crystallizations if desired.

Solvent Extraction

Batch Solvent Extraction

The batch solvent extraction cell (Cell 9) contains two contactors of 66-gal capacity each. Controlled agitation, interface determination devices, samplers, and specific gravity instruments allow close control of the process. Hold-up tanks, transfer vessels, and piping make possible repeated extraction, washing, and back-extraction. This cell can be used to extract contaminants from the process stream or to concentrate fission products for purification. Batches of 50,000 curies of ^{144}Ce have been separated from ^{147}Pm and the associated mixed rare earths by oxidation of the cerium to Ce(IV) and its extraction into the organic phase.

Evaporation

Large-scale evaporations can be carried out in a steam-heated evaporator (E-16) having a 690-gal capacity and an evaporation rate of 50 gal/hr. This evaporator can be used for concentration of feed or side streams to provide enriched solutions for processing. Certain of the precipitator vessels are designed to operate as evaporators and can be used for reflux digestions.

Decantation

One of the process crystallizers and one precipitator can be used for processes where decantation of the supernate is appropriate. These vessels are fitted with fixed-position decant legs at ~50% of the tank volume; changes in the position of the decant legs would involve minor piping changes. Decantation in all cases is done by steam jetting.

Manipulator Cells

Many chemical operations can be set up in five of the manipulator cells by using standard laboratory glassware and equipment or specially designed apparatus. These five manipulator cells can be entered only by removing the top shielding blocks; therefore, extensive or intricate installations require complete decontamination of the cell. However, small items of equipment may be transferred to and from the cells by means of a dolly and track which runs the length of the cells. Airlocks in the walls between the cells minimize the chances of cross-contamination. Samples and chemicals addition can be handled by the dolly also. A sixth manipulator cell is set up to handle transfers of shielded carriers.

The manipulator cells available for processing are Cells 11, 12, 13, 14E, and 14W. Cell 11 is a combination processing and manipulator cell which contains a permanently installed precipitator with removable filter, two hold-up tanks, and a furnace for calcining of powder, as well as a

work area for manipulator operations. Solids handling is done in Cell 12 which is equipped with a balance, a pellet press, and associated equipment for powder work. Final purification of ^{137}Cs is done in the glass crystallizer equipment in Cell 13. Cells 14E and 14W are used for cesium-glass processing, storage of products, final source fabrication, and welding of containers. Three shielded wells are used for storage of solid products in stainless steel cans; these wells are cooled by chilled water. Cell 14W has two viewing windows and two sets of manipulators; all other manipulator cells have one window and one set of manipulators. The manipulator cells are supplied with normal laboratory services such as steam, water, electrical outlets and off-gas connections.

Three other manipulator cells, Cells 18, 19, and 27, are in use at the FPDL. Cells 18 and 19 are primarily sampling cells used for process control. Sample lines from various tanks in the process cells terminate in the sampling cells. The samples can then be transferred to the analytical laboratories or operations such as pH measurements, titrations, and precipitate volume determinations can be made in the sampling cells.

Investigational work can also be done directly on the process solution in the sampling cells. Cell 27, used for the pelletization and encapsulation of ^{241}Am, operates independently of the other cells and has a separate back-entry door and transfer station. Insertion and removal of equipment, products, and samples may be performed in this cell without transfer through other manipulator cells.

The operating area at the entrance to Cell 27 is held at 0.3-in. w.g. vacuum and is monitored by an alpha constant air monitor. Access to this area is through air locks which also serve as zone portals for the checking of personnel and equipment for alpha contamination. Solid waste from Cell 27 is removed through the transfer station using alpha bag-out techniques.

With proper design and installation of equipment, almost any laboratory-scale chemical process can be adapted to manipulator cell operation. The size of the operation is limited by the work space available in the cell and will normally be limited to volumes of a few liters. In most cases involving long-lived fission products, the batch size is limited by the bulk of material rather than by radiation. A standard batch of $^{137}CsCl$, for example, represents 50,000 curies activity and about 2 kg of powder. Single batches of ^{144}Ce containing 50,000 curies have been processed.

Process Operations

See Appendix No. 2.

Operating Safeguards

The process operations at FPDL are accomplished by standard operating procedures,[1] and any deletion, omission or addition to these procedures

without approval of the building supervisor is considered grounds for disciplinary action. The usual chemical plant safety practices are followed, and specially applicable regulations are published.

The operators follow a standard operating procedure book located at the panelboard and record critical data on process data sheets which are filed for each batch processed. The batch data sheets are used for inventory control as well as a check system on the actual operations. These sheets remain in the inventory control board until all analyses have been received and several batches have been combined for further purification. The completed sheets are then filed for future reference.

Changes in operating procedures must be made because of varying conditions of the feed material. The changes are reviewed by the building supervisor and other appropriate personnel and approved by the Division Radiation Safety Officer. If a procedure change is approved, the operating procedure at the panelboard is corrected and written notification is recorded by the building supervisor in the "FPDL Instructions Log."

Decontamination operations vary depending on the equipment involved, but a standard decontamination solution procedure is used to prevent the faulty mixing of chemicals used during this period. The flow of the decontamination solutions is determined by the building supervisor; all jets and valves leading to critical areas are blocked and tagged at the panelboards.

Shift tank inventories and shift checks are taken each shift, and the recorded data are studied by the incoming supervisor to assure continuity of operations. Additional data are recorded in the Operations Log Book by each shift supervisor for a written record of all operations at the FPDL. The log books when completed are filed for future reference.

A building check sheet is filled out once a day to record the data on the building services and auxiliary equipment. All stored chemicals used in the process are regularly inventoried.

PERSONNEL PROTECTION

Personnel Exposure

The period from January 1, 1959, to January 1, 1963, is representative of the typical radiation problems encountered at FPDL. This period covered normal operations on solutions containing from 5 curies/liter to 15,000 curies/liter and included decontaminations of the plant facilities. This period also included exposure from emergency work performed for Operations Division. The exposure from normal operations during the four year period averages 22.6 mr (Dp) per week per operating man. The following data were calculated from the health physics exposure data for 1959-1962:

Personnel	Average Weekly Dosage (mr/wk Dp) 1959	1960	1961	1962
Chemical Operators	18.7	19.4	13.8	38.5
Supervision	16.5	13.5	5.2	18.5

Exposure Possibilities

The largest source of exposure will come from decontamination work or accidental release of contamination. The decontamination work exposure is organized under standard procedures as listed in the Zoning Procedure for the FPDL[1] and the Procedure for Personnel Entry to FPDL Cells.[1]

All samples and solid waste material are removed from the manipulator cells into a shielded carrier which has no greater reading than 200 mr/hr at contact. The normal exposure for this type of work would be less than 10 mr/manweek.

Entrance into hot cells by access door is controlled by the building supervision through the interlock system and has to be approved by a Health Physics representative. Entrance by way of the top of the cells is controlled by Health Physics through the Zoning Procedure for the FPDL and Procedure for Personnel Entry to FPDL Cells.

Radiation and Contamination Controls

Radiation Monitrons

Twenty-two radiation monitrons are located at strategic points in the building, and ten Victoreen monitors are located in the service tunnels for personnel protection during maintenance operations (Figs. 4 and 5). All monitors are connected to a central alarm and panelboard system which is answered by supervision and Health Physics when the alarm signal is sounded. Monitors are also equipped with local alarms to notify personnel of hazardous conditions. All monitor units are checked daily for operation.

Constant Air Monitors

Three portable beta-gamma monitors and one alpha constant air monitor with local and central alarms are located in selected areas (Figs. 4 and 5). A unit is always available for movement to take direct readings during decontamination and maintenance work. One air monitor station is located on the south wall of the manipulator cell area and is used to actuate the outer door interlock system. If a masking tolerance air count is recorded on this air monitor, it will ring a local alarm and lock all the outside entrance doors. In case the building floors are contaminated, supervision can activate the outer door lock system by throwing a manual switch. All doors can be unlocked by pushing the normal crash-bar hardware from inside. The constant air monitors are checked for operation daily; the outside entrance door interlock is checked on a weekly basis.

Radiation Detection Equipment

Victoreens and cutie pies are located in strategic sections of the building and all operating personnel are trained in the use of these instruments.

Personnel are required to check themselves using a hand and foot counter located adjacent to the locker room before entering the lunch room or leaving the building area. Probes are also available at all personnel exits for checking for contamination.

A Health Physics office is manned on the day shift and contains an alpha smear counter, a beta-gamma smear counter, high-level radiation probes, portable disc air samplers, Hi-Vol air samplers, and additional cutie pies and Victoreens. All operating personnel are trained in the use of this equipment.

Containment Hi-Vol Detection System

Twelve Hi-Vol air samplers, equipped with Geiger tubes, are located at strategic points throughout the building (Figs. 4 and 5). These units are located ~8 ft from the floor level and are adjusted to an air flow of 20 scfm. The alarm and containment settings on these instruments are set for a collection of 1.8×10^{-2} mc of ^{90}Sr. With two exceptions, these units are connected so that a 2-out-of-2 coincidence alarm is necessary to activate the containment system. The detector in the manipulator operating area and the one in the Cell 27 access area will activate containment if either of these alarms.

Central Control Panel

A central panel which shows the condition of all monitrons, CAM's and Hi-Vol detectors and includes signals for alarm, out-of-service and normal conditions is located in the supervisors' office on the second level. Also located in this office is the containment control panel which includes alarms, reset switches, fan start and stop controls, and outer door locking circuits.

Emergency Equipment

Emergency combat mask cabinets are located in the operating areas for immediate use in case of a high air count in the building. Individual gas masks with prescription safety glasses have been issued to personnel who must have prescription glasses for vision while wearing the masks.

Emergency cabinets are located in the west and south air locks and contain an air line mask system, plastic suits, rubber suits, chem-ox gas masks, gloves, safety lines, lanterns, and hard hats.

An emergency evacuation procedure is posted in the building and all personnel have been informed of their duties and procedure.

Cell Door Interlock System

The service tunnels, Cell 20, and the Cell 15 loading station are protected by a cell door interlock system. The Cell 15 system consists of an electrical lock system on the cell door entrance, a pneumatic lock system on the shield between Cell 14W and Cell 15, and a manual bar lock on the Cell 15 roof plug. A special padlock is used on the Cell 15 door in case of electric failure on normal switches. The building supervisors have possession of the key for this lock. The system is designed so that it is impossible for personnel to be in Cell 15 without supervision present when the shield or the loading station door between Cell 14W and Cell 15 is raised. If the Cell 14W shield is raised, the Cell 15 block cannot be opened and the Cell 15 personnel access door is electrically locked. To enter Cell 15 would require the shield and the loading station door to be lowered into place and the supervisor and at least two other employees to open the personnel access door. When the supervisor turns the spring-loaded electrical lock with his key, the electrical lock is de-energized. The supervisor cannot leave this switch until two other employees open the door. As soon as the cell door is cracked open, a switch energizes a pneumatic locking device on the second level which bolts the shield in place and de-energizes the loading station crane. This shield and the loading station door cannot be raised until the Cell 15 door is closed by supervision. The electrical switch box for this circuit is padlocked in the "on" position and the building supervisor and the ORNL Laboratory Shift Supervisor have the master keys.

The service tunnel and Cell 20 interlock system is electrically operated and is locked in the "on" position at all times. If maintenance is required, supervision schedules a panelboard shutdown and then de-energizes the system by turning a spring-loaded electrical switch with his key. The supervisor cannot leave the switch until one other employee opens the door to the service tunnel. When the door is open, an automatic system shuts off the steam supply to the cells and the instrument air to the panelboards so that no accidental transfers of solution can occur.

Process Safeguards

All panelboard instrumentation is protected from radioactive backups by differential-pressure cells located in the service tunnel or in shielded cubicles. Any backup of radioactive solution will be contained in these areas and will be handled under normal decontamination procedures.

The remote in-cell valves are operated from panelboards through a relay system. The panelboard switch activates a 1:1 air relay in the service tunnel which then sends a pneumatic signal to operate the valve. In some cases a combination of electrical and pneumatic signals is used to effect the same operation. This system protects against possible backups resulting from leaking diaphragms in the in-cell valves.

Solution addition to the various process vessels is performed in the operating areas through valved funnels. In the case of vessel pressurization during solution addition, a flapper-valved funnel in the process

cell will open and dissipate the pressure into the cell. The flapper-valved funnel in the solution addition line is equivalent to an open solution addition funnel in the process cell but eliminates the loss of off-gas capacity to the tank.

The ammonia sparging system to the precipitator vessel is controlled by air-to-open valves and has a constant air purge system to prevent suck-back due to NH_3 gas dissolving in the solution and creating a vacuum in the line.

All valves in service lines are designed to close in case of a failure of power or air supply. The only exceptions to this rule are the off-gas header control valves and the evaporator (E-16) condenser water which are open under emergency conditions to prevent pressurization of the process system.

Transfer of radioactive process solution by steam jets is protected against backups by a check valve-vent system. The vacuum formed by the condensation of steam in the line after the jet is closed is relieved by a check valve to a vent header which terminates inside the process cell. Operating experience with this system has proved that it is an automatic preventative of radioactive solution in steam jet lines.

The process vessels for precipitation, crystallization, evaporation, solvent extraction, and high-level storage are protected by an alarm system which indicates high temperature and high or low off-gas. All alarms of this type are signaled at the panelboard and are answered by the operating personnel.

The solvent extraction equipment is protected against fire hazard by a temperature rise regulator system which actuates the fire water spray system. If the cell temperature rises 20°C per minute, the sprinkler system is automatically turned on to spray the cell equipment, and the Gamewell alarm system is actuated.

All cell plugs are sealed on the inside of the cell and bolted to the concrete on the outside of the cell to prevent blowing out in case of an explosion in the cells.

The radioactive powder storage wells in Cells 14E and 14W are cooled by a chilled water cooling coil in a bath of distilled water. A high and low liquid level probe system alarm has been installed to keep the bath at the proper operating level. A high temperature alarm has been installed to prevent overheating of the well. These alarms are answered by the operating personnel. An automatic system activated by a temperature control provides process water cooling to the storage well in the event of failure of the chilled water supply.

The house vacuum system is protected by a surge pot located in Cell 11 and is equipped with a liquid level alarm system to prevent overflowing. The alarm is answered by the operating personnel.

The chilled water recirculating loop provides coolant for all process vessels and condensers and is serviced by two refrigeration units with a combined capacity of 130 tons. The main purpose of this system is to contain any radioactive leak from process vessels or coils within the confines of the building piping. If a leak were to occur the system could be flushed to the ORNL hot waste system and thus prevent any radioactive solution from entering the process waste system. The secondary advantage to this system is the conservation of process water which normally would be discharged to the process waste treatment plant for further processing.

WASTE DISPOSAL

Liquid Waste

Low Level Radioactive Waste

Low level radioactive wastes, which consist of cell floor washings, cell sump solutions, cell decontamination solutions, service tunnel floor washings, and evaporator condensate, are collected in two stainless steel waste collection tanks, S-223 and S-523. The normal volume of this waste is 500 gal/day, and the activity level is 1 curie of mixed fission products per day. These solutions are sampled, and under normal operation are jetted to W-5 tank in the ORNL tank farm when the tank liquid level reaches 60% capacity. If a tank were to burst in the cells, the contents would drain to the low level collection system for storage until the building supervisor determined the best disposition of this solution.

Intermediate Level Radioactive Waste

The intermediate level radioactive waste solutions consisting of the waste stream from the normal process operations plus decontamination solutions are collected in a stainless steel tank, sampled for radiochemical analysis and then jetted to W-5 tank in the ORNL tank farm. The normal volume of these solutions is 1500 gal/day and the average activity is 100 curies of mixed fission products per day. These solutions are generally basic, but could be acidic from nitric acid decontamination solutions.

A special boltaron waste system collects the intermediate level waste from the hydrochloric acid system used for ^{137}Cs purification. The hydrochloric acid wastes are collected in a glass lined tank, sampled for radiochemical analysis, neutralized with sodium hydroxide, and jetted to W-5 tank in the ORNL tank farm.

High-Level Radioactive Waste

High-level radioactive waste streams are comprised of short-lived radioisotopes such as ^{95}Zr-^{95}Nb which are waste products from processes using short-cooled fuel elements. The normal flow is 150 gal/day with an average activity level of 50,000 curies per day. Sixty percent of this

activity is ^{95}Zr-^{95}Nb. If process commitments do not allow a sufficient decay period, the solution is sampled for radiochemical analysis and jetted to W-6 tank in the ORNL tank farm for storage and further decay. This procedure is done only with divisional approval.

Organic Waste

The organic waste from FPDL consists of Amsco and di(2-ethylhexyl)phosphoric acid which have been stripped of nearly all activities which were extracted in the process. The maximum volume of organic waste will be 100 gal/month. After being stripped, waste is pumped directly to tank W-5 or W-6 in the ORNL tank farm system.

Process Waste System

The process waste system collects the building steam condensate, distilled water unit condenser water, and the normal building sink and floor drains. This system has very small flow and the contamination in this system would originate from minor spills in the operating area.

The steam condensate from process vessels is condensed, monitored, and collected in a 2,500-gal surge tank. If no radioactivity is recorded, the solution is pumped to the process waste system; if a radioactive leak were to occur, the solution would be discharged to the FPDL tank farm for disposal.

Storm Sewer System

The storm sewer system receives all roof drainage, building heating condensate, and cooling water to the freon condenser of the chilled water unit. All of these sources are non-radioactive. The only possible contamination would come from an outside source which might settle on the building roofs. During normal operation, the chilled water units recirculate the cooling water from the compressor unit to a cooling tower; however, during maintenance shutdowns on the cooling tower, the cooling water would go through the freon condenser system directly to the storm sewer.

Gaseous Waste

Off-Gas System

The off-gas system at the FPDL exhausts every vessel in the cells under vacuum which is controlled in Cell 20 by two pneumatically operated valves. One pneumatic valve automatically adjusts the off-gas vacuum to 6 to 8 in. w.g. on the process and tank farm cell vessels. The normal flow through this controller is 300 cfm and the gases present are NH_3, $^{106}RuO_4$, and oxides of nitrogen; the particulate matter from entrainment could be any fission product radioisotope that would be in process. The other pneumatic valve maintains a vacuum of 8 to 10 in. w.g. on the manipulator cell equipment. The normal flow through this system is 100 cfm and the gases

present are NH_3, $^{106}RuO_4$, and oxides of nitrogen. The particulate matter could be any fission product that would be in process. The additional off-gas on the manipulator cells is needed to overcome the pressure drop of an additional scrubbing unit located in Cell 13 which consists of a glass bubble cap, continuous flow, caustic scrubber. This scrubber removes hydrochloric acid fumes from the ^{137}Cs purification equipment to prevent corrosion in the main stainless steel off-gas line.

Both off-gas systems are connected to a common header for scrubbing action in Cell 20. The off-gas is scrubbed in two countercurrent flow Berl saddle scrubbers. The first scrubbing solution is chilled 2 N H_3PO_4 and the second 4 N caustic. The off-gas stream flows through a heater section, stainless steel prefilters, and absolute filters for final clean-up. At this point the off-gas flow is monitored and then discharged to the ORNL gaseous waste disposal facilities. The monitor system is instrumented to record and alarm activity levels from 0 counts/min to 25,000 counts/min. In case of an alarm, all processing is stopped by supervision.

A dual filter system is used to continue filtration during the replacement of used filters. The contaminated filters are removed by remote operations into a shielding device which is a component of the cell shielding. The filter is sealed in a steel can which forms a blister on top of the filter cubicle and the completed unit is removed to the burial ground. The sealed can is dropped into the trench, and the shield is returned to the building for permanent shielding.

The ORNL off-gas system is provided with steam turbines which automatically continue the off-gas flow in case of power failure. The FPDL off-gas control system is pneumatically operated and is designed to fail open in case of an emergency.

Cell Ventilation System

The cell ventilation system for the FPDL area draws a vacuum of 1.0 in. to 1.5 in. w.g. on the process cells, manipulator cells, tank farm cells, service tunnels, decontamination cell, and pipe tunnels. The normal volume of air swept through this system is 6,000 cfm.

The filtration of the cell ventilation air is accomplished by stainless steel Neva-Clog roughing filters and a bank of CWS filters for absolute filtration. These units are gasketed and sealed in place by a locking device to prevent leakage around the filters. A monitor station is located on the outlet duct ~20 ft from the filter pit and is used to monitor the activity. An automatic electric sump pump removes the water leakage into the filter pit; in case of pump failure, an automatic steam jet system goes into operation. All ground water leakage and decontamination solutions are piped to S-223 tank in the FPDL tank farm system.

The air entering the cells is filtered by FG-25 glass wool roughing filters. In addition to the building filtering system, the inlet ducts to the cells are equipped with gravity-balanced backflow preventers. Manipulator cells 11, 12, 13, 14E, 14W, and 27 have individual CWS absolute filters on the

cell ventilation exhaust duct risers to remove particles of powdered $^{137}CsCl$, $^{144}CeO_2$, or $^{90}SrTiO_3$ which become suspended in the cell air during handling operations.

A small by-pass system with a capacity of 1,000 cfm has been installed at the FPDL cell ventilation filter pit and is equipped with CWS absolute filters. This system is an operational by-pass to give a slight vacuum on the cells during the period needed for changing the CWS filters or washing the stainless steel roughing filters. The stainless steel Neva-Clog filters are equipped with spray nozzles to permit washing of the filters in place. Either water washing or chemical washing can be performed.

Solid Waste

High-Level Solid Wastes

High-level solid wastes from the FPDL consist of materials and equipment used in the manipulator cells that become contaminated with mixed or separated fission products. Small pieces of material or equipment are washed in the manipulator cell, placed in a plastic bag, inserted into a 1-gal tin can, sealed with a lid, and removed from the cell in a bottom-loading uranium-shielded carrier. The carrier is then transferred by riggers to the burial ground. When the carrier is returned to the building, the surface is smeared and decontaminated to <500 dis/min.100 cm^2.

A 2-gal capacity lead-shielded carrier can be used in Cell 15 to accept solid waste from Cells 11, 12, 13, 14E, or 14W. Waste cans are loaded into this carrier from the top with the aid of manipulators, otherwise the handling procedure is identical to that described above.

Large equipment such as laboratory balances, furnaces, presses, scales, stainless steel filters, and laboratory centrifuges are washed before being removed from a cell. If equipment can be recovered by further decontamination, it is taken by operating personnel to Cell 16 where it can be further decontaminated with low exposure to personnel. If the equipment is to be discarded, a stainless steel lined lead-shielded Dempster Dumpster is used for removal to the burial ground. The Dumpster, which is loaded in Cell 15, can be used to remove canned solid waste as well as large items.

All carriers are handled according to ORNL transfer procedures; FPDL written procedures cover the various transfers.[1]

Low-Level Solid Wastes

The low-level solid wastes are composed of contaminated swabs, sanitary pads, mops, blotting paper, kraft paper, or other materials used in manual decontamination procedures. This material, which normally reads <100 mr/hr, is placed in plastic-lined hot cans located in strategic areas in the building. When a can is full or the radiation level of 6 mr/hr is exceeded,

the plastic bag is sealed with tape and removed to the "hot" Dumpster. The Dumpster truck removes the material to the burial ground on a routine basis. The returning hot Dumpster is checked for contamination by Health Physics and approved for use. A daily survey of the hot Dumpster is made by the Health Physics representative; supervision surveys containers during shift decontamination operations.

PROCESS HAZARDS REVIEW

The process hazards discussed below are considered because the physical requirements for an accident are present. In each case the controls, physical and procedural, that are used to prevent accidents are described. The process hazards are divided into five categories: 1) radioactive gas release, 2) gas formation and pressurization, 3) decontamination hazards, 4) explosion, and 5) fire.

Radioactive Gas Release

Two of the fission products processed at the FPDL can be converted to gaseous form -- ^{106}Ru as $^{106}RuO_4$ and ^{137}Cs as $^{137}Cs_2O$ vapor.

$^{106}RuO_4$ Gas Release

Liberation of $^{106}RuO_4$ gas from the evaporator (E-16) is controlled by the batch evaporation process which controls the acid normality to between 3 and 5 N. Under these conditions no $^{106}RuO_4$ is liberated. If an operational error were made by which the maximum volume of 60% HNO_3 drained from the HNO_3 storage tank into the evaporator, the final concentration would be 7 N and $^{106}RuO_4$ gas would not be liberated. The accidental introduction of acid to the evaporator is considered very unlikely since no chemicals are added to the evaporator under routine procedures and since the solution addition system would overflow to the cell floor if the HNO_3 addition line were placed in the evaporator solution addition funnel by mistake.

The generation of $^{106}RuO_4$ gas could be caused by the introduction of an oxidizing agent, such as potassium permanganate, to a centrifuge bowl during the acid dissolving of a ^{106}Ru precipitate. Potassium permanganate is used in only one process at the FPDL and the cell in which this process is carried out (Cell 9) is separated from any of the cells in which ^{106}Ru is processed. Also, a small stainless steel makeup tank in Area 32 has been designated in the makeup procedure as the only tank to be used for $KMnO_4$ makeup. This tank is piped directly into one of the extractors in Cell 9 (N-29) which is the only tank that uses $KMnO_4$ in normal operations; thus, the possibility of accidental drainage of $KMnO_4$ to the wrong tank is eliminated. The responsibility for training the operating personnel as to the hazards of $KMnO_4$ in the FPDL system remains with the building supervision. Because of the controls described above, the generation and release of significant amounts of $^{106}RuO_4$ are considered very improbable.

$^{137}Cs_2O$ Vapor Release

During the preparation of ^{137}Cs glasses and their casting into source forms, $^{137}Cs_2O$ vapor is released from the molten glass. The melting is done in a closed furnace which is exhausted to off-gas. The off-gas from the furnace passes through a cooling and scrubbing system within the cell before being discharged to the FPDL off-gas treatment system. Cold tests, tracer tests, and full-scale operating experience with this system indicate that the ^{137}Cs which is evolved is all trapped within the fire-brick liner of the furnace. Release of ^{137}Cs to the secondary containment or to the environment by this procedure is not considered credible.

Gas Formation and Pressurization

Chemical Reactions

The normal process operations at the FPDL include chemical additions or reactions which form various types of and quantities of gases. These reactions are listed in Table 5. For all processing, operational procedure requires 6 in. w.g. vacuum which is more than adequate to control the gaseous release from the reactions listed and to prevent pressurization of the vessels.

If an operational error were committed and the chemical addition were increased before or during a reaction, a pressurized vessel could result. The off-gas system would continue to remove the bulk of the gas liberated and the remainder would vent to the cell ventilation through the pressure relief flapper valve on the solution addition line. If extremely high pressure were formed, radioactive solution could be forced up instrument lines, sampler lines, and jet dip-legs. The terminal points of these lines are located in shielded areas which are exhausted to the cell ventilation system; so no release of activity to secondary containment or to the environment would be expected.

Radioactive Solution Burping

Up to 500,000 curies of ^{144}Ce, with a heat output of ~4000 watts, can be stored in solution in a single tank in the FPDL tank farm (Cell 21). Under normal conditions this solution is 2-4 N in nitric acid and is cooled by the flooded-cell, fin-cooler technique. If an operator accidentally jetted a concentrated caustic solution into this tank, the rare earth hydroxide would precipitate and settle out to the bottom of the tank. The cooling system would continue to operate but the possibility of a pressure bubble forming in the rare earth concentrate could not be discounted. This bubble could cause the tank to burp and thus momentarily overcome the off-gas to the vessel. Radioactive solution could back up into the instrument lines and jet dip-legs which terminate in an uncontained shielded area on the FPDL tank farm. This area of 100 ft^2 is formed by a solid concrete block wall 5 ft high and the north wall of Building 3517; it is monitored and all lines are blocked by check valves or diaphragms. A high local radiation field would be caused but no particulate contamination would be expected since the system is normally pressure-tight.

Table 5. Gas Liberation in Fission Products Development Laboratory Chemical Reactions

Process	Chemical addition	Chemical reaction	Gas per batch		
			Liberated	Volume, liter	Est. rate, liters/min
Magnetite precipitation	Hydrazine	Fe^{3+} reduction	N_2	935	31
Cesium-137 purification	Hydrazine	Platinum reduction	N_2	200	7
Cesium-137 purification	HNO_3	NH_4Cl oxidation	N_2	35	7
Technetium-99 precipitation	HNO_3	Neutralized Na_2CO_3	CO_2	1,000	70
Oxalate precipitation	HNO_3	Oxalate destruction	CO_2	220	7
Cerium-144 oxidation	$KMnO_4$	Citric acid destruction	CO_2	111	11
Cerium-144 reduction	H_2O_2	H_2O_2 decomposition	O_2	594	60
Magnetite precipitation	NaOH	Formation of NH_4OH	NH_3	9,000	100
Cesium-137 concentration	None	Radiolytic hydrogen generation	H_2	--	0.01
Cesium-137 oxalate	None	Calcination	CO_2	500	3
Cesium glass	None	Calcination	CO_2	150	2
Strontium-90 concentrate storage	None	Radiolytic hydrogen generation	H_2	--	0.2
Evaporation	None	2:1 concentration	$^{106}RuO_4$	0	--
STT shipment	Decalso	Radiolytic hydrogen generation	H_2	6	--
Strontium-90 shipment	None	$SrCO_3$ decomposition	CO_2	5	--
Cerium-144 shipment	None	None	No available data		

A similar accident of this nature could occur in the ^{90}Sr storage tanks by the accidental introduction of caustic. These tanks contain up to 500,000 curies of ^{90}Sr as $^{90}Sr(NO_3)_2$ solution in 1-2 N nitric acid; they are located in the FPDL process cells. The lines through which the radioactive solution might back up in this case all terminate within FPDL cells.

The burping of a radioactive solution in a storage tank is a credible accident, but the normal safeguards of high-temperature and high-level alarms on the tanks would give adequate warning if the supervisor who answered the alarm correctly determined the problem. Also, the possibility of accidental additions of chemicals to storage tanks is reduced by disconnecting and capping the panelboard switches which operate all valves and jets to and from a storage tank when it is being used for storage. Solution addition funnels to these tanks are kept covered and locked. The fact that a solution had been transferred to the wrong tank would immediately be reported to supervision and corrective action would be taken. An additional measure of protection in this system is provided by an overflow piping arrangement in each storage cell. This system provides a total of over 600 gal of tankage capacity in each cell which would have to be filled before any tank could overflow to the cell.

Hazards created by the burping of radioactive solution would be confined to Building 3517 and no release of radioactive material to the environment should occur. The high local radiation hazard would be dealt with by normal cleanup procedures.

Decontamination Hazards

Decontamination solutions at the FPDL are added in a specific pattern, and the flow of these solutions is controlled by the building supervisor to meet the requirements of the system to be decontaminated. The panelboard switches for all lines to critical areas or vessels are capped to prevent accidental jetting to the wrong vessel.

The major source of a hazardous incident during decontamination is the continuing of routine processing in other cells and the storage of concentrated material in adjacent cells or in the tank farm area. It is impossible to remove all the concentrated radioisotopes from the building for decontamination procedures.

An additional hazard is the decontamination of $^{90}SrTiO_3$ and $^{144}CeO_2$ powdering cells in which the soft beta activity is concentrated into an insoluble powder form. Small amounts of these materials can be shielded to cell entry tolerances by a few inches of water or by thin sheets of lead or steel. When this shielding is inadvertently removed, the operating personnel could be exposed to a concentrated beta source.

The greatest safeguards against a decontamination accident are the use of close supervision, radiation work permits, decontamination procedures, and the intelligence and training of the operating personnel.

Explosion

The explosion possibilities at the FPDL are:

Solvent-nitric acid reaction
Hydrazine-nitric acid reaction
Ammonium nitrate decomposition
Solvent explosion

Solvent-Nitric Acid Reaction

The solvents Amsco and D2EHPA are used in the Cell 9 rare earth processing. During Redox or Purex processing, small amounts of TBP may remain in the feed stream from metal recovery solvent extraction processes. Feed solutions are normally concentrated by a factor of two to one and in no case is the nitric acid concentration greater than 5 N. The normal steam pressure to the evaporator is 60 psi and the maximum evaporation rate is never greater than 50 gal/hr. An evaporation operating error must remain undetected for a period of four hours or more before the nitric concentration would reach the stage of possible solvent nitration.

The Amsco and D2EHPA solvents (~40 gal/batch or 80 gal/wk) used in the rare earth extraction are contacted, separated, back extracted, separated, and discharged without heating or concentrating the solvent. Small quantities of solvent could remain in the aqueous phase and could be nitrated under the present process of dissolving ^{147}Pm oxalate precipitate on a filter. The quantity of solvent remaining on the filter would be very small and the explosive potential very weak.

Hydrazine-Nitric Acid Reaction

Twelve liter quantities per batch of 42.5% hydrazine and 60% nitric acid are used in the FPDL mainstream processing of Purex or Redox solutions. These chemicals are added to the same precipitators but during normal operations they are compatible due to high dilution factors.

An accident has been postulated (scientific evidence lacking) in which there would be an accidental introduction of 12 liters of 42.5% hydrazine to a centrifuge during the dissolving of a rare earth oxalate precipitate. At the time the centrifuge bowl could contain 100,000 curies of ^{144}Ce in a volume of 9 gal of 4 N HNO_3 at 85°C. Pending evidence to the contrary, it is assumed that the force of the explosion could rupture the stainless steel casing of the centrifuge, thus causing release of particulate ^{144}Ce to the cell ventilation system and to the secondary containment shell.

An accident of this nature is considered highly improbable for the following reasons:

1. Hydrazine is not used in any phase of the concentrate rare earth processing (which processing would result in the accumulation of 100,000 curies of ^{144}Ce in the centrifuge). Only two chemical additions, 80 ml of manganous nitrate and 6 gal of 14 M HNO_3, are called for in the procedure for dissolving rare earth oxalates.

2. Hydrazine is used only in the "magnetite" procedure; this is the process by which the mixed fission products are accumulated and concentrated. By the time the rare earth oxalate process is being done at least three separations processes have been done on the stream since the last magnetite process. Thus, the likelihood that both operations would be in progress at the same time is remote.

3. The hazardous nature of hydrazine is recognized by all personnel. Its handling has been the subject of a number of safety meetings. The supply of hydrazine is kept in a drum with a locked dispensing valve. Building supervision is charged with the responsibility of dispensing hydrazine and of supervising the addition of hydrazine to process vessels.

Ammonium Nitrate Decomposition

Ammonium nitrate is formed in the FPDL off-gas system by the reaction of NH_3 gas and nitric acid fumes, both of which are generated during standard operations. The normal process procedures used in the FPDL vessels create a considerable amount of water vapor which condenses in the off-gas lines and tends to prevent the accumulation of NH_4NO_3 deposits.

A possible accident involving NH_4NO_3 could occur during a period of maintenance or construction on the off-gas system. The cutting of a line or the welding of a new nipple into an existing line could ignite the dried NH_4NO_3 in the system. Under building maintenance procedures, the off-gas would be manually valved off at the inlet to the building and the main off-gas line would not be affected. Some particulate contamination would be generated and would vent back to the process vessel or to the cell ventilation.

The scrubber system at the FPDL minimizes the formation of NH_4NO_3 in the main header to the 3039 stack. The formation of NH_4NO_3 in the FPDL off-gas header is controlled at the present time by a periodic cleanup of the off-gas line accomplished by boiling water in the process vessels and allowing the steam condensate to flush the system. This is a standard procedure during decontamination periods for any maintenance or construction work in the cells. Welding on off-gas lines is forbidden unless the line has been thoroughly flushed with hot water.

Solvent Explosion

The possibility of an explosion from solvent vapors during normal operations is not credible. The solvents are not heated or steam jetted and they are removed from the system immediately after use. In the case of accidental heating, the off-gas would remove the vapors from the tank and the relatively large surface area of the off-gas header would serve to cool the vapors.

Fire

Manipulator Cell Fire Hazard

Combustible materials are present in varying amounts inside the manipulator cells. These materials include the manipulator boots and gauntlets which are always present as well as the cellulose wipes and sanitary pads which are used for cleaning at various times. Also cross-contamination protection and waste disposal techniques require bagging of material in polyethylene film. An accident can be visualized in which these materials could be ignited causing a fire inside a manipulator cell. In the event of such a fire, the in-cell fireproof CWS filters would probably remain intact but would become plugged with the combustion products. If the manipulator boots burned, contaminated smoke could leak back through the manipulator barrels. The amount of contamination released to the secondary containment would depend on the cell status at the time of the fire, but in any situation a serious local contamination event would occur.

Fire protection inside the manipulator cells is achieved primarily by minimizing the likelihood of fire rather than by providing for fire-fighting procedures. The amount of combustible material in the cell at any time is kept at a minimum. Cellulose wipes and pads are placed in metal containers immediately after being used and the containers are disposed of routinely. Likewise, manipulator boots, gauntlets and polyethylene bags are canned in metal when no longer in use. No open flames and no flammable solvents are used in manipulator cells.

Tests have been made to determine the amount of various materials that would have to be burned in a cell to cause filter plugging.[4] The results of these tests are tabulated below.

Material	Use	Amount Burned Before Filter Plugging, g
Cellulose wipes	Decontamination	2400
Sanitary pads	Decontamination	2600
PVC—Nylon	Manipulator boots	225
Urethane	Manipulator gauntlets	450
Polyethylene film	Bagging	800

The only material which would normally be exposed in a cell in amounts in excess of those listed above would be the PVC—Nylon. Manipulator boots for two manipulator arms consist of a total of 1400 g of PVC—Nylon.

In the event of a fire inside of a manipulator cell the immediate action is an evacuation of the building. Release of contamination to the secondary containment would be controlled by the building containment system. The contamination thus released would consist of such particulate matter as was on the burning material; bulk powder should not become airborne. After the fire had exhausted itself from lack of fuel, building reentry procedures and cleanup procedures could be initiated.

Solvent Fire

The extractors in Cell 9 are used to separate ^{144}Ce from other rare earths by extraction of the ^{144}Ce into di(2-ethylhexyl)phosphoric acid diluted with Amsco-125. The normal batch size for one extraction is 50,000 curies of ^{144}Ce. Separation of the organic and aqueous phases is done by means of an airlift through a discharge line on the bottom of the extractor. An accident can be visualized in which the bottom discharge line would break at a time when the ^{144}Ce was in the organic phase and at the same time an electrical short-circuit in the cell wiring would create a spark igniting the organic. An accident of this type -- although it requires the coincidence of two very unlikely events at a certain time -- is considered credible. The results of such an accident are described in the following section.

Maximum Credible Accident

The results of the event that is considered to be the maximum credible accident (i.e., the release and burning of solvent during a ^{144}Ce extraction) have been calculated using the following conditions.

1. The cell inventory at the time of the accident is 50,000 curies of ^{144}Ce contained in 50 lb of combustible solvent.

2. Twenty percent of the material burned reaches the filter pit with a size distribution and filter efficiency as follows.[5]

Size, μ	Weight, %	Filter efficiency, %
≥0.3	98.8	99.95
0.1-0.3	1.1	95
<0.1	0.1	87

3. The wind velocity is 3 mph and atmospheric conditions are neutral.

4. The cell leak rate is 10^{-2} cell volume/min with a 1 in. w.g. pressure differential.

5. The gas escaping from the cell carries 10 mg/m^3 of $^{144}CeO_2$.

6. The cell is pressurized during burning.

7. The normal cell exhaust is 100 cfm with a 4 in. w.g. pressure differential.

The calculated results of the postulated accident are given in Table 6; the results under two situations are presented. In the first case, it is assumed that the optimum quantity of air is available to burn 100% of the combustible material in the cell. In the second, it is assumed that only the air in the cell at the time of the fire is available for combustion.

There is sufficient oxygen in one cell volume of air to burn ~5% of the inventory of combustible material. Since the normal replacement rate of air in the cell is only ~0.1 cell volume/min, and this rate will further be reduced by pressurization, the assumption of 5% burning should still be conservatively high. Also, the automatic fire system* would activate and would quench the fire as well as serve to remove suspended radioactive particles from the cell atmosphere.

Table 6. Calculated Results of Maximum Credible Accident

Effect	Result	
	100% Combustion	5% Combustion
Stack discharge	11.7 curies	<0.6 curie
Maximum contaminated area	18 $mile^2$	0.9 $mile^2$
Downwind dose	31.4 mrem	<2 mrem
Normalized 2 min dose to operating personnel	500 mrem	25 mrem

Calculation of the "maximum contaminated area" is based on the presumption that the radioactive material would be dispersed uniformly so as to give a contamination level of 1000 dpm/dm^2. Since the disintegration rate for individual particles would be many times higher than 1000 dpm, the areas listed represent the very maximum contamination spread.

The "downwind dose" is based on a 2 min exposure to the radioactive cloud, and it is the integrated lifetime dose from ingestion. The "normalized 2 min dose to operating personnel" is based on ingestion assuming a uniform dispersion of radioactive material throughout the building atmosphere. Since such dispersion is unlikely, doses to individuals who were close to the release point would be higher. No calculation of the direct radiation dose from surface contamination has been included.

Since the efficiency of the filter system may be different from that used in the calculations, correction factors must be applied to the results given in Table 6 (except for the 2 min dose to operating personnel) to reflect this difference. The graph presented in Fig. 6 gives the correction factor as related to filter efficiency for 0.3 μ particles. Changes in filter efficiency for particles smaller than 0.3 μ would have relatively little effect on the results.

Detailed descriptions of the methods for calculation of the results shown above have been previously reported by the Isotopes Development Center.[6]

*See page 25.

UNCLASSIFIED
ORNL DWG. 64-11725

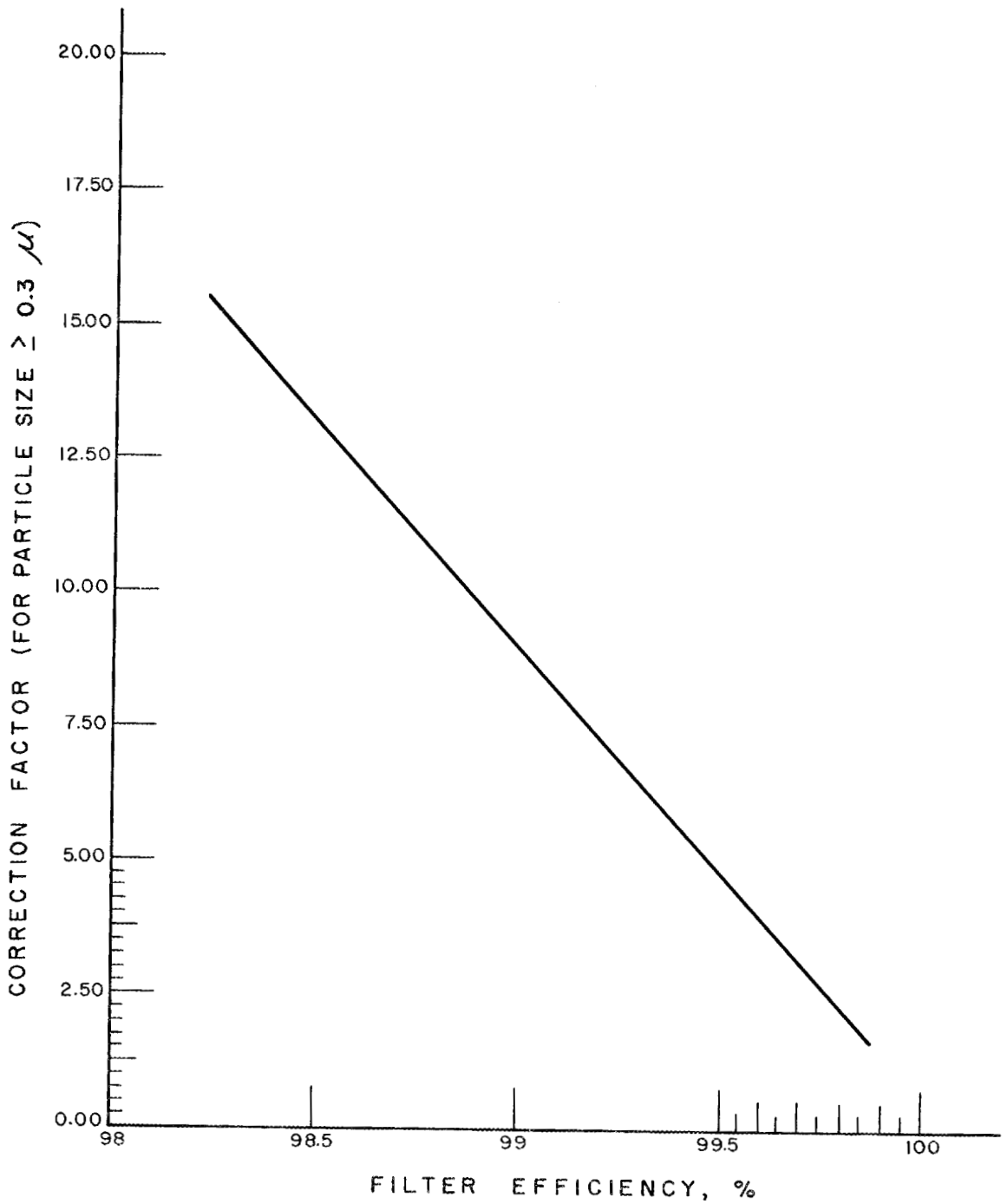

Fig. 6. Filter Efficiency Correction Factors.

REFERENCES

1. C. L. Ottinger and R. W. Schaich, Fission Product Development Laboratory Operational Procedures, ORNL-TM-850 (to be published).

2. C. W. Smith, Strontium-90 Shipping Cask, Design Criteria and Hazards Evaluation, HW-68081, January 1961.

3. C. W. Smith, HAPO-IB Fission Product Shipping Cask Design Evaluation Report, HW-65268, December 1962.

4. S. T. Ewing, Capacity of Absolute Filters for Selected Combustion Products, ORNL-TM-845, August 1964.

5. E. D. Arnold and J. P. Nichols, Hazards Analysis of Fuel Handling Facilities, ORNL-TM-346, August 1962.

6. R. A. Robinson, Radioisotope Development Laboratory, Building 3047 Hazards Report, ORNL-TM-946, October 1964.

APPENDIX NO. 1

FPDL PROCESS EQUIPMENT

The FPDL cell equipment is divided into several categories as shown below.

Equipment number	Type material	Volume, gallons	Agitation	Process
P-12	304 L S.S.	250	Agitator	Dissolution
P-23	304 L S.S.	250	Agitator	Evaporation and storage
P-34	304 L S. S.	250	Agitator	Evaporation and storage
P-45	304 L S.S.	470	Agitator	Cesium-137 processing
P-89	347 S.S.	50	Agitator	Promethium-147 precipitation
P-511	347 S.S.	32	Agitator	Strontium-90 precipitation
G-12	304 L S.S.	13	None	Centrifugation
G-23	304 L S.S.	13	None	Centrifugation
G-34	304 L S.S.	13	None	Centrifugation
G-45	304 L S.S.	13	None	Centrifugation
H-12	304 L S.S.	275	None	Centrifugate holdup
H-23	304 L S.S.	275	None	Strontium-90 storage
H-34	304 L S.S.	275	None	Strontium-90 storage
H-45	304 L S.S.	275	None	Cesium-137 holdup
H-89	347 S.S.	90	Agitator	Supernate holdup
H-511	347 S.S.	110	None	Supernate holdup
F-12	304 L S.S.	280	None	Fission product storage
F-23	304 L S.S.	280	None	Strontium-90 storage
F-34	304 L S.S.	280	None	Strontium-90 storage
F-421	304 L S.S.	500	None	Fission product concentrate storage
F-521	304 L S.S.	500	None	Fission product concentrate storage
F-621	304 L S.S.	250	None	Fission product concentrate storage
F-821	304 L S.S.	250	None	Fission product concentrate storage
F-1021	304 L S.S.	250	None	Fission product concentrate storage
F-1121	304 L S.S.	250	None	Fission product concentrate storage

Equipment number	Type material	Volume, gallons	Agitation	Process
C-17	316 ELC S.S.	450	Agitator	Cesium-137 crystallization
C-27	316 ELC S.S.	450	Agitator	Cesium-137 crystallization
C-38	316 ELC S.S.	125	Agitator	Cesium-137 crystallization
C-48	316 ELC S.S.	125	Agitator	Cesium-137 crystallization
C-513	Glass	12	Agitator	Cesium-137 crystallization
C-613	Glass	12	Agitator	Cesium-137 crystallization
E-16	304 L S.S.	690	None	Evaporation
E-213	Ta-lined S.S.	5	None	Cesium-137 product evaporation
N-19	347 S.S.	55	Agitator	Solvent contactor
N-29	347 S.S.	54	Agitator	Solvent contactor
R-29	347 S.S.	90	None	Waste receiver
R-39	347 S.S.	144	None	Waste receiver
R-111	347 S.S.	42	None	Waste receiver
S-122	304 L S.S.	5500	Air	Cesium-137 feed storage
S-223	304 L S.S.	3000	Agitator	Waste storage
S-523	304 L S.S.	1000	Agitator	Waste transfer
S-324	304 L S.S.	1000	Agitator	Waste transfer
S-424	Glass lined	500	Air	HCl waste storage
P-114	347 S.S.	50	Agitator	Cesium tetraoxalate crystallization
R-18	347 S.S.	45	Air	Waste receiver
N-120	347 S.S.	25	None	Off-gas acid scrubber
N-220	347 S.S.	25	None	Off-gas caustic scrubber
R-11	347 S.S.	100	Air	Eluant storage

Two 2000-gal stainless steel tanks are buried ~8 ft below ground level north of the FPDL tank farm cells. These tanks are used for feed storage for ^{137}Cs and are equipped with liquid level instruments, off-gas, and chilled water cooling coils. The tanks rest on a crushed rock bed that has a drainage system which flows into the process waste system.

APPENDIX NO. 2

FISSION PRODUCTS DEVELOPMENT LABORATORY CHEMICAL PROCESSES

Cesium-137

Feed Material

Feed for the ^{137}Cs process is shipped from the Hanford Atomic Products Operation to ORNL in 500-gal Shielded Transfer Tanks (STT's) containing 400-gal beds of "Decalso", an inorganic ion exchanger. The adsorbed ^{137}Cs is removed from the beds by elution with 5 M NH_4NO_3 at 80°C. The resulting feed solution is stored in underground tankage; there is storage capacity for as much as 500,000 curies of ^{137}Cs feed solution at the FPDL. The STT's are rinsed and returned to the HAPO with the exchanger in the NH_4^+ form.

Mainstream Processing

The ^{137}Cs feed solution is diluted to reduce the NH_4^+ concentration, then, the ^{137}Cs values are accumulated by a series of co-crystallization operations on large ammonium alum beds. When the desired amount of ^{137}Cs has been accumulated (usually 50,000 curies), the ammonium alum is removed by fractional crystallization and the cesium alum is transferred to an accumulation vessel. In addition to concentrating the ^{137}Cs, the mainstream crystallization process removes traces of other radioisotopes which are present in the feed. The processing rate in the mainstream operation is ~50,000 curies/week.

Oxalate Processing

Accumulations of up to 200,000 curies of ^{137}Cs as alum solution are made in the accumulation tanks. Cesium tetraoxalate is crystallized from the alum system by addition of oxalic acid. The yield on this step is ~70% and the filtrate is recycled to the mainstream operation. The cesium tetraoxalate crystals are dissolved in water and this solution is transferred batchwise to the final purification cell where another oxalate crystallization is done. The filtrate is recycled to mainstream and the crystals are calcined in air at 300°C to yield dry powdered cesium carbonate.

Cesium Chloride Preparation

The main product of the FPDL ^{137}Cs processing is dry powdered $^{137}CsCl$. This material is prepared in batch sizes of 50,000 curies by reacting the $^{137}Cs_2CO_3$ in a water slurry with a slight excess of hydrochloric acid. This operation is done in glassware in a manipulator cell. The $^{137}CsCl$ solution is filtered, then it is evaporated in tantalum equipment to yield the dry salt. The powder is baked with constant stirring at 300°C for 4 hr to remove the last traces of HCl; it is then stored in lots of 10,000 curies each in stainless steel storage cans. The cans are stored in water-cooled storage wells.

The usual $^{137}CsCl$ product prepared at the FPDL assays ~26 curies per gram compared to a theoretical specific activity of 26.4 curies per gram. A typical mass distribution of cesium isotopes in this material is: ^{133}Cs - 45.5 atom %; ^{135}Cs - 16.8 atom %; and ^{137}Cs - 37.7 atom %. Traces of aluminum, iron, and nickel are present as well as small amounts of rubidium. The dry powder can be stored for extended periods in stainless steel containers with no attack on storage cans; it can be weighed and handled by standard manipulator procedures.

Cesium-137 Glass Preparation

Another material produced at the FPDL contains ^{137}Cs incorporated in a glass. This glass has a specific activity on the order of 14 curies per gram. Silica, cesium carbonate, and other materials are dry-mixed, then the mix is melted at 1200°C to form glass. The glass can be cast into pellets or other source shapes, then encapsulated in welded stainless steel containers.

Processing Rate

The processing rate for the FPDL ^{137}Cs operation is about one megacurie per year and is dependent primarily on the shipping schedule for the feed. Four shipping casks are presently in use; each will transport 50,000 curies per shipment. One shipping cycle requires eight weeks.

Strontium-90

Feed Material

The feed material for the FPDL ^{90}Sr process is highly purified $^{90}SrCO_3$ received from the HAPO. This feed is radiochemically pure and contains a few percent of other alkaline earths (calcium, barium); no purification is done at the FPDL. The $^{90}SrCO_3$ is shipped to ORNL as a dry solid; it is removed from the shipping cask by water slurrying; and, the slurry is treated with HNO_3 to yield a $^{90}Sr(NO_3)_2$ feed solution. At the FPDL there is storage capacity for 3 megacuries of ^{90}Sr in nitrate solution.

Strontium-90 Titanate

Batches of 40,000 curies of ^{90}Sr are processed in the FPDL manipulator cells. Strontium carbonate is precipitated in the presence of solid TiO_2 using ammonium carbonate as the precipitant. The slurry is filtered and the $SrCO_3$-TiO_2 mixture is calcined at 1100°C to yield $SrTiO_3$. A 5-10% excess of TiO_2 is usually maintained in order to provide powder with good pelletization properties. The specific activity of the $^{90}SrTiO_3$ varies from 30 to 35 curies per gram depending on the amount of excess TiO_2 and the concentration of other alkaline earths in the feed. The dry $^{90}SrTiO_3$ is stored in lots of 10,000 curies each in stainless steel storage cans inside a cooled storage well.

Strontium Titanate Pellets

Sintered pressed pellets of $^{90}SrTiO_3$ can be made in diameters from 0.25 to 3.0 in. The pellets are formed from dry $^{90}SrTiO_3$ then they are sintered at 1400°C. The final pellets have densities of 3.5-4.0 g/cm^3 and activity concentrations well in excess of 100 curies/cm^3. The pellets can be encapsulated in welded stainless steel containers.

Production Rates

Conversion of ^{90}Sr to $^{90}SrTiO_3$ can be accomplished at a rate of 100,000 curies per week. The yearly production rate is dependent upon the availability of feed material. Preparation rate for pellets varies with the pellet size, encapsulation method and number of pellets of a given type.

Cerium-144

Feed Material

A mixed double-sulfate salt of cerium and other rare earths is shipped as a dry solid in shielded filter casks from the HAPO to FPDL. The solid cake is removed from the cask by water slurry action, then the slurry is treated with HNO_3 to dissolve the solid. Single shipments of 500,000 curies of ^{144}Ce can be made.

Mainstream Processing

The ^{144}Ce and other rare earths are concentrated by precipitation as the oxalates; the oxalates are dissolved in HNO_3 to prepare the feed for the solvent extraction cycle.

The first solvent extraction cycle is used to extract ^{91}Y and stable yttrium isotopes from the feed. The yttrium is extracted from the 1 N HNO_3 solution of rare earths into 0.5 M di(2-ethylhexyl)phosphoric acid; the organic phase is discarded. Cerium is oxidized to Ce(IV) by $KMnO_4$ and the Ce(IV) is extracted into 0.5 M D2EHPA in Amsco. The aqueous phase from this extraction contains ^{147}Pm and stable rare earths. An oxalate precipitation is performed on the rare earth solution and the oxalates are dissolved in HNO_3 to yield a feed solution for the ion-exchange separation of ^{147}Pm.

The ^{144}Ce is back-extracted from the organic phase by reduction of the Ce(IV) to Ce(III) with H_2O_2 and stripping with 2 N HNO_3.

Final Processing

Cerium oxalate is precipitated in batches of 20,000 curies in the FPDL manipulator cells. The cerium oxalate is calcined to CeO_2 and the dry CeO_2 is pressed into pellets.

Waste Processing

The FPDL does not currently process raw waste acids; however, the facility retains the ability to handle such feed streams. Both "Redox" and "Purex" types of feed can be processed. In each case, the ^{137}Cs is removed from the feed stream by co-crystallization on ammonium alum. Following the ^{137}Cs removal, the other fission products are concentrated by a series of precipitations at high pH using iron as a carrier ("magnetite" precipitation). The magnetite precipitates are dissolved in HNO_3 and the fission products are separated by a series of controlled pH precipitations using NH_3. Fractions containing: (1) ^{106}Ru - Fe, (2) ^{144}Ce and rare earths, and (3) ^{90}Sr are obtained by this operation. Additional purification and concentration steps are done and the final products are processed in the manipulator cells. A processing rate of 500 gal of waste acid per day can be maintained.

Americium-241

Feed Material

Solid $^{241}Am_2O_3$ is shipped to the FPDL in doubly sealed, shielded cans. The outer can is removed before the sealed shielded can is inserted into the manipulator cell; the shielding and final containment layer are removed only after the cell has been sealed.

Pellet Preparation

The $^{241}Am_2O_3$ is blended in lots of 30 grams each with nine to one volume ratio of aluminum powder. The powder is then mechanically measured and poured into a previously formed aluminum sleeve with a powdered aluminum end cap in a die body. Aluminum is poured on top of the Am_2O_3-Al mix. The pellets are pressed at 20 tsi and ejected from the die body; a die body is used only once. The pellets are cleaned then they are sealed in plastic and stored in the cell storage well.

Pellet Encapsulation

The manipulator cell is decontaminated between pellet preparation operations and encapsulation. Pellets are removed from storage and inserted into aluminum capsules. Spacers and end plugs are placed in the capsules then the capsules are sealed by welding. The capsules are leak tested and inserted into a hydraulic collapsing device which collapses the aluminum capsules around the pellets to ensure good heat transfer. The finished capsule is leak tested, cleaned, and loaded into a shipping container.

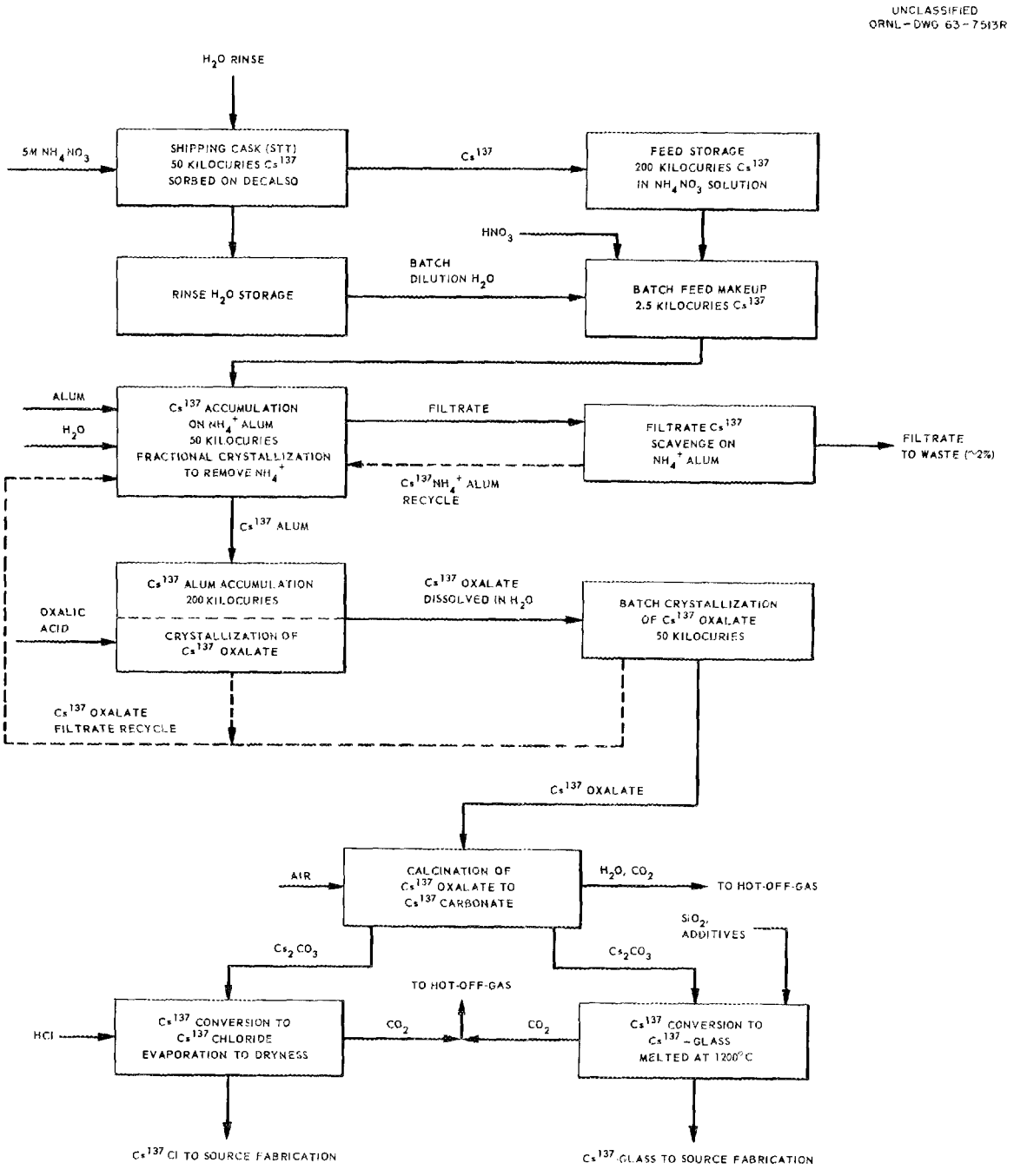

Fig. A-1. FPDL Cs^{137} Processing.

UNCLASSIFIED
ORNL-DWG 63-7511R

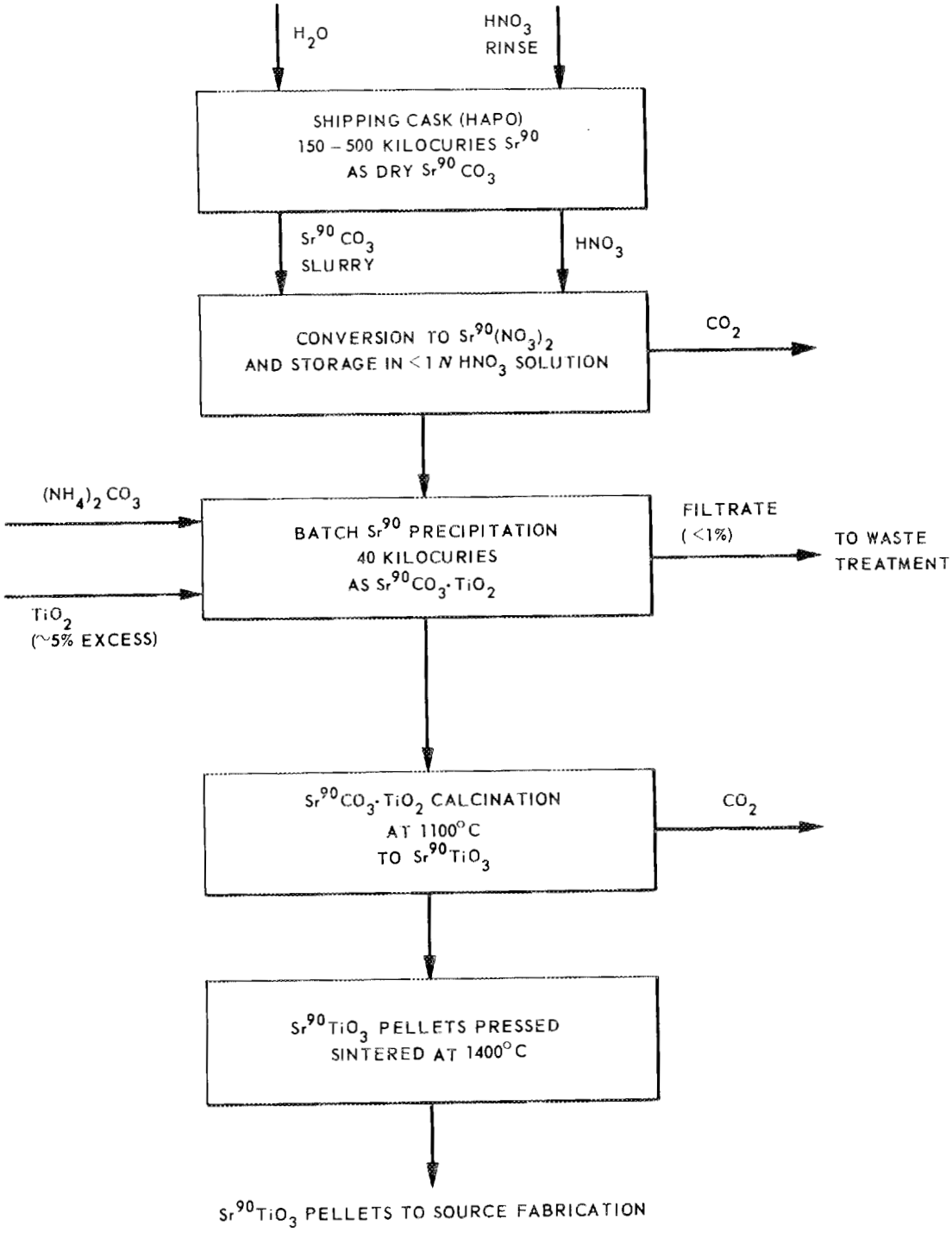

Fig. A-2. FPDL Sr^{90} Processing.

UNCLASSIFIED
ORNL-DWG 63-7512R

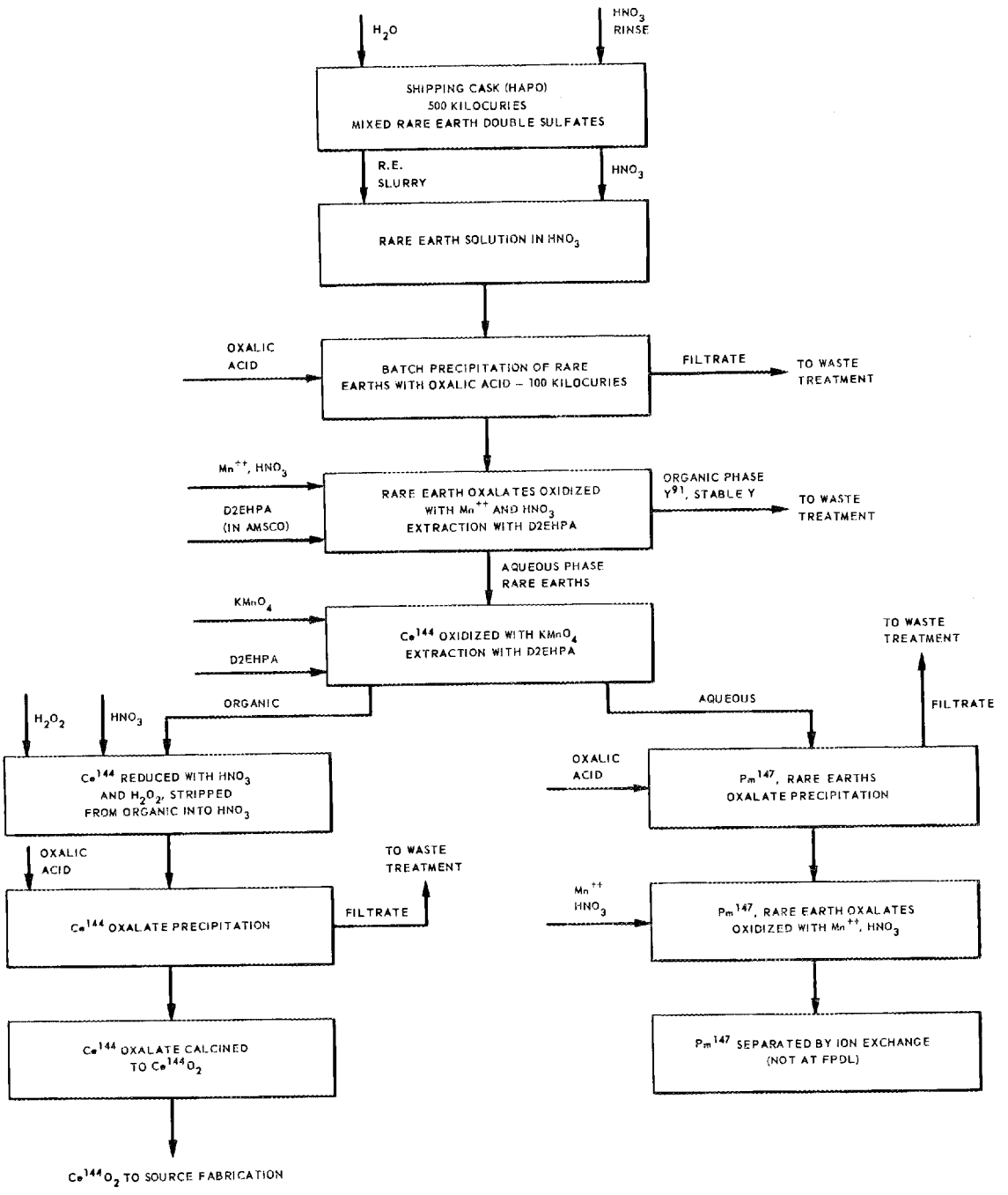

Fig. A-3. FPDL Ce^{144} Processing.

APPENDIX NO. 3

HAZARDS REPORT FOR SHIELDED TRANSFER TANK, MODEL II

Introduction

The Shielded Transfer Tanks, Model II, (STT) have been used to ship aqueous fission product waste from Arco, Idaho, to Oak Ridge National Laboratory since June 1958. During this period 39 cask shipments containing a total of 250,000 curies were made in the six existing casks by rail freight. All shipments have conformed to the existing ICC and Bureau of Explosives regulations, and the casks have been approved for such shipments by the Bureau of Explosives under B of E Permit No. 424. In addition, special attention has been given to routing the shipments to miss large centers of population and to develop special procedures to be followed by the shipper and the carrier both during normal shipments and in the case of emergencies.

Because there is an increased demand for fission products, particularly ^{90}Sr for the SNAP programs and ^{137}Cs for civilian applications, it is desirable to ship higher concentrations of fission products from the Hanford Atomic Products Operation in the STT. In order to increase the safety of the Hanford shipments over that obtained in the less concentrated Arco shipments, the fission products will be sorbed on a bed of 50-80 mesh Decalso, which is an alumino-silicate inorganic ion exchanger. This report is an evaluation of the hazards which may be encountered during shipment of the loaded STT by rail freight.

Summary

The analysis of the STT was made in regard to its structural strength under impact and internal pressure, the strength of its attachment to the rail car, the shielding, the maximum radiolytic gas production expected, and the maximum expected temperature in the center of the Decalso bed.

The force required to rupture the inner tank is 415,000 lb if applied normal to the exterior shell between the fins by an object 6 in. in dia. The cupola of the cask, which contains the nipples of pipes extending into the inner tank, would be breeched by a force of 150,000 lb. The stainless steel inner tank will withstand 235 psig internal pressure based on the yield strength. However, the maximum pressure due to radiolytically produced gas would be 22 psig during the expected shipping time of two weeks. The existing attachment of the cask to the car can withstand a vertical force of 934,000 lb and a horizontal force of 786,000 lb.

The shielding of the cask will reduce the radiation from any of the indicated shipments to less than 5 mr/hr at the external surface. The maximum temperature in the center of the Decalso bed will be 152°F when ^{90}Sr is shipped and 130°F when ^{137}Cs is shipped. Complete insulation of the cask for 48 hr will result in maximum temperatures of 192°F and 153°F for ^{90}Sr and ^{137}Cs shipments, respectively.

Discussion

Radioactive Material Content

Three types of fission product shipments will be made: (1) a crude cut of ^{90}Sr; (2) a purified product of ^{90}Sr; and (3) a crude cut of ^{137}Cs. The amounts of activity normally shipped and the amounts used in calculations for this report are listed below.

Type of Shipment	Isotope	Curies Normally Shipped	Curies Used in Calculations
Strontium-90 crude	Strontium-90	15,000	30,000
	Yttrium-90	15,000	30,000
	Strontium-89	15,000	30,000
	Cerium-144	5,000	10,000
Strontium-90 purified	Strontium-90	25,000	30,000
	Yttrium-90	25,000	30,000
	Strontium-89	25,000	30,000
Cesium-137 crude	Cesium-137	30,000	50,000
	Barium-137m	30,000	50,000

Accident Potential

Collision Frequency and Potential Involvement in Fire. According to the ICC Accident Report for Railways[1], during 1956 there were 7,762 collisions and derailments. Of this number, 504 accidents were either head-on, rear-end or side-swiping train collisions and train-truck collisions, which represents 0.448 accidents per million miles, or figuring a 2,500 mile trip, one accident in 890 trips.[2] It should be noted that only a small fraction of the accidents involve an oil or chemical fire. By positioning the cask car away from cars containing explosives or inflammable materials according to ICC regulations, the possibility of such a fire involving the casks during a derailment can be virtually eliminated.

Evaluation of Results of Release of Radioactive Material. If an accident caused the rupture of the inner vessel, it can be assumed that the cask may be in such a position that all of the supernatant water and a portion of the fission-product-loaded Decalso may be released from the container. Since the Decalso particles are not free-flowing, especially when wetted, only a small portion would be discharged through a hole. A release of 10% of the Decalso is assumed for the purpose of this discussion.

---

[1] Accident Bulletin No. 125, Summary and Analysis of Accidents on Railroads in the United States Subject to the Interstate Commerce Commission Act, ICC Bureau of Transport Economics and Statistics.

[2] C. W. Smith, Design Criteria and Hazards Evaluation Fission Product Shipping Cask, HW-65268 (May 20, 1960).

The discharged Decalso has a much higher probability of falling on the ground beside the track than into a stream because of the distance traveled over dry land relative to that over or beside streams.

If the Decalso is spilled on the ground, the danger to personnel will result from external radiation. Hazards due to airborne particulates would be extremely low because the activity is contained within relatively large particles. If it is assumed that 10% of the total Decalso load is spilled in a small area so that it acts as a small source, the radiation at various distances from the source will be as follows:

Type of Shipment	Radiation in r/hr		
	25 feet	50 feet	100 feet
Strontium-90 crude	3.4	0.9	0.3
Cesium-137 crude	29.2	7.3	1.8

The radiation from the ^{90}Sr crude shipment is due both to the contaminating ^{144}Ce gamma and to Bremsstrahlung radiation. These calculated radiation values are conservatively high because no allowance for self-absorption within the source was made.

The hazard from the supernatant water is very low because of the extremely low distribution coefficient of the fission products between Decalso and water. The calculated concentrations of fission products in the supernatant water under various loading conditions are given below:

Isotope	400 gal Loading of Decalso, c	Conc. in Supernatant water, μc/ml	Total Activity in Supernate, mc
Strontium-90	30,000	2.57×10^{-3}	2.64
Cerium-144	10,000	1.38×10^{-3}	1.42
Cesium-137	50,000	1.9×10^{-2}	19.8

If the Decalso falls into a stream, the particles will sink to the bottom and will be distributed for various distances along the bed depending upon the velocity of the stream. The rate at which the fission products are leached from the Decalso will depend principally upon the calcium content of the water in the stream.

On the basis of a single experiment using water containing 23 ppm calcium, 6 ppm sodium, and 3 ppm magnesium, the time required to elute 50% of the ^{90}Sr from the Decalso in a flowing stream is indicated to be about 40 hr. To obtain a basis of comparison, the maximum concentration in the river water of the Clinch River near ORNL is calculated. The average flow of the Clinch River at this point is 5000 CFS. The rate of elution of the ^{90}Sr will be about 1.04×10^4 μc/sec based on the experimental data.

The concentration in the river, if it is assumed that the activity is completely mixed by lateral movement but does not diffuse in the direction

of flow, would be 7.07×10^{-5} $\mu c/cm^3$. Based on an allowable MPC of 10^{-7} $\mu c/ml$ of ^{90}Sr in water for continuous non-occupational exposure,[3] this value exceeds the MPC by a factor of 700. However, the exposure time to the slug of contaminated water would be in the order of 100 hr. As the slug moves downstream, longitudinal diffusion would increase the exposure time but would decrease the concentration proportionately. The amount of ^{90}Sr actually in solution would be decreased by absorption on the clays of the river bottom.

Cask Description

The Shielded Transfer Tank, Model II (ORNL Dwg. E-29375), is about 69 in. wide, 80 in. high, and weighs ~18 tons. The cask is an externally finned, lead-shielded cylinder. The lead shielding is contained in a 3-1/2-in. annulus between the 3/4-in. thick mild steel outer shell and the 3/8-in. thick 347 stainless steel inner shell or tank.

A small shielded cupola on top of the cask contains the valved nozzles of the pipes extending into the inner tank. Each pipe which extends into the inner tank from the cupola space is equipped with a valve-type Snaptite fitting which provides a positive seal against pressure within the tank. As a second seal against leakage from the inner tank, the end of the pipe with the Snaptite fitting is enclosed within a larger pipe, which is welded to the plate forming the floor of the cupola and is closed with an asbestos gasketed flange on the top end. A third seal is provided by the stainless steel gasketed top cover of the cupola.

In order to prevent pressure within the vapor space of the inner vessel from forcing liquid up the dip-tube against the Snaptite closure, a sliding tube within the upper section of the dip-tube is provided so that the upper section of the dip-tube is vented to the vapor space in the cask while the car is in transit.

Three casks are mounted on one 70-ton gondola car, which has been altered by welding special base plates to the car. Each cask is bolted to a 1-in. thick circular base plate by fourteen 1-1/2-in. bolts. A lock nut is drawn up tight against each holding nut to prevent its backing off due to vibration in transit. All bolts and nuts are replaced after each round trip because of the possibility of weakening of the bolt due to fatigue of the metal or thread wear which can result from the repeated stresses during shipment.

The circular base plate is welded to two boxed beams, which span the car, and to two cross beams, as shown in ORNL Dwg. E-29575. Each beam is welded to the floor of the car, which is specially selected to have a smooth, all-welded floor. In addition, gusset plates are welded to the ends of the two spanning beams and to the sides of the car. Each cask is also tied to the car by four 5/8-in.-dia cables attached to pads welded to the floor of the car (ORNL Dwg. D-33300).

---

[3] NBS Handbook 69, p. 93-94 (June 1959).

Analysis of the Structural Integrity of the STT

The structural calculations indicate the cask mounting holding the STT to the gondola car will withstand a vertical force of 934,000 lb and a horizontal force of 786,000 lb.

The dished heads of the stainless steel inner tank will withstand 235 psi internal pressure and the cylindrical shell will withstand 335 psi internal pressure based on yield strength. The radial dispersion calculated at yield strength is 0.023 in. and at ultimate strength is 0.062 in. The lead shield was not considered as support since the void space between the lead and inner tank is probably greater than the radial dispersion at yield strength.

The force required to breech the inner cask was calculated for the following conditions:

1. A 6-in.-dia unyielding flat object strikes the cask between two fins and normal to the surface. The required force is 415,000 lb.

2. A 6-in.-dia object strikes the cupola side normal to the surface. The required force is 150,000 lb.

A 6-in.-dia object was chosen as being the smallest object likely to absorb the force of the impact without deforming.

For condition No. 1, the force was considered as acting on a 10-in. wide section of the outer shell which is effectively reinforced by one fin. Because of its low tensile strength, the lead was not considered as adding to the strength of the cask, but was considered as transmitting the force to the inner tank. The formulas used to calculate the minimum applied force required to rupture the shells are those applicable to closed-end tanks.[4]

For condition No. 2, the force was considered as applied to the outer and inner shells as open-end cylinders and was calculated by the applicable formulas.[5]

The minimum deflection of the side wall of the inner tank required to cause a break in the tank wall was calculated to be 0.243 in. By the use of this calculated deflection it can be shown that dropping the cask from a height of 2.9 in. or hitting it at a speed of 2.7 mph will cause it to rupture. However, it should be noted that the results obtained by the methods used in these calculations are considered to be conservative. In the case of the allowable deflection, some doubt exists as to the validity of the formulas used, but insufficient time was available to allow an extensive analysis. It is planned to submit this problem to an independent consultant for analysis.

---

[4] R. J. Roark, Formulas for Stress and Strain, McGraw-Hill Book Co., p. 272 (1954).

[5] Ibid, p. 270.

Temperature of Decalso Bed

The temperature at the center of the Decalso bed when the cask is in 90°F ambient air was calculated to be 152°F for the ^{90}Sr shipment, and 130°F for the ^{137}Cs shipment. If the cask were completely insulated for 48 hr, the temperature would rise to 192°F for the ^{90}Sr shipment and to 153°F for the ^{137}Cs shipment.

Gas Production and Pressure Buildup

According to studies made by the Radiation Chemistry Group of the ORNL Chemistry Division, the behaviour of irradiated water will be governed by the following considerations:

1. When pure water is irradiated, the equilibrium pressure of hydrogen and oxygen resulting from the decomposition is very low.

2. Equilibrium is attained within two to three days in practically all cases.

3. The decomposition of water is into $H^+ + OH^-$. These products may react with each other to form H_2O, with themselves to form the molecular products H_2 and H_2O_2, or with oxidizable or reducible products. In completely sealed vessels, a back reaction can take place as follows:

$$H_2 + OH^- \rightleftharpoons H_2O + H^+$$

$$H_2O_2 + H^+ \rightleftharpoons H_2O + OH^-$$

4. These reactions strongly favor the production of water. Oxidizing and reducing ions tend to interfere with the back reactions favoring the building of molecular products. The halides are particularly notable for interfering with the recombination reaction and maintaining the initial H_2 yield.

5. Non-oxidizable or reducible ions have no effect on the molecular yields.

6. Surfaces do not appreciably alter the reaction.

7. The decomposition of H_2O under irradiation is first order while the recombination reaction is a higher order reaction, so that the equilibrium pressure of H_2 and O_2 is increased with increasing radiation flux.

8. The temperature effect on the recombination reaction within the range expected is negligible.

Although the recombination effects which decrease the free gas formation cannot be calculated precisely for the condition in the STT, the maximum gas productions, assuming no recombination reactions, can be calculated from the known "G" value for water. The maximum gas production would

result in a maximum pressure of 22 psig in the 100-gal free space of the cask during a two week period. This pressure is well within the allowable pressure limits of the cask.

Operating Procedure

Loading. The cask will be transported to Hanford on a specially adapted railway car for loading. Prior to shipment to Hanford, the cask will be loaded with 400 gal of Decalso -- a synthetic aluminosilicate, inorganic ion exchanger (produced by Permutit Company) with a 100-gal free space above the ion exchanger bed. The cask will be placed in position, liquid inlet and outlet lines will be connected and a measured volume of liquid will be passed through the ion exchanger bed. The amount of ^{90}Sr or ^{137}Cs in the cask will be determined by difference from samples of the feed effluent solutions.

Unloading. The loaded cask will be received by ORNL and transferred to the FPDL on a low-boy over AEC area roads. The cask will be positioned in the unloading cell and liquid inlet and outlet lines will be connected. A stripping solution will then be pumped through the ion exchanger bed to remove the fission products. A measured volume of stripper solution will be used to elute the material and the effluent solution will be sampled to determine when all the material has been removed from the cask.

Shipping Procedures. The shipping procedures from Hanford to ORNL will be very similar to those followed in making cask shipments from Arco, Idaho, to ORNL.

1. The routing will be made to avoid heavily populated areas, unnecessary switchyards, and natural or man-made potential hazards as much as possible within the limitations of reasonable cost and shipping time.

2. Instructions regarding the shipment will be transmitted to the train crew on the bill of lading. These instructions will include a description of the shipment and will state that the shipper, the consignee, and the Bureau of Explosives must be notified in case of an emergency.

3. The shipper will advise the Superintendent of Transportation of the primary carrier of the shipment and request that he inform all stations under his jurisdiction of the car's movement. The primary carrier will also be requested to notify the connecting carriers to give the car special handling.

4. The shipper will inform the consignee by teletype at the time the shipment departs his plant. Copies of the teletype to ORNL will go to the Laboratory Shift Supervisor, Traffic Department, and Superintendent of the Fission Products Development Laboratory.

5. The shipper will obtain special approval from the Bureau of Explosives for each shipment. By internal procedures the Bureau of Explosives will notify their field representatives, who can inspect the shipment at various points enroute as they desire.

6. In case of an in-transit emergency reported to the ORNL Laboratory Shift Supervisor, he will immediately notify the Manager of OROO, or his designated representative, who will take the proper steps according to the OROO Radiological Incidents Plan (October 23, 1958). According to this plan, the Regional Office responsible for the area in which the emergency occurs will be contacted immediately by the OROO for radiological assistance.

7. The casks will be labeled in conformance with Bureau of Explosives and ICC regulations in Tariff ICC No. 13 regarding shipping containers for radioactive materials. The car will be placarded in conformance with Tariff 13 regulations regarding car-lot shipments of radioactive material.

8. The carrier is responsible for locating the car in the train according to Section 74.589 (N) of Tariff No. 13 to insure that it is not handled next to cars which are placarded to denote that they contain explosives.

9. A representative of ORNL will ride the train containing the first shipment to monitor the casks enroute and to observe conditions along the route.

DISTRIBUTION

1-8. T. A. Arehart
9. P. S. Baker
10. R. E. Blanco
11. J. C. Bresee
12. K. B. Brown
13. T. A. Butler
14. F. N. Case
15. K. E. Ferguson
16. J. H. Gillette
17. H. E. Goeller
18. A. T. Gresky
19. C. V. Ketron
20. E. Lamb
21. L. O. Love
22. H. G. MacPherson
23. K. Z. Morgan
24. C. P. Keim
25-29. C. L. Ottinger
30. R. A. Robinson
31. A. F. Rupp
32-35. R. W. Schaich
36. ORNL - RC
37-46. Laboratory Records
47-48. Central Research Library
49. Document Reference Section
50-64. DTIE, ORO
65. Research and Development Division, ORO