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Sup 2C, Rev. 1
July 1991

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SAFETY ANALYSIS — 200 AREA
SAVANNAH RIVER PLANT

SEPARATIONS AREA OPERATIONS

BUILDING 221-H, B-LINE PLUTONIUM OXIDE FACILITY (Sup 2C)

WILLIAM C. PERKINS
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[redacted]

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Publication date: September 1985

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

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DISCLAIMER

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1.0 INTRODUCTION

The new HB-Line, located on the fifth and sixth levels of Building 221-H, is designed to replace the aging existing HB-Line production facility. The new HB-Line consists of three separate facilities: the Scrap Recovery Facility, the Neptunium Oxide Facility, and the Plutonium Oxide Facility. There are three separate safety analyses for the new HB-Line, one for each of the three facilities. These are issued as supplements to the 200-Area Safety Analysis (DPSTSA-200-10). These supplements are numbered as:

Sup 2A = Scrap Recovery Facility
Sup 2B = Neptunium Oxide Facility
Sup 2C = Plutonium Oxide Facility

The subject of this safety analysis, the Plutonium Oxide Facility, will convert nitrate solutions of ^{238}Pu to plutonium oxide (PuO_2) powder. All these new facilities incorporate improvements in:

1) engineered barriers to contain contamination,

2) barriers to minimize personnel exposure to airborne contamination,

3) shielding and remote operations to decrease radiation exposure, and

4) equipment and ventilation design to provide flexibility and improved process performance.

2.0 SUMMARY

Risks of operation are summarized in Table 2-1. In the event of an accidental criticality, two fatalities could result. Based upon a probabilistic fault tree analysis, the probability of an accidental criticality has been estimated to be once per 70,000 years or 1.4×10^{-5}/yr. Thus, this risk is one fatality per 35,000 years, less than the Du Pont criterion for operating facilities, one fatality per 10,000 years.

Table 2-1 shows that the maximum risk to an offsite individual is 1.97×10^{-5} rem/year due to a low energy event, which is lower than the 3×10^{-1} rem/year an individual in this area is expected to receive from natural background radiation. Thus, this analysis shows that the $^{238}PuO_2$ production facility can be operated without undue risk to operating personnel, to the public, or to the environment.

TABLE 2-1

Risks for HB-Line $^{238}PuO_2$ Facility

	Annual Risk		
	person-rem/year		rem/year
Event	To Onsite Population	To Offsite Population	Maximum to an Offsite Individual
Earthquake	6.62×10^{-4}	2.42×10^{-3}	2.96×10^{-7}
Medium Energy	1.54×10^{-2}	5.59×10^{-2}	6.86×10^{-6}
Low Energy	4.39×10^{-2}	1.60×10^{-1}	1.97×10^{-5}
Residual Releases	5.37×10^{-3}	1.97×10^{-2}	2.41×10^{-6}
Criticality	0.10	2×10^{-5}	9×10^{-9}
Analytical Laboratory (Medium Energy)	9.22×10^{-3}	3.36×10^{-2}	4.13×10^{-6}

3.0 DESCRIPTIONS

3.1 General[1]

The SRP site and Building 221-H have been described elsewhere.[2]

The PuO_2 Facility HB-Line addition will be housed in a reinforced concrete structure located on the roof of the building over part of Section 5 and all of Section 6. The two-story structure will be adjacent to and contiguous with the NpO_2 Facility. See Figure 3-1 for an overall plan of the three facilities.

The new 5th Level will house the process glove box line, the instrument control room, calorimetry laboratory, welding room, waste handling line, PHA room, waste handling conveyor, and a product storage vault. The 6th Level will house the H&V systems for glove boxes and rooms in Phases II and III, Halon™ equipment room, and process air system. See Figures 3-2 and 3-3 for details.

The building population for the $^{238}PuO_2$ line is expected to be fifteen people working on an eight-hour day shift. The composition is two production supervisors, one clerk, two Health Protection Technicians, one Separations Technology engineer, and nine operators.

The main structure will consist of two levels constructed of reinforced concrete exterior walls. The 6th Level and new roof will be supported by the use of precast, prestressed tee beams. The use of tee beams eliminates the need for interior supports. A stair tower will be provided at the northeast corner of the new addition to serve the 5th and 6th Levels and provide access to the roof of the existing canyon building.

On the 5th Level, a tornado barricade corridor along the east wall of the main structure is a one-story high by 4'-8" wide barricade corridor to provide tornado missile protection for the airlocks to operating area 1 and the maintenance area. This corridor will terminate at the airlock entry to the east stair tower serving the 5th and 6th Levels. The west structural wall serves as tornado protection for that side of the facility.

The floors, walls, doors and paint for this area are the same as the main structure. The roof of the corridor and stair tower will be poured concrete with built-up roofing and board insulation.

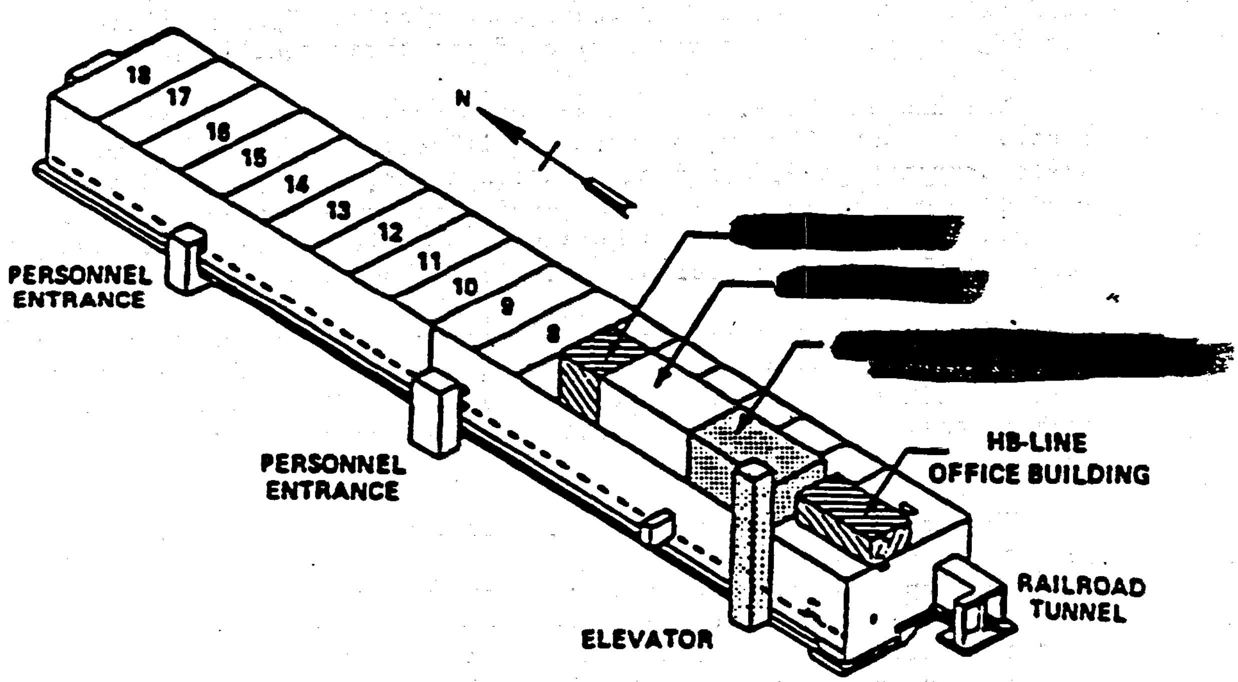

FIGURE 3-1. The Chemical Separations Building 221-H and New HB-Line

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FIGURE 3-2. Floor Plan, Fifth Level, PuO_2 Facility

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FIGURE 3-3. Floor Plan, Sixth Level, PuO_2 and NpO_2 Facilities

3.2 Equipment

3.2.1 Process Glove Boxes

The process glove boxes are of a sandwich stainless steel-lead-water-stainless construction with acrylic/lead glass windows, Central Research glove ports (these allow easier replacement of gloves with a much reduced chance of breaching containment during glove replacement), and HEPA inlet and exhaust filters. The glove box and shielding window design will be similar to the Scrap Recovery Facility design.

A special partition runs from the top of the glove boxes to the underside of the ceiling. The sheetmetal partitions are supported on 2" x 2" x 1/4" angles.

3.2.2 Receipt and Adjustment Tanks

High assay Pu-238 solution is transferred by pump from new canyon tank [redacted] to either of two 300-liter receiving tanks. Each tank is equipped with an agitator, a sampler, and a chemical addition line. The tank instrumentation includes temperature, pressure, and liquid level. These tanks are water-jacketed and lead-shielded for radiation shielding.

3.2.3 Precipitation

Precipitation equipment includes the 150-liter precipitator feed tank, a two-stage precipitator, and chemical addition tanks. The feed tank and precipitator are equipped with agitators and exterior neutron shielding. The precipitator instrumentation includes temperature, pressure, liquid level, temperature control, and feed flow control.

3.2.4 Filtration

Filtration equipment is as follows:

- Filter station assembly.
- Two filtrate tanks, 150 liters, equipped with an agitator, sampler, and a chemical addition line.

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- Four filter boats, 7" diameter, with a 10 micron platinum filter.
- Filter boat flush station.

3.2.5 Calcining Furnaces

Plutonium oxide is transferred between the filter station, calcining furnace, and product dumper in a 7" filter boat. The filter boat is moved by a motor-driven trolley and lifted into the various positions in the furnaces, filter station, filter boat backwash station, and dumper by a motor-driven mechanical actuator.

The two 10 kW calcining furnaces are 10" in diameter with a nominal operating temperature of 740°C. The furnaces may be purged with air, N_2, or $^{16}O_2$. Furnace temperatures are determined by SCR power controllers.

The furnace exhaust is filtered by a sintered-metal filter and discharged to the glove box exhaust system.

3.2.6 Product Handling

Glove boxes are provided in the line to house equipment for manual filter-boat dumping and a breech lock loader similar to existing design.

The following equipment is located in the Calorimetry Room:

- Twin water bath calorimeters, one programmed for analysis of low level scrap samples, and the other programmed for product shipping containers.
- Analytical balance and vibration free stand.
- Laboratory furniture (desk, filing cabinet, storage cabinet).
- Instruments to provide electronic data collection, and controls for the calorimeters.

A welding machine seal-welds the closure cap on the secondary product container. The welding machine is similar to that provided in the existing HB-Line and is comprised of the following individual pieces of equipment (this is located in the Welding Room):

1. Welding Power Supply.

2. Programmer.

3. Meters - Amp and Volt.

4. Pendant Control.

5. Remote Arc Starter.

6. Recorder, strip chart.

7. Turntable.

8. Wire Feeder.

9. Torch Positioner.

10. Exit hood arrangement to house the welding unit.

11. Argon gas supply system.

12. Electrical power for the TIG welder.

13. Wiring and controls to connect welding station with the remotely located power supply.

After the product shipping container is seal welded, it will be leak tested to ensure that the container meets offsite shipment specifications. The shipping container is placed in a Lucite® leak test tank (5" dia. x 10" deep) which is filled with ethylene glycol. The tank is sealed and a vacuum pump is then used to pull a 20" Hg vacuum on the tank. The shipping container is then observed for visible leaks which would be indicated by bubbles around the weld.

3.2.7 Storage Vault

A product storage vault is located on the [redacted] Level adjacent to the glove box line (Room [redacted] The vault room size is 250 ft^2 of floor area. Three product container cooling baths similar to existing designs are provided. The room is constructed of 8" thick reinforced concrete walls and ceiling. A 1" thick steel door, equipped with combination lock, conforming to federal specification AA-D-600B is the single entry; a lockable box covers the combination lock. Security equipment consists of intrusion alarms and television cameras. A Nuclear Incident Monitor is located in the storage vault (see section 4.8.4.5.2).

3.2.8 Solid Waste Handling

The remotely operated waste transport system has a single trolley that travels in a north-south direction on a set of rails at an elevation approximately 6 ft. above the bottom of the glove box. The trolley has a hoist that lowers a container nominally 6 ft. into the waste glove box of each glove box line.

Waste material will be manually loaded into the container. The system will then automatically transport the trolley-hoist to a waste handling glove box line where the material must be manually unloaded. The system operation is controlled by the operators through control stations located at each waste glove box. Additional control stations are located in the waste handling room and in the maintenance area in building section [redacted] The maintenance area in building section [redacted] will also be used to maintain the trolley cart. The system is designed for contact maintenance through gloveports. There are two drives (approximately 1/2 hp each) on the trolley (one to drive the cart and one to raise and lower the container). Cart positioning is controlled by magnetic proximity switches.

Fire dampers in the drop ports to the glove boxes regulate or restrict air flows.

The waste handling line in the PuO_2 Facility includes:

- In-Line PHA
- Filter press
- Washing Machine
- Ultrasonic Cleaner
- Leach Bath
- Filters
- Hold tanks (2)

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3.2.9 Analytical Laboratory

The HB-Line analytical laboratory will receive liquid Pu-238 nitrate samples from the HB-Line Scrap Recovery Facility, the HB-Line Plutonium Oxide Facility, and H-Canyon. Pu-238 oxide samples will be received from the Plutonium Oxide Facility. The location of this laboratory is shown in Figure 3-3A.

All samples from the Scrap Recovery Facility, H-Canyon frame waste recovery operation, and Plutonium Oxide Line are entered into the HB-Line Pu-238 analytical laboratory for preparation and/or analysis. All the analysis is performed in this lab except for isotopic determination and trace Pu concentration. Isotopic analysis and trace Pu concentration are performed, in Building 772-F, on small samples that are prepared in the HB-Line laboratory.

Samples, both liquid and oxide, are delivered to Room [redacted] where their identification is logged into a computer that maintains an inventory of samples and prescribes appropriate analysis to be performed. The samples are carried to bagin/out Room [redacted] (Figure 3-3A), where they are placed into the lab glovebox. In the glovebox cabinet, the appropriate analysis is performed.

Density measurements are a primary means of process control. An automated density meter is used to confirm that samples are representative and within appropriate acid specifications. Solution from the sample vial is pumped into the measuring cell of the oscillator tube. The density meter measures changes in resonant frequency of a hollow oscillator tube when filled with liquids of different densities. The software prompts the technician through the analysis and prints density measurements corrected to 25°C. After the analysis is complete, the system is flushed with 1N nitric acid and reagent grade methanol.

The acidity of liquid samples is determined by measuring the free acid in the nitrate solution. Saturated potassium oxalate is used to complex small concentrations of plutonium. The free acid is determined by manual, volumetric titration with 0.1N or 0.01N sodium hydroxide to the 0.1% phenolphthalein end point.

Determination of plutonium concentration in solutions is performed by Pu(III) diode array spectrophotometry. This method is applicable for Pu-238 samples ranging from 0.1 to 1.15 Pu g/L. A predetermined volume of matrix solution (0.05M ferrous sulfamate, 0.3M sulfamic acid, and 1M nitric acid) and an aliquot of sample are mixed in a plastic vial. The matrix solution converts all plutonium to the +III valence state. The sample is pumped from the sample vial to the measurement cell of the spectrophotometer. The

FIGURE 3-3A. HB-Line Pu-238 Analytical Laboratory absorption spectrum of the sample is obtained, calculations performed, and the concentration of plutonium printed out.

Tap density is performed on Pu-238 oxide samples. A small amount (approximately 10 grams) is weighed to the nearest 10 mg, and poured into a graduated cylinder. The cylinder is placed in the tapping device and preset to 3000 taps. The tapping device has a speed of about 250 rpm and a stroke travel of about 1/8 inch. After the tapping is complete the initial weight is divided by the mean volume of oxide after tapping, to give the tap density in g/mL.

Determination of percent weight loss is done by heating a 1-g sample to 750°C for 1 hour. After heating, the oxide sample is cooled over a dessicant for 1 hour. The cooled sample is reweighed, and the fraction of the original weight that is lost (multiplied by 100) is recorded as percent weight loss.

Isotopic analysis is required for Pu-238 liquid and oxide samples. Only liquid samples of limited volume are analyzed in Building 772-F. Sample preparation is performed in the HB-Line laboratory. Oxide samples must be dissolved by heating a recipe of 14.1M nitric acid and Pu-oxide on a hot plate in the glovebox. A small aliquot (6 nanograms), pipetted into a vial, is transported to Building 772-F for the isotopic analysis. Initial Pu-238 solution samples are also pipetted and sent to Building 772-F.

Total gamma determination is performed using a gamma pulse height analysis (PHA) system. A known aliquot of solution from the original field sample is placed in a dilution vial, and transferred to the sample holder of the PHA. The counting system, a single energy gamma emitter, will slow in a peak that corresponds to that energy and channels lower than that energy. The gamma activity is measured with a Ge(Li) detector fitted with a lead-aluminum absorber. The absorber is used to absorb x-rays and lower energy gamma. Reports are generated that provide qualitative and quantitative analysis, lower limit of detection, or minimum detectable activity calculation.

Particle size analysis (PSA) is performed to provide exact size of particles. A small portion of the sample is placed in a cuvette containing a glycerin medium. The cuvette is placed in a sample cell. The PSA uses a focused scanning He-Ne laser that passes through a prism which rotates the beam at a constant velocity. The beam passes through a microscope objective that is focused inside the sample cell. The beam continues through the sample cell and falls on a PIN photodiode that measures the beams intensity. A particle moving through the measuring zone interrupts the beam, causing an interactive pulse or shadow on the photodiode. With the exception of the sample preparation, the process is controlled by menu driven computer options.

3.3 Process

The process is an improved version of the process used since 1961 in the original HB-Line on the fourth level of 221-H: ^{238}Pu nitrate solution from H-Canyon is converted to plutonium oxide (PuO_2) powder by the oxalate precipitation and calcination method. One improvement is $^{16}O_2$ exchange to reduce the neutron emissions from $^{18}O_2$ (a,n) reactions. The product is shipped to Building 235-F or to offsite facilities for fabrication into heat sources. Theoretical production capacity of this facility is 90 kg of $^{238}PuO_2$ per year, on a one shift, 5 day week schedule.

As shown schematically in Figure 3-4, the feed solutions are received and adjusted. Then, the plutonium is precipitated, separated from the slurry by filtration, and calcined to plutonium dioxide in $^{16}O_2$ at 740°C. After calcination, the product is packaged in primary and secondary containers and sent to a storage vault. It is subsequently taken to the Calorimetry Laboratory where the plutonium content is accurately determined. The product is then returned to the vault until shipment. Off plant shipments will be seal welded in the Welding Room.

3.3.1 Feed Solution

The feed solution contains approximately 6 gm Pu/L and 0.5 M nitric acid. Although the design basis is 83%, this analysis assumes 92% of the plutonium is ^{238}Pu and 8% is ^{241}Pu for conservatism and to include a slightly higher composition as a contingency. Plutonium processed in this facility is expected to contain at least 67% ^{238}Pu. Other isotopes are given in Table 3.3. The specific activity of this plutonium is 25.06 Ci/g. A process batch of plutonium is assumed to contain 388 g of plutonium (357 g ^{238}Pu).

TABLE 3-3

Plutonium Composition

Nuclide	Typical Weight Fraction	Maximum Weight Fraction	Worst Source Term*	Radioactivity (Ci)%**
^{238}Pu	0.75-0.90	0.92	0.92	64.2
^{239}Pu	0.11-0.17	0.48	0	0
^{240}Pu	0.01-0.05	0.20	0	0
^{241}Pu	0.005-0.03	0.16	0.08	35.8
^{242}Pu	0.0005-0.001	0.001	0	0

* The worst source term represents the weight fraction resulting in the highest doses. It is used only to obtain the most conservative dose values and is not an actual isotopic distribution that will occur in normal operations.

** Based on worst source term.

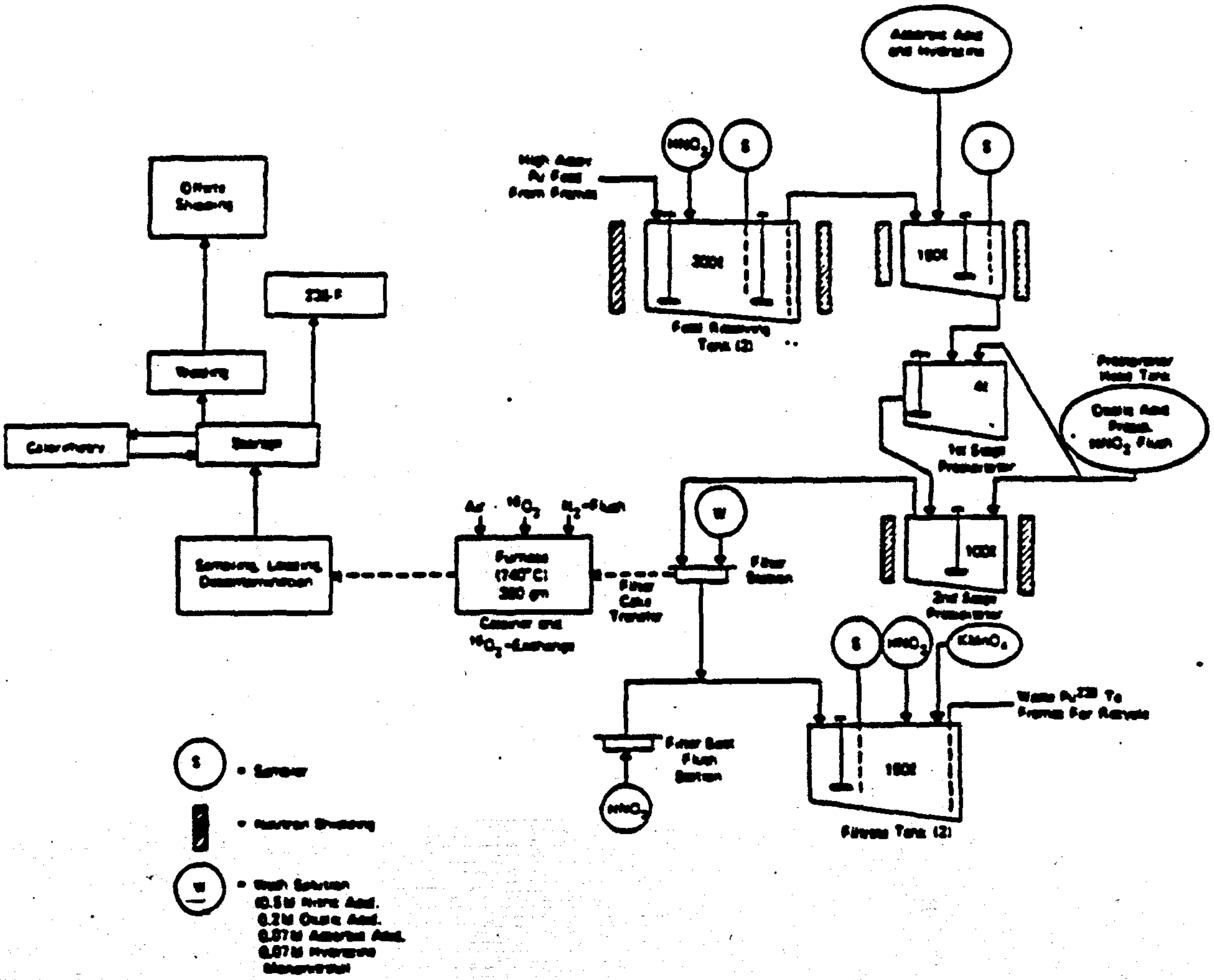

FIGURE 3-4. Schematic of New HB-Line Plutonium Oxide Process

3.3.2 Feed Adjustment

Feed solution is received in either of two receipt and adjustment tanks where it is adjusted to 1.5 M by addition of 64% nitric acid. The adjusted solution contains approximately 5.5 gm/L of total plutonium. The two tanks are used interchangeably for receiving and adjustment. While solution from one tank is adjusted and transferred to the precipitator feed tank, the other tank is available to receive another transfer of solution from the canyon.

In the precipitator feed tank, the plutonium valence is adjusted to the III state with ascorbic acid and hydrazine mononitrate. Ascorbic acid reduces plutonium from the IV to III valence state. Hydrazine mononitrate is added to retard oxidation of plutonium III by radiolytically-formed nitrous acid. Hydrazine mononitrate scavenges nitrous acid and forms highly soluble hydrazoic acid.

Valence adjustment of the feed solution begins with the addition of a predetermined volume of 30% hydrazine mononitrate to the feed tank to give 0.05M hydrazine mononitrate in the feed solution. Ascorbic acid is then added to a 0.03M excess. After approximately 10 minutes reaction time, the adjusted solution can be transferred to the precipitator.

3.3.3 Precipitation and Filtration

Plutonium oxalate is precipitated by adding the adjusted feed solution into oxalic acid at 30-40°C in the two-stage precipitator. Sufficient oxalic acid is added to provide 1.5 moles of oxalic acid for each mole of plutonium and provide 0.23M excess.

When precipitation is complete, the slurry is filtered to recover plutonium oxalate. The precipitator and the precipitate are washed with a wash solution which contains oxalic acid, hydrazine mononitrate, and ascorbic acid in 0.5M nitric acid.

During filtration and washing, the solution is drawn by vacuum from the precipitator through the filter station to the filtrate catch tank. The filtrate and wash solution are mixed, sampled for analysis, and transferred to the canyon.

3.3.4 Calcination

Filtered and washed plutonium oxalate is normally allowed to dry overnite from self-heating prior to calcination. The oxalate is converted to the oxide product by heating to about 740°C for two hours. Air flow of approximately 2 SCFM is maintained during the first hour and the furnace is blanketed with $^{16}O_2$ for the second hour. During cooling, a nitrogen purge is supplied to prevent isotopic exchange of $^{16}O_2$ for $^{17}O_2$ or $^{18}O_2$.

3.3.5 Packaging

After the plutonium dioxide powder has cooled (200°C), it is sampled and loaded into a primary container which is loaded out via breechlock to the secondary container, decontaminated, and sent to the storage vault. The containers are weighed and calorimetered. Containers for offplant shipments are welded prior to being loaded into shipping casks.

3.4 Ventilation

A once-through ventilation system for building and glove boxes maintains air flow from clean to progressively more regulated compartments. The building has three zones of possible contamination. Zone I will have the greatest possiblity of contamination and Zone III will have the least possibility of contamination. Zone II is an intermediate zone. Contamination control will be accomplished by providing an air flow pattern which flows room air from clean to less clean areas. Air will be exhausted from areas of highest potential for contamination.

The following is a list of zone assignments:

Zone I - Glove Box Lines

Zone II - Glove Box Operating and Maintenance Rooms, H&V Glove Box Fan and Filter Room, Welding Room, Calorimetry Room.

Zone III - Facility H&V Equipment Room, Halon Room, Air Monitoring, and Control Room.

Air locks are placed between building zones so differential pressures between zones can be maintained.

3.4.1 Ventilation Supply Systems

3.4.1.1 Air Supply

The HB-Line air is supplied by three air conditioning units. These units are mounted on the canyon roof east of the HB-Line facility. The three units together have a maximum air supply capacity of 51,000 cfm.

The air supply to the facility is controlled by pneumatic "air to open" dampers on the discharge side of each unit. These dampers are interlocked with the fire suppression system and with the high-pressure alarm in the canyon exhaust tunnel. The dampers close to 10% of normal in either of above-alarm conditions. The fan motor on each unit is also interlocked with canyon "high pressure" in the tunnel exhaust. The motor will shut down (along with the facility exhaust blowers) and has to be manually started again by an "Off-Run-Start" hand switch located at each unit. The roll type filter drive motor also stops when the unit fan motor stops and will start again when the fan motor starts.

The "Motor Off" light and alarm, motor "Running" light, and "Low Airflow" for each unit are located in the control rooms.

3.4.1.2 Air Conditioning

HB-Line air conditioning system: (1) supplies conditioned air to the support facility (office area, lunch room; and change rooms); (2) supplies the Scrap Recovery Facility; and (3) supplies the Neptunium and Plutonium Facilities. The units are mounted outside on the canyon roof east of the HB-Line facilities and are of weather tight construction. The cooling media for each unit is chilled water (20 percent ethylene glycol) and the heating media is 15 psig steam.

The support facility (office area, lunch room and change rooms) unit is a multi-zone horizontal blow-through type for low-pressure service. The unit will supply 6,000 cfm of conditioned air. This ventilation system differs from the other two systems in that it recirculates the air from the nonregulated sections of the support facility, whereas the air from the other two systems is once-through and is discharged through the facility exhaust system. The air from the regulated sections of the support facility is discharged to the atmosphere via exhaust fans and HEPA filters located on the roof. The supply air to the unit is obtained from a plenum that is common to all three units. The air to the support facility unit is filtered by a 2-in.-thick throw-away type filter.

The Scrap Recovery Facility unit is a single-zone draw-through type unit using 100% outside air. This means that the air supplied by the unit is not recirculated but is once-through and is discharged through the facility exhaust system. The unit will supply a maximum of 17,000 cfm of conditioned air. The air supplied to the unit from a common plenum is filtered through two stages: (1) an automatically renewable roll type prefilter with a 25% efficiency on atmosphere dust; (2) replaceable high-efficiency filters which are rated at 55% on atmospheric dust based on the dust spot-test method.

The unit supplying conditioned air to the Neptunium Oxide Facility, and the Plutonium Oxide Facility has a 30-hp motor and is capable of supplying 28,000 cfm of conditioned air. It is also a single-zone draw-through type using 100% outside air. The supply air to the unit is the same as for the recovery facility unit described above.

A small 230 cfm air-conditioning unit will condition the Calorimetry Room to 75°F ± 2°F and 60% RH ± 5% year round. The unit will be located in the ceiling space above the Calorimetry room and will contain a cooling coil, electric heater and steam humidifier, and fan. Air will be ducted to the unit's inlet from the main supply duct, conditioned, and delivered to the room through perforated ceiling supply panels.

3.4.2 Ventilation Exhaust Systems

A schematic of the HB-Line exhaust system is shown in Figure 3-5. This section describes the clean and regulated room exhaust, cabinet exhaust, vessel vent, and the sand filter.

3.4.2.1 Room Exhaust (Clean)

The only clean (nonregulated) exhaust system in HB-Line is in the support facilities (office area, change room, lunch room, etc.). Thee exhaust air from this facility is recirculated through the facility air conditioning unit. The facility exhaust air (2775 cfm) is returned to the air conditioning unit via a 26-in. x 14-in. duct which is located at the east end of corridor [redacted] (just outside of lunchroom). The air is filtered through a throw-away filter, reconditioned, and returned to the facility.

3.4.2.2 Room Exhaust (Regulated)

The HB-Line regulated area exhaust consists of two systems. One system exhausts to the atmosphere, and the other system is tied into the canyon exhaust.

The portion of the HB-Line Facility that exhausts to the atmosphere is the regulated sections of the support facility (regulated change rooms, regulated offices, and Health Protection counting room). These areas are of low contamination potential. A platform on top of the support facility roof supports the system's exhaust fan (2 hp) and HEPA filter assembly. Access doors are provided on the enclosure for filter change and repairs to the assembly. The system exhausts 3150 cfm. Running lights for the exhaust motor are provided on a panel in the regulated corridor (599). The discharge stack on top of the assembly has a manually operated damper and an air sample probe.

The process area regulated room exhaust air is exhausted via the canyon exhaust system. A room exhaust header runs the length of the facility, overhead along the east wall on the sixth level. This is a 40-in. x 34-in. duct. One fifth-level room exhaust system (26-in. x 16-in. duct) ties into the sixth-level exhaust duct just upstream of the two exhaust blowers located in H & V Room [redacted] and a second fifth-level room exhaust duct ties into the sixth-level header in Room [redacted]

The room exhaust blowers discharge (36,070 cfm) into a 60-in. x 37-in. duct which crosses the room (east to west) overhead and enters into the exhaust shaft just north of the elevator. The air

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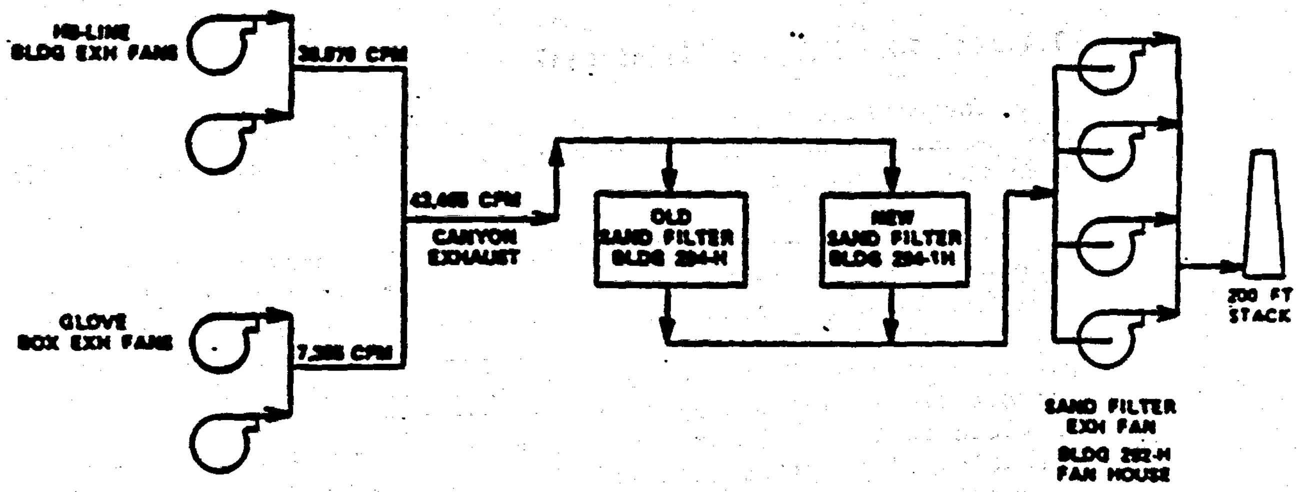

FIGURE 3-5. HB-Line Exhaust System

is forced (positive pressure) to the canyon tunnel by the exhaust blowers where it is picked up (negative pressure) by the four canyon 292-H exhaust fans which pull the air through the sand filter and then discharge the air to the 200-ft stack.

The two HB-Line room exhaust blowers are belt driven by 20-hp motors. One blower operates at a time with the other on "auto" standby. These exhausters are interlocked with the canyon 292 exhausters and with the HB-Line air supply system. Fan-running lights and alarms are located in the control rooms. The exhausters are on emergency power.

The room exhaust fans are provided with pneumatically controlled inlet vanes for static pressure control of the facility with respect to atmosphere. An inside pressure of 0.2 inches WG negative with respect to the atmosphere is the goal.

3.4.2.3 Cabinet Exhaust

The HB-Line cabinet (glove box) air exhaust consists of two assemblies. One assembly is located in Fan and Filters Room [redacted] the second exhaust assembly is in Fan and Filters Room [redacted] Both assemblies are designed to ventilate cabinets and gloveboxes with high levels of contamination. Inlet air will enter the glove boxes through HEPA filters located on the maintenance side of the cabinets. The air will pass through the cabinets, exhaust from the cabinets through HEPA filters at the glove boxes and through two stages of DOP testable HEPA filters in the sixth-level filter rooms. After passing through the exhaust filter-fan assembly the air will be ducted to the 221-H warm canyon exhaust tunnel (via exhaust shaft located north of and adjacent to the HB-Line elevator) and passed through the sand filter and discharged to the 200-ft stack. All glove box air is exhausted in stainless steel ducts. The glove boxes will be controlled to maintain a 0.5-in. to 0.8-in. WG negative with respect to the maintenance areas. Automatic dampers in the glove box exhaust system will be utilized for this purpose. Both assemblies will have one fan operating at a time with the second fan on "standby". An operating hand switch "Standby-Off-Run-Start"-is located at each exhauster. The standby fan will start up (if in the "standby" mode) and discharge dampers will automatically switch when the running fan fails. Interlocks are provided to shut down room supply fans and room exhaust fans if the glove box exhauster fan fails. Fan-running lights and alarms, and a glove box negative-pressure alarm set at 0.3 in. WG are provided in both control rooms. Exhaust fans are on emergency power.

Both systems utilize 24 x 24 x 12-in. HEPA, fluid seal bagout type filters.

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Both cabinets exhaust assemblies (Rooms [redacted] and [redacted]) operate under three basic modes:

(1) Normal mode.

(2) Maintenance mode. Utilize the maintenance exhaust headers which bypass the cabinet HEPA filters (but not the main exhaust dual filters) and utilize the air transfer duct system.

(3) Fire Mode. Supply air fire dampers close to 10% of normal flow and the exhaust system automatic dampers operate as required to maintain desired differential pressure.

The assembly in Room [redacted] consists of eight HEPA filters (4 banks of 2 filters each) of which three banks are required online at a time with one bank on standby to facilitate filter changing. Each exhauster is powered by a 10-hp motor with airflow capacity of 2670 cfm. Other tie-ins to the exhaust system such as vessel vent cabinet and waste conveyor are made to the system prior to the HEPA filters.

A transfer duct system is provided to supply 1350 cfm of room air to needed areas for panel removal during maintenance work. This air quantity will create a 150-fpm face velocity into a 9 ft^2 opening (1,350 cfm) of a removed panel or window. This 150-fpm face velocity provides sufficient air movement to prevent the spread of radioactive material into the room. The transfer duct air is directed to the area of usage by local switches and automatic dampers.

The cabinet exhausters in Room [redacted] exhaust the cabinet or glovebox air from the neptunium line, waste handling line, and the plutonium oxide line. This assembly consists of three banks of filters with two 24 x 224 x 12-in. HEPA filters per bank. Two banks are online at a time with the third bank used to facilitate filter changes. Two 7.5-hp motors are used to exhaust a maximum of 4,725 cfm of cabinet or glove box air. One exhauster operates at a time with the second exhauster in "standby" position. Controls, interlocks, and transfer duct system are the same as that for the cabinet air exhausters in Room [redacted].

3.4.2.4 Vessel Vent

The vessel vent system provides a vent for all HB-Line process vessels. The system consists of a 125-liter vessel vent catch tank (VCT) located in a glove box in Room [redacted]. This tank collects liquid condensed in the vessel vent system piping. This liquid is transfered as required to Canyon Vessel [redacted] by means of a dilute nitric acid transfer eductor or back to the dissolvers in Scrap Recovery by way of sump drawoff tanks. The vent on the VCT is pulled through the vessel vent filter arrangement (VVF) by means of scrubber jets located on each of the 817-liter scrubber tanks, [redacted] and [redacted]

The filter arrangement consists of 12 filters with "Teflon" batting as the filter media. The filter rack is suspended from the ceiling just outside of the scrubber tank containment room which is located along the east wall of Room [redacted]

The vessel vent air is pulled through the filter assembly and into the scrubber by scrubber jets and is sprayed. Process water is used in the scrubber tanks and is circulated by a pump through the jets thereby simultaneously spraying the air and pulling a vacuum on the filter side of the scrubbers. The scrubber water is transferred to either Tank 8.8 or 9.6 when contamination reaches a predetermined level. The water is then replaced with clean process water. The scrubbers are vented through a demister to the 20-in facility cabinet exhaust duct.

3.4.2.5 Sand Filter

Regulated room exhaust, cabinet exhaust, and vessel vent air from the Plutonium Oxide Facility receive a final stage of filtration in a below-ground, nonflammable, sand filter prior to venting through a 60-m stack. The 294-H sand filter is a key element in minimizing radioactive releases in the event of a severe accident in the Plutonium Oxide Facility.

The ventilation exhaust duct from the sixth level descends the west wall of the 221-H canyon building and connects to the existing air tunnel leading to the sand filter. The sand filter will continue to function effectively if subjected to heavy smoke loading from a fire in the 221-H building.

3.4.3 Room Air Monitoring

The room air monitoring system for all rooms and areas of potential high air activity is a high-volume, automatic-sampling type with rapid response capability to minimize the potential for assimilation.

Two air sampling exhausters for the air sampling system are located on the 6th Level in the air monitoring room. Discharge air from the exhausters is piped into the room exhaust system. The controls permit the selection of either unit to be designated as

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the primary unit with the other unit on ready standby. The system is sized for 19 sampling locations at 40 scfm each for a total capacity of 760 scfm @ 60" wg.

Air monitoring blowers for the PuO_2 and NpO_2 Facilities are combined.

3.5 Fire Protection System

The HB-Line Halon® fire protection system is designed to remotely detect fire, to dispense Halon® 1301 to the affected area, and to transmit signals to 701-H patrol headquarters, canyon control room, HB-Line control room and to the plant auto-term system. The canyon and HB-Line control rooms also receive trouble lights and alarms indicating a malfunction of equipment. The Halon® discharge signal is activated by pressure from the Halon cylinder being discharged and by command from the sensor unit to discharge the cylinder. Therefore, if a cylinder fails to discharge, the fire alarm will still be activated. Halon® can be discharged manually from a manual control station located outside of each room that is equipped with Halon® suppression. These control stations have a trouble light, alarm light, Halon® manual release button, and a horn silence button. Gloveboxes have the same control station plus a "Main/Reserve" solenoid switch. After a discharge, fire protection in the gloveboxes may be maintained by switching to the "Reserve" tanks. After the Halon® has been discharged, the zone detection and alarm system can be kept active by inserting an electrical connector at the Halon® cylinder release valve until the cylinder can be replaced. Facility fire detection and suppression equipment is on emergency power. Halon® is maintained in rooms for 10 min at 5% to 7% concentration. A minimum of 5% is maintained in glove boxes for 10 min. Backup fire protection is provided by the fire brigade.

Fire detectors (or sensors) are of two types, heat or smoke. Smoke detectors are located in all rooms of the process area where any combustible material may be located or where significant fire potential exists. Heat detectors are installed in glove boxes. The activation of only one heat detector in a glovebox is required to releae the Halon®. However, two smoke detectors in a zone are required to be activated before the Halon® will automatically be discharged. This reduces the possibility of a Halon® cylinder being discharged in a room because of a false fire alarm from a faulty smoke detector. This system does not have a zone "bypass" feature nor an "inhibit" switch.

Halon cylinders for the Halon® fire protection system are located in three rooms. Spare cylinders are located in the same room. Room [redacted] houses the Halon cylinders for the Recovery Facility and its support areas, Room [redacted] covers the Neptunium Facility, and Room [redacted] covers the Plutonium Facility.

Indicator panels are located in Control Rooms [redacted] and [redacted] give the zone in which a sensor has been activated. This gives an alarm on the indicator panel and a trouble light and alarm on the control panel in Control Rooms [redacted] and [redacted] A trouble light and alarm are also received in the canyon control room. When the second sensor is activated in that zone, the fire alarm and light are received in the two HB-Line control rooms, the process control station, the canyon control room, and the area patrol office. This information (fire alarm) is also transmitted via the plantwide "auto-term" system to the canyon control room, 200-F firehouse, and to a central station in 700 Area. The Autoterm is a microprocessor based "smart transponder" which serves as a data collection device and the input junction point for all sensors and analog devices. It processes the inputs and multiplexes the appropriate signals to the console from remote points. It also intercepts commands from the central console which it converts to output signals for the control of connected devices. The unit is powered from a 115 VAC, 60 Hz source with a standby battery. A fire alarm panel is mounted on the wall in the HB-Line fifth-level elevator vistible just outside and to the left of the HB-Line entrance door. This is a floor plan of the HB-Line facility. Lights for each fire zone are mounted in this panel. These zone detector lights are activated when smoke is detected, and the fire alarm is activated in the event of a fire in that zone. This enables or aids in directing fire fighters to the fire zone when the facility is not occupied and in locating and correcting a "trouble" condition of the detection system.

3.6 Auxiliary Equipment

3.6.1 Vacuum Transfer System

Solutions are transferred from one vessel to another by establishing a vacuum in the receiving vessel. Vacuum is provided by an air jet for each vacuum vessel. The air jet is operating by 80 psig process air.

3.6.2 Cold Feed Preparation

The PuO_2 Facility uses the Cold Feed Preparation Area located on the 6th Level, provided in the NpO_2 Facility.

3.6.3 Instrument Air

Adequate instrument air capacity is available from equipment provided for the Scrap Recovery Facility and the NpO_2 Facility.

A 1-1/2" line extended from the NpO_2 Facility H&V equipment room serves the outside air supply unit, 6th Level H&V equipment room, H&V filter room.

3.6.4 Breathing Air

Breathing air stations connect to the breathing air system installed as part of the NpO_2 Facility project. Adequate breathing air capacity is available from equipment provided. A 1-1/2" line extends from the NpO_2 Facility H&V equipment room to the manifolds. Alarm stations near breathing air stations and in the control room warn of system pressure loss.

3.6.5 Water Systems

The Plutonium Oxide Line is supplied with water from five sources: the Chilled Water System, the HB-Line Cooling Water [redacted] System, the Independent Cooling Water [redacted] System, Process Water, and Domestic Water. Each of these sources is discussed in detail in the following sections.

3.6.5.1 Chilled Water System

The chilled water system for the HB-Line facility air conditioning units is located on the canyon roof east of the facility. The system supplies chilled water to the cooling coils on the three facility air conditioning units. The system has two Freon refrigeration units; one is rated at 125 tons and the other at 160 tons. Both units are tied into a common 6-inch-diameter discharge header. However, the units can be isolated to run separately. The water (brine solution) for the system is made up in a 90-gal insulated expansion tank. This is a 20% ethylene glycol-process water solution. The solution from the expansion tank is pumped through the system and back to the tank by two (one 15-hp and one 20-hp) centrifugal pumps. Additional water or ethylene glycol is added manually, as required, to maintain proper level and brine content. This is determined by expansion tank sight glass-readings and periodic sampling of solution.

A chiller unit is installed in Refrigeration Room [redacted]. This unit supplies chilled water (33°F-43°F) to the calorimeter room air conditioning unit (a single-room air conditioner to maintain a required constant temperature for the calorimeter bath and equipment) and to the heat exchanger which supplies cooling water to the plutonium oxide facility precipitator feed tank [redacted] and both precipitator stages ([redacted]

The unit has a 42,000-BTU-per-hr capacity with a capacity controller allowing it to run continuously at 15,000 BTU per hr. The compressor will stop when the return brine (20% ethylene glycol) solution reaches 33°F and restarts when solution reaches 43°F. The chiller pump will deliver 9 gallons per minute from the insulated 30-gal chiller tank to the process heat exchanger and the calorimeter room air conditioning unit.

3.6.5.2 Process Water

The process water used in HB-Line is made up at 211-H in Tanks [redacted] and [redacted] 50% nitric acid is mixed with demineralized water from the power house to obtain a 0.01M process water solution. This water is pumped to the canyon from Tanks [redacted] and [redacted] HB-Line ties into the canyon 4-in. header in section 5, Room [redacted] with a 2-in. header [redacted] Process water is not tied into any return header.

This header, [redacted] and branch headers provide process water to:

• Vessel vent	Scrubber Tank [redacted]	Makeup Water
• Cold feed # 1	Dilute nitric acid [redacted]	Tank Makeup
• Cold feed # 2	Reconditioning solution [redacted] Elutriant solution [redacted] Partitioning solution [redacted] Resin mix tank [redacted] Oxalic acid solution [redacted] Cake wash solution [redacted] Precharge solution [redacted] Dilute nitric acid [redacted] Ascorbic acid solution [redacted]	
• Np process	Recycle Tanks, [redacted]	Dilution & Flushing

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• Np Process	Resin Catch Tank, [redacted]	Dilution & tank flushing
• Waste handling line	Ultrasonic Tank, [redacted]	Cleaning solution
	Washing Machine, [redacted]	Cleaning solution
	Waste Hold Tanks, [redacted]	Cleaning solution
• Pu storage	Finished Product Storage Tanks	Cooling bath
• Pu process	Precipitator, [redacted] heating & cooling jacket	Makeup water for heating & cooling

3.6.5.3 HB-Line Cooling Water (BCW)

The HB-Line independent cooling water system [redacted] is an internal recirculating "loop" consisting of a makeup (hold) tank, recirculating pumps, heat exchangers (coolers), filter, and an alpha monitoring system. This equipment is located in Room [redacted] It is basically independent of any other cooling water system. The only tie-in to another water stream is the domestic water connection to the BCW makeup tank. An independent cooling water (jacket) which is used to cool the system's heat exchanger tubes is isolated with no valve connections to the internal loop.

Domestic water is added to the 545-gal capacity makeup tank as required. Water is added manually by operating one valve, located just above the makeup tank. The tank is equipped with low, low-low, high, and high-high level lights and alarms. The low-low alarm stops the recirculating pumps.

The water is pumped by two 250-GPM capacity pumps from the makeup tank through the coolers, through process vessel coils, storage tank coils, cooling jackets and condensors, and back to the makeup tank. The pumps discharge to a common 4-in. header upstream of the coolers, and therefore, can be operated separately or simultaneously. The pump switches (standby-off-run-start) are located in the [redacted] Room [redacted]

The 4-in. header from the pumps to the heat exchangers (coolers) branches into a 3-in. line to each cooler and then again from a common 4-in. header to the process. Therefore, the coolers can also be operated separately or simultaneously.

Certain process operations in the old HB-Line facility (third and fourth levels) will remain an integral part of the cooling system on a permanent basis. The [redacted] is, therefore, tied into these operations. The old facility operations that will be permanently tied into the new system are:

- Storage vault, Room [redacted] - cooling coils
- Neptunium receipt tanks, [redacted] - cooling coils

Main isolation valves for the above systems are located on the fifth-level 4-in. headers (supply and return). In addition, each segment has individual isolation valves on the branch supply and return lines.

The operations in the new facility that will be serviced by the [redacted] system are:

- Scrubber tanks, [redacted] - solution cooler.
- Vessel vent system, hood - condenser refrigerator unit.
- Neptunium precipitators, [redacted] - cooling coils.
- Storage vault, Room [redacted] - tank cooling coils.
- Plutonium oxide refrigeration Room [redacted] - chiller condenser.

The system is equipped with a single-element filter (with filter bypass) and alpha monitoring instrumentation as shown in Figure 3-6. A pump is used to circulate the return water through the alpha monitors. Trouble lights and alarms are located in the control room. In the event of high alpha content in the water system determined by an alpha monitor and/or lab analysis of water sample pulled via a vacuum sampler port, the water can be pumped from the hold tank to canyon Tanks [redacted] or drained to canyon Cold Feed Prep Tank [redacted] In the event of leakage from the tank flanges, connections, or valves, the tank catch pan can also be drained to Tank [redacted] A low point in the system piping (third level) is also provided with hose-fitting taps to enable a more complete drainage of the system.

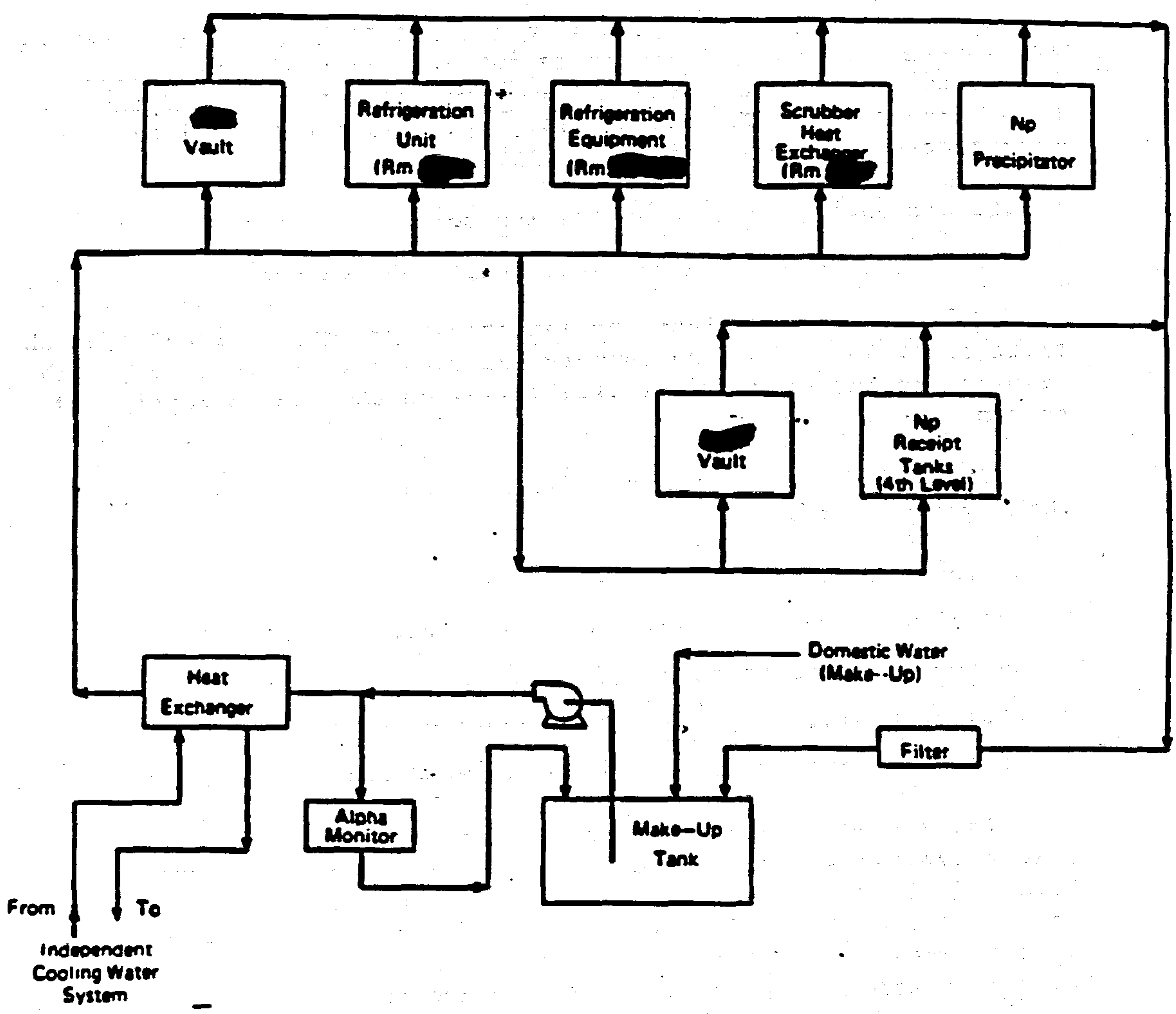

FIGURE 3-6. Schematic of HB-Line Cooling Water System

3.6.5.4 Independent Cooling Water [redacted]

The [redacted] supplying HB-Line is obtained from a tie-in to the 20-in. [redacted] header located west of the 221-H Building. This 20-in. header is tied into a 36-in. header which comes from the cooling tower. The tie-in to the 36-in. header is made upstream of the power failure cutoff valve which closes in the event the water pressure in the header drops below 50 psig. Tieing in upstream of this valve ensures a water flow to critical equipment in the canyon and B-Line during a power outage. HB-Line tie-in to the 20-in. header is an 8-in. line reduced to 6 inches. A 4-in. tie-in is made to the 6-in. line which supplies cooling water to the HB-Line independent cooling water "loop" [redacted] heat exchangers. The 6-in. header also supplies cooling water to the compressors on the three HB-Line air conditioning units. This line supplying the air conditioning compressors with CW has a valve that automatically closes in conjunction with the valve in the 30-in. header when pressure drops below 50 psig in the 30-in. header. The purpose of this valve is to shut down noncritical or nonessential operations (air conditioning) during a power outage to ensure sufficient cooling water for the [redacted] system and operation of critical canyon equipment supplied by the 20-in. header.

The [redacted] from the HB-Line facility (except the internal loop, [redacted], condensate, and domestic water used to cool compressors on the instrument air, process air, and breathing air is returned to the cooling tower via a return water alpha-gamma monitoring station located at 281-H. Should excessive activity in the cooling water be detected, a diversion system would be activated which would divert the water to a rubber-lined retention basin, where the contaminated water may be decontaminated before it is released to the environment. The alarms for the monitors and controls for the possible diversion of the return water are located in the canyon control room.

3.2.5.5 Domestic Water

Domestic water [redacted] for H Area is supplied from wells located throughout the area. It is received in HB-Line from two sources. One source is a 2-in. header tied into the canyon domestic water in canyon cold feed preparation. This source supplies all domestic water used in the HB-Line support facility (office area, lunch room and change rooms). If the canyon has a building [redacted] shutdown, this supply to HB-Line is also shut down. The second source is a 3-in. header tied in underground prior to the canyon cutoff valve. This source supplies domestic water to the process area support equipment. This equipment includes the water fountains, eyewash stations, safety showers, sinks, cooling water for aftercoolers, and air compressors (instrument air, process air, and breathing air). A header also provides domestic water to the HB-Line cooling water [redacted] makeup tank. Also, stuboffs with valves and hose connections are provided throughout the facility.

The domestic water from the aftercoolers and compressors is drained into the independent cooling water return header. Depending on its use, domestic water is drained to one of three systems. Water used for cooling the instrument, breathing, and process air compressors, and their respective aftercoolers, is piped into the independent cooling water return line. That which is used in regulated areas is drained to Tank [redacted] located in canyon cold feed preparation. Domestic water used in the nonregulated area is drained to the sanitary sewage system. The DW from regulated area sinks and drains is drained to Tank [redacted] located in canyon cold feed preparation.

The domestic water used in the nonregulated area (shower drains, lavatories, sinks) is sent to the sanitary sewage system.

3.6.6 Steam

A 3 inch, 15 psig, steam line provides for the winter heating requirements of the facility. The line provided on the Scrap Recovery and NpO_2 Facility projects extends north along the east side of the new facility to serve the outside air supply unit.

Condensate collected in a receiver is pumped into the 6-inch cooling water return line located on the building roof in Section 2.

Steam requirements for PuO_2 Facility will be 600 lb/hr.

3.6.7 Emergency Power

Emergency power is available to critical equipment in HB-Line to maintain certain operations and to enable orderly shutdown of other equipment if normal power fails. Panels [redacted] and [redacted] in [redacted] are on emergency power. There are no emergency power panels in [redacted]

[redacted]

Systems considered essential for operation on emergency power are:

- HVAC - Air exhausters and ventilation interlock system
- Instrument air compressor and dryer
- Essential lighting during power outage
- B-Line cooling water system
- Fire detection and suppression equipment

The source of the emergency power is a 300-kW generator mounted on a concrete pad at ground level west of the canyon building (section 3). The generator is enclosed in a weatherproof shelter. A generator control panel is mounted on the concrete pad outside of the weatherproof enclosure. This control panel includes 13 status indicating lights and an alarm horn. In addition to the panel a trouble light and alarm and a generator running light are located in Process Control Room [redacted]

The fuel tank on the diesel generator has a capacity of 550 gallons. The average fuel consumption during full operating load is about 25 gallons per hour. This allows approximately 22 hours operating time per full tank.

3.6.8 Process Air

Process air is supplied within the HB-Line facility at 80 psig by means of two (2) air compressor units located on the sixth level, Room [redacted] One compressor operating in the continuous mode, is designated as a "primary" and the other operating in the auto modes as a "support" compressor. In the event the primary compressor is unable to provide or maintain the designated pressure on the receivers due to excessive usage or system malfunction, the support compressor will come online. The support compressor will operate in conjunction with the primary until the designated upper limit pressure is regained in the two receiver tanks. The controls for the compressors are located on a control panel mounted to the compressor "package" frame. The control rooms (Scrap Recovery CR and the NpO_2-PuO_2 Facilities CR) are equipped with a running light, a trouble light, and alarm for each compressor. These are tied into the compressor motor. A main header low-pressure alarm is also located in each control room.

Each compressor is equipped with a 25-hp motor, aftercooler and separator, filters, a 240-gal-capacity receiver, and an air dryer. The units supply air to the process cabinets to enable jet transfers of solutions, operate the cold feed hydrazine pump, operate furnace off-gas jets, and provide air purge to certain vessels. Process air is also used to operate the waste conveyor drop port damper cylinder.

3.7 Engineered Safety Features

An engineered safety feature is a system or device that contributes to the safety of process operations. These features are provided to reduce the consequence, or the frequency of a potential accident. The primary protective devices which control or minimize exposure to radiation and the release of contamination are the confinement barriers, ventilation systems, and monitoring systems. The ventilation and monitoring system are described in detail in this chapter (Section 3.0). The confinement barriers systems is discussed below.

3.7.1 Confinement Barrier System

It is important to protect operating personnel from radioactive contamination. To do this, special confinement barriers were designed to confine radioactive contamination in solid, liquid, and airborne forms. The facility was designed to minimize buildup of contamination and personnel exposure.

3.7.1.1 Liquid and Finely Divided Solid Barriers

Process solutions and solids in finely divided form are confined primarily within a container (tank or package). The second confinement barrier is the cabinet. Cabinets are provided with sumps to collect material that may escape primary confinement. The sump has a sampler and an acid flush line. The sumps also have dip tubes which are used to transfer by vacuun the solutions to a collection tank. The third level of confinement is the room. The room is a confinement barrier which helps to protect workers in other rooms as well as people outside the facility. The fourth barrier is the building itself, which helps to protect people outside. The confinement barriers are shown schematically in Figure 3-7.

3.7.1.2 Airborne Barriers

Protective barriers for airborne materials are barriers within the ventilation system. The primary barrier is the process vessel. The vessels in the PuO_2 Facility are vented to the scrubber system, via a knock-out tank and filter prior to release to the sand filter. Cabinet air is filtered through nontestable HEPA filters in the glove box then through two sets of DOP testable HEPA filters before passing through the sand filter. The confinement barriers are shown schematically in Figure 3-8.

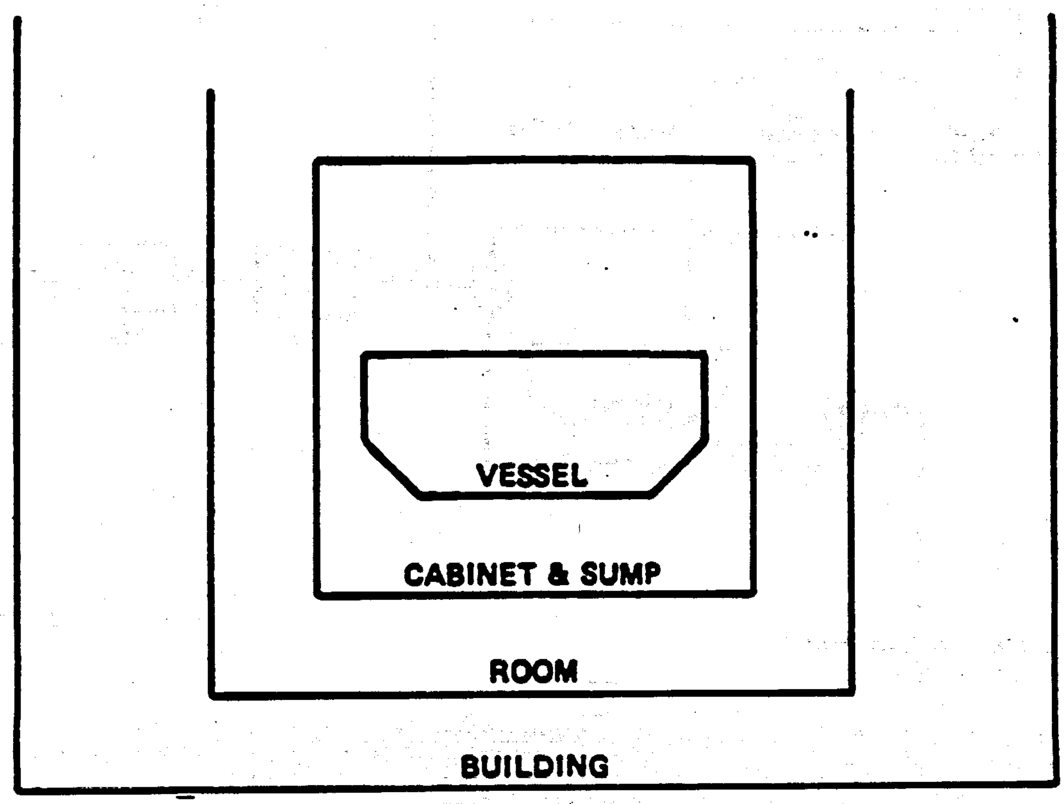

FIGURE 3-7. Liquid and Finely Divided Solids Barriers

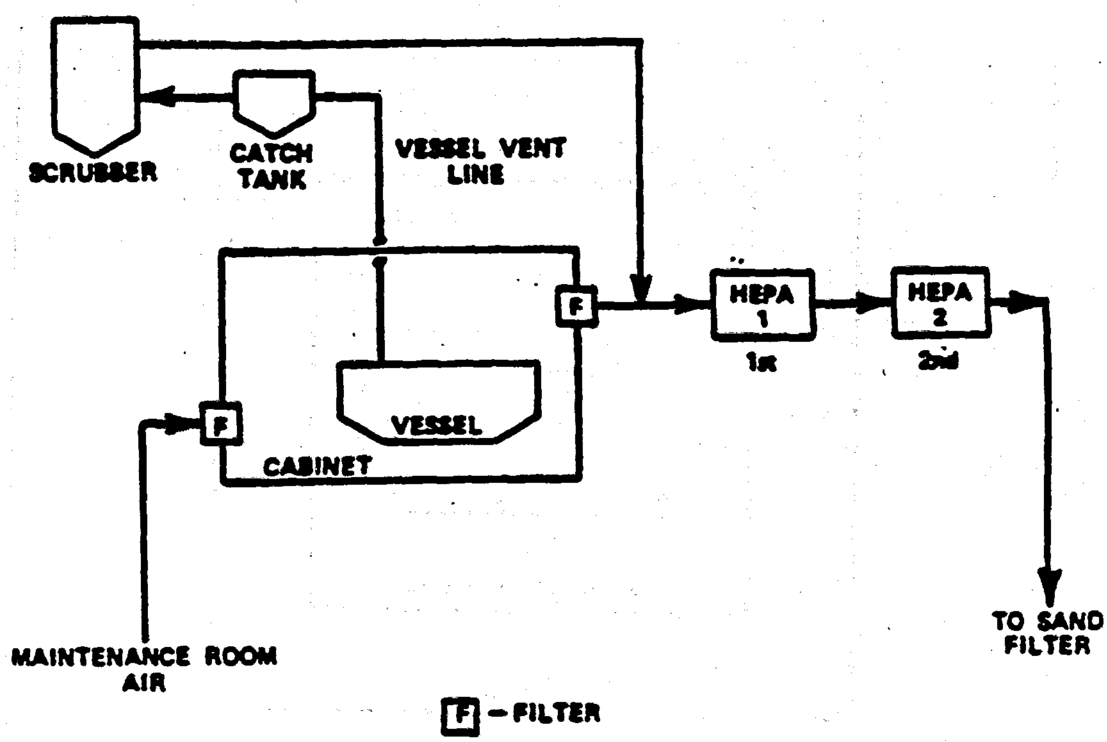

FIGURE 3-8. Airborne Confinement Barrier

3.7.1.3 Shielding

The PuO_2 Facility is designed to meet requirements of ERDA (DOE) Manual Chapter 0524, Standards for Radiation Protection, and ERDA (DOE) Manual Appendix 6301, Facilities General Design Criteria, Section B - Plutonium Facilities. Shielding requirements for the PuO_2 Facility were based upon processing ^{238}Pu oxide.

Shielding for the Plutonium Oxide Facility was determined by calculations that limit yearly whole body radiation exposure to 1 rem during normal recovery operations provided that administrative controls are effectively utilized and design throughput values are not exceeded. Recommended shielding will limit whole body radiation exposure dose rates to as low as economically practical, not to exceed 5 mrem/hr, during normal operations in the intermittently occupied (<10% of workday) process areas. Shielding requirements are described in detail in Reference 3.

3.8 REFERENCES

1. T. S. McElrath. Conceptual Design Report, Replace Obsolete Plutonium 238 Facilities, Building 221H, B-Line. DPE-3614, March 1980.

2. W. S. Durant and W. C. Perkins. Systems Analysis - 200 Area, Savannah River Plant, H-Canyon Operations. DPSTSY-200-1H, October 1983.

3. G. W. Earle. Memorandum to D. J. Mahoney, "Shielding Requirements - Phase III - Pu-238 Oxide Facility." May 12, 1981.

4.0 DESCRIPTION OF OPERATIONS

4.1 Organizational Structure

The Savannah River Plant is operated by the Atomic Energy Division (AED) of the Petrochemicals Department of E. I. du Pont de Nemours and Company.[1] The structure of the AED, for purposes of this description, is shown in Figure 4-1. The two major divisions are the Technical Division, which includes the Savannah River Laboratory (SRL) and the Manufacturing Division, which includes the Savannah River Plant (SRP). The Departmental Engineer's Office reports separately to the AED in Wilmington.

The Savannah River Laboratory (SRL) provides technical support to the Manufacturing Division. The SRP organization has two major divisions; Operations, and Plant Facilities and Services. The Manager of Operations has custodial and operating responsibilities for all production facilities. The Manager of Plant Facilities and Services has responsibilities for nonproduction facilities and central services.

Primary responsibility for safe operation of the HB-Line lies with the Separations Department of the Separations Program Management Team (PMT), with support from other departments, such as Equipment Engineering, Health Protection, Personnel, and Separations Technology.

4.2 Operational Description

The Plutonium Oxide Facility provides capability for processing up to 0.3 kg ^{238}Pu/day (on a one shift per day basis). This process is designed to convert nitrate solutions of plutonium-238 to $^{238}PuO_2$ powder suitable as feed for fabrication of heat sources for thermoelectric generators. The Plutonium Oxide Facility is a Department of Energy (DOE) facility, and DOE is responsible under the law for maintaining appropriate control over the operations.

Objectives of the operations include personnel and equipment safety and efficient operation. Basic and important operating decisions are made by management after review throughout the organization. Decisions which affect safety or operability are reviewed by a competent technical organization independant of the organization that has direct responsibility for operation. Process operations are performed according to detailed written procedures.

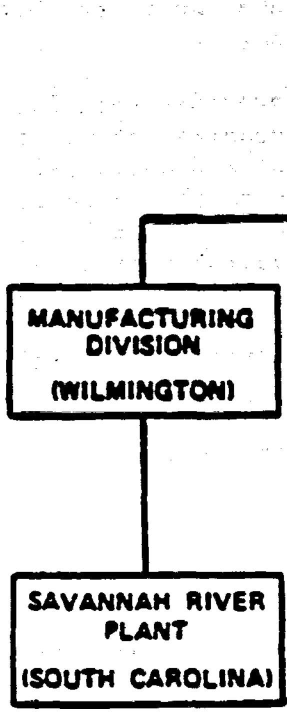

FIGURE 4-1. Organization of Atomic Energy Division

4.3 Procedures

4.3.1 Administrative Procedures and Control

The primary administrative control document is the contract (DE-AC09-76SR00001) between Du Pont and the U.S. Department of Energy (DOE). The contract describes certain obligations with regard to safety on the part of both the contractor (Du Pont) and the contracting officer (DOE). Although Savannah River process facilities are operated by Du Pont, DOE exercises appropriate control over operations because DOE is responsible for conduct of the program under the law, as expressed by regulatory requirements of various governmental agencies. The basic principles of the Du Pont controls system for AED non-reactor processes are described in Reference 1.

4.3.2 Operational Control Documents

Du Pont imposes an internally authorized system of control procedures to ensure that facilities are operated and maintained in conformance with Du Pont management policies as prescribed in the adminstrative control procedures for non-reactor nuclear facilities. The system has the familiar Du Pont operating objectives:

- Maintain safety of personnel, equipment, and facilities
- Maintain continuity and increase efficiency of operations
- Maintain compliance with applicable governmental regulatory requirements to ensure public health and safety and protect the environment.

Inherent in the controls system is the precept that all process operations are performed according to approved written procedures that have been reviewed in an effort to preclude unsafe consequences, either directly or as a result of a possible chain of unfavorable events. Audits of procedures are performed and documented, and periodic reassessments of facilities and processes are conducted with the objective of identifying any previously unrecognized hazards that may have been created by changes in process conditions, operating practices and equipment, or knowledge of the condition and behavior of construction materials.

Operational control documents are listed in Table 4-1 and are described in detail in Reference 1.

TABLE 4-1

Operational Control Documents

- Safety Analysis Reports
- Operational Safety Requirements
- Systems Analysis Reports
- Technical Standards
- Technical Manuals
- Mechanical Standards
- Test Authorizations
- Nuclear Criticality Safety Control Documents
- Plant Interpretive Documents
- Quality Assurance Assessment Reports and Action Plans
- Operating Procedures
- Du Pont Procedures Requiring DOE-SR Concurrence
- Plant Manuals
- Training, Qualification and Certification Records

4.3.3 Nonoperational Work

Included in nonoperational work are areas involving projects, maintenance, and electrical and instrument (E&I). These efforts are also controlled by detailed documentation including:

- Projects, Project Objective Letters, and Work Orders
- Works Engineering Procedures and Job-Plans

Details of this documentation are presented in Reference 1.

4.3.4 Emergency Procedures and Plans[2,3]

The SRP staff has the organizational responsibility for determining emergency plans and courses of action for each plan. Periodically, the staff reviews the performance of the plant in emergency plan practice drills. The effectiveness of the plans are also reviewed periodically, and revisions are made as necessary. The policy of SRP is to limit the radiation dose to workers to 25 rems (whole body), and 100 rems (hands) in an emergency which involves protection of property or personnel. For life-saving acts, an exposure of 100 rems (whole body) plus 200 rems (hands) is considered as the guide value.

Both F and H Areas have an area emergency committee. Members include representatives from each department resident in the area. This group resolves problems of area-wide significance, adapts the emergency plans approved by the staff to their particular location, and initiates and conducts practice drills.

SRP has an Emergency Operating Center (EOC) located in Building 703-A (located in A Area in Figure II-3, see DPSTSA-200-10). The EOC is equipped with emergency materials such as radio equipment, telephones, maps, and plotting boards. Food and sleeping gear are also provided.

There are three basic plans discussed in this report. They are:

1. Shelter or Evacuation Plans (Section 4.3.4.1)
2. Nuclear Incident Plans (Section 4.3.4.2)
3. Offsite Warning Plans (Section 4.3.4.3)

4.3.4.1 Shelter or Evacuation Plans

There are three types of emergencies considered which involve sheltering or evacuating personnel; all are practiced. They are:

1. Facility Emergency (where an emergency may exist in only a single building)
2. Area Emergency (where all buildings in an area are involved)
3. Plant Emergency (where a local condition, or a condition created offsite, affects the plantsite)

A Separations Department supervisor is the emergency Facility Coordinator (FC). Based upon his evaluation of any given situation, the FC determines whether evacuation or sheltering of personnel in the facility is or is not necessary. He announces that the facility emergency exists, provides instructions on the handling of personnel and facilities, and notifies the Area Emergency Coordinator. The FC has an announcement made over the area public address (PA) system. The announcement is made at two-minute intervals for a total of four times. Evacuating personnel assemble at the appropriate location as instructed by the Facility Coordinator.

An Area Emergency is declared by the Area Emergency Coordinator, who notifies the plant EOC. He announces the emergency over the areawide public address system and sounds the alarm signal (normally a fast warble, but also could be five short blasts from the powerhouse whistle). Area emergencies are handled in the same fashion as Facility Emergencies.

The Emergency Operating Center Staff provide overall guidance in the protection of personnel, buildings, and equipment, and in the maintenance of vital production prior to, during, and after an emergency. The EOC Shift Crew directs and coordinates emergency activities outside the incident area.

If personnel are sheltered, the Area Emergency Coordinator may adjust building ventilation as necessary and will evaluate the need for an area evacuation. Evacuating personnel will form a caravan at the parking lot and proceed to a safe location. The normal evacuation route is to the main parking lot, through the main gate. The Area Emergency Coordinator may designate an alternate route. In the event of an area evacuation, all personnel in the area are evacuated or sheltered with the exception of a small predesignated group, consisting of Emergency Duty Personnel.

4.3.4.2 Nuclear Incident Plans

When the Nuclear Incident Monitor (NIM) bell alarms, all personnel hearing the alarm evacuate immediately by predesignated routes and gather at a predesignated rallying point. The alarms are connected to instruments in the control rooms of the production facilities. When the NIM alarm bell rings in the affected area, a light is lit on the annunciator panel and an alarm sounds in the control room. The facility is shut down and personnel are evacuated or sheltered. If the alarm is later verified to be real, the Facility Coordinator declares a Facility Emergency and notifies the Area Coordinator. If other buildings or areas may be affected, the Area Emergency Coordinator declares an Area Emergency. He may adjust building ventilation as necessary, and evaluates the need for an area evacuation. He also initiates action to locate persons not accounted for. When all personnel have been monitored, the Facility Coordinator directs Health Protection to survey the area for re-entry.

All personnel are trained in the proper evacuation routes in their individual facilities. These routes are well marked with Nuclear Incident Evacuation signs. Practices are held periodically to keep personnel familiar with the evacuation routes.

4.3.4.3 Offsite Warning Plans

The Offsite Warning Plan determines the need for alerting offsite areas of a hazardous condition originating at SRP which may affect them. Following an incident of sufficient severity to threaten offsite areas, the EOC Supervisor may elect to dispatch monitor teams, each consisting of a Health Protection inspector and driver-radio operator, to predesignated monitor points downwind of the incident. They attempt from ground level to evaluate the spread of radioactive contamination, and radio the results back to the EOC.

In the EOC, when the source of the release, wind direction, velocity, and concentration are known, the results are extrapolated to estimate the potential exposure to offsite areas. The information is given to the EOC staff members who make the decision to warn the offsite population center. If EOC staff members are not available, the EOC Supervisor may issue the warning.

4.4 Training

Personnel receive training in the safety aspects of new jobs with periodic retraining in certain areas (e.g., chemical properties, self monitoring on radiation exposure, etc.), and utilize scheduled safety meetings to implement plantwide programs. Personnel also receive training in emergency actions through scheduled drills and practices under simulated emergency conditions. Training records are kept for all employees.

New employees receive an orientation series on the following subjects:

- Safety rules and requirements
- Security rules and requirements
- Industrial relations, plans, and benefits
- Automobile traffic rules and regulations on plant property
- Equal employment opportunity policy

4.4.1 Separations Department

Personnel receive on-the-job training in the operation of equipment or systems. Operators are considered qualified after demonstrating capability to perform the operation. Operating personnel receive training in the safety aspects of jobs, and utilize scheduled safety meetings to implement plantwide programs. Operating personnel are continually observed and periodically evaluated. They also receive training in emergency actions and rescue operations through scheduled drills and practices under simulated emergency conditions.

A training status record for each operator is maintained. The job performance of all employees is periodically evaluated and recorded in writing.

4.4.2 Mechanical Maintenance Department

Maintenance mechanics are given basic training consisting of classroom and laboratory instruction. Records of each trainee's performance are kept. Special training is also given as needed for special skills such as welding, machining, refrigeration and air conditioning, sheet metal work, and pipefitting. In addition, on-the-job instruction is given in specialized maintenance techniques for certain equipment.

4.4.3 Electrical and Instrument Maintenance Department

All Electrical and Instrument personnel are trained in the safety aspects, operation, and maintenance of electrical equipment and instrumentation. Training received is documented. Courses are also taught on new equipment and in reading logic diagrams.

4.5 Review and Audit (Reference 1)

Audits to determine if procedures are properly used are carried out independently by the Separations and Separations Technology Departments independently. In addition to this, special criticality audits are performed.

Reviews of procedures, operation, maintenance and training are performed at several levels within AED. Detailed information on the responsibilities for these reviews may be found in Reference 1.

4.5.1 Separations Department Audits

Separations Department conducts a cross-audit of each operation by a committee that does not have direct responsibility for the operation. In addition, the facility is audited monthly or at least quarterly by a facility audit team to determine compliance with procedures. Individual audits within the Plutonium Oxide Facility by first-line supervision are made monthly to provide a detailed examination of specific job assignments. Individual audits are recorded on Job Observation Reports.

4.5.2 Separations Technology Department Audits

Auditing functions are performed by the Separations Technology group as part of their routine surveillance. This group observes operations in progress, collects and analyzes data, and reviews operating logs or runbooks. Special surveillance is provided when chances of error are greater than normal or when consequences of errors would be hazardous.

4.5.3 Criticality Audits

A committee composed of members from the Separations Department, the Separations Technology Department, and the Health Protection Department audits material handling and storage. This audit occurs once per quarter to determine compliance with procedures, adequacy of procedures, and the training of personnel. A report on each audit and any followup action is submitted to Separations Department Management.

4.6 Inspection and Testing

This section gives a brief description of the inspection and testing of equipment included in the Engineered Safety Features, Section 3.3.

4.6.1 Ventilation Systems

Project Department heating and ventilating engineers provide services for balancing the ventilation systems of the 221-H Building. Airflow is measured in hoods and glove boxes to establish conformance with standards. The Health Protection Department routinely inspects and tests the flow of air in potentially contaminated areas. Fans and blowers are routinely inspected by operating personnel. Filters such as HEPA types are inspected and tested for efficiency and leakage at the Oak Ridge Filter Test Facility before being sent to SRP. The Health Protection Department tests the HEPA filters after they are installed by Traffic and Transportation Department. A HEPA[4] by definition is a throw-a-way, extended-medium, dry-type filter having (1) a minimum particle removal efficiency of not less than 99.97% for 0.3 micron particles, (2) a maximum resistance of 1.0 in. H_2O when clean and operated at rated flow capacity, and (3) a rigid casing extended full depth of the medium.

Although all HEPA filters are tested at Oak Ridge, testing after installation is essential because of damage that can take place during handling, shipping, and installation. In place tests of HEPA filter systems are to be conducted immediately after each filter change to ensure proper leak-free installation; and at regular intervals, not to exceed one year, to detect deterioration of components, relaxation of gaskets, or other causes resulting in leaks.[5]

Tests are conducted with poly-dispersed aerosol of dioctyl-phthalate (DOP) droplets having a light scattering mean diameter of 0.7 micron. The test is made by charging the upstream side of the filter or filter bank with DOP "smoke", then measuring the down-stream side for smoke penetration using a linear-readout, forward light-scattering photometer.

4.6.2 Cooling Water Diversion

The H-Area Cooling Water System (of which the Independent Water System is a part, see Section 3.6.5.4) is provided with a diversion system which is inspected and tested as follows:

4.6.2.1 Instruments

An alpha and gamma response test is made to determine whether the detectors will respond to a radiation source.[5] The gamma device is normally tested daily, and the alpha device is normally tested weekly. The alpha detector must be valved out and drained during this test. The monitors are calibrated using four different activities of calibration solutions.

4.6.2.2 Other Equipment

In the process of the instrument response tests, the alarms are automatically tested. A visual inspection of the equipment is made during walk-through inspections and during the response tests.

4.6.3 Confinement Barriers

Inspections and tests on the integrity of confinement barriers are made routinely and in many instances, continuously.

4.6.4 Radiation Shielding

Continuously operating ion chambers with recorders and alarms are located throughout shielded facilities. These instruments continuously monitor radiation levels in the facility. An increase in radiation levels, as measured by these monitors, could indicate a shielding failure. Also, personnel working in shielded areas wear dosimeters which measure radiation dose. These dose data are recorded monthly. Daily radiation surveys are made of the facility by a qualified Health Protection Inspector.

4.6.5 Emergency Power

Emergency diesels are load tested monthly. Each week the diesels are tested with no load. The emergency diesels are run for 30 minutes in each case.

4.7 Unique Hazards

During the analysis for potential radiological hazards, effort was given toward identifying potential conditions uniquely different from normal industrial practice. There were none found other than those studied and discussed in the radiological part of this report.

4.8 Control and Management of Effluents

The basic controls of Plutonium Oxide Facility are the requirements and limits defined in Technical Standards. Standards are the responsibility of the Technical Division and usually originate there. They are authorized by the Technical Director after approvals by both the Technical and Manufacturing organizations.

The-Plutonium Oxide processes may be operated outside Technical Standards (but within Operational Safety Requirements), for tests or for other short-term special purposes using Test Authorizations (TAs). The approval for TAs are similar to those for Standards, but they are authorized by the Director of Manufacturing. Operating limits for the Plutonium Oxide Facility, are included in operating procedures and are set well within the limits derived from the Standards. Operating limits are approved by the Separations and Separations Technology organizations both of which are intimately familiar with the processes and equipment.

4.8.1 Effluent Radioisotopes (Pollutants)

The only potentially radioactive discharges from the Plutonium Oxide Facility are the ventilation air, contaminated cooling water, and solid wastes.

4.8.2 Effluent Treatment and Control

4.8.2.1 Solid and Liquid Effluents

All liquid processing streams and waste solutions are returned through double wall piping to the canyon facility for processing or disposal. The double-walled piping is sloped to several "low points". Conductivity probes are located at these low points and are used to detect any leakage into the double-walled annulus. If liquid is detected by a conductivity probe, hard-wired interlocks prevent further transfers using the leaking line.

The solid waste will be sent to the SRP radioactive solid waste storage site[6] for retrievable storage.

4.8.2.2 Airborne Effluents

The process cabinet ventilation air is exhausted through two stages of DOP testable high efficiency particulate air (HEPA) filters within the facility and will be discharged through an existing sand filter. Process area regulated room exhaust is pulled through the sand filter prior to discharge through the 200 ft stack. HEPA filters are discussed in detail in Section 4.6.1, Inspection and Testing of Ventilation Systems.

4.8.3 Effluent Monitoring Program

All effluents from the Plutonium Oxide Facility are monitored for radioactive material content. The content of radioactivity may dictate the action (if any), to be taken to reduce a release.

Alpha monitors are installed in the B-Line Cooling Water System and the Independent Cooling Water System. When contamination is detected, the individual loop is isolated and decontaminated.

All regulated Building 221-H air is monitored before it leaves the building and enters the stack exhaust tunnel.

4.8.4 Safety Management Systems

It is the policy of SRP that safety and protection of employees come first.[7] There are two separate organizations dealing with safety. One concerns itself with the protection of man and his environment from the harmful effects of radiation and the other deals with the industrial safety of the operating personnel.

4.8.4.1 Radiation and Contamination Control

The Health Protection Department concerns itself with radiation and contamination control. It is SRP policy to limit the radiation exposure of employees to as low as reasonably achievable level (ALARA).[8] Radiation exposure plant guides are used to help control the exposure of operating personnel. These values are given in Table 4-2. The HB-Line facility was designed to limit individual exposures to less than 1 rem/year.

The exposure of whole body (penetrating radiation) is estimated by combining:

1. The radiation dose determined from thermoluminescent dosimeter (TLD) reading.

2. The neutron radiation dose as determined by thermoluminescent neutron dosimeters (TLND).

Internal deposition of radionuclides may be detected by a routine program for analysis of urine and by whole body or chest counting (in vivo) techniques.

Locations within the Plutonium Oxide Facility are classed into three categories that depend upon expected levels of radiation or contamination. A Clean Area is an area where no radioactive materials are handled and where the radiation and contamination levels are equivalent to natural background. A Regulated Area (RA) is where radioactive materials are handled, or where radiation or contamination exceeds natural background, but where the radiation level does not exceed 300 mrads or 50 mrems/hr and contamination is low. A Radiation Zone (RZ) is where radiation or contamination levels exceed limits for a Regulated Area.

All work within a RA or RZ is controlled by procedures. These procedures are prepared and approved prior to entry into a RZ, or prior to starting nonroutine work in a regulated area.

TABLE 4-2

Administrative Exposure Limits

Annual Administrative Exposure Limits	rem per year
Effective dose equivalent (sum of internal and external exposure to the whole body)	3
Lens of the eye	15
Skin, bone, thyroid, other organs and extremities	50
Additional Administrative Exposure Limits (effective dose equivalent from both internal and external sources)	
Employee with cumulative occupational effective dose equivalent greater than 50 rem*	0.5
Unborn child of a worker	0.5
Employee or student under age 18 or an employee who is not a radiation worker**	0.1
Planned special exposure	10
Site Emergency***	10

*Occupational effective dose equivalent is the sum of:
(1) the total dose equivalent from external radiation since the beginning of employment at the site, and
(2) the total effective dose equivalent from assimilation of radionuclides from time of intake to age 75.

**Sum of the committed effective dose equivalent from internal radiation and annual effective dose equivalent from external irradiation.

***This guide does not apply to the saving of human life. Guide values for attempts to rescue victims will be determined based on an evaluation of the probability of success versus the total risk to the volunteers.

The Radioactivity Concentration Guide (RCG) is the concentration of radioactivity in the environment which is determined to to result in whole body or organ doses equal to the Radiation Protection Guide as defined by Nuclear Regulatory Commission, 10 10 CFR 20 and 10 CFR 50. An airborne concentration of 2×10^{-12} µCi/cc is defined as 1 RCG for ^{238}Pu.

All building areas occupied by personnel are surveyed routinely using portable or permanently installed instruments. Air samples are taken where the potential for airborne activity exists. When air alpha activity exceeds 2×10^{-12} µCi/cc, respiratory protection equipment is required.

Protective clothing is prescribed in the procedures for work in RAs or RZs when an actual or potential contamination hazard exists.

4.8.4.2 Industrial Safety

The SRP safety policies are to help employees avoid injuries and provide a safe environment in which to work. Management directs the program through the Plant and Area Central Safety Committees. The program includes planned educational activities on a daily, weekly, and monthly basis.

The Plant Central Safety Committee is composed of top level managers, Chairmen of Area Central Safety Committees, and Safety and Fire Protection Supervision. This body establishes policy and plantwide procedures. There are nine permanent subcommittees as shown in Figure 4-2. The primary functions of each of these subcommittees are listed in Table 4-3.

The H-Area Central Safety Committee is composed of a representative from each of the departments regularly working in H Area. This committee is primarily a coordinating group for the departments in the area. The committee reviews all departmental reports of injuries and accidents within the area. The collective membership of the committee supplements departmental responsibility for personnel safety.

4.8.4.3 Industrial Hygiene

The purpose of the industrial hygiene program is to protect plant personnel and plant environs against hazards from nonradioactive materials. This includes hazard recognition, evaluation, and other environmental control factors.

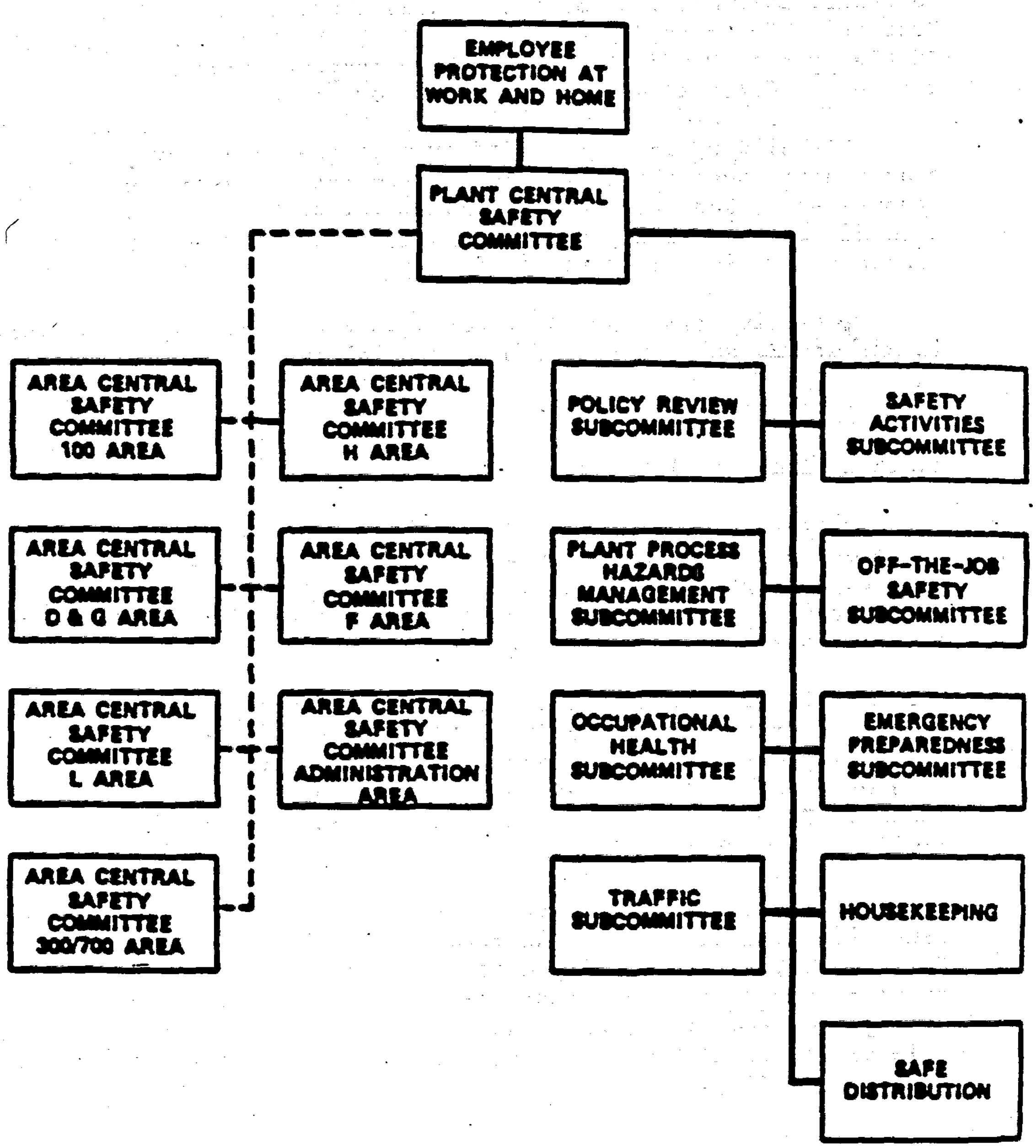

FIGURE 4-2. SRP Safety Program

TABLE 4-3

Safety Subcommittee Primary Functions

Subcommittee	Primary Function
Policy Review	Review and approve changes in the Safety Manual. Review and approve injury and unusual incident investigation reports. Evaluate plant safety performance.
Traffic	Devotes itself to traffic problems, road hazards, vehicle accidents, and handling of hazardous materials (RHYTHM program).
Occupational Health	Devotes itself to special hazards involving industrial hygiene, hearing conservation, handling of radioactive and toxic materials.
Emergency Preparedness	Devotes itself to the ability of Plant forces to respond to emergency situations. Included are fire protection, firefighting capability, emergency procedures, and emergency training of employees.
Off-the-Job-Safety	Reviews off-the-job injuries, and develop programs and procedures to improve off-the-job safety performance.
Process Hazards Management	Responsible for coordinating and auditing process hazards management programs.
Safety Activities	Devotes itself to increasing the involvement in and expanding efforts in the planning of onplant safety programs.
Housekeeping	Reviews plant housekeeping standards and develops programs and procedures to improve housekeeping performance.
Safe Distribution	Coordinates and directs the receiving, handling, and shipment of hazardous materials ("RHYTHM").

The Health Protection Department is responsible for the program including noise and ventilation surveys and epidemiological studies. The Industrial Hygiene Group provides technical expertise, procedural guidance, and conducts special hygiene surveys. The Health Protection Area Survey Group in F and H Area provide surveys within these areas.

Inspections are conducted in operating areas, and newly purchased materials used are reviewed for potential hazard. Special procedures are used when handling potentially carcinogenic materials.

4.8.4.4 Emergency Preparedness

An Emergency Preparedness Subcommittee of the Plant Central Safety Committee devotes itself to fire prevention, fire fighting capabilities, and review of all emergency procedures for the plant. This subcommittee works closely with the Fire Protection Group within the Safety and Fire Protection Division. The Fire Protection group maintains adequate mobile fire fighting equipment, trains personnel, and inspects protection equipment.

4.8.4.5 Criticality Control

There is a remote possibility that plutonium containing a large fraction of fissile isotopes could be inadvertently transferred to the PuO_2 Facility.

Procedures are the administrative controls used to ensure nuclear criticality control. These procedures are based upon Technical Standard Limits and on criticality calculations.

In certain instances, equipment and/or facilities are designed and built to be "safe" from a nuclear criticality accident. In some instances instrumentation is used as a secondary control to guard against criticality. In addition to these controls, detection and alarm instrumentation audits and training are basic control devices.

This section discusses procedural and personnel controls as they relate to criticality control.

4.8.4.5.1 Procedural Control

Technical Standards for PuO_2 Facility operations represent the highest level of control of the process. They specify limits to ensure that operation of the various process steps will be safe to personnel, and to the environment. Technical Standards on Nuclear Safety provide limits or specifications for the following:

1. Handling and storage.

2. Maximum permissible amounts of fissionable isotopes and mixtures of fissionable isotopes.

3. Permissible methods for quantity and concentration determinations.

Operating procedures are prepared by Separations Department personnel assigned to the PuO_2 Facility. These operating procedures are reviewed by the Separations Technology Department for their nuclear criticality control adequacy. If special nuclear criticality control items are considered necessary, they are prominently included directly in the procedure.

Area Criticality Audit Committees are maintained in the 200 Area with membership from the appropriate Production Department (Chairman), Health Protection, and from both Separations Technology and Reactor and Reactor Materials Technology. These committees conduct audits of conditions, practices, and procedures to assess their adequacy for nuclear criticality control. The committees issue a report of each audit, and the Production Department issues a followup report stating the action taken on each deficiency and recommendations.

The Nuclear Safety Review Committee (NSRC) reviews methods of handling and processing fissionable materials and management systems to ensure that a critical mass will never be accidentally accumulated. It reports to management periodically and is available to production and technical supervision for consultation. The NSRC is chaired by the General Superintendent of Technical in SRP. The Program Managers of Reactors, Separations, and Waste Management, and the Director of the SRL Nuclear Reactor Technology Section are members.

The NSRC meets annually for a general review of nuclear safety presented by the Superintendents of the Reactor, Separations, and Raw Materials Departments. A member of Wilmington Management participates in these reviews. Annual reviews are also presented to the NSRC by Area Criticality Audit Committees (see below). The NSRC provides guidance to the area committees on policy and on changing conditions that may affect nuclear safety in a specific area. The adequacy of performance of each area committee will be evaluated by the NSRC at least every three years.

Special meetings of the NSRC may be called at any time by the Plant Manager, a department superintendent, or a member of the NSRC to consult on plans for new or altered facilities or conditions or to review process incidents or other circumstances involving nuclear safety.

Reports and memoranda routinely sent to the NSRC by the originating groups include:

- Routine and special audits and investigations by the Area Criticality Audit Committees
- Special hazards investigations of potential nuclear hazards
- Process incidents involving a potential nuclear hazard
- Meeting notices of committees appointed to investigate incidents or conditions involving potential nuclear hazard.

Criticality training is the responsibility of line supervision, with the assistance of appropriate safety and technical specialists. Criticality safety training is one aspect of the overall program to ensure the safety of the process and the personnel. The continuing effort is to keep the subject of criticality safety fresh and alive by presenting it in new forms and with new aids such as films and booklets. Knowledge of the subject is verified through questions by supervision and the audit committee.

4.8.4.5.2 Personnel Control

Nuclear Incident Monitors (NIM's) are provided wherever fissionable materials are stored or processed in sufficient quantity for a potential critical configuration (References 8 and 9). There is one set of nuclear incident monitors in the new PuO_2 Facility. This set is located in the Product Storage Vault, Room [redacted]. Each set consists of two units to increase reliability.

The alarm rate for a NIM is defined as the minimum steady radiation rate that will sound an alarm within five seconds. NIM's shall be set so that the alarm rate in service remains between the limits of 0.5 and 3 R/hr. An alarm shall also sound if the total dose received at the detector within one minute exceeds 50 mR. However, for instruments in normally unattended, shielded areas, alarm rates shall be set well above the prevailing radiation background and may be as high as 100 R/hr.

Remote alarm bells are used in areas where it would otherwise be difficult to hear the alarm. Personnel are trained to respond to a NIM alarm by immediately going to a specified location by a previously prescribed route (Reference 3). There are nineteen NIM bells on the system. Twelve are located on 5th level and seven on 6th level. Two of the twelve on 5th level are located in the support facility (office area), one is located on the Canyon 4th level roof, and one in the elevator vestibule. The remaining eight are located in the corridor around the process area and in the maintenance rooms. Five of the seven 6th level bells are located in the corridor. One is located in the heating and ventilating Room [redacted], and one in Room [redacted].

NIM operating power is obtained from three power supplies (normal and emergency power) and a rechargeable battery. The battery will automatically continue NIM operation up to 48 hours if both normal and emergency power supply fail.

DELETED VERSION

4.9 References

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2. Summary — SRP Emergency and Disaster Plans. Internal Report DPSOP-175, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC (1974).

3. 200-Area Emergency and Disaster Plans. Internal Report DPSOP-115-FH, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC (1977).

4. SRP - Air Filtering Systems Specifications. Internal Report DPSOP-40-2, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken SC (1974).

5. Health Physics Water Monitoring. Internal Report DPSOP-193-2, E. I. du Pont de Nemours & Co., Savannah River Plant,. Aiken, SC (1976).

6. Final Environmental Impact Statement, Waste Management Operations, Savannah River Plant, Aiken, South Carolina. U.S. Energy Research and Development Administration, ERDA-1537 (1977) and DOE/EIS-0062, Supplement to ERDA-1537.

7. Safety Manual. E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC (1976).

8. Savannah River Plant Radiation and Contamination Control. Internal Report DPSOP-40, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC (1981).

5.0 RISK ANALYSIS

Postulated events that could potentially release radioactive material either to the environment or inside the Plutonium Oxide Facility are analyzed in the sections below. The initiating events for these releases are identified in Section 5.1. Then, the analysis methodology is explained in Section 5.2, followed by frequencies and consequences in Sections 5.3 and 5.4. Mitigation of these releases is also discussed in Section 5.4. Risks are summarized in Section 5.5.

For this analysis, the postulated events are grouped in the following categories:

Natural Phenomena
External Events
High Energy Events
Medium Energy Events
Low Energy Events
Residual Release Events
Airborne Containment System Failures

5.1 Initiators

The initiators for each event category were taken from References 1 and 2; a list is given in Table 5-1. A list of initiators for the analytical laboratory is given in Table 5-3B. Natural phenomena and external events are discussed in Reference 2 and thus are not repeated here.

5.1.1 High Energy Event Initiators

A high energy event is defined as one that would destroy the first containment barrier. It would also damage the secondary containment barrier (cabinet), allowing radioactive materials to directly reach rooms occupied by personnel.

No high energy events were identified. None of the applicable events involve sufficient potential energy to meet the definition.[1-3]

TABLE 5-1

Potential Release-Initiating Events

Category	Initiator	Frequency, yr^{-1}	HB-Line Consequences
Natural Phenomena			
	175 mph Straight Winds	$<1 \times 10^{-5}$	None*
	F5 Tornado Strike	3×10^{-8}	None*,**
	0.1g PHA Earthquake***	2×10^{-3}	None*
	0.2g PHA Earthquake***	2×10^{-4}	Section 5.4.1.2
	Flood	nil	None**
	Lightning	large	Power Failure
External Events			
	<1-Ton Meteorite Strike	1×10^{-11}	Hypothetical**
	Aircraft Crash	2×10^{-8}	Section 5.4.1.5
High Energy Events			
	None		
Medium Energy Events			
	Cabinet Fires	4×10^{-2}	Section 5.4.2
	Uncontrolled Reactions	4×10^{-2}	Section 5.4.2
	Criticality	1.4×10^{-5}	Section 5.4.5
Low Energy Events			Section 5.4.3
	Process Equipment Leaks	6	
	Transfer Errors	3×10^{-1}	
	Overflows	2×10^{-1}	
	Spills	2×10^{-1}	

* Design basis not exceeded. Design basis is 175 MPH for straight winds and F5 strength for tornadoes.

** Not analyzed because of low frequency.

*** PHA = peak horizontal acceleration; 0.1g = OBE (Operating Basis Earthquake); 0.2g = DBE (Design Basis Earthquake).

TABLE 5-1 (Contd)

Category	Initiator	Frequency	HB-Line Consequences
Residual Release Events			Sections 5.4.4, 5.4.7
	Process Related	7.2×10^1/yr	
	Glove Failure	5.8×10^1/yr	
	Material Handling	3.8×10^1/yr	
	Room Maintenance	2.0×10^0/yr	
	Air Reversals	1.1×10^0/yr	
Airborne Containment System Failure			Section 5.4, Loss of system
	Ventilation Failure	8×10^{-4}/d	
	HEPA Filters By-Passed	9×10^{-2}/d	

5.1.2 Medium Energy Event Initiators

A medium energy event is defined as one that will cause penetration of the primary container, and will cause materials to bypass the second containment barrier for a short period of time. Medium energy initiators are listed in Table 5.1 and are discussed in detail below.[1-3]

5.1.2.1 Cabinet Fires

A cabinet fire could potentially release contamination into the maintenance and operating rooms. The fire can cause failure of secondary containment (e.g. cabinet gloves). The ventilation system provides filtration of the maintenance and operating room air prior to discharge to the atmosphere and, therefore, minimizes the consequences of this event.

Combust ble materials are kept at a minimum inside the cabinets. Fires in HB-Line since 1961 have not caused significant damage to the cabinets. Several fires were caused by the placement of combustible materials near thermally hot equipment. The improper disposal of waste may also lead to a cabinet fire. The reaction between nitric acid and cellulosic materials have resulted in smoldering of the material. HEPA filter materials containing heat-generating ^{238}Pu resulted, on one occasion, in vaporization of the liquid (acid-water); the Halon fire supression system was activated, but no actual fire occurred.[4]

5.1.2.2 Uncontrolled Reactions

Uncontrolled reactions are a rapid means of losing control of materi: s in a process. The potential can exist if a chemical additic: error occurs. Eructations can potentially occur when the vessel ventilation system is unable to handle the large volumes of gases produced during a violent reactions. Eructations result in a release of material through vessel openings into secondary containment.

5.1.2.3 Criticality

There have been no criticality accidents at SRP. The vessels, lines, and sumps that routinely receive significant quantities of fissile materials have geometrically-favorable design.

The criticality limit, or maximum safe mass of 8.15 kg for handling and processing $^{238,239}PuO_2$ is based on calculations for a theoretically dense oxide sphere composed of 67% $^{238}PuO_2$, 33% $^{239}PuO_2$ surrounded by an infinite water reflector.[5] A k_{eff} = 0.9 was used to define the maximum safe mass. The 83.5% $^{238}PuO_2$, 14% $^{239}PuO_2$ has a larger safe mass because of the higher $^{238}PuO_2$ content. The heat output of $^{238}PuO_2$ precludes, for practical purposes, the accidental assembly of a critical mass of high assay $^{238}PuO_2$.

Criticality controls for ^{238}Pu in solution are generally not required because the minimum critical mass in aqueous solution is quite large. The high neutron emission rate of ^{238}Pu (by alpha,n reactions) requires handling in small batches for effective radiation control. Concern for nuclear criticality in the $^{238}PuO_2$ facility, therefore, involves an inadvertent transfer of a ^{239}Pu-rich solution to HB-Line from the Scrap Recovery Facility or from the canyon, as explained in Section 5.3.1.3.

5.1.3 Low Energy Event Initiators

A low energy event will not destroy the primary containment barrier (the primary container) but may release activity from it. The events do not necessarily expose personnel to radioactivity; low energy initiators include leaks, transfer errors, overflows, and spills.[1]

5.1.3.1 Process Equipment Leaks

Leaks cause material to penetrate primary containments such as vessels, pipes, and instruments. The consequence of these leaks results in loss of a few milliliters of solution to all of the material in holdup. Leaks can also occur due to failure of valve packings, welds or instruments.

5.1.3.2 Transfer Errors

Transfer errors are defined as the intentional movement of material to an unintended location. No release occurs if the transfer error is between tanks in the same facility. If the transfer error results in transfer of material outside primary containment, then there can potentially be a release of radioactive materials.

5.1.3.3 Overflows

Overflows are caused by exceeding the capacity of a vessel. The consequence of this event is minimized by providing a vessel vent system. Exceeding the capacity of the vessel will result in transfer of the material to the vessel vent catch tank. In order for overflows to release material to the secondary containment the primary containment (vessel) must have an opening to the secondary containment (cabinet) and the vessel vent capacity exceeded.

5.1.3.4 Spills

Rupture of a polyethylene bottle can cause relese of ^{238}Pu solution to the cabinet sump. Spill of oxide power in the cabinet is not expected to cause a release to the room because of the negative pressure inside the cabinet. Some of the powder would be exhausted through the cabi-et exhaust system, but most of that would be removed by the HEPA filter system and sand filter.

5.1.4 Residual Release Event Initiators

A residual release event is similar to the low energy release except that it considers only the residual activity already in the cabinet (outside process equipment) as being available for transport through the containment barriers. These releases represent releases due to failures of secondary containment (the cabinet). It is assumed that, in this new facility, residual activity will be available soon after startup because of incidents such as those discussed above in Section 5.1.3.

5.1.4.1 Process Related Releases

Routine residual releases include events such as sampling, cabinet filter changes, hut construction and/or removal, decontamination, and maintenance. These operations have the potential of releasing residual airborne activity to the ventilation system. The ventilation filter system reduces the amount of activity released through the stack.

5.1.4.2 Glove Replacement and Glove Failures

Gloves are used throughout this facility in both the maintenance and operating rooms. Glove failures are minimized by a routine glove change program. Gloves may also fail during operation due to puncture or rupture. Spread of residual activity is minimized by the ventilation system. Negative pressure is maintained in the cabinets with respect to the maintenance and operating rooms. The ventilation system also provides filtration prior to discharge to the stack. Procedures require monitoring after a job is completed to minimize the spread of contamination.

5.1.4.3 Material Handling

A residual activity release can occur while introducing material into the line, bagging materials/tools, and during waste handling. Waste generated in the main line cabinets are passed down to the waste conveyer and transfered to the waste handling line. Cabinet waste generated in the wing cabinets must be bagged out. Residual activity releases will likely occur during these operations. The ventilation system will provide filtration prior to discharge to the stack.

5.1.4.4 Room Maintenance

Room maintenance may result in resuspension of activity from prior releases to the room. Examples of residual release caused by room maintenance include replacement of ceiling panels and floor tiles, painting, or relamping.

5.1.4.5 Air Reversals

Airborne activity can be released from process cabinets and spread to clean rooms and corridors during an air reversal. Airborne contamination is a potential inhalation hazard to personnel not wearing respiratory protection equipment.

5.1.5 Airborne Containment System Failures

These systems provide containment of airborne activity. They include the ventilation system, HEPA filters, and sand filter. For the purpose of this analysis the sand filter is assumed to always be available with an efficiency of 99.51% if no prior HEPA filtration has occurred.[6] The ventilation system and HEPA filters are discussed below.

5.1.5.1 Ventilation Failure

Total loss of the ventilation system could result in a radioactive release to the operating and maintenance rooms. (Loss of the ventilation system is defined as loss of normal and emergency power to the ventilation system.) However, several interlocks are provided to prevent releases to the operating and maintenance rooms due to the ventilation system.

Air supply to the facility is interlocked with the fire suppression system and the insufficient vacuum alarm in the tunnel exhaust. If the fire suppression system is activated, both the air supply and air exhaust are throttled to 10% of their normal flows. This allows discharge of the Halon® system and maintenance of the proper Halon® concentration without pressurizing the glove boxes or losing ventilation airflow. Mechanical stops on the supply and exhaust dampers prevent closure to less than 10% of normal flow. If the alarm for insufficient vacuum in the exhaust tunnel is activated, the ventilation air supply is also throttled to 10% of normal flow.

The HB-Line exhausters are interlocked with the HB-Line air supply system. If the air supply was throttled back due to discharge of the fire suppression system, the air exhaust will throttle back also.

5.1.5.2 HEPA Filter Failure

Failure of a HEPA filter in the cabinet exhaust system results in increased activity released to the sand filter. Based on statistical analysis of HEPA filtration systems, the unavailability is 0.093. For this analysis, the penetration factor for one stage is 4.9×10^{-3}. The penetration factor for two filter systems is 4.9×10^{-5}. The penetration factor for three filter systems is 4.9×10^{-7}.[6,7]

5.2 Analysis Methodology

The purpose of this safety analysis is to evaluate the operating risk to onsite personnel and offsite populations from this facility. The first step was to review the facility and equipment design, and the methods for operating and controlling the process. The knowledge obtained from this review was then used in a systematic analysis of the Preliminary Hazards Analysis[1] to identify the hazards in the operation.

Risk (man-rem/hr) in this analysis is defined as the product of the expected frequency of an event that will release radioactivity and the dose to the recipient. The characterization of the radioactivity releases were defined by dividing the types of initiating events leading to these releases according to their energetics. A logic diagram called an event tree was used to define the possible sequences of events subsequent to the initiating event. These event trees provided a basis for analyzing the physical processes occurring during operations and for determining containment failure modes. These sequence definitions then provide estimates of the amount of radioactivity that would be released from the occurrence.

To obtain the expected frequency for a given event consequence, it was necessary to determine the expected frequency of the initiating event and the failure rate per demand for the sequenced conditions. Some frequencies were obtained through the use of fault tree analysis. Fault tree analysis produces a logic diagram to which failure rates and probabilities can be assigned and combined to derive the expected frequencies for system failures.

5.2.1 Data Base

Sources of raw data for risk assessment include published data from DOE reprocessing sites, environmental impact statements, safety analysis reports, experimental studies, and risk assessments by engineering firms on existing or proposed reprocessing plants. Sources also include data from all 200-Area operations,[4] including HB-Line operations; data entries range from minor equipment malfunctions to incidents with potential for injury or contamination of personnel. Several types of information have been extracted from these reports, including actual incidents, potential incidents, consequences, and engineered safety features designed to prevent, detect, or mitigate such incidents.

Data are stored in several data banks in a manner suitable for sorting and retrieval of information for risk assessment. The data banks include a generic incident data bank[8] that contains known potential incidents that could occur in each of the unit operations associated with fuel reprocessing.

The 200-Area Fault Tree Data Bank[4] contains actual deviations from normal operation, including dates of occurrence. These incidents are coded by site location, facility, unit operation, and keyword so that they can be retrieved by a variety of specifications. A computer code[9] provides the capability of selecting data by any of nine separate specifications. These specifications are: area, facility, unit operation, key word, "and" logic, "not" logic, source document, date, and text words. From these data, component failure frequencies and repair times are calculated.

5.2.2 Radionuclide Distribution

Consequences are reported in terms of curies of activity released from containment. To calculate dose resulting from transport of this material to man, the individual radionuclides present and their relative abundance must be known. This information is referred to in this report as a radionuclide distribution. It is a list of biologically hazardous radionuclides along with their respective curie fractions. Table 5.2 shows the radiation properties of typical ^{238}Pu processed in HB-Line.

5.2.3 Event Trees

An event tree is a logic diagram identifying the various possible outcomes of a given initiating event. The number of

TABLE 5-2

Radiation Properties of ^{238}Pu as processed in HB-Line

Nuclide	Specific Activity, Ci/g	Typical Weight Fraction	Maximum Weight Fraction	Worst Source Term*	Radioactivity (Ci)%**
^{238}Pu	1.75E+01	0.75-0.90	0.92	0.92	64.2
^{239}Pu	6.13E-02	0.11-0.17	0.48	0	0
^{240}Pu	2.30E-01	0.01-0.05	0.20	0	0
^{241}Pu	1.12E+02	0.005-0.03	0.16	0.08	35.8
^{242}Pu	3.90E-3	0.0005-0.001	0.001	0	0

* The worst source term represents the weight fraction resulting in the highest doses. It is used only to obtain the most conservative dose values and is not an actual isotopic distribution that will occur in normal operations.

** Based on worst source term.

possible final outcomes depends upon the various options that are applicable following the initiating event. In this analysis, the initiating event for each tree was chosen based on its energetics and physical form (i.e., liquid or airborne). Events subsequent to the initiating event are determined by system characteristics and engineering data. In these event trees, a particular sequence from the initiating event to final outcome is termed an accident sequence.

For convenience, release sequences were based on the physical containment equipment (sometimes referred to as confinement barriers). For airborne materials, the ventilation equipment became the significant containment barriers. Event trees provide combined accident sequences from the initiating event to the release of activity at the points of interest. The points of interest for liquids and solids are releases to the rooms, which may ultimately reach the outside ground, or may be a source of an airborne release. Release points of interest for airborne materials include releases to the cabinets, rooms, and stack.

The starting point for the development of an event tree is the event (failure) that initiates a potential accident situation. These initiating events, which may be referenced according to the energy associated with the event, were defined in Section 5.1. Containment barriers are discussed detail in Section 3.3.1 of Supplement 2A.[2]

In the preparation of an event tree, the first step is to determine which systems might affect the subsequent course of events. As an example (Figure 5-1), given the initiating event, the systems which affect the subsequent course of events are the cabinet, the room, and the ventilation system. Each of these barriers are ordered in their sequence across the top of Figure 5-1. The upper branch of the tree represents failure of the system to fulfill its containment function. In the absence of other constraints, there are $2^{(n-1)}$ accident sequences where n is the number of headings (functions, systems, etc.) included on the tree. However, there are known relationships (constraints) between system functions. For example, if the cabinet or sump contains the release, then no consequence will occur. Once these relationships are determined, some sequences can be eliminated because they represent illogical or inconsequential sequences. These reduced event trees are used in this analysis.

If the event sequences are independent, then the expected frequency of occurrence of a given sequence is the product of the initiating event frequency and the individual demand probabilities of the individual systems in that sequence. Since the failure demand probabilities are often 0.1 or less, it is common practice to approximate success (1-p) as 1. It should be noted that as

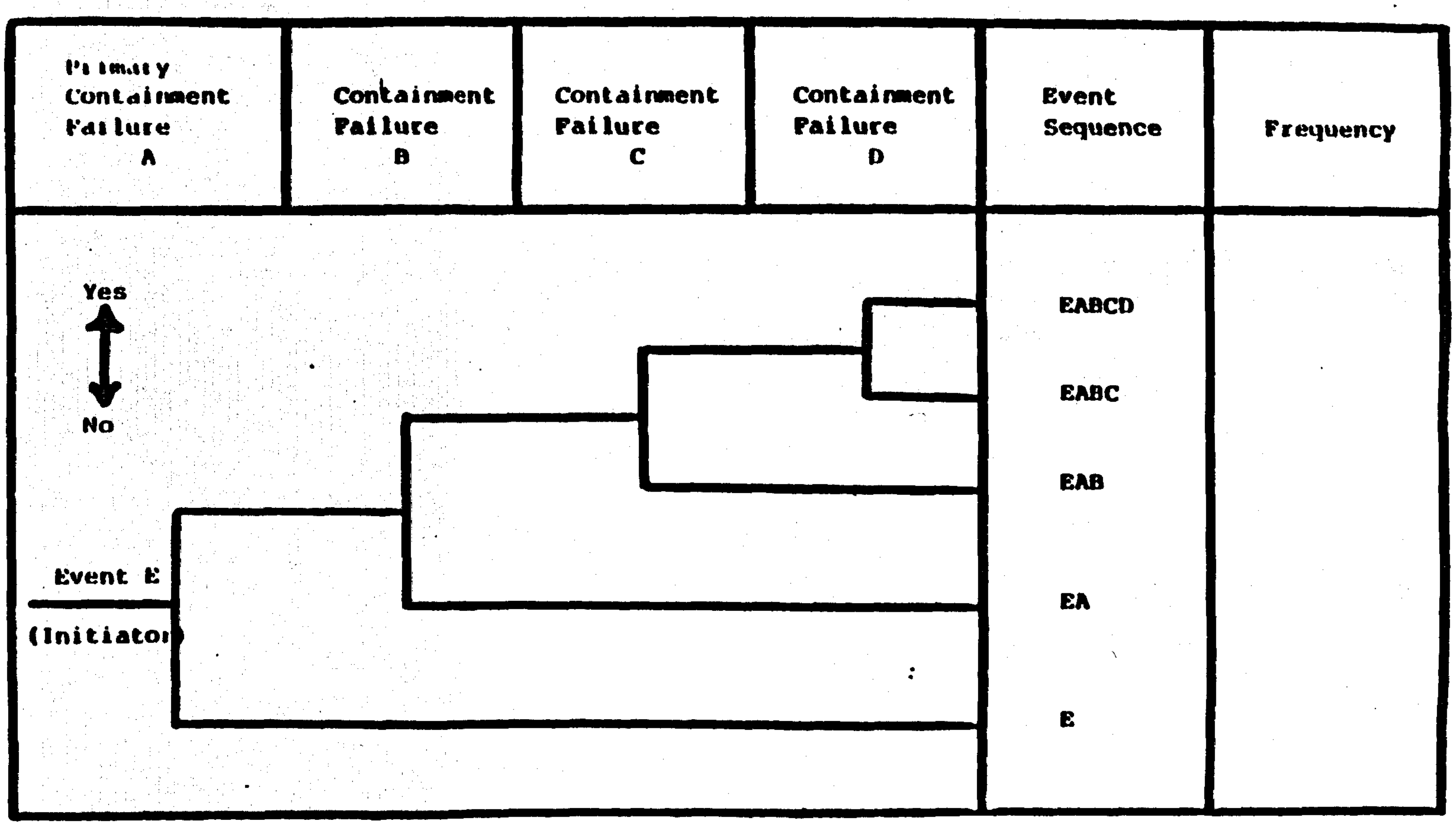

FIGURE 5-1. Example Event Tree

indicated in Figure 5-1, the study developed event trees in which each branch point provides only two options, system failure or success. No consideration is given to partial system success within an accident sequence

5.2.4 Fault Trees

The fault tree method was used to estimate expected frequen-cies for the top event, for each energy category. The method uses a logic that is essentially the reverse of that used in event trees. Given a particular failure, the fault tree method is used to identify the various combinations and sequences of other failures that lead to the given failure.[10]

The fault tree method, illustrated in Figure 5-2, shows a fault tree for a low energy release event. The fault trees developed in this study were kept simple, and were developed downward only to the point where data are available. In devel-
oping the trees, consideration was given to intrinsic component failures, human factors, testing, and maintenance. The expected frequencies of the failures were assigned to the appropriate elements of the tree, and the expected frequencies of the top event were calculated.

A number of computer codes are currently available for the qualitative and quantitative evaluation of fault trees. FTAP and IMPORTANCE computer codes were used to evaluate some of the fault trees. FTAP is a computer code that performs the qualitative evaluation of a fault tree (i.e., computer minimal cut sets). IMPORTANCE is a computer code that performs quantitative analysis of a fault tree.[11]

FTAP is used to obtain minimal cut sets. FTAP determines minimal cut sets of any order for fault tree with AND, OR, K-of-N, and NOT gates. The minimal cut sets are used by IMPORTANCE to calculate the probability, unavailability, unreliability, or importance. Details about the methods for determining minimal cut sets, can be obtained from the Fault Tree Handbook.[10]

The FTAP[11] algorithm is based on one of three methods selected by the user: top-down, bottom-up, and Nelson. The top-down and bottom-up approaches are basically akin to the methods used in MOCUS[12] and MICSUP[13], respectively. The MOCUS algorithm uses successive Boolean substitution starting from the top event and working down the tree until all gates have been replaced by primary events. The MICSUP algorithm is similar to that used in MOCUS, except that MICSUP starts with the primary inputs of the lowest level gate and works upward to the top event.

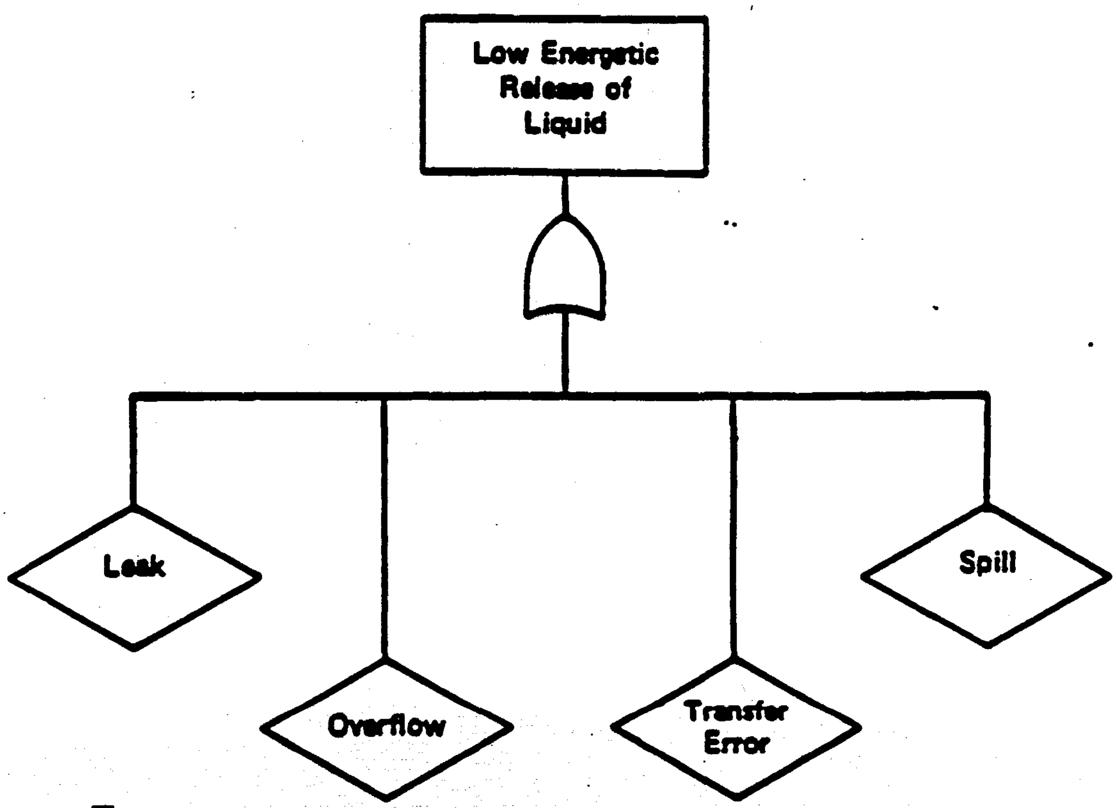

FIGURE 5-2. Example Fault Tree

Input information required by FTAP consists of control information and a description of the fault tree. Eight-character alphanumeric names are used for the event in the fault tree. The output, which can be printed, includes the list of minimal path and cut sets.

IMPORTANCE ranks primary events and cut sets according to various available importance measures.[11] It is capable of handling fault trees with time-dependent primary events under the assumption that primary events are statistically independent and their failure and repair distributions are exponential in time.

The importance measures that are included in IMPORTANCE are as follows:

1. Birnbaum[14]

2. Criticality[15]

3. Upgrading Function[15]

4. Fussel-Vesely[16]

5. Barlow-Proschan[17]

6. Steady-state Barlow-Proschan[17]

7. Sequential Contributory[15]

The input is a list of cut sets and primary failure data. Cut sets generated by FTAP are suitable for input. The input events can have up to 8-character alphanumeric names. The output consists of the probability, importance, and ranking of the top events, primary events, and cut sets on the basis of one or more of the above mentioned measures.

5.2.5 Dose Models

Significant onplant and offplant doses from the operation of the Plutonium Oxide Facility are considered in this analysis. A description of the dose models used is included in the following sections.

5.2.5.1 Dose to Personnel

The mechanisms for radiation dose to employees include:

- o Direct dose from external penetrating radiation.
- o Internal dose from inhalation, injection, and ingestion of radionuclides.

The maximum radiation dose limits[18] are given in Table 4-2. When personnel doses approach or exceed these guide values, the personnel are reassigned to work in locations with reduced dose potential. The dose to operators from direct radiation is measured on thermoluminescent dosimeters worn by the personnel.

Internal doses to individuals are determined using bioassay samples, whole body counting techniques, and other methods. For this study, internal doses to workers from accidental releases in rooms occupied by personnel were computed using the models
described in Reference 19. Fifty-year inhalation dose commitment factors which are used are based on most recent recommendations of the International Commission on Radiological Protection (ICRP Publications 26, 30, and 48).[24]

The dose (D) to the worker breathing contaminated air is the product of the dose commitment factor (F), the volume breathed (V), and the activity concentration (C) shown below:

$$D(rem) = F(rem/Ci) \times V(cc) \times C(Ci/cc)$$

The Dose Commitment Factor, F

Dose commitment factors are used to convert assimilated radio-active isotopes into an integrated radiation dose. These factors are a function of a particular radionuclide and its radiation type, intensity, and radiological and biological half-life and the mode of assimilation considered. For plutonium isotopes, the bone is the organ receiving the largest dose.

The Volume of Air Breathed, V

Adults are assumed to breath a volume of about 1×10^7 cc/8 hr workday. This is equivalent to 350 cc/sec.

The Concentration of Radioactivity in the Air, C

The accident description includes the activity released into the room as a result of the accident. It is assumed that this activity is diluted instantaneously into the volume of air in the room.

5.2.5.2 Models for Calculating Doses from Atmospheric Releases for Accidents

The radiological consequences of radionuclides released during an accident are evaluated for three population groups: 1) maximum 50-year dose commitment to an offsite individual, 2) 50-year dose commitment to onsite personnel, and 3) 50-year dose commitment to offsite people residing within 80 kilometers (50 mi).

For each accident scenario postulated, the associated radiological consequences are analyzed using the AXAIR computer code. The AXAIR code is used to calculate the consequences resulting from the release of radioactivity to the atmosphere. A complete description of the AXAIR89Q can be found in Reference 37.

For the maximum individual dose calculations, 42 air dispersion factors (X/Q) values at the plant boundary were calculated for each sector, corresponding to seven wind speeds and six atmospheric stability classes. A cumulative probability distribution of X/Q (in decreasing order) was constructed for each sector to determine the sector X/Q which corresponds to the 0.5% worst meteorological condition of the five-year period. The highest of the 16 sector X/Q values is termed the maximum sector X/Q. An overall cumulative probability distribution of X/Q (in decreasing order) was constructed to determine the 5% overall site X/Q, which corresponds to the 5% worst meteorological conditions of the five-year period. The higher the value of the maximum sector X/Q and the 5% overall site X/Q is then selected as the two-hour X/Q value evaluating postulated accidental airborne releases. The maximum individual doses were computed for the 50-year effective dose equivalent and six organs of interest. Both inhalation and immersion pathways were considered.

For the onsite population dose calculations, the X/Q values used were computed for distances inside the plant boundary in a manner similar to those described for the maximum individual dose.

The onsite population database represents a typical day-time population during the months of August-September, 1989 and is described in detail in Reference 38. The onsite population doses were computed for the 50-year effective dose equivalent and six organs of interest. Both inhalation and immersion pathways were considered.

For the offsite population dose calculations, the X/Q values used were computed for distances within a 50-mile region of the Savannah River Site in a manner similar to those described for the maximum individual dose. The offsite population database is based on the 1980 census of the U.S. population. This distribution can be projected to a later calender-year distribution. The offsite population database is described in detail in Reference 37. The offsite population doses were computed for the 50-year effective dose equivalent and six organs of interest. Both inhalation and immersion pathways were considered.

AXAIR89Q. The radiological consequences from the release of nuclides via atmospheric paths are analyzed using the AXAIR89Q code. The AXAIR89Q code performs both environmental transport and radiation dosimetry calculations for the postulated accidents involving airborne releases. The environmental transport models used are based on the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145.[21] The exposure pathways considered in the AXAIR89Q code include inhalation of radionuclides and gamma-irradiation from the radioactive plume.[22]

Radiation doses from inhalation of radionuclides in air depends on the amount of radionuclides released; the gaseous dispersion factor; the physical, chemical, and radiological nature of the nuclides; and various biological parameters such as breathing rate. Standard sets of breathing rates are used in the AXAIR89Q code.[23] Fifty-year inhalation dose commitment factors which are used are based on the most recent recommendations of the International Commission on Radiological Protection (ICRP Publications 26, 30, and 48).[24]

Radiation doses from gamma-shine result from radiation emanating from the traveling plume and depend on the spatial distribution of the radionuclides, the energy of the radiation, and the extent of shielding. In the AXAIR89Q code, no shielding is assumed in calculating population doses; the gamma-shine doses are calculated using a non-uniform Gaussian model because of its more realistic modeling compared to a conventional uniform semi-infinite plume model.[25]

In addition to the use of the worse-sector, worse-case meteorology, and conservative breathing rates and shielding factors, the AXAIR89Q code also provides no credit for the probable plume rise from stack releases. Therefore, the doses calculated by the AXAIR89Q code should be considered on upper bound of radiological consequences for the atmospheric releases postulated. (For population dose calculations, meteorological conditions are weighted by sector, wind speed, and dispersion class based on actual Savannah River Site meteorological data).

5.3 Accident Frequencies

Frequencies used in this analysis are discussed in detail below. The frequencies of natural phenomena and external events are as discussed in Reference 2 and are repeated in Table 5-1. Table 5-3 summarizes the calculated upper-limit frequencies for accident release sequences that begin with the initiators in Table 5-1. The event trees for these release sequences are shown in the Appendix. These release sequences represent the combined frequency of the medium energy, low energy, and residual activity release events, along with failure probabilities for the filtration system.

5.3.1 Medium Energy Events

The total expected frequency of medium energy events is 8×10^{-2}/yr. The frequencies of the initiators are listed in Table 5-1 and are discussed below. Calculated frequencies for medium energy release sequences are shown in Table 5-3. The event tree for these releases is in the Appendix.

5.3.1.1 Cabinet Fires

There have been 5 fires in HB-Line since startup in 1961. They occurred without damaging containment or resulting in a release of radioactive materials to the rooms. Four of them occurred in the Scrap Recovery Facility and one in the NpO_2 calciner cabinet. Only two are applicable to the $^{238}PuO_2$ facility: (1) burning plastic on top of a calcining furnace and (2) heat buildup in ^{238}Pu-containing wastes in Scrap Recovery. Based on these fires, the frequency in the new $^{238}PuO_2$ facility is 2×10^{-6}/hr, and the frequency in the adjacent solid waste cabinets is 3×10^{-6}/hr.

5.3.1.2 Uncontrolled Reactions

Four uncontrolled reactions have occurred in HB-Line since startup in 1961, three in Scrap Recovery and one in the NpO_2 coupling cabinet. None of these incidents resulted in a release of radioactive material to the environment or in the penetration of the primary containment barrier. Further, none of these incidents involved conditions found in either the old or the new $^{238}PuO_2$ facility, so the expected frequency is no greater than 5×10^{-6}/hr (1/23 yr).

TABLE 5-3

Expected Frequencies of Sequenced Releases

Event	Event Sequence[1]	Expected Frequency, yr^{-1}	Exhaust System	Release Sequence Description[2]
Medium Energy	MA	6×10^{-5}	-	Medium energy event and ventilation fans fail
	MBCD	7×10^{-4}	Cabinet	Medium energy event and both HEPA's fail
	MBC	7×10^{-3}	Cabinet	Medium energy event and first stage HEPA fails
	MBD	7×10^{-3}	Cabinet	Medium energy event and second stage HEPA fails
	MB	7×10^{-2}	Cabinet	Medium energy event with no filtration system failure
	MB'	8×10^{-2}	Room	Medium energy event - activity released to room exhaust system
Low Energy	LA	6×10^{-3}	-	Low energy event and ventilation fans fail
	LBCD	6×10^{-2}	Cabinet	Low energy event and both HEPA's fail
	LBC	6×10^{-1}	Cabinet	Low energy event and first stage HEPA fails
	LBD	6×10^{-1}	Cabinet	Low energy event and second stage HEPA fails
	LB	6×10^{0}	Cabinet	Low energy event with no filtration system failure
	LB'	7×10^{0}	Room	Low energy event with activity activity released to room exhaust system
Residual Activity Release	RA	1×10^{-1}	-	Residual release event and ventilation fans fail
	RBCD	1×10^{0}	Cabinet	Residual release event and both HEPA's fail
	RBC	1×10^{1}	Cabinet	Residual release event and first stage HEPA fails
	RBD	1×10^{1}	Cabinet	Residual release event and second stage HEPA fails
	RB	1.4×10^{2}	Cabinet	Residual release event with no filtration system failure
	RB'	1.7×10^{2}	Room	Residual release event with activity released to room exhaust system

[1] Event sequences are shown in the Appendix.
See Table 5-1 for expected frequencies of specific event initiators.

[2] Filtration system consists of two stages of DOP testable HEPA filters for the cabinet exhaust. A sand filter provides the final filtration prior to discharge to the 200-ft stack.

A potential cause of uncontrolled reaction is a chemical addition error in a process solution. The frequency in HB-Line is about 1/year. However, none of these errors has resulted in an uncontrolled reaction or loss of process solution from primary containment. The types of chemical addition errors are: wrong amount added (57%), wrong chemical added (35%), and chemical added too fast (8%).

5.3.1.3 Criticality

Because accidental criticality has not occurred in HB-Line or elsewhere at SRP, the probability must be estimated. The probabilistic fault tree method was used to calculate a frequency of 1.4×10^{-5}/yr or about once in 70,000 years. The fault trees are shown in Figures A-4 and A-5 of the Appendix.

The only potential mechanism for achieving an accidental criticality in the PuO_2 Facility is through the inadvertent transfer of material rich in ^{239}Pu from the Scrap Recovery Facility or the canyon. This would require the breakdown of administrative controls and continued processing of the fissile material in spite of redundant samples that should detect fissile material. In this scenario, processing would continue and the material would be concentrated sufficiently to achieve a criticality.

5.3.2 Low Energy Events

The total expected frequency of low energy events is 7/year; frequencies of the individual events are given in Table 5-1. Frequencies of low energy release sequences begun by these initiators are calculated from the event tree, Figure A-2 of the Appendix, and are shown in Table 5-3.

5.3.3 Residual Activity Release Events

The expected frequencies of residual activity release events, described in Section 5.1.4, are based on analyses of airborne activity in HB-Line.[4] The expected frequencies for residual activity release sequences are shown in Table 5-3. Only a fraction of HB-Line releases are related to Plutonium Oxide operations. The total expected frequency for a residual activity release is 1.7×10^2/yr. The event tree for these release sequences is shown in Figure A-3 in the Appendix. Table 5-1 shows the expected frequencies of the specific initiators of residual activity releases.

TABLE 5-3A

Expected Frequencies of Sequenced Releases for the Analytical Laboratory

Event	Event Sequence*	Expected Frequency, /yr	Exhaust System
Medium Energy	MBCD	5.4E-04	Cabinet
	MBC	5.8E-03	Cabinet
	MBD	5.8E-03	Cabinet
	MB	6.3E-02	Cabinet
	MB'	6.9E-02	Room
Low Energy	LBCD	1.4E-02	Cabinet
	LBC	1.5E-01	Cabinet
	LBD	1.5E-01	Cabinet
	LB	1.6E+00	Cabinet
	LB'	1.8E+00	Room
Residual Activity Release	RBCD	2.3E-02	Cabinet
	RBC	2.5E-01	Cabinet
	RBD	2.5E-01	Cabinet
	RB	2.6E+00	Cabinet
	RB'	2.9E+00	Room

*Release sequence description same as those in Table 5-3.

TABLE 5-3B

Expected Frequencies of Specific Event Initiators for the Analytical Laboratory*

Event	Initiator	Frequency, yr^{-1}
Medium Energetic	Cabinet Fire	2.8E-02
	Uncontrolled Reactions	4.1E-02
	Criticality	--
Low Energetic	Leak	4.7E-01
	Overflow	1.7E-02
	Spill	4.7E-01
	Other (plugged line, dropped container)	8.2E-01
Residual Activity	Total	2.9E+00

*Frequency for each medium energetic, low energetic or residual activity release is estimated as the mean per room frequency of the events which have occurred in Building 772-F.

5.3.4 Analytical Laboratory

Frequencies for the proposed analytical laboratory are based on frequencies for similar events in Building 772-F.[35,36] Building 772-F was used as a basis since the operations for the HB-Line analytical laboratory have been performed in Building 772-F. The recorded experience at 772-F is directly applicable to HB-Line analytical laboratory operations. The frequencies of accident events in the HB-Line laboratory were estimated as the average per room/cell frequency in Building 772-F. The frequency of transfer errors was not a separately listed low energetic event for Building 772-F. However, the total frequency of low energetic events includes other events (e.g., plugged line, dropped container). Calculated frequencies for medium energy, low energy, and residual activity release sequences are shown in Table 5-3A. The frequencies of the initiators are listed in Table 5-3B.

5.3.5 Airborne Containment System Failures

5.3.5.1 Ventilation Failure

Based on a study of failures of HB-Line exhaust fans, the expected frequency of incidents that would disable the system is once in ten years, and the system failure probability is approximately 8×10^{-4}/demand.[26]

5.3.5.2 HEPA Filter Failure

Data from 200-Area filter test were analyzed to determine the unavailability of HEPA filter systems. Based on this statistical analysis, a HEPA filter system unavailability of 0.093 is used in this analysis.

5.3.6 Aircraft Crash

Studies related to power reactors based on U.S. Civil Aviation accident data, indicates that the expected frequency of aircraft overflights becomes essentially constant at distances greater than five miles from an airport runway. The expected frequency is about 3×10^{-9}/(flight)(mile^2) for commercial aviation and about
7×10^{-9}/(flight)(mile^2) for general aviation.

Based on an estimated frequency of 4000 flights over SRP per year and the 8×10^{-4} mi^2 "target" area of the PuO_2 Facility, the aircraft crash frequency for PuO_2 Facility is calculated to be
2.3×10^{-8}/yr (2.6×10^{-12}/hr). The frequency is less than once in one million years and is, therefore, classified as incredible.

5.4 Accident Consequences

This section discusses the consequences of the accidents and release sequences that are described in Section 5.3, Accident Frequencies. These consequences are first calculated in terms of activity released from the process stack and then converted to doses. A summary of the consequences is shown in Table 5-4. These calculations are described in detail in the subsections below.

Calculations for airborne release consequences were performed using the methodology described in Reference 2, 27, and 28. A batch size of 388 grams of Pu was used as a basis for consequence calculations. Double batching was assumed for all source term calculations except where noted otherwise. The maximum inventory of 390 g of Pu was used as a basis for consequence calculations for the analytical laboratory.

The techniques used to estimate the amount of activity released to the stack are described in detail in the subsections below.

Maximum offsite individual doses, as well as onsite and offsite population doses, were then calculated for the postulated release accidents in terms of 50-year effective dose equivalents. Tables 5-4 and 5-4A summarize these doses.

TABLE 5-4

Summary of Consequences

		50-Year Effective Dose Equivalent		
		person-rem		rem
Event/ Sequence	Ci Released to Stack	Onsite Population	Offsite Population	Maximum Offsite Individual
MBCD	1.92E-02	1.22E+01	4.44E+01	5.44E-03
MBC	1.92E-04	1.22E-01	4.44E-01	5.44E-05
MBD	1.92E-04	1.22E-01	4.44E-01	5.44E-05
MB	1.92E-06	1.22E-03	4.44E-03	5.44E-07
MB'	9.90E-05	6.29E-02	2.29E-01	2.82E-05
LBCD	9.53E-04	6.05E-01	2.21E+00	2.71E-04
LBC	9.53E-06	6.05E-03	2.21E-02	2.71E-06
LBD	9.53E-06	6.05E-03	2.21E-02	2.71E-06
LB	9.53E-08	6.05E-05	2.21E-04	2.71E-08
RBCD	4.58E-08	2.91E-05	1.06E-04	1.30E-08
RBC	4.58E-10	2.91E-07	1.06E-06	1.30E-10
RBD	4.58E-10	2.91E-07	1.06E-06	1.30E-10
RB	4.58E-12	2.91E-09	1.06E-08	1.30E-12
RB'	4.95E-08	3.14E-05	1.15E-04	1.41E-08
Earthquake	6.13E-03	3.89E+00	1.42E+01	1.74E-03
Criticality:				
Fission Products	1.00E+04	2.5	1.7	6.00E-04
Radiation	- 0 -	7000	- 0 -	- 0 -

* Release sequences are explained in Table 5-3 and the appendix: the curies released are calculated from data in Section 5.4.1, Table A-1 (Appendix), and Table 5-2.

TABLE 5-4A

Summary of Consequences Analytical Laboratory

Event/ Sequence*	Ci Released to Stack	50-yr Effective Dose Equivalent, person-rem: Onsite Population	50-yr Effective Dose Equivalent, person-rem: Offsite Population	50-yr Effective Dose Equivalent, rem: Maximum Offsite Individual
MBCD	1.47E-02	9.04E+00	3.30E+01	4.05E-03
MBC	1.47E-04	9.04E-02	3.30E-01	4.05E-05
MBD	1.47E-04	9.04E-02	3.30E-01	4.05E-05
MB	1.47E-06	9.04E-04	3.30E-03	4.05E-07
MB'	7.64E-05	4.70E-02	1.71E-01	2.09E-05
LBCD	7.38E-04	4.53E-01	1.65E+00	2.03E-04
LBC	7.38E-06	4.53E-03	1.65E-02	2.03E-06
LBD	7.38E-06	4.53E-03	1.65E-02	2.03E-06
LB	7.38E-08	4.53E-05	1.65E-04	2.03E-08
RBCD	3.54E-08	2.17E-05	7.95E-05	9.76E-09
RBC	3.54E-10	2.17E-07	7.95E-07	9.76E-11
RBD	3.54E-10	2.17E-07	7.95E-07	9.76E-11
RB	3.54E-12	2.17E-09	7.95E-09	9.76E-13
RB'	3.82E-08	2.34E-05	8.56E-05	1.05E-08

*Release sequences are explained in Table 5-3 and curies released are calculated from data in 5.4.2, 5.4.3, 5.4.4, and appendix

There were no credible accident scenarios which would result in a significant liquid release from this facility. The HB-Line cooling water system is an internal recirculating loop consisting of a makeup (hold tank), recirculating pumps, heat exchangers, filter, and an alpha monitoring system. In the event of high alpha content in the water system, the water can be pumped from the hold tank to canyon tanks [redacted] or drained to canyon cold feed prep tank [redacted]. Cooling water is also supplied from the H-Area cooling tower, which supplies cooling water to the HB-Line cooling water "loop" heat exchanger and three HB-Line air conditioning units. The independent H-Area cooling water, condensate, and domestic water used to cool compressors on the instrument air, process air, breathing air and air monitoring units is returned to the cooling tower via a return water alpha-gamma monitoring station located at 281-H. Controls for the possible diversion of the return water are located in the canyon facility control room. The recirculating loop minimizes the potential for release of liquid contamination through either the HB-Line or H-Area cooling water systems.

5.4.1 Natural Phenomena and External Events

Extremes in weather, earthquakes, and an aircraft crash were analyzed. The following paragraphs discuss these effects.

5.4.1.1 Winds

Two types of winds are experienced at SRP: straight winds (includes hurricanes) and whirling type winds (includes tornadoes).

The new HB-Line structure is not expected to be affected by straight winds, even at speeds up to 175 miles per hour, because it is designed to withstand a DBE and DBT.[29,30] The radiological consequences of high straight winds are therefore nil for HB-Line.

Because this facility is designed to withstand a Design Basis Tornado (DBT), corresponding approximately to a Fujita Intensity Five (F5) tornado, no release of activity from this facility in liquid or finely divided solid form is expected due to this event.[30] Radiological consequences from a more severe tornado are not included in this analysis because of the low probability of occurrence and the low probability of striking HB-Line.

To prevent the possibility of the "suck-back" of radioactive material through the ventilation supply system, fast-acting tornado dampers have been installed in the ventilation inlets. In the event of an inlet airflow stoppage or reversal, these counter-balanced dampers automatically close, preventing the escape of any radioactive material.

5.4.1.2 Earthquake

A Design Basis Earthquake (DBE) for SRP production facilities is assumed to have 0.2 g horizontal ground acceleration. In this earthquake, standard construction buildings and houses may fall. The new HB-Line is designed to withstand blasts (reinforced concrete rigid frame construction) and to remain standing after a DBE.[29,31]

A small amount of activity, 6.13×10^{-3} Ci, is expected to become airborne in the facility caused by the earthquake. This activity is released through the ventilation system. It is assumed that this released material is entirely respirable. This assumes 5×10^{-6} percent of total 4890 g inventory (4500 g plutonium oxide facility and 390 g analytical laboratory) becomes airborne and is released through the room ventilation.[27]

5.4.1.3 Meteorite Impact

For this study, it was assumed that no significant release of activity would be caused by small meteorite.[2] Damage due to large meteorites are not included in this analysis due to the low probability of occurrence. This event is considered to be hypothetical.

5.4.1.4 Other Natural Phenomena

Cold weather is expected to have little effect within the Plutonium Oxide Facility, except through its effect on auxiliary services. This results in pluggage of lines and valves that are located outside of the building. Pipes may burst and instrumentation may become inoperative.

There have been no known adverse effects on equipment due to hot weather. However, personnel effectiveness may be affected due to extremes in temperature.

Snow represents an aggravation that can affect normal operations. The largest snowfall recorded of 18 inches fell in February 1973. The average annual snowfall over the last 40 years has been ~0.9 inches. Snowfall of 1 inch or more has fallen in seven of the last years.[30]

The principal adverse effect of lightning is interruption of electrical power.

5.4.1.5 Aircraft Crash

For this study, it was assumed that no significant release of activity would be caused by an aircraft crash and due to the low probability of occurrence, this event is considered to be hypothetical.

5.4.2 Medium Energy Event

A medium energy event is described in Section 5.1.2. Events of this energy are expected to contaminate the maintenance and operating rooms, as well as the ventilation systems. Consequences of release through the stack are given in Table 5-4. Event release sequences are shown in Figure A-1 in the Appendix.

The calculations for airborne releases were performed using the methodology described in Reference 2. The source term for this event is 788 g double batch of plutonium with a specific activity of 25.06 Ci/gram. This source term is used to estimate consequences for medium energy, low energy, and residual release events.

The source term for the analytical laboratory is 390 g total inventory of plutonium with a specific activity of 25.06 Ci/g. This source term is used to estimate consequences for medium energy, low energy, and residual release events. Release calculations for the analytical laboratory are shown in the appendix.

After a medium-energy event, 2×10^{-2}% of the material is released directly to the cabinet exhaust and 1×10^{-3}% is released from the cabinet.[27] One-fifth of the activity released from a cabinet (2×10^{-4}%) is expected to be airborne in both the Operating Room and the Maintenance Room.[27] Data from releases in the existing HB-Line indicate that 17% is released to the Operating Room and 83% to the Maintenance Room if the event is sufficiently energetic to breach containment on both sides of a cabinet.[13] Thus, the released material is temporarily distributed as follows:

Direct Release to Cabinet Exhaust

$$(776\ g)(25.06\ Ci/g)(2 \times 10^{-4}) = 3.89\ Ci$$

Airborne Release to Operating Room

$$(776\ g)(25.06\ Ci/g)(1 \times 10^{-5})(0.2)(0.17) = 6.61 \times 10^{-3}\ Ci$$

Airborne Release to Maintenance Room

$$(776\ g)(25.06\ Ci/g)(1 \times 10^{-5})(0.2)(0.83) = 3.23 \times 10^{-2}\ Ci$$

Airborne activity in the Operating Room is exhausted through the room exhaust system only. However, there are two exhaust routes from the Maintenance Room; 58% exhausts back through the cabinet and the cabinet exhaust system, and 42% exhausts through the room exhaust system. (Cabinet air is supplied only from the

Maintenance Room.)[2] Thus, the challenges to the two exhaust systems from a medium-energy event are:

Room Exhaust System

$$6.61 \times 10^{-3}\ \text{Ci} + (3.23 \times 10^{-2}\ \text{Ci})(0.42) = 2.02 \times 10^{-2}\ \text{Ci}$$

Cabinet Exhaust System

$$3.89\ \text{Ci} + (3.23 \times 10^{-2}\ \text{Ci})(0.58) = 3.91\ \text{Ci}$$

To determine the amount of activity released from the stack, it is necessary to consider the exhaust filtration systems. Cabinet exhaust air passes through two stages of HEPA filtration and the sand filter. Room exhaust air passes through the sand filter only. Event sequences for releasing this material to the stack are shown in Figure A-1 in the Appendix. Filtered cabinet and room exhausts must be combined to give the total amount of material release through the stack. Penetration of the filtration systems, two stages DOP testable HEPA's and sand filter, were determined by statistical analysis, as discussed in Section 5.1.5.2.

5.4.3 Low Energy Event

A low energy event will not destroy the secondary containment, as discussed in Section 5.1.3.

The consequences associated with an event of this energy are calculated in the same way as medium energy events above. Low energy events are not expected to contaminate the maintenance area or operating room. One hundred percent of the material is assumed to be released to the secondary containment (cabinet); 10^{-3} percent of the material is assumed to be released to the cabinet exhaust.[27]

Consequences of releases through the stack are summarized in Table 5-4. Event sequences for these releases are shown in Figure A-2 in the Appendix.

5.4.4 Residual Activity Release Event

A residual release event is similar to the low energy release except it considers only the residual activity already in the cabinet (but outside the process equipment) as being available for transport through the containment barriers. These releases include routine releases due to maintenance and operation of the facility.

The consequences associated with the event may contaminate the maintenance and operating rooms.[27] The amount of activity available is assumed to be 1 percent of the source term, of which 1 percent is assumed to be dispersible. This event is estimated to release 1.7×10^{-4} percent of the dispersible material to the operating room and 8.3×10^{-4} percent to the maintenance room. Consequences of release through the stack are given in Table 5-4. Event sequences for these releases are shown in Figure A-3 in the Appendix.

5.4.5 Nuclear Criticality

A criticality accident could potentially have significant consequences: severe penetrating radiation exposure, spread of contamination, and offsite consequences.

The size of a nuclear criticality event may be predicted from recorded accidents at other sites. The mean number of fissions for accidents which occurred in solutions is 2×10^{18}; these fissions were presumed to occur in an oscillating type accident where the first burst contributes 2×10^{17} fissions.[30] It was also assumed that the area affected by the accident is evacuated before the second burst occurs.

When nuclear criticality occurs, prompt neutron and gamma rays are emitted, and radioactive isotopes (fission products) are produced. Radiological significance of a nuclear criticality event can be related to its total fissions and knowledge of the physical layout surrounding its location. Two types of exposures to people result from a nuclear criticality accident: external and internal radiation doses.

External radiation dose potentially may result because of the close proximity (and/or lack of shielding) of personnel. Potentially lethal radiation doses (approx. 600 rad total body) can be received by a person about seven meters from an event of 2×10^{17} fissions. The data in Figure 5-3 was used to estimate personnel doses. In addition to the prompt gamma dose, an eventual gamma radiation dose similar to the prompt gamma dose could result to personnel in the facility from the fission products formed. However, this dose would only be received if someone were to stay in the vicinity of the incident after the criticality occurs. As stated above, this analysis assumes that the area around the incident is evacuated after the first burst.

Among these fission products are the volatile isotopes of bromine, iodine, krypton, and xenon. These isotopes are assumed to penetrate the ventilation exhaust filter system and be released out the stack, beginning minutes after a nuclear incident. Table 5-5 lists the most significant volatile fission products produced from a 2×10^{18} fission event. Isotopes with half-lives of less than three minutes were assumed to be too short to produce significant offsite consequence. Isotopes with half-lives greater than eight days do not contribute significantly to the total curies and, therefore, were omitted.

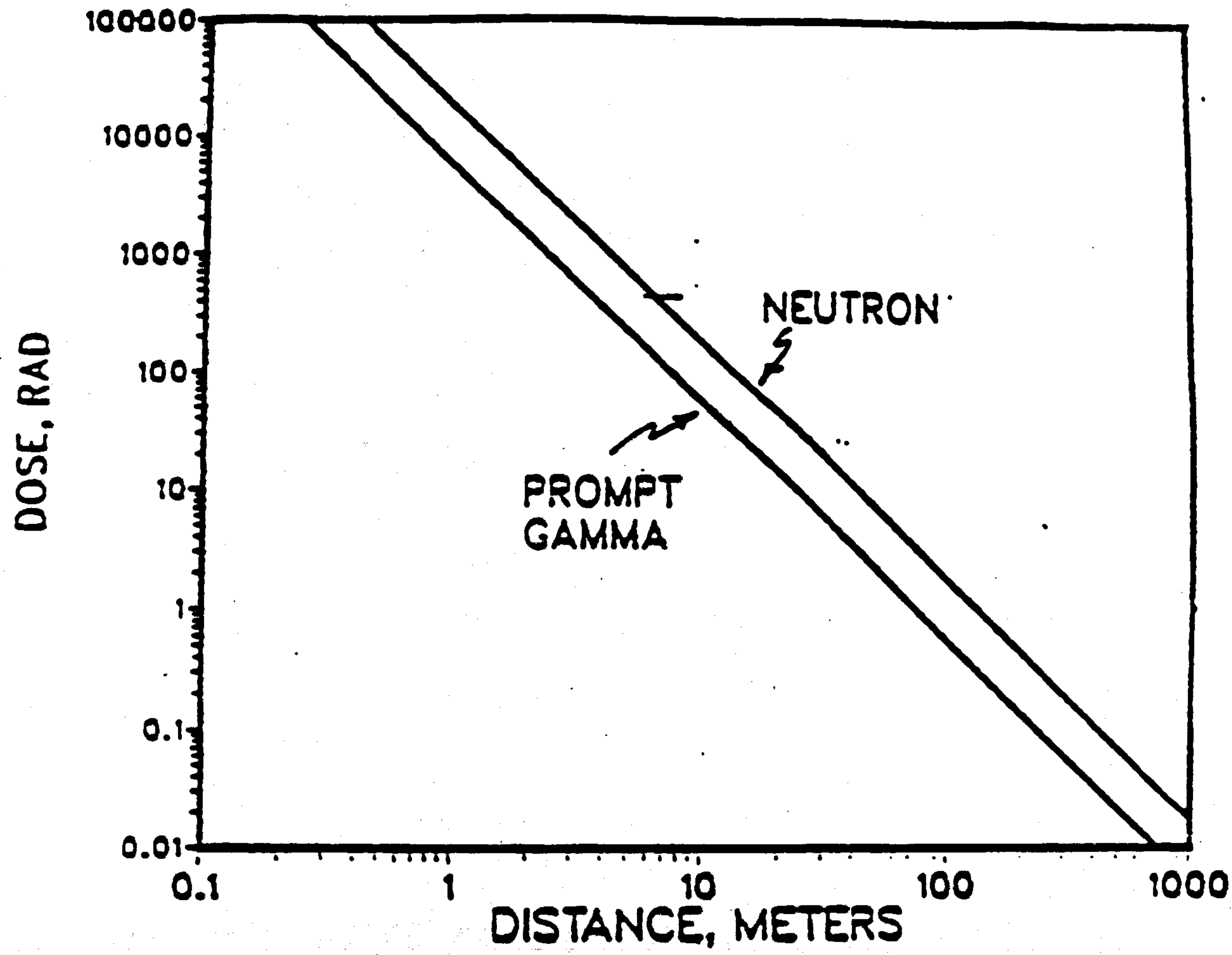

FIGURE 5-3 Dose as a Function of Distance in Air from a Nuclear Criticality Incident of 2 x 10^{17} Fissions[32]

TABLE 5-2

Curies of Volatile Fission Products Available Following 2×10^{18} Fissions of ^{239}Pu[32]

Nuclide	Curies After[1] Half-Life	Curies After[2] 1 Minute	45 Minutes
^{83}Br	2.4 hr	3.0×10^{0}	9.4×10^{0}
^{84}Br	33 min	2.0×10^{1}	3.6×10^{1}
^{85}Br	3 min	7.0×10^{2}	4.2×10^{-2}
^{131}I	8.1 day	3.2×10^{-2}	6.8×10^{-1}
^{132}I	2.4 hr	1.4×10^{1}	1.2×10^{1}
^{133}I	22 hr	5.2×10^{0}	2.2×10^{1}
^{134}I	55 min	3.0×10^{2}	3.8×10^{2}
^{135}I	6.7 hr	7.6×10^{1}	9.6×10^{1}
^{83}Kr	1.9 hr	-0-	2.0×10^{0}
^{85}Kr	4.4 hr	1.4×10^{0}	1.2×10^{1}
^{87}Kr	78 min	5.6×10^{1}	6.0×10^{1}
^{88}Kr	2.8 hr	2.6×10^{2}	7.6×10^{1}
^{89}Kr	3.2 min	2.4×10^{3}	1.7×10^{-1}
$^{133}Xe_2$	5.3 day	-0-	1.2×10^{-1}
$^{135}Xe_1$	15 min	1.1×10^{2}	4.0×10^{1}
$^{135}Xe_2$	9.2 hr	1.2×10^{0}	8.4×10^{0}
^{137}Xe	3.9 min	7.8×10^{3}	3.6×10^{0}
$^{138}Xe_1$	17 min	1.8×10^{3}	3.0×10^{2}
	Total	1.4×10^{4}	1.1×10^{3}

1 Used to compute onsite population dose.

2 Used to compute offsite population dose.

Internal radiation doses result from people inhaling, ingesting, or injecting radioactive material. Within one second of an event of 2 x 10^{18} fissions, nearly 1 x 10^7 Ci of nonvolatile fission products will be present.[2] Most of these radioactive isotopes will not contribute to doses outside the facility, but will be contained within the ventilation and filtering system. The internal contribution of dose to personnel working within the room where the incident occurred will be negligible compared to the external dose received. The internal dose to an individual located at the plant perimeter can be predicted using the activity available about 45 minutes after the incident occurred. The dose is based on release from the 200-ft stack. A summary of the consequences of a criticality accident is listed in Table 5-6. The consequences of the release of volatile fission products from the H-Area stack are shown in the Appendix, Tables A-4 to A-6.[2,20]

TABLE 5-6

Summary of Criticality Consequences

Assumptions	
Total number of fissions	2E+18
Number of fissions in 1st burst	2E+17
Personnel assumed to evacuate immediate area of criticality before further bursts occur	
45 persons in new HB-Line, 15 in $^{238}PuO_2$ line.	
In-Facility Dose	
Total persons exposed	45
Highest individual doses, rem	
Sections 2 and 3 (24 meter)	8E-7
Sections 5 and 6 (1.5 meter)	3E+4
Section 4 (12.2 meter)	3E-6
Office Area (39 meter)	4E-11
6th level above	2E+2
4th level below accident	2E-5
Number of persons exposed to >LD90/60* (600 rem)	2
Total dose to persons living after accident, person-rem	7E+3
Outside Facility Dose	
50-year onsite population dose, person-rem	2.5
50-year offsite population dose, person-rem	1.7
50-year maximum offsite individual, rem	6E-4

* Dose which would prove fatal within 60 days to 90% of the people so exposed.

5.4.6 Airborne Activity Model

It is possible to predict the range and concentration of migrating airborne activity in this and similar facilities. The basis is an empirical model constructed from air sampler data during a number of large airborne activity releases in HB-Line and JB-Line.[19] A floor plan is shown in Figure 5-4 with modeling positions superimposed. Position No. 1 is arbitrarily placed in Operating Room 1 and represents a point near an airborne release from the cabinet, e.g., due to a glove failure. If the ventilation systems are functioning properly and all doors are closed, the model predicts that the airborne activity in occasionally-occupied areas, such as the east corridor, (Position No. 4) will be 1 RCG or less, so long as the activity at Position No. 1 is <12,000 RCG. If all doors are assumed open, the value at Position No. 1 must be <500 RCG for <1 RCG at Position No. 4. Values at other positions on the floor plan can be predicted similarly, using the model factors in the table on the figure. The terminology for airborne concentrations has been changed from RCG (Radioactivity Concentration Guide) to DAC (Derived Air Concentration), 1RCG = 1DAC.

The probability of large releases of airborne activity into an operating room has been calculated for several mechanisms identified in the 200-Area Fault Tree Data Bank.[4,33] Because improved performance is expected in the new facility, application of data based on past HB-Line performance with ^{238}Pu is presumed to be conservative. One release of >1.2 x 10^4 RCG occurred in an operating room during the period July 1976 to June 1982 for a frequency of about 0.2/yr. Releases >500 RCG occurred there about 1.5/yr, and releases >100 RCG occurred at about 6/yr.[4,34] It should be noted that in most cabinet operations, and especially glove replacements, the operator must wear protective clothing and respiratory protection, as required by SRP procedures. Also, fewer personnel will be exposed to airborne activity, because more process operations will be conducted from the control room.

Circled numbers are Position Numbers for which relative airborne activity values are given in the table below:

Position Number	Relative Activity All Doors Closed	All Doors Open
1	100	100
2	5	5
3	0.03	1
4	0.008	0.2
5	0.2	0.2

FIGURE 5-4. Airborne Activity Model

5.4.7 Assimilations

Inhalation of airborne ^{238}Pu can occur in HB-Line as a result of ventilation failures, air reversals, glove failures, and protec-tive equipment failures. In addition to inhalation, assimilations of ^{238}Pu can also occur by ingestion and injection. Such assimila-tions are minimized by procedural controls. Food is not allowed in regulated areas. Sharp objects are kept at a minimum to minimize personnel injury.

Based on old HB-Line operating experience,[33] there have been 73 confirmed cases of ^{238}Pu assimilation. These data represent the period from January 1967 to December 1981. These assimilations were caused primarily by inhalation or ingestion; only five of these assimilations were caused by injection. The frequency of an assimilation based on old HB-Line data is 5.2/year (5.4×10^{-4}/hr).

The consequences of assimilations are assumed to occur only from inhalation. Based on a study of airborne activity, the mean air concentration was calculated to be 108 RCG.[34] (The terminology for airborne concentrations has changed since the time of this study from RCG - Radioactivity Concentration Guide, to DAC - Derived Air Concentration, 1RCG = 1 DAC.) This value is used to calculate the dose to an operator, using the methodology described in Section 5.2.5. The 50-year effective dose equivalent to an individual exposed to airborne activity was calculated to be 3.48×10^{-4} rem.

5.5 Accident Risks

Risk is defined as the product of the consequence and expected frequency of an event or sequence. The risk for each event is calculated by multiplying the expected frequencies from Table 5-3 by the consequences in Table 5-4. The 50-year population and
50-year maximum offsite risks are shown in Table 5-7. The risk for each event for the analytical laboratory is calculated by multiplying the expected frequencies from Table 5-3A by the consequences in Table 5-4A. The 50-year population and 50-year maximum offsite risks for the analytical laboratory are shown in Table 5-7A.

Risk for any specific organ of interest and accident can be computed by multiplying the expected frequency in Table 5-3 and dose commitments from the appropriate table in the Appendix. Worker assimilations are discussed in Section 5.4.7.

5.6 Release Mitigation

Building 221-H and the new Plutonium Oxide Facility is a maxi-mum resistance construction (MRC) structure. The Plutonium Oxide Facility is designed to withstand a Design Basis Earthquake and Design Basis Tornado. The engineered safety features are discussed in Sections 3.0 and 6.0. Administrative controls are discussed in Section 4.3.

Regulated Building 221-H air is monitored before it leaves the building and enters the stack exhaust tunnel.

TABLE 5-7

$^{238}PuO_2$ Facility Risks

		Annual Risk**		
		person-rem/yr		rem/yr
Event/ Sequence*	Expected Frequency	Onsite Population	Offsite Population	Maximum Offsite Individual
MBCD	7.0E-04	8.54E-03	3.11E-02	3.81E-06
MBC	7.0E-03	8.54E-04	3.11E-03	3.81E-07
MBD	7.0E-03	8.54E-04	3.11E-03	3.81E-07
MB	7.0E-02	8.54E-05	3.11E-04	3.81E-08
MB'	8.0E-02	5.03E-03	1.83E-02	2.26E-06
	Total M	1.54E-02	5.59E-02	6.86E-06
LBCD	6.0E-02	3.63E-02	1.33E-01	1.63E-05
LBC	6.0E-01	3.63E-03	1.33E-02	1.63E-06
LBD	6.0E-01	3.63E-03	1.33E-02	1.63E-06
LB	6.0E+00	3.63E-04	1.33E-03	1.63E-07
	Total L	4.39E-02	1.60E-01	1.97E-05
RBCD	1.0E+00	2.91E-05	1.06E-04	1.30E-08
RBC	1.0E+01	2.91E-06	1.06E-05	1.30E-09
RBD	1.0E+01	2.91E-06	1.06E-05	1.30E-09
RB	1.4E+02	4.07E-07	1.48E-06	1.82E-10
RB'	1.7E+02	5.34E-03	1.96E-02	2.40E-06
	Total R	5.37E-03	1.97E-02	2.41E-06
	M + L + R	6.47E-02	2.36E-01	2.90E-05
Earthquake	1.7E-04	6.62E-04	2.42E-03	2.96E-07
Criticality	1.4E-05	1.0E-01	2.0E-05	9.0E-09

* See Table 5-3 for an explanation of sequences and event symbols.

** Risk is the product of the frequency and the 50-yr effective dose equivalent as a consequence of an accident (Table 5-4).

Table 5-7A

Analytical Laboratory Risks

Event/ Sequence*	Frequency (/yr)	50 year Population Risk (person-rem/yr) Onsite	Offsite	50 year Maximum Offsite Individual Risk (rem/yr)
MBCD	5.40E-04	4.88E-03	1.78E-02	2.19E-06
MBC	5.80E-03	5.24E-04	1.91E-03	2.35E-07
MBD	5.80E-03	5.24E-04	1.91E-03	2.35E-07
MB	6.30E-02	5.70E-05	2.08E-04	2.55E-08
MB'	6.90E-02	3.24E-03	1.18E-02	1.45E-06
	Total M	9.23E-03	3.36E-02	** 4.13E-06
LBCD	1.40E-02	6.34E-03	2.31E-02	2.85E-06
LBC	1.50E-01	6.79E-04	2.47E-03	3.05E-07
LBD	1.50E-01	6.79E-04	2.47E-03	3.05E-07
LB	1.60E+00	7.24E-05	2.64E-04	3.25E-08
	Total L	7.77E-03	2.83E-02	3.49E-06
RBCD	2.30E-02	4.99E-07	1.83E-06	2.25E-10
RBC	2.50E-01	5.43E-08	1.99E-07	2.44E-11
RBD	2.50E-01	5.43E-08	1.99E-07	2.44E-11
RB	2.60E+00	5.65E-09	2.07E-08	2.54E-12
RB'	2.90E+00	6.79E-05	2.48E-04	3.05E-08
	Total R	6.85E-05	2.51E-04	3.07E-08
	M+L+R	1.71E-02	6.21E-02	7.65E-06

* See Table 5-3 for an explanation of sequences and event symbols.

** Risk is the product of the frequency and the 50-yr effective dose equivalent as a consequence of an accident (Table 5-4A).

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6.0 SAFETY RELATED ITEMS

Engineered safety systems in the Plutonium Oxide Facility include the following:

- Emergency power for critical equipment
- Permanently installed radiation monitoring equipment
- Emergency escape routes and evacuation alarms
- Nuclear Incident Monitor System (NIM) and alarms
- Once through ventilation system which maintains air flow from clean to progressively more regulated compartments. Room exhaust goes directly to the sand filter, without passing through any HEPA filters. Cabinet exhaust goes through two stages of DOP testable HEPA's before passing through the sand filter.
- Automatic fire detection and suppression. Audible alarms are provided in all rooms.
- Safety related interlocks on process systems are hard-wired.
- Emergency eye wash stations and safety showers in chemical handling areas.
- A breathing air system to supply air for fresh air masks, plastic fresh air hoods, and plastic suits.
- Process, waste, and any solution containing radioactivity transferred in pipes are encased in a secondary containment, such as a cabinet, duct, or another pipe.
- Vessels and sumps that could receive significant quantities of fissile material have geometrically favorable design.
- Sumps have an alarm, sampler, and a means for flushing and removing liquid to a specified tank.

Safety features to prevent, detect, or mitigate potential incidents in Plutonium Oxide Facility are discussed in detail in Reference 1.

6.1 Reference

1. P. M. Allen and ·onald Lee. Preliminary Hazards Analysis for Replacement of ..solete Processing Facilities, Building 221-H, B-Line Phase II. Internal Report DPST-82-1045, E. I. du Pont de Nemours & Co., Savannah River Laboratory, Aiken, SC (January 1983).

7.0 QUALITY ASSURANCE

7.1 Quality Assurance Manuals

A series of manuals, DPW-78-111-2.1 through DPW-78-111-2.6, provide general procedures for implementing the QA policy principles. DPW-78-111-2.4 is the QA manual for the Manufacturing Division. The manuals establish methods, practices, and requirements for the Savannah River Quality Assurance Program. Although the QA requirements in the manuals are specific, additional instructions and procedures in lower level documents are normally required in order to perform the QA functions. The particular organization performing the quality assurance function provides for compliance with its manual in its organization procedures and instructions.

7.2 Quality Assurance Assessments

QA Assessment Criteria from the Savannah River QA Manual, DPW-78-111-2.2 was translated by AED into the following QA Design Criteria discussed below.

7.2.1 QA Design Criteria[1-2]

Release of radioactive materials to the environment from normal operations or credible accidents must not exceed the following annual doses at the site boundary.

Type of Exposure	Exposure, mrems Maximum*	Exposure, mrems Average**
Whole body, gonads, or bone marrow	500	170
Other Organs	1500	500

* Based on dose to individuals at points of maximum probable exposure.

** Based on average dose to suitable sample of exposed population.

Unexpected Costs (Criterion 2)

Unexpected costs, such as damage and/or cleanup expenses, to facilities or processes must not exceed 5 million dollars per event.

Loss of Production (Criterion 3)

Loss of production of an acceptable product in a single-production process must not exceed a six-month period.

Unplanned Nuclear Criticality (Criterion 4)

Unplanned nuclear criticality must not occur in any facility or process.

The Nonradioactive Hazardous Gas Release criteria does not apply to this project since these gases are not used, produced, or involved with the process.

7.2.2 "Q" Items[2]

The QA Assessment Criteria translates into specific requirements for a project to prevent, avoid, or reduce the risk of a "Q" Incident. A "Q" Incident is defined as any occurrence which results in consequences that exceed QA design criteria. A "Q" Item is any item or service that is judged to have one or more characteristic whose quality requirements must be controlled by a formal QA program. "Q" Items are shown in Table 7-1.

Action plans for "Q" items are found in Reference 3.

TABLE 7-1

QA Assessment of Scrap Recovery Systems

Major Segment (System)	Why System is "Q"
Canyon 221-H Building consisting of the main structure that will support the HB-Line facilities (Section No. 2 and 3).	The existing building supports the new structure which contains factilities for processing radioactive materials. (Criteria 1,2,3,4).
HB-Line building shell consisting of a structure that contains processing facilities for radioactive materials.	The building is the last line of defense to confine radioactive materials during a Design Basis Accident (Criteria 1,2,3,4
Fire Detection and Suppression consisting of a Halon distribution system.	Excessive damage and extensive shutdown may result if system fails to operate (Criteria 2, 3).

7.3 References

1. QAAM Report No. 1, Initial Assessment, April 27, 1981.

2. QAAM Report No. 2, QA Classification, June 5, 1981.

3. QAAM Report No. 3, Action Plan, August 31, 1981.

8.0 SYMBOLS AND ABBREVIATIONS

AED	Atomic Energy Division
BCW	HB-Line cooling water
BIS	Bell Intercom System
CAC	Control and alarm center
CFM	Cubic feet per minute
CR	Control room
DBE	Design basis earthquake
DBT	Design basis tornado
DOE	Department of Energy
DOP	Dioctyl phthalate
DW	Domestic water
FC	Facility coordinator
ECR	Electrical control room
EOC	Emergency operating center
E & I	Electrical and instrument
FPM	Feet per minute
F5	Fugita intensity five tornado
GPM	Gallons per minute
HEPA	High efficiency particulate air filter
ICR	Instrument control room
ICW	Independent cooling water
MBA	Material balance area
MID	Maximum individual offsite dose
MRC	Maximum resistance construction
MM VIII	Modified Mercalli intensity eight earthquake
NBS	National Bureau of Standards
NIM	Nuclear incident monitor
NSRC	Nuclear Safety Review Committee
PC	Programmable controller
PHA	Pulse height analyzer
RZ	Radiation zone
RA	Regulated area
SNM	Special nuclear materials
SRL	Savannah River Laboratory
SRP	Savannah River Plant
PA	Public address system
TA	Test authorization
T & T	Traffic and Transportation
TLD	Thermoluminescent dosimeter
TLND	Thermoluminescent neutron dosimeter
VCT	Vessel vent catch tank
VVF	Vessel vent filter

9.0 APPENDIX

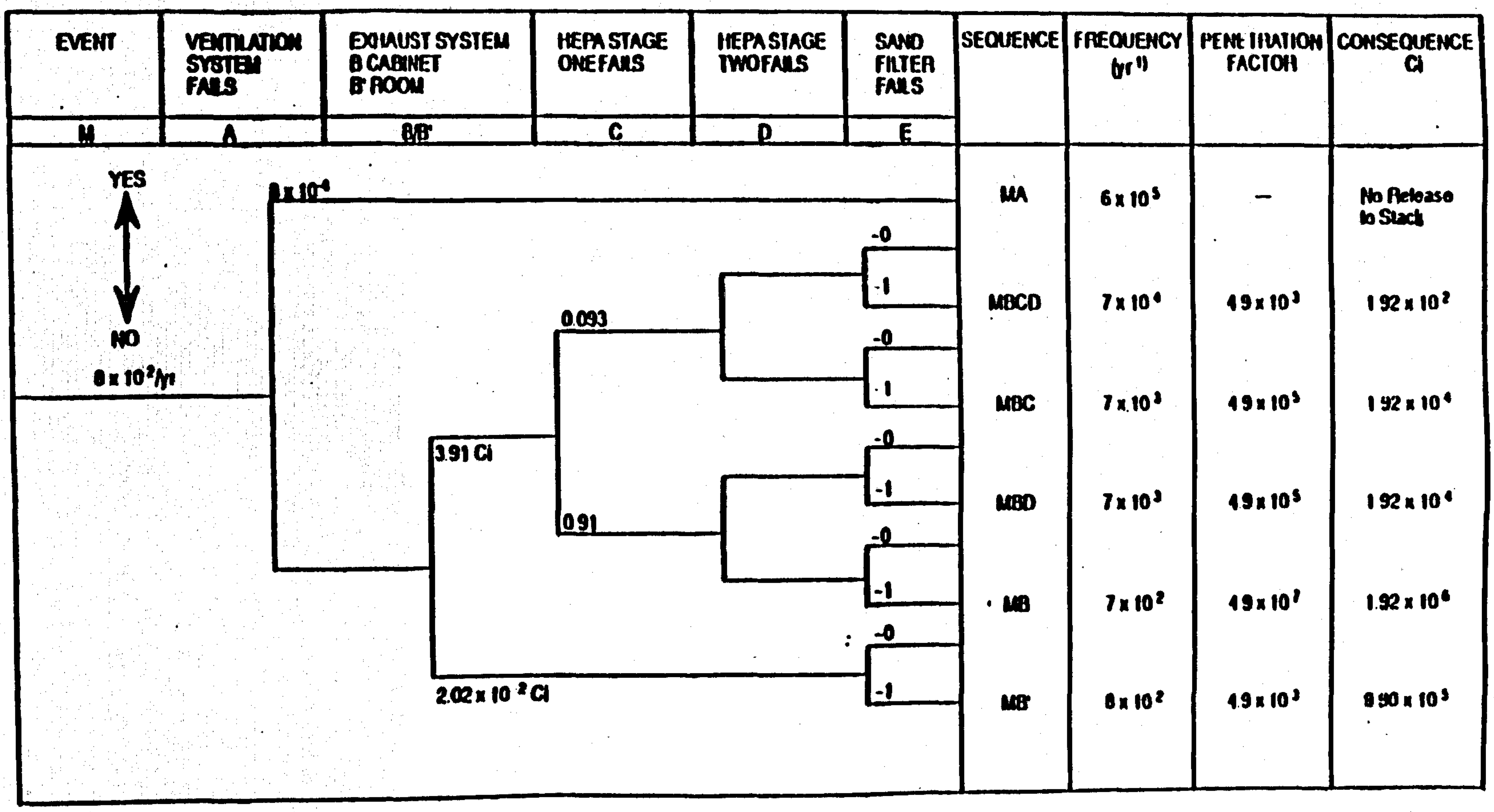


Figure A-1. Event Tree - Medium Energy Event

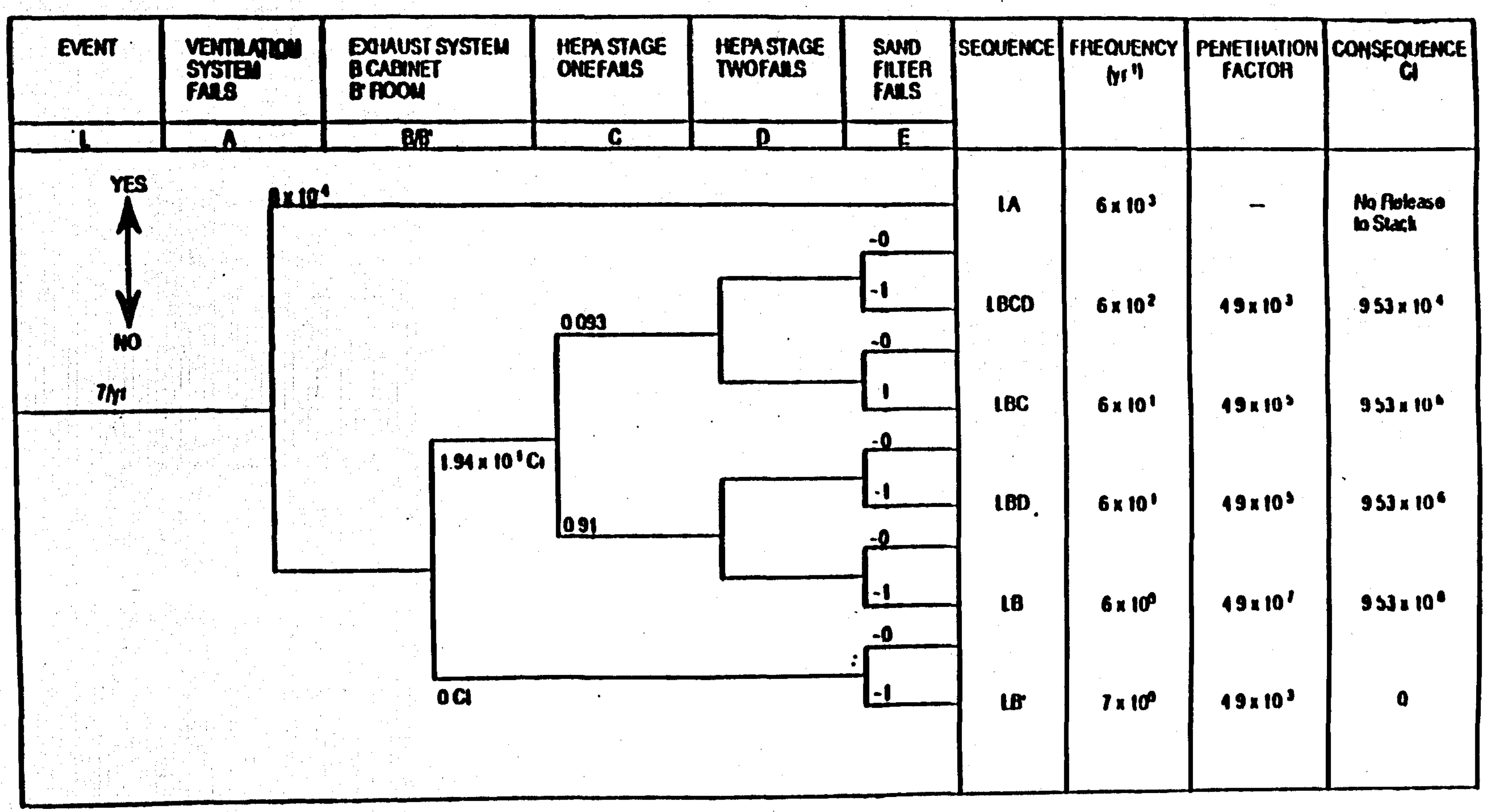
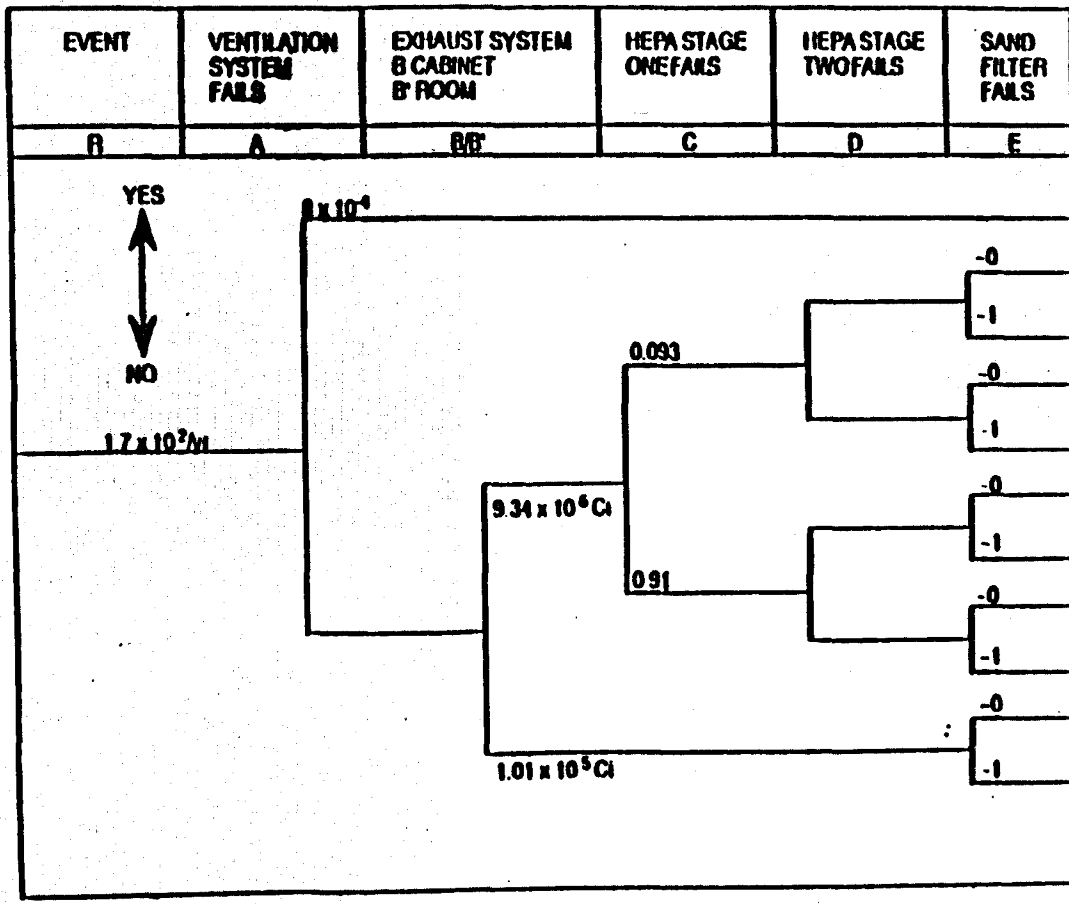


Figure A-2. Event Tree - Low Energy Event



SEQUENCE	FREQUENCY (yr⁻¹)	PENETRATION FACTOR	CONSEQUENCE Ci
RA	1×10^{1}	--	No Release to Stack
RBCD	1×10^{0}	4.9×10^{3}	4.58×10^{8}
RBC	1×10^{1}	4.9×10^{5}	4.58×10^{10}
RBD	1×10^{1}	4.9×10^{5}	4.58×10^{10}
RB	1.4×10^{2}	4.9×10^{7}	4.58×10^{12}
RB'	1.7×10^{2}	4.9×10^{3}	4.95×10^{8}

Figure A-3. Event Tree - Residual Activity Release Event

PLUTONIUM OXIDE FACILITY
RELEASE CALCULATIONS
REV 1 - HB-LINE SAR

PLUTONIUM OXIDE FACILITY
LOW ENERGETIC EVENT RELEASE CALCULATIONS

Cabinet Activity
776 g x 25.06 Ci x 1 x 1E-05 = 1.94E-01 Ci
Maintenance Room Activity
776 g x 25.06 Ci/g x 0 x 1E-05 = 0 Ci
Operating Room Activity
776 g x 25.06 Ci/g x 0 x 1E-05 = 0 Ci
Room Exhaust
0 + (1 - 0.58)(0) = 0 Ci

RESIDUAL ACTIVITY RELEASE CALCULATIONS

Cabinet Activity
776 g x 25.06 Ci/g x 0.01 x 0 x 0.01 = 0 Ci
Maintenance Room Activity
776 g x 25.06 Ci/g x 0.01 x 8.3E-06 x 0.01 = 1.61E-05 Ci
Operating Room Activity
776 g x 25.06 Ci/g x 0.01 x 1.7E-06 x 0.01 = 3.31E-06 Ci

Cabinet Exhaust
0 + (0.58)(1.61E-05) = 9.34E-06 Ci
Room Exhaust
3.31E-06 + (1 - 0.58)(1.61E-05) = 1.01E-05 Ci

EARTHQUAKE RELEASE CALCULATIONS

Facility Inventory = 4500 g
Analytical Laboratory Inventory = 390 g
Total = 4890 g

4890 g x 25.06 Ci/g x 5E-08 = 6.13E-03 Ci

ANALYTICAL LABORATORY
RELEASE CALCULATIONS
REV 1 - HB-LINE SAR

ANALYTICAL LABORATORY
MEDIUM ENERGETIC EVENT RELEASE CALCULATIONS

Cabinet Activity
    390 g x 25.06 Ci/g x 2.0E-04 = 1.95 Ci
Maintenance Room Activity
    390 g x 25.06 Ci/g x 1E-05 x 0.2 x 0.83 = 1.62E-02 Ci
Operating Room Activity
    390 g x 25.06 Ci/g x 1E-05 x 0.2 x 0.17 = 3.32E-03 Ci

Cabinet Exhaust
    1.95 Ci + (0.58)(1.62E-02 Ci) = 1.96 Ci
Room Exhaust
    3.32E-03 Ci + (1 - 0.58)(1.62E-02 Ci) = 1.01E-02 Ci

LOW ENERGETIC EVENT RELEASE CALCULATIONS

Cabinet Activity
    390 g x 25.06 Ci x 1 x 1E-05 = 9.77E-02 Ci
Maintenance Room Activity
    390 g x 25.06 Ci/g x 0 x 1E-05 = 0 Ci
Operating Room Activity
    390 g x 25.06 Ci/g x 0 x 1E-05 = 0 Ci

Cabinet Exhaust
    9.77E-02 Ci + (0.58)(0) = 9.77E-02 Ci
Room Exhaust
    0 + (1 - 0.58)(0) = 0 Ci

RESIDUAL ACTIVITY RELEASE CALCULATIONS

Cabinet Activity
    390 g x 25.06 Ci/g x 0.01 x 0 x 0.01 = 0 Ci
Maintenance Room Activity
    390 g x 25.06 Ci/g x 0.01 x 8.3E-06 x 0.01 = 8.11E-06 Ci
Operating Room Activity
    390 g x 25.06 Ci/g x 0.01 x 1.7E-06 x 0.01 = 1.66E-06 Ci

Cabinet Exhaust
    0 + (0.58)(8.11E-06) = 4.70E-06 Ci
Room Exhaust
    1.66E-06 + (1 - 0.58)(8.11E-06) = 5.07E-06 Ci

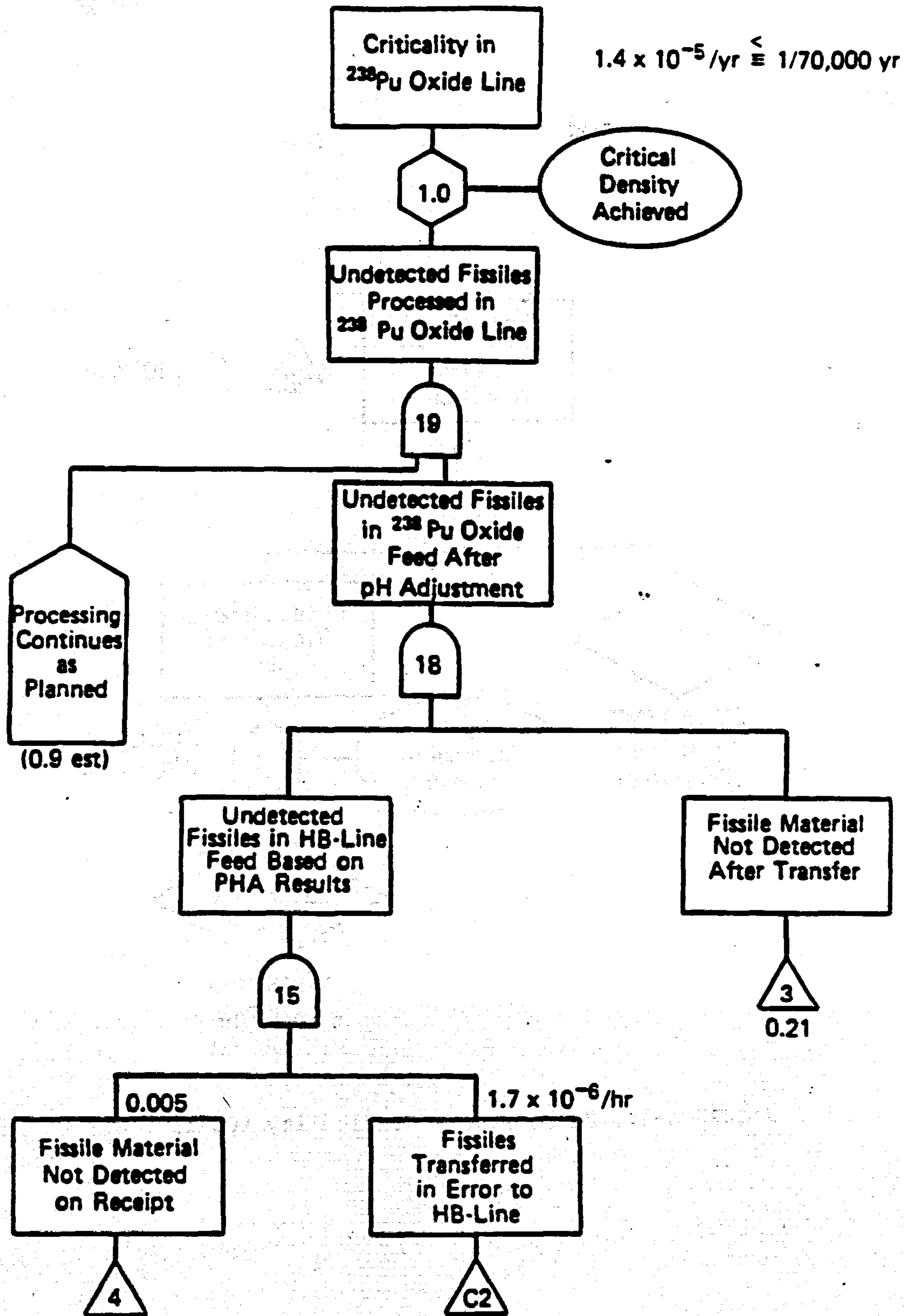


FIGURE A-4. Fault Tree - Criticality

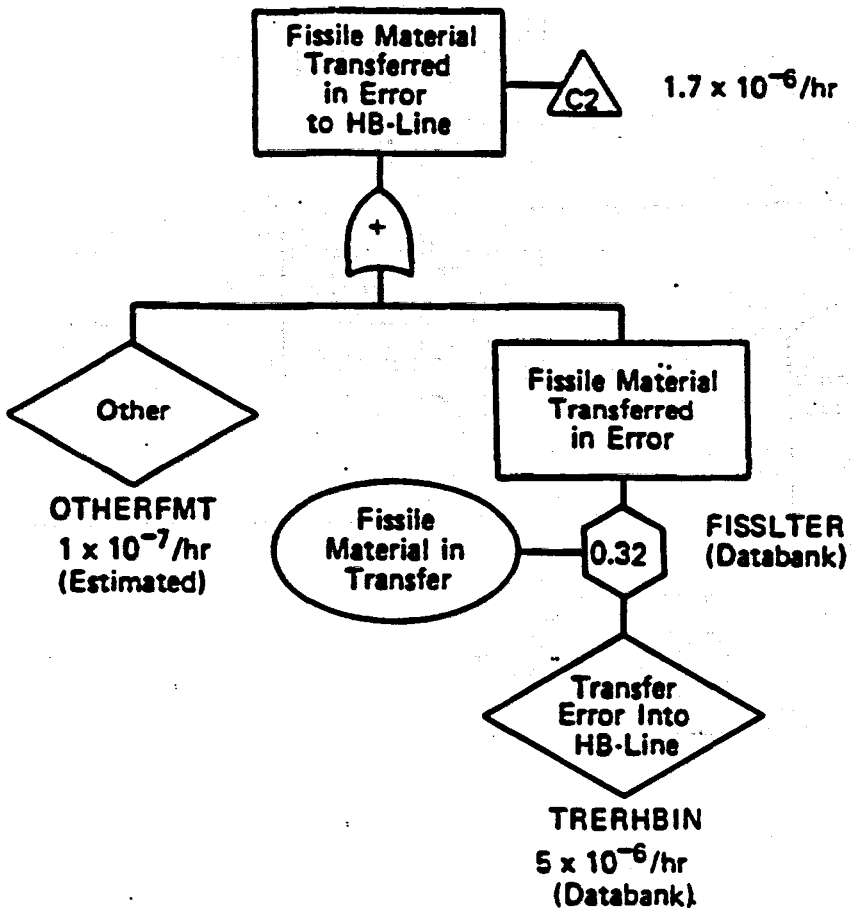


FIGURE A-5. Fault Tree - Criticality (Continued)

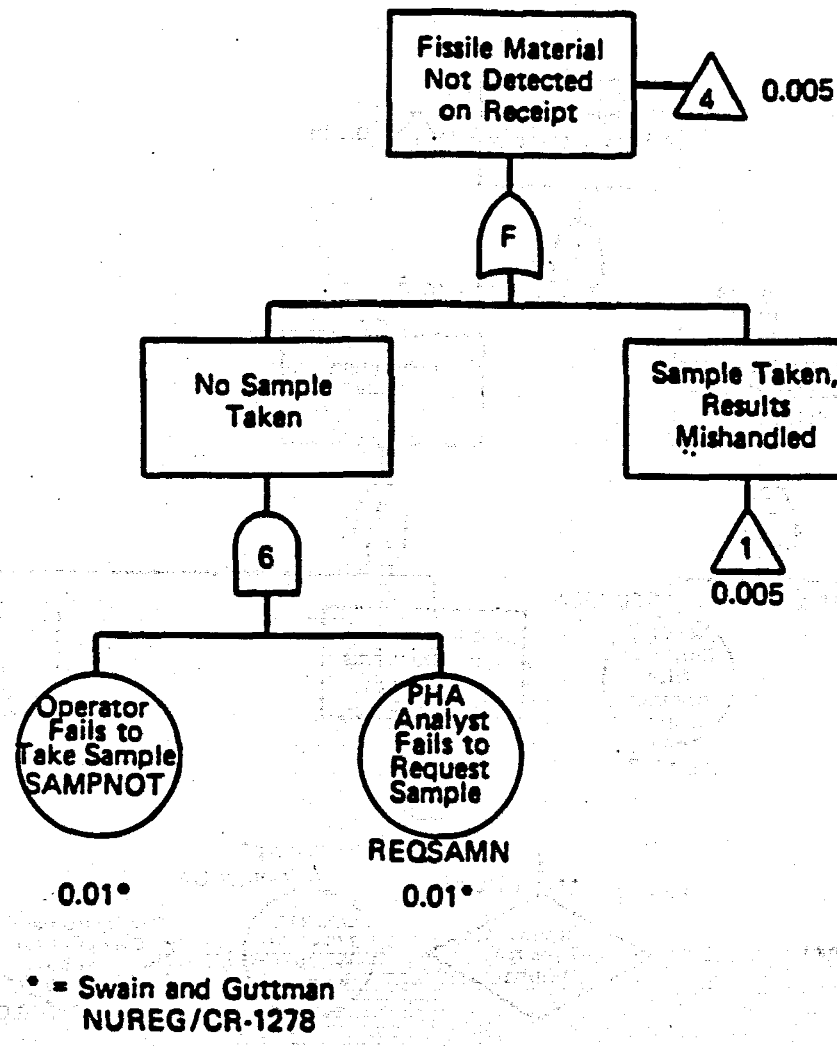


FIGURE A-6. Fault Tree — Criticality (Continued)

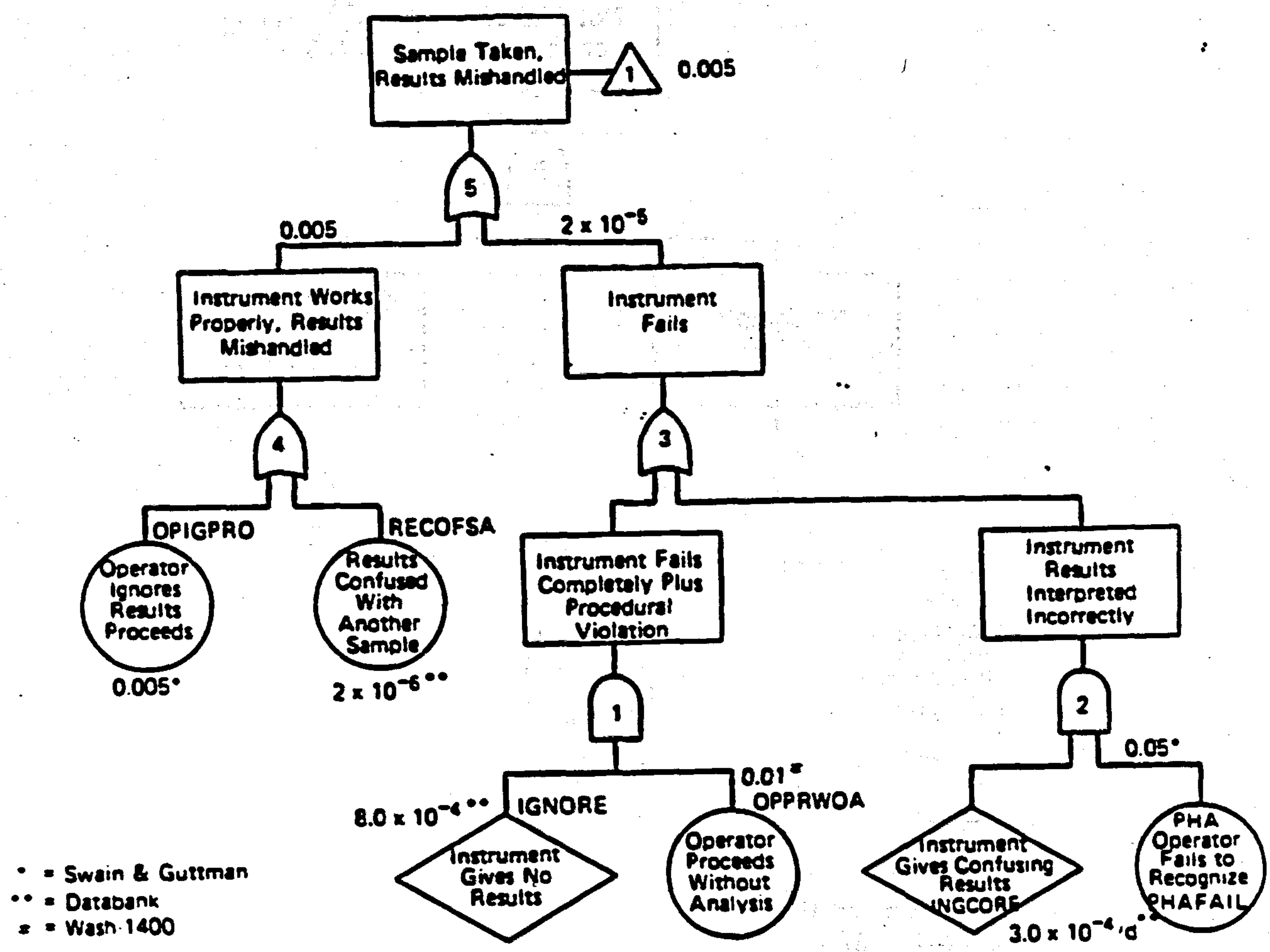


FIGURE A-7. Fault Tree — Criticality (Continued)

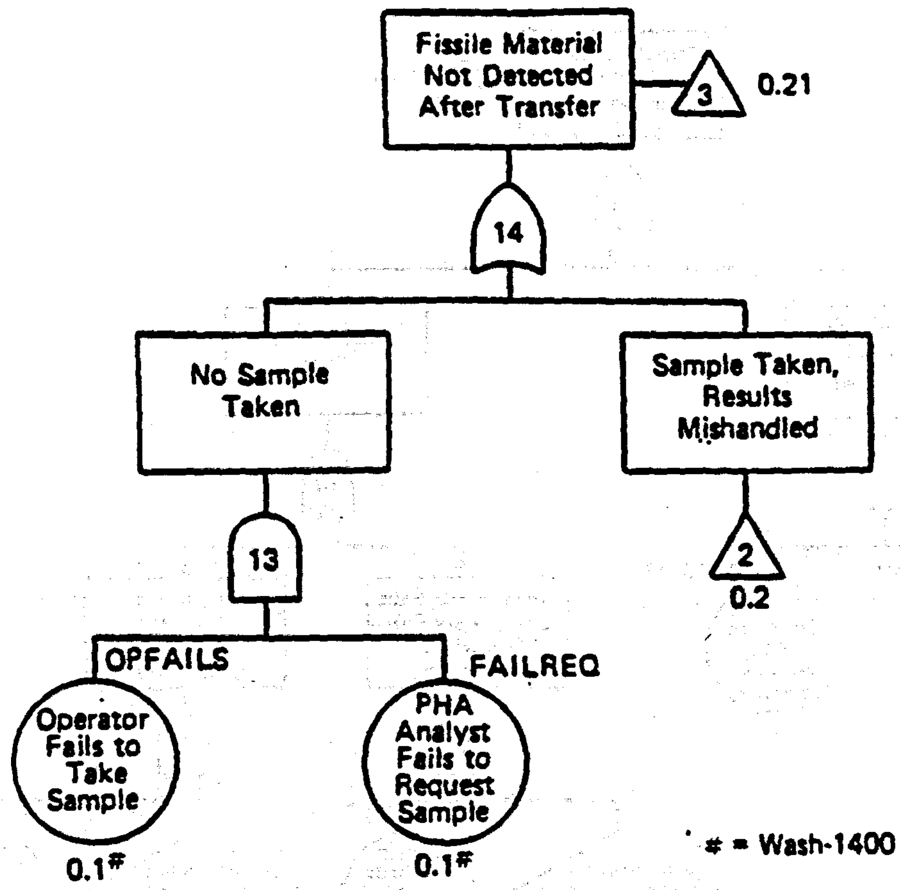


FIGURE A-8. Fault Tree — Criticality (Continued)

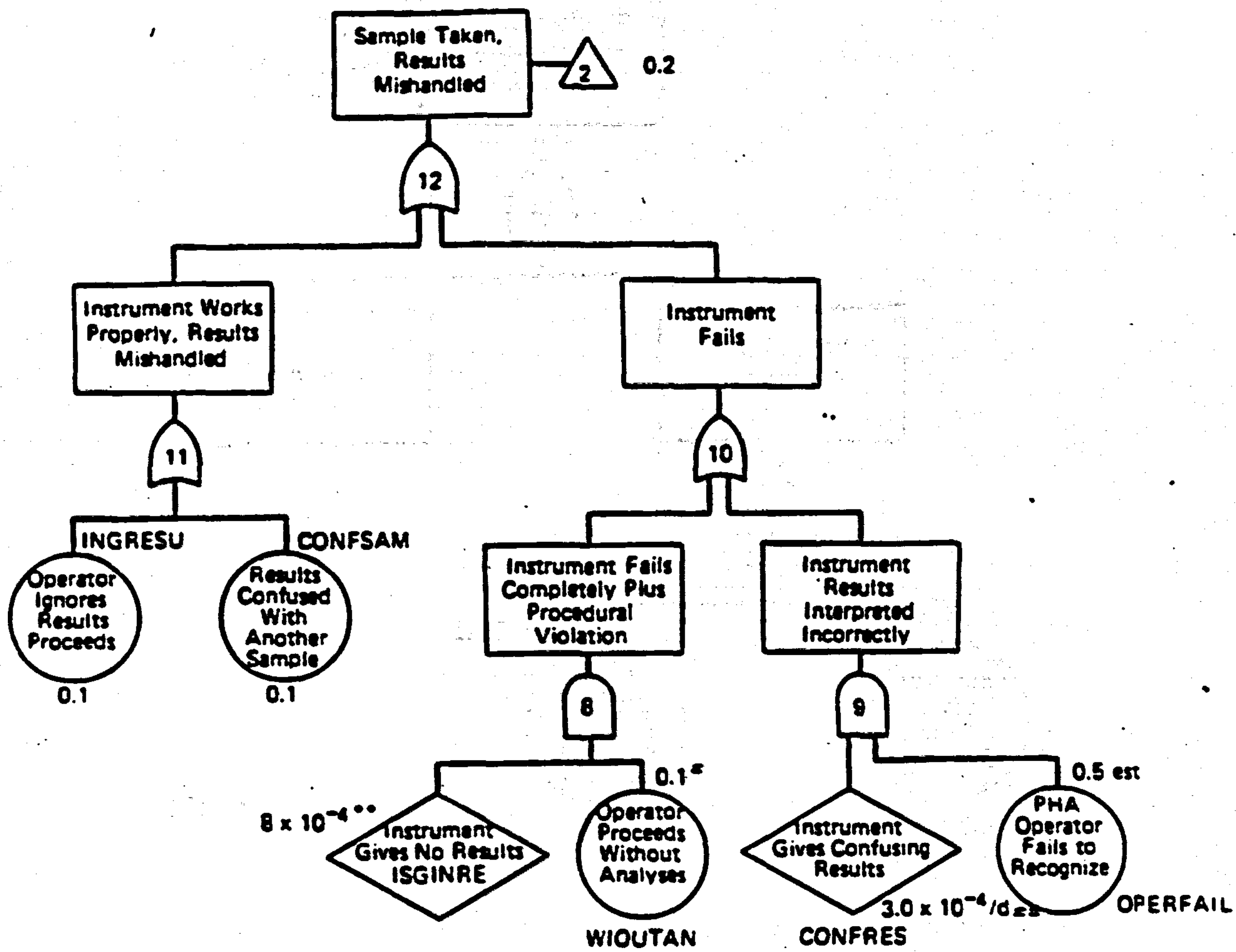


FIGURE A-9. Fault Tree — Criticality (Continued)

TABLE A-1

Onsite Population Doses from Accidents in $^{238}PuO_2$ Facility

Type of Event	Exhaust System	Event Sequence	Ci Release	Dose (person-rem)* Inhalation: Eff. D.E.**	GI-LLI	Red Mar	Liver	B. Surf.	Thyroid	Lung	Eff. D
Medium Energetic	Cabinet	MBCD	1.92E-02	1.22E+01	0	9.76E+00	2.72E+01	1.26E+02	0	4.81E+01	3.27E-10
	Cabinet	MBC	1.92E-04	1.22E-01	0	9.76E-02	2.72E-01	1.26E+00	0	4.81E-01	3.27E-12
	Cabinet	MBD	1.92E-04	1.22E-01	0	9.76E-02	2.72E-01	1.26E+00	0	4.81E-01	3.27E-12
	Cabinet	MB	1.92E-06	1.22E-03	0	9.76E-04	2.72E-03	1.26E-02	0	4.81E-03	3.27E-14
	Room	MB'	9.90E-05	6.29E-02	0	5.05E-02	1.41E-01	6.52E-01	0	2.50E-01	1.69E-12
Low Energetic	Cabinet	LBCD	9.53E-04	6.05E-01	0	4.86E-01	1.35E+00	6.27E+00	0	2.41E+00	1.63E-11
	Cabinet	LBC	9.53E-06	6.05E-03	0	4.86E-03	1.35E-02	6.27E-02	0	2.41E-02	1.63E-13
	Cabinet	LBD	9.53E-06	6.05E-03	0	4.86E-03	1.35E-02	6.27E-02	0	2.41E-02	1.63E-13
	Cabinet	LB	9.53E-08	6.05E-05	0	4.86E-05	1.35E-04	6.27E-04	0	2.41E-04	1.63E-15
Residual Activity	Cabinet	RBCD	4.58E-08	2.91E-05	0	2.33E-05	6.51E-05	3.01E-04	0	1.16E-04	7.82E-16
	Cabinet	RBC	4.58E-10	2.91E-07	0	2.33E-07	6.51E-07	3.01E-06	0	1.16E-06	7.82E-18
	Cabinet	RBD	4.58E-10	2.91E-07	0	2.33E-07	6.51E-07	3.01E-06	0	1.16E-06	7.82E-18
	Cabinet	RB	4.58E-12	2.91E-09	0	2.33E-09	6.51E-09	3.01E-08	0	1.16E-08	7.82E-20
	Room	RB'	4.95E-08	3.14E-05	0	2.52E-05	7.04E-05	3.26E-04	0	1.25E-04	8.46E-16
Earthquake	Room		6.13E-03	3.89E+00	0	3.12E+00	8.70E+00	4.03E+01	0	1.54E+01	1.05E-10

*All doses are calculated using the most conservative committed dose equivalent factors.

**Eff. D.E. - Effective Dose Equivalent
GI-LLI - Gastrointestine - Lower large intestine
Red Mar - Red Marrow
B. Surf. - Bone Surface
Eff. D - Effective Dose

TABLE A 2

Offsite Population Dose from Accidents in $^{238}PuO_2$ Facility

Type of Event	Exhaust System	Event Sequence	Ci Release	Dose (person rem)* Inhalation: Eff. D.E.**	GI-LLI	Red Mar	Liver	B. Surf.	Thyroid	Lung	Eff. D
Medium Energetic	Cabinet	MBCD	1.92E-02	4.44E+01	0	3.56E+01	9.94E+01	4.60E+02	0	1.77E+02	1.27E-09
	Cabinet	MBC	1.92E-04	4.44E-01	0	3.56E-01	9.94E-01	4.60E+00	0	1.77E+00	1.27E-11
	Cabinet	MBD	1.92E-04	4.44E-01	0	3.56E-01	9.94E-01	4.60E+00	0	1.77E+00	1.27E-11
	Cabinet	MB	1.92E-06	4.44E-03	0	3.56E-03	9.94E-03	4.60E-02	0	1.77E-02	1.27E-13
	Room	MB*	9.90E-05	2.29E-01	0	1.84E-01	5.14E-01	2.38E+00	0	9.13E-01	6.55E-12
Low Energetic	Cabinet	LBCD	9.53E-04	2.21E+00	0	1.77E+00	4.94E+00	2.29E+01	0	8.79E+00	6.30E-11
	Cabinet	LBC	9.53E-06	2.21E-02	0	1.77E-02	4.94E-02	2.29E-01	0	8.79E-02	6.30E-13
	Cabinet	LBD	9.53E-06	2.21E-02	0	1.77E-02	4.94E-02	2.29E-01	0	8.79E-02	6.30E-13
	Cabinet	LB	9.53E-08	2.21E-04	0	1.77E-04	4.94E-04	2.29E-03	0	8.79E-04	6.30E-15
Residual Activity	Cabinet	RBCD	4.58E-08	1.06E-04	0	8.52E-05	2.38E-04	1.10E-01	0	4.22E-04	3.03E-15
	Cabinet	RBC	4.58E-10	1.06E-06	0	8.52E-07	2.38E-06	1.10E-05	0	4.22E-06	3.03E-17
	Cabinet	RBD	4.58E-10	1.06E-06	0	8.52E-07	2.38E-06	1.10E-05	0	4.22E-06	3.03E-17
	Cabinet	RB	4.58E-12	1.06E-08	0	8.52E-09	2.38E-08	1.10E-07	0	4.22E-08	3.03E-19
	Room	RB*	4.95E-08	1.15E-04	0	9.21E-05	2.57E-04	1.19E-03	0	4.57E-04	3.28E-15
Earthquake	Room		6.13E-03	1.42E+01	0	1.14E+01	3.17E+01	1.47E+02	0	5.65E+01	4.05E-10

*All doses are calculated using the most conservative committed dose equivalent factors.

**Eff. D.E. - Effective Dose Equivalent
GI-LLI - Gastrointestine - Lower large intestine
Red Mar - Red Marrow
B. Surf. - Bone Surface
Eff. D - Effective Dose

TABLE A-3

Maximum Doses to an Offsite Individual from Accidents in $^{238}PuO_2$ Facility

Type of Event	Exhaust System	Event Sequence	Ci Release	Dose (rem)* Inhalation: Eff.D.E.**	GI-LLI	Red Mar	Liver	B. Surf	Thyroid	Lung	Eff. D
Medium Energetic	Cabinet	MBCD	1.92E-02	5.44E-03	0	4.37E-03	1.22E-02	5.65E-02	0	2.17E-02	1.86E-10
	Cabinet	MBC	1.92E-04	5.44E-05	0	4.37E-05	1.22E-04	5.65E-04	0	2.17E-04	1.86E-12
	Cabinet	MBD	1.92E-04	5.44E-05	0	4.37E-05	1.22E-04	5.65E-04	0	2.17E-04	1.86E-12
	Cabinet	MB	1.92E-06	5.44E-07	0	4.37E-07	1.22E-06	5.65E-06	0	2.17E-06	1.86E-14
	Room	MB'	9.90E-05	2.82E-05	0	2.26E-05	6.30E,05	2.92E-04	0	1.12E-04	9.60E-13
Low Energetic	Cabinet	LBCD	9.53E-04	2.71E-04	0	2.18E-04	6.07E-04	2.81E-03	0	1.08E,03	9.24E-12
	Cabinet	LBC	9.53E-06	2.71E-06	0	2.18E-06	6.07E-06	2.81E-05	0	1.08E-05	9.24E-14
	Cabinet	LBD	9.53E-06	2.71E-06	0	2.18E-06	6.07E-06	2.81E-05	0	1.08E-05	9.24E-14
	Cabinet	LB	9.53E-08	2.71E-08	0	2.18E-08	6.07E-08	2.81E-07	0	1.08E-07	9.24E-16
Residual Activity	Cabinet	RBCD	4.58E-08	1.30E-08	0	1.05E-08	2.91E-08	1.35E-07	0	5.18E-08	4.44E-16
	Cabinet	RBC	4.58E-10	1.30E-10	0	1.05E-10	2.91E-10	1.35E-09	0	5.18E-10	4.44E-18
	Cabinet	RBD	4.58E-10	1.30E-10	0	1.05E-10	2.91E-10	1.35E-09	0	5.18E-10	4.44E-18
	Cabinet	RB	4.58E-12	1.30E-12	0	1.05E-12	2.91E-12	1.35E-11	0	5.18E-12	4.44E-20
	Room	RB'	4.95E-08	1.41E-08	0	1.13E-08	3.15E-08	1.46E-07	0	5.60E-08	4.80E-16
Earthquake	Room		6.13E-03	1.74E-03	0	1.40E-03	3.90E-03	1.80E-02	0	6.93E-03	5.94E-11

*All doses are calculated using the most conservative committed dose equivalent factors.

**Eff. D.E. - Efective Dose Equivalent
GI-LLI - Gastrointestine - Lower large intestine
Red Mar - Red Marrow
B. Surf. - Bone Surface
Eff. D - Effective Dose

TABLE A-4

50-Year Onsite Population Dose from a Criticality Accident

	Dose (person-rem)						
Nuclide	Eff.D.E.	GI-LLI	Red Mar	Liver	B. Surf.	Thyroid	Lung
KR-83M	4.77E-09	4.77E-09	4.77E-09	4.77E-09	4.77E-09	4.77E-09	6.87E 07
KR-85M	1.21E-03	1.21E-03	1.21E-03	1.21E-03	1.21E-03	1.21E-03	1.21E-03
KR-87	2.93E-02	2.93E-02	2.93E-02	2.93E-02	2.93E-02	2.93E-02	2.93E-02
KR-88	3.79E-01	3.79E-01	3.79E-01	3.79E-01	3.79E-01	3.79E-01	3.79E-01
KR-89	2.53E-01	2.53E-01	2.53E-01	2.53E-01	2.53E-01	2.53E-01	2.53E-01
XE-133	4.95E-07	4.95E-07	4.95E-07	4.95E-07	4.95E-07	4.95E-07	4.95E-07
XE-135M	2.04E-02	2.04E-02	2.04E-02	2.04E-02	2.04E-02	2.04E-02	2.04E-02
XE-135	1.17E-03	1.17E-03	1.17E-03	1.17E-03	1.17E-03	1.17E-03	1.17E-03
XE-137	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01
XE-138	6.55E-01	6.55E-01	6.55E-01	6.55E-01	6.55E-01	6.55E-01	6.55E-01
BR-83	7.32E-04	1.79E-05	1.79E-05	1.79E-05	1.79E-05	1.79E-05	6.00E-03
BR-84	2.12E-02	1.76E-02	1.76E-02	1.76E-02	1.76E-02	1.76E-02	4.20E-02
BR-85	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03
I-131	3.44E-03	1.11E-05	1.11E-05	1.11E-05	1.11E-05	1.18E-01	1.11E-05
I-132	3.84E-02	2.47E-02	2.47E-02	2.47E-02	2.47E-02	2.86E-01	6.62E-02
I-133	1.21E-02	2.78E-03	2.78E-03	2.78E-03	2.78E-03	3.10E+00	2.78E-03
I-134	5.82E-01	5.01E-01	5.01E-01	5.01E-01	5.01E-01	1.31E+00	8.85E-01
I-135	3.65E-01	9.69E-02	9.69E-02	9.69E-02	9.69E-02	7.66E+00	4.87E-01
Total	2.49E+00	2.11E+00	2.11E+00	2.11E+00	2.11E+00	1.40E+01	2.95E+00

TABLE A-5

50-Year Offsite Population Dose from a Criticality Accident

	Dose (person-rem)						
Nuclide	Eff.D.E.	GI-LLI	Red Mar	Liver	B. Surf.	Thyroid	Lung
KR-83M	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	2.16E-05
KR-85M	2.71E-03	2.71E-03	2.71E-03	2.71E-03	2.71E-03	2.71E-03	2.71E-03
KR-87	5.08E-03	5.08E-03	5.08E-03	5.08E-03	5.08E-03	5.08E-03	5.08E-03
KR-88	9.66E-02	9.66E-02	9.66E-02	9.66E-02	9.66E-02	9.66E-02	9.66E-02
KR-89	2.24E-13	2.24E-13	2.24E-13	2.24E-13	2.24E-13	2.24E-13	2.24E-13
XE-133	2.02E-04	2.02E-04	2.02E-04	2.02E-04	2.02E-04	2.02E-04	2.02E-04
XE-135M	1.40E-02	1.40E-02	1.40E-02	1.40E-02	1.40E-02	1.40E-02	1.40E-02
XE-135	3.85E-02	3.85E-02	3.85E-02	3.85E-02	3.85E-02	3.85E-02	3.85E-02
XE-137	9.86E-12	9.86E-12	9.86E-12	9.86E-12	9.86E-12	9.86E-12	9.86E-12
XE-138	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04
BR-83	1.34E-03	3.61E-05	3.61E-05	3.61E-05	3.61E-05	3.61E-05	1.09E-02
BR-84	6.59E-04	5.52E-04	5.52E-04	5.52E-04	5.52E-04	5.52E-04	1.28E-03
BR-85	3.77E-16	3.77E-16	3.77E-16	3.77E-16	3.77E-16	3.77E-16	3.77E-16
I-131	3.27E-01	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.12E+01	1.18E-03
I-132	1.91E-02	1.27E-02	1.27E-02	1.27E-02	1.27E-02	1.34E-01	3.20E-02
I-133	1.85E-01	4.65E-02	4.65E-02	4.65E-02	4.65E-02	4.62E+01	4.65E-02
I-134	4.44E-02	3.86E-02	3.86E-02	3.86E-02	3.86E-02	9.68E-02	6.61E-02
I-135	9.73E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	1.98E+01	1.29E+00
Total	1.71E+00	5.38E-01	5.38E-01	5.38E-01	5.38E-01	7.76E+01	1.61E+00

TABLE A-6

50-Year Maximum Offsite Individual Dose from a Criticality Accident

	Dose (rem)						
Nuclide	Eff.D.E.	GI-LLI	Red Mar	Liver	B. Surf.	Thyroid	Lung
KR-83M	3.38E-11	3.38E-11	3.38E-11	3.38E-11	3.38E-11	3.38E-11	3.01E-09
KR-85M	8.51E-07	8.51E-07	8.51E-07	8.51E-07	8.51E-07	8.51E-07	8.51E-07
KR-87	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E 05	1.17E-05
KR-88	4.86E-05	4.86E-05	4.86E-05	4.86E-05	4.86E-05	4.86E-05	4.86E-05
KR-89	1.49E-11	1.49E-11	1.49E-11	1.49E-11	1.49E-11	1.49E-11	1.49E-11
XE-133	7.73E-09	7.73E-09	7.73E-09	7.73E-09	7.73E-09	7.73E-09	7.73E-09
XE-135M	3.76E-06	3.76E-06	3.76E-06	3.76E-06	3.76E-06	3.76E-06	3.76E-06
XE-135	2.20E-06	2.20E-06	2.20E-06	2.20E-06	2.20E-06	2.20E-06	2.20E-06
XE-137	1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10	1.67E-10
XE-138	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05	1.61E-05
BR-83	8.88E-07	2.48E-08	2.48E-08	2.48E-08	2.48E-08	2.48E-08	7.25E-06
BR-84	1.05E-05	8.83E-06	8.83E-06	8.83E-06	8.83E-06	8.83E-06	2.02E-05
BR-85	5.66E-14	5.66E-14	5.66E-14	5.66E-14	5,66E-14	5.66E-14	5.66E-14
I-131	3.49E-05	1.33E-07	1.33E-07	1.33E-07	1.33E-07	1.19E-03	1.33E-07
I-132	1.37E-05	9.20E-06	9.20E-06	9.20E-06	9.20E-06	9.50E-05	2.28E-05
I-133	2.46E-05	6.40E-06	6.40E-06	6.40E-06	6.40E-06	6.07E-03	6.40E-06
I-134	2.51E-04	2.19E-04	2.19E-04	2.19E-04	2.19E-04	5.39E-04	3.70E-04
I-135	2.09E-04	6.08E-05	6.08E-05	6.08E-05	6.08E-05	4.23E-03	2.76E-04
Total	6.28E-04	3.88E-04	3.88E-04	3.88E-04	3.88E-04	1.22E 12	7.86E-04

TABLE B-1. FAULT TREE DATA FOR PROBABILITY OF CRITICALITY IN HB-LINE

Mnemonic[a]	Freq. Per hr	Probability	Event Name	Source[b]
CRITMAHB		.9	Critical mass achieved	Est.
FISSLTER		.32	Solution involved in transfer error contains fissile material.	*
HUMFAIL1		.01	Human failure: feed not analyzed, so fissiles not detected.	◆
IGNORE		8.E-04	PHA instrument gives no sample results.	*
INGCORE		3.E-04	PHA instrument gives confusing results.	*
OTHERFMT	1.E-07		Other transfer error into HB-Line.	Est.
OPIGPRO		.005	Operator ignores results indicating Pu was transferred, proceeds to process receipt normally	◆◆
OPPRWOA		.01	Operator ignores lack of analytical results and proceeds to process receipt normally	◆
PHAFAIL		.05	PHA operator fails to recognize confusing results, certifies results are normal	◆◆
PLANNED		.9	Processing continues	Est.
RECOFSA		2.E-06	PHA Analyst confuses the sample results, reports results are normal	*
REQSAMN		.01	PHA Analyst fails to request missing sample	◆◆
SAMPNOT		.01	Operator fails to take sample as requested	◆◆
TRERHBIN	5.E-06		Transfer error into HB-Line.	*

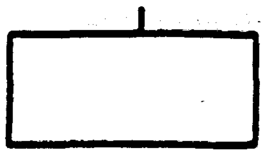
a Mnemonics refer to data input points on the fault trees.
b SOURCE KEY:

Est. = estimated value
* = 200-Area Fault Tree Databank
◆ = WASH-1400
◆◆ = Swain and Guttman, NUREG/CR-1278.

Mnemonic[a]	Freq. Per hr	Probability	Event Name	Source[b]
OPFAILS		.1	Operator fails to take a sample as required by procedure after trans.	◆
FAILREQ		.1	PHA operator fails to request missing sample after transfer.	◆
INGRESU		.1	Operator ignores results indicating Pu was transferred, proceeds to process receipt normally	◆
CONFSAM		.1	PHA Analyst confuses the sample results, reports results are normal	◆
ISGINRE		8.E-04	PHA instrument gives no sample results.	*
CONFRES		8.E-04	PHA instrument gives confusing results.	*
WIOUTAN		.1	Operator ignores lack of analytical results and proceeds to process receipt normally	◆
OPERFAI		.5	PHA operator fails to recognize confusing results, certifies results are normal	Est.

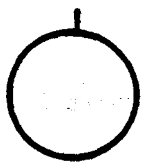
a Mnemonics refer to data input points on the fault trees.
b SOURCE KEY:

Est. = estimated value
* = 200-Area Fault Tree Databank
◆ = WASH-1400



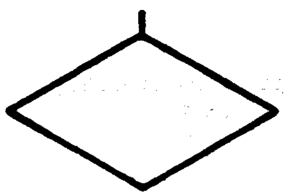
RECTANGLE

A Fault Event Usually Resulting from the Combination of More Basic Faults Acting Through Logic Gates



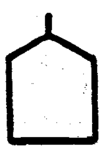
CIRCLE

A Basic Component Fault - An Independent Event



DIAMOND

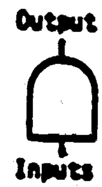
A Fault Event Not Developed to its Cause



HOUSE

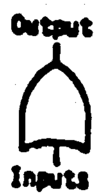
An Event That is Normally Expected to Occur Also, Useful As a "Trigger Event" for Logic Structure Change Within the Fault Tree

FIGURE AC-1. Fault Tree Event Symbols



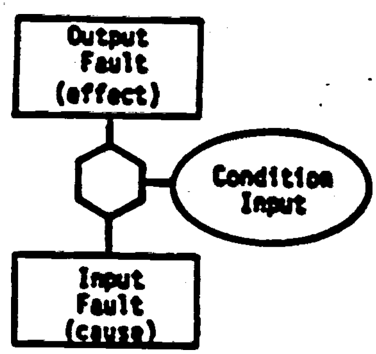
AND Gates

Coexistence of All Inputs Required to Produce Output



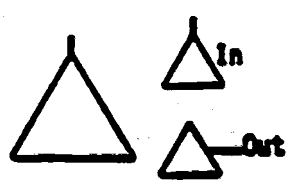
OR Gates

Output Will Exist if at Least One Input is Present



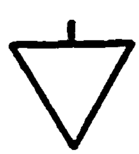
INHIBIT Gates

Input Produces Output Directly When Conditional Input is Satisfied



TRIANGLE

A Connecting or Transfer Symbol



UPSIDE DOWN TRIANGLE

A Similarity Transfer - The Input is Similar But Not Identical to the Like Identified Input

FIGURE AC-2. Fault Tree Logic Symbols