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SAFETY ANALYSIS REPORT
PLUTONIUM FUELS LABORATORY
308 BUILDING

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by

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FEBRUARY, 1969

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

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INTRODUCTION

The Plutonium Fuels Laboratory (308 Building), 300 Area, is operated for the USAEC by Battelle-Northwest Laboratories of the Battelle Memorial Institute. The Laboratory is specifically designed and constructed for the development and fabrication of experimental nuclear reactor fuels containing highly toxic radioactive materials. Several major activities are conducted within the building: plutonium fuels development, FFTF fuel fabrication, isotopic heat source development, and experimental studies of basic properties of radioactive materials. This report is a safety analysis of all the facilities and activities within the building, and is divided to describe each separately. Pertinent details on design, construction, etc. of the entire building are described in Part I. Nuclear safety limits for the entire building and for individual facilities therein are presented below. Interactions between the various facilities are discussed at the end of the report.

General Nuclear Safety Limits For the Plutonium Fuels Laboratory (308 Building)

In this document only those limits stated in the section, "Nuclear Safety Limits," are regarded as binding. All other material presented is intended to be descriptive or to be justification for the nuclear safety limits.

1. Type and Quantity of Materials

Fissile materials and other radioactive materials will not be routinely processed and stored in the building in solution forms. The maximum amount of fissile material in the building in solution form will not be allowed to exceed 230 grams.

The quantity of a given fissile material handled as a batch in transfer, processing, and storage will not exceed 45% of the critical mass of that material.

The Polonium Glove Box Facility

1. Inventory Limits

- a) The total amount of polonium in the building will not exceed 10 grams at any one time.
- b) The amount of unencapsulated, exposed polonium in the glove box will not exceed 0.5 grams.
- c) The amount of polonium in the waste receptacle in Room 213 will not exceed 1 mg.

Promethium Glove Box Facility

1. Inventory and Storage Limits

- a) The total amount of ^{147}Pm in the building shall not exceed 860 grams. This material shall be stored only within the glove box in Room 114.
- b) The total amount of ^{147}Pm in the glove box which is not double canned or encapsulated in heavy walled containers shall not exceed 400 grams.

2. Limit on Flammable Gases

No flammable gases shall be introduced into the glove box in Room 114.

Experimental Studies Facilities

1. Inventory Limits

The only radioactive materials (other than ^{235}U , ^{233}U , and ^{239}Pu) that will be received or handled and the permissible amounts are listed below.

<u>Nuclide</u>	<u>Maximum Amount in Building, Curies</u>
^{147}Pm	50,000
^{244}Cm	1,100
^{241}Am	44.5
^{238}Pu	450

PART I

THE PLUTONIUM FUELS ENGINEERING FACILITIES

SUMMARY PART I

Work in the Plutonium Fuels Engineering Facilities is directed to the development, fabrication, and examination of plutonium enriched reactor fuels. The Facilities are managed by the Fuels and Materials Department. Support is provided by Radiation Monitoring, Critical Mass Physics, Chemical Research and Analysis, Nondestructive Testing, and others.

The equipment used in the facilities provides extremes of temperatures or pressure. The materials processed are either fissionable or of high specific activity. The experimental nature of the work and the volumes of material processed cause safety to depend largely on administrative controls which are based on approved manuals and the Battelle-Northwest operating guides. Engineered safety features, such as the glove box ventilation system, the building ventilation system, and controlled fissile material storage areas promote contamination and criticality control.

Two credible accidents have potential for high radiation levels or serious contamination incidents within the building and some contamination release to the environs. These would be general fire in one or more rooms, and a criticality during the glove box processing of PuO_2 . Consequences of these accidents are discussed at the end of this section.

PART I: THE PLUTONIUM FUELS ENGINEERING FACILITIES

DESCRIPTION OF 308 BUILDING AND ENVIRONS

Site Description

Plutonium Fuels Laboratory (308 Building) is located in the southeast corner of the 300 Area. Refer to Document No. BNWL-CC-1693 for a description of the 300 Area, and to Figure I-1 for a plot plan. BNWL-CC-1693 discusses flood and earthquake contingencies for the Area; it is classed as Zone II for expected earthquake severity. Tornados are extremely rare in the area, and hurricanes "apparently unknown."

308 Building Description

The 308 Building is a two-story reinforced concrete structure with a gross floor area of 49,000 square feet. Nine thousand square feet of the first floor is an attached service and office area, and eight thousand square feet of the second floor is devoted to maintenance shops and ventilation equipment. Two service corridors run the length of the building: a tunnel runs underneath the ground floor main corridor, and another service corridor runs between the first and second floor levels. The corridors provide primary access to building utilities and exhaust ventilation ducts. Refer to Figures I-2 and I-3 for plan and elevation drawings of the first and second floors, the tunnel, and the service corridor.

The construction is of 9" reinforced concrete, with two-foot-square reinforced concrete columns supporting a slab-type second floor. Non-load-bearing partition panels are made of 8" concrete block, and blocks exposed to the building interior are plastered to form a smooth, easily decontaminated surface. The structure is designed to resist forces of earthquakes of credibly severity for Zone II, and withstand windstorms involving wind speeds of 100 mph.

308 Building Description - Systems

Ventilation System

The confinement of radioactive materials within the building is based on the operation of the ventilation system and a nearly airtight

FIGURE I-1
300 Area

FIGURE I-2a
308 Bldg. 1st Floor

TUNNEL
FLOOR EL 9'5 3/4"

SERVICE CORRIDOR
FLOOR EL (+) 9'0"

Legend:

- ① Criticality Detector
- ② Radiation Detector
- ③ Fire Alarm Pull Box
- ④ Criticality Alarm
- ⑤ Fire Alarm Gong
- ⑥ Siren
- ⑦ Pressure Loss Alarm (Bell)

FIGURE I-2b

FIGURE I-2c
 Section Views of the Plutonium Fuels Laboratory
 Two-Story Portion is 43 m (142 ft) Square

Legend:

- ① Criticality Detector
- ② Radiation Detector
- ③ Fire Alarm Pull Box
- ④ Criticality Alarm
- ⑤ Fire Alarm Gong
- ⑥ Siren
- ⑦ Pressure Loss Alarm (Bell)

FIGURE I-3
308 Bldg. 2nd Floor

building shell. The ventilation supply system provides washed and filtered air to the building through ceiling diffusers, and exhausts the air through high efficiency filters located at floor level. Up to 15 air changes are provided per hour, and it has been demonstrated that the downward sweep of the air is effective in confining contaminatio spills to a small area. Exhaust air from the rooms is filtered a minimum of two times (and that from the glove boxes three times) before release to the atmosphere. All air is sampled at least once before release to the atmosphere. Primary glove box filters are changed after prolonged and severe release of fissile material within a glove box and definite loss of material. Appreciable (gram quantity) accumulations of fissile material in filters beyond the first stage have not been noted.

The building exhaust system is separate from that for the glove boxes, except that the final filter bank serves both systems (Figure I-4). The building exhaust system capacity is 135,000 CFM. The glove box exhaust system provides a normal capacity of 1 CFM per glove box, and an emergency capacity of 450 CFM per glove box. These systems maintain pressure levels within the building consistent with potential contamination levels: the glove boxes are 1.0 in. H_2O negative relative to the laboratory rooms; the rooms are slightly negative relative to the corridors; and the entire laboratory area is 0.05 in. H_2O negative relative to the atmosphere. The of office area and change rooms are maintained at a positive 0.15 in. H_2O relative to the atmosphere.

Two high efficiency filters (described as "absolute filters" in Figure I-4) are in series between any laboratory room and the environs. Before installation these filters are DOP tested to be at least 99.97% efficient for particles 0.3 micron in diameter and larger at flow rates not in excess of five feet per minute. The filters are rated as "fire resistant". Each filter is protected from dust loading by a 1 or 2 inch thick fiberglass roughing filter. The final filter bank just ahead of the exhaust fans is protected from fire damage by an automatic fog deluge system.

Air samples are taken daily of glove box and room air after primary filtration (Numbers 1 and 2 in Figure I-4). Samples are checked weekly on the air coming out the stacks after final filtration (No. 3).

None of the installed samplers are connected to alarms. However, portable air monitoring devices with alarms are used when needed.

Gas, Water, and Waste Systems

All laboratory rooms are provided with steam, dry air, nitrogen, and process water. In addition, some glove boxes are connected to bottles of 8% H₂-92% Ar mix located on the loading dock. Liquid waste exits the building in three separate sewers: a sanitary sewer, a process sewer (to 300 Area retention system), and a contaminated waste sewer (to 300 Area crib waste storage). Contaminated dry waste is sealed in packages for disposal in the 200 Area burial site.

Alarms and Emergency Systems

Refer to Figures I-2 and I-3 for the location of fire alarm pull boxes, criticality detectors, radiation detectors, fire alarms, criticality alarms, and other alarms. (Note that the radiation detectors are not connected to alarms but simply record total radiation received.)

The criticality detectors presently used are gamma ray sensitive, and will activate alarms within the building and at 300 Area Patrol headquarters when the radiation dose rate to them exceeds 5 R/hr. Neutron sensitive detectors (set to alarm at 20 mrem/hr) are installed but have not been used routinely. The neutron sensitive detectors are scheduled to replace the gamma sensitive detectors.

In addition to the above, the office area has a heat-sensitive sprinkler system utilizing 160°F sprinkler heads which will activate individually if the temperature around them exceeds 160°F. There are no sprinklers in the laboratory area, because of the criticality potential, but each laboratory room has heat sensors which will activate the fire alarms if the temperature exceeds 160°F or if the rate of temperature rise exceeds 10°F/min.; these are located on the ceilings of the rooms.

The fire, evacuation, and criticality alarm systems are tested once a month.

FIGURE I-4
 308 Building Ventilation Flow Diagram

Emergency power is available for lights, alarm systems, the vault freezer, and a 6,000 CFM exhaust fan. The power comes from 384 Building via a 2400 volt cable, a 225 KVA transformer, and a 480 volt circuit breaker which is isolated from the normal switchgear by a bus tie breaker. Loss of normal power causes the tie breaker to open and the emergency incoming breaker to close automatically, thus maintaining power to equipment. The fan is connected to the glove box exhaust system, and will maintain the glove box negative pressure. Regular power has been lost over 20 times in the past nine years, but the emergency fan has never failed to operate on these occasions. The fire alarm system will operate on a standby battery power source if both normal and emergency power is lost.

Electrical System

The normal electrical supply to the building transformer is 2400 volts. A 1,000 KVA transformer and a 480 volt switchgear is located in a sheet metal shed adjacent to the 308 Building. Refer to Figure I-5 for a line drawing of the system.

PLUTONIUM FUELS ENGINEERING FACILITIES DESCRIPTION

The Plutonium Fuels Engineering Facilities include those areas of the Plutonium Fuels Laboratory not occupied by the FFTF Fuel Fabrication Demonstration Facility, the isotopic heat source projects, and the experimental studies projects. Thus, Rooms 102, 106, 112, 120, 131, are considered part of these facilities. Rooms 101, 103, 105, 107, 111, 219, 215, and 231 are used jointly by Plutonium Fuels Engineering and other building occupants.

The facility is primarily a pilot-scale reactor fuel development and fabrication laboratory, specialized in handling plutonium and other toxic materials. The installed equipment allows for production of a wide variety of fuels, along with high temperature x-ray diffraction, metallography, radiography, and other research and development activities.

The processes in fuel fabrication include casting, extruding, machining, draw sizing, straightening, rolling, annealing, autoclaving and welding for metal fuels, and densification, particle sizing, blending, pellet

pressing and sintering, vibratory compacting, and cladding for ceramic fuels. See Figures I-6 and I-7 for examples of metal and oxide reactor fuel preparation.

Plutonium metal and oxide are the most common fissible materials in the laboratory, along with natural uranium oxide. ^{235}U , ^{233}U , and ^{237}Np are less common, but are also processed and stored.

ORGANIZATION

The Fuels and Materials Department is responsible for the safety of the work conducted within the Plutonium Fuels Engineering Facilities as well as the rest of 308 Building. The initiation, administration and enforcement of safety practices are promoted by the safety representatives, the building manager, and the radiation monitoring specialists assigned to the building. Their duties include the following:

The criticality safety representative originates Criticality Safety Specifications (CSS) as needed, and checks to see that the Specifications and their limits are read, understood, posted, and followed. This includes requesting proofs of compliance from operating management (e.g., physical hood inventories) whenever circumstances seem to warrant such requests. It also includes reviewing all process changes involving fissile material.

The building manager is responsible in a general way for the safety aspects of every activity within the building, and particularly for the safe and continued operation of "facility services" such as electric power, containment integrity, alarm systems, etc. He oversees design changes in both equipment and the facilities. He is also responsible for giving orientations to people unfamiliar with the building, to acquaint them with the criticality, radiation and contamination potentials.

The radiation monitoring specialists determine the radiation levels that exist in the building, monitor operations, and recommend radiation control practices to management.

The specialists monitor all non-routine activity in which radiation exposure and contamination spread are possible, such as receiving or shipping radioactive material, or moving contaminated equipment.

FIGURE I-5
308 Building Electrical Service

PHOENIX MTR FUEL PLATE CORE ALLOY PREPARATION

FIGURE I-6a
Core Alloy Preparation

FIGURE I-6b
Fuel Plate Fabrication

FIGURE I-6c
Finishing Operations

FIGURE I-7
Characterization of Fuel Materials

G-272

The Plutonoum Fuels Engineering Section of the Fuels and Materials Department directly supervises work in the PFE facilities.

Administrative Controls

Administrative controls for the facilities include the following:

1. Formalized Nuclear Safety Procedures set forth in BNW Operating Guides and Procedures manuals.
2. Criticality Safety Specifications (CSS), which give safe procedures for handling and storage, usually on the basis of batch control. Batch control always limits the size of the batch (in terms of grams of fissile material or numbers of fuel rods, plates, etc.) and gives spacing requirements to isolate each batch from other fissile materials.* The technical basis for the CSS is provided by the Senior Specialist, Critical Mass Physics Section. His approval is required, as well as that of the Manager, Nuclear Safety and the operating management, before a CSS is in effect. CSS are based on the two-contingency policy.**
3. Bi-monthly audits for criticality safety by Nuclear Safety Personnel.
4. Frequent inspections of the building by management for the purpose of:
 - (a) Determining if operations are being carried out safely and within the limits and controls of applicable CSS's.
 - (b) Determining need for revision of a CSS or addition of a new one.
 - (c) Checking the labeling of material, the posting of limits and safety rules, and the correctness of fissile material inventories.

* Batches representing more than 0.45 of the critical mass of the material as described in the CSS are never allowed.

** The two-contingency policy states that two or more unlikely, unrelated events (such as operator error or equipment failure) must take place simultaneously before criticality is even possible.

5. Posted Radiation Work Procedures (RWP's), prepared by Radiation Monitoring, and process engineers. These outline the methods to be used for the prevention of contamination spread and excessive radiation doses to personnel.

6. Orientation program for people unfamiliar with the building.

SAFETY ANALYSES

The following sections describe contingencies and controls related to specific areas of activity within facilities used and shared by the Plutonium Fuels Engineering Section. Most of these descriptions involve only criticality contingencies and criticality control. The last sections, however, deal with fires, radiation and contamination control, and natural contingencies.

RECEIVING AND SHIPPING FISSILE MATERIAL

Criticality Limits and Controls

Fissile material is only received in nonsolution forms, and only through the loading dock located at the north end of the building. No non-routine shipments greater than 230 grams* are received or sent without prior knowledge and consent of the Senior Specialist, Critical Mass Physics, the Fuels and Materials Department criticality safety representative and the Manager, Nuclear Safety. Most large shipments (greater than 5 kg) are either from offsite or from another contractor, and these shipments arrive in drums or birdcages similar to those pictured in Figures I-8, 9, and 11.

Specific controls are enforced when fissile material is received or gathered for shipment:

1) Spacing requirements and stacking limitations (if any) applicable to shipping containers are explained to the personnel who are to do the load-

* 230 grams is 45% of 520 grams, which is the minimum critical mass of the most reactive fissile material (Pu) under the optimum conditions of shape (sphere), moderation (H/Pu=800), and reflection (full water reflection). Thus, even if this limit were exceeded by an additional 230 grams, and all the conditions for criticality optimized, criticality would still not occur.

FIGURE I-8
Model 30 Shipping Container

FIGURE I-9
Models 55 (#23) and 10 (#5)

FIGURE I-10
Transfer and Storage Cans

KKD-1 and LLD-1 Dot Permit SP-4960
(M-101 and M-102)

FIGURE I-11
LLD-1 Shipping Container

ing or unloading; these requirements are met during the loading or unloading and for as long as the containers remain unemptied.

2) Within the building the spacing between fissile material in shipping containers and any other fissile material is at least 3 feet.

3) As quickly as practical, the contents of receiving containers are removed, repackaged if necessary, and placed either in vault 107, Room 215, or in glove boxes.

4) As soon as fissile material is removed from the container, the following controls are applied:

a) The material is divided into allowed batches.* (The amount that constitutes an allowed batch is either defined by a specific CSS or a 230 gram limit is used).

b) The spacing between allowed batches, and between such batches and all other fissile material, is at least three feet (except in storage).

5) The Fuels and Materials Department Criticality Safety Representative is present during the loading or unloading of a shipment involving more than one unmoderated minimum critical mass of a given material.

6) Only one shipping container is normally loaded or unloaded at a time.

7) Only personnel experienced in handling fissile material and cognizant of the hazards involved are authorized to unload large shipments.

* This merely involves separation of packages. Shipment of fissile material are never received in which the amount of material in a single package exceeds a total allowed batch limit.

Criticality Contingencies

The amount of fissile material in one shipment may vary from a few grams to over 50 kg. The majority of shipments involving more than 230 grams are of unmoderated Pu metal buttons or Pu oxide powder. These materials are commonly received double-canned and in LLD-1 type shipping containers (Figure I-11) with two cans (of the types in Figure I-10) per container and 1 to 2 1/2 kg Pu per can. The dimensions of the button can are usually 4 1/8 x 5 1/2 inches. Typically, these containers are assembled in front of the storage area after being unloaded from a truck, and the cans are removed, marked, and stored.

In almost all cases, a shipment of such cans could not be made critical even if all cans were removed at once and heaped together, providing moderating materials were not allowed between or in the cans. Clayton's experiments⁽⁶⁾ indicate that criticality cannot be achieved with 100 such cans containing loose (2 g/cc smear density) PuO₂, even if the cans are in a tight, cubic, fully reflected array. Abbey⁽¹⁾ states that more than 30 such cans with 2 kg of metal per can would not be critical in a fully reflected, cubic, tight array. The above number of cans and material quantities would never be received or sent in a single shipment.

Thus, the introduction of moderators in and between the cans would be necessary for criticality to occur during the receiving of fissile material even if the above controls are exceeded. Water flooding is the most obvious mechanism by which this could take place, and the flooding is improbable while the cans are being unloaded and stored. All this can be summarized as follows:

a) Criticality will not occur in the absence of water flooding (or some other mechanism for inadvertent moderation) during the loading and unloading of a shipment of fissile material, provided it is isolated from other fissile material.

b) Even in the event of water flooding, criticality is not possible if the fissile material remains in watertight packages and if the controls listed in this section are exercised.

STORAGE OF FISSILE MATERIAL IN VAULT 107

Criticality Limits and Controls

Vault 107 is a small, high room with a vault type, combination locked, 2 hour fire-rated door. The safety of fissile material storage in the vault is maintained by simple administrative controls supplemented with design features. Access to the vault is extremely limited. The door combination is known to only three people and is changed periodically.** The minimum spacing between safe masses* of fissile material within the vault is 12 inches edge-to-edge (or center-to-center in special cases). Only one safe mass is permitted to be moved into or within the vault at one time. The usable storage areas and applicable controls include:

a) The cubicles: Ranged along the south wall of the vault are 32 cubicles, 18 on the first level and 14 on the second, with about two feet between levels (see sketch, Figures I-13, I-14). The cubicles are made of 1/8" steel plate and are diamond-shaped, with a cross section of 2 feet x 2 feet. Each level of cubicles is shielded by a row of 1/8" thick lead doors, supported from the floor and from two steel beams running the length of the vault. Storage controls in the cubicles are:

*One safe mass = 45% of the minimum (reflected) spherical critical mass of a fissile material as packaged. Fissile material is allowed in the vault only in watertight-sealed cans and will remain as packaged.

** The three people assigned access to the vault are also directly responsible for the physical entry, movement, and storage of fissile material therein. They also control and post the fissile mass inventory of each cubicle

1) The amount of fissile material allowed in the storage cubicle is limited to one safe mass of the most reactive material stored in that cubicle.

2) The minimum edge-to-edge spacing allowed between material in a large cubicle and that in adjacent cubicles is 12 inches. (Thus only the area under the dotted line in Figure I-13 is to be used for storage). The diamond shape of the cubicles aids in maintaining this control, since a dislodged can will fall only toward the bottom of the diamond.

3) Cans of fissile material in the 12" x 12" cubicles may be stored only end-to-end in a single row along the bottom of the diamond.

4) Moderated fissile material is stored only in large cubicles along one edge of the array. This reduces the interspersation of moderators within the array.

5) A fissile material inventory sheet is posted on each cubicle door.

b) The freezer: Freezer #1, a 7 1/2 cubic foot upright freezer, is positioned in the northwest corner of the vault, under the stairway to the second level. Storage within the freezer is limited to positions marked by 14 metal rings, with a minimum center-to-center distance of 13 inches between the rings. Only Pu metal buttons, Pu metal alloys, and double-sealed cans of PuO₂ may be stored in the freezer. These materials are stored there because their spontaneous heat is harmful to the metal and plastic inner containers. The freezer is connected to emergency power to assure continued operation.

1) Only 2.6 kg of fissile material may be stored per marked location and only in one container; the material in that container must be in a single watertight package. The ring at each location prevents accidental movement of the container.

FIGURE I-12 Storage Vault Floor Plan (scale 1/2" = 1')

FIGURE I-13
Plutonium Storage Array in Vault
(elevation)

FIGURE I-14
Vault 107, before the addition of
the upper level of cubicles

2) Only one container may be moved into or within the freezer at one time.

c) Storage on the Floor: There is room under the stairway for two storage locations on the floor, spaced 3 feet apart and 3 feet from the freezer and cubicles. Only unmoderated fissile material may be stored at these locations.

Criticality Contingencies in Vault Storage

The estimated maximum capacities of the vault storage areas are shown below:

<u>Storage Area</u>	<u>Capacity, kg of fissile material</u>
Cubicles	315
Freezer	39.2
Floor	<u>5.6</u>
Total	360

The amount of fissile material in the vault has not normally exceeded 150 kg, of which no more than 1.5 kg has been moderated material. In the absence of full reflection it is not probable that cans of this material ranging in volume from 0.23 liter to more than 10 liters would become critical if piled loosely together. Refer to Abbey's table⁽¹⁾ of minimum critical numbers of cans in cubic array (pg. 306).

In order for criticality to occur in the vault, there would have to be a mechanism by which (a) the cans of material were thrown violently together and fully reflected, or (b) moderating materials (such as water) are introduced into the cans. Mechanism (a) would probably involve the collapse of the building due to earthquake. Occurance of mechanism (b) is minimized by the fact that entry of water into the vault is forbidden, even for fire fighting purposes. It is improbable that experienced personnel assigned access to the vault would commit the gross errors in storage and handling necessary to cause criticality with the material as packaged.

STORAGE IN ROOM 215

Criticality Limits and Controls

Room 215 is used for the storage of Pu-Al and mixed $\text{PuO}_2\text{-UO}_2$ fuel blends in cans, rods, and finished fuel elements. Figure I-15 indicates the distribution of this material within the room. Shelves for Pu-Al and a beam for hanging PRTR elements in a single-slab array are located along the west wall. Metal cabinets for oxide storage are arranged around the south and east sides of the room; and carts and racks for fuel rod storage are located in the room center.

The major criticality safety controls are:

- 1) The metal shelves for Pu-Al storage are quite narrow (9" deep). The total fissile weight on them is limited to 36 kg.
- 2) The density and wt% Pu of the Pu-Al are limited so that even if the array were fully reflected, criticality would not occur.
- 3) The amount of fissile material in each cabinet is limited to less than 0.45 MCM for the as-packaged material stored in that cabinet. The spacing between cabinets is greater than 3 feet. Only limited amounts of material as determined by CSS may be moved among the cabinets at one time.
- 4) The room is locked, and only three people have access to it.
- 5) The room is classed "D" for firefighting purposes.

Criticality Contingencies

In the absence of accidental moderation of some of the fissile material stored in this room, criticality is improbable. Furthermore, simple water flooding of properly stored material will not cause sufficient moderation for criticality.

*As in vault 107, the three people assigned access to the room are directly responsible for the physical entry, movement and storage of fissile material therein.

FIGURE I-15
Room 215: Fissile Storage Area

If flooding were to occur, the Pu-Al would probably stay on the shelves and remain sealed watertight, the PRTR elements would remain hanging in a single row (thereby remaining safe) and cans of oxides, even if dislodged, should remain separated and sealed, thus reducing the chance for criticality. Only some mechanism by which containers of fissile material become both unsealed and flooded (such as earthquake plus flooding, or fire plus flooding) would make criticality in this room a real possibility. The existing doors and drainpipes make flooding from internal sources quite remote.

PROCESSING FISSILE MATERIAL IN A TYPICAL GLOVE BOX

Criticality Limits and Controls

Unpackaged, unclad fissile material in the facilities is processed in hoods or in glove boxes of the type pictured in Figure I-16. The glove boxes have sloping steel frames supporting 0.375 inch acrylic plastic and occasionally overlapping sheets of 0.25 inch 105 Kev x-ray lead glass. These glove boxes are airtight in order to contain alpha contamination within the boxes, and this provides the added advantage that only controlled amounts of moderators can even come near unmoderated fissile material, except for cases where moderating liquids (water or oil) pass through the glove box in pipelines. In these cases, flooding and moderation from a leak in the line is prevented by limiting the capacity of the liquid system, or by continuous operator surveillance of the glove box, or by electronic liquid detectors, which can detect a water buildup on the box floor of less than 1/8 inch, and which close the lines by means of solenoid valves. These valves are "fail-safe" in that they fail closed; they must be energized to remain open. The likelihood of a valve remaining open due to sticking or damage will be minimized by periodic testing and protective maintenance.

Where no lines of liquids traverse the box internally, moderation of unmoderated material can only occur if a person deliberately enters the moderator and mixes it with the material. Where such mixing is routine, and the amount of moderator entered is not limited, the amount of fissile

material in the box is limited to 230 grams. Only where such mixing is strictly controlled are safe (reflected)* unmoderated masses of up to 2.8** kg (metal) or 5.0 kg (oxide) of fissile material allowed per glove box. The most important controls are that no more than 2.0 liters*** of hydrogenous liquids are permitted in a glove box, and that no more than 15 grams of fissile material are to be mixed with moderating materials at any one time.

Certain fissile materials are in a form such that the normal regulations may be modified. However, general rules may only be modified if replaced by specific CSS relating to specific materials and designated glove boxes and processes.

The mass limits for individual glove boxes are clearly designated by a standard sign posted on the box, and a minimum spacing of 1 foot is required between fissile material within a glove box and any other fissile material. Continuous inventories are kept of the fissile material collected in a glove box. A person making a transfer of fissile material must record the transfer, determine the new balance, and sign the inventory sheet. A second person is required to witness the transfer, check the balance, and sign the sheet. The same kind of inventory control is exercised on hydrogenous liquids. Frequent regular inspections are carried out by management to assure that these limits and controls are adhered to. CSS 7A40-1 is appended to show the kind of controls currently in effect on processing fissile material in glove boxes. It is provided only as an example of the type used to cover all phases of processing and storing fissile material within the building.

-
- * Full reflection is always assumed in establishing criticality safety limits; thus, one can exceed accepted safety factors in handling unmoderated fissile material only by exceeding the allowed amount, the allowed moderation level, or the approved geometry and spacing.
 - ** This limit will soon be changed to 2.60 kg, which is 45% of the minimum reflected critical mass of Pu alpha phase metal with more than 5% ^{240}Pu content. All plutonium handled in 308 Building has ^{240}Pu contents in excess of 5%.
 - *** Besides the 2.0 liter limit, the presence of more than 2 kg Be, 10 kg carbon, or 3.0 liters D_2O is forbidden in glove boxes under general "unmoderated material" mass limits. The moderating effect of such materials as plastic bags, plastic sample vials and tubes, etc. is examined by the Senior Specialist, Critical Mass Physics, before use of such materials is allowed to become routine.

FIGURE I-16
Typical Glove Box Construction

Criticality Contingencies

Fissionable materials in a variety of types and forms may be handled in the glove boxes, including pure metals, alloys, loose ceramic powders, pressed ceramic pellets, and cermets. Processes within glove boxes are varied; they include (but are not limited to) weighing, sieving, spheroidization, blending, mixing binder into a ceramic powder, pressing, sintering, and grinding pellets, casting, extruding, cutting, machining, etching, and welding.

When the entry of fissile and moderating materials into glove boxes is allowed, the possibility exists for entering more than the allowable limit, and for ignoring rules concerning the use of moderators; in short, a critical assembly can be brought together within a glove box. However, it is worthwhile to examine the number of gross operator errors or equipment failures that would be necessary for criticality to occur.

1) Exceeding the 230 gram limit: Theoretically, if an operator enters as little as 520 grams of Pu in a glove box where moderation is not limited (and where the fissile material inventory should be no more than 230 grams), he could build a critical assembly without breaking any more rules; but he would have to work at it with educated deliberation. The material would have to be finely divided (such as loose oxide powder) so that it could be mixed thoroughly with over 12 liters of water in a single container with a minimum diameter of 12 inches. In many glove boxes it would be impossible to enter such a container. The container would then have to be completely surrounded by several inches of water or by some solid reflecting material like beryllium. If any of these conditions were not met, the amount of fissile material needed for criticality would be more than 520 grams, or more than 2.2 times the glove box limit.

2) Exceeding unmoderated fissile material limits: Simply exceeding the stated mass limits for unmoderated fissile materials will not cause a criticality, unless those limits are exceeded at least two-fold in the case of pure metals and at least four-fold in the case of tap density (5.6 g/cc) oxides. Other controls would have to be exceeded as well. To be specific:

a) The material would have to become moderated. The specified limit for moderated fissile materials in a glove box with "unmoderated"

limits is 15 grams. This rule must be broken for criticality to occur.

b) The material would have to be concentrated. At least one container would have to contain over twice the entire volume of moderating liquids allowed in the glove box, in addition to over 520 grams of finely divided fissile material. The only procedurally allowed moderators in the 308 Building glove boxes are hydrogenous liquids.

Despite all the contingencies required, an accidental criticality in a glove box operation, particularly one involving plutonium oxide, cannot be completely ruled out. Consequences of such a criticality are discussed at the end of Part I.

PROCESSING FISSILE MATERIAL IN AN INTERCONNECTED GLOVE BOX LINE

Criticality Limits and Controls

A typical 308 Building glove box is not connected to another glove box; however, interconnected lines of glove boxes exist in the building, and discussion of the one in Room 131 will provide examples of the controls that are imposed on such lines.

Refer to Figure I-17. Note that the glove box line is divided into three sections (box no.'s 27-29, 30-31, and 32-36) by the walls on each end of glove box 31. Separate limits and procedures may be applied in each glove box, provided the fissile material in each remains separated from that in the other by at least 1 foot. There is a general rule that the total amount of fissile material allowed in a section shall not exceed 0.45 of the critical mass for that material.

Criticality Contingencies

As previously discussed, simply exceeding fissile mass limits in a single glove box will not cause a criticality. If mass limits in more than one glove box in a section are exceeded (by no more than two-fold), and if all the material in that section is assembled in the most hazardous array, criticality will not occur as long as the form of the material remains as

FIGURE I-17

specified when the limits were established. The most important change in form is, in general, increases of the moderation of the material, and this would be the most probable cause of criticality.

Two possibilities exist for accidental moderation: the leaking of oil from the 200-Ton Clearing press (Section 1) and the leaking of cooling water from the vacuum induction furnace (Section 2). Most of the oil in the Clearing press system is located below the level of the glove box floors; therefore, it must be pumped into the glove boxes to flood them. In order for this to happen, the press must be operating while unattended (a procedural violation) and the packing glands in the press cylinders must fail catastrophically. In order for a leak in the furnace cooling coils to flood section 2, an external hose to the coil must be left connected and a valve left open while the operator is not in attendance, which involves two violations of standard procedure, and the coolant line must develop a gross leak which is undetected for at least two hours.*

PROCESSING FISSILE MATERIAL IN ENCLOSED FURNACES

In glove boxes employing water-cooled furnaces to heat or melt fissile material, there are two major nuclear safety concerns: 1) a cooling line leak that floods the fissile material sufficiently to make it critical, and 2) a leak that would cause steam formation rapid enough to rupture the glove box or initiate a metal-water reaction.

Criticality Controls

The general controls on glove box flooding from leaks have been outlined in previous sections: continuous operator surveillance is required as long as water can flow through lines that run inside a glove box (unless the box has two independent electronic liquid detectors which will shut off the water if liquid level on the box floor exceeds 1/8 inch).

* This last condition stems from the fact that the maximum flow from a leak in the 1/4" cooling coils would be 1.6 gal/min., and that the water would fall into glove box #30, which is located below the general box floor level, is held to a 230 gram limit, and has a capacity of about 340 gallons.

Most of the continuous cooling systems inside glove boxes are designed so that when the system is properly turned off, more than one mechanical failure or human error would have to take place before water could flow again in the system. In cases where this is not true, liquid detectors are in operation to protect the glove box from flooding. If power is lost to these detectors, it will also be lost to the solenoid valves to which they are attached; and these valves will automatically close off the water flow upon loss of power.

Where vacuum or special-atmosphere furnaces are enclosed in chambers, a liquid detector on the glove box floor could not detect a line leak on the inside of the chamber. In such cases, continuous operator surveillance is required.

Steam Formation Contingencies

Separate analyses of the designs of the various water-cooled furnaces in the building show that steam formation sudden enough and contained sufficiently to rupture a glove box and injure personnel would only occur under the following conditions: a water leak occurs inside the furnace which sprays more than 50% of the line flow directly into the hot zone. In no case are such conditions credibly attainable.

Metal-Water Reactions

In only one furnace in 308 Building is a metal-water reaction possible: the large vacuum induction furnace in Room 106, which is an induction heated furnace in a 16 cubic foot bell jar.

The furnace is inoperable at the present time, and before it is put back in operation, the following precautions will be taken:

- 1) Flow switches on all cooling lines inside the vacuum chamber will be tested. These switches shut off the water flow in the event of a pressure decrease in the lines.

- 2) Electronic liquid or vapor detectors will be installed in the vacuum chamber. These detectors will shut off both power and water to the furnace if water or water vapor is detected inside the vacuum chamber.

AUTOCLAVING FUEL RODS

The large autoclaving facilities in Room 115 consists of two upright cylindrical autoclaves with 6-1/2 in. inner diameters, 12 foot inner lengths and 1 1/8 inch thick steel walls. Up to 40 1/2 inch-diameter rods may be loaded into an autoclave at one time, covered with water, sealed, and heated slowly to approximately 400°C. As the heat increases, some of the water forms steam which forces the rest of the water from the autoclaves into two large horizontal blowdown tanks. (These tanks are located in the same 15-foot deep well in which the autoclaves sit). Simultaneously, a pump will draw the water out of the tanks and into a sewer leading to the 300 Area crib waste system. When operating pressures (approx. 1,000 psia) have been reached in the autoclaves, they are valved off from the tanks. If pressure rises in the autoclave, a preset pressure relief valve will allow steam to escape into the blowdown tanks. If this relief valve fails, a rupture disc will break when autoclave pressures exceed 1300 psia, which will also allow steam to rapidly drain off into the tanks. At the end of a normal run steam is slowly drained into the tanks, condensed, and pumped out.

There are two nuclear safety concerns connected with the operation of the autoclaves:

1) Can criticality occur either in the blowdown tanks or in the autoclaves themselves?

2) Could (possibly contaminated) steam somehow escape from the autoclaving system at any point at any time?

Criticality Contingencies and Controls

If only fissile material which is encased in welded tubes is placed in the autoclaves, and if one assumes that these tubes would not rupture until steam pressure had driven most of the water out of the autoclave, the only likely way that criticality could occur within the autoclave itself would be a gross mistake on the operator's part about the number of rods of a given type that may be safely entered and covered with water. Limits on these numbers are established in criticality safety specifications, and

would have to be exceeded by over a factor of two in order for criticality to occur; such a gross mistake is remote, since only personnel who are cognizant of the criticality rules and hazards involved are permitted to operate this facility.

The major potential causes of criticality in the blowdown tanks are: the failure of several tubes or welds in a single run, and subsequent injection of loose fuel into the blowdown tanks (at least 520 grams of fissile material would have to be injected or accumulated).

The first of these situations would most likely occur after operating temperature and pressure had been exceeded. Two temperature control circuits and two pressure relief devices exist to assure that these conditions shall not be exceeded, and the record of one weld failure out of several thousand autoclaved rods indicates that multiple failures in one normal run are indeed unlikely.

Even if fuel and steam were injected violently into the tanks, the solution level in the tanks could not exceed 0.5 inch (the residue of condensed steam). It is not credible that at autoclaving temperatures (not exceeding 500°C) metal fuel could be melted and forced into the tanks. This leaves only the possibility that some ceramic fuel may be mixed with the steam residue. But 0.5 inch is well below the critical slab heights of solutions of ceramic fuels in water.

The possibility of accumulations from single failures in many runs causing a criticality is negated by the fact that the tanks would be pumped dry and cleaned of all fissile material after each failure.

Steam Escape Controls

The lids of the autoclaves are held in place by circumferential clamps which are fastened together by 2 bolts, 7/8 inch in diameter. An estimated 4,000 psi would be necessary to blow off the lids. It is estimated that some of the pipe fittings for pipes leading from the autoclaves to the blowdown tanks might rupture at 1500 psi; however, even attaining that pressure would require operator error in setting the tripping level on the pressure control system (or failure of the system to detect and trip) plus failure of the rupture disc to rupture (or else installation of an improper disc).

FIRE CONTINGENCIES

Fires within a Glove Box

In over half the glove boxes in 308 Building, devices such as furnaces, lathes, welders, etc. exist which are capable of igniting flammable materials. Several factors make large glove box fires and gross contamination spread unlikely:

1) General operating procedures prohibit accumulations of combustibles in a glove box. Without large accumulations of combustibles, a fire large enough to ignite bags, gloves, or plastic panels is not likely to occur.

2) Where a potential ignition source exists (as in a glove box containing a frequently used furnace), the glove box is commonly operated on an inert atmosphere, which inhibits oxidation of any sort.

3) Use of flammable liquids (e.g., cleaners) in glove boxes is only allowed in special, limited operations under stringent controls.

4) Fires are most likely to happen in an area of high work activity and during a time when people are present. MgO sand is available in every glove box for instant use. Special connections are installed on every glove box for the use of dry chemical fire extinguishers. The extinguishers also are equipped with probes for penetrating gloves. Personnel are trained in the use of these extinguishers; Figure I-18 depicts one in operation.

Fires Outside a Glove Box

No fissile material is stored in the 308 Building in such a way that credible collapse of racks, shelving, etc., due to fire could lead directly to a criticality. Therefore, the major nuclear safety concern with a fire outside a glove box is whether the spread of flames could be large enough and prolonged enough to destroy a glove box or other means of contamination containment, and whether people might breathe any released contamination. Several controls make this unlikely:

1) Combustibles are not allowed to accumulate near glove boxes or storage areas.

2) A fire large enough to consume a glove box or release double-canned material would almost certainly set off the automatic alarm system if not first extinguished or at least detected by people. Trained firemen would be on the scene before extensive damage had been done.

3) Evacuation of the building would be prompt and certainly in advance of any significant contamination release. Reentry is limited to those with assault masks (under established procedures), until it is assured that airborne contamination and surface contamination throughout the building are below permissible levels.

4) Significant contamination release to the environs is not expected. No laboratory rooms have any windows, and doors would normally remain shut. It is unlikely that both sets of filter beds between room air and the stacks would be destroyed by fire, since a heat-activated deluge system is installed in the main exhaust duct to protect the final filter beds.

CONTAMINATION AND RADIATION CONTROL

Contamination Control

"Contamination" is a term used herein to describe the presence of alpha-emitting material (mostly plutonium) in quantities larger than 10^{-8} uCi (or 10^{-13} uCi/cc in air). The control of radioactive materials other than alpha emitters present in the building is discussed in Part III.

The principal engineered features of contamination control within the building are the glove boxes and the overall ventilation system, which were discussed earlier. Procedural controls are very important in discovering the limiting contamination spread:

1) Strict procedures have been established for bagging material out of glove boxes and for changing gloves, in order to prevent solid or airborne contamination from escaping from a glove box.

2) Gloves are checked periodically for weakening and holes, and contamination spills due to glove ruptures are held to a small number.

FIGURE I-18
Dry Powder Extinguisher

3) Portable alpha detection equipment is available for people actually working in glove boxes, and they are procedurally required to survey their hands and arms before leaving the box.

Contamination spills not connected with glove box work are rare. Fissile and other high activity materials are stored within the building only after being double canned and sealed in welded metal containers. Material leaving a laboratory room is surveyed for surface contamination, and every person is required to survey his hands and feet upon leaving any laboratory room and upon leaving the laboratory section. If at any time contamination is discovered, the contaminated person or article is not moved until radiation monitoring personnel have had an opportunity to remove or control the contamination and determine the source and extent of the incident.

Unless a primary means of containment (e.g., a glove box or sealed metal can) is destroyed, gross contamination release in the building is unlikely. Even under such circumstances, the contamination would probably be confined to a small area by compartmentation and ventilation control.

During the life of the building, there have been about twenty electrical outages, ranging in duration from a few minutes to two and a half days. Emergency precautions such as covering glove ports, sealing bags, and taping hoods shut are taken as soon as power loss is detected, in order to prevent radioactive materials from escaping into rooms. Except in one case*to date, emergency power has been maintained during outages, and the emergency glove box exhaust fan has operated and maintained negative relative glove box pressures. Room air samples and surface smear samples have never revealed spread of contamination from glove boxes during electrical outages in the building.

Radiation Control

The activities of the radiation monitoring specialists assigned to the building constitute the majority of day-to-day radiation controls. These specialists assess the radiation hazards of new or non-routine operations, and inform management immediately of any unusual radiological conditions within the building. They assist in establishing maximum expected dose rates, marking off radiation zones, distributing and collecting dosimeters, and

*For one 36 hour planned outage all ventilation was shut off.

reporting personnel exposures. At their suggestion, management occasionally institutes special radiation controls, such as special shielding limited access storage and work areas, etc.

In almost no case in 308 Building is sudden exposure to high amounts of radiation credible. Two cases where this is not strictly true are the x-ray units in Rooms 220 and 105. The unit in room 220 is contained in a glove box and exposure to hands is the only radiation hazard. The unit in Room 105 is larger and not contained in a glove box; however, an interlock mechanism prevents the 105 unit from being turned on until the lead-lined door to the room is completely closed; and the door must remain closed for the unit to remain operating. Limits on the operation of both units are specified in radiation work procedures.

CONTINGENCIES ARISING FROM NATURAL CAUSES

Windstorms

Destructive tornadoes and windstorms of hurricane intensity are virtually unknown in the 300 Area. The strongest recorded wind gusts in the Area have not exceeded 75 mph. Since the 308 Building was built to withstand winds of up to 100 mph, it is not considered likely that windstorms will cause damage to the 308 Building.

Flood

The high-water level of the Columbia River during 100 year maximum flood stage at 300 Area is estimated to be 364 ft. above sea level. 308 Building is situated 404 ft. above sea level. River flooding of the building is not considered likely.

Earthquakes

Recorded earthquakes in the Hanford area have not exceeded three on the Modified Mercalli Scale (MM-III), and are not expected to exceed MM-VII. The 308 Building is designed to withstand earthquakes of up to MM-VIII intensity. Serious damage to the PFL due to earthquakes is not expected.

CONSEQUENCES OF ASSUMED ACCIDENTS

Criticality in a Glove Box

The safeguards which have been established to prevent a criticality are described in a previous section. This section discusses the consequences of a criticality in the unlikely event that one occurs.

A criticality incident in a glove box probably would not exceed 5×10^{17} total fissions, and would probably be limited to a single burst since it would involve fissile material in nonsolution form; thus the energy of the criticality would be expected to put the material in a noncritical configuration. The principal consequences of such an incident would be the neutron and gamma radiation exposure to people within the building. Table I-1 was adapted from Aspinall's report.⁽²⁾ It gives an estimate of the dose a person could receive from external radiation, starting at various distances from the incident and evacuating promptly (2 second delay) at a speed of 16.5 ft/sec.⁽²⁾ Comparison of Table I values with Wachter's report⁽¹⁷⁾ and a review of criticality accidents⁽¹⁵⁾ shows reasonable agreement. It is evident that anyone within a radius of 20 feet of the incident might receive more than 450 Rem. The number of people within this radius depends upon the work done in the vicinity; there could be as many as five, but would more likely be two.

Mechanical damage to the glove box might include rupture of bags, gloves, and the glove box panels. 5×10^{17} fissions would provide 3850 kcal of heat which is sufficient to produce 350 cubic feet of steam if water is available. This would pressurize the average glove box (volume, 200 cubic feet) to 700 inches H₂O (300 in. H₂O above atmospheric pressure). Gloves and bags tend to fail at differential pressures above 20 in. H₂O. Water probably would be present if a criticality did occur, since accidental water moderation is the most likely cause of a criticality in the PFL. Safeguards such as limited volume water systems, operator surveillance during cooling water usage, and automatic water detection and shut-off systems nearly assure the prevention of accidental flooding.

TABLE I-1Dose Received from a Criticality (5×10^{17} fissions)

<u>Initial Distance from the Incident (feet)</u>	<u>Calculated Dose from Radiation (Rem)</u>
3	11,000
6-1/2	3,100
10	1,350
16	550
33	80

If serious damage to the glove box occurred, some plutonium release to the room would be expected. However, the dose in the vicinity of the criticality from inhalation of airborne plutonium or fission products would probably not be significant compared to the external dose from exposure to neutrons and gamma radiation.

In the environment a potentially significant exposure pathway would be via inhalation of iodine or plutonium. There would not be enough fission gases released to cause a significant offsite exposure from external radiation.

The quantity of several fission gases formed during a 5×10^{17} fission criticality is given in Table I-2.

TABLE I-2Radioactive Fission Gases Formed in a Criticality
(5×10^{17} fissions)

<u>Isotope</u>	<u>Quantity (Curies)</u>
^{131}I	0.505
^{133}I	6.70
^{135}I	22.5
^{133}Xe	1.41
^{135}Xe	20.90

Much of the iodine would be expected to remain in the plutonium-water mixture but since we lack data on release which we feel are surely applicable we assume complete release of iodine. We also assume complete release from the critical mixture of the noble gases. We use 50% plate-out of iodine prior to release to the environment but take no credit for filtration. There are high efficiency filters but no charcoal absorbers in the 308 ventilation system. With these assumptions the resultant release to the environment is:

1/2 the iodine

all the noble gases

Airborne plutonium would be effectively filtered by the high-efficiency filters which remove at least 99.95% of particles of 0.3 micron minimum diameter. If all the plutonium involved in a criticality became airborne inside the building, a most unlikely occurrence, the estimated Pu release to the environment would be 0.85 grams or 0.05 Ci of ^{239}Pu .

As a consequence of this release of iodine and plutonium the calculated consequences to individuals 1 mile downwind of the building would be a dose of 0.3 rem to the thyroid, 15 rem lifetime dose to bone and 0.12 rem to the lung. If the plutonium was of mixed isotopic composition, 65% ^{239}Pu , 29% ^{240}Pu , 5% ^{241}Pu and 1% ^{242}Pu , the dose would be 55 rem to bone and 2 rem to lung tissue.

In the event of a criticality the airborne plutonium would be only a small fraction of the actual total involved and the dose to bone and lung tissue would be proportionally smaller than the values given in the preceding paragraph.

Fire Within a Glovebox

In the event of a fire in a glove box plutonium would become airborne and if the glove box failed, a serious plutonium inhalation exposure could occur to individuals within the room unless they evacuated before plutonium was released from the glove box. Experience has shown that individuals wearing effective respiratory protection (masks) would probably receive about 1/1000 of the inhalation exposure that non-protected individuals would receive.

Assault masks are strategically located in areas of low contamination such as in hallways for use as needed. It is believed that even during a large fire within the building the final filter bank would remain intact due to the presence of the fog deluge system mentioned on page 3. The system is activated by temperature sensors when the air temperature rises to 300 °F. The system is installed in the main exhaust plenum and has the capacity to cool 135,000 CFM of air from over 900 °F to less than 150 °F.

A large fire could spread plutonium contamination to other rooms of the building. A period of loss of use of the facility would occur. This and the decontamination of the facility and equipment in order to return them to use could be costly.

The assumptions used for calculating projected doses presented in this section are given in Appendix A.

PART II

THE FFTF FUEL FABRICATION DEMONSTRATION FACILITY

SUMMARY - PART II

The FFTF Fuel Fabrication Demonstration Facility is located in the Plutonium Fuels Laboratory (308 Building), and is designed to produce FFTF fuel pins on a developmental basis. The facility is comprised of two parallel fuel lines enclosed in a series of glove boxes normally operated under dry air or inert atmospheres. A glove box ventilation exhaust of up to 450 CFM is automatically attainable should emergency conditions require large air flows.

The fabrication work is under the direction of the Deputy Manager, FFTF Fuels Department. In addition to technical personnel from FFTF Fuels Department, support is provided by members of Radiation Monitoring, Nuclear Safety, Reactor Physics, Fuels and Materials Department, Ceramics Department, and Craft Services.

Administrative controls are based on approved manuals and BNW operating guides.

Limits of the quantity of fissionable material are established for each operating station, and portable alpha detection devices are located throughout the facility.

PART II: THE FFTF FUEL FABRICATION DEMONSTRATION FACILITY

DESCRIPTION

Facility Description

Approximately 10,000 square feet on the first floor of the Plutonium Fuels Laboratory (Rooms 101, 103, 105, 111, 113, 117, 119, 125, 134, and 138) are occupied by the FFTF Fuel Fabrication Demonstration Facility. Refer to Figure II-1 for a plan of the Facility, and to Figures I-2, 3 for the PFL plan.

Versatility inherent in the design of the PFL permits the isolation of rooms 117, 119, and 125 without changes to the existing room ventilation supply, room exhaust, or basic laboratory utilities. The compartmented rooms and the glove box orientation provide for isolating areas from other building functions and other portions of the development line to promote safety and insure continuity of work.

Alternating between the two pellet lines will provide pilot scale processing. The functions of plutonium storage, fuel pin decontamination, welding, etching, radiography, and main corridor travel share joint facilities with other users.

Glove Boxes

Primary containment of plutonium is provided by the glove boxes. FFTF glove boxes are constructed of stainless steel with acrylic panels or safety glass and are essentially leak-free. Dry air or inert atmospheres are used within the boxes with variable purge rates and exhaust capacities of approximately 450 CFM under emergency conditions. Glove box atmospheres are automatically controlled at a negative pressure by self-sensing supply and exhaust valves; and the exhaust air is filtered three times before release to the atmosphere.

FIGURE II-1
TFTF Fuel Fabrication Demonstration Facility

Standard gloveboxes provide complete contamination containment of fuel material containing high energy gamma emitters.

Fire detection devices are located in the ceiling of each room, and the top of each glove box, to give early warning of an excessive temperature rise due to fire. These precautionary devices are expected to prevent or greatly minimize, the spread of contamination to the surrounding area in case of fire. (See Figure I-2a, Part I, for alarm location.)

Firemen have received training in extinguishing glove box and other fires. Special dry chemical extinguishing systems are available and installed on all glove boxes. In addition, the operating staff of the Plutonium Fuels Laboratory have been trained to fight glove box fires.

Process Description

Each pellet line consists of six operating stations, the first four of which are isolated in the first rooms of the line. These include (1) UO_2 -powder blending, (2) ballmilling or particle surface preparation, (3) particle binding and (4) UO_2 - PuO_2 powder granulating (Figure II-2).

The characteristics of the work make the pellet lines a potential source of radioactive contamination, thus the two lines assure continued pilot scale operation in event of contamination of one line. Normally, the second pellet line is used for development studies and only used when equipment fails or when additional capacity is required. Once the powder is granulated, the contamination potential is reduced. The process is then continued in the next room with steps 5 and 6 (Figure II-1) for pressing and sintering of pellets. Further steps are pin loading, decontamination, welding, and x-ray. Pin gaging, leak checking, gamma scan, eddy current, and ultrasonic nondestructive testing steps are located in a separate room and provide in-line fuel pin check inspection before delivery of the pin to the clean room fuel assembly area.

A dust-free environment is required for the fuel pins, pin assembly equipment, and subassembly testing equipment. Rooms 138, 134, and 132 are provided with airlocks and the existing controlled ventilation will provide

clean room conditions. A 15-foot deep assembly and storage pit is provided in room 134-138. In the pit, the pins and other hardware are assembled into subassemblies which are approximately twelve feet long and are transported by monorail and bridge crane to the subassembly storage pit in room 134. The assembly and storage pit is designed for the necessary physical separations and radiation shielding. For criticality considerations, no water lines are permitted within Room 134-138.

ORGANIZATION AND ADMINISTRATIVE CONTROLS

Organization and Assignment of Responsibilities

1. Project Director: Deputy Manager, FFTF Fuels Department
2. Technical Staff:
Project Leader: Manager, Process Demonstration Section is responsible for coordination of activities and direction of pilot line effort.

Engineers are assigned responsibility for operation of the facility. Two engineers are involved in the fuel preparation areas of the pilot lines (Rooms 117 and 119).

An engineer supervises the pellet pressing, sintering, and grinding areas (Room 113).

An engineer is responsible for nondestructive testing (Room 125). An engineer supervises the subassembly fabrication area (Rooms 134, 138).

Each of the engineers is supported by one or more technicians.

Supporting Departments:

Critical Mass Physics
Atmospheric Sciences
Radiation Monitoring

3. Building personnel providing support activities:
 - Engineering personnel from Plutonium Fuels Engineering; responsible for review of the facility and coordination of facility installation and operation relative to other 308 building activities.

FAST REACTOR MIXED OXIDE FUEL PIN FABRICATION

FIGURE II-2

PROPOSED ADMINISTRATIVE BATCH SIZE LIMITS FOR PROCESS DEMONSTRATION PILOT LINE

FIGURE II-3

- Maintenance personnel assigned to 308 Building
- Radiation Monitoring personnel assigned to 308 Building

Administrative Controls

1. Formal industrial radiation and nuclear safety procedures as described in BNW Operating Guides and Plutonium Fuels Laboratory 308 Building General Instructions for Radiation Zone Work, and all revisions thereto are adhered to at all times.

2. Minimum qualifications for personnel administering the Radiation Monitoring system -- Personnel assigned radiation protection responsibilities will have demonstrated competence in evaluating radiation problems associated with high exposure plutonium oxides and the instigation of proper contamination control measures.

3. Training Program for Operating Personnel -- All personnel involved in the project will have an understanding of the proper operation of special process equipment thru specialized training, and in general radiation work procedures used in the 308 Building.

Training in glove box techniques and special handling problems related to plutonium is provided to each man before fissile materials are introduced. Special attention is given to the use of air locks, bag-out procedures, waste disposal, decontamination, care of hood gloves, use of instrumentation, the general building procedures, criticality safety specifications and RWP's written specifically for the Demonstration Facility.

4. Inventory/Criticality Control -- Criticality limits are posted at each station with an inventory sheet maintaining a balance of fissile material present in the hood. A transfer of material requires independent verification by two operators. A log sheet is located on each glove box which reflects the quantity and type of material present in the station. Accounting on a by-difference basis will accumulate residue material remaining in each box for criticality considerations.

Administrative control on the fuel line is augmented by utilization of an on-line computerized data acquisition system maintained in the

office area of the 308 Building. Features of this system allow access to material status and quantities at all essential stations on the line. Inputs on movement of fuel from station to station are analyzed within the computer to assure the established parameters are not exceeded. The analysis will consist of:

- verification of the shipping station by lot or batch number to assure that the material is shown as residing in that station
- verification of the receiving station to assure the present status and the material transferred will not exceed the established criticality safety limits.

The operating station remains on standby status pending authorization of the transfer.

SAFETY ANALYSIS

Criticality Potential

The batches of fissile material that will be processed through the line allows little possibility that a critical mass could be assembled.

The hoods in the main part of the powder-pellet line are spaced 16 inches apart. All other hoods are at least three feet apart. Each hood will be limited to 45% of a critical mass; or the fuel will be limited to a safe geometry. In all operations, administrative controls are imposed such that no single error, accident, or equipment failure can result in a criticality hazard.

Criticality Limits and Controls

Each hood will either be limited to 45% of a critical mass, or else the fuel will be limited to a safe geometry.

Table II-1 presents estimated minimum critical masses and numbers of pins that will be in the line. The values for pins are for cylindrical geometry and full water reflection; all other values are for spherical geometry, full water reflection.

TABLE II-1
ESTIMATED MINIMUM CRITICAL MASSES

<u>Unmoderated Systems</u>	<u>Fuel Density (g/cm³)</u>	<u>Min. Critical Mass (kg Pu)</u>
PuO ₂ Powder	5.6	22
PuO ₂	11.46	10.8
31 wt% PuO ₂ -UO ₂ (Nat. U) Powder	5.7	72
31 wt% PuO ₂ -UO ₂ (Nat. U) Pellets	11.1	26
31 wt% PuO ₂ -UO ₂ (Nat. U) Pins	11.1 approx.	1900 pins**
31 wt% PuO ₂ -UO ₂ (94% ²³⁵ U) Powder	5.7	22*
31 wt% PuO ₂ -UO ₂ (94% ²³⁵ U) Pellets	11.1	10.8*
<u>Water Moderated Systems</u>		
PuO ₂ Powder in Water	Optimum	.52
31 wt% PuO ₂ -UO ₂ (Nat. U) Powder in water	Optimum	.60
31 wt% PuO ₂ -UO ₂ (Nat. U) Pins in water	Optimum approx.	95 pins
31 wt% PuO ₂ -UO ₂ (94% ²³⁵ U) Powder in water	Optimum	.52+*
31 wt% PuO ₂ -UO ₂ (94% ²³⁵ U) Pins in water	Optimum approx.	65 pins

* This value not yet available; so conservatively assumed to be same as for plutonium system.

** Fuel Pin - A single piece of clad tubing (√0.230" dia.) containing both fuel pellets and internal hardware components, and having a welded cap in each end.

Controls on transfers between glove boxes and storage areas include the following:

1. Transfers will be limited either to 45% of a critical mass, or be on a vehicle designed to assure criticality safe geometry.
2. Two operators must verify the form and the fissile weight of the material to be transferred before the transfer takes place.
3. In addition to operator verification, a computerized Data Acquisition System will check the transfer. Verification that the transfer does not violate any safety limits must come from both systems before the transfer is made.
4. Fuel movement outside the containment of the glove box line is accomplished through utilization of geometrically safe PuO_2 carts and fuel element carts (Figures II-4 and II-5). Engineered safety features of these carts include the provision of a fixed center-to-center spacing between fissile masses in separate carts at all times. The loading area of the oxide cart provides an inclined surface which prevents placing more than one container on the cart. Fuel cannisters are transported in a six-inch diameter receptacle in the loading surface which limits transfer to one five-inch cannister per cart.

Design of the fuel pin cart provides for loading in a horizontal position. A cranking mechanism provides for tilting the pin column to a vertical position prior to any movement of the cart. When the pins are placed in a vertical position, a 36-inch center-to-center spacing is provided with reference to all other fuel carts.

For administrative control purposes each cart is clearly labeled with its contents and the criticality safety limits.

Fuel pins in storage and subassemblies will be neutronically isolated by concrete maintaining eighteen inches edge-to-edge spacing. Individual cells will be safe dry and under water flooding.

FIGURE II-4
 PuO_2 Cart

NOTE:
FUEL ROD RACKS SHOWN
WITHOUT RODS IN PLACE

FIGURE II-5

Several engineered safety features in the glove box line are:

Hydrogen Sintering Furnace (water cooled):

Limited volume cooling system -- The one cooling circuit which is internal to the glove box is limited 1.3 gallons (about 5 liters) of water volume.

Automatic shutoffs -- In the event of a cooling failure, an automatic power shutdown should activate; if it does not, and water reached the inner shell, a pressure sensing device shuts off heater element power.

Hydraulic Pellet Press (Total oil volume = 11 gallons):

Check Valve -- A check valve is installed in the hydraulic system of the pellet press to prevent more than one gallon of oil from flowing out of a rupture in the oil line. (Continued operator surveillance is required to operate the press, and so it is unlikely that more than a few liters of oil could be forced into the glove box, even if the check valve failed).

Criticality Contingencies

Exceeding Mass Limits - The double checks on fissile material transfers outlined above make the probability of exceeding safe fissile material mass limits extremely unlikely at every point in the line.

Accidental Moderation - There are two sources of accidental moderation in the line, both of which are located at points where unmoderated fissile material limits are to be applied; these sources are a possible leak in the internal cooling circuit of the hydrogen sintering furnace, and a possible leak in the oil line (inside the glove box) for the pellet press. In both cases, a combination of engineered safety features and procedural controls make criticality contingent upon more than two simultaneous, independent, and unlikely events.

If a leak occurred in the cooling circuit located on the lid of the sintering furnace and internal to the glove box, a maximum of 1.3 gallons

of water could be released to the glove box. Engineered design of the furnace is such that the level of water would have to exceed one inch before there could be any flow past the lid. With dispersal of the entire cooling system to the glove box floor the maximum depth of the coolant water would be .3 inches. In addition, the furnace lid is attached with air-tight O-ring seal which would have to fail before any water could leak past the lid. If there were a leak in the oil line to the pellet press the total volume of oil released to the glove box would not exceed 1 gallon. If all 11 gallons of oil available were allowed to drain into the glove box, it would spread out on the box floor in a layer 3.5 inch thick (max.). Most of the pellets would be in the press, 18 inches above the box floor.

Explosion and Contamination Contingencies

Under normal operating conditions (a) if there is an internal cooling failure and (b) simultaneously the automatic power shutdown did not activate and (c) water passed the O-ring seal reaching the inner shell, a pressure-sensing device automatically shuts off the element power, avoiding a steam-generated explosion. All other gases used for sintering are non-explosive. If, due to a faulty lid seal a negative hood pressure is created by the vacuum system, a sensing device will automatically shut down the vacuum system to avoid loss of gloves. Should this device fail, the normal glove box exhaust ventilation systems and alarms would activate upon the loss of glove box integrity.

CONSEQUENCES OF MAXIMUM CREDIBLE ACCIDENTS

The maximum credible accidents in the FFTF Fuel Fabrication Demonstration Facility are taken to be the same as in Part I: (1) a criticality during process and (2) an uncontrolled fire in or out of a glove box. The consequences of both types of accidents would be the same as discussed in the PFL section of this report.

P A R T I I I

THE POLONIUM ENCAPSULATION PROJECT

SUMMARY - PART III

The polonium work in Room 213 of the 308 Building is directed to development and limited production of small, hollow, refractory metal microspheres containing a rare earth polonide. The enclosure system includes five glove boxes and two fume hoods. The glove boxes are normally ventilated by a recirculating inert gas system. The fume hoods are supplied by laboratory air which is exhausted to the normal building exhaust system. An emergency exhaust system is provided for the glove boxes in the event of loss of either containment or the recirculating inert gas system.

The polonium work is under the direction of the Manager, Isotopes Development and Applications Section. In addition to technical personnel from this section, support is provided by personnel from Radiation Monitoring, Electronics Measurement Research, Biomedical Electronics, Laboratory Engineering, Chemical Research and Analysis, and 308 Building personnel. Administrative controls are based upon the BNW Operating Guides and approved manuals.

Accidents which might result in an uncontrolled release of polonium within the 308 Building are possible. Up to 10 grams of polonium may be stored in the 308 Building at one time, but the majority of this would not be available for possible contribution to radiological accidents. A maximum credible accident is postulated: the release of one (1) milligram of polonium to the 308 Building and its environs due to a fire in Room 213.

PART III: THE POLONIUM ENCAPSULATION PROJECT

DESCRIPTION

Project Description

The polonium project is designed to demonstrate the feasibility of fabricating polonium microspheres for advanced radioisotopic heat sources meeting the safety requirements of the Atomic Energy Commission for a SNAP-29 mission.

Facility Description - General

The glove box system in Room 213 for polonium work consists of five glove boxes and two fume hoods arranged so that all transfers of material into or out of the glove boxes must be carried out inside the two fume hoods. (See Fig. III-1).

The glove boxes are provided with an inert gas (argon or helium) atmosphere which is maintained by a recirculation, purification and make-up system or a once-through flow of high purity gas. The gas pressure in the glove boxes is maintained between 0.4 inches and 1.0 inches of water below room pressure. Absolute filters are installed in each of the glove boxes on the exhaust side of the system.

The atmosphere recirculation and purification equipment is capable of limiting output impurity to < 10 ppm total impurities. The purification apparatus specifically removes H_2O , O_2 , H_2 , and N_2 from the inert gas. Expected operating impurity concentrations are ~ 30 ppm total impurities.

Each glove box is provided with an exhaust duct connected to the building exhaust system. These ducts are normally closed but are activated automatically in case of containment failure. For the once-through gas flow operation, these ducts will remain open as the expended inert gases will be exhausted to the building system. This exhaust system is connected to the 300 Area emergency power system.

The two fume hoods draw air from the room and exhaust it to the building exhaust system. Each exhaust duct is provided with an absolute particulate filter at the point of attachment to the fume hoods.

FIGURE III-1
Polonium Glove Box System

A vacuum system is located under the glove box line in a separate fume hood. The vacuum system consists of a mechanical roughing pump and an oil diffusion final pump. The vacuum system is provided with conventional oil traps for collection of impurities, including radioactive materials. Disposal tanks for drainage of dirty and contaminated oil are included as part of the vacuum system.

This hood also contains a cooling water heat exchanger and recirculating pump. Recirculated cooling water is supplied to the vacuum vapor deposition chamber, furnace cooling coils, and the oil diffusion vacuum pump.

The hood containing the vacuum and cooling water systems draws air from the room through an absolute filter and exhausts to the building exhaust system through another absolute filter.

Process Description

Figure III-2 depicts the general process. Figure III-3 illustrates the relationship of components for the typical microsphere heat source.

The process involves: (1) formation of a rare earth polonide fuel compound on the surface of refractory metal microballoons by solid-vapor reaction, (2) deposition of a refractory metal containment cladding either by vacuum vapor deposition (VVD), ion sputtering, or chemical vapor deposition (CVD), (3) CVD of a refractory metal structural cladding, and (4) CVD of a refractory metal oxidation resistant cladding. Refractory metals are those with melting points above 3600 °F (1980 °C). They are generally characterized by high temperature strength, corrosion resistance, and high melting points. Potentially hazardous materials used in the fabrication include hydrogen and refractory metal chlorides and fluorides e.g. WF_6 , WCl_6 , ReF_6 , $TaCl_5$.

Receiving and Storing Polonium

Shipments of polonium received at the 308 Building originate from Mound Laboratories, Miamisburg, Ohio. Individual shipments are limited to about 1 gram (4500 Ci) each, and are under armed surveillance enroute.

Polonium is present in the shipping package (Figures III-4 to III-6) as metal plated onto platinum gauzes. The gauzes are contained in the innermost container (See Figure III-6).

Polonium is transferred from the shipping containers into the glove box line under RWP 308-9-68. All components of the shipping package except the B of E 1349 Drum and vermiculite are passed into the system. The package is disassembled further inside a glove box to the stainless steel-brass container shown in Figures III-5 and III-6. This primary container is "wrench" tight and employs a stainless steel O-ring to insure containment. This container is stored inside a lead "cave".

Mound Laboratory has recently adopted a new shipping container designed to Department of Transportation specifications. The new container consists of a 30 gallon steel drum as an outer container, spacing material composed of particle board, and an inner container composed of a 6" diameter pipe nipple capped on both ends. A small amount of vermiculite is used to cushion the pipe nipple in the center of the shipping container.

Each 6" pipe nipple container has two smaller 1 1/4" pipe nipple containers inside, each holding 0.1 gram of polonium in a small stainless steel container like that illustrated in Figures III-5 and III-6.

Difficulty has been encountered in opening the 6" pipe nipple, requiring it to be partially opened on the laboratory floor. It is then transferred into the fume hood where the inner 1 1/4" pipe nipple containers are removed and transferred into the adjacent glovebox.

ORGANIZATION

Organization and Assignment of Responsibilities

1. Project Director

Manager, Isotopes Development and Application Section.

2. Technical Staff

Project leader - engineer, responsible for overall coordination of activities.

RADIOISOTOPE HEAT SOURCES

ALPHA EMITTERS

FIGURE III-2

<u>Symbol</u>		O.D.	
		<u>μ</u>	<u>Mil</u>
A	Void Volume	137	5.4
B	Refractory Metal Hollow Microsphere	152	6.0
C	Rare Earth Polonide	164	6.5
D	Refractory Metal Compatibility Cladding	179	7.5
E	Refractory Metal Strength Cladding	266	10.5
F	Refractory Metal Oxidation Cladding	317	12.5

FIGURE III-3 Hollow Microsphere Heat Source, Component Relationship.

FIGURE III-4 B of E 1349 Drum Containing Vermiculite and Successive Internal Containers.

FIGURE III-5 Internal Containers Opened to Stainless Steel Container with Brass Cap. This Stainless Steel-Brass Container Utilized for Glove Box Storage. Pipe Nipple and Caps are Schedule 80 Black Iron. Next Container is Copper Tube with Rubber Stopper.

FIGURE III-6 Stainless Steel Container is Sealed with Internal Stainless Steel Disc and O-Ring. Innermost Container is Tantalum or Stainless Steel with a Press-Fit Cap. Platinum Gauzes are Inside the innermost Container.

Four engineers are involved in various aspects of the technical development work. All of the engineers are supported by one or more technicians who assist the engineers and carry out assigned activities.

3. Supporting Specialists

Facilities support is provided by the Plutonium Fuels Laboratory Operation, and additional support is obtained from Laboratory Engineering as required.

One Radiation Monitoring Specialist is assigned overall responsibility for investigation and planning of radiation protection aspects of the project, procurement of necessary radiation protection instruments and supplies, and hazards analysis including writing the hazards analysis for the work.

4. Building Personnel Providing Support Activities

Engineering personnel from Plutonium Fuels Engineering - responsible for review of the facility and coordination of facility installation and operation relative to other 308 Building activities.

Maintenance personnel assigned to the 308 Building.

Radiation Monitoring personnel assigned to the 308 Building.

Administrative Controls

1. Formalized industrial radiation and nuclear safety procedures as described in Operating Guides and Manuals of Battelle-Northwest.
2. Minimum qualifications for personnel administering the radiation monitoring program.

Personnel assigned radiation protection responsibilities have:

- a) demonstrated competence in controlling radiation problems involving alpha radiation and materials of high specific activity,

- b) a good understanding of the special problems associated with handling polonium. The majority of this function is assigned to the Radiation Monitoring Specialist.

3. Training Program for Operating Personnel

All personnel involved in the project will have a satisfactory understanding of the proper operation of special equipment they will use and general radiation work practices in the 308 Building. Training in glove box technique and special handling problems related to polonium will be provided to each man on the glove box before radioactive materials are introduced. Matters given special attention will include the use of air locks, bagout procedures, waste disposal, decontamination, care of hood glove, use of instrumentation, the general building procedures, and RWP's written specifically for the polonium facility.

SAFETY ANALYSIS

Polonium Inventory

The expected inventory of polonium in the 308 Building may range up to 10 grams (45,000 curies); however, normal inventory will be < 5 grams (22,500 curies). Polonium will be present in the glove box in three distinct ways: (1) as-received metal plated onto platinum gauzes and maintained in the stainless steel-brass shipping container (refer to Figures III-5 and III-6), (2) as a rare earth polonide fuel coating, being the outermost coating on some microspheres, and (3) as an encapsulated rare earth polonide fuel coating beneath from one to four additional refractory metal coatings.

As development work proceeds, a greater percentage of polonium inventory will shift from as-received polonium to the encapsulated polonide stage. The unencapsulated, polonide coating exposed state will be limited to 0.5 grams polonium inventory.

Potential Accidents and Principal Control Mechanisms

Hydrogen Combustion -- Hydrogen gas is used as the reducing agent in CVD portions of the process. Since hydrogen is a combustible material,

special control mechanisms are provided to insure its safe use. Figure III-7 depicts the hydrogen network as used for CVD operations. Hydrogen must be considered at four distinct places: (1) outside the 308 Building, (2) inside Room 213 but outside the glove box, (3) inside the glove box, and (4) inside the fume hood.

Hydrogen located outside the 308 Building is not considered to offer any unusual hazard. When not in use, the hydrogen feed line is doubly valved off and locked to prevent inadvertant supply of hydrogen to the building during off shifts.

The hydrogen feed line penetrates the 308 Building only at Room 213. This line is approximately 15 feet long between the wall and the glove box. Control mechanisms to prevent supply of hydrogen to the Room 213 air atmosphere include:

- a) The hydrogen is valved on only when CVD operations are in use and operating personnel are present
- b) The hydrogen is shut off at the bottle and feed line valves by operating personnel in the event of any cause to evacuate the building.
- c) An electric valve is provided to shut hydrogen flow off automatically in the event of normal building power failure
- d) That portion of the hydrogen feed line which is in the room is leak tight as fabricated, and is inspected for leaks routinely. No mechanical equipment which might be capable of accidentally rupturing the line is planned for use in the facility.

Inside the glove box, hydrogen is routed through CVD apparatus as previously described. Controls on hydrogen inside the glove box include the following:

- a) The glove box is provided with an inert gas atmosphere. The purification unit removes hydrogen from the atmosphere.
- b) The CVD apparatus is tested for leaks, using argon under operating conditions of temperature and pressure, prior to introduction of hydrogen to the system.

- c) The exhaust system changes the glove box atmosphere a minimum of two times an hour.
- d) The exhaust system is on the 300 Area emergency power system.
- e) A solenoid valve located in the hydrogen line is provided to automatically shut hydrogen flow off in the event of power failure.
- f) Operating personnel are instructed to turn the hydrogen off in the event of any equipment malfunction, loss of flame at the burn-off termination, or before any evacuation except for the criticality alarm. A fast action, one-quarter turn valve is provided for this purpose.

Excess hydrogen and coating gases from the CVD process are routed through the glove box wall and into a fume hood. Here the gases are water scrubbed and excess hydrogen is burned off. Control mechanisms to prevent an accumulation of hydrogen in the fume hood include:

- a) The burn-off termination contains steel wool which maintains an ignition source for several seconds after flameout. This is sufficient to reignite hydrogen if momentary interruptions to the flow occur.
- b) The fume hood is exhausted to normal building exhaust.
- c) A solenoid operated valve is provided in the hydrogen line to shut it off in the event of normal exhaust power failure.
- d) Operating personnel are instructed to shut the hydrogen off manually in the event of any malfunction or evacuation, other than for criticality.

Fire in Combustibles

Non-essential combustibles are not allowed to accumulate inside the glove box line. Essential combustibles are limited and protected from thermal exposure. Such combustibles include wire insulation, glove box gloves, metallography polishing paper, and plastic "bagout" bags. Dry chemical fire extinguishers are provided to combat any fire inside the glove box line.

FIGURE III-7
Schematic of Hydrogen Flow for CVL Process - Room 213

There is some possibility of fire in contaminated wastes, waste rags, filters and other materials removed from the glove box system. The potential fire problems with these materials are minimized through the use of a metal cover for the waste carton and by requiring all waste of significant polonium content to be enclosed in tinned steel cans.

A maximum total of one milligram of polonium is allowed to be present in the Room 213 contaminated waste receptacle. The Po inventory in the waste is monitored by surveying the surface of the waste receptacle with a GM counter. A reading of 15,000 counts/min. or less on the receptacle surface is believed to indicate that less than one milligram of Po is contained therein. A major fire in the room could conceivably engulf the waste receptacle.

A total of one milligram polonium release to the 308 Building is considered possible from such a fire. A fire of this magnitude could not be supported by combustibles in Room 213 alone. This would require a major 308 Building fire. Based on the excellent fire protection facilities available, and on the 308 Building construction, a fire of a magnitude which would result in more than one milligram polonium release is considered incredible.

Containment Breach

Other than containment breach resulting from fire, the only possible ways to lose containment would be the breaking of a glove box window or the loss of a glove or bag. The viewing windows in the glove box are double, with plexiglass inner panes and safety plate glass outer panes; therefore, loss of containment through window breakage is unlikely. Plexiglass shields are provided over the top windows to prevent inadvertent breakage.

Containment breach through loss of a glove or a bag is possible and might result in release of polonium to the room. However, the gas recirculation system would shut down and the building exhaust system would be activated by release of the negative pressure differential between the glove box and the room. This exhaust system will draw approximately 100 cfm of room air into the box through such a breach. A serious release of polonium to the room would require failure of the building exhaust system and its emergency backup exhaust system.

Loss of Building Power, Normal Exhaust

Loss of power and normal exhaust would cause: (1) the hydrogen feed line to be automatically closed, (2) the processes and instrumentation to shut down, and (3) glove box exhaust to be switched from the recirculation system to the building emergency exhaust system. All processes are capable of immediate interruption without hazardous effect. In such an event, operating personnel would take additional precautionary measures such as completely disconnecting the hydrogen supply to Room 213 and stopping all work. The glove box line would be prepared to withstand a safe loss of even the 300 Area emergency power system. Loss of power and normal exhaust would not have hazardous effects on the polonium glove box line.

CONSEQUENCES OF MAXIMUM CREDIBLE ACCIDENT

The accident assumed for estimating potential environmental consequences is the release of 1 milligram of ^{210}Po to the building interior, due to a fire which engulfs the waste container in Room 213. The size of the polonium particles which would be released in such a fire is not known. Nor have accurate measurements been made of the size distribution of particles which become airborne as a result of normal procedures in the facility. However it is known that some of the particles are smaller than 0.04 micron, since particles that size and smaller have been observed to penetrate the primary (glove box) filters. The actual effectiveness of in-place high efficiency filters for removing such particles is not known.* If they are as effective for this particle size as for 0.3 micron or larger particles, (there is evidence in references 8 and 10 that they are not), then the release to the environs would be less than 5×10^{-4} milligrams or 2.2 millicuries, which is an insignificant amount.

To summarize, there is uncertainty both in what fraction of particles may be less than 0.3 micron, and in the filter effectiveness for such particles. Therefore two conservative assumptions are made:

- 1) All of the particles released in the building interior are considered much less than 0.3 micron in diameter.

* However, no polonium particles have been observed to pass through two high efficiency filters in series. The detection limit is at least 2×10^{-12} $\mu\text{Ci/cc}$.

- 2) The penetration of such particles through two high efficiency filters is assumed to be 100%.

On this basis, the projected dose to critical organs of an individual at 1 mile from the building due to ^{210}Po inhalation is 4 rem to the kidneys and 3 rem to the spleen. Assumptions on which the dose calculations were made are given in Appendix A.

PART IV

PROMETHIUM OXIDE PELLET FABRICATION

SUMMARY - PART IV

Fabrication of pellets of $^{147}\text{Pm}_2\text{O}_3$ is carried on in Room 114, 308 Building (as part of a heat source development project), by the Isotopes Development Section of the Fuels and Materials Department. The process includes pressing and sintering the pellets in the single glove box in Room 114.

PART IV: PROMETHIUM OXIDE PELLET FABRICATION

DESCRIPTION

Project Description

The purpose of the promethium project is to develop and produce medium-sized heat sources (15-60 watts) made of pellets of $^{147}\text{Pm}_2\text{O}_3$. ^{147}Pm is a beta emitter of high specific activity (912 Ci/gm), and heat sources made of it would be useful in aerospace and other applications.

Facility and Process Description

Pellets of promethium oxide up to 200 grams in weight are fabricated from the oxide in the single glove box in Room 114, 308 Building. Refer to Fig. I-2 for the relative location of Room 114 and to Fig. III-8 for a photograph of the glove box. This glove box is similar to a hot cell in construction; the window ports are small and the windows are sandwiches of 1 inch high density leaded glass surrounded by acrylic plastic. The gloves are made of 0.030 inch lead-loaded neoprene.

Up to 100 grams of the oxide are hand-carried at one time from 325 Building to 308 Building. The material is double-canned in tape-sealed metal cans similar to those used for shipping PuO_2 powder; the outer can contains a lining of lead. The oxide is taken immediately to the glove box in Room 114; it is neither stored nor left anywhere else in the building.

In the pelletizing process, powder is placed into a die (1/4 to 2 inches in diameter) and pressed at 100,000 to 150,000 psi for about 30 seconds. The press is connected laterally to the glove box, and containment is maintained by means of a steel bellows welded to the lower platen and to the glove box extension above it, which has the upper platen on its top. Data on this bellows appear in the following table:

TABLE III-1DATA ON THE ROBERT SHAW CONTROL CO. EXPANSION JOINT

Bellows:

I.D. = 6 inches

Bolt Circle Diameter = 9-1/2 inches

O.D. = 10 inches

No. of Holes = 8

Drill Size = 7/8 inch

Flanges:

I.D. = 6.72 inches

Traverse = 3 inches

O.D. = 11 inches

Pressure range - vacuum to 150 psi, maximum

Temperature range - 800°F for 150 psi

Once pressed, the pellets are removed from the die and sintered in a Hanford-built, 1500 W resistance-heated furnace at 1500°C for 16-24 hours.* This furnace is not water cooled. The pellets are occasionally ground to fit the tantalum inner lining of the heat capsule; they are then double-canned and taken to other buildings for encapsulation and welding.

ORGANIZATION

The promethium project is headed by the Manager, Isotopes Development Section. One engineer is responsible for the work carried on in Room 114. Supporting groups include Radiation Protection and Non-Destructive Testing.

* The furnace is not fused, and could conceivably "burn out" if its voltage regulator failed; however, the highest attainable temperature would be 1790°C, the melting temperature of the platinum windings; the melting temperature of promethium oxide is 2350°C.

Administrative controls on the movement and processing of promethium oxide are based on approved manuals and BNW operating guides. Specific controls on glove box work with promethium are outlined in radiation work procedures.

SAFETY ANALYSIS

Inventory of Promethium

The total inventory of promethium within 308 Building is not expected to exceed 400 grams. As mentioned, all this material would be located in Room 114.

Spread of Promethium from a Ruptured Can - Oxide is brought to the building after being canned so that the spontaneous heat generated will not heat the can air up to the point where the tape seal is broken. Experience indicates that this would never happen, since 60-watt (210 gram) sources have been contained in tape-sealed cans for months without heating can air sufficiently to break the seal. However, as an added safety precaution, a portable refrigerator is used to prevent even this remote possibility from occurring.

It is unlikely that in being hand-carried to the 308 Building, the double-canned oxide could be dropped in such a way that the seal on both cans is broken, particularly considering the cans will be carried inside a metal refrigerator.

Promethium is not left unattended outside a glove box within 308 Building; therefore, it is not probable that a fire within the building could result in the release of promethium.

Spread of Contamination from the Glove Box - There are three likely sources of promethium release from the glove box which will be examined in order.

- 1) Ruptured (or burned) gloves.
- 2) Ruptured press bellows.
- 3) The exhaust duct.

FIGURE IV-1
Promethium Glove Box, Room 114

BNML-CC-1906

It has been found that promethium in air produces ozone which attacks and in a few weeks seriously deteriorates rubber gloves. The gloves in this box are therefore coated with a polyester to slow down the ozone attack. To guard against this and the more routine causes of glove ruptures, the gloves are inspected regularly and changed at the first sign of weakening. If an undetected fire occurred in the glove box, there is a possibility that gloves might be burned; however, unless the fire were quite large and spread out, the glove box exhaust would probably prevent extensive release of promethium to the room air. Accumulations of combustibles both in the glove box and in the room are procedurally limited, and gloves are not permitted to extend into the box when not in use.

The bellows welded around the press are very unlikely to rupture unless stretched beyond the design limitations. To assure that this will not happen, metal stops (visible in Fig. III-8) have been set on the posts surrounding the press, to prevent its traverse from exceeding 3 inches.

The exhaust duct for this glove box is equipped with the standard high efficiency filter. Measurements on the downstream side of this filter revealed no detectable amounts of promethium being passed by the filter. In the event this filter were destroyed by fire, the two back-up filter beds downstream would do an equally effective job of stopping the oxide.

CONSEQUENCES OF MAXIMUM CREDIBLE ACCIDENT

The maximum inventory of unencapsulated, exposed ^{147}Pm is 400 grams, stored only in the Room 114 glovebox. If an accident is postulated in which all 3.65×10^5 Ci of ^{147}Pm as oxide is airborne in the facility, the release to the environs would be 180 curies. (A filter penetration factor of 5×10^{-4} was used: 99.5% removal efficiency.)

The projected dose to the critical organ of an individual at one mile from ^{147}Pm inhalation is estimated to be 3.4 rem to bone tissue.

Assumptions on which the calculations are based are given in Appendix A.

P A R T V

EXPERIMENTAL STUDIES WITH HIGH ACTIVITY MATERIALS

SUMMARY: PART V

Basic experimental work on thermal and other properties of highly radioactive materials will be carried out in glove boxes in Rooms 219, 220, 223, and 225, 308 Building. Two studies, one on melting point determination and the other on thermal diffusivity measurement, are discussed to show the type and scale of work involved.

PART V. EXPERIMENTAL STUDIES WITH HIGH ACTIVITY MATERIALS

DESCRIPTION AND ORGANIZATION

Equipment and Process Description

Glove boxes in Rooms 219, 220, 223, and 225 will be used for experimental studies on small amounts of ^{147}Pm , $^{147}\text{Pm}_2\text{O}_3$, $^{244}\text{Cm}_2\text{O}_3$, $^{241}\text{Am}_2\text{O}_3$, $^{238}\text{PuO}_2$, and perhaps other high activity materials. These studies will include, but are not necessarily limited to, melting point and thermal diffusivity tests and x-ray diffraction experiments.

Although the total inventory of radioactive material may exceed 10 grams, the amount actively studied at any one time is about one gram or less; transfers between glove boxes are infrequent and usually involve less than 1/2 gram. Two studies are discussed in some detail to indicate the limited scale of operations and the type of equipment used: the melting point and thermal diffusivity experiments, both carried on in glove box 113, Room 219.

The melting points of various materials are to be determined by means of a small, 20 kW induction-heated furnace. The outer wall of the furnace is a stopped glass cylinder about 4 inches in diameter and 1 foot in length. The hot zone is in the center of a centrally located water-cooled copper block (about 3-1/2 inch diameter), which is surrounded by copper heat shields and atmosphere insulated from the furnace outer wall. In the center of the copper block sits a 3/4 inch diameter graphite crucible with a 1/4 inch deep x 1/4 inch diameter depression for holding samples. The maximum sample temperature attainable with this arrangement is less than 3000 °C; melting is determined by photodiodes.

Water cooling in 1/4 inch metal lines goes to the induction leads, as well as to the copper block current concentrator. The total volume of the recirculating water system in the glove box is approximately 10 gallons. Continuous surveillance is required while this furnace is operating. The

furnace has a quick response; it will cool at 1,000 °C/min. after power to it is shut off. Automatic shutoff will occur if the cooling water system fails.

Heat capacity and thermal diffusivity tests will be performed on ceramic materials in a high-temperature, resistance heated, laser-pulsed diffusivity furnace. The furnace consists of a metal outer shell and lid (cooled externally) and a water-cooled inner shell (4 in. diam.) containing both heat shields and a 1-1/2 inch diameter x 4 inch tungsten mesh heater. In the center of the heater a tungsten tube is suspended with a 1/4 inch hole. One ceramic pellet (200 mg) is held in this hole by tungsten prongs. Thermal diffusivity measurements can be made to approximately 2500 °C. The sample is instantaneously heated to slightly higher temperature by a pulsed, 5-joule, 1/2 inch (0.6 micron wavelength) laser beam, which comes through a glass-covered aperture in the bottom of the furnace. Cooling water flows inside the furnace in two separate coils: one to the heater electrodes and one to the copper shell. Continuous surveillance is required during operation of this furnace. Automatic shutdown occurs if the cooling system fails.

Organization

The experimental work is directed by the Manager, Physical Ceramics Section, Metallurgy and Ceramics Department. Support is provided by Radiation Monitoring.

SAFETY ANALYSIS

The nuclear safety concern with this work is to determine credible contingencies for gross release of radioactive materials.

Inventory

The following are maximum expected inventories:

<u>Material</u>	<u>Grams (net)</u>	<u>Grams of Radioactive Material</u>	<u>Curies</u>
^{147}Pm (as metal)	20	20	18,000
^{147}Pm (as ceramics)	40	35	32,000
$^{244}\text{Cm}_2\text{O}_3$	15	13.6	1,100
$^{241}\text{Am}_2\text{O}_3$	15	13.6	44.5
$^{238}\text{PuO}_2$	30	26.5	450

Controls on Contamination Release

Radioactive material is placed in a tape-sealed metal can, double bagged, and taped in a metal outer can before being transferred between glove boxes. It is not left outside of glove boxes (except in insignificant quantities or in approved shipping containers). Gross release during transfer within the building is not considered likely.

Gloves and bags are checked routinely for softening and holes, and glove boxes are equipped with standard self-sensing exhaust and ventilation valves to maintain negative box pressure.

Standard fire prevention practices are in effect: accumulations of flammable materials are not allowed to build up in the glove box, and fire extinguishers are close at hand which may be inserted into the box through a special attachment.

Contingencies

If all the water in the recirculating system were released in the glove box, the water level would be far below the lower row of glove and bag ports. Therefore, flooding is not a contingency for contamination release in this glove box.

A gross leak in a cooling line inside the melting point furnace could conceivably cause rapid enough steam formation to blow the furnace

apart, perhaps resulting in rupture of one or more gloves and release of some glove box air. However, such a leak is exceedingly improbable considering the construction of the metal tubing and fittings inside the furnace; and a slow leak would be readily detected by the operator who would shut down both the water system and the furnace. The same comments apply to the laser-pulsed furnace; it should be further noted that in the latter case no cooling lines run above the hot zone, so that water from a leak would tend to fall away from it.

A fire inside the glove box which destroys one or more gloves is left as the most credible cause of contamination release. Such a fire would most likely be started by an overheated furnace or electrical short occurring while an operator was in attendance; it would probably be extinguished before more than a few liters of air were released to the room.

CONSEQUENCES OF MAXIMUM CREDIBLE ACCIDENT

To estimate the potential environmental consequences of accidents involving ^{147}Pm , ^{244}Cm , ^{241}Am , and ^{238}Pu , we have assumed that all the inventory of these isotopes within the facility became airborne. We do not postulate how this would occur. It seems unlikely that more than a small fraction would become airborne in an accident. For each of the materials the expected effectiveness of the high efficiency filters would be at least 99.95%. The resulting release to the environs would be 25 Ci of ^{147}Pm , 0.55 Ci of ^{244}Cm , 0.022 Ci of ^{241}Am and 0.23 Ci of ^{238}Pu .

Table V-I shows the projected dose to individuals at one mile distance from inhalation of these nuclides.

TABLE V-I

Projected Dose to Bone, Lung or Kidney Following Inhalation at 1 Mile

	<u>Projected Dose - Rem</u>		
	<u>Bone</u>	<u>Lung</u>	<u>Kidney</u>
^{147}Pm	0.47		
^{244}Cm	45		
^{241}Am	3		2
^{238}Pu	90	8	

Assumptions on which the calculations are based are given in Appendix A.

PART VI

INTERACTIONS BETWEEN FACILITIES

PART VI: INTERACTIONS BETWEEN FACILITIES

The Plutonium Fuels Laboratory was designed structurally and mechanically to minimize interactions between rooms within the building. The addition of administrative operational procedures are instrumented to further reduce the probability of interaction. Ten years of operation has demonstrated the effectiveness of the design and the procedures. The initial years of operational experience revealed deficiencies in the ventilation system controlling interlocks. These were corrected, and a low rate of interaction in the building with unusual conditions existing in one or more laboratory rooms has been achieved.

The 308 Building design provides for contamination control and containment. Compartmentation is attained with non-load bearing walls that limit contamination spread. The directional ventilation system supply and exhaust ducts are systematically arranged to permit almost unlimited compartmentation of the building. With these design features, additional room compartmentation is feasible without increasing the probability of interaction. Ventilation is essentially independent in each laboratory room. Air balance between rooms is not effected by changing building air flow volumes. Air balance between rooms may be changed, however, when it is desirable to do so. Almost all laboratory work within the PFL building involves materials presenting radiological hazards which are handled with similar PNL cautions.

Unencapsulated materials are handled in glove boxes. The glove boxes are not subject to ventilation interaction. The major potential interaction is the contamination of one glove box exterior by release from another glove box in the same room.

Minor contamination releases (encountered during glove and bagging operations) are controlled by the directional room ventilation, so will not contaminate an adjacent glove box. Only a major incident (e.g. fire or explosion) will result in contamination spread to other glove boxes or equipment in the same room. In such an event, all operations within the room are effected by the contamination.

Duplication of expensive equipment or facilities is avoided by sharing equipment between different groups whenever operational interaction or interference with product quality is not likely. Examples of facilities shared in 308 Building include:

Room 101	fuel closure and component
(shared by)	FFTF and Plutonium Fuels Engineering
Room 111	decontamination of weld closure zones
(shared by)	FFTF and Plutonium Fuels Engineering
Room 103-135	radiography
(shared by)	FFTF and Plutonium Fuels Engineering
Room 138	vibrational compaction
(shared by)	FFTF and Plutonium Fuels Engineering
Room 219	metallography and ceramography
(shared by)	FFTF and Plutonium Fuels Engineering, and Chemical Ceramics
Room 231	etching of fuel components
(shared by)	FFTF and Plutonium Fuels Engineering

A room monitor system is established in the 308 Building to provide administrative control of interaction in and between rooms. The functions and safety of each room are controlled by at least one monitor and an assistant. The monitors are selected from the operational group responsible for the space. In joint use areas, monitors may be selected from each of the occupant groups.

Free laboratory access is restricted to those persons having necessary laboratory business. These include assigned operational and service personnel. A building orientation is required before free access is permitted. Visitors are required to be under escort of assigned personnel. An accountability board is located at the entrance to the laboratory, and those entering or leaving are required to so indicate on the board. The board also provides a means of accounting for personnel in event of an emergency. The controlled access to the building, plus the accountability requirement assist in interaction control between groups.

A crew of experienced personnel from all operating groups in the building is assigned to act in emergency situations. Building patrol by the emergency crew is provided when emergency alarms (except criticality) are inactivated by fault or for test. Building operations are completely suspended without criticality detection.

The foregoing items of this section are presented to demonstrate that the multiple group occupancy of the building does not compromise safety. Years of operating experience in the building support the conclusion that interactions during normal and abnormal conditions are minimal, and with planned continuing effort they will remain so.

REFERENCE LIST

1. Abbey, F., "The Criticality of Interacting Arrays," (Criticality Control of Fissile Material, IAEA, 1966).
2. Aspinall, R.J., "Criticality Detection Alarm Systems: Design Features" (Criticality Control of Fissile Material, IAEA, 1966).
3. Report of Committee II on Permissible Dose for Internal Radiation, ICRP Publication II, 1959.
4. Bailey, W.J. Burnham, J.B., and Merker, L.G., "Facility Hazard Analysis for 308 Building" (HW-70047, 1963).
5. Clayton, E.D., and Hansen, L.E., "Criticality of Pu Compounds" (Nuclear Applications, August 1, 1967, pp. 481-487).
6. Clayton, E.D. et al, "Criticality Research on Plutonium," (Criticality Control of Fissile Material, IAEA, 1966).
7. Coffinberry, A.S., and Miner, W.N. (Editors): The Metal Plutonium University of Chicago Press, 1961).
8. J. Dymant. The Penetration of Fibrous Media by Aerosols as a Function of Particle Size. (undocumented).
9. M.M. Hendrickson, EXDOSE, A Computer Program for Calculating the External Gamma Dose from Airborne Fission Products BNWL-811, 1968
10. R.F. Hounam, Calculations of the Filtration of Airborne Dust by an Asbestos-Bearing Filter Paper AERE HP/M 119.
11. King, G.E., and Howell, W.P., "Radiation Protection Aspects of Work with Promethium-147," (BNWL-SA-1038, 1968).
12. Lbov, A.A., Sel'chenkov, L.I., and Zysin, Yu. A., Fission Product Yields and their Mass Distribution (Consultant's Bureau, 1964).
13. Merker, L.G., and Thomas, I.D., "Hanford Plutonium Fuel Development Laboratory" (HW-SA-2904, 1963).

14. "Development of Plutonium-Bearing Fuel Materials" (NUMEC P-100, 1962).
15. Stratton, W.R., "A Review of Criticality Accidents," (LA-3611, 1967).
16. "SEFOR Safety Analysis Report, Vol. II" (AEC Docket No. 50-231).
17. Wachter, J.W., "A Study of Y-12 Area Monitoring for Critical Bursts."
18. Wick, G.J., (Editor), Plutonium Handbook, Vols. I and II (Gordon and Breach, 1967).
19. Wittenbrock, N.G., "300 Area Site Description" (BNWL-CC-1693).

APPENDIX A

All estimates of the projected dose to individuals in the environs made use of the following assumptions and models.

Bivariate normal mode equations were used to calculate the atmospheric dispersion of the released material. Parameters commonly used for Hanford conditions and terrain were used in these equations. (Ref. 9).

The release of material from the facility occurred at a height of 50' during unfavorable (low wind speed, moderately stable) atmospheric conditions when dilution of material in a plume was minimal. The release occurred during a short period of time (10 minutes) so there was no dilution from plume spreading by wind direction variations. At the exposure point the individual remained at the plume centerline where exposure is greatest for the duration of plume passage. The rate of inhalation (breathing rate) was 20,000 cc/min (350 cc/sec average).

Standard man parameters as recommended by the ICRP^(Ref. 3) were used. The projected lifetime dose was calculated.