An Increment of Analysis

**Estimated Airborne Release
of Plutonium from the 102
Building at the General Electric
Vallecitos Nuclear Center,
Vallecitos, California, as a
Result of Damage from Severe
Wind and Earthquake Hazard**

December 1980

**Prepared for
Division of Environmental Impact Studies
Argonne National Laboratory
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

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ESTIMATED AIRBORNE RELEASE OF PLUTONIUM
FROM THE 102 BUILDING AT THE GENERAL
ELECTRIC VALLECITOS NUCLEAR CENTER,
VALLECITOS, CALIFORNIA, AS A RESULT OF
POSTULATED DAMAGE FROM SEVERE WIND AND
EARTHQUAKE HAZARD

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ABSTRACT

This report estimates the potential airborne releases of plutonium as a consequence of various severities of earthquake and wind hazard postulated for the 102 Building at the General Electric Vallecitos Nuclear Center in California. The releases are based on damage scenarios developed by other specialists. The hazard severities presented range up to a nominal velocity of 230 mph for wind hazard and are in excess of 0.8 g linear acceleration for earthquakes. The consequences of thrust faulting are considered. The approaches and factors used to estimate the releases are discussed. Release estimates range from 0.003 to 3 g Pu.

SUMMARY AND CONCLUSIONS

The potential mass of airborne plutonium that could be released to the atmosphere around a facility (the source term) as a result of wind and earthquake damage was estimated for the 102 Building at the General Electric Vallecitos Nuclear Center in California. The source terms can be used for estimating potential inhalation dose to the "maximum" individual and to the total population living within a prescribed radius of the site. The respirable fraction of airborne particles is thus the principal concern.

The estimated source terms were based upon the damage ratio, i.e., the fraction of the equipment holding plutonium that would be crushed or perforated during events of varying severity, and the potential airborne releases if all the equipment suffered that level of damage. In an attempt to provide a realistic bound of potential source terms that included the range of facility use, "high" and "low" estimates are provided. The range of source terms was calculated by combining the upper and lower bounds of damage ratios for equipment (glove boxes, and exhaust filters attached to glove boxes) with the airborne releases from the equipment. The releases were based only on the presence of a maximum probable inventory of surface contamination. Factors used to evaluate the fractional airborne releases of materials and the exchange rates between enclosed and exterior atmospheres are discussed.

The postulated damage and source terms are discussed for wind and earthquake hazard in order of increasing event severity.

The largest postulated airborne releases from the building are for the maximum wind hazard (nominal wind speed 230 mph) and for the most severe earthquake hazard (peak ground acceleration in excess of 0.8 g) considered in this study. Both hazard scenarios postulate essentially complete destruction of the ground-level portion of the building. The source terms are expressed as the mass of plutonium particles 10 μm in aerodynamic equivalent diameter^(a) (AED)

(a) Aerodynamic equivalent diameter: particles exhibiting the aerodynamic behavior of a unit density sphere of the stated size.

released with time (up to 4 days). The overall source terms for the damage scenarios evaluated are shown in Table 1 in the order of increasing severity of wind and earthquake hazard.

TABLE 1. Source Term Estimates for the 102 Building at the General Electric Vallecitos Nuclear Center as a Result of Wind and Earthquake Hazard

Event	Mass Release of Plutonium in Respirable Size Range, (a) g	
	High Estimate	Low Estimate
Wind Hazard		
Maximum wind speed 95 mph (42.5 m/s), 3×10^{-6} per year probability of occurrence	No significant damage postulated	
Maximum wind speed 135 mph (60 m/s), 6×10^{-7} per year probability of occurrence		
Instantaneous	0.003	(0.05)(b) 7×10^{-4}
Additional mass released in next 2 hours	0.008	5×10^{-5}
Additional mass released in next 6 hours	0.01	1×10^{-4}
Additional mass released in next 16 hours	0.06	4×10^{-4}
Additional mass released in next 3 days	0.3	0.002
Maximum wind speed 180 mph (80.5 m/s), 1×10^{-7} per year probability of occurrence		
Instantaneous	1	(2)(b) 0.3
Additional mass released in next 2 hours	0.04	0.02
Additional mass released in next 6 hours	0.1	0.06
Additional mass released in next 16 hours	0.3	0.2
Additional mass released in next 3 days	2	0.8
Maximum wind speed 230 mph (103 m/s), 1×10^{-8} per year probability of occurrence		
Instantaneous	2	(3)(b) 0.8
Additional mass released in next 2 hours	0.06	0.06
Additional mass released in next 6 hours	0.2	0.2
Additional mass released in next 16 hours	0.5	0.4
Additional mass released in next 3 days	2	2
Earthquake Hazard		
Peak ground acceleration less than 0.4 g, probability of occurrence greater than 4×10^{-3} per year	No significant damage postulated	
Peak ground acceleration in the range of 0.4 to 0.8 g, 1×10^{-3} per year probability of occurrence		
Instantaneous	0.03	(0.05)(b) 7×10^{-4}
Additional mass released in next 2 hours	3×10^{-4}	5×10^{-5}
Additional mass released in next 6 hours	8×10^{-4}	1×10^{-4}
Additional mass released in next 16 hours	0.002	4×10^{-4}
Additional mass released in next 3 days	0.01	0.002
Peak ground acceleration in excess of 0.8 g, less than 10^{-3} per year probability of occurrence		
Instantaneous	2	(3)(b) 0.8
Additional mass released in next 2 hours	0.001	6×10^{-4}
Additional mass released in next 6 hours	0.003	0.002
Additional mass released in next 16 hours	0.008	0.004
Additional mass released in next 3 days	0.04	0.02
Peak ground acceleration 0.6 g with 1 m displacement caused by thrust fault		
Instantaneous	1	0.2
Additional mass released in next 2 hours	0.02	0.2
Additional mass released in next 6 hours	0.02	0.05
Additional mass released in next 16 hours	0.05	0.003
Additional mass released in next 3 days	0.2	0.01

(a) Particles 10 μ m and less in aerodynamic equivalent diameter.

(b) Total mass of plutonium airborne.

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INTRODUCTION

If the structure and equipment that provide the containment of radioactive materials fail because of the stresses imposed by the impact of a natural phenomenon, the downwind population can be subjected to a radiological hazard from the airborne material. The estimated airborne releases of contained radioactive material form the basis for calculating dose which is one component of an overall risk analysis.

This report is a part of an interdisciplinary study sponsored by the United States Nuclear Regulatory Commission (NRC) and coordinated by the Division of Environmental Impact Studies of the Argonne National Laboratory (ANL). It is one increment in a series dealing with the potential airborne releases of plutonium from licensed plutonium fuel fabrication facilities. The study estimates the potential release from the 102 Building at the General Electric Vallecitos Nuclear Center in California, from the impact of severe wind and earthquake hazard.

The estimates of airborne plutonium release were developed by identifying the damage sustained by the structure and equipment at varying severities of wind and earthquake. The Pacific Northwest Laboratory (PNL)^(a) staff used data developed by other specialists. The Los Alamos Scientific Laboratory (Endebrock 1979) provided data on the potential responses of the structure and equipment to various severities of earthquake hazard. The Disaster Research Institute of Texas Tech University provided similar information for wind hazard (Mehta, Smith and McDonald 1980).

The primary concern in the calculation of downwind dose for this study is inhalation (McPherson and Watson 1978, p. 3), and in this increment of the series the primary emphasis is the release of plutonium particulate material of a size range that can be carried downwind and inhaled. Particles of 10- μ m aerodynamic equivalent diameter (AED)^(b) or less are conservatively assumed

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

(b) Aerodynamic equivalent diameter: Particles exhibiting the aerodynamic behavior of a unit density sphere of the stated size.

to be the respirable fraction. Such an assumption overstates the potential effect by a factor of 1.5 to greater than an order of magnitude, depending upon the lung deposition model chosen (Mercer 1977, Figure 1). The behavior of the structure and equipment in accident situations is not precisely understood. With such uncertainties, the estimates of airborne releases tend to be conservative, that is, estimates are probably greater than the releases that would actually be experienced.

BUILDING AND PROCESS DESCRIPTION

The initial step in estimating the potential airborne releases of plutonium is to find out what materials and equipment are present and to identify those features and operations that could influence the material released. The information was gathered from documents issued by Engineering Decision Analysis Company (EDAC), the NRC, and PNL. This information includes descriptions of the structure and of the process (which influences the types and locations of equipment). The amounts and forms of materials present, and information on engineered safety systems are also included.

BUILDING DESCRIPTION (EDAC 1977)

The 102 Building (Radioactive Materials), of one-story construction, is located in the fenced portion of the I00 Area of the Vallecitos Nuclear Center (VNC) (Figure 1). The primary plutonium processing laboratory is housed in the basement. The basement floor and ground floor slabs are composed of reinforced concrete, as are the basement walls, columns, and footings. The construction is monolithic, with conventional joints and is heavily reinforced. The Radio Metallurgy Laboratory (RML) cells are of heavy, reinforced concrete and are structurally joined with the basement walls and the first floor slab.

The ground floor interior walls are composed of 8-in. and 4-in. reinforced concrete blocks, precast reinforced concrete, and wood studs with gypsum board. Resistance to horizontally-acting loads on the ground floor is provided by interior 8-in. concrete block partition walls and exterior precast concrete walls that connect to the roof system, steel columns, intersecting walls, and floor slab. The roof has structural steel framing and a metal deck supported by structural steel columns. Although the structural steel framing was not designed for earthquake loads, it functions as a bounding frame for the interior concrete-block shear walls and thus acts as a part of the lateral load system.

FIGURE 1. Plan View of the 100 Area, Vallecitos Nuclear Center

Plan views of the ground floor showing the location of the Plutonium Analysis Laboratory (PAL) and the Radio Metallurgy Laboratory (RML) hot cells, and of the basement in which the Advanced Fuel Laboratory (AFL) is housed, are shown in Figures 2 and 3, respectively.

Radio Metallurgy Laboratory Hot Cells

The RML is located on the south end of the ground floor of the 102 Building (see Figure 2). Most operations involving by-product materials (dissolution, separation, conversion to final product or waste form, etc.) are performed in the RML hot cells. The four principal hot cells are relatively compact, massive structures with 2- to 3-ft-thick walls of high-density concrete. Cells handling mixed-fission products and alpha-emitters are equipped with a 3/16-in.-thick, free-standing, stainless steel liner.

Plutonium Analytical Laboratory

The PAL is located in the middle of the east side of the ground floor of the 102 Building (see Figure 2). The laboratory's primary function is to analyze plutonium solutions and compounds. Although the quantity of plutonium in this area is limited, the plutonium in this location is included in this description because of its apparent vulnerability.

Advanced Fuel Laboratory (Endebrook, 1979, p. 12)

The AFL is located in the basement (see Figure 3). The AFL perimeter walls consist of reinforced concrete and concrete masonry. The exterior walls of the basement are constructed of reinforced concrete and supported on concrete footings. The heavily reinforced concrete roof slab is supported by the exterior walls, by the reinforced concrete columns, and by the interior walls. The basement floor slab is not connected structurally to the walls, columns, or footings. The critical glove boxes and exhaust equipment in the basement have recently been modified and connected to the basement construction to provide additional seismic support. The arrangement and number of the enclosures is shown in Figure 3 and their functions designated in Table 2.

FIGURE 2. Building 102 Main Floor

FIGURE 3. Building 102 Basement and Advanced Fuel Laboratory Glove Box Arrangement

TABLE 2. Identification Key--Advanced Fuel Laboratory

Enclosure I.D.	Enclosure Function or Use
007	Pellet sintering (used only periodically)
017	Check-source storage cabinet
022	Fume hood (used to open shipping containers); scaled fuel rod decontamination; temporary storage of nitrate solutions
023	Powder vibratory compaction
024	Fuel rod welding
027	Pellet characterization--immersion density measurements
028	High-temperature properties studies
029	Metallography
030	Microthermogravimetric analysis
031	Inert-atmosphere capsule welding; thermal migration studies
032	Auxilliary support of 031
034	Neutron coincident measurements
035	General purpose; vacuum outgassing; dissolution studies
037	Powder blending and hammermilling
038	Powder densification and granulation
039	Pellet pressing
040	Sintering furnace
041	Pellet grinding
042	Macrothermogravimetric analysis and characterization
043	Fuel rod loading and decontamination
044	Maching (pellet studies)
046	Storage
050	Scrap recycling
050A	Load-out for scrap recycle
051	Nitrate conversion and coprecipitation
051A	Load-out for nitrate conversion
051B	Off-gas scrubbing
065-074	Fuel pin storage cubicles
090	Waste barrel storage
096	Waste barrel storage
Vault	48 storage cubicles
Vault	9 storage cubicles--nitrate solution storage
Vault	Floor storage area--limited to material contained in DOT/NRC approved shipping containers

PROCESS (Mishima et al. 1979a)

The primary plutonium processing area at VNC is the AFL. Powder characterization and chemical tests only are performed in the ground floor PAL. The AFL is an experimental facility involved in the production of mixed oxide (MO) fuel. The plutonium dioxide content of MO fuel ranges from 10% to 25% with an average value of 20%.

Operations are nonroutine in that this is not a production facility, although the procedures followed may be the same from run to run. The AFL has the capability to dry-blend oxides, however the primary emphasis is on co-precipitation of uranium and plutonium, which are handled as an entity after the initial mixing of solution. (Definition of the process and scrap recovery chemistry of the co-precipitation process is one of the tasks of the facility.) Thus, the plutonium and uranium compounds and physical forms may be more varied than those encountered in a dry-blending production facility. Fuel elements may be produced by pellet loading or vibration compaction.

INVENTORY (Burkhardt 1977)

Essentially three types of activities are conducted in the 102 Building: hot cell operations, chemical and physical analysis in laboratories located on the first floor, and development of advanced fuel processes in the laboratory located in the basement of the building. Additionally, there is a small storage pool and a dry-storage pit with access on the first floor.

Radio Metallurgy Laboratory Hot Cells

Cell 1--is used to encapsulate ^{60}Co , ^{192}Ir and to prepare nuclear power reactor start-up sources (Sb-Be for GE, Am-Be-Cu for B and W). Sealed sources of ^{124}Sb are given nondestructive examination in this cell. A maximum and normal working inventory in the cell is: ^{60}Co , 100,000/20,000 Ci; ^{192}Ir , 50,000/10,000 Ci; ^{124}Sb , 20,000/5,000 Ci.

Cell 2--is not used for by-product material. It is dedicated to destructive and nondestructive examination of irradiated fuel elements and structural materials. Fixed contamination in this cell is primarily actinides.

Cell 3--has a stainless steel liner and internal high efficiency particulate air (HEPA) and charcoal filters. It is used for fission product separation of ^{99}Mo and ^{133}Xe produced by the General Electric Test Reactor (GETR). The fuel has been exposed to less than 100 kw for 7 days and has approximately a 10 hour cooling time. The maximum radioactivity inventory is estimated by General Electric (GE) to be:

Noble gases	13,500 Ci
Halogen	17,900
Particulates	54,000,000
Actinides	72

The normal working inventory would be about one-half the above.

The GETR reactor was shut down on October 27, 1978 and it was estimated that there would be about one week's more operation in this cell. GE advised that a new procedure was ready for installation and use to minimize a I_2/Xe offgas problem; further details were not obtained.

Cell 4--also has a high-integrity stainless steel liner. A portion of the cell is used for double encapsulation of ^{60}Co . The remaining portion of the cell is used for miscellaneous alpha-type source preparation. Fixed and loose contamination is primarily alpha.

Cell 5--is a small cell dedicated to sample preparation and metallographic examination of irradiated fuels and structural components--usually those from Cell 2.

Cell 6--is used to handle, package and, at times, store miscellaneous B/ γ emitters (Se, Sr, Sn) that are present to a maximum 60 Ci and normally to 10 Ci.

Cell 7 and 8--do not exist.

Cell 9--is used to handle and package Beta emitters (C-14, P-32 and Ni-63). The packaged isotopes are stored in a nearby glove box.

Inventory at these locations varies from 1-100 Ci.

Analytical Laboratories

A radiochemical laboratory and a plutonium analytical laboratory are located on the first floor. Only small quantities of isotopes are analyzed in

the radiochemical laboratory. Solutions, powders and ceramics are analyzed in the plutonium laboratory. A maximum inventory of 200 g Pu is allowed with a normal working level at one-half this amount.

Advanced Fuel Laboratory

Three types of operations are conducted in the AFL. The quantities of plutonium, its location and form, and the process conducted are listed in Table 3. Duty cycle (the fraction of time the quantities of plutonium listed are in jeopardy) is not given. Not all operations are conducted simultaneously nor are the operations conducted continuously as in a production facility.

ENGINEERED SAFETY SYSTEMS (Mishima et al. 1979a, pp. 8-9)

Heat, Ventilation, and Air Conditioning

Room air in the AFL is drawn into most of the enclosures via filters equipped with rain shields. The room is at a negative pressure with respect to the atmosphere, and the enclosures are at a negative pressure with respect to the room. Glove Box 40, the sintering furnace, is an exception and is held at a few inches water guage (WG) positive with respect to the room pressure. All overhead exhaust ducts are currently being converted to a stainless steel pipe. During the transition period, they are composed of a combination of stainless steel, painted mild steel, and plastic. Some enclosures have flexible (spring-reinforced plastic) connections attached to the exhaust system. Exhaust flows are controlled by valves designed to maintain a constant pressure differential between the enclosure and exhaust system. Loss of a single gloveport or similar item would not result, then, in an airborne release of a significant amount of the contained radionuclides.

Exhaust air from the glove boxes and RML cells pass through two sets of HEPA filters, in series, inside the 102 Building before entering the 60-in.-dia stainless steel duct on the roof-high bay area (southeast corner) of the building. The duct is supported on a steel truss bridge. The fans and final HEPA filters for the exhaust system are housed in the 102A Building (Mechanical Equipment).

TABLE 3. Normal Maximum Inventory, Advanced Fuel Laboratory
(Potential Material at Risk)

Operation	Box	Process	Container	Form ^(a)	Pu, g	Condition
Ceramic Line	37	Equilibration	Pan	PuO ₂	2,500 ^(b)	Powder
Processing	37	Blending	Cans or blender	MO	2,500 ^(b)	Powder
	37	Hammermilling	Cans or hammermill	MO	2,500 ^(b)	Powder
	38	Prepressing and granulating	Cans, press or granulator	MO	2,500	Slugs or coarse powder
Scrap Recovery	50	Preparing for dissolution	Can	MO	1,200	Powder or pellets
	50	Dissolution	Dissolver	MO	1,200	Solid/liquid
	50	Concentration	Concentrator	MN	1,200	Liquid
	50	Product loadout	Glass tank	MN	1,200	Liquid
Nitrate Conversion	51	Holding	Glass tank	MN	2,400	Liquid
	51	Blending	Glass tank	MN	2,400	Liquid
	51	Holding	Can	MO	1,200	Powder
	51	Reduction	Reduction vessel	MO	1,200	Powder
	51	Storage	Can	MO	1,200	Powder

(a) MO = mixed oxide. MN = mixed nitrate.

(b) Only one quantity in box at a time.

Fire Protection System

Fire detection and protection is provided in the AFL. Both thermal and smoke detectors are used. An overhead sprinkler system, and dry extinguishers fitted with a special probe for piercing gloves are currently provided. The fire potential in the facility is limited. Most of the structural material (concrete, metal, etc.) will not burn under normal circumstances. A limited amount of combustible material (celluloic waste in 55-gal drums, rubber and plastic gloves, wood, etc.) and materials that can provide fuel when heated (plastics, such as the enclosure windows and exhaust ducts) are sometimes present. Two hydraulic fluid reservoirs are located in the ceramics processing area under Glove Boxes 38 and 39. The hydraulic fluid currently in use is water soluble and a limited volume of isopropanol^(a) is available in Glove Box 39 where it is used as a die lubricant. The normal amount of isopropanol present is 50 mL; the maximum inventory is 200 mL.

AREAS OF CONCERN (Mishima, Schwendiman, and Ayer 1977)

Prior to the availability of an inventory at risk, a subjective evaluation was made of the enclosures having the greatest potential for airborne releases of plutonium in the event of a serious loss of integrity. The relative importance of the plutonium forms routinely handled in the enclosures are ranked below in order of decreasing relative difficulty of suspending in air that form and its plutonium content:

- concentrated plutonium solutions
- dry, mixed-oxide powders
- concentrated mixed-oxide solutions
- damp/wet, mixed-oxide powders
- mixed-oxide powder
- contaminated materials.

Undiluted plutonium dioxide powder is potentially present only in Enclosure 37 (powder blending and hammermilling) and is uncontained during equilibration. Concentrated plutonium solutions are not normally present.

(a) Flammable limits in air: 2% to 12%; flash point: 58°F; autoignition temperature: 750°F.

Ion exchange separation of the plutonium and evaporative concentration are nonstandard and infrequent operations. Dry, mixed-oxide powder is found part-time in Enclosures 37 and 51 (nitrate conversion-coprecipitation) but is primarily found in storage cans or equipment. Concentrated mixed-oxide (or nitrate) solution always in equipment or vessels is found in Enclosures 50 (scrap recycling) and 51. Thus the enclosures of principal concern (based upon quantity and physical form of plutonium potentially present) are 37, 38, 50, and 51.

Two other potential sources of airborne plutonium must also be considered since they are found in all enclosures: surface contamination and accumulation on exhaust filters. A value for surface contamination of 7.5 g powder/m^2 (estimated in previous work by Mishima, Schwendiman and Ayer 1979b, p. 44) is used. An inventory of 1 g Pu is assumed for exhaust HEPA filters on enclosures, 100 mg Pu per filter for the first stage of the final HEPA filter bank, and 0.05 g Pu per filter for the final stage of HEPA filters (Mishima, Schwendiman and Ayer, 1979b, p. 35).

DAMAGE SCENARIOS

Once the significant features of the facility are defined, the damage leading to loss of containment and stresses upon the contained material that can make them airborne must be described. The damage to the structure and equipment from the impact of increasing levels of wind and earthquake hazard has been assessed. The wind damage responses developed by Mehta, Smith, and McDonald (1980) range from the loss of the exhaust duct between Buildings 102 and 102A to general failure of the ground-level structure. Endebrock (1979) developed the earthquake damage scenarios for both vibratory motion and thrust faulting. Damage to the structure due only to vibratory motion is postulated to range from minor damage to general failure of the ground-level structure. Extreme levels of thrust faulting could cause extensive damage to the equipment in the AFL and allow an unfiltered path to the ambient atmosphere.

WIND DAMAGE (MEHTA, SMITH AND McDONALD 1980, p. 50-55)

The estimated damage to the areas and equipment within the 102 Building is described in order of increasing severity of wind hazard.

- Nominal Wind Speed 95 mph (42.5 m/s), 3×10^{-6} /yr probability of occurrence
 - First Floor Laboratory Area: No significant damage.
 - AFL: No significant damage.
 - Exhaust Air Handling System: A 60-in. dia duct between the 102 and 102A Buildings overturns, is severed and blows away. No significant damage to the 102A Building.
- Nominal Wind Speed of 135 mph (60 m/s), 6×10^{-7} /yr probability of occurrence
 - First Floor Laboratory Area: Roof panels (14 ft x 14 ft) in the windward corners are uplifted. Door in the north, south, or east walls could fail. The 4-inch reinforced-concrete masonry and gypsum partition walls fail because air enters the building. One-tenth

of the enclosures are damaged (upper and lower bounds are one-eighth and one-half respectively). One-third of the exhaust filters on the enclosures are similarly damaged (upper and lower bounds are seven-sixteenths and one-quarter respectively). RML cells retain integrity.

- AFL: No significant damage.
- Exhaust Air Handling System: Final HEPA filter bank could be subjected to reverse flow created by pressure differentials of up to 11.5 inches WG. Doors in the 102A Building fail. Air circulating in the building damages one-tenth of the HEPA filters (upper and lower bounds are one-eighth and one-half respectively).
- Nominal Wind Speed of 180 mph (80.5 m/s), 1×10^{-7} /yr probability of occurrence
 - First Floor Laboratory Area: A 14-ft strip of roof along the windward eaves is uplifted. A 14-ft section of the wall panel in the windward corner collapses. The increased air velocity circulating in the building causes failure of all interior walls including the 8-inch concrete masonry walls. One-half the enclosures in the PAL are crushed (upper and lower bounds are two-thirds and three-eighths respectively). No estimate is given for the crushing of the exhaust filters so the conservative assumption is made that all are crushed. Three-quarters of all filters on top of the RML cells (inlet) are disconnected and displaced. The cells themselves do not sustain damage.
 - AFL: No significant damage.
 - Exhaust Air Handling System: Filters in the final filter bank could be subjected to reverse flow for 6.2 sec at a linearly increasing rate to a final differential pressure of 20.4 in. WG. A 5-ft strip of wall cladding is lost at the windward corners and doors are lost. Air circulating in the building could damage one-third of the filters (upper and lower bounds are seven-sixteenths and one-quarter respectively).

- Nominal Wind Speed 230 mph (103 m/s), 1×10^{-8} /yr probability of occurrence
 - First Floor Laboratory Area: The precast concrete wall panels and the entire roof is uplifted. All the equipment and filters in the PAL are crushed. All inlet filters on the RML cells are displaced but the cells are not damaged.
 - AFL: No significant damage.
 - Exhaust Air Handling System: Filters in the final HEPA banks are subjected to reverse flow at linearly increasing pressure differential for 3.2 sec to a final value of 33 in. WG. Most of the wall cladding is stripped from the 102A Building and all the filters are crushed.

EARTHQUAKE DAMAGE (ENDEBROCK 1979, pp. 59-64)

- Peak Ground Acceleration 0.1 g, 10^{-1} /yr probability of occurrence
 - No significant damage in any area of concern.
- Peak Ground Acceleration in the Range of 0.1 to 0.4 g, 4×10^{-3} /yr probability of occurrence
 - First Floor Laboratory Area: No significant damage.
 - AFL: No significant damage.
- Peak Ground Acceleration in the Range of 0.4 to 0.8 g, 10^{-3} /yr probability of occurrence
 - First Floor Laboratory Area: Partial collapse of roof and shear wall system breaches PAL. Interior concrete masonry in the RML fails; however, no significant damage to the hot cells occurs.
 - AFL: No failure of the AFL but the contained equipment may exhibit some displacement.

- Peak Ground Acceleration in Excess of 0.8 g, less than 10^{-3} /yr probability of occurrence
 - First Floor Laboratory Area: Severe damage to structure with some collapse. RML cells retain integrity.
 - AFL: Structure is not breached although enclosure or exhaust system may be damaged by local failures of interior walls.
- Fault Displacement up to 0.5 to 1 ft (with concurrent 0.4 g ground acceleration)
 - No significant damage beyond that postulated for vibratory motion alone.
- Fault Displacement 0.5 to 1 ft (with concurrent 0.4 g ground acceleration)
 - AFL: Moderate cracking in basement walls and roof slab around the columns adjacent to the fault zone. AFL retains its integrity. Moderate heaving of floor slab results in light damage to floor-to-ceiling glove boxes.
 - RML Cells: Light cracking is possible in soil-retaining walls and base slab.
- Fault Displacement 1 to 5 ft (with concurrent 0.4 g ground acceleration)
 - AFL: Severe cracking in basement walls and separation of walls from roof slab allows soil to enter space between basement and AFL walls. Heaving of floor slab could partially crush floor-to-ceiling glove boxes and penetrating cracks in roof slab could provide pathways to the low bay area.
 - RML Cells: Moderate to severe cracking occurs in soil-retaining walls and base slab.
- Fault displacement 5 to 9 ft (with concurrent 0.4 g ground acceleration)
 - AFL: Collapse of basement walls allows soil to enter space between basement and AFL walls. Heavy localized damage along the fault line in the ceiling and floor slabs could severely damage floor-to-ceiling glove boxes. Other boxes could be damaged by falling concrete.

- RML Cells: Damage to retaining walls allows soil to enter below-grade area. Base slab cracks severely. Ventilation ducts to secondary filters are severed but above-grade functional portions of cells are not damaged.

In a subsequent assessment, Hall and Newmark (letter to Winston Burkhardt, U.S.N.R.C., dated March 18, 1980,) defined the potential damage to the 102 Building from earthquakes as:

- 0.1 g Horizontal Ground Acceleration
Even minor damage is unlikely in critical facilities or equipment.
- 0.1 to 0.4 g Horizontal Ground Acceleration
Walls crack requiring remedial action and minor distortion of equipment is anticipated.
- 0.4 to 0.8 g Horizontal Ground Acceleration
Frames distort and walls crack, are damaged or partially fail in the high and low bay areas; basement walls crack severely. Roof and floor slab are expected to experience some cracking. RML retains its integrity but interior masonry walls fail. Some glove box connections may fail and boxes may move.
- In Excess of 0.8 g Horizontal Ground Acceleration
Damage would be progressively worse. Many parts are clearly capable of shaking consistent with a 1 g earthquake; hence, damage could be heavy in some portions and light in others.
- Thrust Faulting (conservative values, 1 m maximum fault motion concurrent with 0.6 g horizontal ground acceleration)
Basement floor lifts, tilts and cracks; walls fail. The main floor (basement ceiling) cracks and could tilt the RML cells. Equipment could shift or be damaged by distortion or falling cement.

SUMMARY OF DAMAGE SCENARIOS

The damage to the 102 Building and the equipment it holds appears to fall roughly into the three categories outlined in Mishima et al. (1979a)--moderate,

severe, and major. Moderate damage (partial loss of integrity of the ground-level structure and glove boxes) is estimated for wind speeds of 135 and 180 mph and for horizontal ground acceleration in the range of 0.4 to 0.8 g. Severe damage (complete loss of integrity of the ground-level structure and equipment) is estimated for a wind speed of 230 mph and a horizontal ground acceleration in excess of 0.8 g. Major damage (partial loss of integrity of below-grade structure and equipment with an unfiltered pathway to the ambient environment) is only postulated for a thrust-faulting displacement of 1 m with a concurrent horizontal ground acceleration of 0.6 g. The term "horizontal ground acceleration" is used to show the direction of the measured value and does not indicate that the vertical components were ignored.

Although at a wind speed of 95 mph the 60-in.-dia exhaust duct is severe and the final HEPA filters are subjected to a reverse differential pressure of 6 in. WG, the conditions did not appear to be sufficiently rigorous to cause the release of a significant quantity of accumulated material for two reasons: the quantity of plutonium accumulated is small since effluents have passed through two stages of filtration prior to exiting the 102 Building; and, once the pressure is equilibrated, the airborne material must diffuse out, which is a slow process (Dennis 1976b, p. 52 and Fig. 6.4, p. 124). At higher wind speeds (135, 180, and 230 mph), the release from direct damage is calculated.

The RML cells are not damaged significantly under any of the postulated conditions. The inlet filters are lost at wind speeds over 130 mph and the ducts to the secondary exhaust filters are lost through thrust faulting. In the latter case, the cells are still sealed. In the former case, the cells could be pressurized by air forced into them via the openings, and some air could be exhausted during depressurization. The quantity expelled would be much less than a cell volume. Only if air flowed through the cells could a significant amount of airborne material be released. Thus, it appears unlikely that the RML cells would contribute to the radioactive airborne burden.

APPROACH AND FACTORS USED IN ESTIMATING SOURCE TERMS

Once the damage to the facility and equipment is assessed, source terms are estimated to provide data for the calculation of potential radiation dose to the general population from the 102 Building. A principal concern is the quantity of particulate material in the size range that can be transported downwind, inhaled by humans and deposited in the lung. Answers to several questions are required to arrive at an estimate of the source term. How much material can be affected by the event. How much of the material is made airborne and what is its size distribution. What is the behavior of the airborne material in the time span required for release. The factors and considerations to answer the latter two questions are discussed below.

FRACTIONAL AIRBORNE RELEASE OF PARTICULATE MATERIAL

The various factors applied to estimate the airborne release of plutonium as a result of the postulated damage scenarios are listed in Table 4. Some considerations that influence the applicability of these factors for the damage scenarios described are noted in the following paragraphs.

Crushing of Glove Box

Crushing is defined as a complete loss of containment such as rupture of the steel shell or loss of one or more of the large viewing windows. The event is assumed to generate sufficient excess force to inject uncontained powders into the air, and break glass or thin-wall, rigid plastic containers.

- Glove Box Containing Powder. Vibrating powder resting on a surface does not appear to provide as much dispersion of the powder as tumbling. The mass airborne concentration is indicated by experimental data measuring the value within seconds after tumbling of a powder with a density and size distribution similar to the PuO_2 assumed for this study (Mishima, Schwendiman, and Ayer 1978, p.
- Glove Box Containing Liquids. Subdivision of liquids during breakage of glass and plastic containers appears to be less effective than forcing a liquid through a small opening such as a larger spray nozzle designed to

TABLE 4. Fractional Airborne Release Factors

Event	Factor
• Crushing of Glove Box	
- containing powder	Volume of glove box x 300 mg powder/m ³
- containing liquid	Volume of glove box x 500 mg liquid/m ³ (a)
- containing surface contamination only	10 ⁻² /m
• Perforation of Glove Box	
- containing powder	Fraction of volume of glove box x 100 mg powder/m ³
- containing liquids	Fraction of volume of glove box x 167 mg liquid/m ³ (b)
- with surface contamination only	10 ⁻⁴ /m
• Damaged to Filters	
- crushing	10 ⁻¹ of accumulated material airborne
- perforation	10 ⁻² of accumulated material airborne
• Aerodynamic Entrainment	
- powder, less than 5 mph	10 ⁻¹⁰ /s of exposed material
- powder, greater than 5 mph	10 ⁻⁸ /s of exposed material
- liquids, less than 5 mph	10 ⁻¹¹ /s of exposed material
- liquids, greater than 5 mph	10 ⁻⁹ /s of exposed material

(a) Drops $\leq 100 \mu\text{m}$ in AED. Airborne mass concentration of drops $\leq 10 \mu\text{m}$ is 10 mg/m³.

(b) Drops $\leq 100 \mu\text{m}$ in AED. Airborne mass concentration of drops $\leq 10 \mu\text{m}$ AED is 3.3 mg/m³.

perform that function. The distribution chosen represents larger spray openings (0.125 in. dia) at higher pressures (200 psi) and smaller openings (0.063 in. dia) at lower pressures (50 psi) (Mishima, Schwendiman, and Ayer 1978, p. 33).

- Glove Box Containing Surface Contamination Only. Surface contamination can range from particles settled on the surface to material mixed into

the surface. The resuspension factor applied is a value measured for a combination of mechanical and aerodynamic stresses (Mishima, Schwendiman and Ayer 1979b, p. 44).

Perforation of Glove Box

Perforation is defined as a partial loss of containment (loss of one or more glove ports, loss of a portion of a viewing window, etc.) that allows air to circulate through the glove box. The rate of release from the break will depend upon the size of the opening, whether the exhaust system continues to function, and the velocity of air entering the opening. The particulate materials airborne within the volume are released from the glove box with time. If the exhaust flow is zero, the release is exponential with time. Release of greater than 99% of the airborne material within 30 min is considered instantaneous.

- Glove Box Containing Powders. The force transmitted to the glove box during perforation is assumed to be considerably less than during crushing. Since a finite period of time is required to release the airborne particulate material, a mass concentration measured approximately 1 min after tumbling a fine powder and considered quasi-stable, was selected. Furthermore, the disturbance due to perforation can be more localized than in crushing and it was judged that the powder only occupied a fraction of the volume of the glove box (Mishima, Schwendiman and Ayer 1979b, p. 39).
- Glove Box Containing Liquids. For the reasons stated above, a reduced mass airborne concentration and volume was selected for the dispersal of liquids held in glass and thin-wall, rigid plastic containers (Mishima, Schwendiman and Ayer 1978, p. 38).
- Glove Box Containing Surface Contamination Only. A reduced resuspension factor of $10^{-4}/\text{m}$ was selected to reflect the reduced force and area involved in perforation (Mishima, Schwendiman and Ayer 1980, p. 18).

Damage to Exhaust HEPA Filters

Unless otherwise stated, filters attached to glove boxes are assumed to suffer the same damage as the glove box to which they are attached. Secondary filters within the building are treated the same. The final two banks of HEPA filters are housed in the 102A Building and have a separate response (similar to the ground level of the 102 Building if not specified). It should be noted that the filters in the 102A Building are the third and fourth level of HEPA in the filtration series.

- Crushing of HEPA Filters. Although the filter material (glass fiber mats) is fragile, the plutonium particulate material accumulated can be embedded in the filter and associated with other materials such as dust, condensed organic vapors, etc. The material may not be readily dispersed in a respirable, transportable size-range. A conservative airborne fractional value of 10% of the accumulated material released is assumed in the absence of experimental data (Mishima, Schwendiman, and Ayer 1979b, p. 46).
- Perforation of HEPA Filters. A reduced fractional airborne release factor of 1% is applied to reflect the reduced level of stress required for this level of damage (Mishima, Schwendiman and Ayer 1979b, p. 47).

Aerodynamic Entrainment

Powders and liquids can be entrained in the air passing over their surfaces. Particle suspension results from initiation of movement in larger particles which subsequently transfer momentum to particles in the size-range that allows suspension. Under similar conditions of air flow over a liquid film, droplets are much less likely than particles to be airborne because of the higher energy required to break up the film and form droplets.

- Powder by Air Velocities Greater than 5 mph (2.2 m/sec). A conservative suspension rate ($10^{-8}/s$), measured for a homogeneous bed and with wind velocity variations over a year's duration, is applied (Mishima, Schwendiman and Ayer 1978, p. 39).

- Powder by Air Velocities Less than 5 mph (2.2 m/sec). A suspension rate ($10^{-8}/s$) measured from a homogeneous bed at these velocities is applied (Sehmel and Lloyd 1974, p. 853, Figure 3).
- Liquids by Air Velocities Greater than 5 mph (2.2 m/sec). A conservative measured suspension rate is applied. It is consistent with the assumed larger energy input required to disperse liquids of $10^{-9}/s$ (Mishima, Schwendiman and Ayer 1978, p. 39).
- Liquids by Air Velocities Less than 5 mph (2.2 m/s). The suspension rate applied for higher air velocities ($10^{-11}/s$) was reduced by a factor consistent with the reductions found for powder.

ATMOSPHERIC EXCHANGE RATE

After the particulate material is injected into the air, it requires airflow to move it from its point of generation to the ambient atmosphere. Diffusion is only a serious consideration for particles less than $1\text{ }\mu\text{m}$ (Dennis 1976, p. 52). The two areas of the 102 Building where plutonium can be made airborne are the PAL and the AFL. The PAL is located in the low-bay portion of the ground-level structure and is approximately 42 ft long by 20 ft wide by 14 ft high. The AFL is located in the basement and is made up of two continuous sections -- east and west. The east section houses the scrap recovery and nitrate conversion processes and is approximately 40 ft long by 40 ft wide by 12 ft high. The west section houses the ceramics line and is "L" shaped. The north-south leg of the "L" is 43 ft long by 20 ft wide by 12 ft high and the east-west leg is 30 ft long by 28 ft wide by 12 ft high. A 30 ft long by 10 ft wide by 12 ft high annex which houses materials and properties studies extends to the north from the east-west leg. Described below are the estimated airflow through the two areas and through the equipment as a result of the postulated damage and wind speeds.

Wind Hazard

Only the ground level is affected by the range of wind speeds considered and the only area of concern is the AFL. The initial loss of containment for the area and for the glove boxes in the area occurs at a wind speed of 135 mph.

At that speed a 14 ft by 14 ft (196 ft^2) corner of the windward roof panels is uplifted and one-tenth of the enclosures are damaged. It is assumed that there is an equivalent opening to allow the air to be expelled without a significant pressure build up. 2.33×10^6 cfm could enter the 102 Building. Assuming all the air flows through the PAL in a north-south direction, the wind speed in the facility would be 94.5 mph and there would be 198 air changes per min. If the airborne concentration were diluted exponentially, the mass airborne concentration would be reduced by a factor of 10^3 after seven volume changes. Thus 99.9% of the material airborne in the PAL could be carried away in 2.1 sec. It is conservative to assume the material is transmitted through the remainder of the facility without loss. If it were assumed that all the interior walls in the laboratory area failed, the wind speed would decrease to 19 mph and the air would change 40 times per min. The volume of air in the PAL changes seven times each 10.5 sec. Thus any material made airborne during the event is released instantaneously to the ambient atmosphere.

The size of the openings in the damaged glove boxes can vary greatly. It is assumed that air enters and exits via openings 1 ft^2 in area at the wind speed calculated--94.5 and 10 mph. A glove box with the typical dimensions of 2.5 ft wide by 7 ft long by 4 ft high was used for calculations. Wind speeds in the glove box under these conditions range from 1.9 to 9.5 mph. There would be from 24 to 119 air changes per min. and 99.9% would be released in 3.5 to 14 sec. The release is considered instantaneous.

Damage is greater at higher wind speeds. Releases of airborne material are faster with larger openings and higher wind speeds. Thus all airborne releases are considered instantaneous.

Earthquake Hazard

There are no wind speeds specifically associated with earthquakes. Measured wind-frequency data indicate that 83.7% of the time the speed is less than 12 mph with calm conditions prevailing 9.85% of the year (Rouse 1980, Table 6, p. 11). A wind speed of 12 mph is assumed to occur during the earthquake.

- Horizontal Ground Acceleration. If the same sized openings (196 ft) were assumed for the 0.4 to 0.8 g and 135 mph scenarios, the wind speed in the PAL would range from 1.7 to 8.4 mph and there would be from 3.6 to 17.7 air changes per min. In 24 to 117 sec. 99.9% of the airborne mass would be carried away. Releases from the PAL are considered instantaneous.

Releases in glove boxes are in the range of 40 sec. to 15 min. and are also considered instantaneous.

Although the wind speed remains the same at higher postulated ground accelerations, postulated damage increases allowing greater air access. Thus all releases from horizontal ground acceleration are considered instantaneous.

- Thrust Faulting with Concurrent Horizontal Ground Acceleration. A 0.6-g horizontal ground acceleration is assumed concurrent with a 1-m thrust displacement. The ground-level structure is assumed to suffer the damage specified for a 0.4- to 0.8-g ground acceleration. Wind speeds of 1.7 to 8.4 mph are assumed for the PAL.

Loss of containment alone does not appear to induce a significant airflow through the below-grade areas (PAL); special circumstances are required. Openings from the low-bay area to the basement are in the floor and air flowing through the ground-level structure passes at right angles to the openings. Since all openings are in the same airflow and each receives the same pressure, airflow is not induced by pressure differences. If the airflow within the facility is distorted by an obstruction and directed into an opening, air at the velocity in the facility could then be induced to flow into the basement.

Under the assumed conditions (10 m^2 opening with air velocities ranging from 1.7 to 8.4 mph in the low-bay area), from 1500 to 7390 cfm of air could enter the AFL and air velocities could range from 0.9 to 8.8 fpm (0.01 to 0.1 mph). The time required to pass one volume through the AFL ranges from 6 to 49 min and, assuming exponential dilution, from 41 min to 5.7 hr would be required to release 99.9% of the material into the AFL.

Under the conditions postulated for damaged glove boxes (air enters and exits via 1 ft² openings), from 0.9 to 8.8 cfm of air passes through the boxes at velocities of 0.09 to 0.88 fpm. From 8 to 77 min are required to pass a single volume through the box, and from 56 min to 9 hr are required to release into the AFL 99.9% of the material initially airborne in the box. Thus from 97 to 881 min (1.6 to 14.7 hr) would be required to release material initially airborne in glove boxes into the ambient atmosphere.

SOURCE TERM RANGES

In order to provide some quasi-realistic bounds to the quantity of plutonium estimated to be released from the damage scenarios, two estimates are provided:

- High Estimate
 - The upper-bound damage occurs.
 - The stated inventory that can be present is found at each location.
 - All areas have a maximum loading, on the average, of surface contamination.
 - All exhaust filters are fully loaded.
- Low Estimate
 - The lower-bound damage occurs.
 - No process material is present and the maximum loading, on the average, of surface contamination is found at each location.
 - All exhaust filters are clean.

SOURCE TERM ESTIMATES

The previous sections of this document describe inventories of dispersible materials in various areas, damage levels, fractional airborne releases, and atmospheric exchange rates required to estimate the source terms for the postulated damage scenarios. These components are combined in this section with the specific conditions postulated for each hazard to arrive at two source-term estimates for each scenario--a high and a low estimate.

The estimates are divided into the mass of airborne plutonium particulate material in the respirable size fraction released during five time intervals covering a four-day period. The quantity designated as instantaneous is the mass released from the facility within a few minutes following the hazardous event. The mass estimated in the remaining four time periods comes from two sources: the delayed release of material airborne in enclosures and the resuspension of dispersible materials exposed to the ambient wind field.

Drawings are used to illustrate the type and range of damage in key areas that could result from the scenarios described. The illustrations are not an attempt to show what actually happens; the data available and the state-of-the-art are not sufficient to predict the precise levels of damage that would be inflicted upon each item. Certain details of the facility have been omitted for clarity in the drawings.

The discussion is divided into wind and earthquake hazard in order of increasing severity.

SOURCE TERM ESTIMATES FROM WIND HAZARD

- Nominal Wind Speed 95 mph, 6×10^{-3} /yr probability of occurrence
No significant damage occurs leading to unfiltered release of contained radioactive materials to ambient atmosphere.
- Nominal Wind Speed 135 mph (60 m/s), 6×10^{-7} /yr probability of occurrence

The damage postulated to occur to the ground-level structure has been described and is shown in Figure 4. It is assumed that the PAL contains 6 standard-sized glove boxes which hold a maximum probable

FIGURE 4. Type and Range of Postulated Ground-Level Damage at a Nominal Wind Speed of 135 mph

inventory of 200 g of Pu -- 100 g as powder, and 100 g as solution. One-eighth of the glove boxes are perforated at the upper bound and one-twelfth at the lower bound. Under any configuration of internal partitions, the nominal velocity within the PAL exceeds 5 mph and the higher entrainment rates are applied. Velocities within the glove box are calculated to range from 2 to 10 mph. The higher entrainment rates are applied to material in the glove boxes for the high-release estimates and low entrainment rates are used for the low estimates. Greater than 99.9% of the material airborne in the glove boxes and PAL was calculated to be released to the ambient atmosphere around the facility within 30 min and all releases were considered instantaneous. They are listed in Table 1.

- Nominal Wind Speed 180 mph (80.5 m/s), 1×10^{-7} /yr probability of occurrence

The damage is confined to the ground-level portions of the facility and is illustrated in Figure 5. The maximum probable inventory of Pu and its distribution into physical forms remains the same. Two-thirds of the glove boxes are crushed at the upper bound and three-eighths at the lower bound. All the filters on the glove boxes are assumed to be crushed. Wind velocities in the PAL and glove boxes are calculated to exceed 5 mph under all damage conditions and the higher entrainment rates are applied. The estimated releases are shown in Table 1.

- Nominal Wind Speed 230 mph (103 m/s), 1×10^{-8} /yr probability of occurrence

The damage is still confined to the ground-level structure and is shown in Figure 6. The inventory remains the same as in the previous two scenarios. All glove boxes and filters attached to glove boxes are crushed. All significant wind velocities within the facility are calculated to exceed 5 mph and the higher entrainment rates are applied. The estimated release rates are shown in Table 1.

FIGURE 5. Type and Range of Postulated Ground-Level Damage of the 102 Building at a Nominal Wind Speed of 180 mph

FIGURE 6. Type and Range of Postulated Ground-Level Damage at a Nominal Wind Speed of 230 mph

SOURCE TERM ESTIMATES FROM EARTHQUAKE HAZARD

- Peak Ground Acceleration Less Than 0.4 g, Greater than 4×10^{-3} /yr probability of occurrence

In the absence of a thrust fault, damage from earthquakes in the range studied is still confined to the ground-level structure and no significant damage is inflicted to any area of concern.

- Peak Ground Acceleration in the Range of 0.4-0.8 g, 1×10^{-3} /yr probability of occurrence

The only area in the ground-level structure holding significant quantities of plutonium is the PAL. The postulated damage to the ground-level structure is shown in Figure 7. The inventory at risk remains the same as for all wind-hazard scenarios. The damage to the equipment is assumed to be equal to that postulated for the nominal wind speed of 135 mph -- one-eighth and one-twelfth of the glove boxes and the filters attached to the glove boxes are perforated. A wind speed outdoors of 12 mph is assumed (see ATMOSPHERIC EXCHANGE RATES) giving wind speeds of 2 to 8 mph within the facility. Entrainment rates for the higher wind speed were applied to the high-release estimates and rates for the lower wind speed to the low-release estimates. Releases from the glove boxes and the facility qualified under the definition of "instantaneous". The releases calculated are shown in Table 1.

- Peak Ground Acceleration in Excess of 0.8 g, less than 1×10^{-3} /yr probability of occurrence

The postulated damage sustained by the 102 Building remains confined to the ground-level structure and is shown in Figure 8. The PAL remains the only area involved holding significant quantities of Pu and the inventory at risk remains the same. All glove boxes and filters attached to glove boxes are crushed. The ambient wind field is assumed to be 12 mph and, due to the degree of damage to the glove boxes and structure, is used as the velocity imposed upon the materials exposed. Calculated releases are shown in Table 1.

FIGURE 7. Type and Range of Postulated Ground-Level Damage in the Range of 0.4- to 0.8-g Peak Ground Acceleration

FIGURE 8. Type and Range of Postulated Ground-Level Damage at Peak Ground Accelerations in Excess of 0.8 g

- Fault Displacement of 1 m with 0.6 g Linear Acceleration

- PAL: (See 0.4 to 0.8 g linear acceleration)
- AFL: The location of the fault line dictates the glove boxes and thus the quantities of plutonium in jeopardy. The highest inventories of materials are located in Glove Box 50 and 51 and a fault location intersecting these glove boxes was assumed to maximize the consequences. Thus, Glove Box 50, 50A, 51 and 29 are postulated to be crushed (See Figure 9). Such an assumption precludes crushing of Glove Box 37 and 38, the other glove boxes containing large quantities of plutonium. These glove boxes were assumed to have the same probability of damage as all the remaining glove boxes and a fraction of the release. If all the glove boxes suffered the designated degree of damage equal to the fraction of glove boxes damaged is used for the airborne release. The high and low damage ratios used were one-third and one-sixth.

The AFL is below grade and is not assumed to be completely open to the ground-level structure (see ATMOSPHERIC EXCHANGE RATE). Two wind speeds can result from various assumptions of damage to the partitions in the low-bay area. This results in two release rates for airborne material in the glove boxes and the AFL: air exchange rates of 8 to 77 min for air moving from the glove boxes to the AFL, and 6 to 49 min for air moving from the AFL to the PAL. Exponential depletion is assumed and seven air changes are required to transfer greater than 99.9% of the airborne material. With such long time periods, only airborne material less than 10- μ m in AED makes a significant contribution to materials carried out of the AFL. Although there is a resulting time delay, high and low rates were used to estimate high and low estimates of consequence.

Surface contamination entrained from the interior surfaces of glove boxes, because it is small in volume and quantity, produces airborne concentrations resulting in releases from the glove boxes equal to the entrainment rate. No delays were incorporated in these estimates.

FIGURE 9. Type and Range of Damage Postulated for the East Portion of the Advanced Fuel Laboratory with a 1-m Fault Displacement and Concurrent 0.6-g Peak Ground Acceleration

The high-release estimates for the AFL were calculated using the following assumptions:

- The maximum probable inventory is present in all boxes.
- The maximum probable inventory is present in each glove box exhaust and suffers the same degree of damage as the glove box to which it is attached. The secondary filters are located just under the ceiling in the northeast corner of the east AFL and are not assumed to be damaged.
- The maximum probable surface contamination is present in each glove box.
- Glove Box 29, 50, 50A, 51 and their filters are crushed. Six of the remaining 24 glove boxes are perforated.
- The material airborne in the glove boxes and the AFL are exponentially released in 56 and 41 min respectively.

Under these assumptions, 1.34 g of Pu (as particulate material of 10- μ m AED or less) is instantaneously released into the AFL by the crushing of glove boxes 29, 50, 50A, 51, and their filters. The greatest fractions of released materials are from the exhaust filters (an estimated 0.6 g) and from entrainment of surface contamination. Approximately 0.01 g is estimated to be made airborne in glove boxes by their perforation and is released with time to the AFL. The total resuspension rate was estimated to be 0.003 g Pu/hr. The estimated releases are shown in Table 1. The concurrent releases from the PAL were insignificant.

The low-release estimates for the AFL were calculated using the following assumptions:

- The maximum probable surface contamination is the only source for airborne radioactive materials.
- Glove Boxes 29, 50, 50A, 51, and their filters are crushed. Three of the remaining 24 glove boxes are perforated.
- The particulate material airborne in the glove boxes and the AFL are released exponentially in 9 and 5.7 hours.

Under these assumptions, approximately 0.5 g of Pu are instantaneously released in the AFL. The quantity of material released with time from the glove boxes (a total of approximately 0.001 g of Pu) does not have a significant impact on the release from the AFL until all the material initially airborne is depleted. The calculated entrainment rate is 1×10^{-4} g Pu/hr. The estimated releases are tabulated in Table 1.

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