BNWL-1730
Special
Distribution

6A

FRACTIONAL AIRBORNE RELEASE
OF URANIUM (REPRESENTING PLUTONIUM)
DURING THE BURNING
OF CONTAMINATED WASTES

J. Mishima and L. C. Schwendiman

Battelle

Pacific Northwest Laboratories
Richland, Washington 99352

APRIL 1973

Prepared for the U.S. Atomic Energy
Commission under Contract AT(45-1):1830

BNWL-1730

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately-owned rights.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
U.S. ATOMIC ENERGY COMMISSION
Under Contract AT(45-1)-1830

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.95

FRACTIONAL AIRBORNE RELEASE OF URANIUM (REPRESENTING
PLUTONIUM) DURING THE BURNING OF CONTAMINATED WASTES

J. Mishima

L. C. Schwendiman

Atmospheric Analysis Section
ATMOSPHERIC SCIENCES DEPARTMENT

April 1973

BATTELLE
PACIFIC NORTHWEST LABORATORIES
RICHLAND, WASHINGTON 99352

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	ii
LIST OF FIGURES	ii
ABSTRACT	1
INTRODUCTION	1
OBJECTIVE	3
SUMMARY	3
EXPERIMENTAL PROGRAM	3
Filters, Glass Impactor Dishes, Residue	10
Fallout Trays	10
Aluminum Foil Wall Strips	10
DISCUSSION AND CONCLUSIONS	11
REFERENCES	16

LIST OF TABLES

	<u>Page</u>
TABLE I -- AIRBORNE RELEASE DURING BURNUP OF CONTAMINATED WASTE -- EXPERIMENTAL PARAMETERS	5
TABLE II -- FRACTIONAL AIRBORNE RELEASES OF URANIUM DURING THE BURNING OF CONTAMINATED WASTE	12
TABLE III -- VARIATION OF FRACTIONAL AIRBORNE RELEASE DUE TO PACKAGING CONFIGURATION AND URANIUM FORM USED AS SOURCE	14

LIST OF FIGURES

FIGURE 1 -- URANIUM DIOXIDE POWDER SIZE DISTRIBUTION BY WHITBY CENTRIFUGE	6
FIGURE 2 -- RADIOACTIVE AEROSOL RELEASE TANK	8
FIGURE 3 -- STAINLESS STEEL SCREEN & SUPPORT USED IN BURNING OF FLAMMABLE MATERIALS	9

FRACTIONAL AIRBORNE RELEASE OF URANIUM (REPRESENTING PLUTONIUM) DURING THE BURNING OF CONTAMINATED WASTES

ABSTRACT

Plutonium is a highly radiotoxic substance, but one of increasing importance as a source of fission energy. Detailed pre-planning and evaluation are essential to insure safety in handling this element and its compounds. A source term containing both a fractional release and aerodynamic size distribution of the released material is required to evaluate the potential downwind hazard from a postulated inadvertent release.

The approach taken in this study of a potential accident situation in a radiochemical processing plant was to measure the fractional airborne release and aerodynamic size distribution released using a simple but realistic simulation. The release of uranium (as a stand-in for plutonium) was measured during the burning of flammable, solid materials containing either uranium dioxide powder or uranium nitrate solution. The flammable materials used are representative of the typical types of solid wastes generated in such a process and were packaged in a typical manner. The packaged waste containing the uranium was allowed to burn in a 9-1/2 ft. diameter by 10 ft. tall tank to simulate a small enclosure. The uranium airborne, deposited on the walls and floor, and remaining with the residues was measured. The fractional airborne release of uranium measured under these conditions was 0.05 to 0.003 percent of the uranium used in the source.

INTRODUCTION

Under the auspices of the U.S. Atomic Energy Commission, the safety record of the nuclear industry has demonstrated that plutonium can be processed and handled without undue hazard to persons involved in the industry or to the public. Respect for the hazards involved and careful pre-planning have been the cornerstones of the safe manipulation of plutonium. Unique features of the pre-planning in the nuclear industry are the Safety Analysis Report and the Hazards Review.

A Safety Analysis Report is a detailed review conducted by an applicant to identify the potential consequences to the public from a severe accident which could theoretically occur in a proposed operation. The applicant must review the proposed operation or facility and identify the mechanisms, conditions, sequence of events that could result in a severe accident. Adequate safeguards must be

provided in each step of the operation to prevent such occurrences. Finally, the applicant must evaluate the danger to the public if all safeguards fail and the worst accident occurs. The Hazards Review is made after procedures are available and such things as plutonium airborne contamination are carefully studied.

In this study sponsored by Atlantic Richfield Hanford Company, Battelle scientists are investigating potential hazards involved from the inadvertent burning of scrap and waste materials. Information from this study should help to better estimate potential problem areas considered in Safety Analysis Report and Hazards Review.

To evaluate the hazards off-site, the plutonium aerosol generated by the particular set of conditions is considered a source term. The aerosol is transported and acted upon by meteorological phenomena. At some point in its travels, the aerosol reaches the ground constituting a potential inhalation hazard and deposition of the particles presents a contamination problem with attendant resuspension potential. Various formulae are available to calculate the transport, diffusion and deposition of such aerosols.^[1] Since the response of particles to the various transport, diffusion and deposition mechanisms is dependent upon their aerodynamic equivalent size, a size distribution of the particles comprising the aerosol is required for a complete source term.

Specifying a realistic source term for a particular set of postulated conditions is not a trivial task. The quantity and characteristics of the plutonium aerosol generated depend upon many factors -- the amount and form of plutonium involved, the stresses applied to the material, the entrainment mechanism, the direction and velocity of entraining gases, the surface from which the material is entrained, and the presence and behavior of materials which can alter the behavior of the aerosol. Since accidents are unique events, specifying the exact conditions for a postulated accident is an impossible task.

The approach used in our studies of plutonium aerosol generated in potential accident situations in a radiochemical processing operation is to measure the fractional airborne release and size distributions from plutonium forms probably involved using the simplest mechanisms operative.^[2-7] Since major accidents which might occur in a radiochemical separations plant are, in general, of the same nature as those in any chemical plant,^[8-9] the accident situations chosen reflect typical industrial accident situations. The current

study is concerned with the inadvertent burnup of flammable waste contaminated with plutonium. Flammable wastes -- various paper products, rubber, rags, plastic and cardboard containers -- are as a rule used and stored in an enclosure. A serious accident would be the inadvertent burning of a large number of stored waste cartons. Since waste cartons are relatively standard, but the facilities in which waste cartons are used vary greatly, the quantity and size distribution of the aerosol generated by mechanisms inherent in the burnup of contaminated, flammable wastes in a standard form was measured.

OBJECTIVE

The objective of this research was to measure the fractional airborne release and size distribution of the aerosol produced during the burning of contaminated, flammable waste packaged in a standard configuration. No extraneous mechanisms to make material airborne were applied.

SUMMARY

Eleven cartons of flammable waste containing realistic quantities of representative materials and uranium compounds (as a stand-in for plutonium) were burned in a 9.5 ft. diameter by 10 ft. tall enclosure. The airborne concentration was monitored by taking a series of continuous air samples and the aerodynamic size distribution of the airborne uranium determined by cascade impactors. The uranium on the walls and floor and associated with the residue was also measured. Almost all (greater than 98 percent) of the uranium recovered was found in the residue. Measured airborne concentrations indicated relatively low fractional releases ranging from 0.05 to 0.003 percent of the uranium used in the source. Greater than 50 percent of the uranium airborne was found associated with particles less than 10 microns Aerodynamic Equivalent Diameter in all cases. In 8 of 11 experiments, greater than 80 percent of the uranium was associated with particles in that size range.

EXPERIMENTAL PROGRAM

The fractional airborne release and size distribution of the particles comprising the aerosol produced by mechanisms inherent in the process of burning

contaminated, flammable wastes was determined by direct measurements on the aerosol produced during the burnup of a standard waste carton in a 710 cu. ft. enclosure (9.5 ft. diameter by 10 ft. tall). From practical considerations for the complexities involved in the use of plutonium on such a scale, use of a less toxic simulant was desirable. Uranium compounds were chosen as useful simulants.^[10]

Eleven individual experiments were conducted in this study. Pertinent data on the experiments are tabulated in Table I. Three forms of uranium -- uranium dioxide powder, uranium nitrate liquid, and the solid residues from an air-dried uranium nitrate solution -- corresponding to the plutonium forms most frequently involved with flammable wastes, were mixed with from 4.4 to 4.7 kg of flammable waste held in a standard waste carton.* The waste composition used in the individual experiments is shown in Table I. The average composition and range of compositions was:

Cardboard	17.5%	(15.7-20.9%)
Paper	41.1%	(31.7-43.9%)
Plastic	9.7%	(8.0-14.4%)
Rubber	2.4%	(1.8-4.2%)
Miscellaneous	29.3%	(23.8-38.2%)

The uranium dioxide was a ball-milled powder. The size distributions for 3 degrees of dispersion were measured by liquid sedimentation (Whitby centrifuge) and the results plotted in Figure 1. For these experimental conditions, the 5-minute, hand shaken distribution is assumed. The uranium nitrate solution was in dilute nitric acid with a concentration of 0.51 g uranium per milliliter. In experiments where the solid residues from air dried uranium nitrate solution was used as a source, the appropriate volume of uranium nitrate solution plus three nitric acid rinses of the container were poured onto a measured quantity of absorbent paper held in plastic bags. The open bags were left in an open-faced hood for at least three days before use.

The standard waste container used in these experiments is that routinely used on-site. The carton is a corrugated cardboard box, 18 in. by 18. in. by 24 in. high marked with a magenta radiation symbol. A large polyethylene bag, 39 in. x 54 in. x 0.04 in. thick, is draped in the box and the waste placed

* At the inception of the program, the standard waste container was the item used in the experimental program described. The standard waste container has subsequently change to metal drums.

TABLE I

AIRBORNE RELEASE DURING BURNUP OF CONTAMINATED WASTE -- EXPERIMENTAL PARAMETERS

<u>Experimental Designation</u>	<u>FW-1</u>	<u>FW-2</u>	<u>FW-3</u>	<u>FW-4</u>	<u>FW-5</u>	<u>FW-6</u>	<u>FW-7</u>	<u>FW-8</u>	<u>FW-9</u>	<u>FW-10</u>	<u>FW-11</u>
Uranium form used*	UO ₂	a.d.UNH	UNH	UNH	UO ₂	UO ₂ /UNH	UNH	UO ₂	a.d.UNH	UNH	UO ₂
Grams Uranium	9.1	25.5	25.5	25.5	64.1	51	25.5	50.2	25.5	51	51.6
Uranium Distribution in Waste**	1	2	1	2	2	2	2	3	3	3	2
Total Wt. Flammable Materials, kg	4.70	4.34	4.38	4.57	4.43	4.37	4.44	4.47	4.57	4.65	4.57
<u>Cardboard</u>											
Waste Carton	0.74	0.76	0.77	0.77	0.77	0.76	0.77	0.78	0.77	0.77	0.77
Scrap				0.18							
Ice Cream Carton					0.05						
<u>Paper</u>											
Tissue	0.73	0.38	0.38	0.38	0.30	0.40	0.40	0.40	0.37	0.37	0.37
Towels	0.74	0.75	0.74	0.74	0.79	0.78	0.75	0.77	0.77	0.72	0.76
Wipes		0.72	0.76	0.77	0.72	0.72	0.77	0.74	0.74	0.76	0.73
<u>Plastic</u>											
Wst. Carton	0.25	0.26	0.26	0.26	0.26	0.25	0.26	0.26	0.25	0.25	0.25
Bags	0.13	0.32	0.13	0.13	0.05	0.09	0.03	0.07	0.08	0.07	0.08
Gloves	0.09	0.05	0.07	0.06	0.09	0.07	0.07	0.08	0.08	0.07	0.08
<u>Rubber</u>											
Gloves	0.20	0.08	0.11	0.12	0.14	0.08	0.08	0.08	0.12	0.11	0.08
<u>Miscellaneous</u>											
Rags	1.80	0.89	0.72	0.79	0.83	0.89	0.96	0.97	0.93	1.08	1.05
Oil			0.34	0.30	0.43	0.32	0.33	0.31	0.46	0.42	0.37
Tape		0.04		0.07	0.01	0.02	0.02	0.02	0.01	0.01	0.02
Other		0.09									

*UNH: Uranyl nitrate hexahydrate solution

a.d.UNH: Air dried following addition to waste as UNH solution.

**1. 50% on loose waste, 50% in sealed plastic bags, carton sealed.

2. 100% distributed throughout waste, carton sealed.

3. 100% distributed throughout waste, carton open.

in the bag. When the amount of waste in the bag reaches the capacity of the carton, the air is expelled and the end of the bag twisted into a tail. The four end pieces of the carton are folded over, and all openings sealed with masking tape.

Three waste configurations were used. The first type, half the uranium was placed on loose waste sealed in 10 plastic bags. The sealed bags were randomly mixed into loose waste held in the waste carton and the remainder of the uranium dispersed in the loose waste. The second waste configuration used in this study was to disperse the contamination randomly on the loose waste held in the waste container. Finally, unsealed cartons with the uranium dispersed on loose waste were burned.

FIGURE 1

URANIUM DIOXIDE POWDER SIZE DISTRIBUTION BY WHITBY CENTRIFUGE

All experiments were performed in the Radioactive Aerosol Release Tank (RART) located in the Radioactive Aerosol Release Facility -- 242-B Building. The facility and procedures in use have been described.^[10] The RART is a cylindrical, stainless steel vessel, 9.5 ft. in diameter $\times$ 10 ft. tall. Its volume is approximately 710 cu. ft. The vessel is equipped with ten 4-inch diameter sampling ports and a 24 in. $\times$ 42 in. entry port. Exterior air is drawn into the vessel through the wind tunnel via a 2 ft. $\times$ 2 ft. opening and exhausted through a 24-inch diameter stainless steel mesh mist entrainment separator located in the top of the tank. Air within the vessel can be circulated via a closed loop made of 4 inch, SCH. 10 stainless steel pipe at 100 cfm by a forge pump. Air is drawn from the top of the vessel and returned near the floor (see Figure 2).

The flammable material was burned on a stainless steel screen (shown in Figure 3) placed on the floor of the RART. Aluminum foil strips, 2 in. wide $\times$ 10 ft. long, were taped to the walls approximately 120° apart to monitor wall deposition during the experiments. Sheet steel trays, 11 in. $\times$ 17 in., with a thin film of oil were placed on the floor of the RART approximately 6 inches from the wall in front of each aluminum foil strip. A hole was punched into the side of the waste carton and the contents remotely ignited by an oil soaked cloth fuse with an incandescent nichrome coil. Once ignited, the flammable material was allowed to burn to completion. In nine of eleven experiments, smoke rapidly filled the vessel, obscuring vision and limiting burning.

The quantity and size distribution of the uranium particles airborne was monitored by taking periodic filter and cascade impactor samples of the atmosphere in the vessel. Filter samples were taken by an open-faced, 2-inch diameter glass fiber filter holder inserted approximately 5 feet into the vessel on the end of a stainless steel tube, 1/2 inch OD. The probe was inserted via a sampling port approximately 7 feet above the floor of the vessel. Cascade impactor samples were extracted by a stainless steel tube 1/2 inch OD inserted about 4 feet into the vessel via a sampling port opposite that used for the filter sample. Both filter and cascade impactor samplers were operated at 1 cfm. Sampling times varied from 1 to 60 minutes for filter samples -- during periods of high smoke density sampling rate could not be maintained for more than a minute. Cascade impactor samples were collected for at least 10 and up to 60 minutes.

After the filter and cascade impactor samples were placed into solution

FIGURE 2

RADIOACTIVE AEROSOL RELEASE TANK

FIGURE 3

STAINLESS STEEL SCREEN & SUPPORT USED IN BURNING
OF FLAMMABLE MATERIALS

(generally a period of two to three days), the RART was entered and cleaned. The residue in the burner tray was carefully collected. In experiment FW-8 to FW-11, an air sample was taken during this operation. The fallout trays and aluminum foil wall strips were carefully gathered for analyses. The interior of the vessel was then washed with detergent and scoured as required.

The procedure used to dissolve the particles collected in various samples has been published.^[10] The various procedures are:

Filters, Glass Impactor Dishes, Residue

The item is placed in a pre-marked beaker, covered with 9N nitric-0.1N hydrofluoric acid mixture, warmed for 1 hour, and repeated if required. The glass dish or filter residue was removed and the acid evaporated to incipient dryness. The residue was taken up in 6N nitric acid, warmed gently and filtered. The volume was reduced to less than 5 ml (or minimum volume to retain dissolved salts), then washed into volumetric flask and brought to the mark using 6N nitric acid.

Fallout Trays

The material adhering to the oil film was carefully washed into a #41 Whatman filter paper. The material caught on the filter paper was treated as above.

Aluminum Foil Wall Strips

The aluminum foil was placed in a pre-marked beaker and covered with dilute sodium hydroxide solution. The solution was warmed gently if necessary until all the foil dissolved. The liquid was filtered through a #41 Whatman filter and the filter rinsed with distilled water. The filter was then treated as any other filter (see above).

The uranium content of the solutions was measured by fluorimetry. A measured aliquot of the sample was dried on a platinum dish and fluxed with sodium fluoride. The quantity of uranium on the dish was determined by measuring the uranium fluorescence under ultraviolet light. A background level was determined prior to the start of the experimental program by collecting samples using the aforementioned techniques under actual experimental conditions without uranium. A value of 5×10^{-8} g uranium per milliliter was greater than 90 percent of the values measured from all types of samples and was selected as the lower detection limit for uranium under these test conditions. The lower

detection for the fluorimetric method is 1×10^{-8} g uranium per milliliter. A "spike" run is performed with each analysis to eliminate matrix effects. Even with the "spike" runs, a variance of $\pm 35\%$ is assigned to individual analysis on the 95% confidence level due to the high salt content of many of the solutions.

DISCUSSION AND CONCLUSIONS

Very little of the uranium incorporated in flammable materials became airborne during combustion. The maximum quantity detected airborne was 0.053% of the uranium used in the source in experiment FW-1. The maximum quantity airborne calculated from the uranium found deposited on the walls was as high as 0.23% (FW-5). Fractional releases tended to be higher from dry material incorporated with flammable materials (uranium dioxide powder or solid residues from drying UNH solutions) than from solutions. Greater than 50 percent of the uranium airborne in all experiments was associated with the size fraction less than 10 microns Aerodynamic Equivalent Diameter. In 8 of the 11 experiments, greater than 80 percent of the uranium airborne was associated with these fractions.

The fractional airborne release, the distribution of the uranium after the experiments and some descriptive information is tabulated in Table II, "Fractional Airborne Releases of Uranium During the Burning of Contaminated Waste". The fractional releases calculated from measured airborne concentrations range from 0.003 to 0.053%. The quantity potentially airborne calculated from uranium found deposited on the walls subsequent to each experiment showed greater variation ranging from 0.0029 to 0.23%.

The fractional airborne releases are consistent with laboratory-scale experiments previously reported.^[7] Gram quantities of various flammable materials impregnated with dilute plutonium nitrate solution were burned in a 12-inch diameter stainless steel pot. From 0.02 to 1.0 percent of the plutonium was entrained in an upsweep of air with a nominal velocity of 5.6 cm per sec. Much greater quantities could be entrained if air, at higher velocities, was drawn through the burning mass. As much as 40 percent of uranium dioxide powder on tissue paper was entrained at a nominal velocity of 100 cm per sec.^[7] As much as 8 percent of the uranium present as a nitrate solution was entrained under the same conditions.^[7] Less than 1 percent of uranium present as a nitrate

TABLE II

FRACTIONAL AIRBORNE RELEASES OF URANIUM DURING THE BURNING OF CONTAMINATED WASTE

Experiment No.	Uranium Compound Used	Weight Uranium Used (grams)	Waste Config.	Fractional Airborne Release (% of Uranium Used As Source)			Percent Uranium Recovered	Percent Uranium Recovered In		
				Max. Concentration	Airborne Deposition	Wall		Residue	Floor	Walls Airborne
FW-1	UO ₂	9.1	1	0.053	0.048		78	98.2	1.7	0.06 0.07
FW-2	a.d.UNH	25.5	1	0.003	0.045		80	99.9	0.06	0.008 0.003
FW-3	UNH	25.5	2	0.0083	0.011		85	99.5	0.46	0.013 0.01
FW-4	UNH	25.5	1	0.0047	0.11		177	99.9	0.01	0.06 0.003
FW-5	UO ₂	64.1	2	0.017	0.23		69	98.6	0.9	0.5 0.02
FW-6	UO ₂ /UNH	51	2	0.0041	0.0033		89	99.9	0.08	0.004 0.005
FW-7	UNH	25.5	2	0.0030	0.0094		85	99.9	0.1	0.01 0.004
FW-8	UO ₂	50.2	3	0.0052	0.010		74	99.3	0.7	0.01 0.007
FW-9	a.d.UNH	25.5	3	0.015	0.016		65	99.9	0.07	0.03 0.06
FW-10	UNH	51	3	0.015	0.0029		66	99.7	0.3	0.004 0.02
FW-11	UO ₂	51.6	2	0.015	0.024		91	99.4	0.5	0.03 0.008
							$\bar{x}$			97

UNH -- Uranyl nitrate hexahydrate solution

a.d.UNH -- Air dried following addition to waste as UNH solution.

solution was entrained from materials producing heavier ash.^[7]

The burning of a solid is heterogeneous reaction. Heat causes the generation of a flammable vapor which burns in the air. Under static conditions, as in these experiments, only materials injected into the buoyant, heated gases in the flame would be made airborne giving low fractional release values. Small, light ash particles from exposed surfaces and materials entrained during the break-up of solids are likely candidates. Materials deeper in the mass have a more tortuous path. Thus, in the experiments using plutonium nitrate and low air velocities, much of the plutonium was on exposed surfaces yielding slightly higher fractional releases. In the experiments where air was drawn through burning materials impregnated with uranium dioxide or nitrate, the fractional release reflected the break-up of the solid structure during burning. When a fine ash was produced as in the case of uranium dioxide on tissue paper, a considerable quantity of the uranium could be carried off with the ash. In the presence of a concentrated salt solution as uranium nitrate, fragments of salt adhered together making entrainment more difficult.

In a closed system as used in these experiments, some degree of correlation is anticipated between the quantity airborne and the quantity deposited on various surfaces. If there were complete separation between the burning materials and the vessel, all materials found on the surfaces could be considered as having been airborne at some point. Visual observations during and after the experiments indicate that varying portions of the material on the floor was due to spillage from the receptacle during the collapse of the burning box. The uranium found on the walls probably resulted from the flux from the heated interior to the cool walls and material made airborne as a result of the collapsing box.

The manner in which the waste was packaged in these experiments appears to have little effect upon the fractional airborne release. Table III lists the fractional airborne releases from the three forms of uranium used in these experiments utilizing three packaging configurations. Some variation is discernible within each uranium form for three packaging configurations, but no configuration appears to show a consistent trend.

In most instances, the dry forms (powders or residues from drying solutions) appear to release a somewhat higher fraction than liquid incorporated in flammable materials under the same conditions. Again, the fractional air-

TABLE III

VARIATION OF FRACTIONAL AIRBORNE RELEASE DUE TO PACKAGING
CONFIGURATION AND URANIUM FORM USED AS SOURCE

	Percent of Source Airborne With Particles Less Than 10 Microns Aerodynamic Equivalent Diameter		
	Packaging Config.	Packaging Config.	Packaging Config.
	No. 1	No. 2	No. 3
Uranium Dioxide Powder	0.048	0.0041	0.0024
Uranium Nitrate Solution	0.014 0.015	0.0074 0.0026	
Solid residues from air drying uranium nitrate solutions	0.0026	0.009	0.012

borne releases measured were erratic but low. The releases using dry uranium as the source ranged from 0.002 to 0.05% while releases using solutions as the source ranged from 0.002 to 0.009%.

Although the mass balances measured show considerable variation, all are within the stated anticipated variance of the uranium procedure. In every experiment, almost all (greater than 98 percent) the uranium was associated with the solid residues found in the burner receptacle. The quantities of solid residue found ranged from 200 to 400 grams and contained large pieces of unburned material in some experiments. Separating the uranium from this quantity of material is not a trivial task. The presence of a large quantity of salt also increases the difficulty of making accurate fluorometric measurements. Thus, the greatest uncertainty is associated with uranium results in residue samples. Even if the fractional airborne release values are adjusted to compensate for variance in mass balance, the fractional release values would remain very low. Thus, although the limiting parameter or combination of parameters was not identified, fractional airborne releases under the conditions of the study are low. Small fractional releases are not unexpected under the static conditions used in these experiments and found in fires in enclosures. In the absence of extraneous forces, mechanisms which can inject particles into the buoyant plume of the fire are limited.

REFERENCES

- [1] D. H. Slade. Meteorology and Atomic Energy, TID-24190, U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tennessee (July, 1968).
- [2] J. Mishima. Plutonium Release Studies -- I. Release from the Ignited Metal BNWL-205, Battelle, Pacific Northwest Laboratories, Richland, Washington (December, 1965).
- [3] J. Mishima. Plutonium Release Studies -- II. Release from Ignited Bulk, Metallic Pieces, BNWL-357, Battelle, Pacific Northwest Laboratories, Richland, Washington (November, 1966).
- [4] J. Mishima, L.C. Schwendiman, and C.A. Radasch. Plutonium Release Studies -- III. Release from Heated Plutonium Bearing Powders, BNWL-786, Battelle, Pacific Northwest Laboratories, Richland, Washington (July, 1968).
- [5] J. Mishima, L.C. Schwendiman, and C.A. Radasch. Plutonium Release Studies -- IV. Fractional Release from Heating Plutonium Nitrate Solutions in a Flowing Air Stream, BNWL-931, Battelle, Pacific Northwest Laboratories, Richland, Washington (November, 1968).
- [6] L.C. Schwendiman, J. Mishima, C.A. Radasch. Airborne Release of Particles in Overheating Incidents Involving Plutonium Metal and Compounds. BNWL-SA-1735, Battelle, Pacific Northwest Laboratories, Richland, Washington, (August, 1968).
- [7] J. Mishima and L.C. Schwendiman. The Amount and Characteristics of Plutonium Made Airborne Under Thermal Stress, BNWL-SA-3379, Battelle, Pacific Northwest Laboratories (October, 1970).
- [8] G.E. Guthrie and J.P. Nichols. Theoretical Possibilities and Consequences of Major Accidents in ^{233}U and ^{239}Pu Fuel Fabrication and Radioisotope Processing Plants, ORNL-3441, Oak Ridge National Laboratory, Oak Ridge, Tennessee (April, 1964).
- [9] J. Mishima and L.C. Schwendiman. "The Airborne Release of Plutonium During Overheating Incidents," Transactions of American Nuclear Society, 12, No. 12, P. 445 (1969).
- [10] J. Mishima and L.C. Schwendiman. Facility Description and Procedures -- Large Scale Aerosol Release Facility, 242-B Building, BNWL-B-91, Battelle, Pacific Northwest Laboratories, Richland, Washington (June, 1971).

DISTRIBUTIONOff-site

- 1 AEC Chicago Patent Group
G.H. Lee
- 3 AEC Technical Information Center

On-Site, Hanford

- 1 AEC Patent Attorney
R.M. Poteat
- 2 AEC Richland Operations
W.E. Lotz
- 10 Atlantic Richfield Hanford Company
R.E. Isaacson/L.E. Bruns
- 43 Battelle-Northwest
 - R.E. Burns
 - R.L. Conley
 - J.J. Fuquay
 - J.M. Hales
 - J. Mishima (25)
 - A.K. Postma
 - L.C. Schwendiman (7)
 - J.M. Selby
 - C.L. Simpson
 - Technical Information (3)
 - Technical Publications