INTERIM REPORT

**QUARTERLY PROGRESS REPORT COVERING PERIOD
APRIL 1 THROUGH JUNE 30, 1978—FOR STUDY
OF PLUTONIUM OXIDE LEAK RATES FROM
SHIPPING CONTAINERS**

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August 29, 1978

This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

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APRIL 1 THROUGH JUNE 30, 1978 -- FOR STUDY
OF PLUTONIUM OXIDE LEAK RATES FROM SHIP-
PING CONTAINERS

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INTERIM REPORT

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Quarterly Progress Report
April 1, 1978 -- June 30, 1978

STUDY OF PLUTONIUM OXIDE LEAK RATES FROM SHIPPING CONTAINERS

INTRODUCTION

This study was initiated in October 1976, as outlined in the 189 research proposal submitted previously. Several tasks are to be undertaken in this study which, when combined, have the end objective of defining the leak rates of plutonium oxide powder from characterized leaks.

This is the seventh quarterly report of this work. Previous reports were issued as BNWL-2260-1, -2, -3, -4, -5, and -6. Each task will be identified and the progress during the reporting period briefly described.

PROGRESS TO DATE

TASK A -- Review literature and theoretical work relating to transmission of particles through channels

Task objective has been fulfilled, and two reports issued: "Supporting Information for the Estimation of Plutonium Oxide Leak Rates Through Very Small Apertures," by L.C. Schwendiman, BNWL-2198, and "Transport of Particles Through Gas Leaks -- A Review," by L.C. Schwendiman and S.L. Sutter, BNWL-2218, January 1977.

TASK B -- Investigate the relationship of gas flow rates, leak geometries, pressure and temperatures

Milestone 1. Review literature on topic.

Milestone 2. Report on technical literature.

These milestones were reached and a document, "Estimation of Gas Leak Rates Through Very Small Orifices and Channels," by H.J. Bomelburg, BNWL-2223, was issued.

Milestone 3. Select method and design apparatus for flow experiments.

Milestone 4. Fabricate and assemble apparatus.

Milestone 5. Test apparatus.

Milestone 6. Conduct first test.

Milestones 1 through 6 were completed in FY-1977.

Milestone 7. Complete test series (orifices). January 1978.

Milestone 8. Draft report. March 1978.

Milestone 9. Issue report.

The document, "Measured Airflow Rates Through Microorifices and Flow Prediction Capability," NUREG/CR-0066 (PNL-2611) was issued in July 1978.

Milestone 10. Fabricate microcapillaries

Milestone 11. Complete test series. April 1978.

Milestone 12. Draft report.

A preliminary draft of a document, "Measured Airflow Rates through Tubing of Fine Bore," is being circulated for internal review.

TASK C -- Measure transmission of a well characterized simulant (UO₂ powder) through leaks characterized in Task B

Milestone 1. Pressure vessel for simulating container available for experiments.

The Agitated Powder Leak Apparatus (APLA) was placed into service for 100-1000 psi pressure range in February 1978. During this quarter, the 0-100 psi pressure transducer was calibrated after repeated efforts and minor problems. A manifold has also been installed to allow longer experimental periods at high airflow rates.

Milestone 2. Convert airflow apparatus. Completed January 1978.

Milestone 3. First experiment completed.

Initial experiments to measure the transmission of UO₂ when the leakpath is above (APLA) or below (UPL) the powder level were completed in the third quarter of FY-1978.

- Leakpaths above the static powder level with powder agitation.

Forty-one experiments under constant upstream pressure have been completed. Twenty-seven of these experiments involved individual orifices or capillaries, while the other twenty-four involved multiple orifices of the same nominal diameter. The results of 30 experiments for which the uranium measurements have been completed are shown in Table I. The quantity of UO₂ (DUO) measured are reported as total µg DUO transmitted, µg DUO/min, and µg DUO/cc air.

- Individual orifice or capillary experiments

Single orifices or capillaries were placed in a sample collection chamber attached to the APLA pressure vessel. The powder in the vessel is continuously agitated using compressed air, and the aerosol in the vessel is leaked through

TABLE I
DEPLETED URANIUM DIOXIDE TRANSMITTED THROUGH WELL CHARACTERIZED LEAKS

APLA	ORIFICE OR CAPILLARY DESIGNATION	MEASURED DIAMETER μm	CHAMBER PRESSURE psig	TIME min	AIR FLOW cc/min	TRANSMITTED ⁽⁴⁾ DUO, μg	DUO $\mu\text{g/min}$	DUO $\mu\text{g/cc}$
1	1-110	100	1000	20	7100 ⁽²⁾	5.23 ± 1.6	0.26	4×10^{-5}
2	1-200	200	1000	20	16400 ⁽²⁾	$2.5 \times 10^4 \pm 8.7 \times 10^3$	1.25×10^3	8×10^{-3}
3 ⁽¹⁾	1-110	100	1000	10	2100 ⁽²⁾	140 ± 42	14	7×10^{-3}
4	2-110	125	500	30	4300-3800 ⁽³⁾	1330 ± 410	44	1×10^{-2}
5	2-200	200	500	30	6200 ⁽²⁾	1300 ± 340	43	7×10^{-3}
6	2-63.5	61	1000	10	2100	55.6 ± 17	6	3×10^{-3}
7								
7-1	1-20	22	500	10	111	60.7 ± 18	6	5×10^{-2}
7-2	1-20a	23	500	30	133	16.4 ± 4.9	0.5	3.8×10^{-3}
7-3	2-20	20	500	60	94	36.7 ± 11	0.6	6.5×10^{-3}
7-4	3-20	23	500	120	140	10.6 ± 3.2	0.1	7.1×10^{-4}
8	2-20	20	1000	10	210	13.2 ± 4	1.3	6×10^{-3}
9	2-36	33	1000	10	580	33.1 ± 9.9	3.3	6×10^{-3}
10	2-63.5	61	500	30	1000	54.7 ± 16	1.8	2×10^{-3}
11	3-36	38	500	30	470	21.7 ± 6.5	0.7	2×10^{-3}
12	2-20	20	500	30	94	42.8 ± 13	1.4	2×10^{-2}
13	1-200	200	1000	10	22000	5090 ± 2600	509	2×10^{-2}
14	250 A	274	500	30	5400 ⁽²⁾	30.4 ± 9.1	1	2×10^{-4}
15	150 A	189	1000	10	10500	1280 ± 660	128	1.2×10^{-2}
16	2-200	200	1000	10	22000	8730 ± 4400	873	4×10^{-2}
17	1-200	200	30	60	1000	80.3 ± 24	1.3	1×10^{-3}
18	1-110	100	30	60	245	56.3 ± 17	0.9	4×10^{-3}
19	1-63.5	66	30	60	80	17.8 ± 5.3	0.3	4×10^{-3}

(1) DUPLICATE OF 1 BECAUSE OF POOR PRESSURE CONTROL IN RUN 1

(2) LESS THAN DESIRED FLOW

(3) DROPPED 1 MINUTE INTO RUN

(4) THE $\pm$ IS THE UNCERTAINTY IN THE URANIUM ANALYSIS AT THE 2 σ CONFIDENCE LEVEL

Table I: (continued)

APLA	ORIFICE OR CAPILLARY DESIGNATION	MEASURED DIAMETER μm	CHAMBER PRESSURE psig	TIME min	AIR FLOW cc/min	TRANSMITTED ⁽⁴⁾ DUO, μg	DUO $\mu\text{g/min}$	DUO $\mu\text{g/cc}$
20								
20-1	3-30	33	500	10	350	19.3 ± 5.8	1.9	5×10^{-3}
20-2	1-36	43	500	30	435	32.2 ± 9.7	1.1	3×10^{-3}
20-3	2-36	33	500	60	285	10.3 ± 3.1	0.2	6×10^{-4}
20-4	3-36	38	500	120	470	15 ± 4.5	0.1	3×10^{-4}
21	1-200	200	500	30	6400 ⁽²⁾	12.8 ± 3.8	0.4	7×10^{-5}
22								
22-1	3-30	33	500	30	350	10.5 ± 3.2	0.5	1×10^{-3}
22-2	1-36	43	500	30	435	20.4 ± 6.1	0.7	2×10^{-3}
22-3	2-36	33	500	30	285	12.3 ± 3.7	0.4	1×10^{-3}
22-4	3-36	38	500	30	470	11.3 ± 3.4	0.4	9×10^{-4}
23	250 A	274	1000	10	0-1000 ⁽²⁾	12.7 ± 3.8	1.3	1.3×10^{-3}
24								
24-1	1-20	22	500	30	111	7.9 ± 2.4	0.3	2×10^{-3}
24-2	2-20	20	500	30	94	5.5 ± 1.6	0.2	2×10^{-3}
24-3	3-20	23	500	30	140	4.5 ± 1.3	0.2	1×10^{-3}
24-4	1-20 a	23	500	30	133	10.9 ± 3.3	0.4	3×10^{-3}
25								
25-1	1-63.5	66	500	30	1100	75.6 ± 23	2.5	2×10^{-3}
25-2	2-63.5	61	500	30	1000	78.7 ± 24	2.6	3×10^{-3}
25-3	3-63.5	65	500	30	1200	87.3 ± 26	2.9	2×10^{-3}
26	150 B	176	500	30	5600	720 ± 330	24	4×10^{-3}
27								
27-1	1-63.5	66	500	10	1100	4 ± 1.2	0.4	4×10^{-4}
27-2	2-63.5	61	500	30	1000	6.1 ± 1.8	0.2	2×10^{-4}
27-3	3-63.5	65	500	60	1200	10.8 ± 3.2	0.2	2×10^{-4}
28	200 B	231	1000	10	20000	2690 ± 1100	269	1×10^{-2}
29								
29-1	1-20	22	1000	10	275	36.5 ± 11	4.0	1×10^{-2}
29-2	1-20 a	23	1000	10	275	9.2 ± 2.8	0.9	3×10^{-3}
29-3	2-20	20	1000	10	210	20.9 ± 6.3	2.1	1×10^{-2}
29-4	3-20	23	1000	10	290	6.0 ± 1.8	0.6	2×10^{-3}
30								
30-1	1-20	22	1000	10	275	6.8 ± 2	0.7	3×10^{-3}
30-2	1-20 a	23	1000	20	275	3.3 ± 1.2	0.2	7×10^{-4}
30-3	2-20	20	1000	30	210	13.2 ± 3.9	0.4	2×10^{-3}
30-4	3-20	23	1000	60	290	5.8 ± 1.7	0.1	3×10^{-4}

the leakpath positioned approximately 1 inch above the powder level. The leak rate is maintained at the airflow rate measured in the flow experiment for the upstream pressure condition by applying negative pressure downstream of the collector. The principal variable parameters in these experiments are leak diameter and upstream pressure. The time span of the experiment also varied for some of the initial experiments because of the limited quantity of air that could be used from a single 1A gas cylinder. A manifold providing for simultaneous use of up to five cylinders has alleviated the problem. (The quantity of DUO leaked is not expected to always be linear with time, since the aperture may be blocked during the run.)

The powder transmission rates ($\mu\text{g DUO/min}$) for orifices appear to increase with orifice diameter, but not necessarily with upstream pressure. Figure 1 is a plot of the transmission rates available for the five nominal diameters as a function of upstream pressure. In most cases the powder transmission rate increases with orifice diameter under a given upstream pressure, but the transmission rate for a given diameter does not necessarily increase with increased upstream pressure (at least for this preliminary data) except for the 200 μm orifice. The powder transmission rate for a 20 μm orifice at 1000 psi was approximately 1.5×10^{-3} of that through a 200 μm orifice at the same pressure. The ratio of the area and airflow rates for the two orifices are 1×10^{-3} and 1×10^{-2} , respectively.

Figure 2 shows the powder transmission rate of a 200 μm orifice and a 1-inch long 180 μm capillary at 1000 and 500 psi. It appears that increasing the path length decreases the powder transmission rate, although these data are too few to show the functional relationship.

- Multiple leak path experiments

Experiments are also being performed to assess the standard deviation to be anticipated for individual powder transmission rates for leakpaths of each nominal diameter under the upstream pressure conditions used in this study, and for changes in powder transmission rates as a function of time. Multiple orifice runs for the same time period (APLA #22, 24, 25, and 29) are generally within a factor of two with the 20 μm orifice at 1000 psi, showing a range of a factor of six.

The powder transmission rates indicate a decrease with time. Figure 3 is a plot of the calculated powder transmission rate for the 20 μm orifice

FIGURE 1

APLA POWDER LEAK RATES THROUGH ORIFICES AS A
FUNCTION OF PRESSURE

FIGURE 2
APLA POWDER LEAK RATES AN ORIFICE AND A
CAPILLARY (WITH AGITATION)

FIGURE 3

APLA POWDER LEAK RATES AS A FUNCTION OF TIME

at 500 and 1000 psi with time (APLA #7 and 30). The calculated powder transmission rates with time for the nominal 36 (APLA #20) and 63.5 μm (APLA #27) orifices show similar decreases. The apparent drop in transmission rates may be indicative of powder bridging at the orifice opening or an artifact of the normal variation in rates. In three out of four instances, the DUO collected for the shortest time period exceeded some of the values for longer collection periods. Some additional experiments are planned to ascertain variations in the mass airborne concentrations in the vessel under experimental conditions.

An experiment was performed to measure powder transmission rates under a decaying pressure regime. Three nominal 63.5 μm orifices in sample collectors were installed on the APLA pressure vessel, the powder agitated, and the vessel pressurized to 1000 psi. The vessel was allowed to depressurize through the leakpaths to 40 psi in 20 hours during which no attempt was made to maintain any specific flowrate. The pressure decay is shown in Figure 4. The measurements of DUO transmitted have not been received.

- Leakpath under the powder level (UPL)

Seventy-three experiments have been performed using individual orifices or capillaries whose openings were under approximately 1-mm (3g) DUO at constant upstream pressure. All measurements of the DUO transmitted are tabulated in Table II. The powder transmission rates appear to increase with increasing orifice/capillary diameter but not necessarily with pressure (see Figures 5 and 6). The transmission rates for all nominal sizes under 200 μm appear to maximize at approximately 100 psig, to decrease at 500 psi, and to increase at 1000 psi, although not always to the 100 psi rate. The effect may indicate initial movement of the powder (to 100 psi), compaction and blockage of particle flow with or without loss of airflow (to 500 psi), and reestablishment of particle flow because of increased pressure or channeling.

Figure 7 shows the powder transmission rates for 200 μm orifices and the nominal 150 μm capillaries (actual diameters of 189 and 175 μm) and indicates that powder transmission decreases with leakpath length. Because of the uncertainties in DUO measurements and normal variations under these conditions, additional experiments are planned to verify these results.

FIGURE 4
PRESSURE DECAY IN VESSEL AS A FUNCTION OF TIME

TABLE II
DEPLETED URANIUM DIOXIDE TRANSMISSION RATES FOR LEAKPATHS UNDER
THE POWDER LEVEL

UPL	ORIFICE OR CAPILLARY DESIGNATION	MEASURED DIAMETER, μm	CHAMBER PRESSURE psig	AGITATION	LENGTH OF RUN min	AIR FLOW cc/min	TRANSMITTED ⁽³⁾ DUO, μg	DUO μg/min	DUO μg/cc
1	2-200	200	1000	NO	5	12200-21000	$3.54 \times 10^3 \pm 1.3 \times 10^3$	(1)	(1)
2	2-200	200	1000	NO	5	13800	$1.61 \times 10^3 \pm 5.9 \times 10^2$	3.2×10^2	2×10^{-2}
3	2-200	200	1000	YES	5	6200	$4.89 \times 10^3 \pm 1.7 \times 10^3$	9.8×10^2	2×10^{-1}
4	2-200	200	5	NO	60	16.6	6.96 ± 2.1	0.1	7×10^{-3}
5	2-200	200	5	YES	60	18.2	4.05 ± 1.2	0.1	4×10^{-3}
6	2-110	125	1000	NO	20	4600	118 ± 35	5.9	1×10^{-3}
7	2-110	125	1000	YES	20	8000	133 ± 40	6.7	8×10^{-4}
8	2-110	125	15	YES	60	76	37.2 ± 11	0.6	8×10^{-3}
9	2-110	125	15	NO	60	18	25.2 ± 7.5	0.4	2×10^{-2}
10	2-63.5	61	1000	NO	20	1900	58.9 ± 18	2.9	2×10^{-3}
11	2-63.5	61	1000	YES	20	2000	111 ± 33	5.6	3×10^{-3}
12	2-63.5	61	15	NO	60	18	51.5 ± 1.5	1.0	5×10^{-2}
13	2-63.5	61	15	YES	60	16	17.4 ± 5	0.3	2×10^{-2}
14	2-36	33	1000	NO	20	31	14.8 ± 4	0.7	2×10^{-2}
15	2-36	33	1000	YES	20	26	72.5 ± 22	3.6	1×10^{-2}
16	2-36	33	15	NO	120	0.3	4.5 ± 1.8	0.04	1×10^{-1}
17	2-36	33	15	YES	120	1.1	12.6 ± 3.8	0.1	9×10^{-2}
18	2-20	20	1000	NO	20	30	82.4 ± 25	4.0	1×10^{-1}
19	2-20	20	1000	YES	20	61	11.2 ± 3.4	0.6	1×10^{-2}
20	2-20	20	15	YES	120	ND ⁽²⁾	21.2 ± 6	0.2	
21	2-20	20	15	NO	120	ND	13.6 ± 4	0.1	
22	2-200	200	500	NO	20	6500	812 ± 220	40.6	6×10^{-3}
23	2-200	200	500	YES	20	5750	1960 ± 330	98.0	2×10^{-2}
24	2-110	125	500	NO	20	3250	150 ± 45	7.5	2×10^{-3}

(1) ALMOST ALL DUO EXPELLED IMMEDIATELY

(2) ND, NOT DETECTABLE, LESS THAN 0.2 cc/min

(3) THE $\pm$ IS THE UNCERTAINTY IN THE URANIUM ANALYSIS AT THE 2 σ CONFIDENCE LEVEL

Table II (Continued)

UPL	ORIFICE OR CAPILLARY DESIGNATION	MEASURED DIAMETER, μm	CHAMBER PRESSURE psig	AGITATION	LENGTH OF RUN, min	AIR FLOW cc/min	TRANSMITTED ⁽³⁾ DUO, μg	DUO $\mu\text{g/min}$	DUO $\mu\text{g/cc}$
25	2-110	125	500	YES	20	2550	86.3 ± 26	4.3	2×10^{-3}
26	2-63.5	61	500	NO	30	470	71.8 ± 22	2.4	5×10^{-3}
27	2-63.5	61	500	YES	30	275	37.0 ± 11	1.2	4×10^{-3}
28	2-36	33	500	NO	60	225	20.4 ± 6	0.3	1×10^{-3}
29	2-36	33	500	YES	60	75 ⁽¹⁾	36.1 ± 11	0.6	8×10^{-3}
30	2-20	20	500	NO	60	14	15.0 ± 5	0.3	6×10^{-3}
31	2-20	20	500	YES	60	0.75	13.0 ± 4	0.2	3×10^{-1}
32	250 B	274	1000	NO	5	32500	379 ± 110	75.8	2×10^{-3}
33	250 B	274	1000	YES	10	32000	2830 ± 400	283	9×10^{-3}
34	150 B	176	1000	NO	5	9600	1270 ± 220	254	3×10^{-2}
35	150 B	176	1000	YES	10	7400	498 ± 120	50	7×10^{-3}
36	250 B	274	500	NO	30	14100	311 ± 98	10	7×10^{-4}
37	250 B	274	500	YES	30	11500	585 ± 140	20	2×10^{-3}
38	150 B	176	500	NO	30	3950	374 ± 100	12	3×10^{-3}
39	150 B	176	500	YES	30	5400	395 ± 120	13	2×10^{-3}
40	250 B	274	15	YES	60	410	1950 ± 300	33	8×10^{-2}
41	250 B	274	15	NO	60	28	78.3 ± 23	1.3	4×10^{-2}
42	150 B	176	15	YES	60	29	122 ± 37	2	7×10^{-2}
43	150 B	176	15	NO	60	50	129 ± 39	2	4×10^{-2}
44	2-200	200	100	NO	30	820	740 ± 400	25	3×10^{-2}
45	2-200	200	100	YES	30	485	578 ± 320	19	3×10^{-2}
46	2-110	125	100	NO	30	325	464 ± 140	15	5×10^{-2}
47	2-110	125	100	YES	30	280	120 ± 36	4	1×10^{-2}
48	2-63.5	61	100	NO	30	26.6	68.4 ± 21	2.3	9×10^{-2}

Table II: (Continued)

UPL	ORIFICE OR CAPILLARY DESIGNATION	MEASURED DIAMETER, μm	CHAMBER PRESSURE psig	AGITATION	LENGTH OF RUN, min	AIR FLOW cc/min	TRANSMITTED ⁽³⁾ DUO, μg	DUO $\mu\text{g}/\text{min}$	DUO $\mu\text{g}/\text{cc}$
49	2-63.5	61	100	YES	30	66.4	190 ± 57	6.3	0.1
50	2-36	33	100	NO	30	6.8	139 ± 42	4.6	0.7
51	2-36	33	100	YES	30	15	69 ± 21	2.3	0.2
52	2-20	20	100	NO	30	ND	97.4 ± 29	3.2	
53	2-20	20	100	YES	30	ND	59.2 ± 18	2.0	
54	250 B	274	100	NO	30	1550	1160 ± 600	38.7	3×10^{-2}
55	250 B	274	100	YES	30	2780	338 ± 100	11.3	4×10^{-3}
56	150 B	176	100	NO	30	ND	94 ± 28	3	
57	150 B	176	100	YES	30	900	90.6 ± 27	3	3×10^{-3}
58	150 S	182	100	NO	30	660	395 ± 12	13.2	2×10^{-2}
59	150 S	182	100	YES	30	1180	118 ± 35	3.9	3×10^{-3}
60	250 S	276	100	NO	30	660	1330 ± 580	44	7×10^{-2}
61	250 S	276	1000	NO	10	19900	$7.92 \times 10^4 \pm 3.4 \times 10^4$	7920	0.4
62	250 S	276	500	NO	10	20200	$1.36 \times 10^4 \pm 5.6 \times 10^3$	1360	7×10^{-2}
63	250 S	276	500	YES	10	13900	$1.22 \times 10^4 \pm 5 \times 10^3$	1220	9×10^{-2}
64	150 S	182	1000	NO	10	10800	1690 ± 730	169	2×10^{-2}
65	150 S	182	1000	YES	10	12200	1330 ± 580	133	1×10^{-2}
66	150 S	182	500	NO	30	4200	666 ± 320	22	5×10^{-3}
67	150 S	182	500	YES	30	6800	852 ± 380	28.4	4×10^{-3}

FIGURE 5

UPL POWDER LEAK RATES THROUGH ORIFICES AS A FUNCTION
OF PRESSURE (WITH AGITATION)

FIGURE 6

UPL POWDER LEAK RATES THROUGH ORIFICES AS A FUNCTION
OF PRESSURE (NO AGITATION)

FIGURE 7
UPL POWDER LEAK RATES FOR ORIFICES AND CAPILLARIES

TASK D -- Measure fuel grade PuO_2 leaks through a "standard leak" incorporated into a suitable container

- Milestone 1. Design of experimental equipment.
- Milestone 2. Assembly of experimental System.
- Milestone 3. Simulant experiments.
- Milestone 4. Transfer to glovebox.
- Milestone 5. Conduct "hot experiments".

There are no significant results to report in this task for this period. Primary emphasis during this period was on Task E.

TASK E -- Investigate PuO_2 leaks through simulated and defected containers

- Milestone 1. Fabricate leaky container.
- Milestone 2. Simulant test completed.
- Milestone 3. Complete this PuO_2 test series.

- Room-Temperature Simulated Crack Experiments

- Helium Flow Rate Equal to 11.4 cc/sec

Room-temperature leak rate experiments were conducted using the simulated crack having mating surfaces with a 220-microinch finish (with matching grooves perpendicular to the direction of the helium flow). These experiments are repeats of those carried out last period, which were invalidated after it was discovered that the cotton swabs used to survey the inlet nozzle were contaminated with PuO_2 .

For these experiments, the torque on the leak tube cap was adjusted to obtain an initial helium leak rate of 11.4 cc/sec at 920 psig. This leak rate is comparable to that (8 cc/sec) through a 20- μm orifice. Helium pressures of 920, 440, and 0 psig were used with the leak tube in the up and down positions.

The results of these PuO_2 leak rate experiments are presented in Table III. These data indicate that, with the exception of four experiments, no PuO_2 was emitted through the simulated crack. In the four experiments in which PuO_2 was detected, the amount was extremely small, ranging from 0.29 to 0.98 nanograms.

It should be noted that the actual helium leak rate determined at the midpoint of each of the runs varied from 7.4 to 7.8 cc/sec at 920 psig. This re-

TABLE III

SUMMARY OF ROOM-TEMPERATURE PuO_2 LEAK RATE EXPERIMENTS USING A
SIMULATED CRACK(a) HELIUM FLOW RATE EQUAL TO 11.4 CC/SEC

Run Number	Tube Position	Helium Pressure, psig	Vibration	Helium Leak Rate, cc/sec (c)	Quantity of PuO_2 Detected, μg (b)			
					Inlet Nozzle	Final Filter	Total	Net Total (d)
B-37(e)	Sideways	-	-	-	0.00177	0.00071	0.00248	-
B-38(e)	Sideways	-	-	-	0.00168	0.00070	0.00238	-
B-39(e)	Sideways	-	-	-	0.00188	0.00070	0.00258	-
Pu 46b	Up	920	No	7.8	0.00137	0.00089	0.00226	0
Pu 46c	Up	920	No	7.4	0.00089	0.00018	0.00107	0
Pu 47b	Up	920	Yes	7.8	0.00059	0.00073	0.00132	0
Pu 47c	Up	920	Yes	7.4	0.00094	0.00076	0.00170	0
Pu 48d	Down	920	No	7.8	0.00077	0	0.00077	0
Pu 48e	Down	920	No	7.4	0.00088	0.00061	0.00149	0
Pu 49d	Up	440	Yes	3.0	0.00229	0.00019	0.00248	0
Pu 49e	Up	440	Yes	2.6	0.0072	0.00002	0.00074	0
Pu 49g	Up	440	Yes	2.6	0.00066	0.00122	0.00188	0
Pu 50b	Down	440	Yes	2.2	0.00161	0.00119	0.00280	0.00032
Pu 50c	Down	440	Yes	2.2	0.00142	0.00135	0.00277	0.00029
Pu 51d	Up	Ambient	Yes	-	0.00181	0.00165	0.00346	0.00098
Pu 51e	Up	Ambient	Yes	-	0.00183	0.00160	0.00343	0.00095
Pu 52b	Down	Ambient	No	-	0.00120	0.00066	0.00186	0
Pu 52c	Down	Ambient	No	-	0.00069	0.00030	0.00099	0

(a) The simulated crack has a 220- μm finish perpendicular to the helium flow. The helium leak rate was initially 11.4 cc/sec at 920 psig. All runs were for 10 minutes.

(b) Based on a specific activity of 0.096 Ci/g for the PuO_2 powder.

(c) The leak rate was determined by the pressure decay method at the midpoint of the run.

(d) The net total is the amount above the average containment box background of 0.00248 μg .

(e) Containment box background runs. B-37 was made before the other runs, B-38 was made just prior to Pu 49d, and B-39 was made just prior to Pu 51d. The average background PuO_2 level of these runs was 0.00248 μg for the 10-minute collection period.

duced leak rate, as compared to the initial leak rate, is attributed to the plugging effect of PuO_2 in the simulated crack.

-- Helium Flow Rate Equal to 9.8 cc/sec

In these experiments, the leak tube cap was adjusted until a helium leak rate of 9.8 cc/sec was obtained at 920 psig He. This leak rate was about 25% higher than the highest leak rate (7.8 cc/sec) measured during the previous series of simulated crack experiments (Pu 46b - Pu 52c). The actual leak rate determined at the midpoint of each of these runs varied from 7.8 to 8.7 cc/sec at a helium pressure of 920 psig. The difference between the initial and the run leak rates is also attributed to plugging of the leak path with PuO_2 .

The results of the PuO_2 leak rate experiments are presented in Table IV and in Figure 8. These data indicate that some PuO_2 was emitted from the simulated crack at helium pressures of 0, 440, and 920 psig. For example, the average net PuO_2 emission was 0.00007, 0.02636, and 0.00267 μg at 0, 440, and 920 psig He, respectively. Thus, the average PuO_2 emission appears to be greatest at a helium pressure of 440 psig. At 0 and 920 psig He, the PuO_2 emission appeared to be greatest with the leak tube in the up position, while at 440 psig the PuO_2 emission appeared to be greatest with the leak tube in the down position. Vibration of the leak tube did not appear to have an effect on the PuO_2 emission at 0 and 920 psig He; the effect of vibration at 440 psig was not investigated.

-- Helium Flow Rate Equal to 11.6 cc/sec

In this series of experiments, the helium flow rate was adjusted to an initial value of 11.6 cc/sec. The actual leak rate varied between 6.5 and 9.3 cc/sec, presumably for the same reasons mentioned earlier. The results of these experiments are tabulated in Table V, and displayed in Figure 9.

The average PuO_2 emission was greatest (2.73096 μg) at 920 psig, followed by the emission at 440 psig (0.31306 μg). An ambient pressure release only occurred during one run, Number 67, which had the leak tube in the down position without vibration. This very small release average is only 50% of background, which averaged 0.00074 μg for this series of experiments. Overall, the PuO_2 emission was greatest with the leak tube in the down position, although, at 920 psig in the up position, the PuO_2 emission increased slightly with vibration.

TABLE IV

SUMMARY OF ROOM-TEMPERATURE PuO₂ LEAK RATE EXPERIMENTS USING A
SIMULATED CRACK^(a) HELIUM FLOW RATE EQUAL TO 9.8 CC/SEC

Run Number	Tube Position	Helium Pressure, psig	Vibration	Helium Leak Rate ^(c) , cc/sec	Quantity of PuO ₂ Detected, μ g ^(b)			
					Inlet Nozzle	Final Filter	Total	Net Total ^(d)
B-44 ^(e)	Sideways	-	-	-	0.00142	0.00280	0.00422	-
B-45 ^(e)	Sideways	-	-	-	0.00133	0.00018	0.00151	-
B-46 ^(e)	Sideways	-	-	-	0.00038	0.00062	0.00100	-
54a	Up	920	No	8.7	0.00099	0.00436	0.00535	0.00311
54b	Up	920	No	8.7	0.00251	0.00304	0.00555	0.00331
57	Up	920	Yes	8.7	0.00081	0.00895	0.00976	0.00752
57a	Up	920	Yes	8.7	0.00137	0.00130	0.00267	0.00043
58	Down	920	No	8.7	0.00080	0.00286	0.00366	0.00142
58a	Down	920	No	7.8	0.00048	0.00201	0.00249	0.00025
59	Up	440	Yes	2.6	0.00083	0	0.00083	0
59a	Up	440	Yes	2.6	0.00030	0.00377	0.00407	0.00183
59b	Up	440	Yes	2.6	0.00013	0.00013	0.00026	0
53	Down	440	Yes	3.0	0.00843	0.09015	0.09858	0.09634
53b	Down	440	Yes	3.0	0.00118	0.03468	0.03586	0.03362
55	Up	Ambient	Yes	-	0.00116	0.00502	0.00618	0.00394
55a	Up	Ambient	Yes	-	0.00186	0.00002	0.00188	0
56	Down	Ambient	Yes	-	0.00051	0	0.00051	0
56a	Down	Ambient	Yes	-	0.00052	0	0.00052	0
60	Down	Ambient	No	-	0.00066	0.00070	0.00136	0
60a	Down	Ambient	No	-	0.00032	0.00019	0.00051	0

(a) The simulated crack has a 220-microinch finish perpendicular to the helium flow. The helium leak rate was initially 9.8 cc/sec at 920 psig and 2.5 cc/sec at 440 psig. All runs were for 10 minutes.

(b) Based on a specific activity of 0.096 Ci/g for the PuO₂ powder.

(c) The leak rate was determined by the pressure decay method at the midpoint of the run.

(d) The net total is the amount above the average containment box background of 0.00224 μ g.

(e) Containment box background runs B-44 and B-45 were made prior to the other runs. B-46 was made after Pu 59a. The average background PuO₂ level of these runs was 0.00224 μ g for the 10-minute collection period.

FIGURE 8. EFFECT OF EXPERIMENTAL CONDITIONS ON PuO_2 EMISSIONS THROUGH A SIMULATED CRACK AT ROOM TEMPERATURE WITH AN INITIAL He FLOW RATE OF 9.8 CC/SEC AT 920 PSIG

TABLE V

SUMMARY OF ROOM-TEMPERATURE PuO_2 LEAK RATE EXPERIMENTS USING A
SIMULATED CRACK(a) HELIUM FLOW RATE EQUAL TO 11.6 CC/SEC

Run Number	Tube Position	Helium Pressure, psig	Vibration	Helium Leak Rate(c), cc/sec	Quantity of PuO_2 Detected, μg (b)			
					Inlet Nozzle	Final Filter	Total	Net Total(d)
B-49(e)	Sideways	-	No	-	0.00038	0.00020	0.00058	} avg = 0.00074
B-50	Sideways	-	No	-	0.00025	0.00014	0.00039	
B-51	Sideways	-	No	-	0.00069	0.00056	0.00125	
Pu 61	Up	920	No	9.3	0.00235	0.56619	0.56854	0.56780
Pu 61a	Up	920	No	8.5	0.00132	0.13712	0.13844	0.13770
Pu 61b	Up	920	No	6.5	0.00120	0.01239	0.01359	0.01285
Pu 61c	Up	920	No	6.9	0.00043	0.00386	0.00429	0.00355
Pu 62	Up	920	Yes	7.4	0.23390	1.51659	1.75049	1.74975
Pu 62a	Up	920	Yes	7.4	0.00069	0.00107	0.00176	0.00102
Pu 62b	Up	920	Yes	6.9	0.00303	0.01011	0.01314	0.01240
Pu 62c	Up	920	Yes	6.9	0.00041	0.00237	0.00278	0.00204
Pu 63	Down	920	No	6.1	0.00057	0.26917	0.26972	0.26898
Pu 63a	Down	920	No	6.5	0.00585	0.40680	0.41265	0.41191
Pu 63b	Down	920	No	6.9	0.00188	0.14262	0.14450	0.14376
Pu 63c	Down	920	No	6.9	5.4580	29.327	34.785	34.784
Pu 63d	Down	920	No	6.9	0.00571	0.09338	0.09909	0.09835
Pu 63e	Down	920	No	6.9	0.00309	0.02043	0.02352	0.02278
Pu 64	Up	440	Yes	1.7	0.00032	0.00138	0.00170	0.00096
Pu 64a	Up	440	Yes	2.2	0.00017	0.00032	0.00049	0.0
Pu 65	Down	440	Yes	1.7	0.01541	1.73227	1.7417	1.7470
Pu 65a	Down	440	Yes	1.7	0.00868	0.11008	0.11876	0.11802
Pu 65b	Down	440	Yes	2.2	0.00158	0.00140	0.00298	0.00224
Pu 65c	Down	440	Yes	2.2	0.00808	0.00277	0.01085	0.01011
Pu 66	Up	0	Yes	-	0.0	0.0	0.0	0.0
Pu 66a	Up	0	Yes	-	0.00007	0.00029	0.00036	0.0
Pu 67	Down	0	No	-	0.00086	0.00129	0.00215	0.00141
Pu 67a	Down	0	No	-	0.00004	0.0	0.0004	0.0

(a) The simulated crack has a 220-microinch finish perpendicular to the helium flow. The helium leak rate was 11.6 cc/sec at 920 psig. All runs were for 10 minutes.

(b) Based on a specific activity of 0.096 Ci/g for the PuO_2 powder.

(c) The leak rate was determined by the pressure decay method at the midpoint of the run.

(d) The net total is the amount above the average containment box background of 0.00074 μg .

(e) Containment box background runs.

FIGURE 9. EFFECT OF EXPERIMENTAL CONDITIONS ON PuO₂ EMISSIONS THROUGH A SIMULATED CRACK AT ROOM TEMPERATURE WITH AN INITIAL HELIUM FLOW RATE OF 11.6 CC/SEC AT 920 PSIG

-- Helium Flow Rate Equal to 13.2 cc/sec.

The general observation that the PuO₂ leak rate is increased with increasing helium leak rate warrants further study at higher helium leak rates. Work is continuing with this experimental setup at a helium leak rate of 13.2 cc/sec. Results of these experiments will be presented in subsequent reports.

STAFF CHANGES

Mr. M. Pobereskin, Battelle Columbus Laboratory, accepted a position in the newly formed Office of Nuclear Waste Isolation with Battelle Project Management Division (BPMD). Mr. D.C. Drennen left BCL to accept a position in private industry. Dr. J. David Yesso will replace Dave Drennen as Research Scientist on this program. Dr. W.J. Madia will be the Principal Investigator, replacing Dr. Pobereskin.

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