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AIRBORNE RELEASE FRACTIONS/RATES AND RESPIRABLE FRACTIONS FOR NONREACTOR NUCLEAR FACILITIES

Volume II - Appendices

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Washington, D.C. 20585

AREA SAFT

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Appendix A. Source Data

Table A.1. Fractional Release During Air Drying of Concentrated Plutonium Nitrate Solutions (using 0.72 g plutonium as a source).

(Table I - Mishima, Schwendiman and Radasch November 1968)

Run No.	Temp. (°C)	Air Velocity (cm/sec)	Sampling Time		Weight Percent Plutonium Found In			
			Evap. (hr)	Residue (hr)	Containment Vessel Wash	Condensate + Wash	Sweep Air During Evaporation	Sweep Air Following Evaporation
N1*	Ambient	10	24		0.0033	8.7×10^{-3}	$< 10^{-7}$	--
N2*	75	10	5	20	0.00027	9.5×10^{-8}	$< 10^{-6}$	$< 10^{-6}$
N3	100	10	2	4	0.0046	1.7×10^{-6}	0.001	3×10^{-7}
N4	Ambient	50	24	24	0.00035	4.5×10^{-7}	2.5×10^{-7}	1×10^{-7}
N5	100	50	1½	3	0.027	1.4×10^{-4}	0.003	6×10^{-7}
N6	90	50	2	4½	0.00051	5.4×10^{-6}	5.3×10^{-5}	1×10^{-6}
N7	Ambient	100	24	24	0.020	7.5×10^{-8}	$< 2 \times 10^{-8}$	$< 2 \times 10^{-8}$
N8	50	100	2	4	0.00045	9.4×10^{-6}	1.3×10^{-5}	$< 2 \times 10^{-8}$
N9	90	100	1½	4	0.00013	9.4×10^{-5}	5.7×10^{-5}	3×10^{-6}

* 0.86 g plutonium used during these runs.

Table A.2. Fractional Release During the Heating of Pools of Plutonium Nitrate Solutions

(Table II - Mishima, Schwendiman and Radasch November 1968)

(90% solution boiled off, 700 μg plutonium as source,
2.9 cm/sec air up sweep during evaporation.)

Run No.	Average Hot Plate Temp. (°C)	Average Boil-Off Rate (ml/min)	Period Time Heated (min)	Plutonium Recovered				Visual Appearance of Solution During
				Exhausted by Sweep Air		Fall-Out		
				(dpm)	(wt. %)	(dpm)	(wt. %)	
A	218	1.4	63	2×10^5	.18**	2.3×10^4	.02	Boiling
B	190	0.9	80	9.4×10^4	.084	3×10^5	.27	Disturbed Surface
C	175	0.73	124	2.7×10^4	.024	1.3×10^4	.012	Disturbed Surface
D	150	0.6	151	500	4.5×10^{-4}	500	4.5×10^{-4}	Simmering
E*	220	2.1	42	~5*	$\sim 4.5 \times 10^{-5}$†	~23	$\sim 2 \times 10^{-4}$	Boiling
F	150	0.5	150	150	1.3×10^{-4}	~3	$\sim 3 \times 10^{-6}$	Simmering
G	164	0.66	121	6.5×10^3	.0058	1.9×10^4	.016	Disturbed Surface
H	188	1.2	64	1×10^4	.008	8×10^5	.71	Disturbed Surface
I	218	1.4	59	3×10^4	.03	2.3×10^4	.02	Boiling
J*	200	1.4	66	1.2×10^{4}*	.11†	1.9×10^5	1.7	Boiling

★ No air flow through containment vessel, 70 μg plutonium as source. ("Airborne" is that found on containment vessel wall following this run.)

★★ Filter ruptured. All plutonium found in acid washes of equipment downstream of filter position.

† Plutonium in condensate.

Table A.3. Uranium Results -- Engineering Scale Experiments
(Table III - Mishima and Schwendiman August 1973)

Uranium Form Used	Wind Speed	AERODYNAMIC ENTRAINMENT Expt. No.	Wt. Percent Source Airborne (hours sampled)	Less Than[1] 10 microns	PETROLEUM FIRE Expt. No.	Wt. Percent Source Airborne (hours sampled)	Less Than[1] 10 microns
Smooth Sandy Soil							
UO_2	low[2]	2	0.43 6 hrs.	56	3+	0.63 6 hrs.	5
		22a	0.042 24 hrs.	54	22b	0.048 1 hr.	72
		22c*	0.0092 24 hrs.	54			
	moderate[3]	1	2.3 24 hrs.	75			
		23a	24.4 24 hrs.	40	23b	0.34 0.3 hrs.	62
		23c*	1.0 24 hrs.	68			
Air Dried[4] UNH	low[2]	4b	0.0069 24 hrs.	74	5+	0.0074 5.5 hrs.	64
		8b	0.0054 24 hrs.	77	9+	0.004 5 hrs.	18
	moderate[3]	6b	0.93 24 hrs.	22	7+	0.12 7 hrs.	32
		26b*	1.1 24 hrs.	64			
UNH^5	low[2]	4a	0.049 6 hrs.	76	10+	0.0017 5.5 hrs.	75
		8a	0.012 24 hrs.	84			
	moderate[3]	6a	0.039 28 hrs.	68	26a	0.54 0.13 hrs.	40
Vegetation							
UO_2	low[2]	11	0.046 24 hrs.	82	12+	0.014 6 hrs.	91
	moderate[3]	13	1.0 24 hrs.	40	14+	3.1 6 hrs.	19
UNH^5	low[2]	--	-- --	--	16+	0.096 6 hrs.	78
	moderate[3]	--	-- --	--	15+	0.2 6 hrs.	86
Stainless Steel							
UO_2	low[2]	17b*	0.09 4.8 hrs.	83	17a	0.12 0.12 hrs.	66
	moderate[3]	25a	7.6 24 hrs.	14	25b	1.3 0.13 hrs.	7
		25c*	0.7 24 hrs.	42			
UNH^5	low[2]	19b*	0.023 6 hrs.	76	19a	1.1 0.22 hrs.	40
	moderate[3]	18b*	2.6 5 hrs.	30	18a	11.4 0.17 hrs.	34
Road-like Surface							
UO_2	low[2]	21b*	0.14 6 hrs.	62	21a	0.041 0.37 hrs.	70
UNH^5	moderate[3]	20b*	0.063 5 hrs.	58	20a	0.24 0.28 hrs.	68

[1] Percent airborne less than 10 microns aerodynamic equivalent diameter.
[2] Approximately 2.5 mph.
[3] In range of 20 to 23.5 mph.
[4] Dried in flowing air at stated velocity for a minimum of 24 hours.
[5] Uranyl Nitrate Hexahydrate.
* Residue after gasoline fire.
+ During and immediately following a gasoline fire.

Table A.4. Mass Airborne from Pressurized Release of Uranine Solution

(Table A.4 - Sutter August 1983)

Source cm^3	Rep.	Run	psig	Uranine Collected on Samples, g	Mass Airborne, g	Avg Mass Airborne, g	wt% Airborne	Avg wt% Airborne
350	1	1	500	2.0648×10^{-3}	0.206		0.06	
	2	13	500	1.2855×10^{-3}	0.129	0.167	0.04	0.05
	1	6	250	2.2858×10^{-4}	0.023		0.007	
	2	14	250	4.1983×10^{-4}	0.042	0.033	0.012	0.010
	1	4	50	1.2902×10^{-5}	0.0013		0.0004	
	2	8	50	4.2090×10^{-5}	0.0042	0.0028	0.0012	0.0008
100	1	7	500	1.8406×10^{-3}	0.18		0.18	
	2	12	500	1.1070×10^{-3}	0.11	0.15	0.11	0.15
	1	3	250	4.4711×10^{-4}	0.04		0.04	
	2	9	250	6.5027×10^{-4}	0.07	0.06	0.07	0.06
	1	2[a,b]	50	4.4217×10^{-6}	0.004		0.004	
	2	11	50	5.0652×10^{-5}	0.005	0.005	0.005	0.005

(a) Impactor sample suspect, removed from analysis
(b) lg/ℓ, other runs used 10 g/ℓ solution

Table A.5. Mass Airborne from Pressurized Releases of UNH Solutions

(Table A.5 - Sutter August 1983)

Source		Rep.	Run	psig	Uranium Airborne,	Mass[b] Airborne,	Avg Mass Airborne,	wt%	Avg wt%
cm^3	Uranium, g[a]				μg	g	g	Airborne	Airborne
350	72.03	1	1	500	15,746	0.1180		0.0219	
		2	8		20,092	0.1504	0.1342	0.0279	0.0249
		1	5	250	7,261	0.0544		0.0101	
		2	10		6,386	0.0480	0.0512	0.0089	0.0095
		1	4	50	245	0.0016		0.0003	
		2	12		259	0.0022	0.0019	0.0004	0.0004
100	20.58	1	6	500	14,057	0.1052		0.0683	
		2	9		19,598	0.1466	0.1259	0.0952	0.0818
		1	3	250	9,156	0.0685		0.0445	
		2	11		12,058	0.0902	0.0794	0.0586	0.0516
		1	2	50	354	0.0026		0.0017	
		2	13		369	0.0028	0.0027	0.0018	0.0018

(a) Source = 0.2058 g/cm^3; g/cm^3 x cm^3 = g in source
(b) Calculated using a measured UNH density of 1.54 g/cm^3

Table A.6. Median AED of Particles Produced by Pressurized Releases of Uranine Solution

(Table B.4 - Sutter August 1993)

Source, cm^3	Rep.	Run	psig	Median Diameter, μm	σg	% 10 μm and less	wt% of Source that becomes Airborne 10 μm and Less
350	1	1	500	4	3	86	0.05
	2	13	500	4.3	2.4	85	0.03
	1	6	250	4	1.6	98	0.007
	2	14	250	3.6	3	84	0.01
	1	4	50	1.5	3	83	0.0003
	2	8	50	2.1	4	87	0.001
100	1	7	500	4	3	90	0.16
	2	12	500	4.0	4	70	0.08
	1	3	250	2.4	4	78	0.03
	2	9	250	4	3.6	77	0.05
	2	11	50	2.1	4	80	0.004

Table A.7. Median AED of Paricles Produced by Pressurized Releases of UNH

(Table B.5 - Sutter August 1983)

Source, cm^3	Rep.	Run	psig	Median Diameter, μm	σg	% 10 μm and less	wt% of Source that becomes Airborne 10 μm and Less
350	1	1	500	17	4.0	34	0.0074
	2	8		14	2.9	37	0.0103
	1	5	250	45	5.9	20	0.0018
	2	10		12	2.9	45	0.0040
	1	4	50	3	4.8	76	0.0002
	2	12		5	5.2	70	0.0003
100	1	6	500	14	2.5	46	0.0314
	2	9		14	2.9	38	0.0362
	1	3	250	14	2.7	36	0.0160
	2	11		11	4.6	45	0.0264
	1	2	50	6	7.5	61	0.0010
	2	13		8	4.6	60	0.0011

Table A.8. Mass Airborne from Flashing-Spray Releases of Superheated Liquids

(Table A.3 - Ballinger, Sutter and Hodgson May 1987)

Source Volume, cc	Pressure psig	Uranine Collected, cc	Wt% Airborne	Total Volume Airborne, cc	Total Volume not Ejected from Chamber, cc	Volume Ejected but not Airborne, cc
700	125	9.7×10^{-2}	1.51	7.7		692.3
350	240	1.6×10^{-1}	4.96	10.5		339.5
-	125	7.1×10^{-2}	2.22	17.2		332.8
-	60	2.8×10^{-2}	8.92	3.1	83	263.9
100	125	7.8×10^{-2}	8.51	8.5		91.5

(a) Uraniune solution density 1.0 g/cc.
(b) Estimated from volume airborne and amount not ejected from PARE.

Table A.9. Median AED of Particles Produced by Flashing-Spray Releases of Superheated Uranine Solution

(Table A.4 - Ballinger, Sutter and Hodgson May 1987)

Source Volume, cc	Pressure, psig	Median Diameter, μm	σ_g	% 10μm and Less	Wt% of Source that Becomes Airborne and is 10 μm and Less
700	125	5.9	2.6	78	1.18
350	240	6.2	2.7	73	3.63
	125	7.7	2.7	66	1.46
	60	8.4	5.6	62	5.53
100	125	6.4	3.3	69	5.87

Table A.10. Airborne Releases of 10g/l Uranine Solution, Releases Resulting from a Free-Fall Spill in Static Air

(Table A.2 - Sutter, Johnston and Mishima December 1981)

Run	Source Volume cc	Source Weight Uranine g	Spill Height m	Uranine Airborne g	Estimated Total Wall Deposition g	Percent Collected on Wall	Calculated Total Mass Airborne g	Weight Percent Mass Airborne
30	500	5	3	1.94×10^{-4}	ND		1.94×10^{-2}	0.0039
31				1.567×10^{-4}	1.55×10^{-4}	49.7	1.57×10^{-2}	0.0031
32				1.534×10^{-4}	6.79×10^{-5}	30.8	1.53×10^{-2}	0.0031
33				2.79×10^{-4}	4.58×10^{-4}	39.1	2.79×10^{-2}	0.0056
34				2.55×10^{-4}	3.02×10^{-4}	15.4	2.55×10^{-2}	0.0051
35				1.63×10^{-4}	2.41×10^{-4}	32.4	1.63×10^{-2}	0.0033
40[a]				2.04×10^{-4}	4.31×10^{-5}	17.4	2.04×10^{-2}	0.0041
41[a]				1.85×10^{-4}	7.35×10^{-6}	3.8	1.85×10^{-2}	0.0037
55	1000	10		1.270×10^{-3}	1.23×10^{-4}	9.7	1.27×10^{-1}	0.013
58	1000	10	1	3.037×10^{-4}	ND		3.0374×10^{-2}	0.003
59	1000	10	3	8.0237×10^{-4}	5.079×10^{-5}	6.0	8.0237×10^{-2}	0.008
60[b]	125	1.25	3	2.00×10^{-4}	ND		2.00×10^{-2}	0.016
61	500	5	1	2.913×10^{-5}	ND		2.913×10^{-3}	0.0004
62	125	1.25	1	7.7685×10^{-6}	ND		7.7685×10^{-4}	0.0006
63	125	1.25	3	4.147×10^{-5}	ND		4.147×10^{-3}	0.003

[a] Spill initiated by pulling stopper
[b] High release due to splashes
ND Not Detectable

Table A.11. Airborne Releases of 208.7 g U/1 Solution, Releases Resulting from a Free-Fall Spill

(Table A.4 - Sutter, Johnston and Mishima December 1981)

Run	Source Volume cc	Source Weight Uranium g	Spill Height m	Uranium Airborne μg	Weight Percent Airborne	Total Mass Airborne[a] g
1	1000	208.7	3	2271.4	0.0011	1.85×10^{-2}
2	125	26.1	1	141.1	0.0005	1.15×10^{-3}
3	500	104.4	1	137.5	0.0001	1.12×10^{-3}
4	125	26.1	3	346	0.0013	2.82×10^{-3}
5	1000cc H_2O		3	22.7		
6	500	104.4	3	1067.6[b]	0.0013	1.12×10^{-2}
7	1000	208.7	1	223.2	0.0001	1.82×10^{-3}
8	125	26.1	3	514	0.0020	4.19×10^{-3}
9	500	104.4	1	161.5	0.0002	1.32×10^{-3}
10	1000cc H_2O		3	42.36		
11	125	26.1	1	43.4	0.0004	3.50×10^{-4}
12	1000	208.7	1	254.0	0.0001	2.07×10^{-3}
13	1000	208.7	3	2378.2	0.0011	1.94×10^{-2}
14	500	104.4	3	1412.5	0.0014	1.15×10^{-2}

(a) Calculated using solution density of 1.7 g/cc.

(b) Q2 dropped and contaminated. Collection estimated at 313 μg would raise the value to 1380.6. The weight percent airborne and total mass airborne were calculated using this value.

Table A.12. Median AED Particle Size Generated by a Free-Fall Spill in Static Air, 10 g/l Uranine Solution

(Table B.2 - Sutter, Johnston and Mishima December 1981)

Run	Source Volume, cc	Uranine Weight, g	Spill Height, m	Median Diameter, μm	σ_g	Percent of Collection 10 μm and Less	Weight Percent of Source Airborne 10 μm and Less
30	500	5	3	8.0	3.5	56	0.0022
31				11.0	2.8	44	0.0014
32				4.5	2.4	80	0.0025
33				4.8	2.6	82	0.0046
34				5.4	2.6	74	0.0038
35				4.8	3.0	70	0.0023
40				7.3	3.2	59	0.0024
41				6.8	3.1	64	0.0024
55	1000	10		11.5	3.1	45	0.0058
58	1000	10	1	8.6	4.1	53	0.0016
59	1000	10	3	10.0	2.6	50	0.0040
60	125	1.25	3	9.2	3.7	52	0.0083
61	500	5	1	6.0	2.1	62	0.0002
62	125	1.25	1	4.2	1.8	72	0.0004
63	125	1.25	3	7.2	3.0	63	0.0019

Table A.13. Median AED Particle Size Generated by a Free-Fall Spill in Static Air, 208.7 g U/l Solution

(Table B.4 - Sutter, Johnston and Mishima December 1981)

Run	Source Volume, cc	Spill Height, m	Median Diameter, μm	σ_g	Percent 10 μm and Less	Weight Percent of Airborne 10 μm and Less
1	1000	3	34	4.1	21	0.0002
13	1000		32	3.6	19	0.0003
6	500		4.2[a]	2.2	99.4	0.0013
14	500		34	2.1	16	0.0002
4	125		20	7	36	0.0005
8	125		30	6	26	0.0005
7	1000	1	9.6	5	51	0.00005
12	1000		40	5.8	24	0.00002
3	500		2.3	1.9	85	0.00009
9	500		27	6.6	30	0.00006
2	125		3.2	2.3	62	0.0003
11	125		5.0	7.8	61	0.0002

[a] Collected in second half of run, so the size distribution is in smaller range, not used in analysis

Table A.14. Mass Airborne from Slurry Spill (source volume 1 liter, height 3 meters)

(Table B.4 - Ballinger and Hodgson December 1986)

Slurry Number	Uranine Collected, mg[a]	Total Solution Airborne, mg	Measured Weight Percent Airborne
1	0.15[a]	9.8	0.0009
2	0.20[a]	12.7	0.0011
3	0.14	10.9	0.0009
3	0.27	21.1	0.0018
4	0.85	61.4	0.0046
4	0.57	36.6	0.0027
5	0.41	32.2	0.0030
6	0.31	22.5	0.0016

[a] One of the filters dropped to the floor and became contaminated. Based on the other runs it was assumed that 23% of the total mass would have come from this filter.

Table A.15. Size of Particles Produced by Slurry Spills

(Table B.4 - Ballinger and Hodgson December 1986)

Slurry Number	Aerodynamic Mass Median Diameter, μm	σ_g	Percent <10 μm	Measured Weight Percent Airborne x 10^4 that is <10 μm
1	2.3	8.0	73	0.0007
2	4.7	6.1	64	0.0007
3	2.1	7.1	77	0.0007
3	2.5	8.4	76	0.0014
4	3.0	3.8	78	0.0036
4	3.1	5.6	81	0.0022
5	2.6	7.8	78	0.0023
6	4.7	6.9	72	0.0012

Table A. 16. Mass Airborne from Sucrose Solutions Spills
(source volume 1 L, source height 3m)

(Table B.1 - Ballinger and Hodgson December 1986)

Concentration, percent sucrose	Uranine Collected, mg	Total Solution Airborne, mg	Measured Weight Percent Airborne x 10^4
0	0.54	32.4	32.2
0	0.49	28.2	28.0
22	0.12	8.0	7.3
22	0.19	12.2	11.1
40	0.07	4.6	3.8
40	0.10	6.8	5.7
49	0.05	3.4	2.7
49	0.04	2.7	2.1
56	0.03	2.0	1.6
56	0.04	3.0	2.3

Table A.17. Size of Particles Produced by Sucrose Solution Spills

(Table B.2 - Ballinger and Hodgson December 1986)

Concentration, percent sucrose	Aerodynamic Mass Median Diameter, μm	σ_g	Percent <10 μm	Measured Weight Percent Airborne x 10^4 that is <10 μm
0	7.0	5.8	59	19.0
0	4.3	7.2	74	20.7
22	4.8	7.7	70	5.1
22	2.7	7.5	76	8.4
40	1.6	10.0	80	3.0
40	0.6	28.0	83	4.7
49	2.2	5.5	78	2.1
49	1.6	4.6	90	1.9
56	1.9	7.7	84	1.3
56	0.6	10.0	89	2.0

Table A. 18. Fractional Airborne Release of Selected Isotopes in 30 Percent n-Tributyl Phosphate in a Kerosine-Type Diluent During Combustion

(Table I - Mishima and Schwendiman June 1973)

Element	Percent of Source Airborne[1]			
	Self-Sustaining Burning Up to the Point of Spontaneous Extinguishment[2]		Self-Sustaining Burning but Heat Added with a Propane Torch in a Later Stage, Taken to Dryness	
	1cfm	2cfm	1cfm	2cfm
Uranium (~270 g/L)	0.027%	0.023%		0.3%
Cesium (~0.2 ppm)	0.22%	0.25%	0.19%	1.0%*
Cerium (~0.2 ppm)	0.74%	0.56%	0.77%	0.71%*
Zirconium (~0.2 ppm)	0.65%*	ND	0.55%*	0.24%*
Iodine (~0.2 ppm)	65.7%*	65.3%*	81.7%*	84.3%*
				82.8%*
				83.3%*

[1]Activity measured in all samples except residue.
[2]Experiment ended when flame self-extinguished. Usually 5 to 10 ml of liquid remained.
*Percent of total activity collected.
ND Not Detectable.

Table A.19. Results From Burning 30% Kerosine/Tributylphosphate (TBP)

(Table A.6 - Halverson, Ballinger and Dennis February 1987)

Run #	Time, min	Cumulative % Release Uranium	Cumulative % Release Smoke	Notes[a]
44	0	0.0	0.0	Pure acid/organic with uranium
	13.2	0.009	0.10	
	16.3	0.040	0.53	
	22.5	0.132	1.32	
	27.5	0.404	1.89	
45	0.0	0.0	0.0	Pure acid/organic with uranium
	14.7	0.054	0.10	
	18.0	0.395	0.70	
	25.5	0.529	1.00	
	34.8	0.557	1.10	
46	0.0	0.0	0.0	Pure acid/organic with uranium
	19.0	0.006	0.04	
	25.5	0.081	0.17	
	35.7	0.031	0.33	
	53.3	0.434	0.76	
47	0.0	0.0	0.0	Acid with fission product/organic
	13.3	0.032	0.15	with uranium
	16.0	0.105	0.69	
	19.0	0.343	1.46	
	24.8	2.517	3.18	
48	0.0	0.0	0.0	Acid with fission product/organic
	17.0	0.034	0.10	with uranium
	22.0	0.335	0.69	
	26.3	2.054	2.28	
	34.0	2.697	2.88	
52	0.0	0.0	0.0	
	8.3	0.068	0.18	
	12.5	0.170	1.10	
	20.5	0.606	2.03	
	61.3	5.978	8.11	
53	0.0	0.0	0.0	Acid with uranium and fission
	9.3	0.097	0.22	product/pure organic
	14.2	0.206	1.1	
	37.0	2.620	4.64	
	65.0	7.088	8.94	
56	0.0	0.0	0.0	Acid with uranium and fission
	24.8	0.032	0.18	product/organic with uranium
	31.5	0.060	1.15	150 ml acid/50 ml organic
	39.3	0.330	2.45	
	57.3	1.563	6.51	
57	0.0	0.0	0.0	Acid with uranium and fission
	19.2	0.010	0.10	product/organic with uranium
	28.5	0.028	0.83	100 ml acid/50 ml organic
	39.5	0.621	2.52	
	51.0	0.809	3.03	
58	0.0	0.0	0.0	Acid with uranium and fission
	16.0	0.003	0.20	product/pure organic
	23.0	0.006	2.04	150 ml acid/50 ml organic
	30.0	0.012	4.55	
	40.0	0.170	6.44	
42	0		0	Pure acid/pure organic
	17.3		0.25	
	19.2		0.79	
	23.0		1.60	
	36.8		2.53	
49	0		0	Acid with fission product/pure organic
	14.8		1.06	
	18.5		1.94	
	30.0		2.87	
43				No ignition. Slight boiling loss. Pure acid/pure organic
50	0		0	Acid with fission product/pure organic
	12.5		0.28	
	17.0		1.36	
	21.0		2.79	
	31.5		4.51	
54	0		0	Pure acid/pure organic
	12.3		0.16	
	16.8		1.10	
	27.0		2.74	
	32.0		3.81	

(a) 100 ml of acid/100 ml organic unless otherwise noted.

Table A.20. Small Scale Test Results

(Table I - Malet, Duverger de Cuy, Gasteiger and Janberg April 1983)

Test N°	Additive	Solvent Volume ml	Initial Ce or Th Concentration	Ignition Temperature °C		Combustion Ting mn	Quantity Consumed ml	Combustion Rate $1/m^2xmn$	Final O_2 Concentration %	Transfert Coefficients in air	Decontamination Factor
				Interior	Surface						
1	Ce	157	0.55	68	72	3.1	21	0.86	12.35	$4.7\ 10^{-1}$	1310
2	Ce	78.5	0.55	88	75	1.5	20.5	1.74	12.5	$3.2\ 10^{-1}$	>5270
3	Ce	39	0.55	90	82	1.6	19	1.53	12	$2.7\ 10^{-1}$	>4890
4	Ce	20	0.55	79	72	1.3	14.6	1.4	13.25	$4.9\ 10^{-1}$	>3760
5	Th	157	0.64	64	72	2	16	1.02	15	$4.5\ 10^{-1}$	112
6	Th	79	0.64	86	78	2.6	22	1.1	13	$2.3\ 10^{-1}$	159
7	Th	39	0.64	86	84	2.9	20	0.86	12.75	$1.2\ 10^{-1}$	137

Table A.21. Large Scale Test Results

(Table II - Malet, Duverger de Cuy, Gasteiger and Janberg April 1983)

Test N°	Characteristics	Final O_2 Conc %	Combustion Time mn	Fire Propagation Time sec	Pool Temperature °C				Quantity Consumed kg	Mean Combustion Rate kg/m².mn	Max Ventilation Air Flow m³/h
					Thermovision		Thermocouples				
					Ignition Point	Mean	Ignition Point	Mean			
KER 1	1 m²	13	9	14			67.9	63.3	13	1.4	3170
KER 2	1 m² + Ce	13.5	7.4	14	64	55	64.5	63.2	10	1.35	3600
KER 3	5 m² + LOCAL 1 KW HEATING	13.75	1.75	29		65	59.4	71.4	13	1.5	8000
KER 4	4 m² + LOCAL HEATING 2 KW + PARTITION	13.75	1.72	46			47	43	12	1.7	7390
KER 5	0.4 m² + Ce	13.7	20.5	6	80	70	73.5	76	12	1.5	1520
KER 6	0.4 m² + Ce	14.5	22	8	80	70	70	71	13	1.5	1095
KER 7	4 m² + Ce + LOCAL HEATING 2 KW + PARTITION	13.5	2.5	75		25	75.6	24.5	15	1.5	8850
KER 8	4 m² + Ce + LOCAL HEATING 2 KW + PARTITION	14.2	2	30	72	53	57	53	15	1.9	7380
KER 9	1 m² + KEROSENE FLOW + Ce + 2 KW LOCAL HEATING	13.75	8	14	65	46	54.2	50.7	12	1.5	3650

Table A.21. Large Scale Test Results (continued)

(Table II - Malet, Duverger de Cuy, Gasteiger and Janberg April 1983)

TEST	FILTERS			AEROSOLS				TEMPERATURES (°C)						TRANSFERT COEFFICIENT IN AIR Initial Ce Final Ce mass - mass / Initial Ce mass	DECONTAMINATION FACTOR Initial Ce Volume mass consumed / Filtered Ce mass
										VENTILATION		FLUID			
N°	Δ P MAX mn CE	EFFI-CIENCY	g	mn	(m) g/m³	μ m	σ	MAX GAS	MAX FLAME	INLET	FILTER	MAX	MEAN		
KER 1		5.3 X 10^4 AFTER FIRE			2	3.2	2	251	951 (h=1.5m)	175	137				
KER 2	87	6.7 X 10^4 AFTER FIRE			1.7	1.1	1.7	236	993 (h=1.5m)	175	147	195	150		
KER 3	>250	DAMAGED FILTER		NO MEASUREMENTS				720	1533 (h=1.5m)	382	340	104	97.5		
KER 4	480	DAMAGED FILTER			1.4	2.3	3.55	696	1400 (h=1.5m)	402	342	72			
KER 5	10	1.9 X 10^4 5.2 X 10^4	180	2 10	0.6 1.2	1.4 2.2	2.77 1.85	160	897 (h=0.5m)	130	92	286.5	257	2.3 10^{-1}	4260
KER 6	880	NON-STANDARD FILTER		2 10	0.6 0.9	1.5 1.7	2.98 2.13	165	850	122	85	249	234	4.2 10^{-1}	1110
KER 7	>500	DAMAGED FILTER		NO MEASUREMENTS				790	1343 (h=1.5m)	397	344	60	53	9.2 10^{-1}	
KER 8	>500				2.7	2.25	2.1	763	1448 (h=1.5m)	347		95	70	8.9 10^{-1}	
KER 9	90	6.7 X 10^3	300		1.4	1.8	2.4	283	995 (h=1.5m)	195	156	118	95	4.7 10^{-2}	5620

Table A.22. Comparison Between Exploding Wire Aerosol and Droplet Fume in Liquid Suspension

(Table III - Carter and Stewart September 1970)

PuO_2 size in nm	Exploding wire dispersed in water: (1)	Droplet fume dispersed in acetone: (1) (2)
< 300	0.95	0.90
< 100	0.49	0.47
< 30	0.02	0.12
< 10	0.004	0.03
< 5	0.003	0.02

Notes: (1) Fraction Pu in suspension by centrifuge.
(2) Fume from droplets at 660°C.

Table A.23. Summary of Source Fractions Involved in Aerosol Formation

(Table IV - Carter and Stewart September 1970)

	Fraction of source released as aerosol < 10 μm unit density	
	Plutonium	Uranium
Ignition and burning in air	7×10^{-6}(a)	1.1×10^{-4}(a)
	1×10^{-4}(b)	3.6×10^{-4}(b)
Melting	7×10^{-6}(a)	(1)
	1×10^{-4}(b)	
Partial Disruption of liquid into droplets (2)	3.5×10^{-3}(a)	1.9×10^{-3}(a)
	1×10^{-2}(b)	6×10^{-3}(b)
Vapour formation from droplets	About 0.5	

Notes: (a) Geometric mean.
(b) 95% confidence limit.
(1) Massive U does not melt after ignition unless there is an external heat supply. Heat losses cause self extinguishing unless some form of insulation (oxide) is present.
(2) Height of fall approximately 0.75 m.

Table A.24. Fractional Release From Unalloyed Plutonium Rods During Oxidation and Cooling

(Table III - Mishima December 1965)

Run		Time (Min)	Temperature Range (°C)	Air Velocity (cm/sec)	Airborne w/o	Cumulative w/o
A	Oxidation & Cooling	155	Ambient-900	3.3	2.8×10^{-6}	2.8×10^{-6}
B	Oxidation & Cooling	74	Ambient-560	13.5	3.1×10^{-5}	3.1×10^{-5}
C	Oxidation	46	Ambient-650	50	3.8×10^{-5}	
	Cooling	29	Ambient-610	50	1.5×10^{-5}	5.3×10^{-5}
D	Oxidation & Cooling	146	Ambient-650	3.3	4.1×10^{-6}	4.1×10^{-6}
E	Oxidation	73	Ambient-560	3.3	7.8×10^{-6}	
	Cooling	80	Ambient-550	3.3	1.8×10^{-5}	2.6×10^{-5}
F	Oxidation	77	Ambient-560	20	2.6×10^{-6}	
	Cooling	40	Ambient-540	20	5.2×10^{-7}	3.1×10^{-6}

Table A.25. Plutonium Released During the Oxidation of Large Metal Pieces Above Ignition Temperatures

(Table II - Mishima November 1966)

Run No.	Weight Plutonium (grams)	Weight Pu Released (grams)	Weight % Plutonium Released	Total Time Sampled (min)	Release Rate (w/o hr)
1	569.8	0.268	4.9×10^{-2}	90	3.2×10^{-2}
2	1770	0.257	1.4×10^{-2}	45	1.9×10^{-2}
3	997	0.034	3.4×10^{-3}	22	4.5×10^{-3}
4	455.5	0.00132	3.9×10^{-4}	60	2.9×10^{-4}

Table A.26. Fractions of Plutonium Released by Combustion Under Specific Conditions

(Table A.2 - Edison and Kanapilly February 1983)

Experiment Number	Reaction Atmosphere	Temp. (C°)	Pellet Mass (g)	Plutonium Release Fraction x 10^6							Comments
				Total Release	Filters	Total Wall Losses	Quartz Tube		Sampling Chamber		
							Bottom Foil	Circular Foil	Bottom Foil	Circular Foil	
1*	Argon (air)	1000	0.1	110	0.054		26		84		Air leak occurred
2*	Argon	1000	0.5	12	0.033		4		8.4		
32	Argon + 1HE ash	1000	1.0	16	0.77	16	11	1.4	0.12	3.0	
17*	Air	23	0.5	24	7.1		8.8		8.4		Residue from no. 16
9*		450	0.5	160	1.6		15		140		
16*		450	0.5	20	6.9		5.0		7.6		
25		1000	1.0	9.0	0.31	9.0	1.1	1.5	0.079	6.0	
3*	3% H_2 + Ar	100	0.5	5.7	0.0072		2.5		3.2		
13*		200	0.5	1500	7.8		1300		170		
31		200	1.0	10	0.16	10	0.39	6.3	0.084	3.3	
4*		450	0.5	28	0.088		6.1		22		
5*		450	0.5	41	0.68		23		17		
12*		450	0.5	96	0.50		68		27		
26		450	1.0	37	0.90	36	6.2	1.9	0.27	28	
10*		650	0.5	14	0.13		0.64		13		
23		650	1.0	51	0.56	50	0.97	23	0.29	26	
21		200-1000	0.5	88	2.6	85	2.7	11	1.8	69	
22		200-450	1.0	130	3.4	130	2.9	85	1.4	37	
7*	3% H_2 + 5% H_2 + Ar	100	0.5	18	0.58		5.0		12		
6*		450	0.5	15	0.28		6.2		8.4		
8*		450	0.5	5200	13		2700		2500		
24		450	1.0	23	1.6	21	2.3	4.5	2.4	12	
11*		650-750	0.5	5.2	0.22		1.7		3.3		
14*	KEL-F + Ar	450-650	0.5	10	2.3		1.4		6.6		Range-finding experiment unrelated to KEL-F #800 studies
18	KEL-F #800 + Ar	450	0.5	250	0.15	250	37	100	1.3	110	
28		450	1.0	32	0.43	31	1.4	1.8	0.27	28	
33	KEL-F #800 + Ar	650	1.0	26	0.82	25	4.3	8.9	0.68	11	
15*	Complex (1)	450	0.5	7.6	0.39		2.1		5.1		Surrogate 1HE combustion atmosphere + 100 ppm O_2
19	Complex (2)	450	0.5	28	0.086	28	1.1	10	0.11	17	Surrogate 1HE combustion atmosphere with < 5 ppm O_2
20		650	0.5	240	0.22	240	18	40	6.0	180	
30	Complex (2) + HO + H_2O	200	1.0	13	0.16	13	0.72	0.47	0.040	12	
29		450	1.0	12	0.36	11	1.1	6.5	0.065	3.6	
34		1000	1.0	13	1.4	12	4.4	5.2	0.080	2.4	Chamber liner - 5.7
27	KEL-F #800 Ash	450	-	-	-	-	-	-	-	-	No plutonium used

* Experiment done during equipment development phase of the study.

Table A.27. Fractions of Radioactivity Generated Under Specified Conditions

(Table 1 - Edison, Yeh, and Kanapilly 1988)

Exp. no.	Atmosphere	Linear flow velocity (cm/s)	Pu mass (gm)	Specimen shape	Total aerosol sampler fraction x 10^6	Chamber Fraction x 10^6	Ratio chamber/sampler Fraction	Respirable Fraction x 10^6	Comments
1	3% H_2 + Ar then air	500	0.94040	pellet	25.00	83.0	3.3	108.00	
2	3% H_2 + Ar then air	1000	1.05134	pellet	110.00	940.0	8.5	1050.00	reactive powder
3	3% H_2 + Ar then air	1000	0.92490	pellet	250.00	490.0	2.0	740.00	
4	3% H_2 + Ar	500	1.08150	pellet	610.00	3100.0	5.1	3710.00	
5	3% H_2 + Ar	1000	1.12050	pellet	520.00	4100.0	7.9	4620.00	
6	3% H_2 + 5% N_2 + AR	500	1.04690	pellet	71.00	230.0	3.2	301.00	insufficient powder
7	3% H_2 + 5% N_2 + AR	1000	1.12620	pellet	28.00	38.0	1.4	66.00	insufficient powder
8	3% H_2 + 5% N_2 + AR	1000	1.05040	pellet	51.00	400.0	7.8	451.00	insufficient powder
9	3% H_2 + 5% N_2 + AR	40	1.39120	foil	29.00	63.3	2.2	92.30	
10	3% H_2 + Ar	40	1.40170	foil	34.70	248.0	7.1	282.70	
11	3% H_2 + 5% N_2 + AR	40	9.62510	pellet	1.58	10.3	6.5	11.88	
12	3% H_2 + 5% N_2 + AR	40	10.22480	foil	1.22	7.3	6.0	8.52	reactive powder
13	3% H_2 + Ar	40	9.62340	pellet	1.33	17.0	12.8	18.33	reactive powder
14	3% H_2 + Ar	40	9.64100	foil	3.25	415.0	128.0	418.25	

Table A.28. Oxidation of Plutonium at 123° C - Summary of Results

(Table 3 - Stewart 1963)

Experiment No.	Plutonium phase	Sample weight, g	Surface area, cm^2	Humidity, mgH_2O/ℓ, air	Duration of experiment, hr	Increase in weight, mg	Fraction oxidized	Rate of oxidation, $mgPuO_2/hr$	Fraction of oxide in gas stream	Rate at which oxide entrained in gas stream, $\mu c/cm^2.hr$[3]
1	δ alloy	7.483	3.35	0.03	570	32.6	0.033	0.49	1.5×10^{-3}	1.17×10^{-2}
2	δ alloy	7.344	3.30	1.50	525	53	0.054	0.85	3.2×10^{-5}	4.45×10^{-4}
3	δ alloy	8.602	2.50	16.0	404	40	0.035	0.84	4.8×10^{-6}	8.86×10^{-5}
4	β	11.021	3.74	0.03	125	840	0.57	57	1.4×10^{-6}	1.18×10^{-3}
5	β	10.802	3.91	8.0	98	1450	1.0	125	1.1×10^{-6}	1.88×10^{-3}
6	β	7.191	3.23	8.0	70	730	0.76	88	3.3×10^{-6}	4.86×10^{-3}
7	α	9.397	3.55	16.0	218	263	0.21	10	1.3×10^{-6}	2.19×10^{-4}
8	β	11.265	3.78	16.0	19¼	255	0.17	112	5.6×10^{-7}	9.04×10^{-4}
9	β[2]	8.154	3.00	16.0	18	709	0.65	330	1.0×10^{-6}	5.87×10^{-3}

NOTES:

1. The temperature was 123° C in all experiments except Nos. 2 and 7 which were carried out at the $\alpha \rightleftharpoons \beta$ transition temperature, 113° C.
2. Prior to the start of the 9th experiment the metal specimen had been cycled through the $\alpha \rightleftharpoons \beta$ transition 5 times. In the other experiments with the pure metal this transition, $\alpha \rightarrow \beta$, occurred only once.
3. In estimating the rate at which oxide particulate became entrained in the gas stream the initial area of the sample has been assumed.

Table A.29a. Oxidation of Plutonium Above, and in the Region of, the Ignition Temperature, Summary of Experimental Results

(Table 4 - Stewart 1963)

Experiment No.	Atmosphere	Material	Mass, g	Volume cm^3	Surface area cm^2	Rate of increase in temperature, °C/min	Ignition point, °C	Maximum temperature, °C	Remarks
1	air	δ alloy billet	12·7	0·8	4·7	9·0	490	900	Oxidation complete
2	air	pure metal billet	10·3	0·8	4·7	7·3	520	950	Oxidation complete
3	air	pure metal billet	15·06	0·78	4·7	15·0	350	630	Reaction not self-sustaining, fraction took place ∠ 630°C, about 2/3
4(a)	air	δ alloy billet	12·2	0·8	4·7	150	515	800	oxidized
4(b)	air	residue from 4(a)— metal + oxide	11·9	—	—	120	625	1000	Reaction not self-sustaining
4(c)	air	residue from 4(b)— metal + oxide	5·8	—	—	19	225	470	Reaction not self-sustaining
5	air	δ alloy swarf	1·95	0·12	27	38	180	895	Uneven heating of sample,
6	air	δ alloy swarf	1·84	0·12	16	14	205	820	oxidation complete.
7	air	δ alloy swarf	2·18	0·14	29	9·5	110	780	Oxidation complete
8	air	δ alloy swarf	1·3	0·08	17	6·8	205	950	Uneven heating of sample, oxidation complete
9	carbon	δ alloy swarf	1·15	0·07	15	8·6	750	820	Oxidation complete
10	dioxide	δ alloy swarf	1·34	0·08	19	9·9	—	790	Reaction not self-sustaining
11	nitrogen	δ alloy swarf	1·11	0·07	15	6·4	255	—	No reaction
12	oxygen	δ alloy disc	5·34	0·35	4·5	28	340	>1000	Violent reaction
13	oxygen	δ alloy billet	5·89	0·38	3	16	500	970	Violent reaction
14	O_2:N_2 30:70 O_2:N_2 40:60	δ alloy disc	7·41	0·49	10·6	11	245	~1200	Adherent oxide layer, about ¼ oxidized Oxidation complete

Table A.29b. Oxidation of Plutonium Above, and in the Region of, the Ignition Temperature, Summary of Experimental Results on Particle Formation

(Table 5 - Stewart 1963)

Experiment No.	Atmosphere	Material	MMD, μ total oxide	Fraction airborne	MMD, μ airborne fraction	Deposition velocity airborne material, cm/sec
1	air	δ alloy billet	400	1.5×10^{-5}	8	4.8
2	air	pure metal billet	350	1.5×10^{-5}	8	3.4
3(2)	air	pure metal billet	670	2.4×10^{-3}	11	3.5
4(a)	air	δ alloy billet	400	1.3×10^{-4}	4.5	3.7
4(b)	air	residue from 4(a) metal + oxide	800	—	—	—
4(c)	air	residue from 4(b) metal + oxide	800	—	—	—
5	air	δ alloy swarf	1000	6×10^{-5}	2.1	3.6
6	air	δ alloy swarf		—	—	—
7	air	δ alloy swarf		1×10^{-4}	2.1	4.2
8	air	δ alloy swarf		—	—	—
9	carbon dioxide	δ alloy swarf	750	—	—	—
10	nitrogen	δ alloy swarf	little or no reaction	—	—	—
11	oxygen	δ alloy swarf	very small	—	—	—
12	oxygen	δ alloy disc	"	2.1×10^{-2}	0.3	7.3
13	O_2:N_2 30:70	δ alloy billet	290	1.8×10^{-4}	29	3.2
14	O_2:N 40:60	δ alloy disc	1100	1.9×10^{-4}	16	3.2

NOTES:

(1) After ignition the temperature of the specimen rises rapidly to a value above the melting point, usually to about 800-1000°C.

(2) During experiment No. 3 the temperature of the specimen fluctuated markedly and was in the region of the melting point for only a fraction of the time. The relatively large fraction airborne during these experiments was due probably to the contractions and expansions accompanying the temperature changes.

Table A.30. Combustion of Plutonium in Air-Nitrogen Mixtures

(Table 7 - Stewart 1963)

Experiment No.	Metal	Mass of plutonium, g In all specimens the surface area was ~3 cm^2	Humidity, mg/l.	Temperature range, °C	Range of oxygen partial pressure atm.	Duration, min.	Particulate release, μc/min		Fraction oxidized	Fraction of oxide in airstream	Remarks
							in N_2	during oxidation			
1	δ alloy	5.476	0.03	624 to 690	0 to 0.200	45.0	0.0004(1)	0.56	0.53	1.4×10^{-4}	New sample
2	δ alloy	5.476	0.03	525 to 625	0 to 0.099	3.25	—	0.0096	0.17	5.4×10^{-7}	Residue from expt. 2, Table 6
3	pure	7.216	0.03	500 to 620	0 to 0.167	10.0	0.0006(1)	0.645	0.12	1.2×10^{-4}	New sample
4	pure	7.352	16.0	500 to 560	0 to 0.167	7.5	—	0.162	0.056	4.7×10^{-5}	Residue from expt. 6, Table 6
5	pure	6.340	16.0	560 to 630	0 to 0.138	3.0	—	0.028	—(2)	—	Residue from expt. 4

NOTES:

(1) The small amount of activity released in pure nitrogen in Expts. 1 and 3 is considered to be due to loose material on the surface of the specimen and not to any reaction with nitrogen.

(2) In experiment 5 the oxide was lost prior to weighing.

Table A.31. Detail of Plutonium Ignitions and Residue Analysis From Plutonium-Sodium Ignitions

(Tables 1 & 2 - Chatfield 1969)

Table 1. Detail of plutonium-sodium ignitions

Experiment number	Weight of plutonium (g)	Weight of sodium (g)	Sodium/ plutonium atomic ration	Total plutonium released as airborne material (μCi)	Particulate released per unit area of plutonium foil (μCi/cm^2)	Particle size data * (sodium) % < 11 μm	Particle size data * (sodium) % < 3.7μm	Particle size data * (plutonium) % < 11 μm	Particle size data * (plutonium) % < 3.7μm	Remarks
1	0.0549	1.17	221	1.7×10^{-3}	3.4×10^{-3}	97	89	88	35	
2	0.0570	0.99	180	1.5×10^{-3}	2.4×10^{-3}	99.5	93	80	40	
3	0.0644	0.80	129	1.8×10^{-3}	2.7×10^{-3}	99	92	72	39	
4	0.0830	0.60	75	1.5×10^{-2}	2.4×10^{-2}	97	94	40	17	
5	0.1021	0.42	43	5.0×10^{-2}	4.5×10^{-2}					
6	0.0899	0.35	42	2.8	3.3	99	91	98	93	
7	0.0946	0.38	42	8.0×10^{-2}	1.1×10^{-1}					
8	0.1069	0.38	36	5.6×10^{-2}	5.7×10^{-2}					
9	0.0732	0.25	35	4.0×10^{-3}	5.3×10^{-3}					
10	0.0710	0.25	36	5.0×10^{-2}	7.6×10^{-2}					Sodium added as Na_2O_2
11	0.0981	0.40	43	47	50			28	19	Sodium added as Na_2OH
12	0.0900	0.47	54	1.8×10^{-1}				11	3	Plutonium as PuO_2 powder dispersed in sodium wire
13	0.0763	-	-	5.5×10^{-2}	7.9×10^{-2}			27	9	No sodium in this experiment
14	0.0651	-	-	2.1×10^{-1}	3.5×10^{-1}			41	21	No sodium in this experiment
15	0.0918	0.70	79	3.6×10^{-2}	4.3×10^{-2}			12	6	No ignition: specimen heated in argon only
16	-	0.32	-	1.0×10^{-4}						No plutonium: background experiment

* In these columns the particle diameters are referred to material of unit density.

Table 2. Residue analysis from plutonium-sodium ignitions

Experiment number	Weight of plutonium (g)	Weight of sodium (g)	Sodium/ plutonium atomic ration	Concentration of activity in sizes less than 50 Å (μCi/ml)	Fraction of original plutonium in sizes less than 50 Å (%)	Remarks
5	0.1021	0.42	43	1.8×10^{-1}	2.8×10^{-1}	
6	0.0899	0.36	42	6.4	4.6	
7	0.0946	0.38	42	1.4×10^{-2}	2.4×10^{-2}	
8	0.1069	0.38	36	1.2×10^{-1}	1.8×10^{-1}	
9	0.0732	0.25	35	1.2	3.6	
10	0.0710	0.25	36	1.2×10^{-2}	2.7×10^{-2}	Sodium added as Na_2O_2
11	0.0981	0.40	43	1.9	1.2	Sodium added as NaOH
12	0.0900	0.47	54	1.3×10^{-2}	2.3×10^{-2}	Plutonium dispersed as PuO_2 powder in sodium wire
14	0.0651	-	-	8.3×10^{-3}	1.0×10^{-4}	No sodium: 0.86 g of Na_2O_2 added during residue analysis
15	0.0918	0.70	79	3.7×10^{-4}	6.4×10^{-4}	No ignition: specimen heated in argon
17*	0.0190		-	2.3×10^{-4}	9.6×10^{-4}	Plutonium dioxide added to distilled water: "solubility" study
18*	0.0190	0.20	109	2.3×10^{-3}	9.6×10^{-5}	Plutonium dioxide added to dilute NaOH: "solubility" study

* Experiments 17 and 18 involved no heating. A quantity of finely divided plutonium dioxide was added to water (experiment 17) and NaOH solution (experiment 18) to assess its "solubility" using this technique of residue analysis.

Table A.32. Penetrator Oxidation

(Table IV - Elder and Tinkle December 1980)

Run No.	Date	Nominal Temp (°C)	Time (h)	Penetrator No.	Penetrator Weights		After Wire Brush (g)	Metal Oxidation (g)	Metal Oxidation (%)
					Original	After Light Mechanical Removal (g)			
Air at 223 cm/s									
A-774-7	05-22-79	500	2	61512	3354.0	3130.8	3123.8	230.2	6.8
A-774-2	05-04-79	600	2	59603	3358.8	3162.0	3149.2	209.6	6.2
A-774-4	05-11-79	700	2	61310	3354.9	2640.0	2613.1	741.8	22.1
A-774-6	05-17-79	800	2	61501	3354.5	2794.5	2761.5	593.0	17.6
A-774-5	05-15-79	900	2	61510	3354.0	2869.4	2827.1	526.9	15.7
CO_2-Air Mixture at 223 cm/s									
M-774-1	05-24-79	500	2	61402	3355.0	3156.8	3153.2	201.8	6.0
M-774-2	05-29-79	600	2	61406	3353.0	3149.0	3140.9	212.1	6.3
M-774-3	05-31-79	700	4	45401	3357.0	2652.9	2642.2	714.8	21.3
M-774-5	06-07-79	800	4	45510	3354.2	2405.9	2351.1	1003.1	29.9
M-774-8	07-27-79	800	4	45104	3355.4	2378.1	2343.7	1011.7	30.2
M-774-6	06-12-79	900	4	59613	3352.8	2544.2	2518.8	834.0	24.9
M-774-7	06-19-79	1000	4	45204	3355.0	2586.2	2564.7	790.3	23.6
Air at Zero Velocity									
N-774-1	06-14-79	700	2	45407	3355.9	2929.0	2908.9	447.0	13.3

Table A.33. Amount of Plutonium Entrained in Air from the Heated Oxide (the 15 to 44 u fraction from the air oxidation of unalloyed plutonium metal above ignition temperatures)

(Table V - Mishima, Schwendiman, and Radasch July 1968)

	wt%/hr	
	10 cm/sec	117 cm/sec
Ambient Temperature	6.1×10^{-6}	0.56
800-900 °C	5.3×10^{-6}	0.025

Table A.34. Partially Oxidized Plutonium Oxalate Release Rates (in wt%/hr)

(Table VI - Mishima, Schwendiman and Radasch July 1968)

Temperature, °C	Sample Type	Nominal Air Velocity Through Chimney		
		10 cm/sec	50 cm/sec	100 cm/sec
Ambient	A	0.051	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$
	B	4.6×10^{-3}	$<4 \times 10^{-3}$	0.66
400	A	--	--	0.057
	B	--	--	0.0075
700	A	--	--	0.735
	B	--	--	0.041
1000	A	0.25	0.62	0.82*
	B	0.023	$<4 \times 10^{-3}$	0.057*

A Particles carried through chimney (collected on glass fiber filter).
B Particles entrained but deposited on chimney walls (collected on 0.003-in. mild steel shimstock liner.)
* Average of two runs.

Table A.35. Plutonium Oxalate Release Rates (in wt%/hr)

(Table VII - Mishima, Schwendiman and Radasch July 1969)

Temperature, °C	Sample Type	Nominal Air Velocity Through Chimney		
		10 cm/sec	50 cm/sec	100 cm/sec
Ambient	A	<0.004	<0.004	<0.004 0.073
		<0.004	<0.004	0.38 0.54
	B	<0.004	<0.004	0.006 0.025
		<0.004	0.0096	0.023 0.036
400	A	--	--	0.48
	B	--	--	0.016
700	A	0.0044	<0.004	0.90
	B	<0.004	<0.004	0.047
1000	A	<0.004	0.007	0.25
	B	<0.004	0.005	0.075

A *Particles carried through chimney (collected on glass fiber filter).*

B *Particles entrained but deposited on chimney walls (collected on 0.003-in. mild steel shimstock liner.)*

Table A.36. Plutonium Fluoride Release Rates (in Wt% release per hour)

(Table X - Mishima, Schwendiman and Radasch July 1968)

		Nominal Air Velocity Through Chimney		
Temperature, °C	**Sample Type**	**10 cm/sec**	**50 cm/sec**	**100 cm/sec**
Ambient	A	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$ $<4 \times 10^{-3}$
	B	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$ $<4 \times 10^{-3}$
400	A	--	--	0.0073
	B	--	--	$<4 \times 10^{-3}$
700	A	--	--	0.022
	B	--	--	0.048
1000	A	$<4 \times 10^{-3}$	$<4 \times 10^{-3}$	0.05 0.02
		$<4 \times 10^{-3}$	$<4 \times 10^{-3}$	0.016 $<4 \times 10^{-3}$

A *Particles carried through chimney (collected on glass fiber filter).*
B *Particles entrained but deposited on chimney walls (collected on 0.003-in. mild steel shimstock liner.)*

Table A.37. Fractional Release From Solids Remaining After Evaporation of Plutonium Nitrate Solutions (0.72g plutonium used, 2 hours sampling time.)

(Table IV - Mishima, Schwendiman and Radasch November 1968)

Run No.	Temp. (°C)	Air Velocity (cm/sec)	Plutonium				Total Evolved (wt.%)
			Deposited In Chimney		Carried Through Chimney		
			(dpm)	(wt.%)	(dpm)	(wt.%)	
N1a*	1000	100	9.2×10^6	.0067	1.7×10^7	.012	.0187
N2a*	700	100	5.3×10^6	.004	1.2×10^7	.0092	.0132
N4a	400	100	$1.1.x\ 10^7$	.0097	7.6×10^6	.0068	.0165
N5a	1000	50	3.6×10^7	.032	1.4×10^8	.12	.152
N6a	1000	10	1.8×10^6	.0016	5.1×10^6	.0046	.0062
N7a	700	50	1.7×10^7	.015	8.4×10^6	.0075	.0225
N8a	400	50	6.2×10^6	.0055	7.2×10^6	.0064	.0019
N9a	1000	100	1.4×10^6	.0012	7.9×10^6	.0071	.0013

* 0.864 g plutonium used.

Table A.38. Percentage of Total Radioactivity on Surface Measured by Different Sampling Techniques

(Table 1 - Royster and Fish 1967)

Composition of surface	Percent removed		
	Adhesive paper	Smear	Smair
Polyethylene	70.3	56.6	10.9
Glass	75.0	64.4	27.2
Plexiglas	78.0	71.3	15.8
Fiberboard treated with *Polymer M**	53.8	44.3	10.2
Fiberboard treated with *Soil retardant*†	75.9	34.4	20.0
Fiberboard scrubbed‡	56.9	23.5	9.0
Fiberboard untreated	73.4	23.5	6.6
formica	73.4	70.6	26.5
Aluminum painted**	70.0	50.3	24.8
Aluminum painted, treated with *Soil retardant*†	86.0	67.1	33.0
Asphalt floor tile untreated	58.6	48.5	14.6
Asphalt floor tile waxed††	74.5	74.5	30.3
Concrete unsealed	55.5	39.5	22.0
Concrete sealed (Onex-Seal and Wax)‡‡	62.2	59.5	24.0
Concrete sealed (Gellman and Du-Ev Wax)***	54.8	47.7	27.2
Stainless steel	67.7	50.5	10.5
Concrete, greased†††	43.5	37.5	1.32

* *Polymer M* is a floor treatment manufactured by Johnson Wax Company.

† Soil Retardant Finish Concrete (Eng. 8474, VM-5642) manufactured by E.I. DuPont de Nemours and Company.

‡ Scrubbed for 10 min with *Babbit's cleanser*, soft cloth and water.

** Amercote No. 74.

†† *Du-Ev Wax* (Do Everything Wax) Du-Ev Products Co., Inc.

‡‡ *Onex-Seal*, Hilliard Chemical Company, used with Polymer M.

*** *Gellman Sealer*, Gellman Paint and Varnish Company, used with Du-Ev Wax.

††† Greased lightly with stop-cock grease.

Table A.39a. TiO_2 Powder Airborne, Powder Release Above Chamber (PRAC)

(Table A.3 - Sutter August 1983)

Source, g	Run	psig	Weight, g	wt% Airborne
350	1	500	38.2198	10.9
	5	250	36.6774	10.5
	4	50	15.8639	4.5
100	6	500	28.7369	28.7
	3	250	21.3226	21.3
	2	50	8.1773	8.2

Table A.39b. Median AED of Particles Produced by TiO_2 Powder Release Above Chamber (PRAC)

(Table B.3 - Sutter August 1983)

Source, g	Run	psig	Median Diameter, μm	σ_g	%10 μm and Less	Avg wt% of Source that Becomes Airborne and is 10 μm and Less
350	1	500	20[a] 9	11.8 7	54 40	5.1
	5	250	11 5	5.5 3.6	48 72	6.3
	4	50	12 2.4	9.2 3.8	46 88	3.0
100	6	500	11 4.3	7.7 4.0	48 71	17.1
	3	250	10.1 6.2	5.3 4.4	48 65	12.0
	2	50	8.4 6	6.5 7.0	53 68	5.0

(a) Based on two impactor samples

Table A.40a. Mass Airborne from Pressurized Release of DUO Powder

(Table A.1 - Sutter August 1983)

Source, g	Rep.[a]	Run[b]	psig	Weight, g	Average, wt g	wt% Airborne	Avg wt% Airborne
350	1	1	500	29.7028		9	
	2	13	500	30.7083	30.2056	9	9
	1	6	250	19.1341		6	
	2	14	250	21.9318	20.5330	6	6
	1	4	50	7.0006		2	
	2	88	50	6.7570	6.8788	2	2
100	1	7	500	21.2210		21	
	2	12	500	18.3406	19.7814	18	20
	1	3	250	12.6345		13	
	2	98	250	13.3580	12.9963	13	13
	1	2	50	3.3166		3	
	2	11	50	3.7947	3.5557	4	4

(a) This is the replicate identification number
(b) Run number, used to identify experiment since they were done in a random sequence.

Table A.40b. Median AED of Particles Produced by Pressurized Releases of DUO

(Table B.1 - Sutter August 1983)

Source, g	Rep.	Run	psig	Median Diameter, μm	σ_g	wt% 10 μm or Less	wt% of Source that Becomes Airborne 10 μm and Less
350	1	1	500	16	3.0	34	3.0
	2	13	500	16	3.0	31	2.7
	1	6	250	12	2.1	42	2.3
	2	14	250	18	3.0	29	1.8
	1	4	50	16	3.0	33	0.7
	2	88	50	21	4.8	31	0.6
100	1	7	500	10	2.5	49	10.4
	2	12	500	18	4.0	38	7.0
	1	3	250	9	2.2	54	6.8
	2	98	250	12	1.9	38	5.1
	1	2	50	13	2.9	41	1.4
	2	11	50	25	4.2	25	1.0

Table A.40c. Mass Aiborne from Pressurized Releases of TiO_2 Powder

(Table A.2 - Sutter August 1983)

Source, g	Rep.	Run	psig	Weight, g	Average, wt g	wt% Airborne	Avg wt% Airborne
350	1	5[a]	1000	15.8805	15.8805	4.5	4.5
	1	4	500	21.3782		6.1	
	2	16	500	34.2035	27.7909	9.8	7.9
	1	3	250	10.1143		2.89	
	2	14	250	26.4866	18.3005	7.6	5.2
	1	2[a]	100	3.2783	3.2783	0.94	0.94
	1	1	50	2.1848		0.62	
	2	15	50	12.5796	7.3822	3.6	2.1
100	1	7[a]	1000	12.3933	12.3933	12.4	12.4
	1	13	500	29.4976		29.5	
	2	18	500	18.7731	24.1354	18.8	24.1
	1	11	250	19.8395		19.8	
	2	9	250	16.5683	18.2039	16.7	18.2
	1	10[b]	189	11.0536	11.0536	11.1	11.1
	1	6	50	3.6082		3.6	
	2	7	50	5.1346	4.3714	5.1	4.4
50	1	8[a]	50	0.51	0.51	1.0	1.0

(a) Single value only
(b) Premature rupture

Table A.40d. Median AED of Particles Produced by Pressurized Releases of TiO_2

(Table B.2 - Sutter August 1983)

Source, g	Rep.	Run	psig	Median Diameter, μm	σ_g	%10 μm or Less	Wt % of Source that Becomes Airborne 10 μm and Less
350	1	5[a]	1000	7.0	4.1	64	2.9
	1	4[b]	500				
	2	16	500	15, 12	10.7, 8.6	40, 44	3.9, 4.3
	1	3[b]	250				
	2	14	250	14	8.5	44	3.3
	1	2[b]	100				
	1	1[b]	50				
	2	15[c]	50	20, 16	13, 10.3	38, 48	1.4, 1.7
100	1	7[a]	1000	5.6	8.2	60	7.4
	1	13	500	4.6, 4.2	6.3, 5.5	68, 72	20.1, 21.2
	2	18	500	6.9, 5.0	6.0, 6	54, 66	10.1, 12.4
	1	11	250	10, 8.3	9.5, 5.7	50, 54	9.9, 10.7
	2	9	250	17, 6.4	14, 5.8	42, 61	6.9, 10.1
	1	10[d]	189	14, 10	10.8, 4.5	44, 50	4.9, 5.5
	1	6	50	8.2	5.9	54	1.9
	2	17	50	9.2, 6.8	5.1, 4.3	52, 60	2.7, 3.1
50	1	8[e]	50	12	8.5	48	0.5

(a) Exploratory at 1000 psig
(b) Impactor overload
(c) Data based on 2 impactors where two sizes are shown
(d) Run originally set for 250 psig, went off prematurely
(e) Exploryatory at 50 psig and using 50 g traced TiO_2

Table A.40e. Mass Airborne from Low-Pressure DUO Releases

(Table A.5 - Ballinger, Sutter and Hodgson May 1987)

Source Mass, g	Pressure, psig	Uranium Collected, g	Wt% Airborne	Total Mass not Ejected from Chamber, g	Mass Ejected but not Airborne, g
350	24.5	0.610	0.174	24.4	325.0
	17.5	0.387	0.111	50.1	299.4
	9.0	0.017	0.005	269.6	80.4
100	24.5	0.302	0.302	21.1	78.7
	17.5	0.63	0.63	65.5	34.4
	9.0	0.03	0.03	75.9	24.1

Table A.40f. Median AED of Particles Produced by Low-Pressure DUO Releases

(Table A.6 - Ballinger, Sutter and Hodgson May 1987)

Source Mass, g	Pressure, psig	Median Diameter, μm	σ_g	%10 μm and Less	Wt% of Source that Becomes Airborne and is 10 μm and Less
350	24.5	38	9.3	35	0.061
	17.5	19	6.5	60	0.067
	9.0	6	6.0	61	0.003
100	24.5	24	7.5	42	0.127
	17.5	6	4.6	72	0.045
	9.0	7	4.8	62	0.02

Table A.41a. Airborne Release of TiO_2 Powder Traced with Uranine, Releases Resulting From Free-Fall Spill in Static Air

(Table A.1 - Sutter, Johnston and Mishima December 1981)

Run	Weight g	Spill Weight m	Uranine Airborne g	Uranine Wall Deposition, g		Uranine total g	Percent Deposited On Wall	Calculated Mass Airborne g	Calculated Total Mass Airborne and Deposition g	Weight Percent Airborne	Weight Airborne and Deposition
				1 m	3 m						
37	471.9	3	2.85×10^{-3}	1.87×10^{-5}	2.9615×10^{-3}		3.8	0.9105	0.9462	0.19	0.20
38	450.4		4.38×10^{-4}	3.44×10^{-5}	1.10×10^{-5}	4.83×10^{-4}	9.4	0.1475	0.1628	0.033	0.036
39	431.1		3.07×10^{-4}	5.29×10^{-5}	5.25×10^{-5}	4.12×10^{-4}	25.6	0.0858	0.1151	0.020	0.027
42	460.0		1.17×10^{-3}	5.90×10^{-5}	7.41×10^{-5}	1.30×10^{-3}	10.2	0.3900	0.4333	0.09	0.094
43	100		1.35×10^{-3}	1.92×10^{-4}	1.18×10^{-4}	1.66×10^{-3}	18.7	0.1194	0.1469	0.12	0.15
44	100		1.01×10^{-3}	7.71×10^{-5}	4.00×10^{-5}	1.13×10^{-3}	10.3	0.0990	0.1108	0.099	0.11
47	1000		6.403×10^{-3}	2.357×10^{-4}	1.64×10^{-4}	6.803×10^{-3}*	5.9	1.480	1.5725	0.15	0.15
48	1000		3.742×10^{-3}	2.263×10^{-4}	1.464×10^{-4}	4.1147×10^{-3}	9.1	0.9659	1.062	0.096	0.11
49	25		2.926×10^{-4}	1.445×10^{-5}	2.95×10^{-5}	3.3655×10^{-4}	10.8	0.0240	0.0276	0.10	0.11
50	25		1.855×10^{-4}	ND	5.58×10^{-6}	1.911×10^{-4}	2.9	0.01656	0.0171	0.07	0.08
45	441.1	1	1.48×10^{-6}	7.45×10^{-5}	1.21×10^{-4}	1.68×10^{-6}	11.6	0.0345	0.0391	0.008	0.008
46	451		1.81×10^{-4}	1.59×10^{-5}	7.49×10^{-6}	2.04×10^{-4}	12.9	0.0360	0.0406	0.008	0.009
51	25		3.7882×10^{-5}	ND	ND	3.7882×10^{-5}	ND	0.0030	–	0.01	–
52	25		5.0123×10^{-5}	ND	ND	5.0123×10^{-5}	ND	0.0040	–	0.02	–
53	1000		2.2477×10^{-3}	5.06×10^{-5}	4.18×10^{-5}	2.34×10^{-3}	3.9	0.4984	0.5188	0.05	0.05
54	1000		1.0852×10^{-3}	1.39×10^{-5}	4.965×10^{-7}	1.10×10^{-3}	1.3	0.1742	0.1766	0.017	0.018
56	1000	0	5.3340×10^{-6}			5.3348×10^{-6}		0.0009			
57	1000		3.6031×10^{-6}			3.6031×10^{-6}		0.0006			

(a) Calculate from 1 sq ft deposition sample.
(b) Ceiling deposition 1.98×10^{-5} g not included.

Table A.41b. Median Aerodynamic Equivalent Diameter Particle size Generated by a Free Fall Spill in Static Air, Traced TiO_2 Powder

(Table B.1 - Sutter, Johnston and Mishima December 1981)

Run	Source Weight, g	Spill Height, m	Median Diameter, μm	σ_g	Percent of Collection 10 μm and Less	Weight Percent of Source Airborne 10 μm and Less
37	471.9	3	21.0	6.2	34	0.065
38	450.4		5.8	5.6	62	0.020
39	431.1		16.0	6.6	40	0.008
42	460		17.2	6.9	40	0.036
43	100		27.0	7.5	31	0.037
44	100		13.0	5.9	46	0.046
45	441	1	15.3	7.7	41	0.033
46	451	1	16.8	6.5	42	0.034
47	1000	3	36.0	6.7	25	0.038
48	1000		17.0	7.4	40	0.038
49	25		9.6	3.7	50	0.050
50	25		9.8	4.7	50	0.035
51	25	1	4.7	2.7	62	0.006
52	25		7.2	3.1	58	0.012
53	1000		9.1	2.8	53	0.027
54	1000		16.5	5.9	40	0.068

Table A.41c. Airborne Releases of DUO Powder, Releases Resulting from a Free Fall Spill in Static Air

(Table A.3 - Sutter, Johnston and Mishima December 1981)

Run	DUO Weight, g	Spill Height, m	Total DUO Airborne, g	Weight Percent Airborne
1	1000	3	0.23122	0.023
2	100	1	0.00337	0.003
3	500	1	0.01924	0.004
4	100	3	0.00350	0.004
5	1000g TiO_2	1	0.000100[a]	
6	500	3	0.17579	0.04
7	1000	1	0.05589	0.006
8	100	3	0.04489	0.04
9	500	1	0.03081	0.008
10	1000g TiO_2	3	0.000211[a]	
11	100	1	0.00670	0.007
12	1000	1	0.07703	0.008
13	1000	3	1.19463	0.12
14	500	3	0.54383	0.11

(a) TiO_2 standard indicated 0.00011 g interference in uranium quality assurance tests. Therefore this collection is not significant.

Table A.41d. Median Aerodynamic Equivalent Diameter Particle Size Generated by a Free Fall Spill in Static Air, DUO Powder

(Table B.3 - Sutter, Johnston and Mishima December 1981)

Run	Source Weight, g	Spill Height, m	Median Diameter, μm	σ_g	Percent 10 μm and Less	Weight Percent of Source Airborne 10 μm and Less
1	1000	3	3.1	5.1	25	0.006
13	1000		10.5	3.9	49	0.059
6	500		6.1	3.1	70	0.028
14	500		16	5.2	38	0.042
4	100		<0.1	50	91	0.004
8	100		12.0	3.2	44	0.017
7	1000	1	11.0	2.75	46	0.003
12	1000		9.6	3.2	50	0.004
3	500		3.2	3.5	83	0.003
9	500		9.5	2.6	52	0.004
2	100		0.65	5.2	93	0.003
11	100		11.5	2.9	51	0.004

Table A.42. Summary of Release Fraction Data

(Table 1 - Langer November 1987)

Test No.	Test Powder Specifications						Mass Release Fractions, (%)					
	Material[a]	Density (g/cm^3)	Container	Amount (g)	Mass Med. Dia. (μm)	STD Dev. of Dia.	<3 μm[c] Resp. PMS Probe	<5 μm AED Impactor	<10 μm[c] Inhal. PMS Probe	<5 μm AED Cyclone	<10 μm AED Cyclone	No. of <12 μm[d] Particles Released Per g of Charge
1	Sand, <2000 μm	2	Qt. Can	7.4×10^2	–	–	1.3×10^{-3}	–	2.5×10^{-4}	3.4×10^{-2}	2.6×10^{-2}	1.9×10^8
2	Sand, <500 μm 1.8% <25μm	2	Qt. Can	1.2×10^{3b}	1.9×10^2	2.4×10^0	8.7×10^{-4}	–	2.0×10^{-3}	2.8×10^{-2}	2.8×10^{-2}	1.5×10^5
3	Sand, <500 μm 1.8% <25μm	2	In Open	1.1×10^3	1.9×10^2	2.4×10^0	3.1×10^{-3}	7.1×10^{-3}	3.1×10^{-2}	6.6×10^{-2}	5.6×10^{-2}	6.7×10^5
4	Sand, Plus 2.6% Al_2O_3	2	In Open	1.2×10^3	1.9×10^2	2.4×10^0	1.7×10^{-3}	2.5×10^{-3}	7.2×10^{-3}	1.7×10^{-2}	4.3×10^{-2}	3.4×10^5
5	Al_2O_3 <300 μm 24% <25μm	4	In Open	4.6×10^2	9.1×10^1	3.6×10^0	3.2×10^{-2}	2.6×10^{-2}	3.3×10^{-2}	7.8×10^{-2}	8.9×10^{-2}	2.9×10^6
6	Nickel 0.2% <25μm	8.9	In Open	1.0×10^3	7.0×10^1	1.4×10^0	1.7×10^{-3}	1.9×10^{-3}	1.0×10^{-2}	1.3×10^{-2}	7.5×10^{-3}	3.6×10^5
						AVERAGE	6.8×10^{-3}	9.4×10^{-3}	1.4×10^{-2}	3.9×10^{-2}	4.2×10^{-2}	9.5×10^5
							I=0.89			I=0.88		I=0.86

a. Size in terms of sieve data.
b. 400 g remained in can after impact.
c. AED, converted from geometric diameter using densities in Column 3.
d. Geometric diameter.

Table A.43a. Particle Resuspension Caused by Car Traffic on an Asphalt Road

(Table 1 - Sehmel 1976)

Run	Description	Average air speed at 1.5-m height (mph)	Average air speed at 1.5-m height ($m\ s^{-1}$)	u_* ($m\ s^{-1}$)	Z_0 (cm)	Row (ft)	Normalized fraction: Airborne	Normalized fraction: Deposited	Normalized fraction: Total	Fraction resuspended per pass	Weathering time (days)
2	5 miles h^{-1} Car by-pass	5.5	2.4	0.85	0.12	0	1.00		1.00	4.8×10^{-5}	0
						10	0.86	0.14	1.00		
						20	0.74	0.19	0.93		
						30	0.86	0.22	1.08		
3	15	4.4	2.0	0.68	0.12	0	1.00		1.00	2.8×10^{-4}	0
						10	0.75	0.24	0.99		
						20	0.63	0.30	0.93		
						30	0.38	0.34	0.72		
4	30	6.1	2.7	0.95	0.12	0	1.00		1.00	7.7×10^{-4}	0
						10	0.80	0.20	1.00		
						20	0.57	0.28	0.85		
						30	0.31	0.32	0.63		
5	50	5.5	2.4	0.86	0.12	0	1.00		1.00	1.1×10^{-3}	0
						10	0.87	0.13	1.00		
						20	0.82	0.18	1.00		
						30	0.67	0.22	0.89		
6	5 miles h^{-1} Car through	5.1	2.3	0.80	0.12	0	1.00		1.00	1.9×10^{-4}	0
						10	0.80	0.20	1.00		
						20	0.66	0.28	0.94		
						30	0.56	0.32	0.88		

Table A.43a. Particle Resuspension Caused by Car Traffic on an Asphalt Road (continued)

(Table 1 - Sehmel 1976)

Run	Description	Average air speed at 1.5-m height (mph)	Average air speed at 1.5-m height ($m\ s^{-1}$)	u_* ($m\ s^{-1}$)	Z_0 (cm)	Row (ft)	Normalized fraction: Airborne	Normalized fraction: Deposited	Normalized fraction: Total	Fraction resuspended per pass	Weathering time (days)
7	30	2.4	1.1	0.39	0.12	0	1.00		1.00	6.9×10^{-3}	0
						10	0.84	0.16	1.00		
						20	0.36	0.19	0.55		
						30	0.04	0.19	0.23		
8	50	4.5	2.0	0.70	0.12	0	1.00		1.00	1.09×10^{-2}	0
						10	0.82	0.19	1.01		
						20	0.47	0.24	0.71		
						30	0.51	0.27	0.78		
10	30	9.2	4.1	1.5	0.12	0	1.00		1.00	5.7×10^{-5}	5
						10	0.84	0.16	1.00		
						20	0.97	0.22	1.19		
						30	0.63	0.26	0.89		
11	30	8.2	3.7	1.3	0.12	0	1.00		1.00	5.5×10^{-6}	30
						10	0.81	0.19	1.00		
						20	0.86	0.28	1.14		
						30	0.71	0.32	1.03		
12	50	7.2	3.2	1.1	0.12	0	1.00		1.00	2.6×10^{-5}	30
						10	0.74	0.25	0.99		
						20	0.68	0.35	1.03		
						30	0.46	0.42	0.88		

Table A.43b. Particle Resuspension Caused by a 3/4-Ton Truck Traffic on an Asphalt Road

(Table 2 - Sehmel 1976)

Run	Description	Average air speed at 1.5-m height		u_* (m s^{-1})	Z_0 (cm)	Row (ft)	Normalized fraction			Fraction resuspended per pass	Weathering time (days)
		(mph)	(m s^{-1})				Airborne	Deposited	Total		
28	5 miles h^{-1} truck through	17	7.4	2.2	0.065	0	1.00		1.00	2.5×10^{-3}	0
						10	0.43	0.26	0.69		
						20	0.55	0.37	0.92		
						30	0.41	0.41	0.82		
						60		0.53			
						100		0.60			
29	50	12	5.5	2.2	0.30	0	1.00		1.00	6.7×10^{-3}	0
						10	1.37	0.24	1.61		
						20	1.19	0.37	1.56		
						30	1.79	0.46	2.26		
						60		0.64			
						100		0.80			
16	15	4.3	0.90	0.48	0.022	0	1.00		1.00	1.2×10^{-5}	4
						10	1.57	0.30	1.87		
						20	2.11	0.48	2.59		
						30	2.09	0.60	2.69		
						60		0.81			
						100		1.01			
21	15	4.4	2.0	0.74	0.020	0	1.00		1.00	4.8×10^{-6}	4
						10	1.31	0.31	1.62		
						20	2.58	0.47	3.05		
						30	1.75	0.58	2.34		
						60		0.81			
						100		1.01			

Table A.43b. Particle Resuspension Caused by a 3/4-Ton Truck Traffic on an Asphalt Road (continued)

(Table 2 - Sehmel 1976)

Run	Description	Average air speed at 1.5-m height (mph)	Average air speed at 1.5-m height ($m\ s^{-1}$)	u_* ($m\ s^{-1}$)	Z_0 (cm)	Row (ft)	Normalized fraction: Airborne	Normalized fraction: Deposited	Normalized fraction: Total	Fraction resuspended per pass	Weathering time (days)
17	30	5.2	2.4	0.76	0.068	0	1.00		1.00	8.6×10^{-5}	4
						10	0.88	0.15	1.03		
						20	1.21	0.24	1.45		
						30	1.22	0.30	1.52		
						60		0.41			
						100		0.53			
22	30	7.5	3.3	1.3	0.24	0	1.00		1.00	8.2×10^{-5}	4
						10	1.00	0.30	1.30		
						20	1.18	0.44	1.62		
						30	1.01	0.53	1.54		
						60		0.70			
						100		0.85			
26	5 miles h^{-1} truck through	3.0	1.4	0.56	0.24	0	1.00		1.00	1.3×10^{-5}	4
						10	1.21	0.10	1.30		
						20	1.11	0.19	1.30		
						30	0.69	0.37	1.06		
						60		1.08			
						100		1.75			
18	15	6.9	3.1	1.0	0.067	0	1.00		1.00	5.2×10^{-4}	4
						10	1.35	0.16	1.51		
						20	1.02	0.26	1.28		
						30	0.71	0.30	1.01		
						60		0.37			
						100		0.45			

Table A.43b. Particle Resuspension Caused by a 3/4-Ton Truck Traffic on an Asphalt Road (continued)

(Table 2 - Sehmel 1976)

Run	Description	Average air speed at 1.5-m height		u_*	Z_0	Row	Normalized fraction			Fraction resuspended per pass	Weathering time
		(mph)	($m\ s^{-1}$)	($m\ s^{-1}$)	(cm)	(ft)	Airborne	Deposited	Total		(days)
23	15	9.3	4.1	1.6	0.24	0	1.00		1.00	2.1×10^{-4}	4
						10	0.70	0.28	0.98		
						20	0.88	0.39	1.27		
						30	0.83	0.48	1.31		
						60		0.71			
						100		0.86			
24	30	8.2	3.7	1.3	0.21	0	1.00		1.00	1.0×10^{-3}	4
						10	0.76	0.43	1.19		
						20	0.59	0.60	1.19		
						30	0.84	0.82	1.66		
						60		1.30			
						100		1.74			
25	50	6.6	3.0	1.2	0.27	0	1.00		1.00	2.3×10^{-3}	4
						10	0.74	0.50	1.24		
						20	1.01	0.76	1.77		
						30	0.89	0.88	1.77		
						60		1.06			
						100		1.18			

Table A.44. Size Distribution of Soil Used in Experiments

(Table 1- Sutter August 1980)

Indicated Size, μm	Percent of Soil Less than Indicated Size
1651	99.3
841	95.9
420	71.4
210	51.9
149	42.4
74	18.9
44	4.4
37	2.5
20	0.77
10	0.088
5	0.003

Table A.45. Mass and ^{137}Cs Activity of Samples Collected in Soil Aerodynamic Entrainment Experiments

(Table A-1 - Sutter August 1980)

Sample	Experiment #1 20 mph for 30 min			Experiment #2 15.2 mph for 17 min		
	Weight (g)	μCi/g	Total μCi	Weight (g)	μCi/g	Total μCi
Source	1422.6	6.4×10^{-3}	9.1×10^{0}	1773.9	6.4×10^{-3}	1.1×10^{1}
Soil Under Entry	5.4388	3.1×10^{-4}	1.7×10^{-3}	95.9183	2.3×10^{-3}	2.3×10^{-1}
Wind Tunnel						
4				None		
3	14.0	2.7×10^{-3}	3.8×10^{-2}	None		
2	55.1	5.0×10^{-4}	2.8×10^{-2}	3.6615	4.0×10^{-3}	1.5×10^{-2}
1	114.2	2.4×10^{-3}	2.8×10^{-1}	42.8399	3.5×10^{-3}	1.5×10^{-1}
Floor Foil			5.0×10^{-3}			5.5×10^{-3}
Wall Foil			6.4×10^{-3}			1.0×10^{-2}
Sweepings	181.3	6.4×10^{-3}	1.0×10^{0}	239.2	4.3×10^{-3}	1.0×10^{0}
Tray in Vessel	675.9	3.8×10^{-3}	2.6×10^{0}	857.3	3.4×10^{-3}	2.9×10^{0}
Vessel Floor Foil	344.0	7.7×10^{-3}	2.7×10^{0}	406.6	8.2×10^{-3}	3.3×10^{0}
Vessel Wall Foil			8.2×10^{-5}			8.2×10^{-5}
High Volume Samplers						
Wind Tunnel	1.991	1.7×10^{-2}	3.5×10^{-2}	2.0696	1.1×10^{-2}	2.4×10^{-2}
Vessel Ceiling	2.0207	2.0×10^{-2}	4.0×10^{-2}	2.5921	1.9×10^{-2}	5.0×10^{-2}
Impactor Samples						
Wind Tunnel	2.7295	1.0×10^{-2}	2.8×10^{-2}	3.4233	1.0×10^{-2}	3.5×10^{-2}
Vessel Ceiling	0.6269	1.0×10^{-2}	6.4×10^{-3}	0.2686	2.9×10^{-2}	7.7×10^{-3}
Total	1397.3(1)		6.8×10^{0}	1653.9		7.7×10^{0}

(1) Material balance shows losses to HEPA filters, some RART surfaces, and physical loss during collection. Activity losses include these and changes due to variation in activity levels and physical forms of samples.

Table A.45. Mass and ^{137}Cs Activity of Samples Collected in Soil Aerodynamic Entrainment Experiments (continued)

(Table A-1 - Sutter August 1980)

Sample	Experiment #3 3.2 mph for 17 min			Experiment #4 10.4 mph for 17 min		
	Weight (g)	μCi/g	Total μCi	Weight (g)	μCi/g	Total μCi
Source	1772.5	6.4×10^{-3}	1.1×10^{1}	1808	6.4×10^{-3}	1.1×10^{1}
Soil Under Entry	728.5	3.8×10^{-3}	2.8×10^{0}	230.9	3.6×10^{-3}	8.2×10^{-1}
Wind Tunnel						
4	712.7	6.4×10^{-3}	4.5×10^{0}	125.6	4.3×10^{-3}	5.5×10^{-1}
3	43.3363	1.1×10^{-2}	5.0×10^{-1}	213.4	4.4×10^{-3}	9.5×10^{-1}
2	13.8919	1.5×10^{-2}	2.1×10^{-1}	160.5	5.0×10^{-3}	8.2×10^{-1}
1	7.3994	1.5×10^{-2}	1.1×10^{-2}	238.8	5.9×10^{-3}	1.4×10^{0}
Floor Foil			4.5×10^{-3}			4.5×10^{-3}
Wall Foil			5.9×10^{-4}			5.9×10^{-4}
Sweepings	143.1	7.7×10^{-3}	1.1×10^{0}	447.8	4.2×10^{-3}	1.9×10^{0}
Tray in Vessel	2.1658	1.7×10^{-2}	3.6×10^{-2}	53.4	7.7×10^{-3}	4.1×10^{-1}
Vessel Floor Foil	12.8927	1.9×10^{-2}	6.4×10^{-3}	87.0	1.2×10^{-2}	1.0×10^{0}
Vessel Wall Foil			1.1×10^{-3}			5.5×10^{-4}
High Volume Samplers						
Wind Tunnel	4.6537	3.1×10^{-2}	1.5×10^{-1}	6.7953	2.0×10^{-2}	1.4×10^{-1}
Vessel Ceiling	3.0908	1.9×10^{-2}	5.9×10^{-2}	2.4775	3.3×10^{-2}	8.2×10^{-2}
Impactor Samples						
Wind Tunnel	1.8444	3.5×10^{-2}	6.5×10^{-2}	2.1123	1.9×10^{-2}	4.0×10^{-2}
Vessel Ceiling	1.0894	3.5×10^{-2}	3.8×10^{-2}	0.4673	3.7×10^{-2}	1.7×10^{-2}
Total	1674.6		9.5×10^{0}	1569.3		8.2×10^{0}

Table A.46. Fractional Airborne Releases of Uranium During the Burning of Contaminated Wastes

(Table II - Mishima and Schwendiman April 1973)

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. Airborne Concentration	Wall Deposition		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.

Table A.47. Fractional Release During Burning of Combustible Material Containing Uranium Compounds

(Table III - Mishima and Schwendiman October 1970)

(Area of Pyrex combustion chamber 57 cm^2, 3" ODT x 30" long, aluminum chimney, particles collected on 4" diameter glass fiber filters.)

Combustible Material Used	Uranium Compound Used	Duration Of Flame (min)	Nominal* Velocity Chamber (cm/sec)	Percent Uranium Entrained	Percent Uranium Carried To Filter
10 grams Tissue Paper (Kleenex)	0.32 gram U as Dioxide†	3.7	104	40	34
	0.24 gram U as Dioxide†	6	46	36	33
	0.29 gram U as Nitrate††	2.5	104	14	8
	0.11 gram U as Dioxide†	3.5	104	55	38
10 grams Cheesecloth	0.12 gram U as Dioxide†	2	104	35	20
	0.37 gram U as Dioxide†	2.1	104	44	35
	2.92 gram U as Nitrate††	7.7	104	0.4	0.2
	3.63 gram U as Dioxide†	1.7	104	37	33
	1.33 gram U as Dioxide†	3.2	46	10	7
	0.29 gram U as Nitrate††	2.5	46	1.4	3.4×10^{-4}
	0.29 gram U as Nitrate††	3.1	104	0.7	0.05
10 grams Corrugated Cardboard	0.17 gram U as Dioxide†	2.6	46	20	12
	0.76 gram U as Dioxide†	3.5	104	8.3	8.0
	0.29 gram U as Nitrate††	13	104	1.4	1.3
	2.92 gram U as Nitrate°	7	104	1.1	0.2
	2.42 gram U as Nitrate°	7	46	0.2	0.1
	2.42 gram U as Nitrate°	2.9	104	0.1	0.1
	1.31 gram U as Dioxide†	2.8	46	2.4	1.6
	0.26 gram U as Dioxide†	1.7	104	12	12
Combined Waste""	4.82 gram U as Nitrate††	--	104	1.0	0.8
	2.30 gram U as Dioxide†	6.4	104	17.6	9.8
	4.82 gram U as Nitrate††	4.6	46	0.1	5.4×10^{-4}
	1.22 gram U as Dioxide†	4.2	46	12.5	6.4

* Volume airflow through chamber % cross sectional area.

"" 5 grams cheesecloth + 3 grams tissue paper in polyethylene bag sealed in 2" x 2" x 3" corrugated cardboard box with masking tape.

† As powder.

†† As UNH solution.

° Air dried.

Table A.48. Fractional Release During Burning of Flammable Materials Containing Plutonium Nitrate

(Table II - Mishima and Schwendiman October 1970)

Initial Activity dpm	Flammable Material Used	Duration Of Flame min.	Max. Flame Temperature °C	Percent Collection Filter
4.47×10^5	3 grams Coarse Fir Shavings	1.7	430	0.83
	10 grams Corrugated Cardboard	12	450	1.0
	5 grams Rubber -- Surgeon's Gloves	7	600	0.07
	5 grams Rubber -- Surgeon's Gloves	9	460	0.19
9.18×10^6	3 grams Coarse Fir Shavings	1.2	450	0.41
	10 grams Corrugated Cardboard	6.2	480	0.05
	3 grams Rubber + 3 grams Corrugated Cardboard	3.7	480	0.08
	5 grams Rubber -- Surgeon's Gloves	6.2	430	0.62
	5 grams Cheesecloth	6.2	520	0.43
	10 grams Corrugated Cardboard	6.2	585	0.12
	5 grams Cheesecloth	6.7	525	0.52
	3 grams Coarse Fir Shavings	3.7	500	1.0
	5 grams Rubber -- Surgeon's Gloves	5	610	0.02
	5 grams Rubber -- Surgeon's Gloves	7.2	675	0.08
	3 grams Coarse Fir Shavings -- on bed of sand	3	400	<0.01
	1/2" diam. Fir Plug -- on bed of sand	5.2	420	0.07

Table A.49. Results from Burning Mixed Waste

(Table A.5 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Notes
		Uranium	Smoke	
40	0	0	0.0	Cellulose and PC DUO powder
	1.0	0.016	0.7	
	3.0	0.045	2.2	
	4.5	0.067	3.5	
	9.0	0.095	4.5	
41	0	0	0	Cellulose and PMMA DUO powder
	5.0	0.012	0.2	
	8.8	0.017	0.4	
	14.5	0.031	0.8	
	25.8	0.035	1.2	

Table A.50. Size of Aerosols from Burning Contaminated Combustibles

(Table 4- Halverson, Ballinger and Dennis March 1987)

Run #	Fuel	AMMD, μm	σ_g	Less than 10 μm
10	PMMA[a]	4.3	2.3	84
11	PC[b]	19.9	4.6	16
12	Cellulose	>0.1		97
14	PMMA	4.9	4.6	63
23	Cellulose	10.5	5.7	40
28	Cellulose	7.8	5.2	47
30	PMMA	3.9	2.5	84
38	PS[c]	1.7	3.8	90
51	PMMA	1.4	4.3	95
56	TBP/NPH	0.6	3.1	99

(a) Polymethylmethacrylate.
(b) Polychloroprene.
(c) Polystyrene.

Table A.51. Results from Burning Contaminated Polychloroprene (PC)

(Table A. 1- Halverson, Ballinger and Dennis October 1987)

Run #	Time, min	Cumulative % Release		Notes
		Uranium	Smoke	
7	0	0.0	0.0	DUO powder
	1.0	0.48	4.4	Heat flux = 23 kW/m^2
	1.5	0.97	11.5	
	2.8	1.01	12.9	
	7.5	1.03	13.9	
9	0	0.0	0.0	DUO powder
	1.2	0.64	8.6	Heat flux = 23 kW/m^2
	2.3	0.76	13.1	No ignition
	4.0	0.78	14.2	
	10.0	0.80	14.8	
11	0	0.0	0.0	DUO powder
	8.3	0.24	1.5	Heat flux = 13 kW/m^2
	13.6	0.31	5.0	
	15.1	0.35	6.7	
	15.7	0.37	7.0	
8	0	0.0	0.0	UNH liquid
	0.7	0.11	1.5	
	1.3	2.27	5.8	
	2.3	3.23	7.5	
	9.0	3.47	10.3	
24	0	0.0	0.0	Air-dried UNH
	1.0	0.12	1.2	
	2.0	0.39	6.9	
	4.4	0.42	9.6	
	7.5	0.42	10.0	

Table A.52. Results from Burning Contaminated Polystyrene (PS)

(Table A.2 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Notes
		Uranium	Smoke	
17	0	0.0	0.0	0.17 mL UNH/g PS
	9.0	0.15	0.5	
	10.0	0.15	2.1	
	13.5	0.16	4.7	
	18.5	0.16	5.9	
25	0	0.0	0.0	0.4 mL UNH/g PS
	6.7	0.17	0.6	
	7.8	0.18	2.9	
	9.3	0.18	7.0	
	12.8	0.18	9.6	
38	0	0	0	0.5 mL UNH/g PS
	5.3	0.74	0.8	
	6.5	0.76	2.3	
	12.8	0.77	2.7	
		0.78	3.0	
55	0		0.0	0.6 mL UNH/g PS
	4.0		1.1	Amberlite ion exchange
	7.5		3.8	resin
	20.0		4.0	
			4.1	

Table A.53. Results from Burning Contaminated Polymethylmethacrylate (PMMA)

(Table A.3 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Notes
		Uranium	Smoke	
6	0	0.0	0.0	DUO powder
	14.5	2.9	0.1	
	18.0	3.2	0.4	
	24.5	3.2	0.8	
	31.5	3.2	0.9	
13	0	0.0	0.0	No ignition
	9.0	2.3	0.1	DUO powder
	19.0	2.8	0.3	
	27.3	2.9	0.5	
	34.6	3.0	0.6	
29	0	0.0	0.0	DUO powder
	4.4	1.0	0.1	Thick layer
	9.1	3.3	0.5	
	14.4	3.4	1.0	
	18.4	3.5	1.1	
30	0	0.0	0.0	DUO powder
	5.0	2.0	0.1	Thick layer
	7.9	3.3	0.6	
	13.7	3.5	1.1	
	17.0	3.6	1.1	
31	0	0.0	0.0	DUO powder
	3.9	0.4	0.1	Pile
	7.8	4.2	0.6	
	14.0	4.4	1.1	
	19.5	4.4	1.2	
32	0	0	0.0	DUO powder
	4.5	0.6	0.1	Pile
	9.3	4.1	0.5	
	14.3	4.3	1.1	
	19.3	4.5	1.1	
33	0	0.0	0.0	DUO powder
	10.3	0.3	0.1	Under PMMA
	13.3	1.1	0.7	
	15.5	1.3	1.1	
	21.0	1.3	1.1	

Table A.53. Results from Burning Contaminated Polymethylmethacrylate (PMMA) (continued)

(Table A.3 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Notes
		Uranium	Smoke	
34	0	0.0	0.0	DUO powder
	5.0	0.07	0.003	No burn, only entrainment
	10.0	0.13	0.003	
	15.0	0.21	0.063	
	20.0	0.25	0.063	
36	0	0.0	0.0	DUO powder
	5.0	1.2	0.07	Early sampling to detect
	7.3	2.9	0.17	spike
	12.8	3.2	0.75	
	18.6	3.7	1.09	
51	0	0	0	DUO powder
	4.5	0.42	0.02	
	14.5	1.10	0.35	
	20.5	1.30	0.56	
	30.3	1.52	0.56	
10	0	0.0	0.0	Liquid UNH
	13.8	1.9	0.2	0.12 mL UNH/g PMMA
	15.4	1.9	0.4	Flame above sample
	20.3	1.9	1.0	
	26.0	1.9	1.1	
19	0	0.0	0.0	Liquid UNH
	6.5	0.1	0.1	0.05 mL UNH/g PMMA
	9.6	0.2	0.5	Impinging flame
	12.8	0.2	0.9	No. 3 uranium sample
	15.5	0.2	1.2	suspect
21	0	0.0	0.0	Liquid UNH
	4.1	1.1	0.1	0.12 mL UNH/g PMMA
	7.5	1.6	0.4	Impinging flame
	13.3	1.8	0.8	
	16.7	2.0	1.1	
14	0	0.0	0.0	Air-dried UNH
	7.3	0.3	0.04	
	10.5	0.6	0.3	
	13.3	0.6	0.6	
	16.6	0.6	0.9	

Table A.54. Results from Burning Contaminated Cellulose

(Table A.4 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Cumulative Mass Loss, g	Notes
		Uranium	Smoke		
4	0	0	0	0	DUO powder
	3.0	0.0014	0.1	2.5	
	7.5	0.0084	0.3	20.0	
	11.0	0.0161	1.1	30.0	0.1 g DUO/g cellulose
	14.0	0.0188	1.6	31.0	Smoldering
12	0	0.0	0.0	0.0	DUO powder
	7.4	0.0033	0.1	14.7	
	8.5	0.0086	0.3	21.9	
	12.2	0.0154	0.4	31.1	0.03 g DUO/g cellulose
	17.0	0.0239	1.7	31.1	
15	0	0	0.0	0.0	DUO powder
	21.3	0.0127	1.1	5.4	Heat flux - 13 kW/m[a]
	22.3	0.0144	1.2	9.2	
	29.3	0.0278	1.4	26.8	0.09 g DUO/g cellulose
	33.5	0.0303	1.5	27.8	
23	0	0	0.0	0.0	DUO powder
	3.2	0.0123	0.8	5.7	
	4.0	0.0328	0.9	11.3	
	7.7	0.0475	1.0	24.4	0.09 g DUO/g cellulose
	11.0	0.0478	1.1	23.9	
26	0	0	0	0.0	DUO powder
	3.3	0.0254	1.9	5.3	
	5.0	0.0430	2.1	15.9	
	7.3	0.0515	2.2	21.6	0.08 g DUO/g cellulose
	10.4	0.0546	2.2	22.5	
27	0	0	0	0	DUO powder
	4.1	0.0204	3.2	10.9	0.09 g DUO/g cellulose
	5.9	0.0381	3.7	20.4	
	7.7	0.0431	3.9	23.0	
	12.7	0.0478	4.2	21.8	
28	0	0	0.0	0	DUO powder
	3.7	0.0566	1.2	4.5	Airflow = 17.5 1 ℓpm[b]
	6.1	0.0761	1.3	20.7	0.095 g DUO/g cellulose
	6.8	0.0860	1.4	22.4	
	11.4	0.0903	1.5	23.2	
35	0	0.0	0.0		DUO powder
	1.0	0.273	0.2		No heat flux
	3.0	0.297	0.4		~0.1 g DUO/g cellulose
	7.0	0.299	0.4		
		0.301	0.4		

Table A.54. Results from Burning Contaminated Cellulose (continued)

(Table A.4 - Halverson, Ballinger and Dennis March 1987)

Run #	Time, min	Cumulative % Release		Cumulative Mass Loss, g	Notes
		Uranium	Smoke		
37	0	0.0	0.0		DUO powder
	1.8	0.018	0.03		No heat flux
	3.8	0.077	0.1		~0.1 g DUO/g cellulose
	6.3	0.144	0.3		
	10.3	0.153	0.3		
39	0	0.0	0.0		DUO powder
	5.0	0.006	0.01		No heat flux
	10.0	0.0085	0.03		No ignition
	15.8	0.0098	0.03		Entrainment only
		0.0108			Airflow = 11 lpm
					~0.2 g DUO/g cellulose
20	0	0	0.0	0.0	Air-dried UNH
	1.1	0.011	3.7	5.3	
	2.6	0.019	4.8	11.7	
	4.5	0.021	4.9	13.2	
	9.8	0.029	5.1	14.5	
22	0	0.0	0	0	Air-dried UNH
	1.0	0.008	0.3	8.2	Heat flux = 13 kW/m^2
	2.3	0.009	0.4	12.0	
	8.3	0.010	0.5	14.6	
3	0	0	0	0	Liquid UNH
	7.0	0.003		25.8	
	12.0	0.009		62.5	
	17.0	0.013		93.8	
	20.5	0.014		101.7	
5	0	0.0	0	0	Liquid UNH
	20.0	0.0003	2.3	29.9	Heat flux = 7 kW/m^2
	32.0	0.0005	12.0	64.1	
	39.0	0.0043	18.1	84.9	
	44.5	0.0075	19.0	108.8	
18	0	0.0	0.0	0.0	Liquid UNH
	4.9	0.0015	0.3	6.0	
	6.0	0.0023	0.5	13.2	
	8.3	0.0042	0.8	24.3	
	15.3	0.0070	1.1	38.0	

(a) Heat flux = 23 kW/m^2 in all other runs.
(b) Airflow = 8 lpm in all other runs.

Table A.55. Results of Plenum Filter Particulate Analysis

(Table 3- Arnold 1986)

Filter #	Plenum #	Assay (g fu)	Matrix wt. (g)	Particulate wt. (g)	Matrix wt.% <212μ	Matrix wt.% <10μ
71031-3	FU2B	43.0	4,990[a]	1,500[d]	6.46	<0.12
71031-4	FU2B	38.0	5,105[a]	1,610[d]	5.61	<0.13
71031-5	FU2B	41.0	4,880[a]	1,540[d]	6.44	<0.13
71031-8	FU2B	39.0	5,100[a]	1,465[d]	4.74	<0.11
71031-17	FU2B	45.0	5,125[a]	1,575[d]	4.30	<0.12
71031-21	FU2B	35.0	4,635[a]	1,535[d]	6.76	<0.13
71031-27	FU2B	42.0	4,955[a]	1,475[d]	3.30	<0.12
71031-29	FU2B	46.0	4,740[a]	1,300[d]	4.99	<0.11
71032-1	FU2B-2	6.0	16,790[b]	225	0.515	<0.0054
71032-2	FU2B-2	7.0	16,875[b]	70	0.0775	<0.0017
71032-3	FU2B-2	13.0	17,175[b]	65	0.103	<0.0015
71032-4	FU2B-2	12.0	17,475[b]	95	0.176	<0.0022
71061-1	INCIN.	1.0	20,430[c]	330	0.543	<0.0065
71061-2	INCIN.	0.0	20,670[c]	450	0.692	0.0087
71061-3	INCIN.	2.0	20,295[c]	220	0.481	0.0076
71061-4	INCIN.	1.0	20,325[c]	390	0.779	0.0077
71061-5	INCIN.	1.0	20,460[c]	510	0.825	0.015
71061-6	INCIN.	0.0	19,705[c]	0	-	-
71061-7	INCIN.	2.0	20,520[c]	355	0.676	<0.0069
71061-8	INCIN.	1.0	24,380[c]	610	0.886	0.010
74021-5	202	0.0	16,310[c]	190	0.789	<0.0070
74021-7	202	1.0	16,220[c]	305	1.09	<0.015
74021-8	202	1.0	16,350[c]	195	1.05	<0.0084
74021-9	202	0.0	16,425[c]	155	0.536	<0.0057
74021-M1	202	0.0	16,360[c]	230	1.31	<0.0084
74021-M2	202	1.0	17,020[c]	30	0.170	0.0016
74021-M3	202	1.0	16,725[c]	290	1.65	<0.014
74021-M4	202	0.0	15,905[c]	20	0.107	<0.0010
37061-9	141	1.0	17,310[c]	0	-	-
37061-10	141	0.0	17,525[c]	0	-	-
37061-11	141	1.0	17,630[c]	15	0.0662	0.00043
37061-12	141	0.0	17,305[c]	0	-	-
37061-13	141	0.0	16,560[c]	0	-	-
37061-14	141	0.0	17,250[c]	10	0.0320	<0.00023
37061-15	141	0.0	17,385[c]	5	0.0220	0.00012
37061-16	141	0.0	17,515[c]	0	-	-
37171-1	321	0.0	16,740[c]	35	0.0728	<0.00084
37171-6	321	0.0	13,190[c]	40	0.213	0.0073
37171-8	321	0.0	16,440[c]	5	0.00490	0
37171-14	321	0.0	17,130[c]	20	0.0134	0
37171-18	321	0.0	16,215[c]	10	0.00456	0
37171-23	321	0.0	16,675[c]	5	0.0197	<0.00012
37171-30	321	0.0	16,430[c]	30	0.0278	0
37171-36	321	0.0	16,370[c]	20	0.0982	<0.00061

a - Based on Matrix weight of media + separator (w/o frame) - filterS with >19 g Pu have media & separator loaded into drums
b - Based on Matrix weight of entire filter (w/o packaging) - filters with > 5 g Pu but ≤ 19 g are placed into waste boxes uncrushed (12/box)
c - Based on Matrix weight of entire filter (w/o packaging) - filters with ≤ 5 g Pu are crushed & then placed into waste boxes (30/box)
d - Particulate weight for FU2B 1st stage includes all filter media; all media disintegrated upon being subjected to mechancial stressing

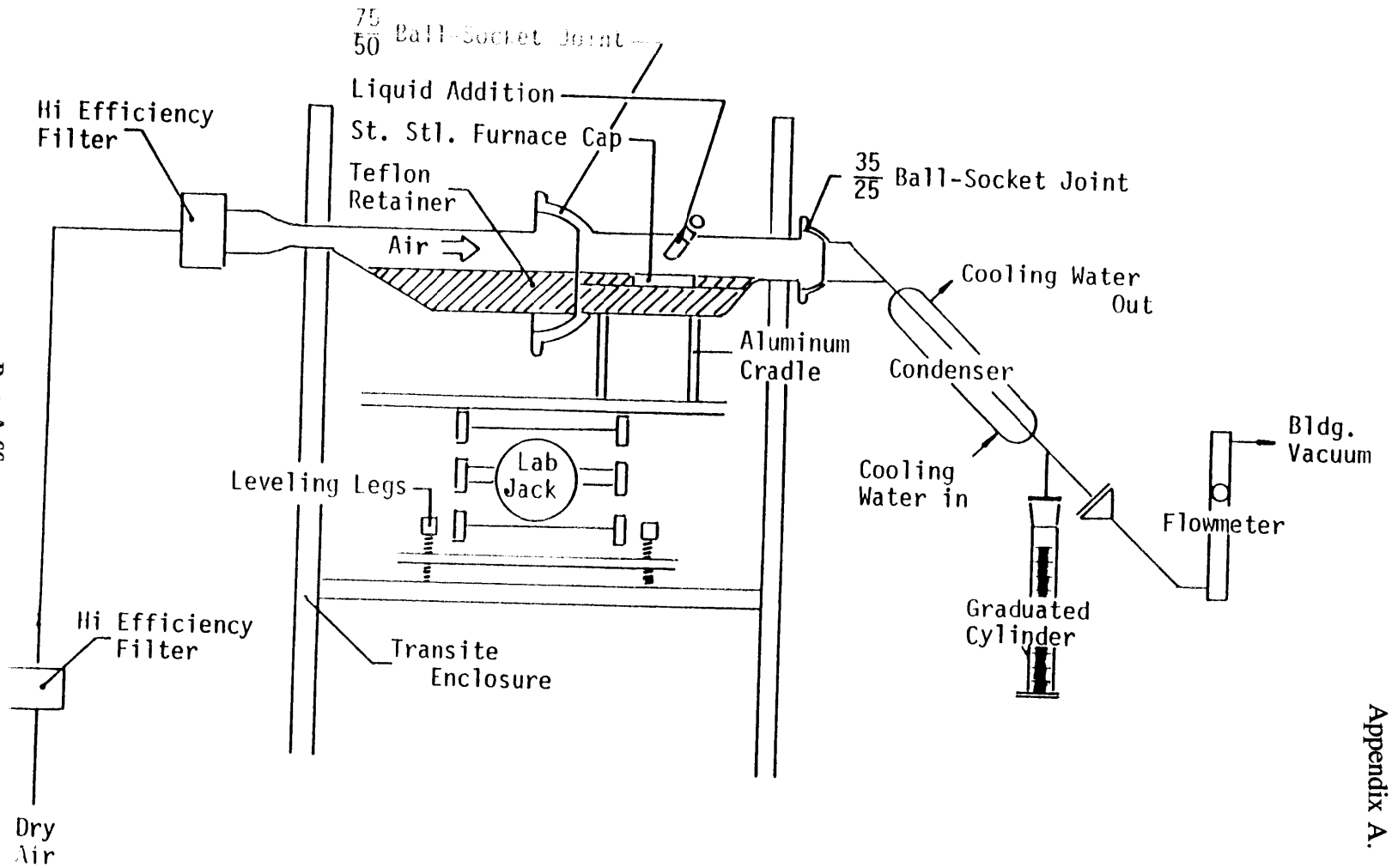


Figure A.1. Diagram of Apparatus Used in Air Drying of Shallow Pools of Concentrated Plutonium Nitrate Solution

(Figure 3 - Mishima, Schwendiman and Radasch November 1968)

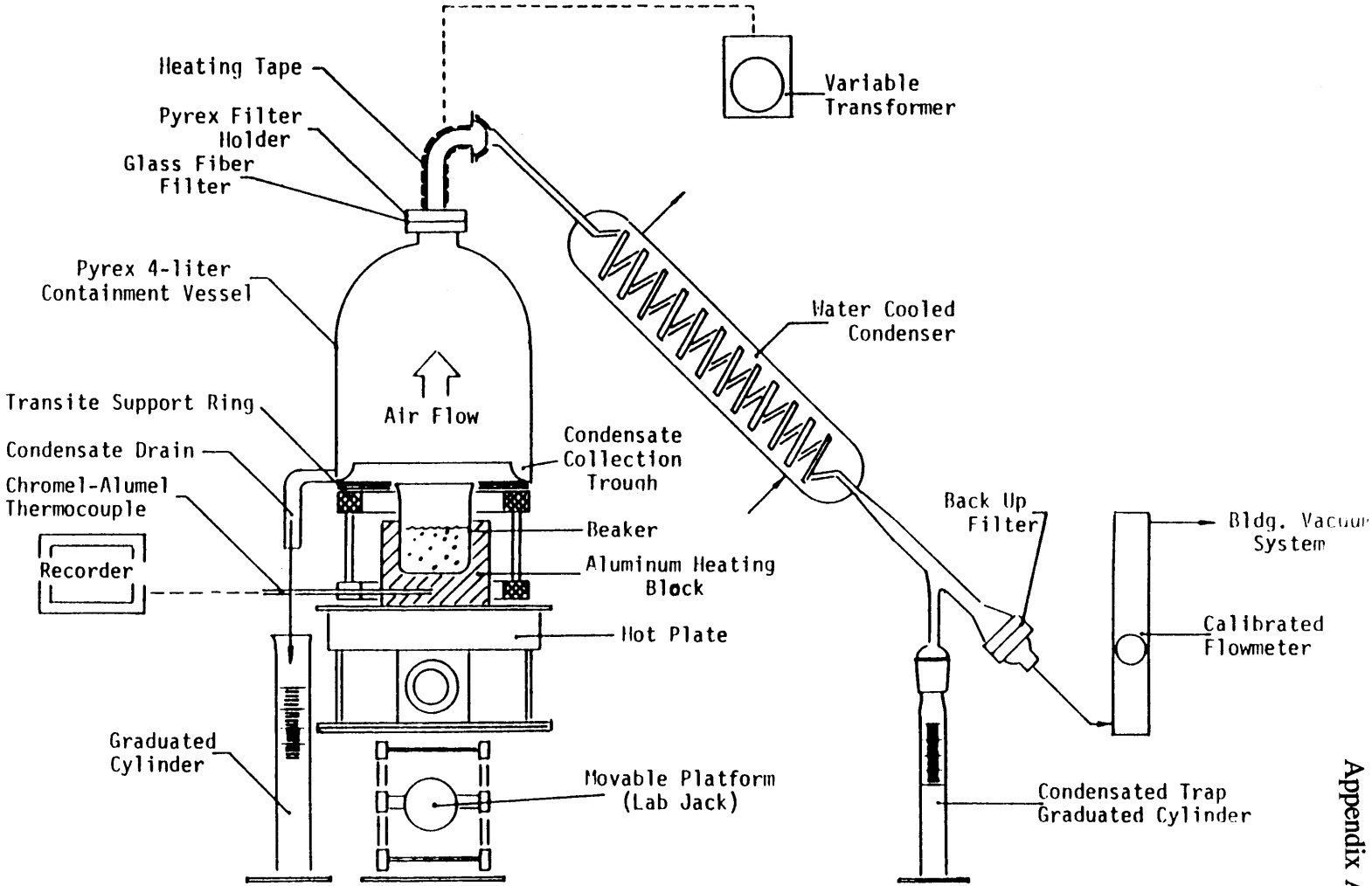


Figure A.2. Diagram of Apparatus Used to Determine Fractional Releases During Heating of Pools of Plutonium Nitrate Solutions

(Figure 5 - Mishima, Schwendiman and Radasch November 1968)

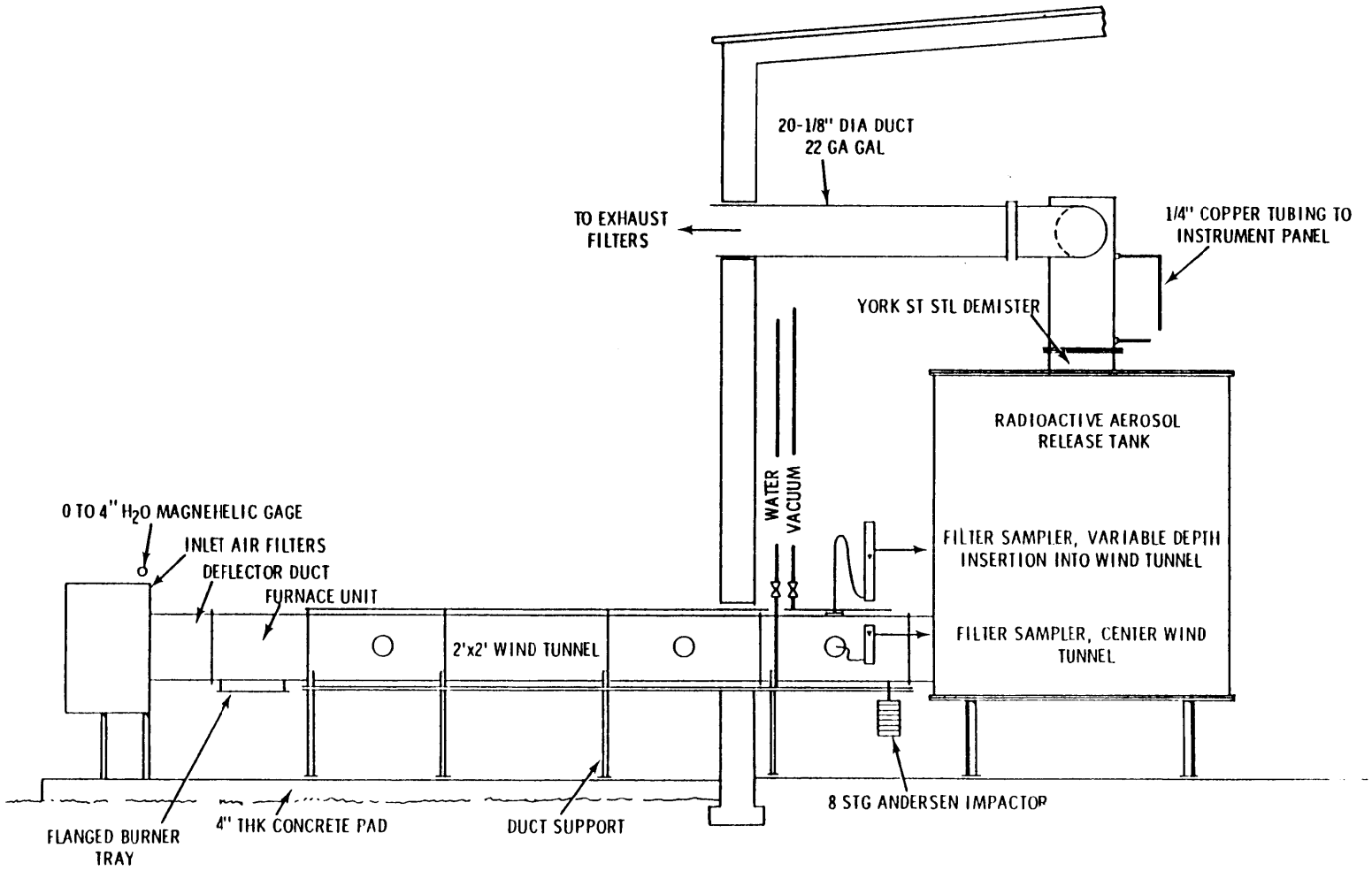


Figure A.3. Radioactive Aerosol Release Facility, 242-B Building

(Figure 1 - Mishima and Schwendiman August 1973)

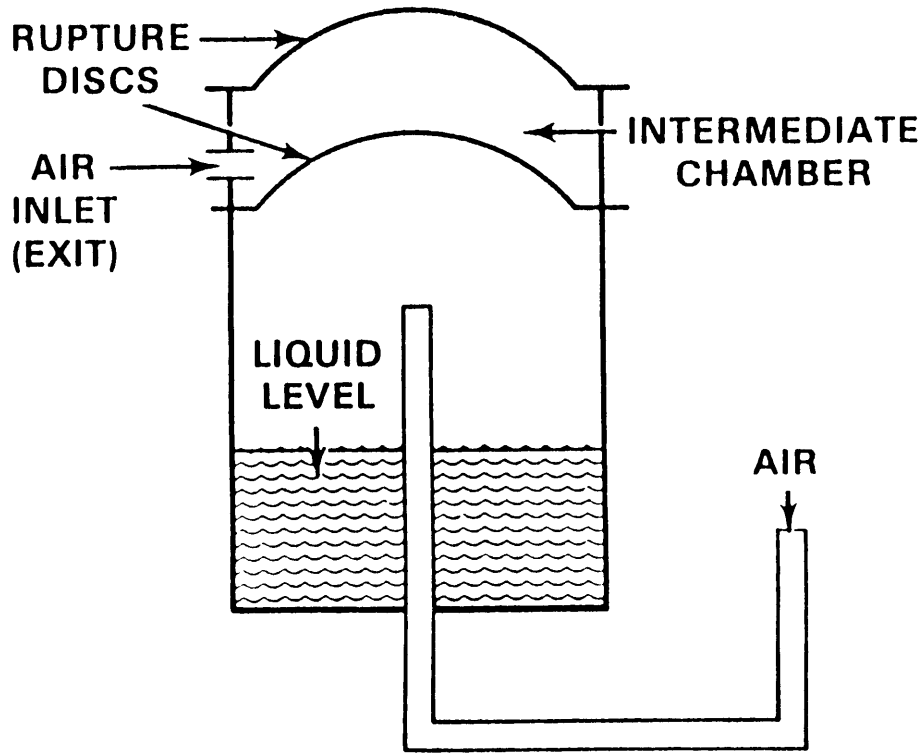


Figure A.4. PARE Modification for Pressurized Liquid

(Figure 5 - Sutter August 1983)

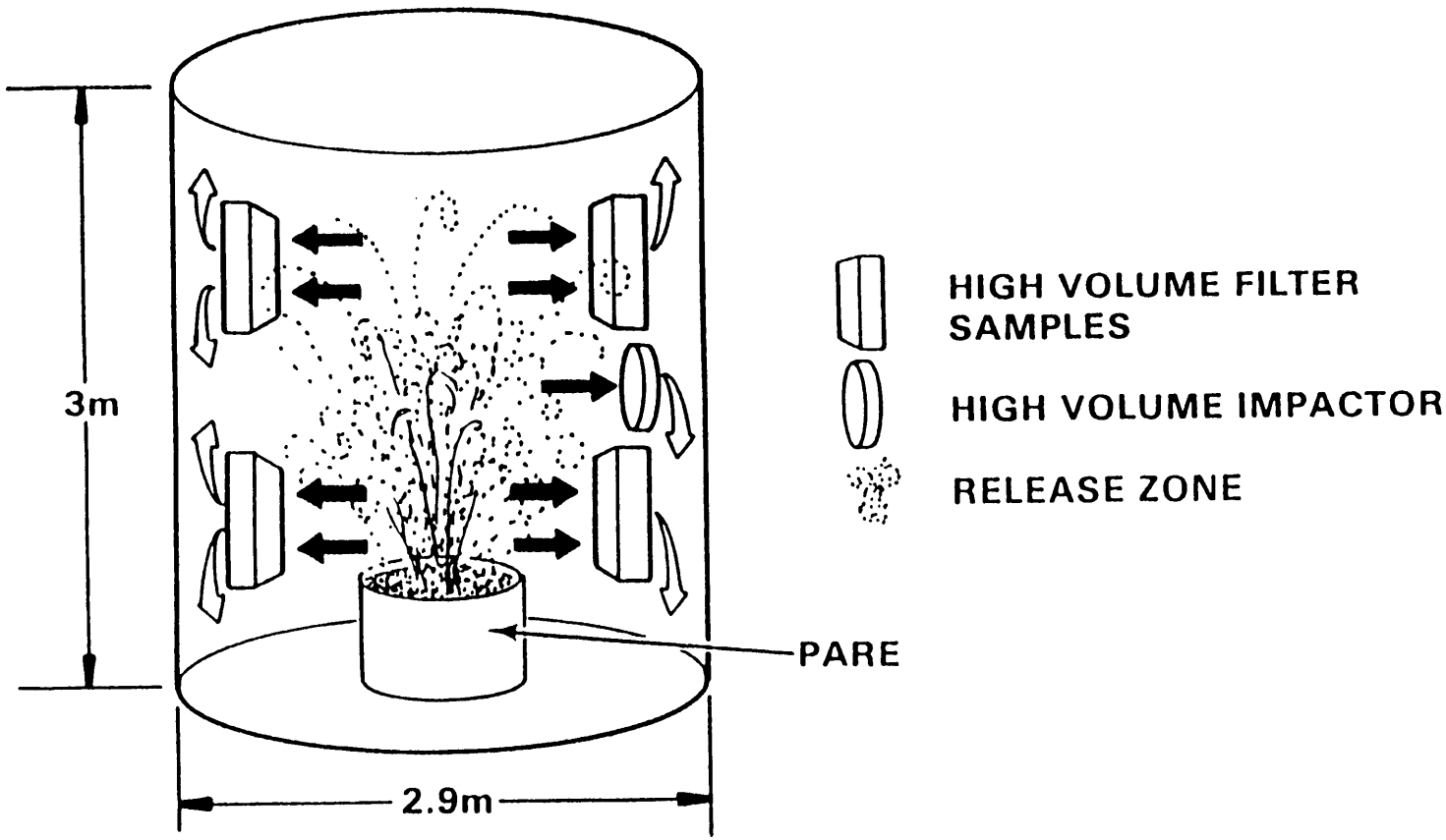


Figure A.5. Sampling for a Pressurized Release with High Volume Samplers

(Figure 2 - Sutter August 1983)

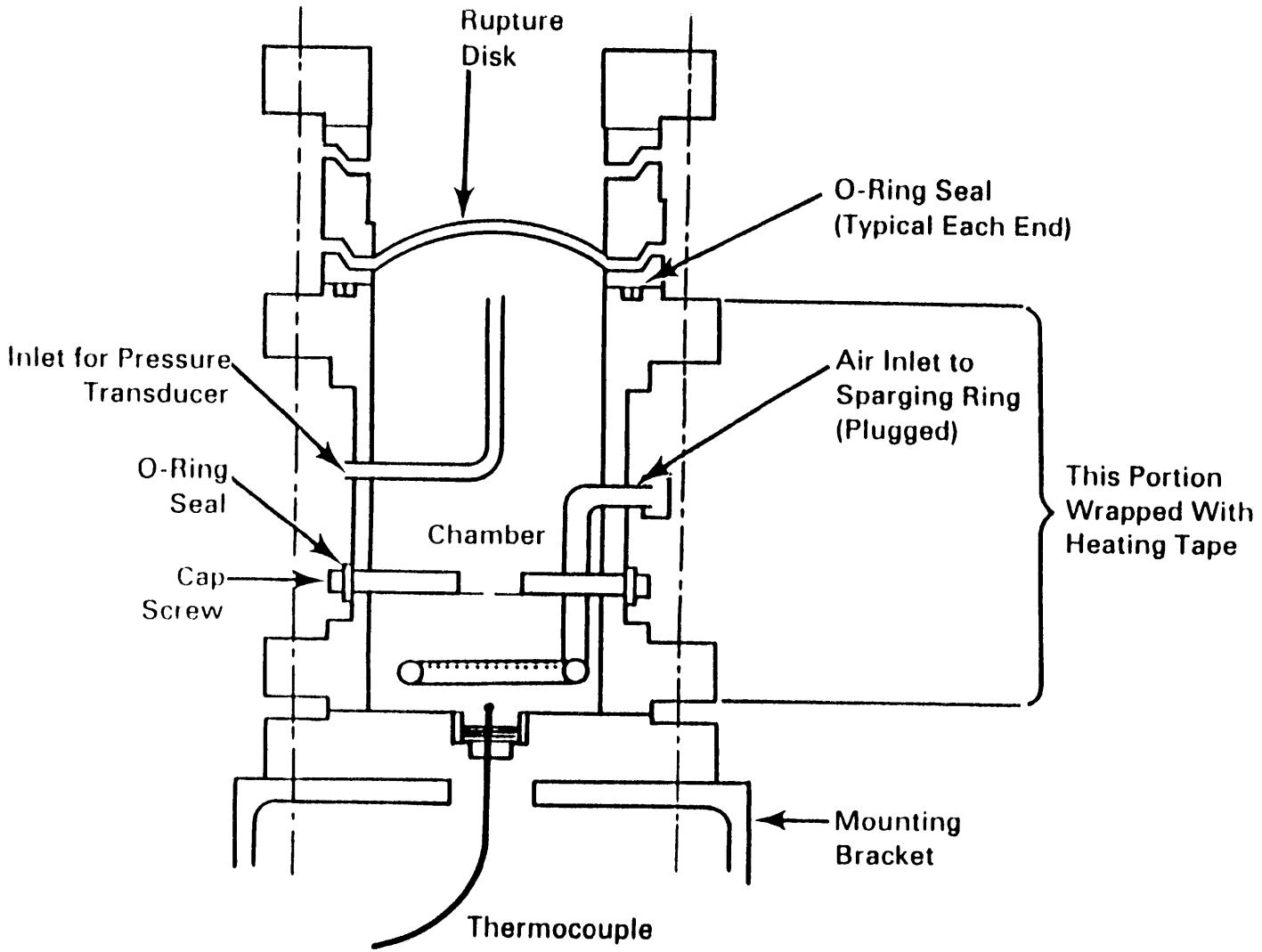


Figure A.6. PARE Modification for Flashing-Spray Experiments

(Figure 2.3 - Ballinger, Sutter and Hodgson May 1987)

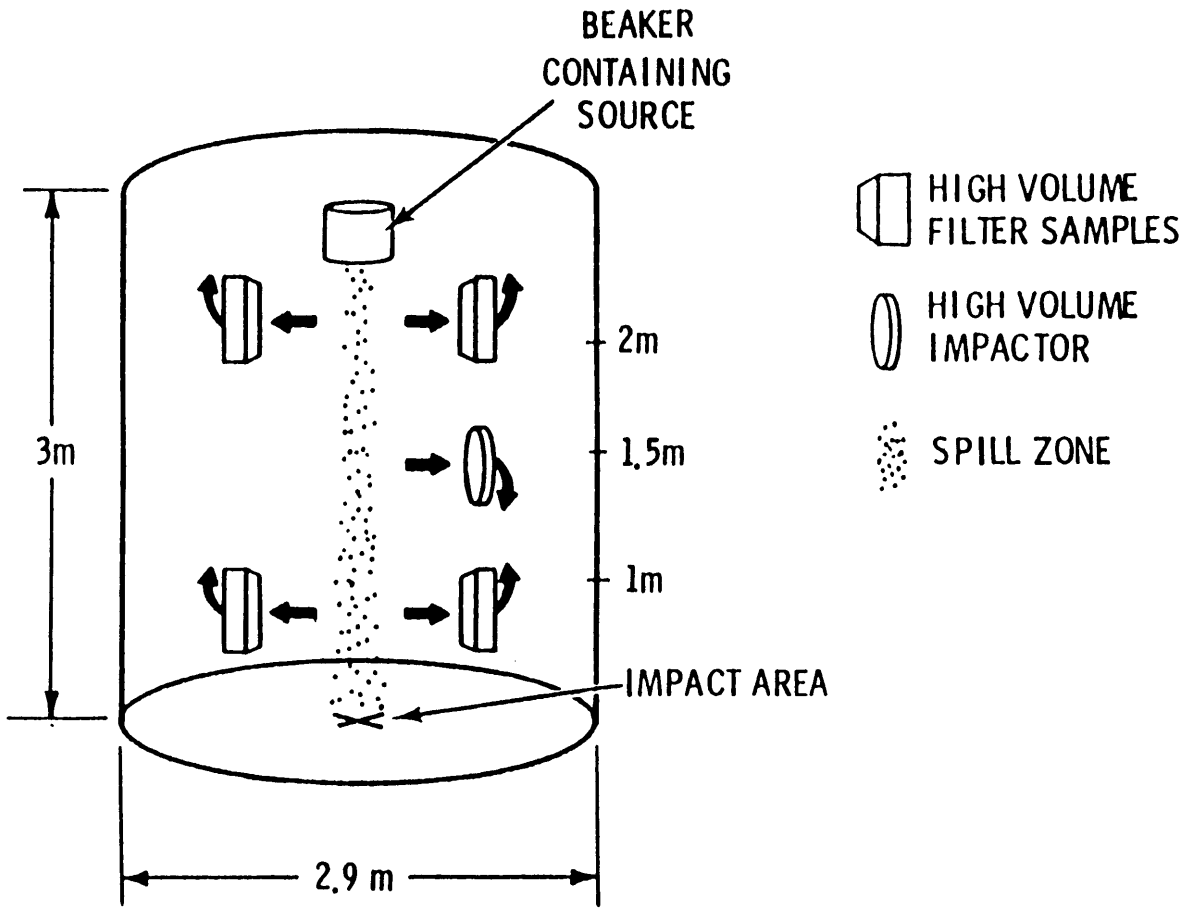


Figure A.7. Sampling for a Free-Fall Spill with High Volume Samplers

(Figure 2 - Sutter, Johnston and Mishima December 1981)

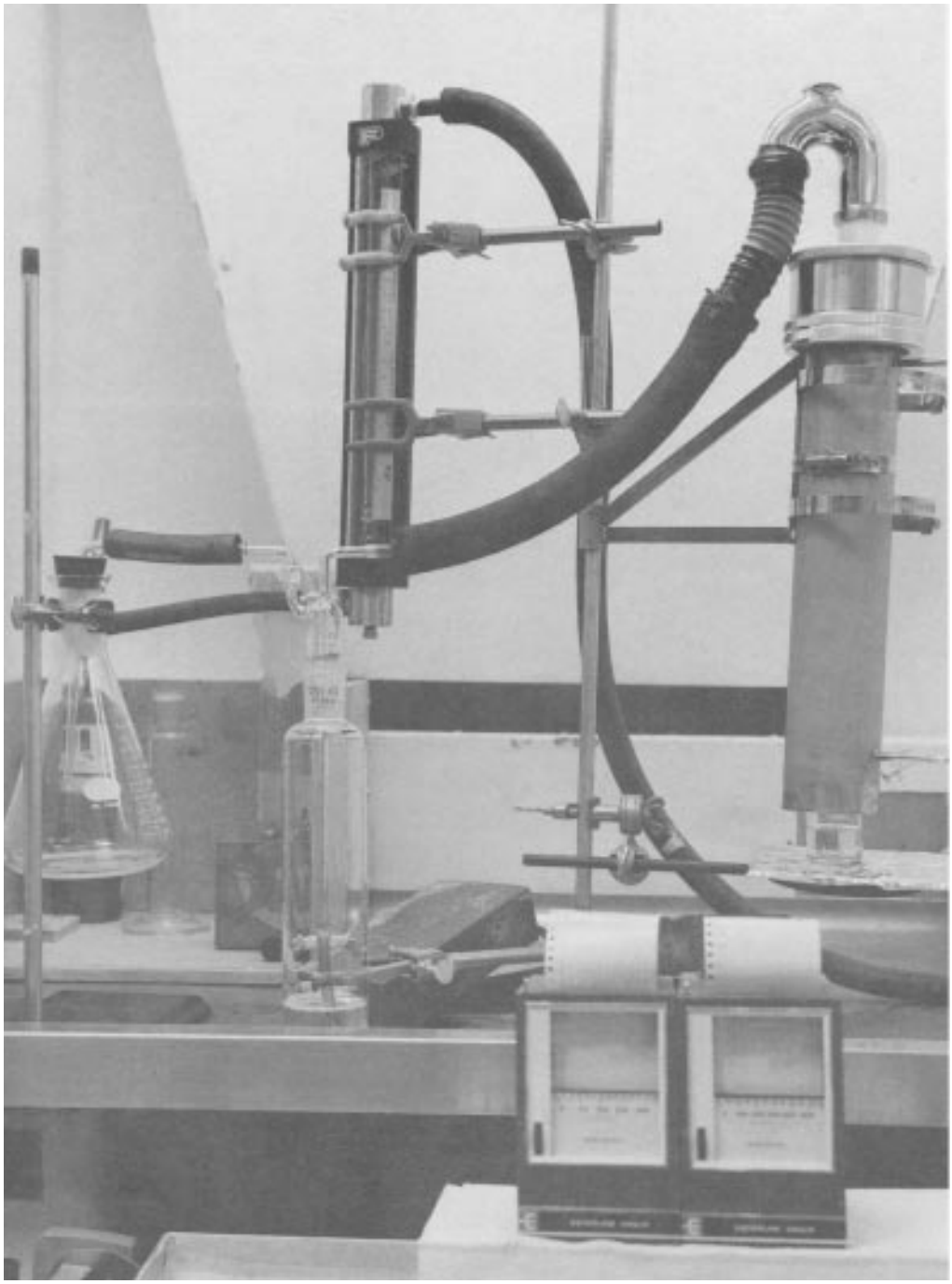


Figure A.8a. Laboratory Apparatus Used in Measuring Fractional Airborne Release

(Figure 1a - Mishima and Schwendiman June 1973)

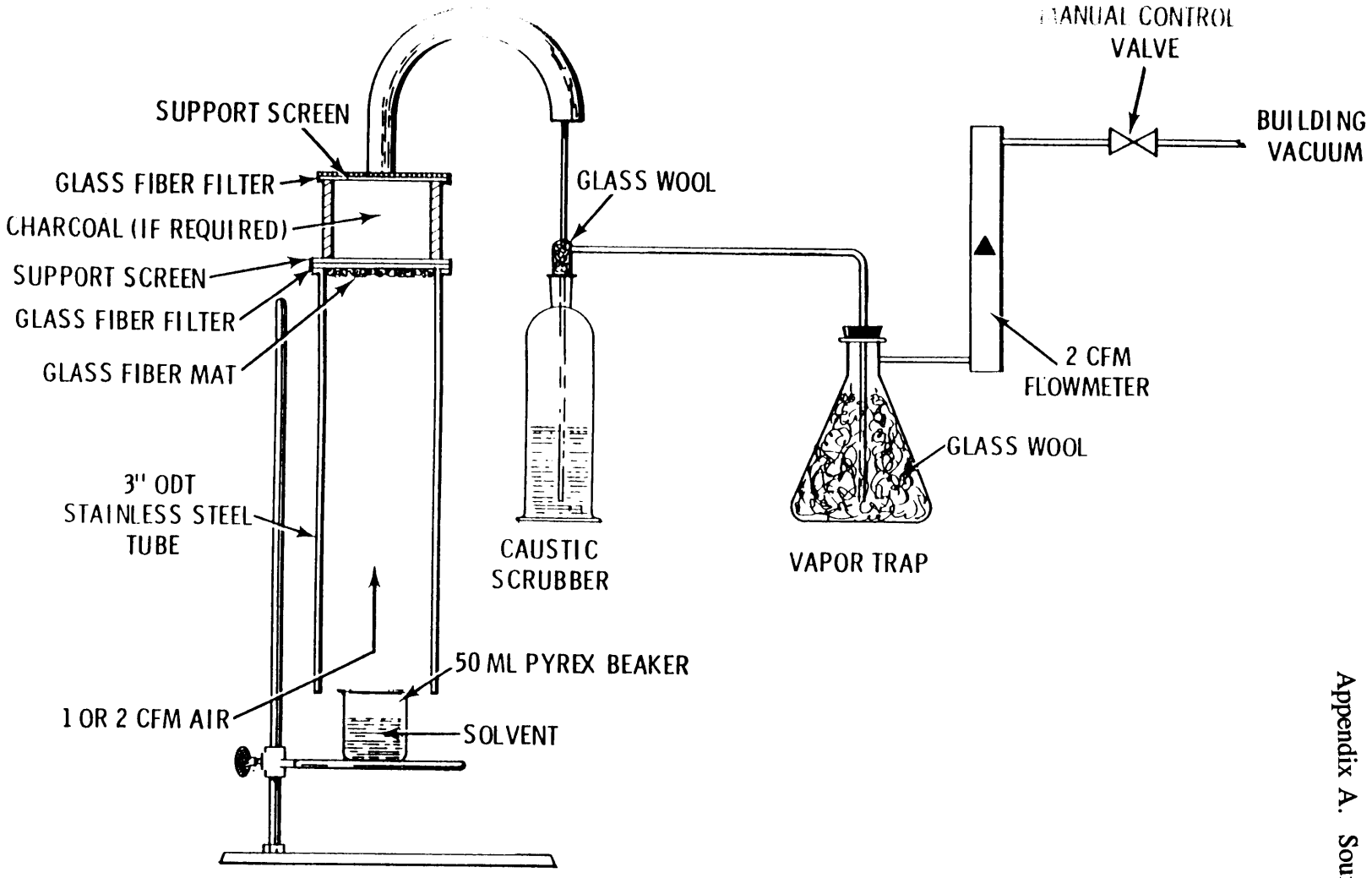


Figure A.8b. Schematic Diagram of Experimental Apparatus

(Figure 1b - Mishima and Schwendiman June 1973)

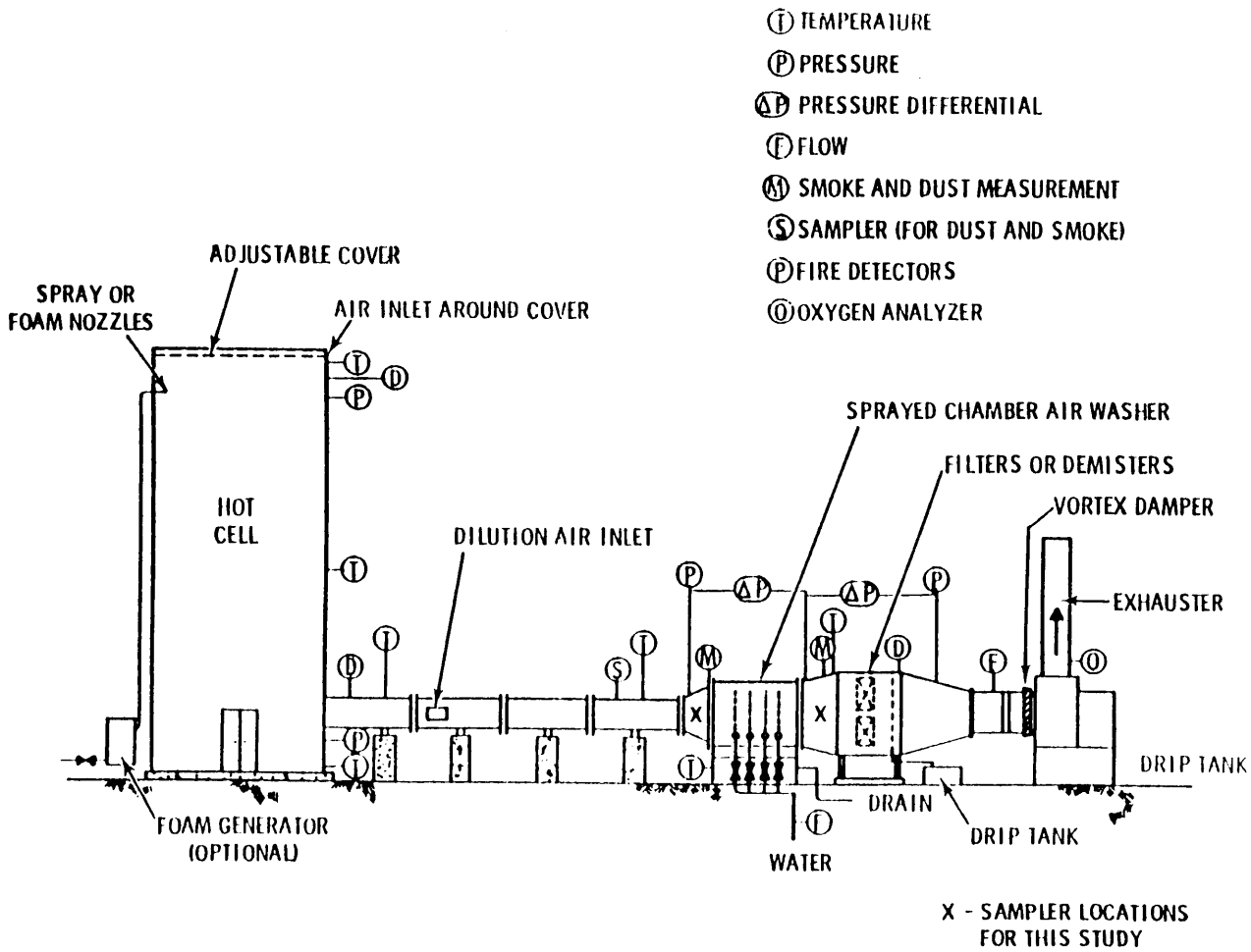


Figure A.9. Diagram of Fire Test Facility

(Figure 1 - Sutter, Mishima and Schwendiman June 1974)

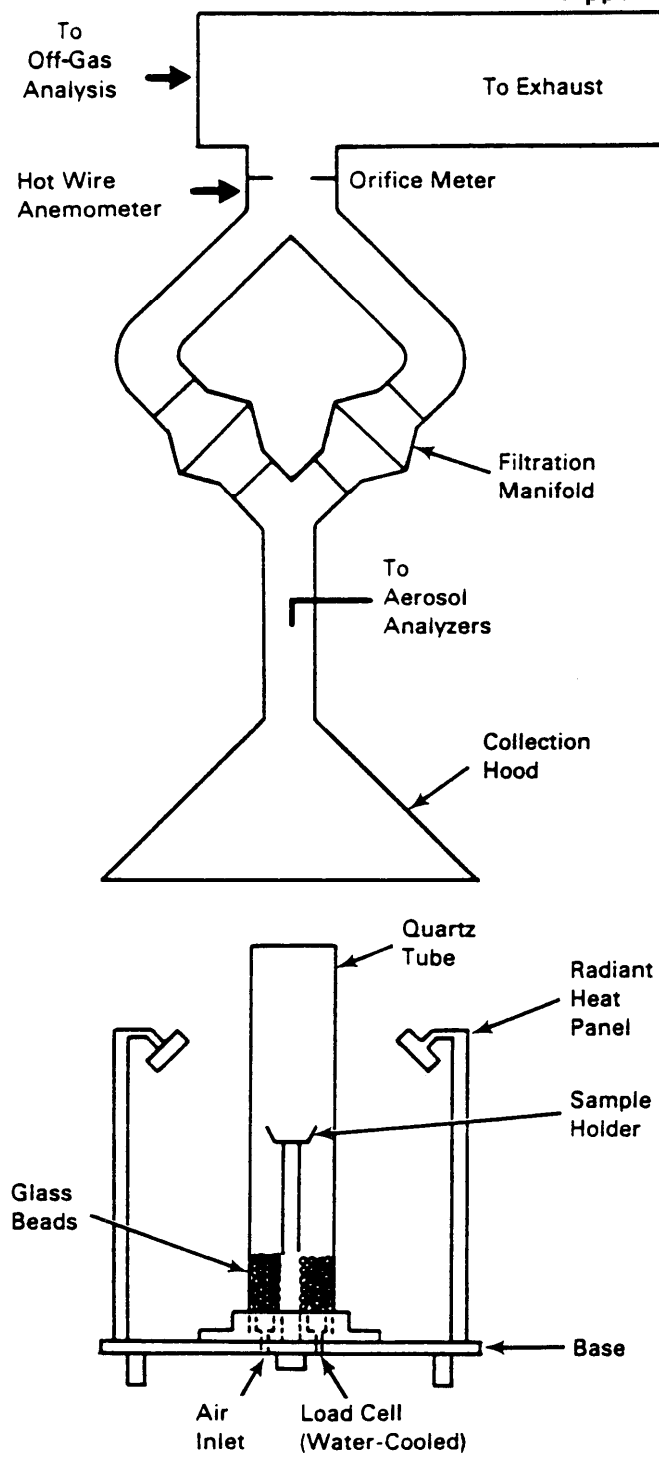


Figure A.10. CARE Combustion Apparatus

(Figure 1 - Halverson, Ballinger and Dennis February 1987)

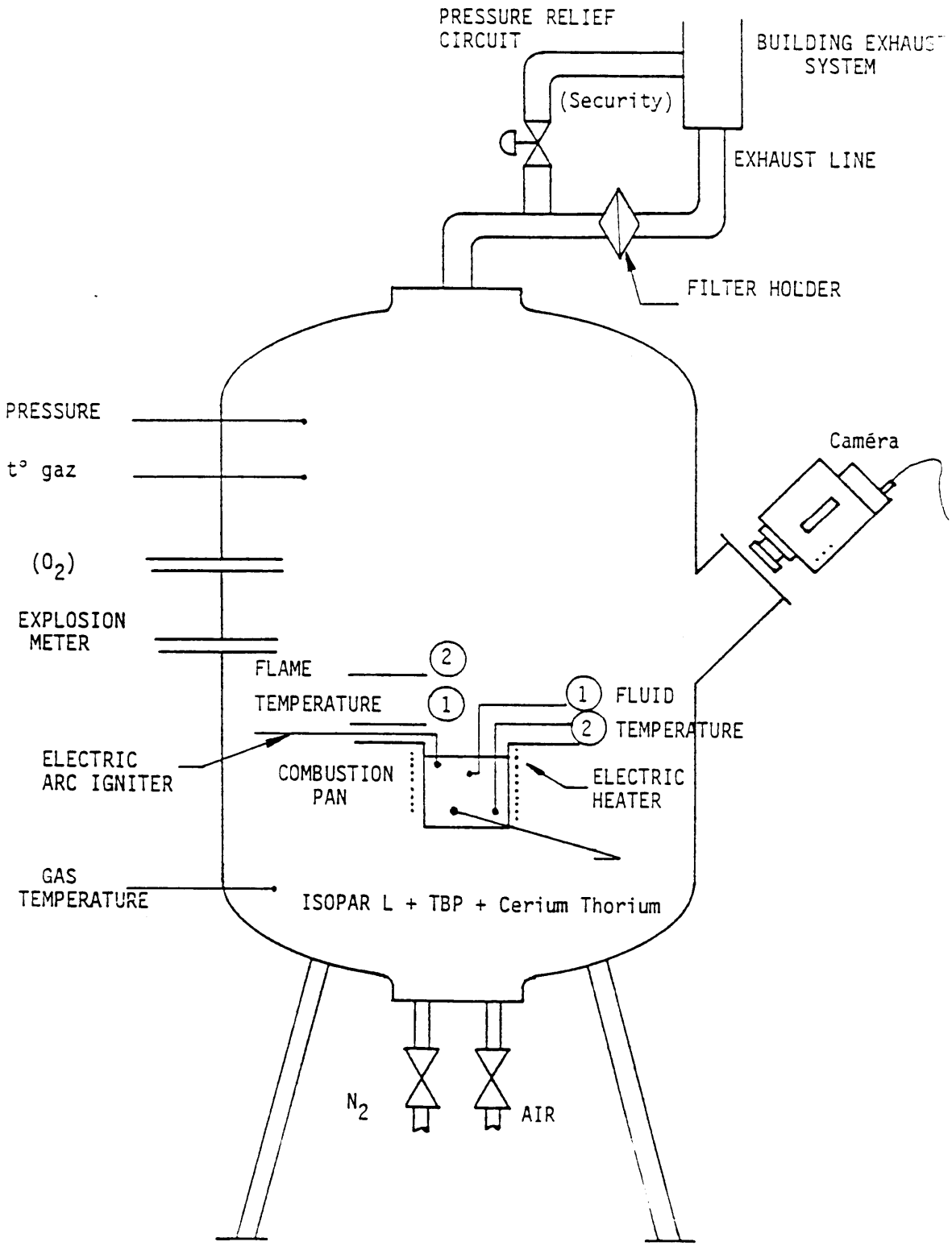


Figure A.11. 316-liter Test Vessel
(Figure 1 - Malet Duverger de Cuy, Gasteiger and Janberg April 1983)

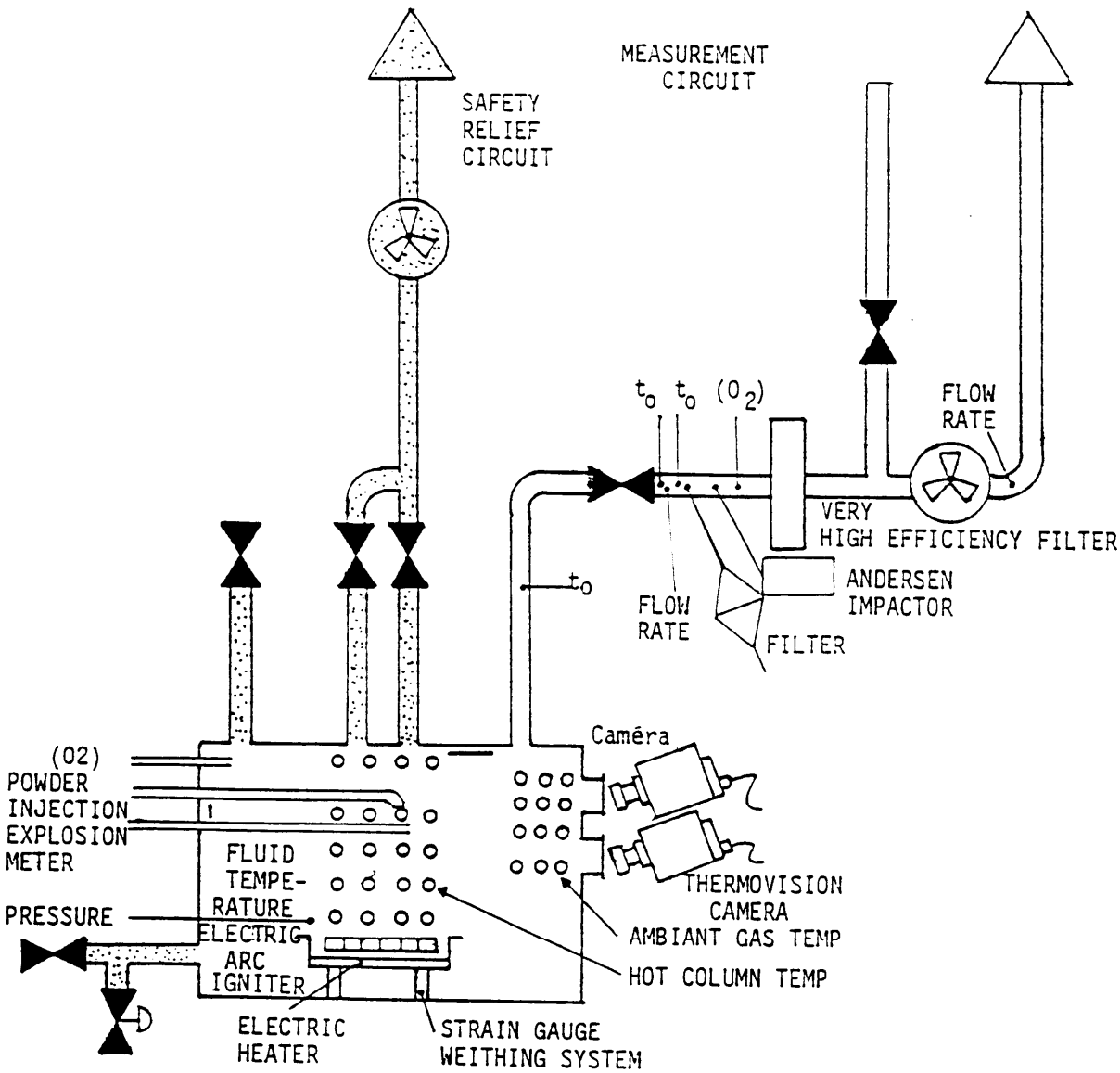


Figure A.12. 400-cubic meter Test Vessel

(Figure 2 - Malet, Duverger de Cuy, Gasteiger and Janberg April 1983)

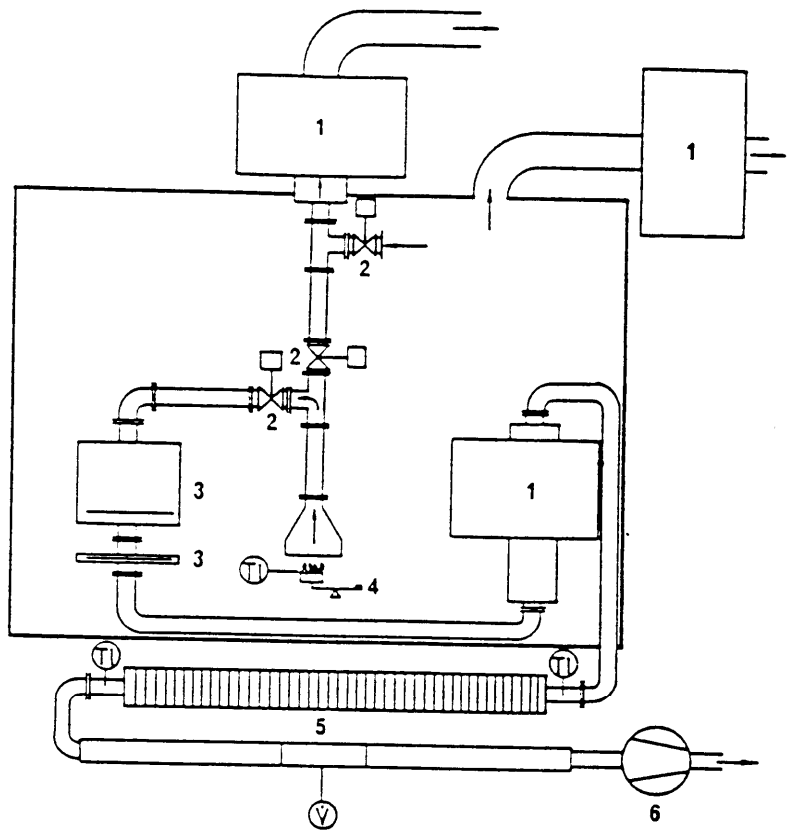


Figure A.13. Facility for the Investigation of Uranium Releases During Solvent Fires

(Figure 5 - Jordan and Lindner September 1986)

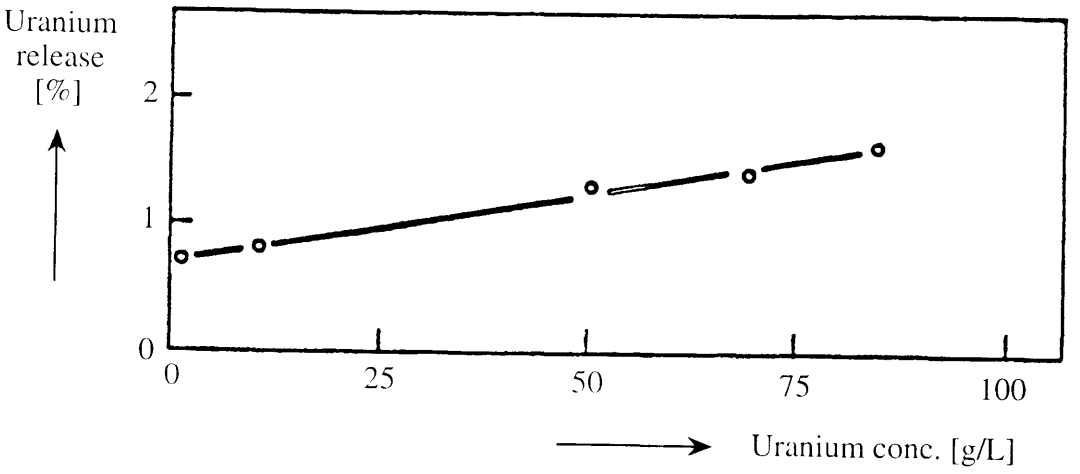
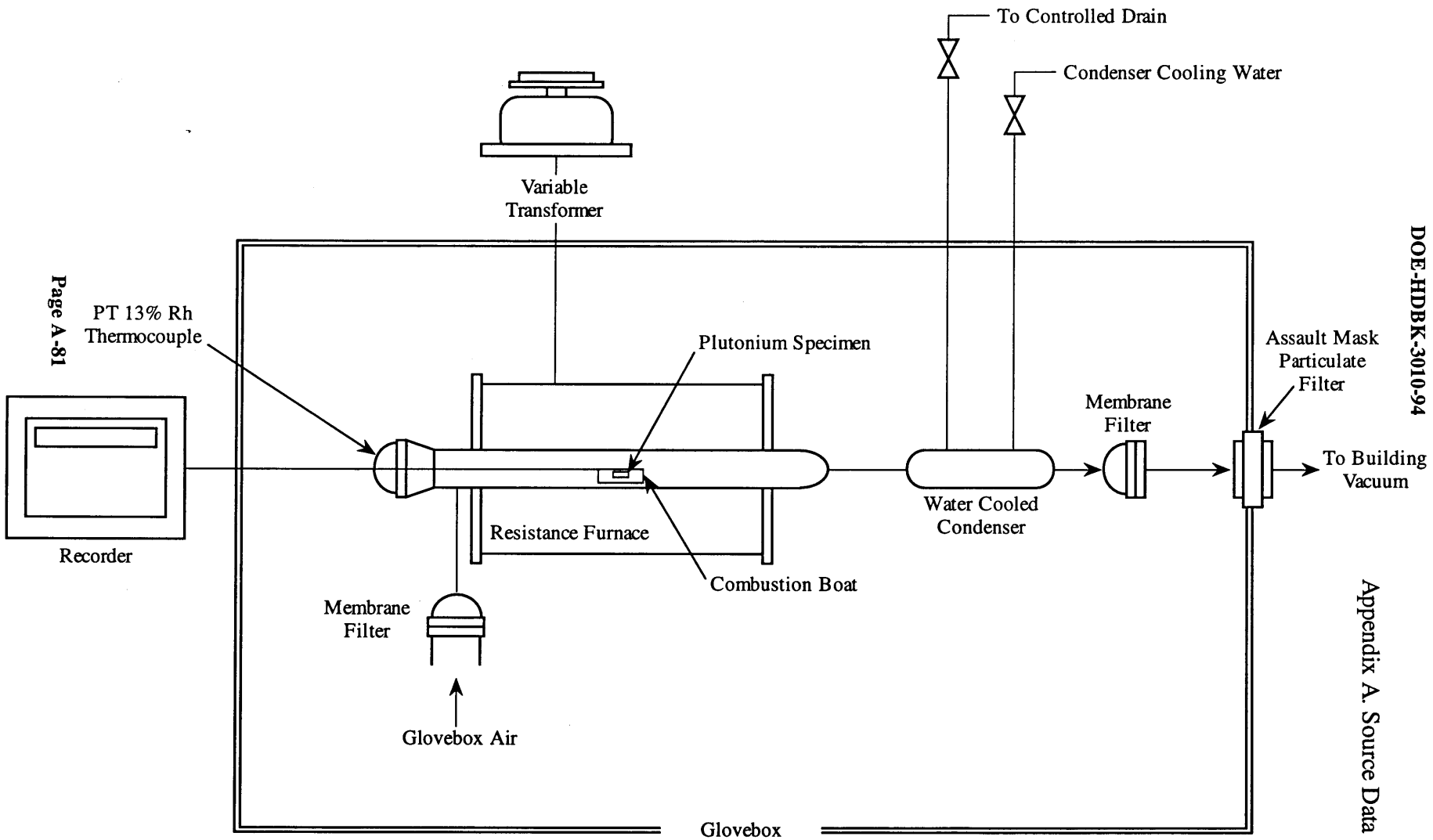


Figure A.14. Uranium Release During Solvent Fires

(Figure 6 - Jordan and Lindner September 1986)

Figure A.15. Schematic Diagram - Plutonium Burning Apparatus

(Figure 1 - Mishima December 1965)



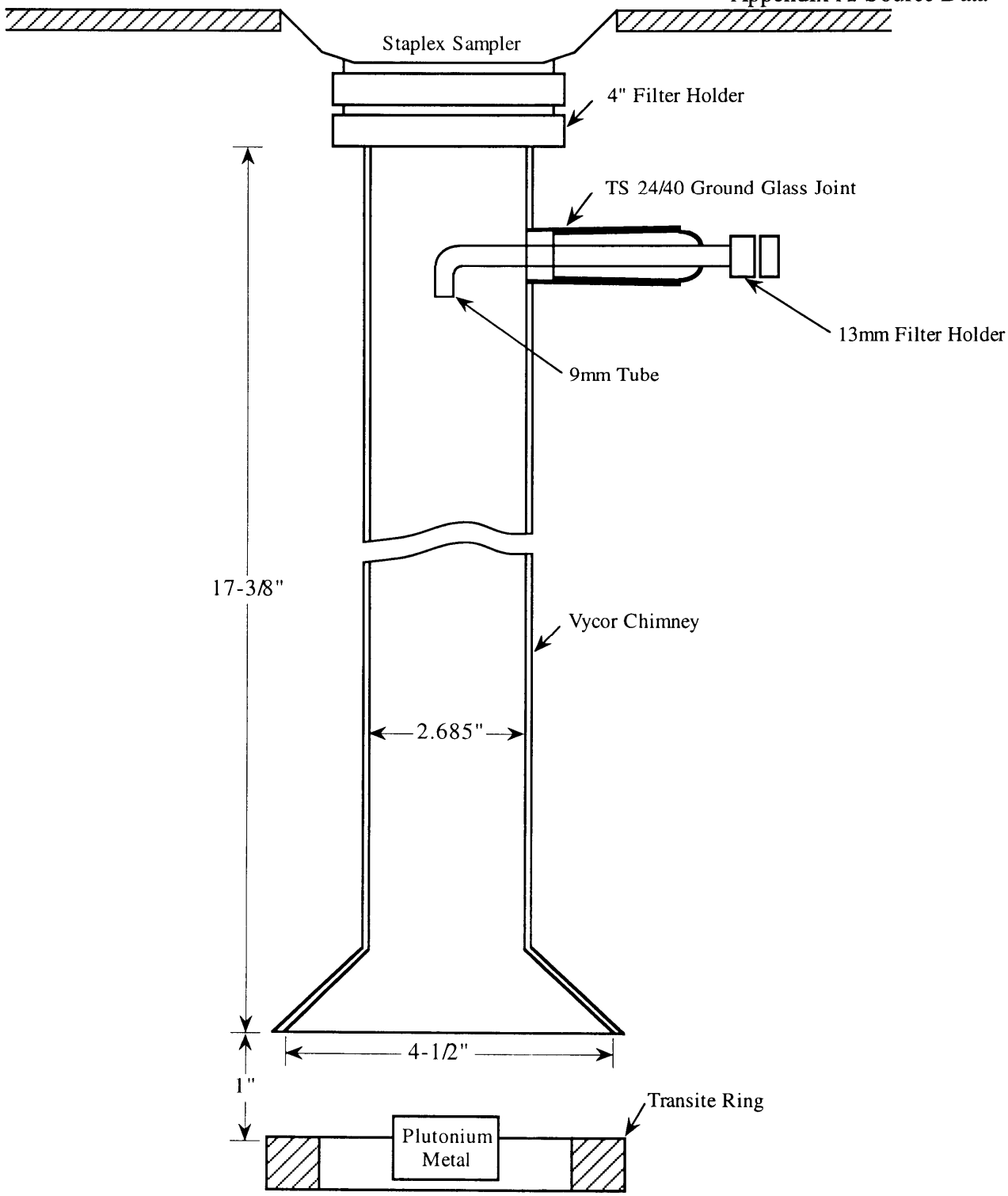


Figure A.16. Schematic Diagram Equipment for the Study of Release from ignited, Bult, Metallic Plutonium
(Figure - Mishima November 1966)

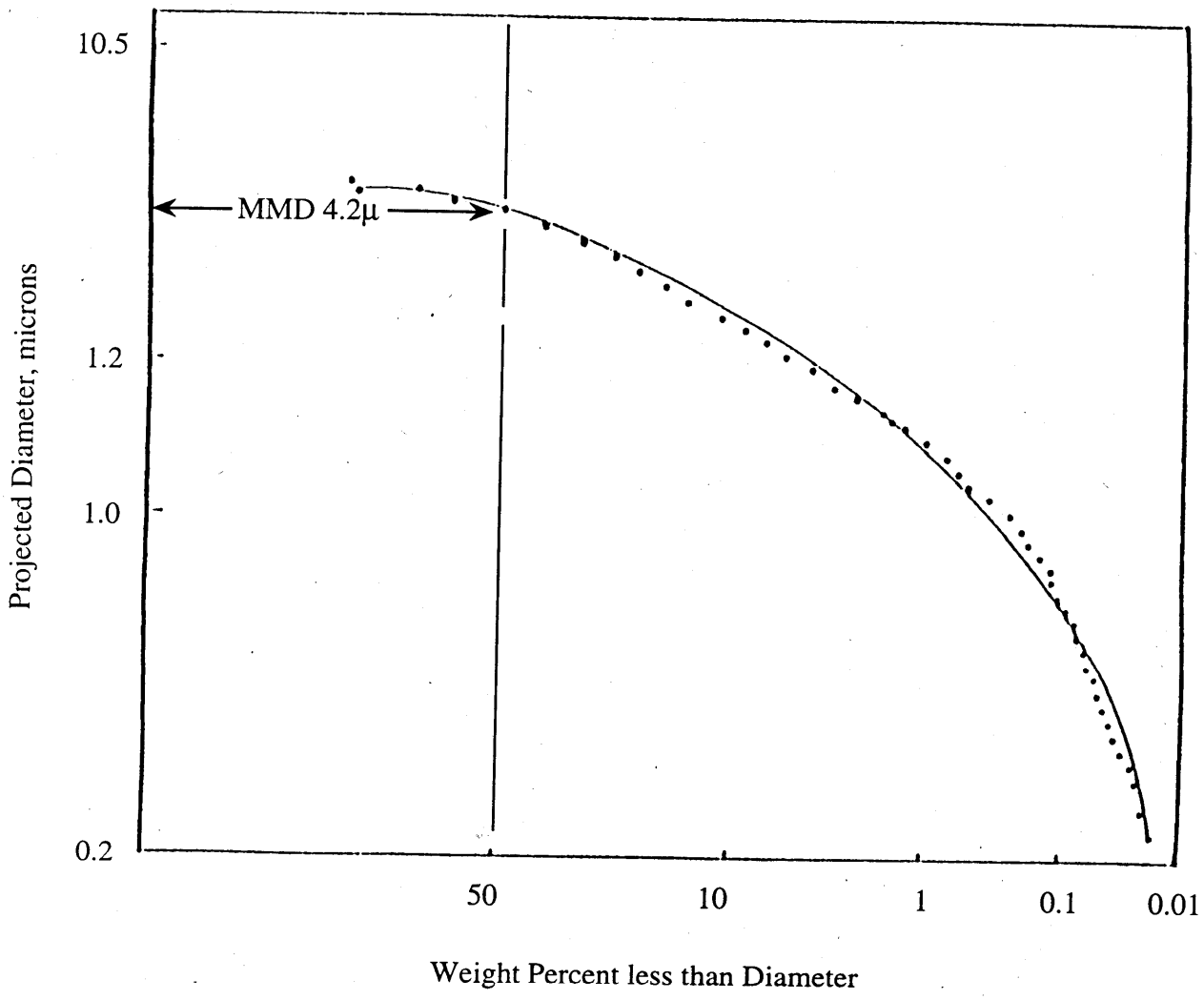


Figure A.17. Particle Size Distribution by Weight of Oxide Entrained in Run 2

(Figure 5 - Mishima November 1966)

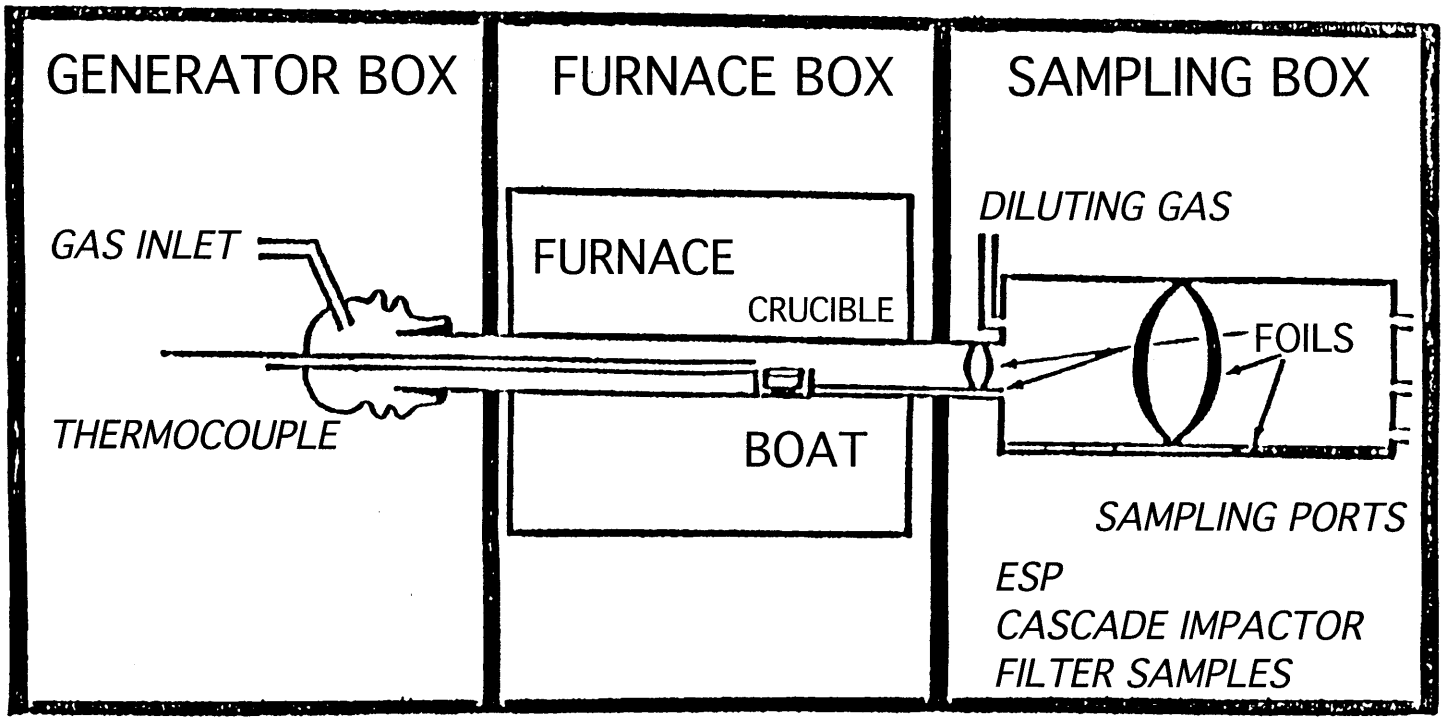


Figure A.18. The Pu reaction system ...

(Figure 1 - Eidson and Kanapilly February 1983)

The Pu reaction system is fabricated from quartz. Pu sample is placed in a tantalum crucible which is held in a boat for handling purposes. After the Pu sample is placed in the reaction system, the entire system is flushed with Ar and brought to the desired temperature in Ar atmosphere. After temperature equilibium is attained, the desired gaseous atmosphere is introduced and sampling initiated.

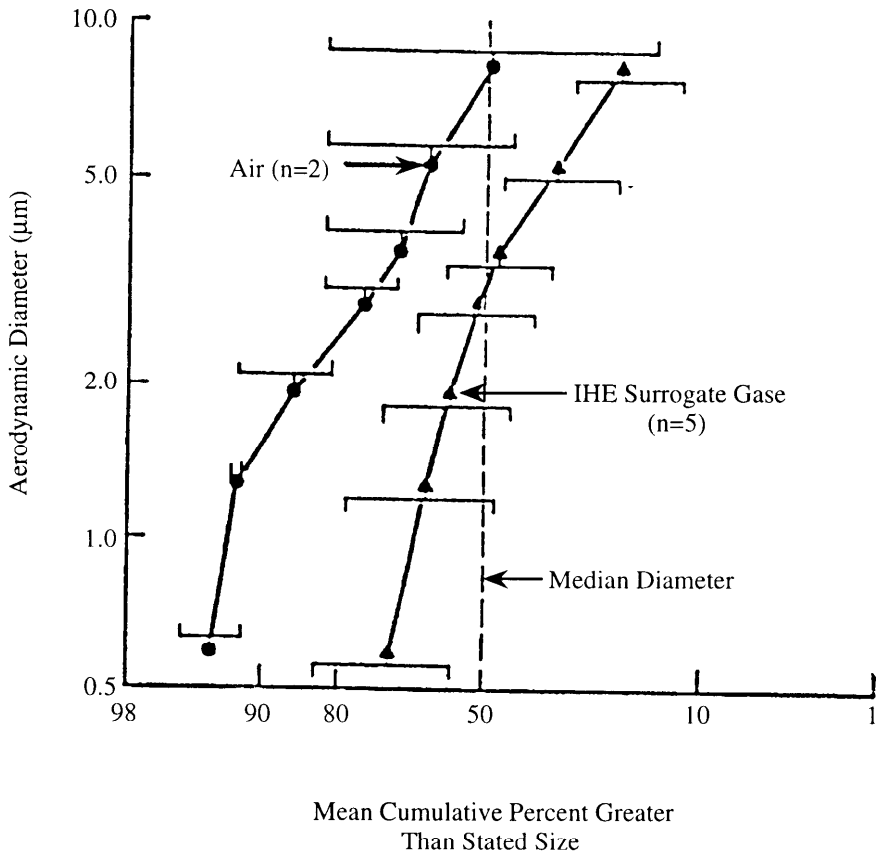


Figure A.19. Particle Size Distribution of Pu Aerosol From Combustion in Air and Surrogate IHE Gas

(Figure 3 - Eidson and Kanapilly February 1983)

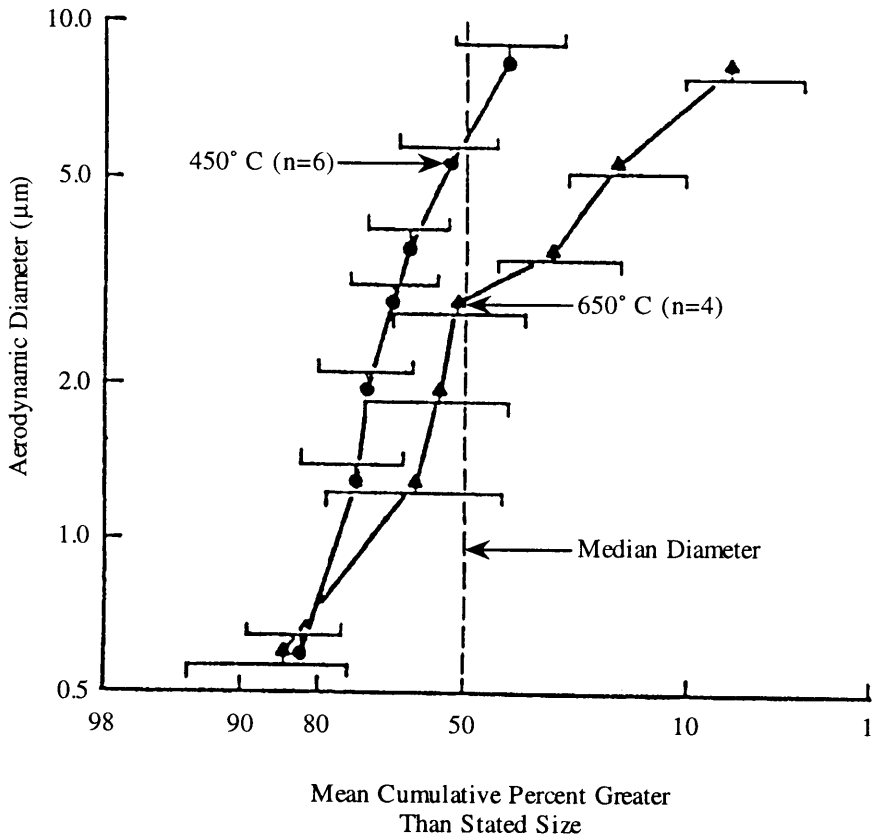
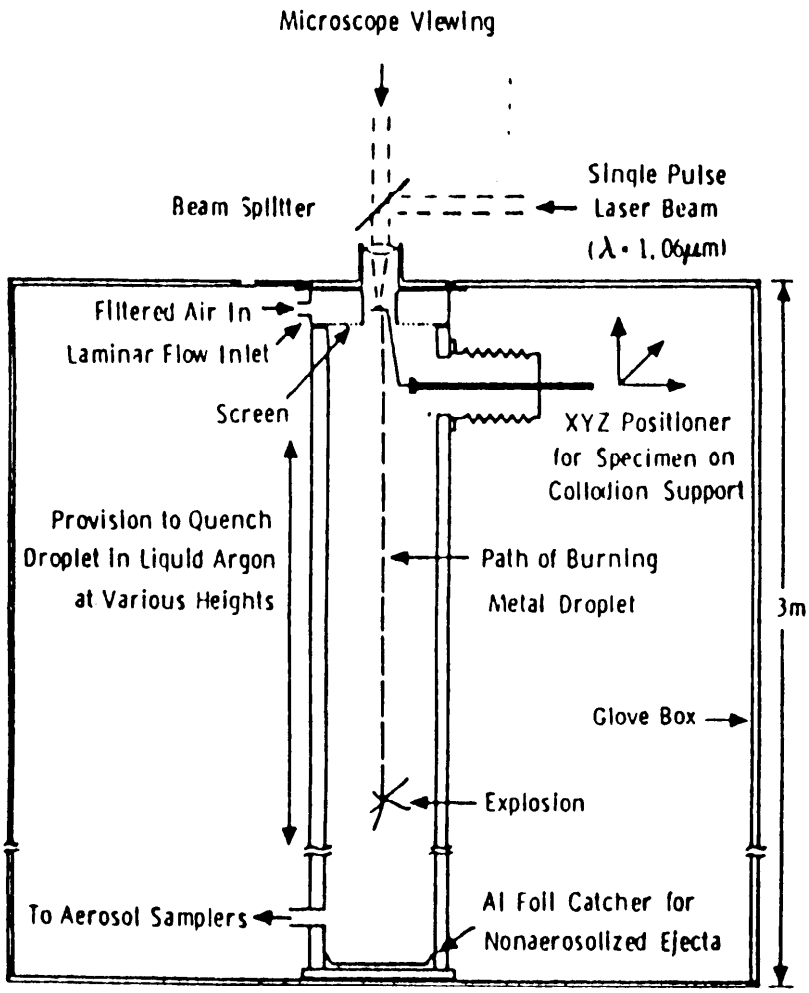


Figure A.20. Particle Size Distribution of Pu Aerosol From Combustion at 450° C and 650° C

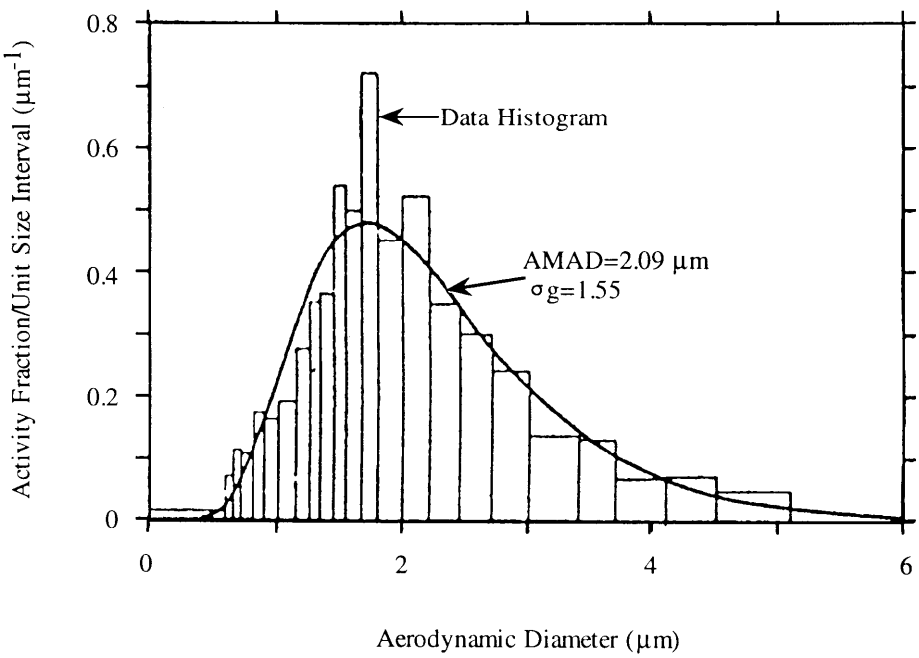
(Figure 4 - Eidson and Kanapilly February 1983)



Schematic drawing of the apparatus used in this study of the combustion of single droplets of plutonium in free fall in air.

Figure A.21. Schematic Drawing of the Apparatus Used ...

(Figure 1 - Raabe et al. November 1978)



Aerosol data with fitted log-normal distribution function for a sample collected with the spiral duct aerosol centrifuge of plutonium oxide fume aerosol from a burning plutonium droplet 400µm in dia. with the probability density of the distribution plotted vs. the aerodynamic diameter and showing the activity median aerodynamic diameter (AMAD).

Figure A.22. Aerosol Data with Fitted Log-Normal ...

(Figure 6 - Raabe et al. November 1978)

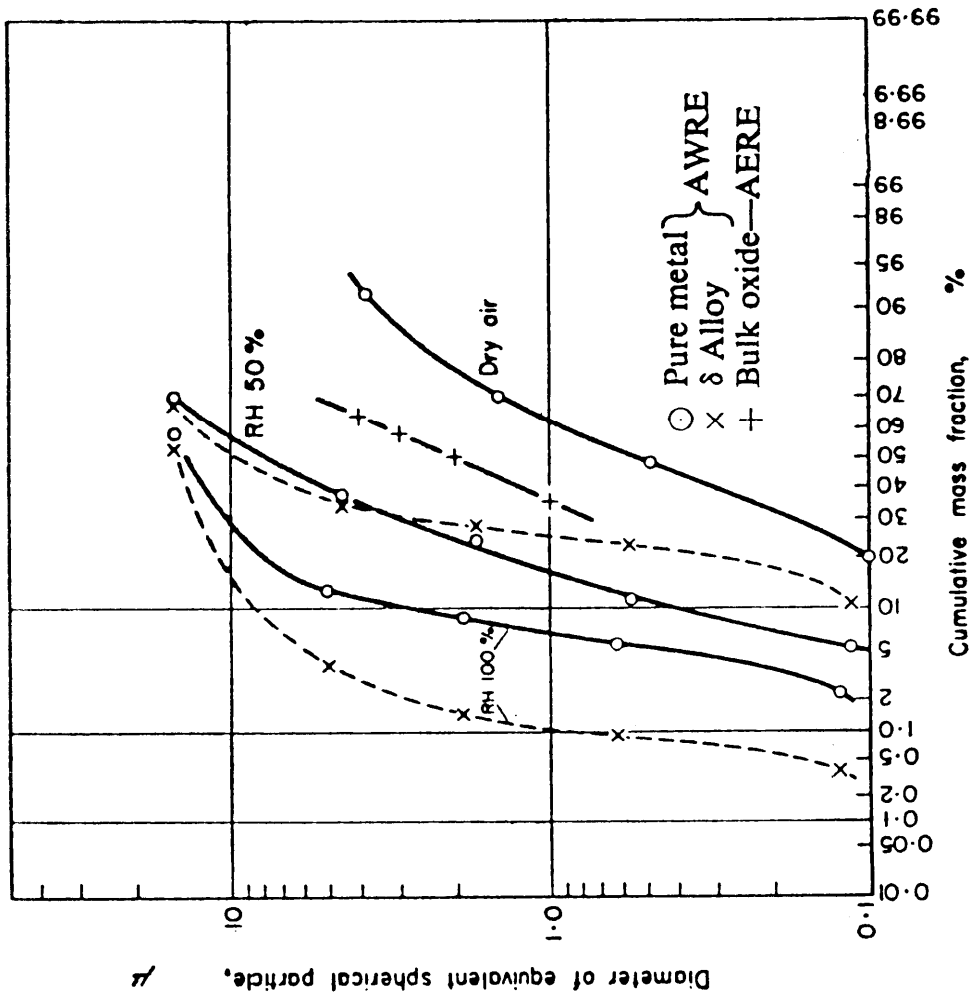
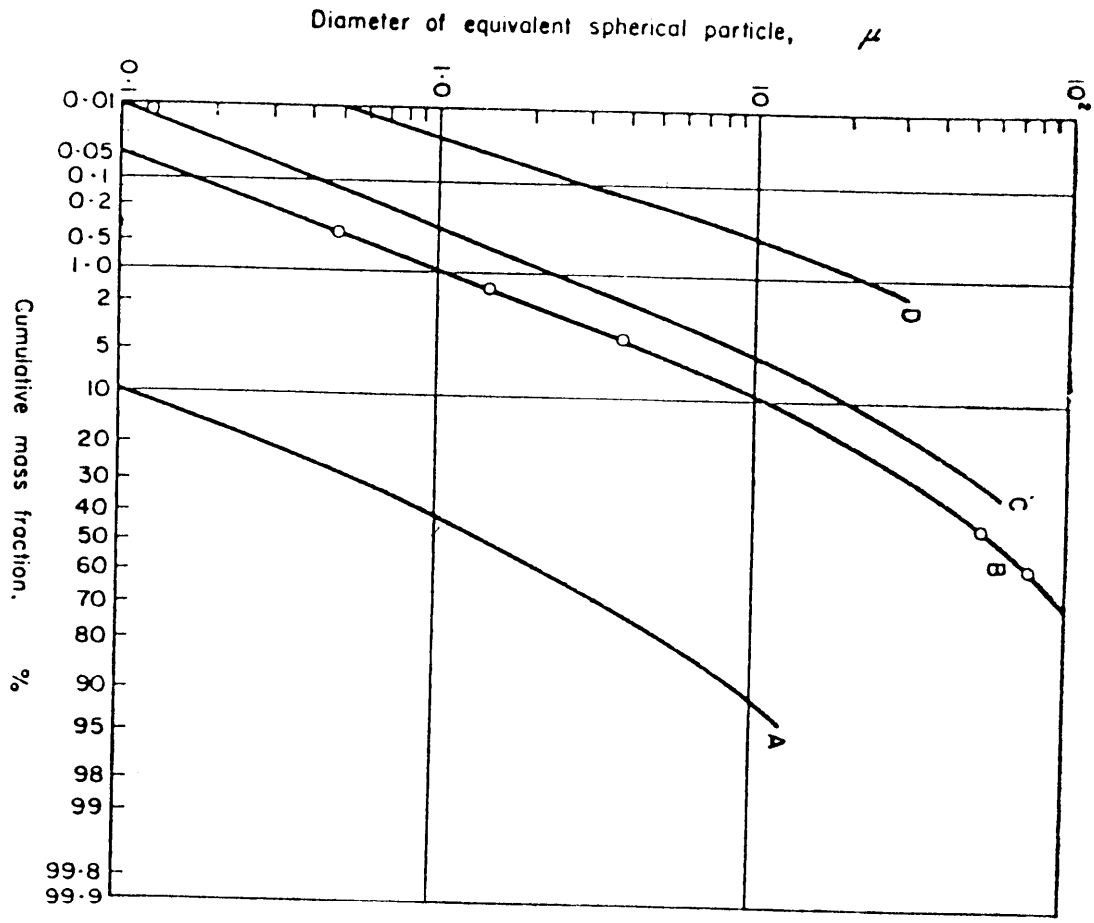


Figure A.23. Oxidation of Plutonium at Room Temperature. Size Distributions of Particulate Oxide Entrained in the Airstream

(Figure 2 - Stewart 1963)



Curve A Material airborne under static conditions at all temperatures in air
B Oxide formed at 123°C from δ stabilized alloy
C Oxide formed at 400°C to 500°C
D Oxide formed above Ignition Point

Figure A.24. Particle Size Distributions Produced by Oxidation of Plutonium Under a Variety of Conditions

(Figure 12 - Stewart 1963)

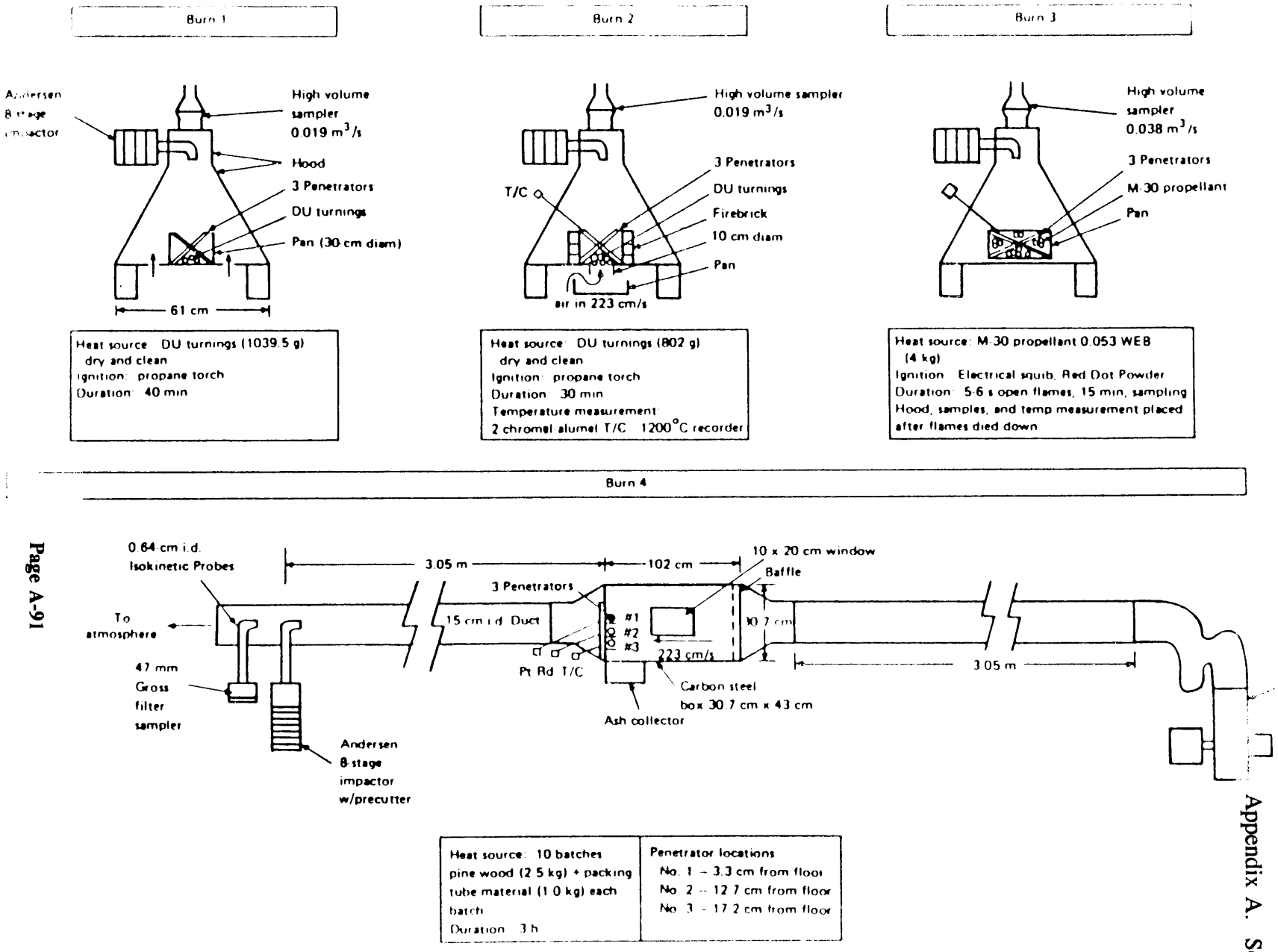


Figure A.25. Summary of Outdoor Burning Experiments, General Layout

(Figure 2 - Elder and Tinkle December 1980)

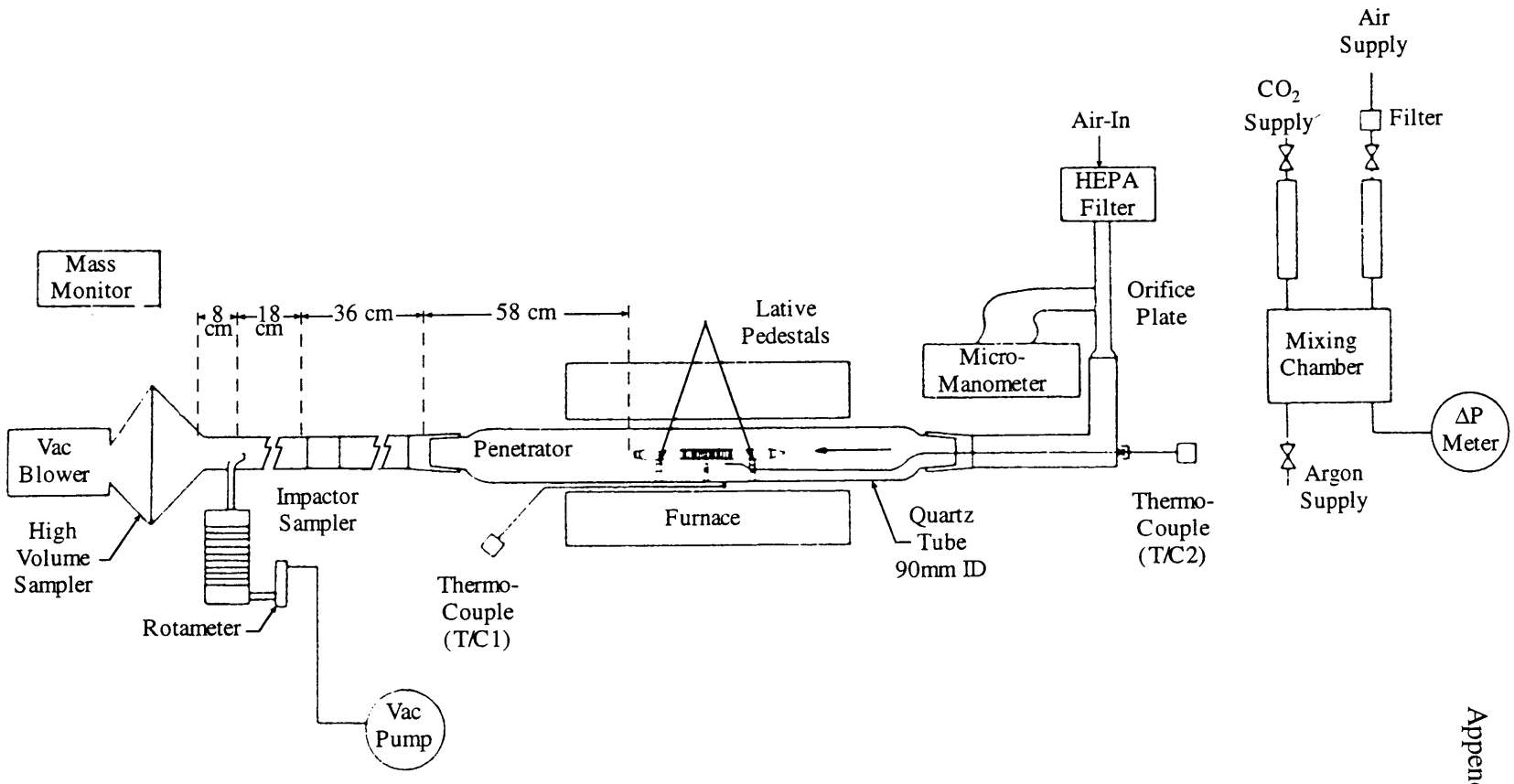


Figure A.26. Laboratory Experimental Apparatus

(Figure 6 - Elder and Tinkle December 1980)

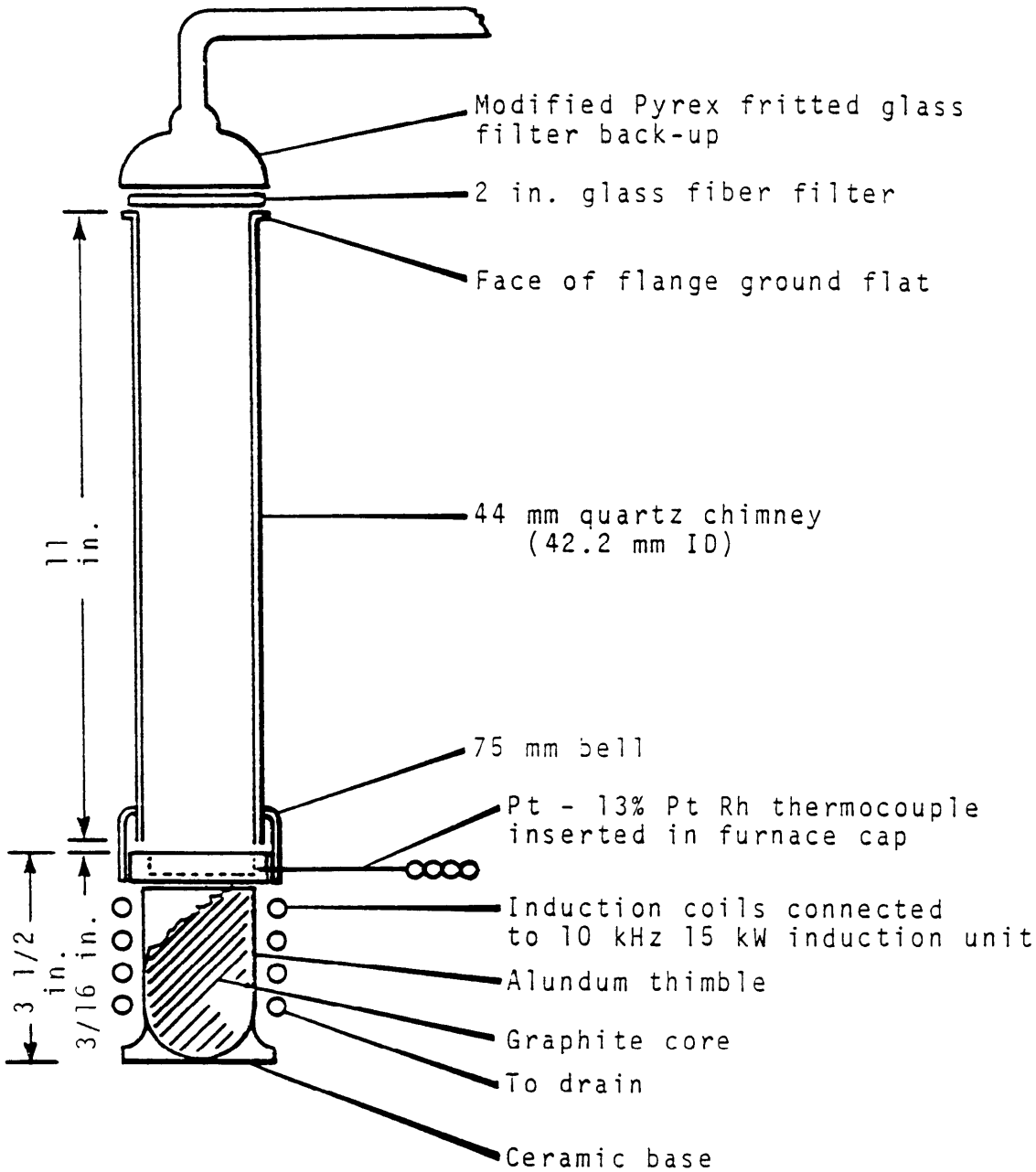


Figure A.27a. Apparatus for Measurement of Release Rates of Overheated Plutonium Powders

(Figure 2 - Mishima, Schwendiman and Radasch July 1968)

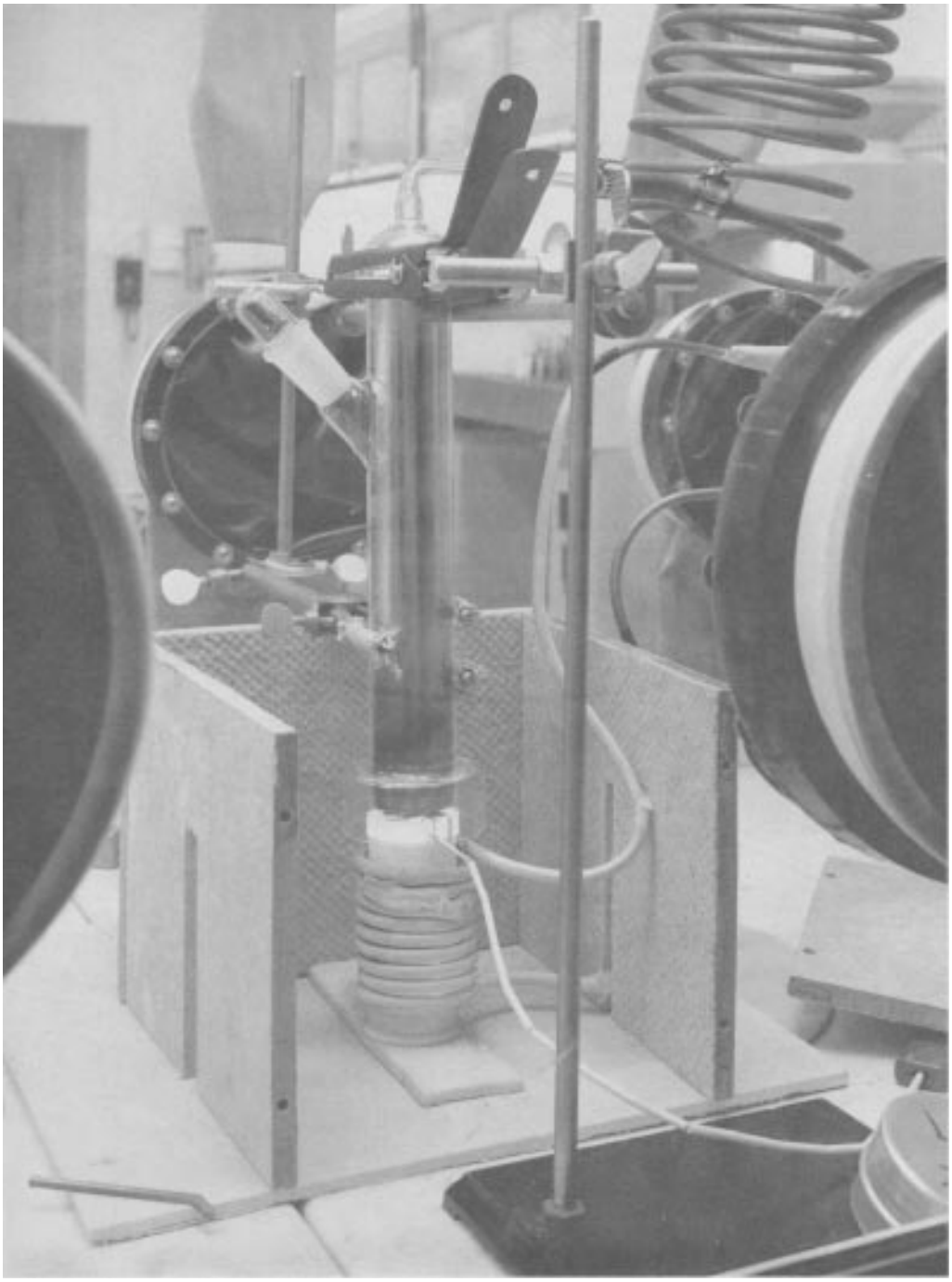


Figure A.27b. Release Rate Apparatus

(Figure 1 - Mishima, Schwendiman and Radasch July 1968)

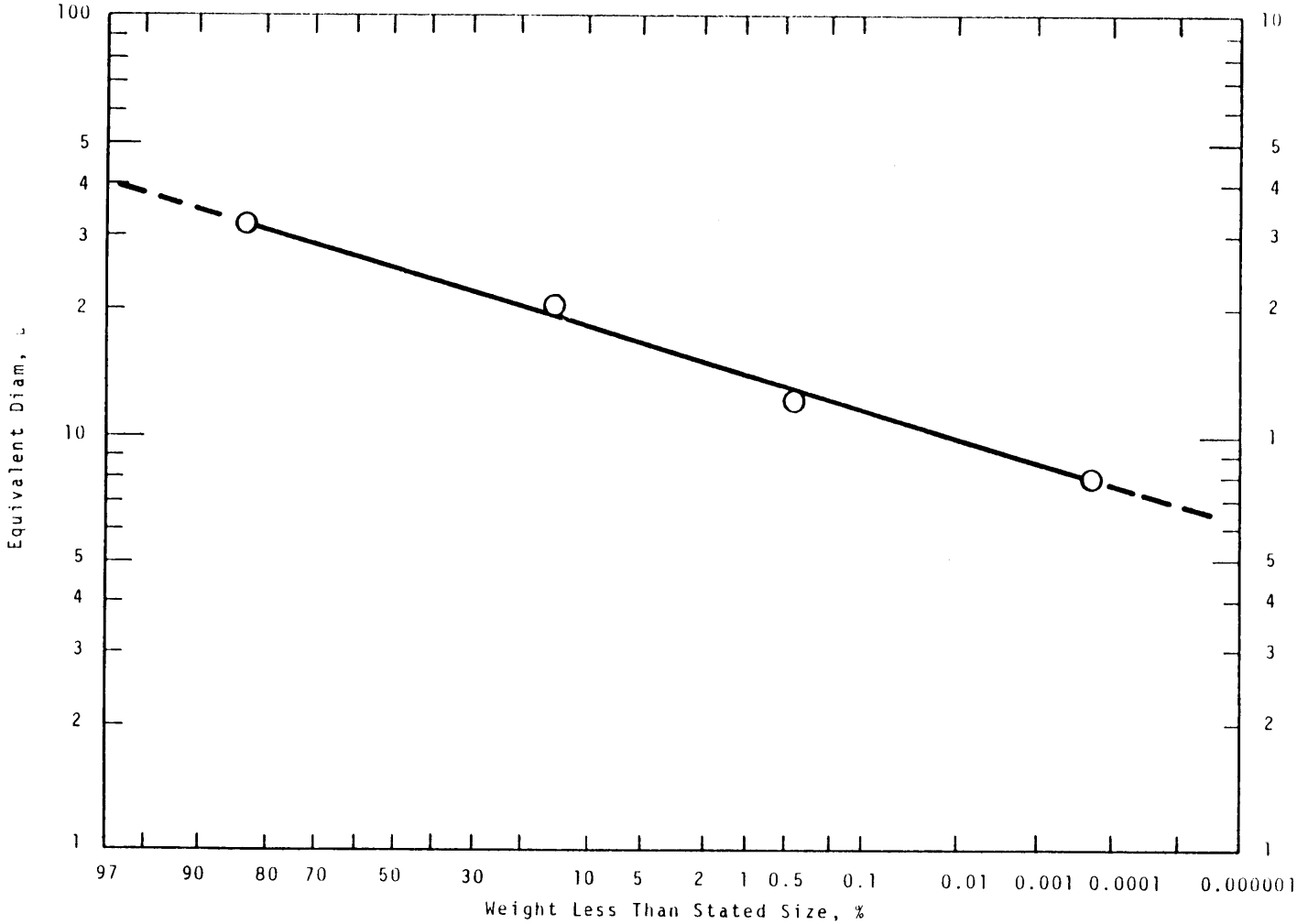


Figure A.28. Distribution of Particles Entrained in Air with a Velocity of 100 cm/sec from Plutonium Oxalate-Oxide Mixture Heated to 700° C. (1156 particles sized optically)

(Figure 9 - Mishima, Schwendiman and Radasch July 1968)

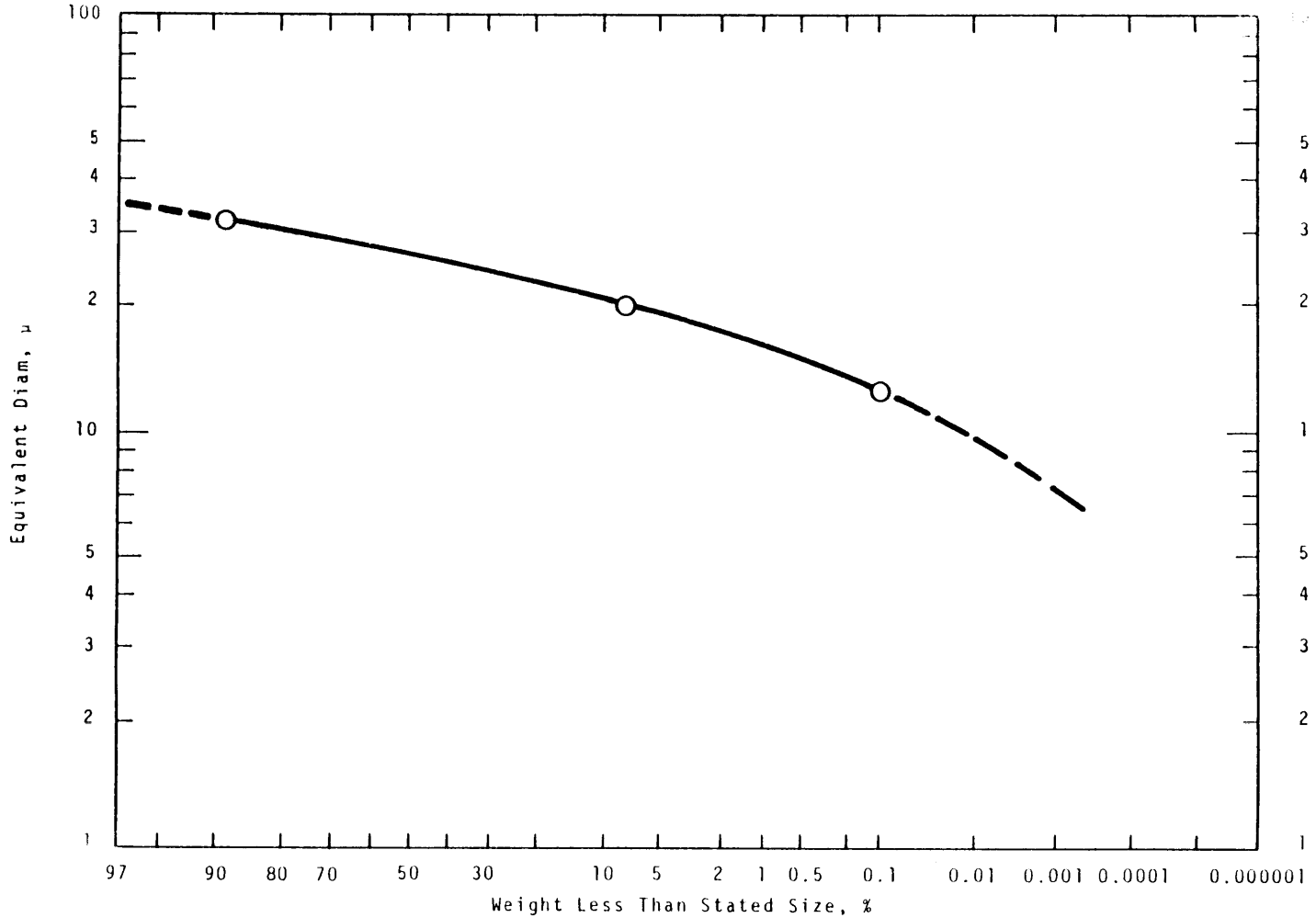


Figure A.29a. Distribution of Particles Entrained by Air with a Velocity of 100 cm/sec from Plutonium Fluoride at Ambient Temperature

(Figure 12 - Mishima, Schwendiman and Radasch July 1968)

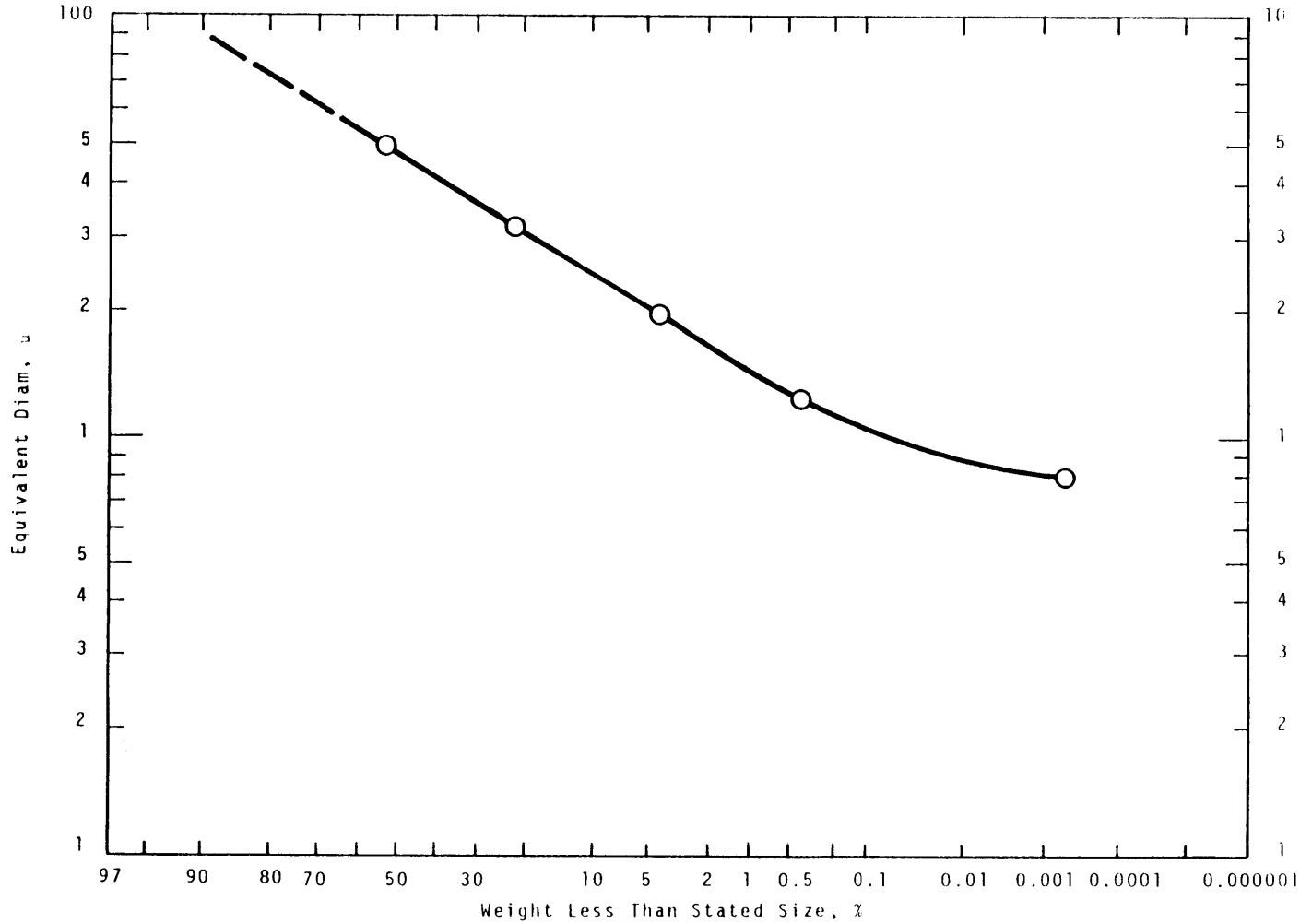


Figure A.29b. Distribution of Particles Entrained in Air with a Velocity of 100 cm/sec from Plutonium Fluoride Heated to 700°C

(Figure 13 - Mishima, Schwendiman and Radasch July 1968)

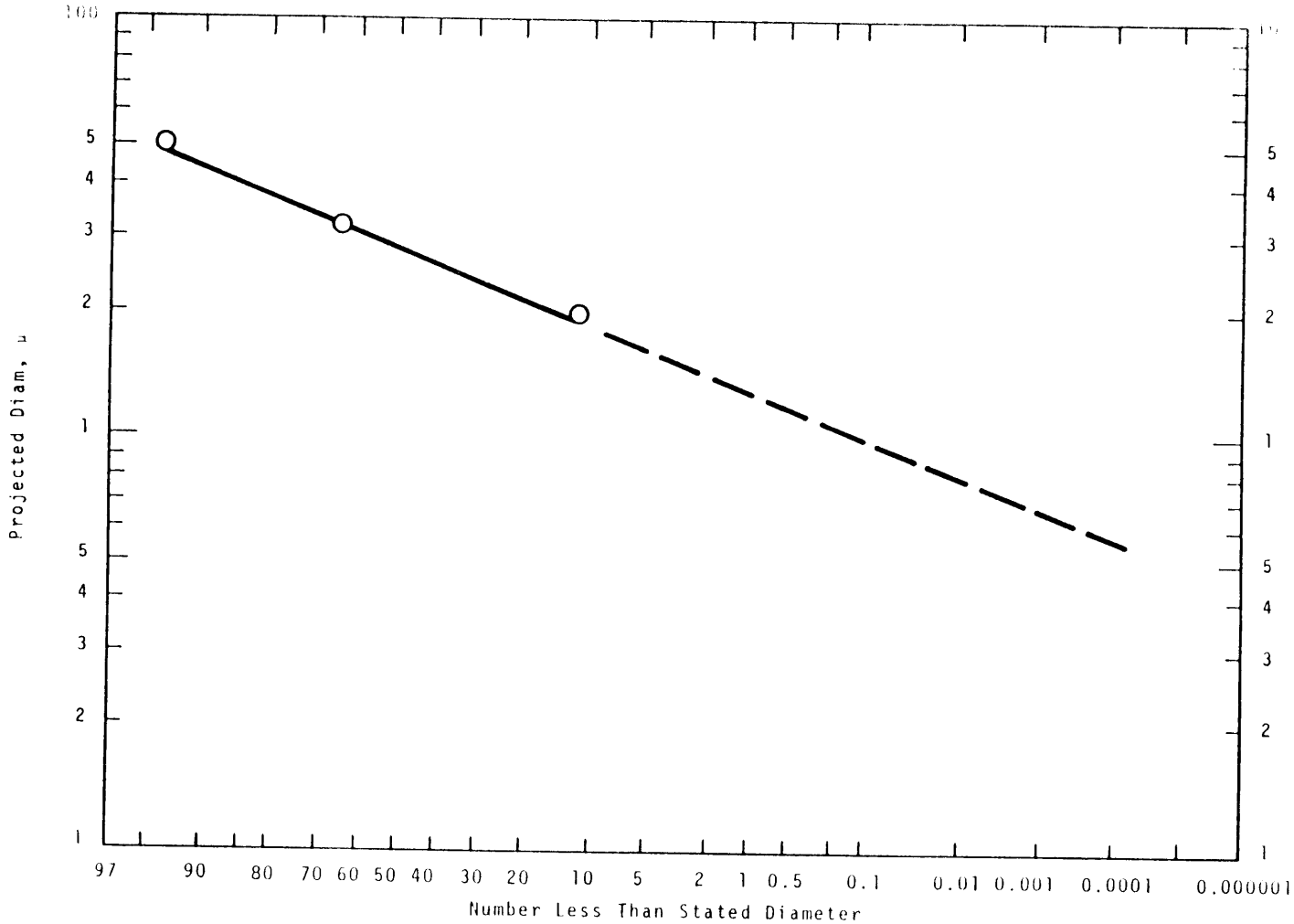


Figure A.29c. Particle Entrained in Air at 100 cm/sec from 1 g PuF_4 Powder at 1000°C (303 particles sized at 100X)

(Figure 14 - Mishima, Schwendiman and Mishima July 1968)

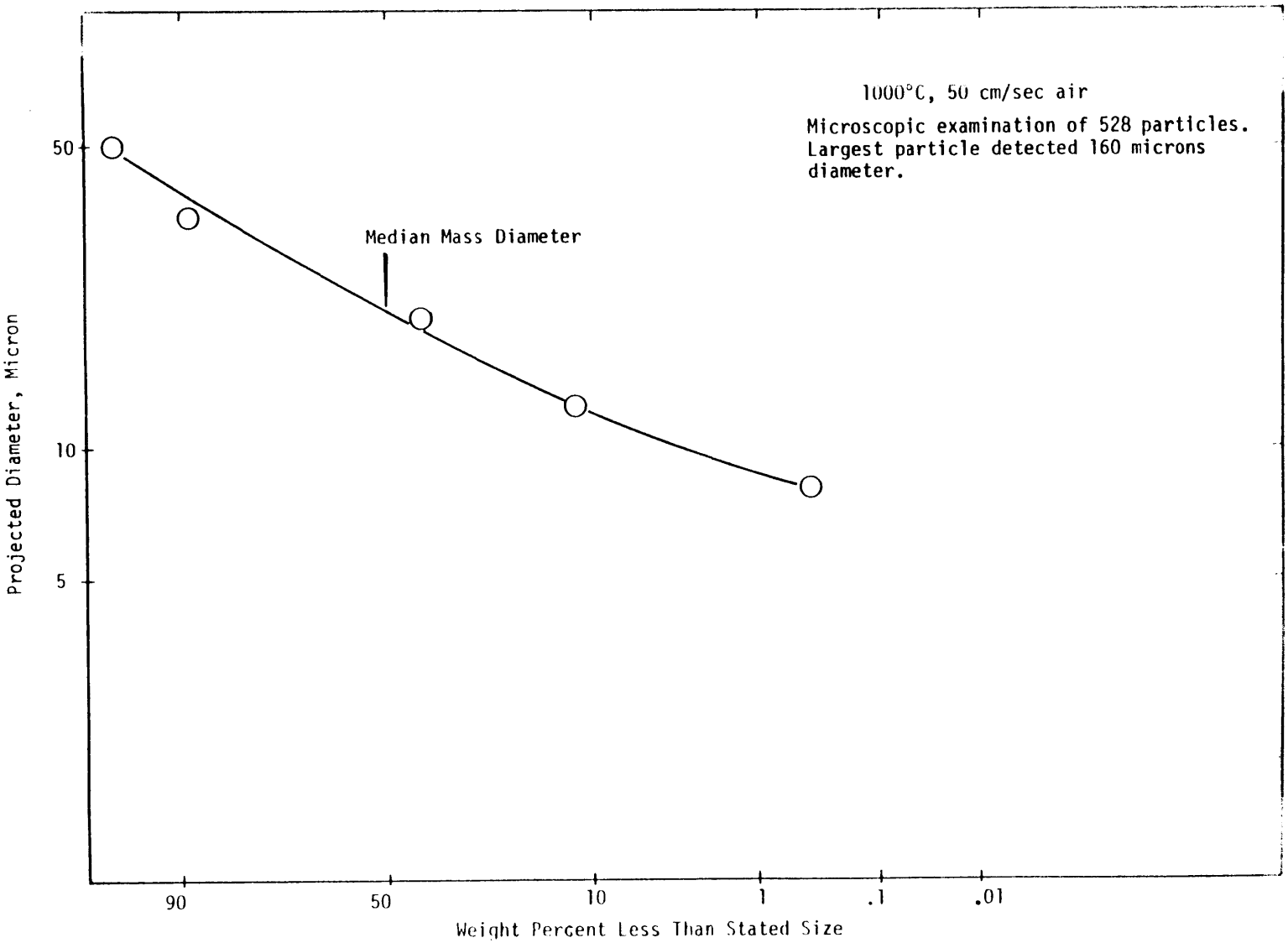


Figure A.30. Size Distribution of Particles Released During Run N-5a

(Figure 12 - Mishima, Schwendiman and Radasch November 1968)

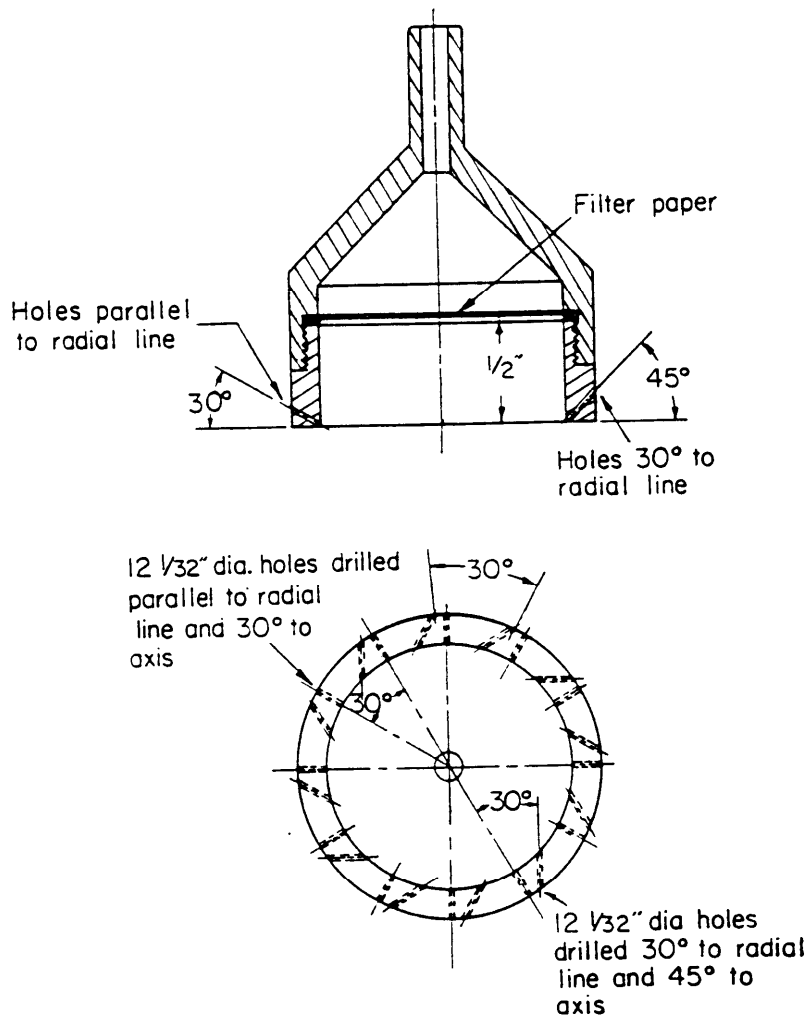


Figure A.31. Smair Sampler

(Figure 1 - Royster and Fish 1967)

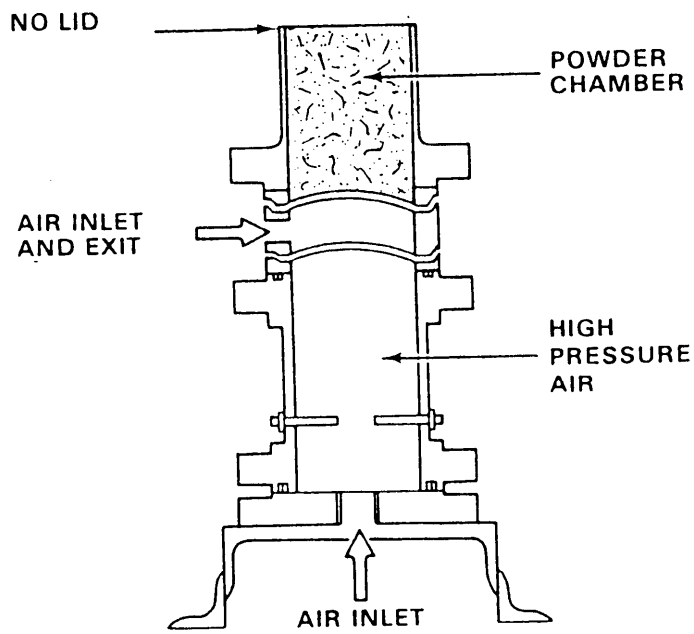


Figure A.32. PARE Modification for Powder Release Above Chamber (PRAC) Experiments

(Figure 4 - Sutter August 1983)

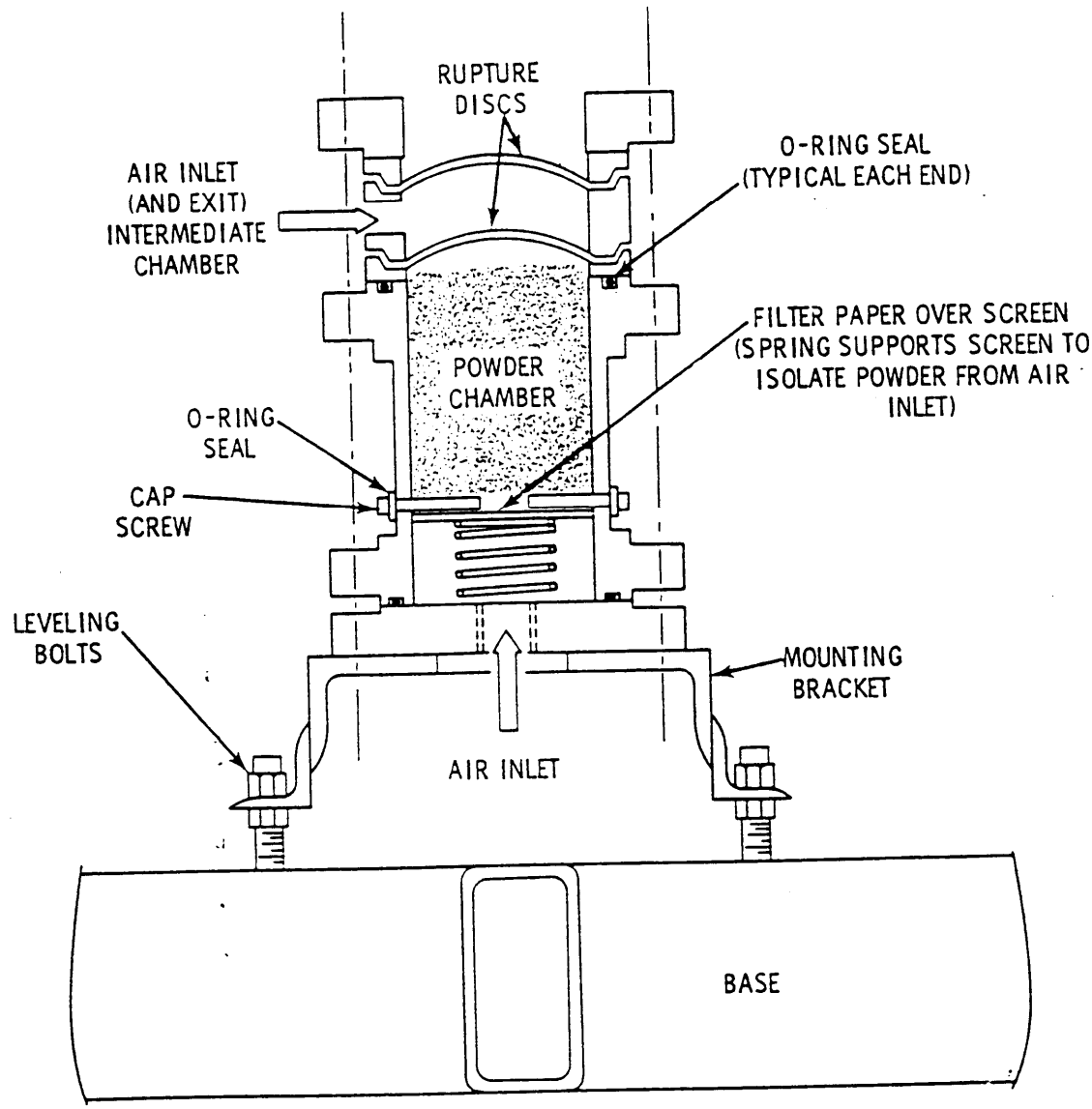


Figure A.33a. PARE, Pressurized Airborne Release Equipment

(Figure 1 - Sutter August 1983)

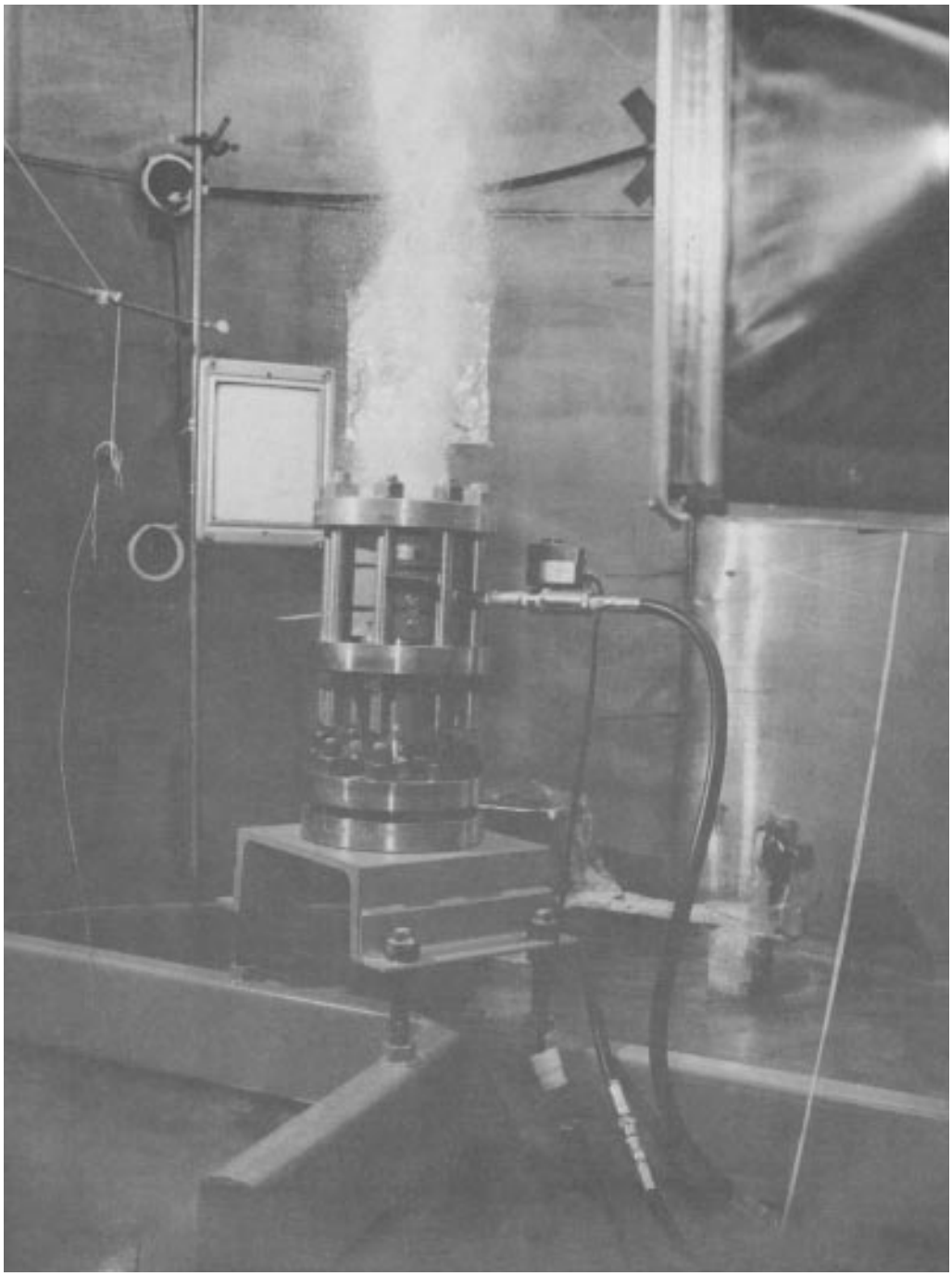


Figure A.33b. PARE Experiment

(Figure 3 - Sutter August 1983

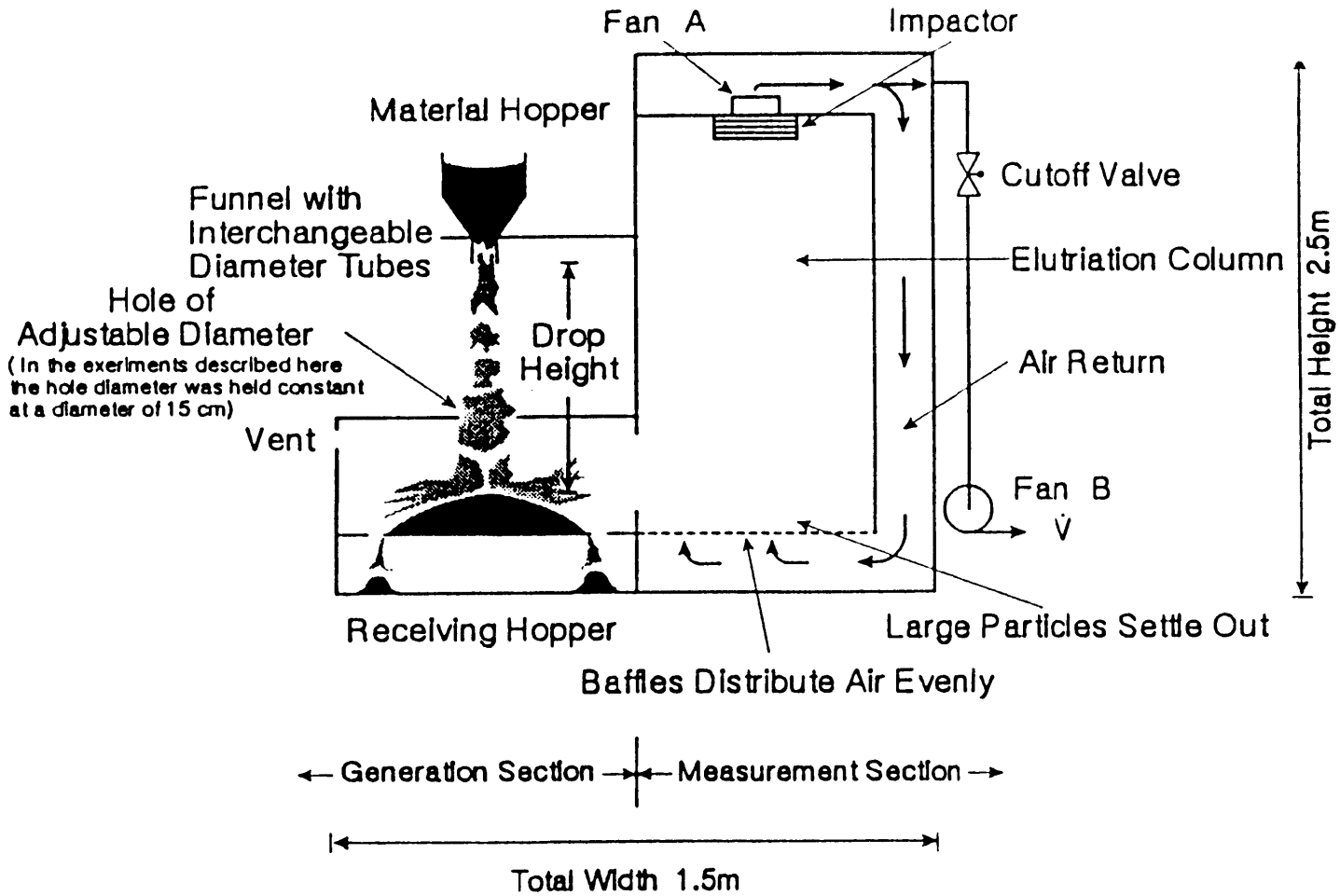


Figure A.34. Schematic Diagram of Test Apparatus

(Figure 1 - Plinke et al. 1991)

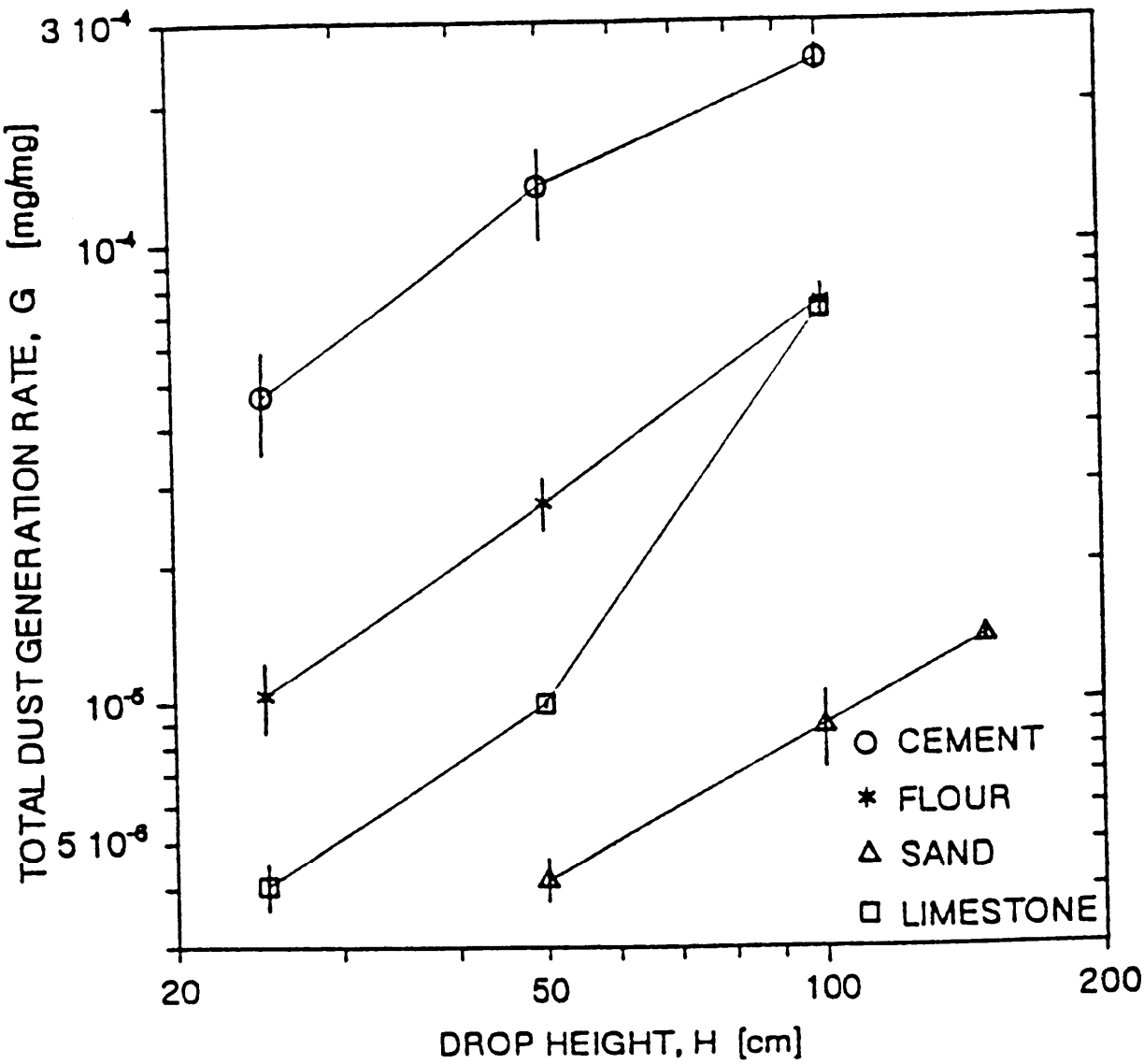


Figure A.35a. Total Dust Generation Rate with One Standard Deviation Confidence Limit versus Drop Height

(Figure 2 - Plinke et al. 1991)

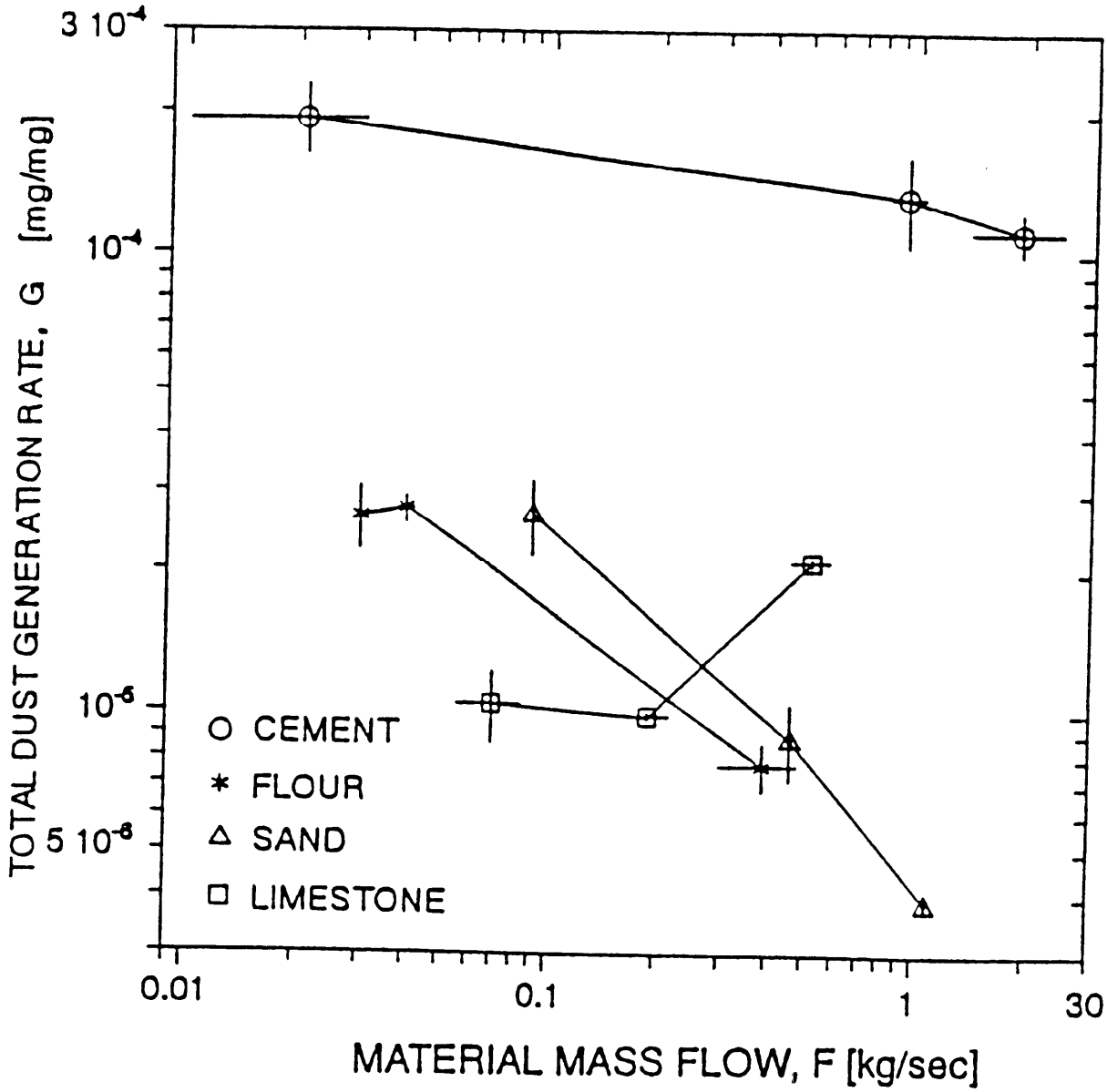


Figure A.35b. Total Dust Generation Rate versus Material Mass Flow, Each with One Standard Deviation Confidence Limit

(Figure 3 - Plinke et al. 1991)

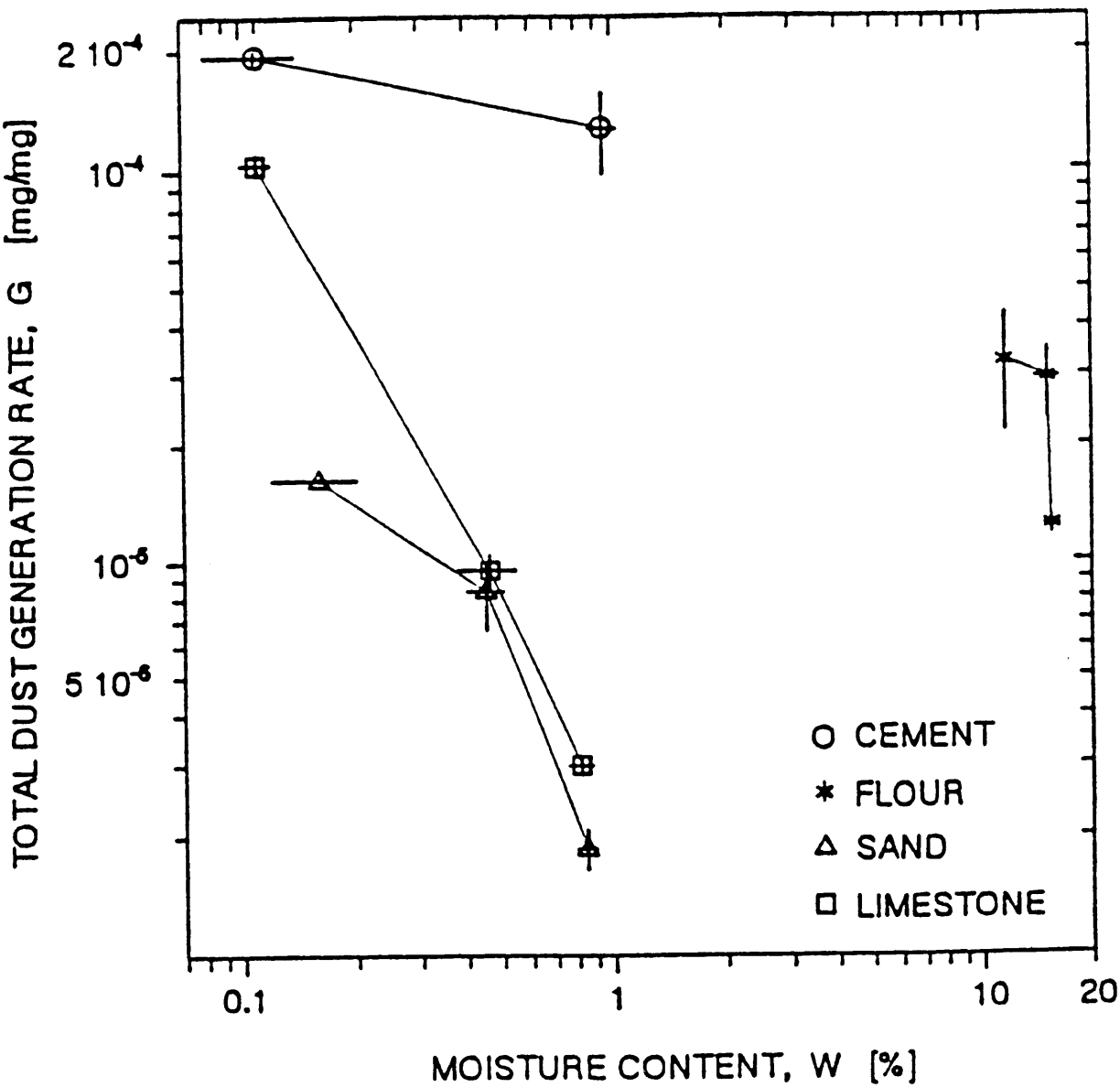


Figure A.35c. Total Dust Generation Rate versus Moisture Content, Each with One Standard Deviation Confidence Limit

(Figure 4 - Plinke et al. 1991)

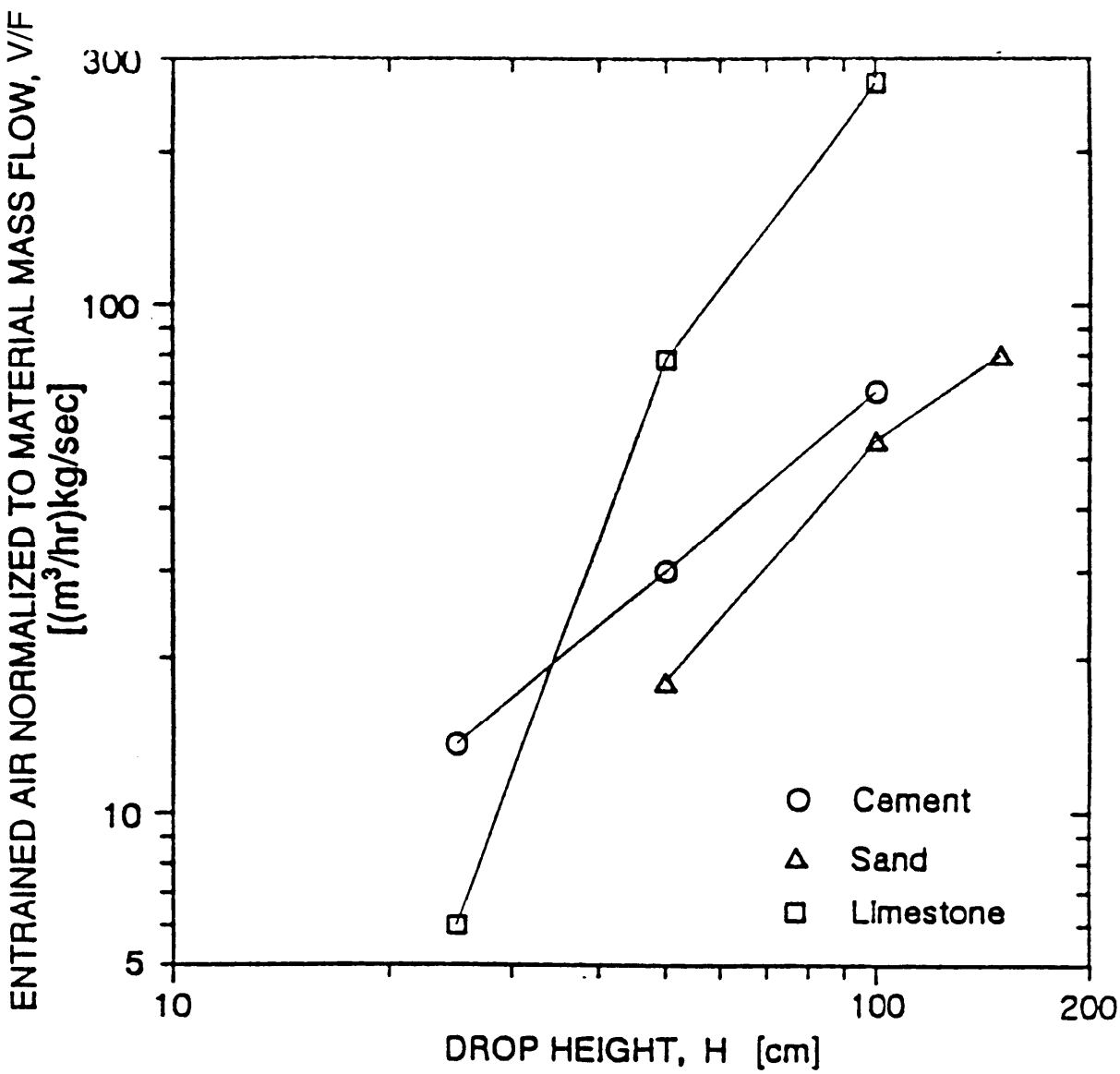


Figure A.35d. Entrained Air Normalized to Material Mass Flow versus Drop Height

(Figure 5 - Plinke et al. 1991)

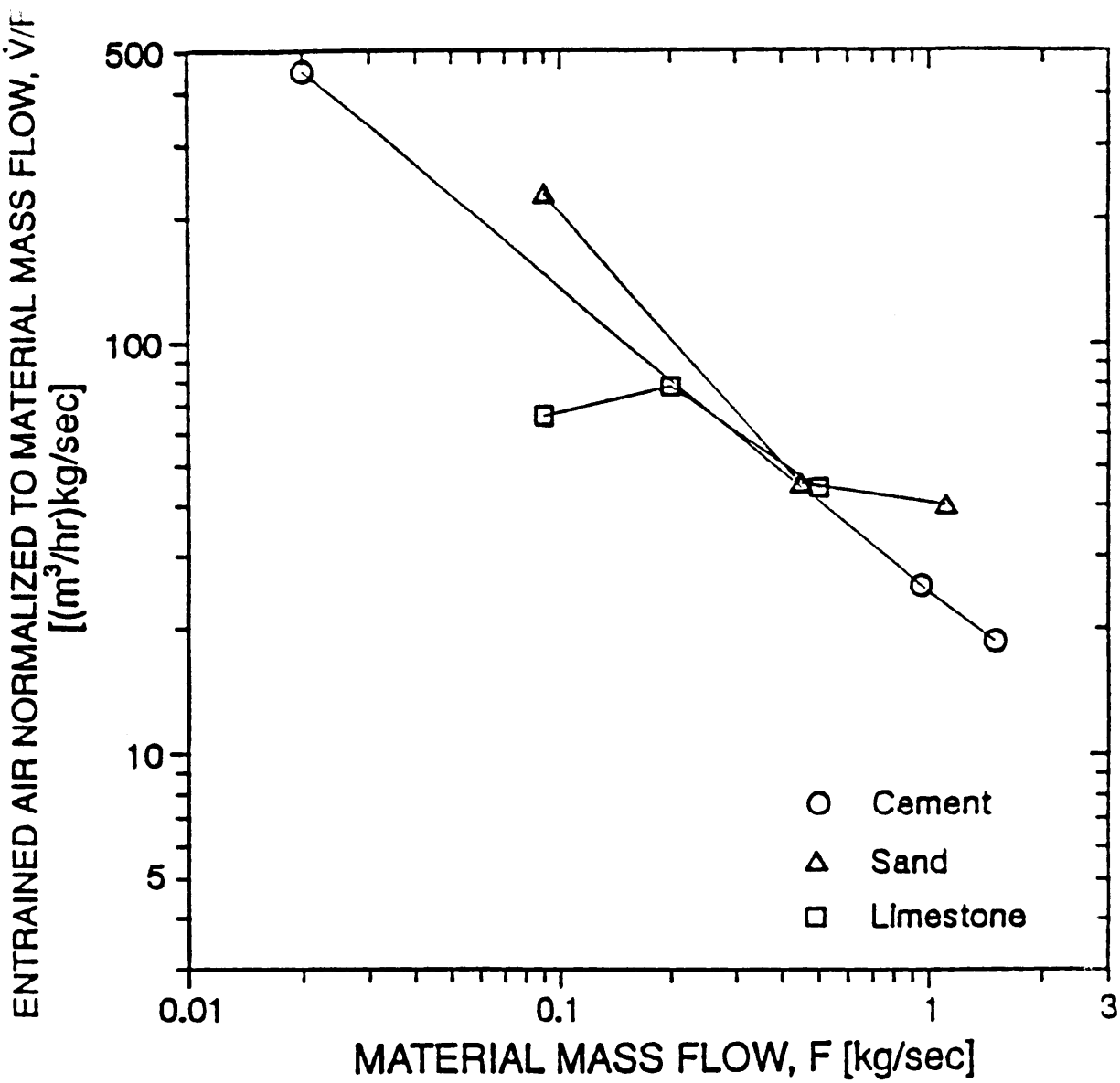


Figure A.35e. Entrained Air Normalized to Material Mass Flow versus Material Mass Flow

(Figure 6 - Plinke et al. 1991)

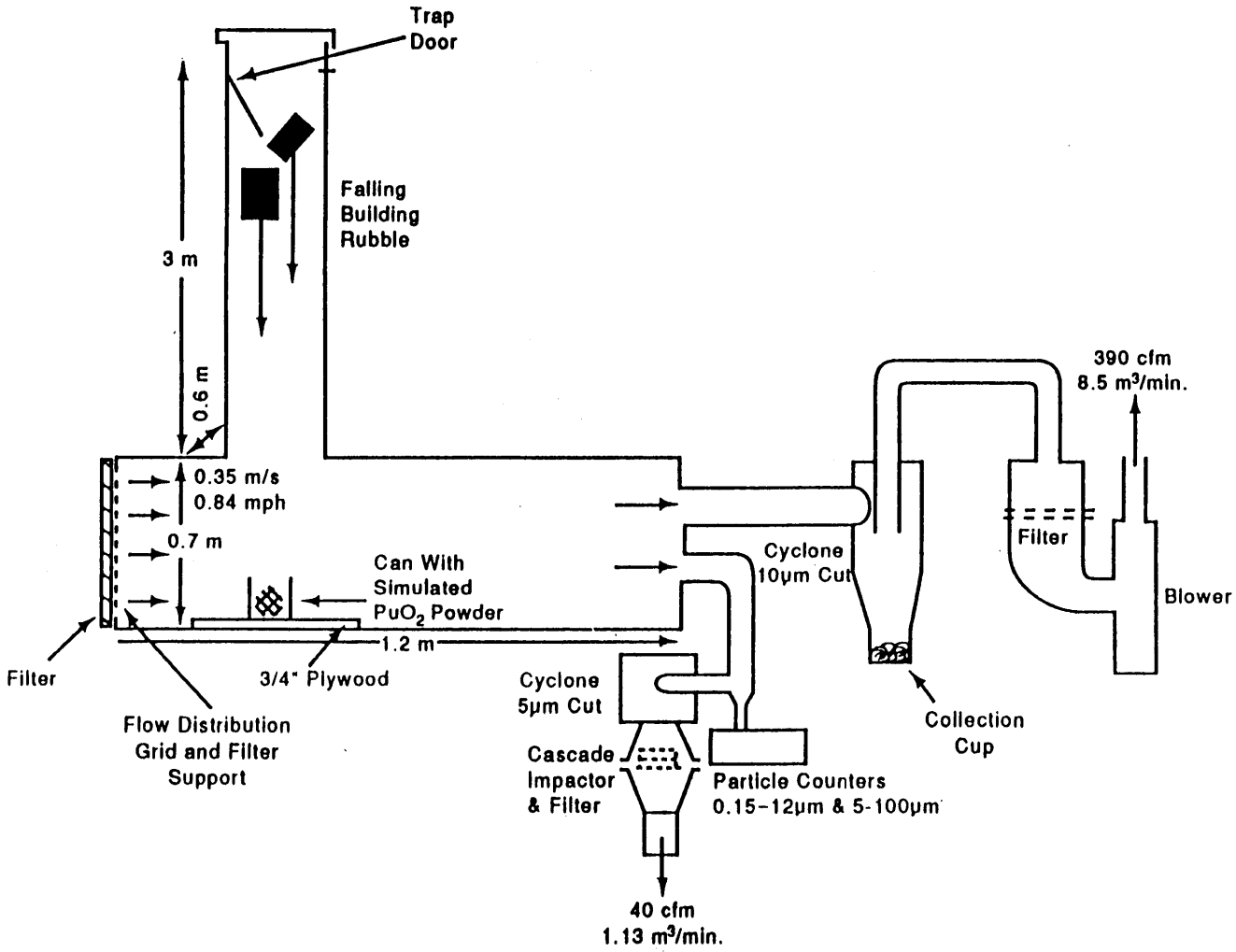


Figure A.36. Schematic of Facility to Simulate Aerosol Generation During Building Collapse

(Figure 1 - Langer November 1987)

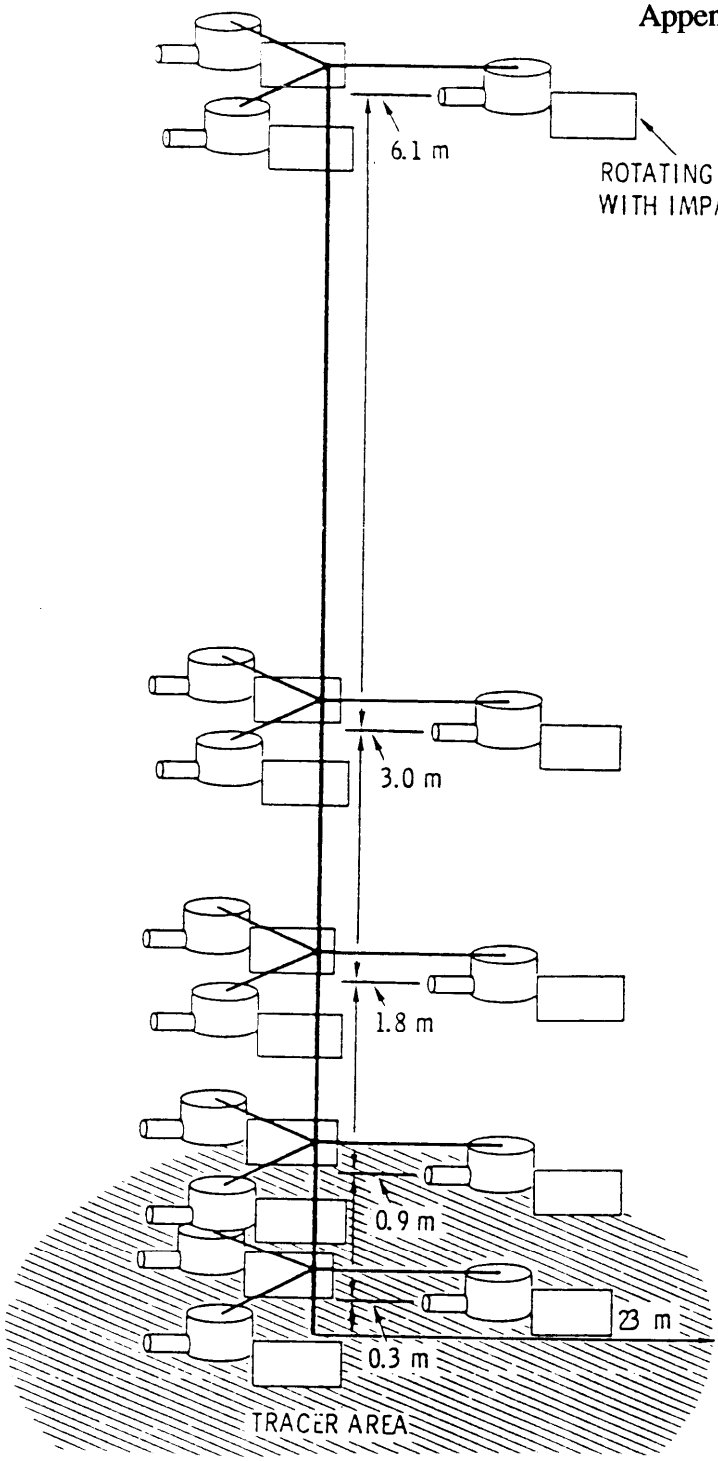


Figure A.37a. Tracer Source and Resuspension Sampling Tower

(Figure 2 - Sehmel and Lloyd 1976)

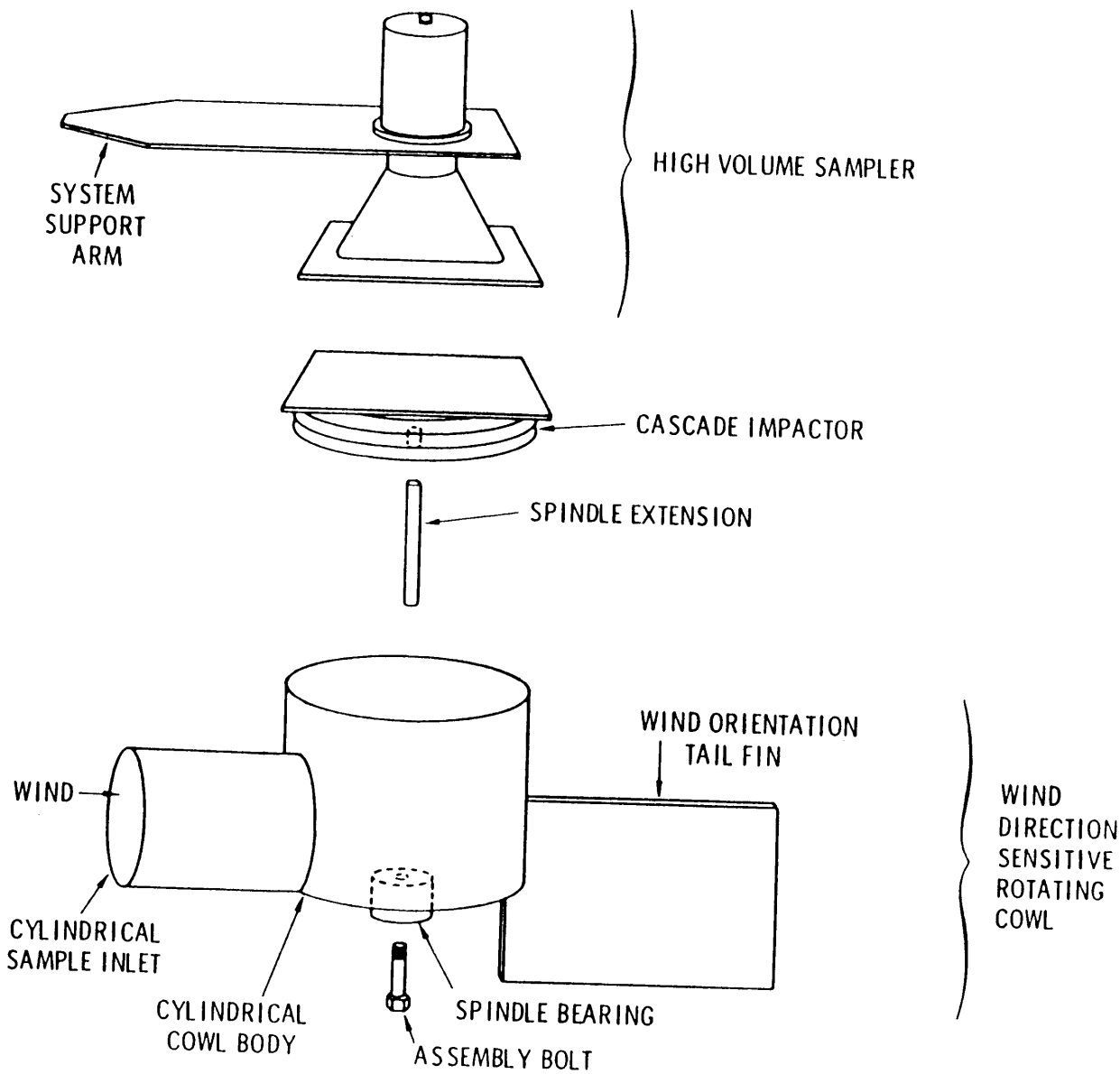


Figure A.37b. Rotating Cowl and Impactor

(Figure 1 - Sehmel and Lloyd 1976)

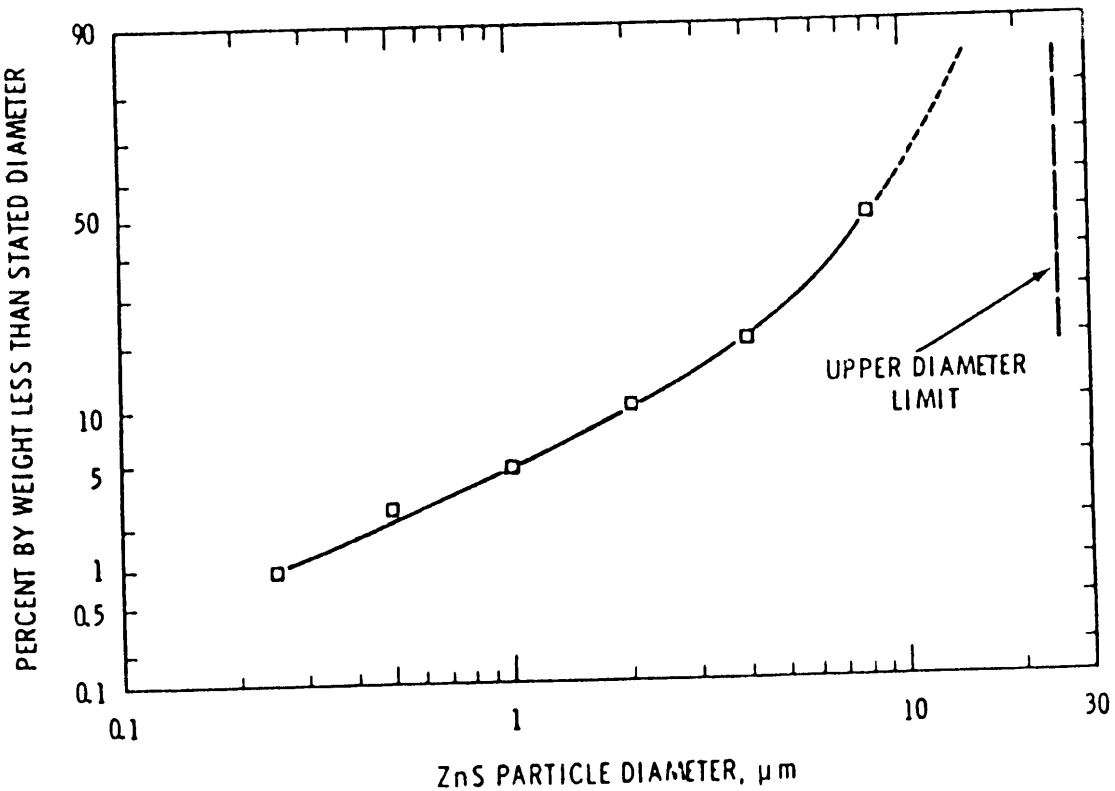


Figure A.38a. ZnS Particle Size Distribution as Disbursed onto Road

(Figure 2 - Sehmel 1976)

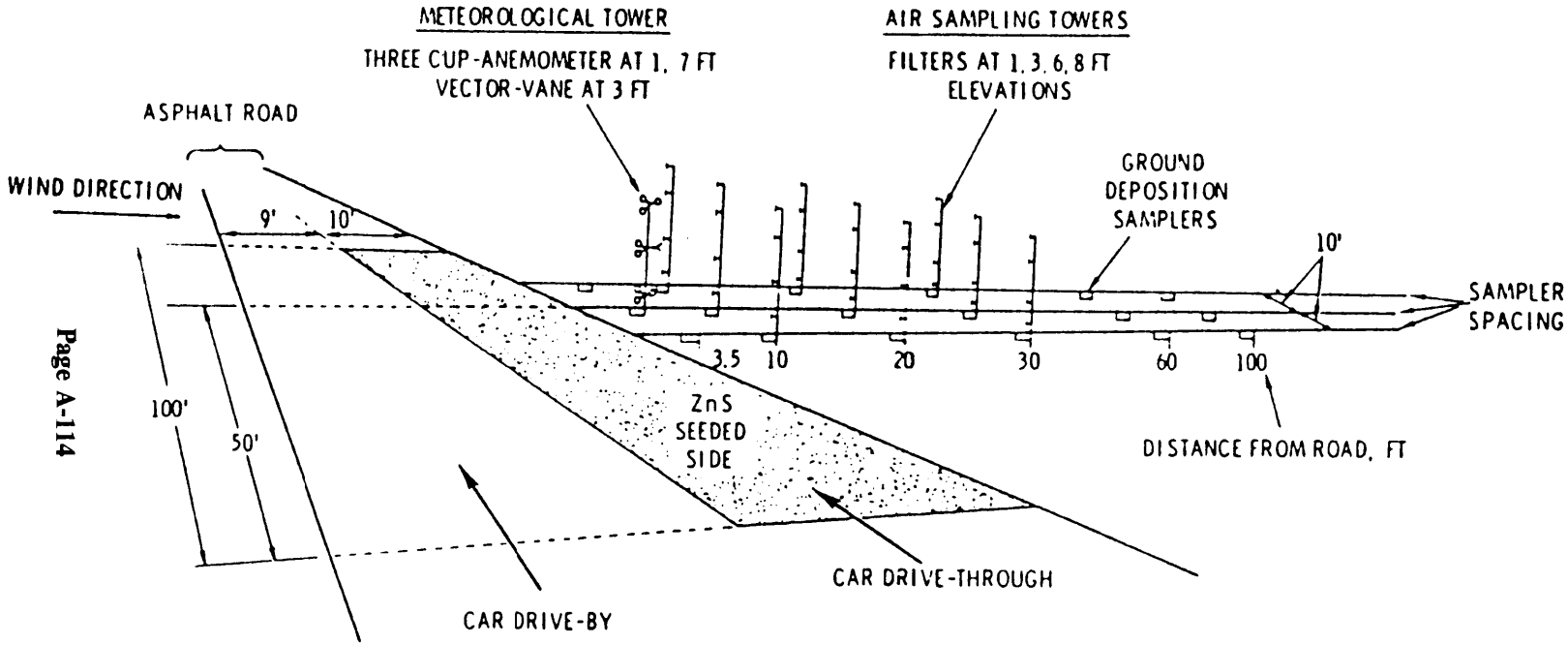


Figure A.38b. Schematic Showing Experimental Design for Particle Resuspension from an Asphalt Road Caused by Vehicle Passage

(Figure 1 - Sehmel 1976)

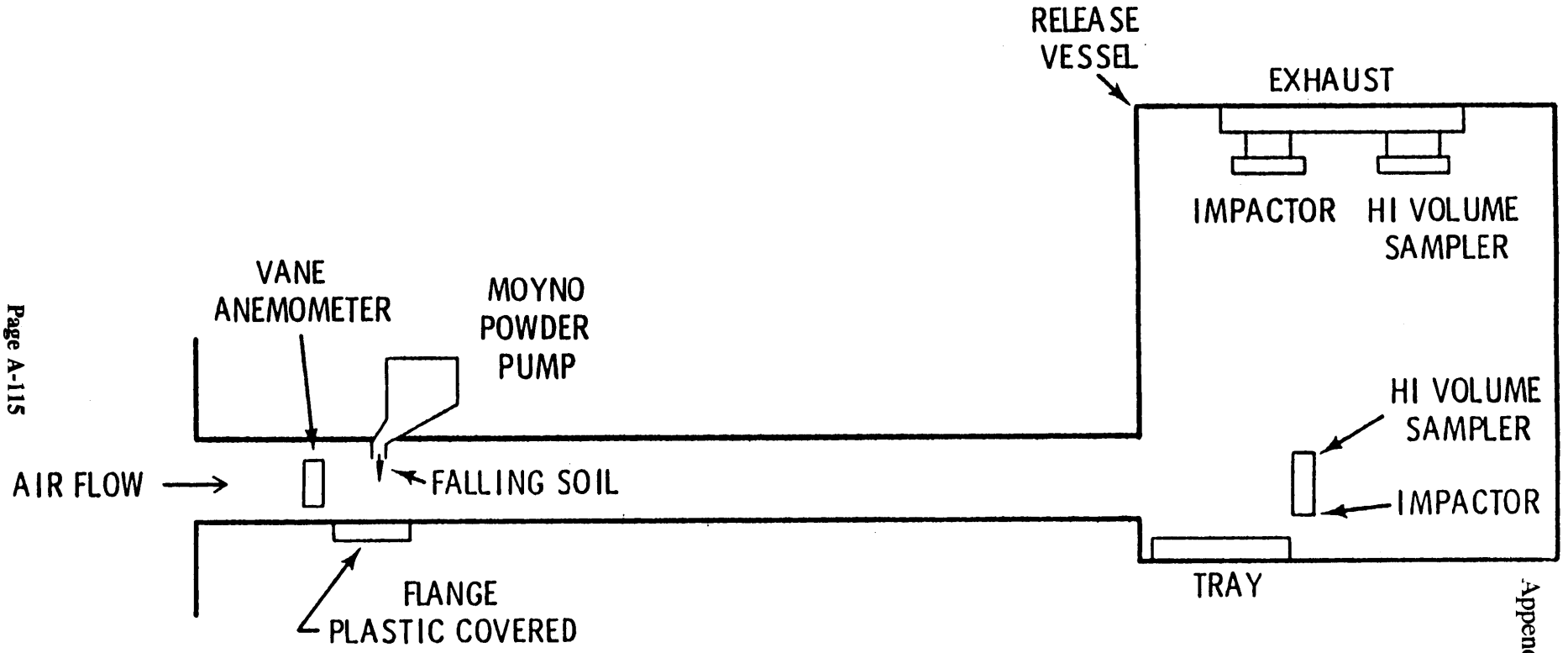


Figure A.39. Wind Tunnel Sampling

(Figure 3 - Sutter August 1980)

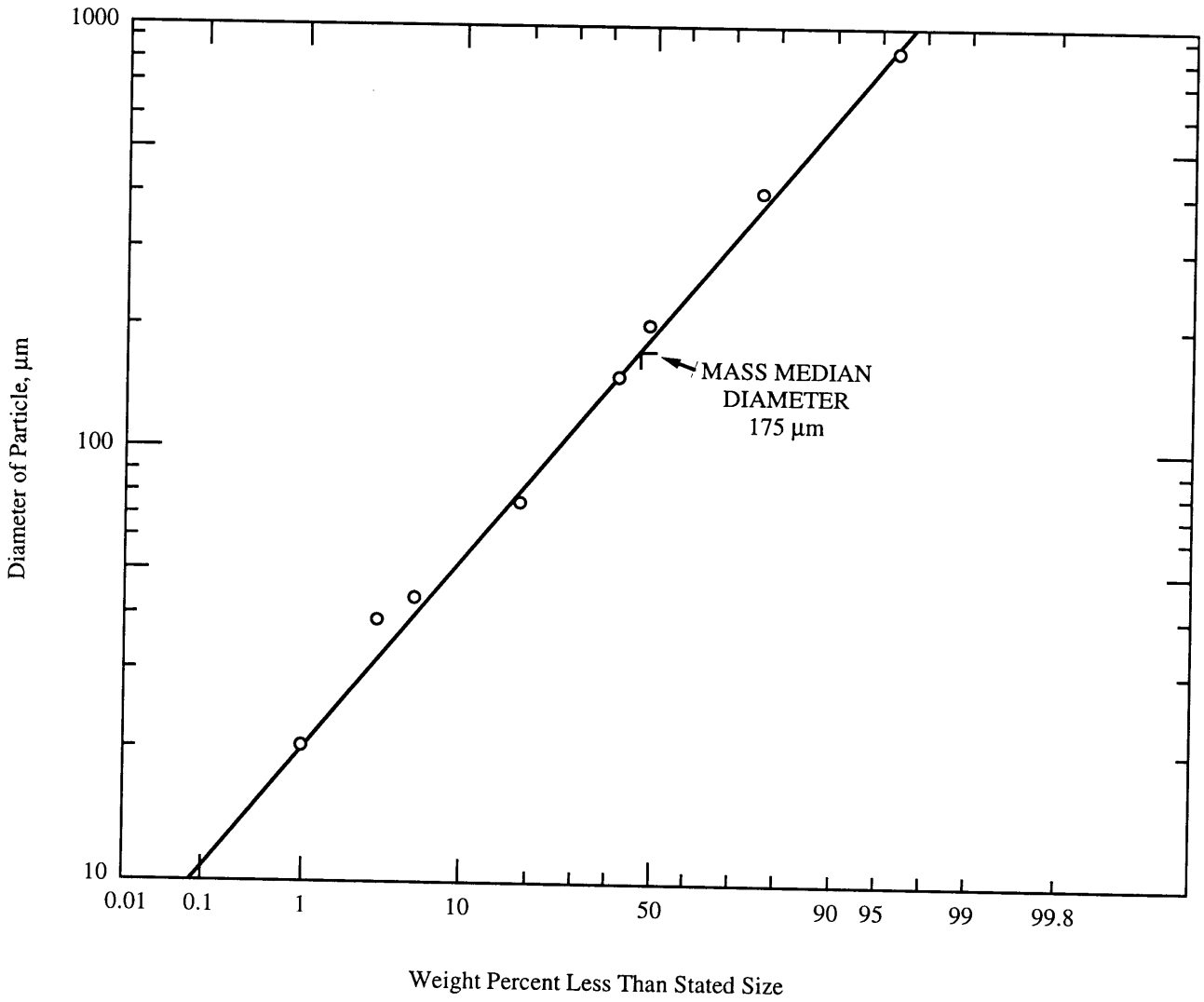


Figure A.40. Size Distribution of Soil Used in Experiments

(Figure 1 - Sutter August 1980)

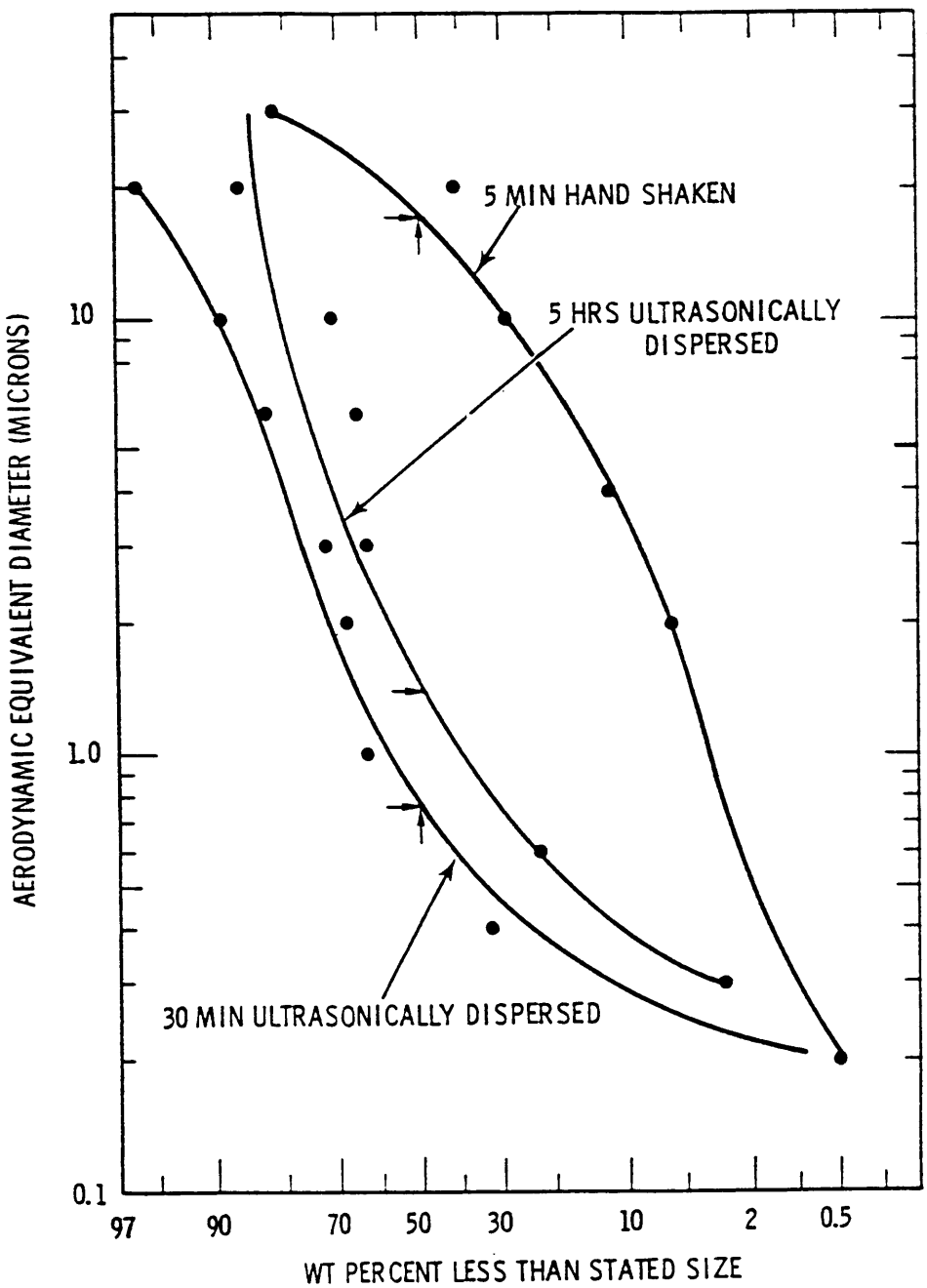


Figure A.41. Uranium Dioxide Powder Size Distribution by Whitby Centrifuge

(Figure 1 - Mishima and Schwendiman April 1973)



Figure A.42. Stainless Steel Screen and Support Used in Burining of Flammable Materials

(Figure 3 - Mishima and Schwendiman April 1973)

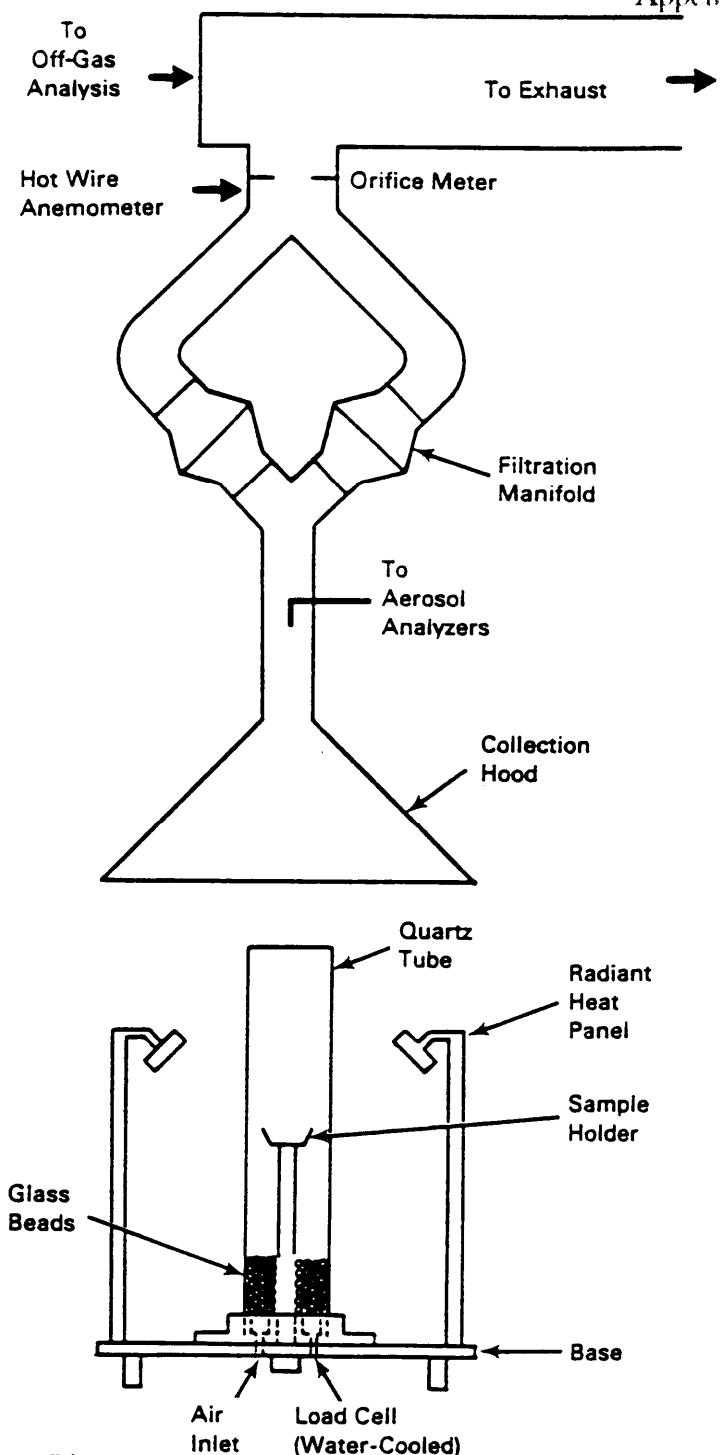


Figure A.43. CARE Combustion Apparatus

(Figure 1 - Halverson, Ballinger and Dennis March 1987)

Appendix A. Source Data

APPENDIX B

Example Facilities

Appendix B

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Appendix B

Appendix B

1.0 PURPOSE

This appendix provides the operational descriptions and material quantities upon which the example calculations in Chapter 7 are based. The examples included in this document were originally developed for the purpose of demonstrating a hazard analysis process and, subsequently, for basic hazard analysis training. The operations and material quantities described do not specifically correspond to any actual facility and should not be directly compared to actual operations. The example is a composite whose various features are based on historical and current plutonium processes and operations throughout the DOE weapons complex. Numerical values based on actual operations have been altered, and specific operational and design inadequacies have been included for the purpose of example. The use of this material as a basis for example calculations is considered preferable to independently documenting calculations for existing facilities.

This appendix presents facility descriptions followed by basic hazard identification tables for the operations described. The descriptions are at a level sufficient to identify accident scenarios and perform source term calculations.

Appendix B

Appendix B

2.0 PLUTONIUM RECOVERY FACILITY (H PLANT)

2.1 FACILITY DESCRIPTION

2.1.1 Overview

The H Plant Plutonium Recovery Facility (PRF) became operational in early 1970. It was originally planned to recover plutonium from oxide residues generated elsewhere and from certain residues generated within the building. A second mission that was added to the facility during construction was to purify plutonium metal received from offsite via dissolution and reformation. The product of the plant is plutonium metal buttons. The major waste streams are acidic and caustic low level liquid waste and solid TRU and low level waste. For the foreseeable future, the H-Plant will only be required to operate at about 25% of its historic capacity.

A schematic of the H Plant Area is provided as Figure B.1 on the following page. The H Plant building (H-1) is a two story structure approximately 300 feet long and 160 feet wide on the west structural wall and 130 feet wide on the east exterior wall. It is immediately adjoined by three other structures associated with its operation. On the west side, the H-17 building Plutonium Vault Facility annex serves as an intermediate storage point for H Plant feedstock as well as product buttons awaiting shipment. On the southeast corner, the H-7 Lab annex provides analytical support to the H Plant processes. Lastly, on the north face of the building, the H-21 TRU Waste Drum Holding Facility has been constructed to hold sealed waste drums awaiting shipment to site storage.

Other significant installations in the vicinity of the plant include the external Chemical Feed area (H-3) consisting of chemical storage tanks and delivery systems, the small H-5 structure at the southwest corner of the building housing the standby diesel generator, the area exhaust stack 230 feet southwest of H Plant, and the H-8 Liquid Waste Treatment Facility located approximately 300 feet south of H Plant.

2.1.2 Facility Structure

The H-1 structure is a two-story reinforced-concrete structure. The exterior walls are supported on continuous wall footings ranging from 4 to 8 feet square and 15 to 20 inches thick. The ground floor is an 8-inch-thick reinforced concrete slab. The main support columns on the first floor are 22-inch diameter reinforced concrete cylinders which support the second floor slab. Reinforced concrete beams anchored to the columns provide the remainder of the support for the second floor slab.

Appendix B; Plutonium Recovery Facility

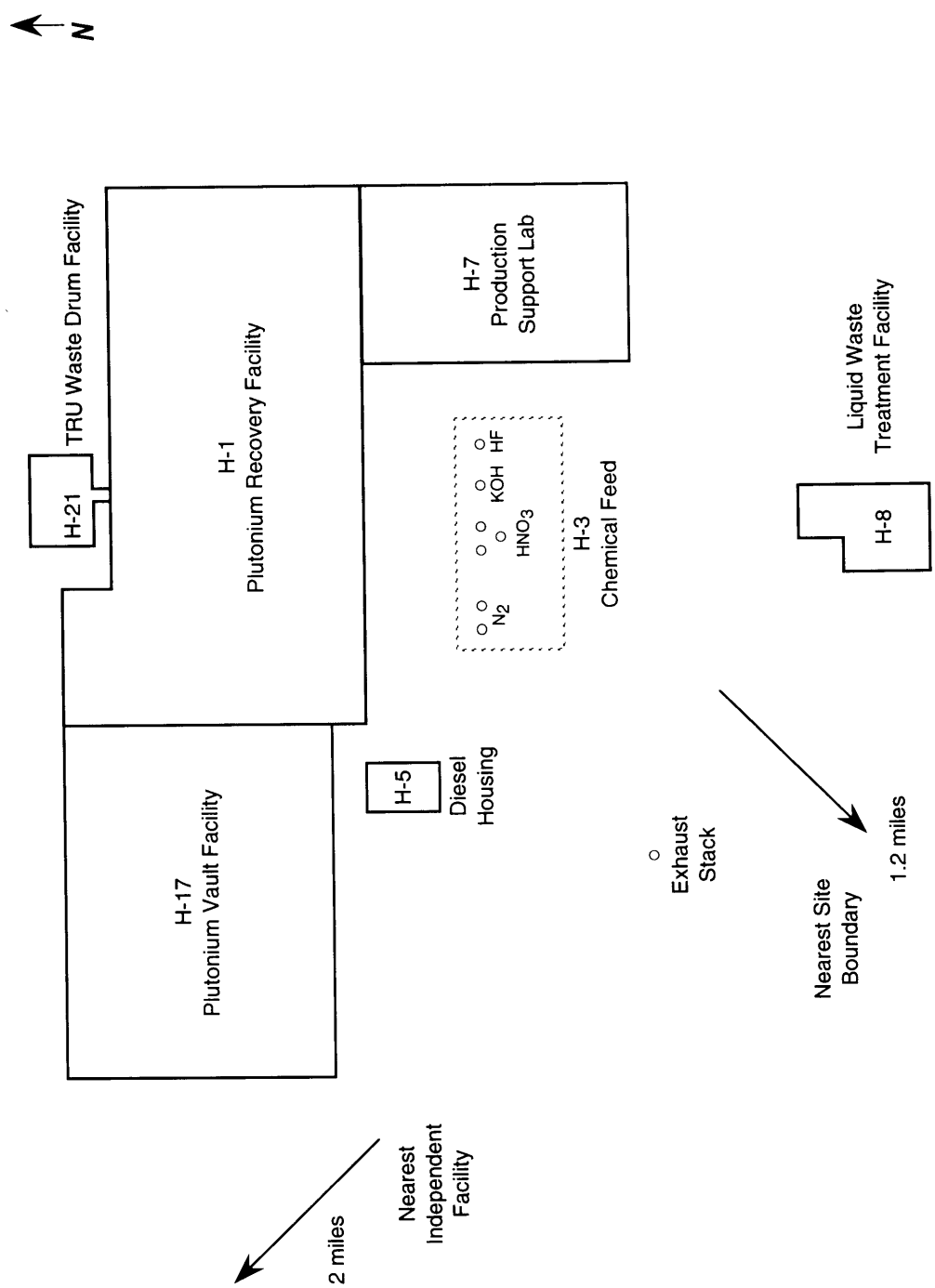


Figure B.1. H Plant

The exterior ground walls are 14-inch-thick bearing type (i.e., reinforced concrete). Some interior walls, particularly in the processing section, are reinforced-concrete load bearing walls. The remaining process interior walls are double gypsum board over metal studs or metal lath and plaster. The interior walls in office space are single gypsum board over metal studs outside of the areas with load-bearing walls.

The second floor reinforced concrete slab is 6 inches thick and was poured monolithically with the concrete beams. The main support columns on the second floor are 20-inch diameter cylinders, and a beam arrangement similar to that supporting the second floor slab exists to support the 6-inch-thick roof slab. The exterior bearing walls on the second floor are 10-inch-thick reinforced concrete. All roof surfaces are covered with metal decking overlaid by a rigid buildup four-ply incombustible insulation and finally covered by coal-tar pitch and gravel. The roof is flat with down spouts to facilitate drainage.

2.1.3 Confinement Systems

The principal sources of confinement are vessels/piping, gloveboxes, airlocks, the HVAC systems, and lastly the facility structure itself. As the structure has already been briefly discussed, this section will concentrate on the first four items.

2.1.3.1 Vessels and Piping

All internal glovebox vessels are mounted to the glovebox structure itself. The normal material of construction is 304L stainless steel alloy except for special uses such as the hydrogen peroxide precipitation vessels that are made of Pyrex. All tanks external to gloveboxes are seismically mounted to the structure floor. Piping leading to external tanks is sheathed stainless steel double pipe with leak detection points for the annular region at piping low points.

2.1.3.2 Gloveboxes

Gloveboxes used in the H Plant are typical 304L stainless steel units machined to a smooth surface inside. The gloveboxes have double walls below the windows filled with lead and water extended polyester for shielding purposes. The windows are 0.5 inch plate glass with, on average, 1 inch of transparent leaded glass and lexan mounted over them on the external glovebox frame. Certain gloveboxes, such as the hydrofluorination unit in the wet line, have Benelex sheets and additional lead mounted on the exterior glovebox surface and thicker windows for additional shielding. The hydrofluorination unit also has sliding panels of Benelex which are placed over the windows of the box when access is not needed.

Potentially flammable materials such as Benelex are painted with intumescent paint to retard fire propagation.

The glovebox units are seismically anchored to and grouted into the concrete floors of the facility. Complete documentation drawings are not available, but the floor on the operating side of three gloveboxes was opened to verify this condition. Verification was successful and the floors have since been repaired.

2.1.3.3 Airlocks

The H Plant is divided into airlock zones to minimize the chance of spreading contamination. One set of airlocks separates those rooms containing radionuclide-handling equipment from the rest of the processing enclosure. A second set of airlocks separates the processing enclosure from the general use areas of the building.

The primary airlocks isolate the operating and maintenance rooms associated with gloveboxes, the TRU waste drumming station, the exhaust HEPA plena room, the vessel vent room, and the cold chemical makeup room from the rest of the facility. The use of the two-room configuration per box is also designed to minimize contamination as entry into the gloveboxes for maintenance and repair is not conducted in the same room where manual monitoring and operation of the box will occur.

The primary airlocks consist of an enclosure defined by two doors. One set leads to a glovebox room (or one of the other areas noted above), while the other set leads out into a corridor. Both the outer and inner doors have a combination lock for entry. A hand and shoe monitor is installed in the airlock for use when exiting the potentially contaminated area.

The secondary airlocks separate the facility control and instrumentation rooms as well as general use space from the primary processing enclosure. There are three of these units on the first floor and one emergency airlock exit to the outside at the northeast corner of the building in the processing enclosure. These airlocks function exactly like the primary airlocks, with the exception of the emergency exit, which is alarmed and has crash bars for opening the doors.

The location of the airlocks in the facility is designated by an AL on the floorplans of the facility provided as Figures B.2 and B.3. Where the A and the L are separate, it indicates two independent airlocks related to one glovebox line. One airlock leads to the operating side of the line, while the other leads to the maintenance side of the line.

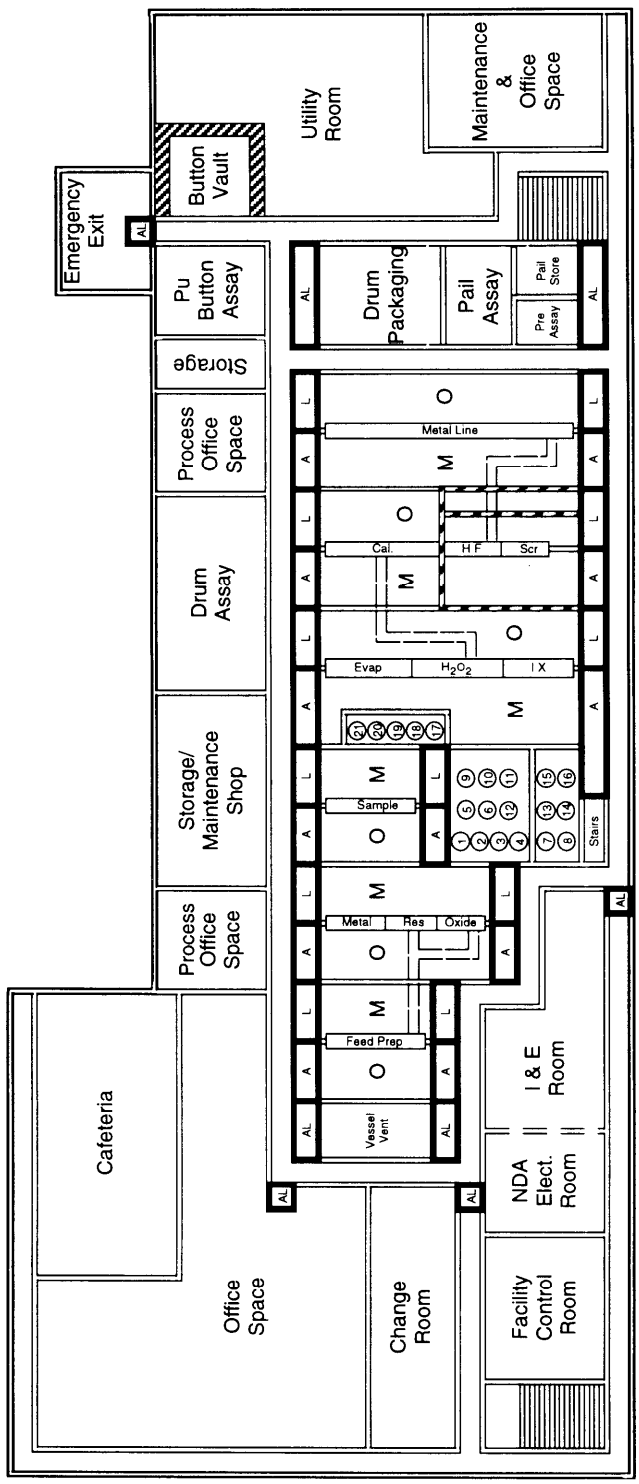


Figure B.2. Plutonium Recovery Facility First Level Floor Plan

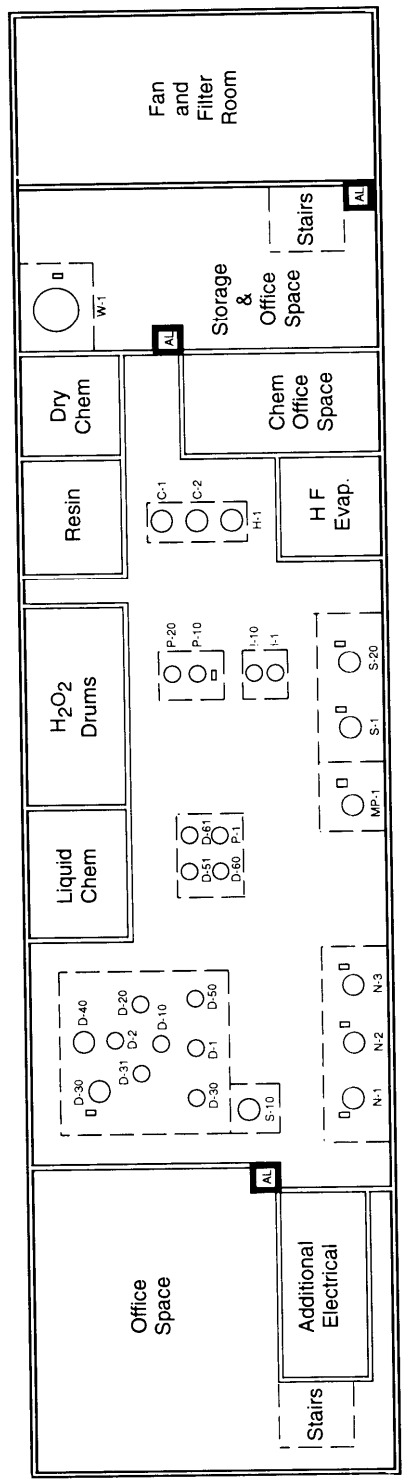


Figure B.3. Plutonium Recovery Facility Second Level Floor Plan

2.1.3.4 HVAC System

The ventilation system, which is depicted in Figure B.4, consists of two independent once-through airflow systems, a recirculating nitrogen system for the metal reducing line, and a vessel vent system that ties back into the main building exhaust. All exhaust goes through High Efficiency Air Particulate (HEPA) filters before entering an underground tunnel where it is joined by exhaust from other nearby facilities and exits from the H Plant stack.

There are six ventilation supply fans for the building. These centrifugal fans operate in sets of two, with one always serving as an automatic start standby fan in the event of failure of the running fan. Two of the fans serve the "clean" areas (System A) (i.e., general access) and four of the fans serve the production areas (Systems B and C). The "clean" areas are designed to have 8 air changes per hour, while the production areas are designed to have 14 air changes per hour. The system is designed to keep the temperature at 75° F and 50% humidity in the summer, 70° F in the winter, and to keep all glovebox temperatures below a maximum of 100° F.

All supply air is prefiltered, filtered, and heated or cooled as appropriate before entry into the building environment. Fail-shut, tornado-proof supply air dampers are provided at each inlet as well. All glovebox ductwork in the building is constructed of galvanized steel piping.

System A sends all of its exhaust through plenum A, which has two HEPA filter banks in series. It is basically a straight through system. System B has three main branches. The first consists of supplied air serving corridors and various areas that are not expected to be routinely contaminated. This branch, like System A, moves straight through the building to Plenum B where there are four HEPA filter banks in series. The second branch is glovebox airflow for the feed preparation glovebox, the dissolving line, the sample glovebox, and the wet processing line. Air entering the associated maintenance rooms is admitted into these gloveboxes through glovebox-mounted HEPA filters. It exhausts through glovebox mounted HEPA filter units as well, and joins up with exhaust air from the third branch discussed below before entering Plenum C.

An additional set of supply fans divert a portion of this airflow through an air dryer to the calcination and hydrofluorination lines, which are considered System C. The air drying system includes a multi-stage dehumidifier to produce 68° F air with a dewpoint of -40° F. This low moisture content is necessary to produce an acceptable product. These calcination and hydrofluorination gloveboxes have piped-in supply air headers, but inlet air still passes through a glovebox-mounted HEPA filter. This air is exhausted through glovebox mounted HEPA filters and progresses to Filter Plenum C.

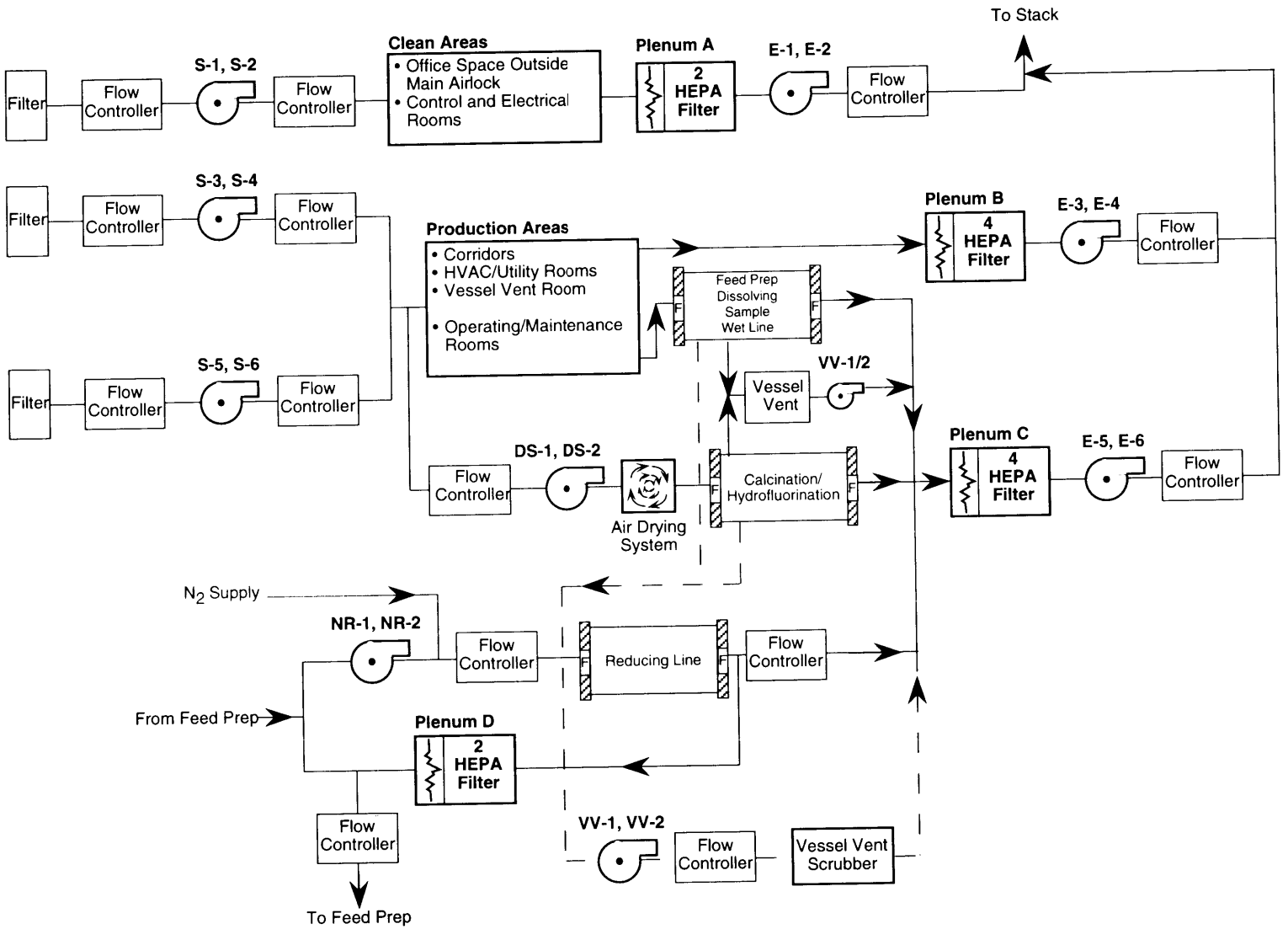


Figure B.4. Plutonium Recovery Facility Ventilation System

Nitrogen is supplied from outside the building to inert the metal reduction line. Inerting is specifically intended to prevent excessive oxidation of the product metal, not to preclude plutonium metal buttons from burning (a highly unlikely event). However, the inerting system provides residual fire prevention benefit as well. Nitrogen is recycled through Plenum D, which has two HEPA filter banks in series, and is regularly bled off the system to join production exhaust at the inlet to Plenum C. Nitrogen can also be diverted from this system to inert the feed preparation glovebox if desired.

The final flowpath in the building is associated with the vessel vent system. Offgases vented from liquid-bearing vessels in gloveboxes and process rooms are drawn to this system. The vessel vent system contains a scrubber that uses 15% potassium hydroxide to neutralize entrained nitric acid vapors. The scrubbed gases are then transferred back to the main process exhaust plenum by two small centrifugal blowers.

For the production areas, negative pressure at specific supply and exhaust inlet points is controlled by pneumatically operated dampers. These units respond to signals from differential pressure detectors. Typical differential pressures maintained between areas and atmosphere are listed below:

Clean Areas	- 0.1" WG
Secondary Air Locks	- 0.15" WG
Regulated Production Areas	- 0.2" WG
Primary Air Locks	- 0.25" WG
Operating Rooms	- 0.3 " WG
Maintenance Rooms	- 0.4 " WG
Gloveboxes	- 0.9 " WG

Differential pressure readout and low-level alarms are available in the facility control room. Local gage indications of differential pressure are available at each glovebox as well. An automatic mechanical sequencer controls restart of fans following loss of ventilation to prevent overpressurizing the facility. This unit will also trip supply fans if an exhaust fan fails and the standby unit does not come on.

2.1.4 Existing Structural Studies

The PRF was designed and built in accordance with standards of the M&O contractor at the time of construction. These standards were based on the Uniform Building Code. The PRF was considered to be a Class 1 structure capable of withstanding a static live load of 1000 psf acting simultaneously on the whole outer surface. However, complete design drawings do

not exist, and questions have been raised as to how exactly corporate standards were followed during construction.

An independent study of the facility was performed by Brown and Associates in 1985. This study relied on extensive facility walk-throughs, review of available documentation, and limited radiography and core tap examinations. The study concluded that the PRF is, in fact, a robust structure, and that the design basis equivalent tornado of 119 mph from UCRL-15910 would not cause significant damage to the structure. The bulk of the remainder of the study dealt with seismic issues.

Site-specific response spectra used in the evaluation were defined in an independent study conducted by Lawrence Livermore National Laboratory. These response spectra provided surface accelerations at an average soil depth. For return periods of one in 1000 years and one in 10,000 years, acceleration levels are 0.13g and 0.26g. The 1985 structural assessment reached the following conclusions about expected seismic damage up to and including a level of 0.30 g:

g-Level	Probable Damage
0.1	Small movement of gypsum board walls. Minor cracking.
0.12	Large cracking in gypsum board walls. Generically supported piping fails.
0.15	Onset of potential for utility equipment failures. Highest value at which continued supply of electrical power can be assumed. Represents threshold of ventilation unavailability due to loss of power.
0.18	General failure of non-concrete walls. Onset of failure of supported process piping.
0.21	Onset of minor cracking of non-shear internal concrete walls. Onset of external glovebox connection pipe and wiring failure. From 10% to 20% of the tanks other than plutonium process tanks fail.
0.24	Onset of minor external wall cracking. Spalling of internal concrete walls possible.

g-Level	Probable Damage
0.26	Gloveboxes may begin to sag. Spalling of external walls possible. From 5% to 10% of the plutonium process tanks in first story tank farm fail.
0.30	Building wide failure of tanks other than plutonium process tanks. All gloveboxes sag, and 10% to 20% of the plutonium process tanks fail. Possible large cracking of internal non-shear concrete walls. It is expected that the building shell will remain intact.

The statement that the building shell will remain intact is stated to be an "expectation" as opposed to a "conclusion" in the Brown and Associates study because of concerns that the tie spacing in columns might be too large. Even with this concern, the majority of the columns in the building were judged adequate. However, column A-17, the support unit located at the L-shaped hinge on the north face of the building, was considered a potential problem. The irregular shape of the PRF structure allows a significant moment to develop at this location and it was considered unlikely but possible for column A-17 to exhibit brittle shear failure. If such a failure occurred, Brown and Associates estimated dominoing failures could lead to partial collapse of the building around the cafeteria, "clean" office space, and the feed preparation, dissolving, and sampling gloveboxes. At this point, the moment characteristics of the new building shape would be considered survivable for the remainder of the structure. A project to provide additional support for column A-17 was developed as a result of this study, but the estimated funding has not been made available.

Based on column and beam locations, this partial collapse case would be expected to include the following process equipment in the collapse zone: (1) the vessel vent scrubber, knock-out tank, and blowdown tank; (2) the impactor, weighing and batching, and furnace stations of the feed preparation glovebox; (3) the metal dissolving glovebox; (4) the back-end half of the residue dissolving glovebox; and (5) the sample glovebox. Outside the partial collapse zone, the base conclusions of the study would remain valid (i.e., gloveboxes would remain upright, but limited sagging could occur, glovebox piping and electric connections could fail).

2.1.5 Facility Support Systems

2.1.5.1 Nuclear Incident Monitors

Twelve sets of two nuclear criticality incident monitors each detect and alarm in excessive radiation fields. These detectors are spaced so as to provide overlapping coverage by a minimum of three detectors at any point in the facility. They provide flashing light and bell ringing indications when activated. The units are designed to alarm on any internal failure and receive power via an uninterruptable power supply.

2.1.5.2 Nuclear Criticality Design Mitigation and Control Systems

With the exception of the tanks in the vessel vent room, the plenum deluge catch tank, and the utility room reboiler and its associated condensate tank, all vessels within H Plant are geometrically favorable in design. Tanks in gloveboxes are slab tanks with a nominal interior width of 3 inches with reinforcing stay-bolts and weep holes to detect corrosion before it can alter control dimensions. Tanks outside gloveboxes in the wet line tank farm are annular vessels with a maximum interior annular diameter of 2 inches. These vessel sizes ensure a subcritical condition for all flowsheet plutonium concentrations, thus preventing a criticality from inadvertent transfer of a solution to the wrong tank. The vessels previously mentioned that are not geometrically favorable are equipped with borated raschig rings to prevent criticality from inadvertent plutonium accumulation due to abnormal conditions.

Glovebox sumps are built into the bottom of all wet process enclosures well below the level of any vessels. Each glovebox is equipped with three separate slab sumps. The sumps are sized so that, in combination, they can hold all of the liquid in the largest vessel in a glovebox when sloping of the lower surface causes overflow from one sump to go to the next sump in line. All sumps are equipped with liquid level detectors that provide local and remote alarms and shut the inlet valves for the main process liquid streams.

The process solution tank farm area has been sized so that all of the liquid available in the tanks should be able to spread across the floor in a thin enough layer to preclude a criticality from occurring due to leaks. However, as an additional safeguard, the storage tank areas have metal-grating floors elevated over a pit filled with borated raschig rings.

All vessels and storage arrays in H Plant have been spaced so as to maintain the materials at geometrically favorable spacings. All transfers of material, whether feedstock, product, or waste pails, are limited to one unit at a time. Portable and in-line holdup monitors are used to measure plutonium accumulation in systems as well.

2.1.5.3 Fire Mitigation Design and Practices

Whenever possible, construction materials are noncombustible or fire resistant. As previously noted, the exterior walls and roof of the building are cast-in-place concrete having a minimum 3-hour fire rating. The concrete interior walls and gypsum board over steel stud walls have minimum 2- and 1-hour fire ratings, respectively. Major structural components of the gloveboxes and process material are made of noncombustible material. Where potentially combustible shielding has been used, such as Benelex, it is coated with intumescent paint to minimize chances of ignition in all but the most severe fires.

Flammable liquids are not allowed in gloveboxes as part of the combustible loading control program in effect. Potentially combustible wipes are limited by this program as well to approximately 10 in line at any one time, a number normally associated with shutdown cleaning in the gloveboxes as opposed to processing. In normal operation, non-installed combustibles in the operating areas are limited to operator logs and procedure manuals. When maintenance on gloveboxes is in progress, tent construction material is made of fire-resistant materials.

The major potential sources of fixed combustibles, aside from Benelex shielding on certain gloveboxes, are electrical wiring and glovebox gloves. Wiring is installed in accordance with appropriate codes and housed in conduits or sealed raceways. Wiring penetrates gloveboxes through pave connectors to prevent an insulation fire from progressing into gloveboxes. The glovebox gloves are made of materials such as Hypalon and will melt and burn at elevated temperatures. However, the number of gloves is limited, and storage of used gloves in a line after removal is forbidden by procedure.

2.1.5.4 Fire Detection and Alarm System

The plant has three types of fire detectors available: ionization, photoelectric, and thermal. All three are used in individual processing rooms, while only thermal detectors are used in gloveboxes and ventilation plenums. Exceeding the setpoint on any detector will initiate an alarm in the operating area, the facility control room, and the site fire department. Failure of a detector and interruption of signal flowpath by such means as a wire break will initiate an alarm as well.

2.1.5.5 Fire Suppression System

All areas of H Plant are equipped with automatic wet-pipe sprinklers in the overhead that actuate at temperatures slightly higher (approximately 155° F) than the fire detection alarm setpoints. A dedicated set of thermal detectors in gloveboxes and rooms are used to provide

initiation input to the sprinkler system, which is equipped with fusible links in the process areas as a backup means of initiation. Nozzle arrangement in the system is in accordance with NFPA standards and will blanket a room as well as direct spray to glovebox walls. A thermal detector-activated deluge system is available for all HEPA plenums as well. This system actuates when air temperature coming to the plenum is above 180° F, providing a continual spray of firemain water upstream of the HEPA plenums. Series demisters are available to protect the plenum from a large flow of water drops. This system and any of the sprinkler systems can be activated manually as well.

2.1.5.6 Air Sampling Systems

There are two air sampling systems in the H Plant, a high- and a low-volume system. The high-volume system has 26 units in the operation and maintenance rooms and the vessel vent room (2 per room) and an additional 15 exhaust duct samplers. Each of these units draws 30 cfm.

There are an additional 50 low-volume air samplers designed to detect airborne contamination in airlocks, regulated corridors, and non-glovebox handling operations such as waste and button assay, drum packaging, etc. These units draw 5 cfm. Both systems use impaction collection and photomultiplier tube detection and provide local audio and visual alarms. However, only the high-volume system provides remote alarm capability in the facility control room. The motive force for both the low- and high-volume air samplers is one of two centrifugal exhausters located in the HEPA plenum room on the second floor. These units discharge into the central facility exhaust duct downstream of the main exhaust fans.

There are also two low-volume air samplers downstream of the HEPA filters for each plenum. These units have remote alarm capability in the facility control room. Continuously on-line filter media particulate samplers are provided for stack exhaust as well. These media are manually collected and sampled at prescribed intervals.

2.1.5.7 Liquid Sampling Systems

Liquid samples are taken from interior glovebox vessels using an installed sampling system. This system consists of a small centrifugal pump that draws liquid through a liquid-liquid eductor and recirculates it back to the tank. The eductor draws liquid through a bypass line around the pump as well. When the required recirculation time is complete, a small sample vial with a diaphragm seal lid is inserted into a sample holder on the bypass line. Opening of a single valve fills the vial, which can then be isolated and removed from the holder.

This vial is transferred to the laboratory annex for analysis in a CRC canister mounted on the back of the glovebox.

For tanks external to gloveboxes, a similar sampling method is used in the sampling glovebox. This glovebox has three separate pumps and sample lines for three general types of solution (e.g., pre-ion exchange process solutions, post-ion exchange process solutions, and waste solutions). Vials are removed from the sample glovebox via an airlock on the maintenance side of the cabinet and placed in plastic waste pails for transfer to the laboratory annex. Different colored labels are used to distinguish samples from different systems.

2.1.5.8 Cold Chemical Storage and Supply

Cold (i.e., not radioactively contaminated) liquid feed chemicals are kept in stainless steel storage tanks on the second floor of the H-Plant. The tanks are grouped together in six major sections, each of which is surrounded by a small retaining dike. All tanks are equipped with sightglass level indication, and certain tanks have local and remote alarms to minimize operational disruptions. Tanks that will be mixed with water or that can experience stagnation problems over a short period of time are equipped with agitators.

Although the cold chemical area is separated from the rest of the facility by an airlock, it is intended that this area remain uncontaminated. To support this goal, all chemical feed lines that go to gloveboxes or contaminated tanks on the first floor are equipped with liquid seal pots on the first floor to prevent drawing liquid from the first floor back into the feed tanks.

Some liquid chemicals that are used in small amounts and prepared to the right concentration by manually mixing with water in tanks are kept in bottles stored in a distinct room. Other distinct storage rooms include the 35% H_2O_2 55-gallon drum storage room, the ion exchange resin storage room, the dry chemical storage room, and the HF evaporator room. The HF evaporator room houses the small evaporator that is heated to generate HF gas from the liquid HF transferred into the building from the chemical farm.

2.1.5.9 Facility Control Room

The H Plant control area is located outside the regulated production area. It provides monitoring capability for significant process parameter indications, such as temperatures, flowrates, and levels for all glovebox and tank farm operations. Operational controls for gloveboxes and tanks are provided at local control stations and are not available in the control room. Local control stations are equipped with a shutdown switch that shuts all air-operated liquid supply valves and secures power to glovebox equipment when operated. Lights in the control room illuminate to indicate when shutdown switches have been used.

The ventilation system (e.g., ventilation sequencer, differential pressure readouts, damper positions) is monitored in the control room as well. Unlike process controls, however, the ventilation system is also operated from the control room via an installed control panel. Significant parameters and alarms for support buildings, such as the H-8 Liquid Waste Treatment Facility receipt tank levels, are also provided in the control room. One of two primary facility announcing system controls is located here as well.

2.1.5.10 Electrical Power Distribution

H Plant is provided with split bus redundant normal power, auxiliary power from the plant diesel, and safe shutdown power from uninterruptable power supplies (UPS). Normal power is received from two separate public utilities. Utility A provides power to one main bus via the 32 substation, while Utility B provides power to the other main bus via the 33 substation. Automatic transfer switches will connect a given bus to the other substation upon loss of power from one supplier.

Auxiliary power is provided to the facility by a 850- kw diesel generator located adjacent to the main building in H-3 B. This small building is constructed in a manner identical to the main building. Loss of power from both normal sources will automatically start the diesel and commence a timing sequence that will transfer auxiliary busses to the diesel once it is running at rated speed. Typical time for power restoration is on the order of 10 seconds. Upon restoration of power, the ventilation fans will automatically restart in the appropriate sequence.

There are three separate UPS in H Plant. The first is dedicated to the criticality alarm system and will provide operational power to the criticality alarm system for up to 3 hours. The second UPS provides power to the air sampling system and local glovebox control panels for approximately 1 hour. The final UPS supplies the facility control room for approximately 0.5 hours.

The building grounding system serves two functions. As the building electrical ground, it offers a path to ground for electrical faults, providing additional protection along with breakers and fuse blocks and allowing "bleedoff" of static electrical charges. Its second function is to provide a "bleedoff" path to ground in the event lightening strikes the building.

2.1.5.11 Process and Instrument Air

Process and instrument air represent two branches of flow from a single source. Filtered air is drawn into one of two air compressors (on-line and standby units) rated for 300 scfm and 125 psig discharge pressure. The compressor outlet passes through drying towers to one of

two surge receivers. Downstream of the receivers, reducing valves are used to provide an 80-psig plant air line and a 65-psig instrument air line. Low-pressure alarms are provided on each line.

The process air line provides air to the process itself. Examples of its use include mixing air jets, purges and sparges, automatic samplers, and air to the calcining unit for oxidation. Purge flows and calcining and hydrofluorination air come off of a reduced pressure 30-psig branch. Calcining and hydrofluorination air go through another drying tower to produce air with a dewpoint of -40° F. In all cases, restriction orifices minimize potential flow inside the glovebox in the event of a line failure.

The instrument air line provides air at 65 psig for all pneumatic instruments and valves. Restriction orifices are used in this system as well to minimize interior glovebox flows in the event of a line failure.

2.1.5.12 Breathing Air

As in the case of process and instrument air, filtered breathing air is drawn into one of two redundant compressors and discharged to receiving tanks. Maximum flowrates and pressures are 450 scfm and 115 psig. A low-pressure alarm is provided on the receiving tank, which allows 5 minutes of breathing air for eight people to exit from any ongoing jobs.

Downstream of the receiving tanks, supplied breathing air passes through two stages of cellulose fiber filters that remove particles greater than 20 μm in diameter. Reducing valves maintain a pressure of 30 psig on the system, which serves sets of manifolds in all of the operating and maintenance areas. A monitoring system is provided inline with the main header, which measures temperature, pressure, and O_2, CO_2, and H_2O concentration levels. An alarm is provided when one of these parameters goes out of a specified band. All alarms on the system are received in the control room and at individual manifold stations.

2.1.5.13 Steam and Condensate System

Steam is received from the site boilerhouse via a 150-psig main. Before entry into the building, it is reduced in pressure to 60 psig. Steam branch lines for use in the facility are reduced to a nominal pressure of 35 psig.

General building use steam condensate is collected in tanks in the utility area and pumped back to the boilerhouse. Boilerhouse steam also serves as the heat source for the reboiler tank in the utility room. Condensate from the reboiler is collected separately from the general building use condensate and sampled prior to transfer back to the boilerhouse. If

contamination is present, the liquid in the tank can be diverted to the H-8 Liquid Waste Treatment Facility.

The reboiler is the source of steam for a separate steam cycle serving vessels in the glovebox lines. Condensate from this steam is collected in one of two raschig ring tanks in the vessel vent room where it is sampled. If no detectable contamination is present, it is recycled to the reboiler for steam generation. If contamination is present, it is diverted to the H-8 Liquid Waste Treatment Facility. Steam lines for dissolvers and evaporators are encased in sheath housings so as to not come in direct contact with process fluids, therefore, the most likely source of contaminant would be from the ion exchange line heat exchanger. Steam pressure is kept greater than dissolver or evaporator pressure so that if any leak does develop, steam and condensate will flow into the process vessel. Three confirmed contamination incidents have occurred due to leaks, but contamination of process condensate has not historically been a major problem.

2.1.5.14 Domestic Water

The domestic cold water main is supplied from site utilities and is equipped with multiple redundant backflow preventers at various points in the system. One branch serves general building needs, a second serves utility needs, and a third serves process needs. The first two branches are disposed of through the sewage system.

The process water branch consists of three separate headers. The first provides water to safety showers in the operating and maintenance rooms. The second provides flushing water for some vessels and is used only in shutdown or maintenance configurations. Both of these lines lead to the wet line tank farm waste tanks either through normal process flow or through special drains for the safety showers. The third branch of the process water system feeds the plant chilled water system that is housed in the vessel vent room.

2.1.5.15 Chilled Water Systems

There are two distinct chilled water systems in H Plant. The first is located in the facility utility room and serves as the chilled water supply for general use. The second is the cooling system for process heat exchangers. It consists of a raschig ring tank in the vessel vent room, which is the initial entry point for process water. This unit serves as the head tank for a chiller and its associated pump and provides loop flow branching off to specific heat exchangers. The process system is periodically sampled for contamination and pumped to the H-8 Liquid Waste Treatment Facility if contamination is found.

2.1.5.16 Sanitary Sewer System

The sanitary sewer system accepts effluent from washrooms, showers, clean utility system drainage or blowdown, etc. It serves as a conduit to deliver waste water to the site sewage plant.

2.1.5.17 Chemical Farm

The chemical farm is a collection of storage tanks and support systems located approximately 60 feet to the south of H Plant. Storage tanks are provided for nitric acid, potassium hydroxide, and hydrogen fluoride, with the areas around both tanks diked to hold the majority of the fluid in the vessels. Two major gas systems are associated with the chemical farm as well. One consists of two nitrogen supply vendor package nitrogen systems. Each system is composed of a large vertical, double-insulated annular vessel for liquid nitrogen with a net supply capacity of 350,000 scf of nitrogen. The vendor supplied system vaporizes the nitrogen and supplies it initially at 90 psig. Tapoffs at this point are used to pressurize the chemical storage tanks as the driving force for transfer into the H-Plant building. Nitrogen pressure is reduced to 15 psig before transfer into the building, where it is used for inerting the metal reduction line and the feed preparation line as necessary.

The second gas system supplies argon from a bank of compressed gas cylinders located along the south wall of the H-1 building. The argon flow in the building passes through gas purifiers to remove trace oxygen and moisture before reaching the metal reduction furnaces where argon is used to establish an inert atmosphere.

2.1.5.18 Diesel Fuel Oil System

The fuel oil supply source for the standby diesel generator is a 5000 gallon underground storage tank on the west side of building H-3 B. This tank is a new installation and currently meets all regulatory requirements. The old tank was removed in compliance with RCRA regulations after it began to leak. The new tank is equipped with automatic pumps that are actuated by a level switch in the diesel fuel day tank. This system ensures there is always a minimum of 100 gallons of fuel in the day tank.

2.2 PROCESS DESCRIPTION

2.2.1 Overview

Figure B.5 provides a basic flowpath for facility processing operations. H Plant accepts plutonium oxide, metal, or residue received from outside the plant as well as certain high assay residues generated by plant operation. Oxides and residues receive initial processing in the feed preparation glovebox, where small metal scrap can be burned to oxide and recoverable residue chunks are reduced in size. A chainveyor takes these materials in packaged batches to the appropriate dissolution lines. Metal returns for recycle processing require no initial handling and are introduced into the metal dissolution glovebox directly by means of an airlock on the maintenance side.

The dissolution line is composed of three gloveboxes in series with each box being a complete glovebox. Therefore, although physically joined, there is no means of passing material from one glovebox to the other. The first two gloveboxes in the line are the oxide and residue gloveboxes, which use a nitric acid dissolution process. The third glovebox is the metal line, which uses a sulfamic acid dissolution process. Upon completion of the dissolution and accountability measurement process, plutonium-bearing solutions are pumped via glovebox gear pumps to Tanks #1 through #6 located in the tank farm on the maintenance side of the wet processing line.

The wet processing line is a continuous line composed of three gloveboxes (ion exchange, H_2O_2 precipitation, and evaporation) joined together in the same fashion as the dissolving line, although there is a piping transfer line passing from the precipitation line to the evaporation line. All of the direct contact process and waste liquid tanks are stored in walled enclosures on the maintenance side of the wet processing line to minimize chances of contaminating multiple rooms and to provide proximity to a central sampling glovebox.

After appropriate chemical adjustments, the dissolver solutions are transferred through the ion exchange columns. Product eluate is transferred to tanks #7 and #8, while waste effluent and wash solutions go to tanks #9 through #12. The acid concentration of the eluate is increased, and then it is transferred to the feed evaporator in the evaporation glovebox. The plutonium concentration of the liquid is increased in the evaporator to a level sufficient to obtain good product yield in precipitation. The evaporator bottoms are transferred to tanks #13 and #14 to serve as precipitator feed, while the distillate is transferred to tanks #17 through #19 to await transfer to the H-8 liquid waste handling facility.

The precipitation line makes a peroxide cake out of the plutonium in solution. This cake is dumped automatically in holding containers from a rotary drum filter and then manually

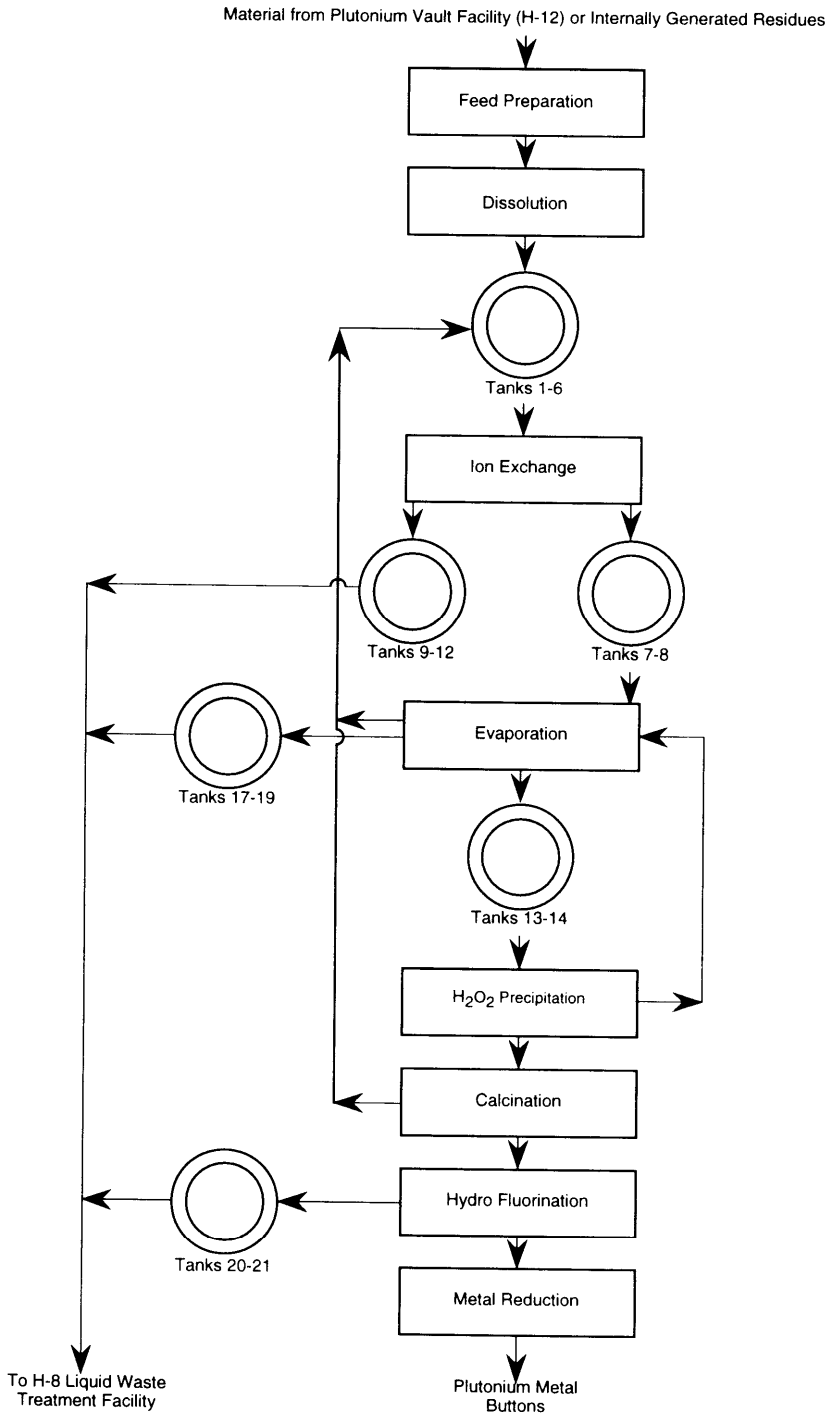


Figure B.5. Plutonium Recovery Facility Simplified Process Flowpath

placed in a chainveyor for transfer to the drying line. Filtrate from precipitation still contains recoverable quantities of plutonium in solution, so it is transferred to the filtrate evaporator in the evaporation line. There the volume is reduced by a factor of approximately 10 and residual peroxide is broken down from the heat. The recoverable bottoms are transferred back to dissolver tanks #1 through #6 for recovery, and the distillate again goes to waste tanks #17 through #19.

The dry line consists of three separate operations in series gloveboxes similar in arrangement to the dissolver lines. These operations are calcination, hydrofluorination, and HF scrubbing. The calcining glovebox has temporary storage capability for peroxide cake. Individual batches are first manually placed into a drying oven that provides an initial low temperature drying cycle. The peroxide cake is then manually dumped into the calciner hopper where the unit screw feeder moves it into the calciner.

Air exiting the calciner often has significant quantities of entrained plutonium even after passing through a separator due to the flaky nature of the peroxide cake and various design difficulties with the air flowpath in the calciner. Therefore, the calciner exhaust is passed through a nitric acid scrubber that dissolves entrained plutonium. The liquid used in the scrubber normally contains recoverable quantities of plutonium by the time a calcination cycle is complete and is transferred to dissolver tanks #1 - #6 for recovery.

The calcining tube and its associated screw feeder extend through the calcining glovebox wall and into the hydrofluorination line. At the end of the screw feeder, there is a machined paddle wheel which scoops the calcined plutonium oxide to a dropoff into a small vessel. The paddle wheel has been machined so as to maintain a physical isolation barrier between the calciner and the hydrofluorinator. The feed vessel serves as a hopper for the hydrofluorinator screw feeder. Plutonium oxide is reacted to plutonium fluoride in the hydrofluorinator and is collected in cans at the opposite end of the unit. The plutonium fluoride is sent by conveyor to the metal reduction line.

The hydrofluorinator is designed to use excess HF, which must be scrubbed before it is exhausted from the building. The HF scrubber line accomplishes this with potassium hydroxide in a venturi scrubber. The liquid from this scrubber normally has only waste concentrations of plutonium and is transferred to tanks #20 and #21 for eventual disposal as liquid waste.

The reduction line is an inerted glovebox where plutonium fluoride is mixed in a magnesium oxide crucible with calcium metal and a pyrotechnic initiator. The crucible is then sealed in a pressure vessel and hydraulically locked into a reduction furnace. The reduction furnace heats the mixture, and the firing of the pyrotechnic initiator commences the reduction

reaction without the necessity of bringing the furnace system itself to high temperatures and pressures and maintaining them. Upon completion of the reduction cycle, the charge is cooled and the crucible broken. The plutonium metal button formed is separated from the sand slag and crucible and passed through an airlock to the pickling station where it is consecutively dipped in nitric acid and water, drilled to obtain a small sample for analysis, weighed and packaged for transfer to assay.

There are other aspects of the production operation that are not captured on the simplified flowsheet. Between the dissolving line and the wet processing line, there is a sample glovebox that consists of three sampling pumps for pre-ion exchange solutions, post-ion exchange solutions, and waste solutions. This glovebox is used to draw samples from the chemical tank farm. There is also the vessel vent system, located before the feed preparation glovebox. This system consists of a fan that draws a vacuum on process vessels to pull acidic vent gases through a potassium hydroxide scrubber before discharge to the exhaust system. A final modification of note is that waste solutions can be diverted to any of the waste tanks (#9 - #12, #17 - #21) if process upsets have led to excessive accumulation from any one process.

Other activities carried out in H Plant include assay and temporary storage. Special assay facilities and a vault are provided for product buttons. A contiguous area of the facility is used to store solid waste pails, assay them, and package them in TRU waste drums.

2.2.2 Detailed Process Descriptions

2.2.2.1 Feed Preparation

The feed preparation glovebox line serves to process oxides and residues as necessary to prepare them for dissolution. This effort consists of burning metallic fragments to oxide, breaking up large residue pieces into smaller pieces, weighing, batching, and temporarily storing material to be processed. The following stations are provided in the glovebox:

- Airlock entry;
- Unpackaging;
- Bag-in/Bag-out port
- Impactor;
- Furnace;

- Weighing and Batching;
- Storage;
- Chainveyor.

There is a hood on the maintenance side of the glovebox that allows placement of material in an airlock that can be opened from the operating side of the glovebox. The airlock is designed with 12" by 12" replaceable inlet and outlet HEPA filters. Oxide is received directly from the H-12 Plutonium Vault Facility. At the access hood, the oxide can is removed from its outer containment vessel and swiped for contamination. It is then placed in the airlock. Residue processed in H Plant consists largely of slag generated in the button forming process, which is brought to the hood in a sealed red plastic pail. The pail is opened in the hood, and the internal doubly bagged package is placed in the airlock.

The unpackaging station is simply an open area for removing the material from its primary packaging and placing it in a critically safe metal can. An automatic can opener is provided for opening sealed cans. Oxide cans and plastic bags are removed with glovebox waste through either a bagport or a Central Research Canister.

Oxide that has no metal fines or other contaminants is moved down to the weighing station where a dissolver batch is prepared and placed in a charge can. Incompletely oxidized material must be burned to oxide before it is sent to the dissolving line. This is accomplished in a small electric muffle furnace located in the glovebox, which can attain maximum temperatures on the order of 1200° F. The unit is sized to oxidize an entire plutonium metal button if necessary, and is insulated sufficiently to prevent exterior surface temperature from rising above a maximum of 125° F. It draws combustion air from the process air system via a small process air line with backflow preventers, and offgas from the furnace is routed to the vessel vent system. The complete burning and cooldown cycle is controlled by an automatic timer. The timer will not allow the furnace door to be opened before a preset minimum time has passed. The door is also interlocked with a temperature signal to prevent opening the door before the burn cycle is complete.

Cans of magnesium oxide are provided wherever oxide is handled in the glovebox. If metal fines were to ignite while the material was unpackaged, heat transfer through the stainless steel glovebox floor should put out the small fire. However, procedure calls for pouring the sand over the material to ensure this is the case.

Slag residues normally require some size reduction prior to dissolution. This is conducted in a small impactor installed in the glovebox. The device is mounted so as to prevent vibration

transfer to the glovebox itself, and is equipped with a hopper that physically prevents operators from reaching into the impaction area. The machine also is interlocked to shut off if the gloveport covers for this area are not in place during operation.

The impactor provides output material less than 1 inch in particle size. This material is then weighed and batched in the same manner as oxide. Only one set of impacted residue is allowed unbatched at a time to prevent inadvertent mixing of already assayed material, and the impactor unit is monitored continuously for holdup.

Once material has been placed in one of the spring-loaded batching cans, it can temporarily be placed in a shielded metal storage rack. The storage compartment can hold up to six batching cans at a time. When material is needed in the appropriate dissolving line, the chainveyor access door is opened and the batch can is placed in one of the carriers on the chainveyor system. The carrier is then sealed and the operator directs the material to either the oxide or the residue dissolution line.

2.2.2.2 Dissolving Line

The dissolving line consists of three physically separate gloveboxes installed as a single mounted unit. The three gloveboxes are for oxide, residue, and metal dissolution respectively. Feed to the oxide and residue gloveboxes comes from the feed preparation chainveyor. Feed to the metal dissolution glovebox is provided by a hood and airlock arrangement identical to that on the feed preparation glovebox. Feed material for the metal dissolution line comes directly from the H-12 Plutonium Vault Facility and consists of recycle material ready for processing upon receipt.

2.2.2.2.1 Oxide Dissolution

A simple representation of the oxide dissolution process is presented as Figure B.6. Plutonium oxide is dissolved in a concentrated nitric acid solution with fluoride catalyst (from potassium fluoride) at near boiling temperatures. Aluminum nitrate nonahydrate is added once dissolution is complete to minimize corrosion and break up any plutonium and fluoride complexes formed. The dissolver solution is transferred via air eductor vacuum through a cartridge filter to the vacuum run tank. The liquid is then transferred to the accountability tank through another cartridge filter by means of a liquid-to-liquid mixing eductor. From the accountability tank, liquid is transferred via a small gear pump to tank farm vessel #1 or #2.

The dissolver is a 30-liter slab vessel with a mechanical agitator. Numerous connection lines to the dissolver include a purge/flush line, a sample line, chemical

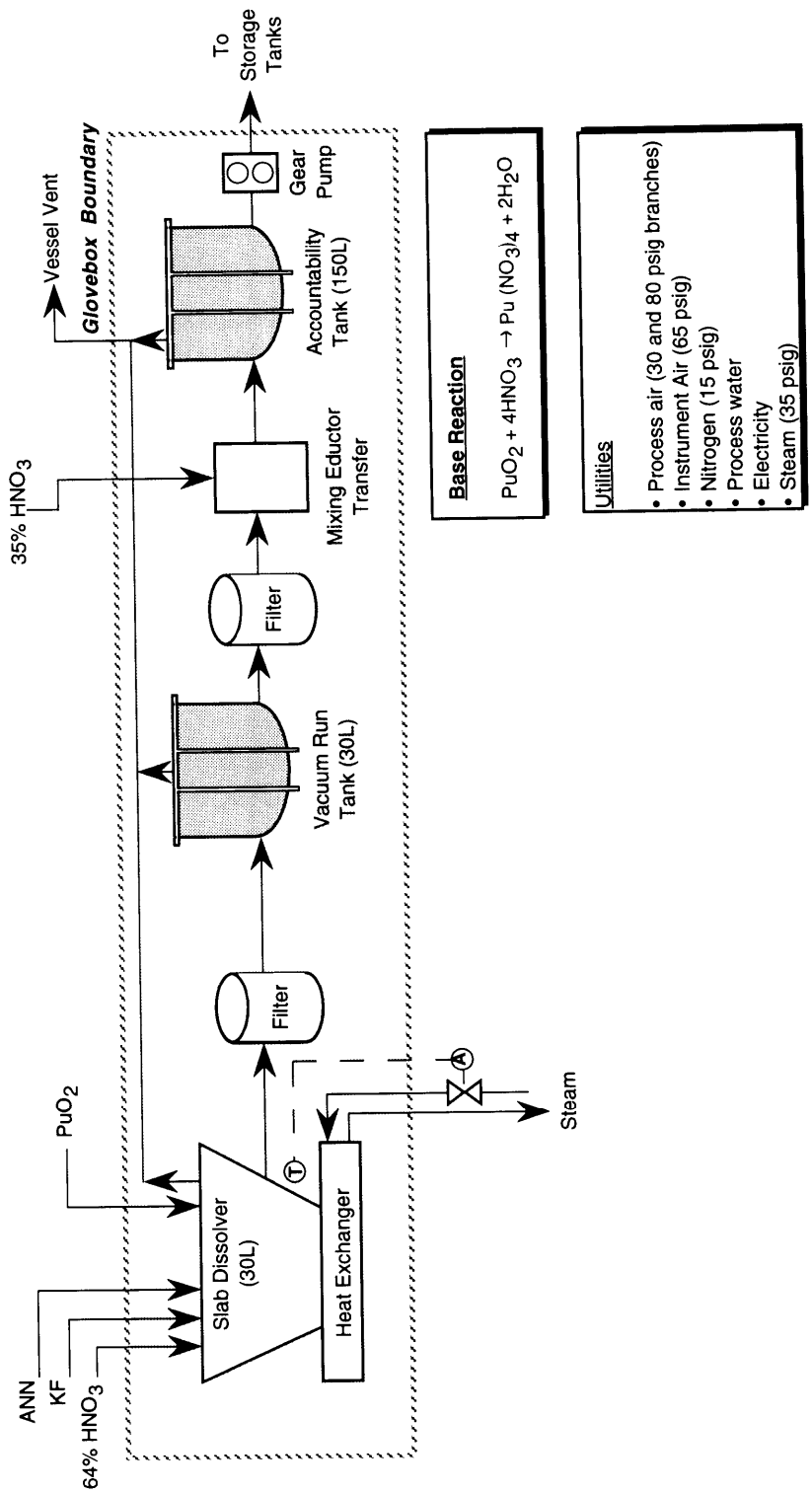


Figure B.6. Oxide Dissolution Line

addition lines, vessel vent connection, and instrumentation support lines. The vent line is always open, and as a secondary precaution, a weighted plug on the oxide charging port is designed to blow out below the rated pressure of the vessel.

Level and temperature indication are available for the dissolver vessel. The temperature signal is used to control the steam inlet valve to the dissolver heating block mounted on the bottom of the dissolver. It will completely close the valve if dissolver temperature reaches 206° F. The sump level interlock will shut the air-operated valves controlling nitric acid flow to the glovebox on high sump level. Finally, the dissolver vessel itself is continuously checked for plutonium holdup by an installed monitor.

The in-line filter elements used are 20-µm cartridge filters that can be backflushed with nitric acid or air/nitrogen if desired. The vacuum run tank is identical to the dissolver vessels. The liquid-to-liquid eductor system, which transfers the product solution to the accountability tank, mixes 35% nitric acid with the product solution to dilute it and reduce temperature. Liquid samples are drawn from the accountability tank by means of a sampling system previously described (section 2.1.5.7). This system can also take samples from the dissolver vessel. The accountability tank is a 150-liter slab tank. Its instrumentation and piping is similar to that of the dissolver vessels. After sample analysis in the H-3 lab annex, the solution is transferred by a small gear pump from this tank to tank #1 or #2 in the tank farm located on the maintenance side of the wet processing line. There, 35% nitric acid is added to create a total volume of ≈ 200 liters to reduce plutonium concentration to the range of 5 - 7 g/l.

2.2.2.2.2 Residue Dissolution

The residue dissolution line is essentially identical to the oxide dissolution line with one major and one minor exception. The major exception is that material is added to the stirred dissolver slowly to avoid a process eructation. Residue chunks are poured into a hopper that supplies material to a screw feed conveyer. The conveyer drops residue into the solution at a controlled rate via a sealed entry port. The minor difference between the residue line and the oxide line is that the dissolver and vacuum run tanks are 20-liter vessels, and the accountability tank is a 125-liter vessel. Product solution from this line is transferred to tank #3 or #4 in the tank farm located on the maintenance side of the wet processing line. There, 35% nitric acid is added, creating a total volume of ≈ 160 liters to reduce plutonium

concentration to the range of 5 - 7 g/l. A schematic of this system is presented as Figure B.7.

2.2.2.2.3 Metal Dissolution

Recycle metal dissolved in the H-Plant is received in a ready-to-process form. This metal contains an impurity whose dissolution is not desired. The metal dissolution process is designed to dissolve all of the plutonium metal while leaving behind an intact residue that is removed for shipment elsewhere. A schematic of this process is presented as Figure B.8. The metal is placed in a small 7-liter spray chamber and the lid on the system is locked. Then, 14% sulfamic acid is added to the 40-liter slab vessel below the spray chamber. Plutonium metal will dissolve in sulfamic acid in the temperature range of approximately 70° F to 195° F. However, a plutonium hydride sludge will form at temperatures below about 120° F, and accelerated dissolution of the impurity will occur at temperatures above 160° F. These two points effectively define the desired operating range. The steam flow control valve on the heat exchanger inlet line is controlled by a temperature sensor on the slab tank. Based on both the flowrate of the dissolving solution and the steam pressure, the valve is fully open at a temperature of 70° F and completely shut at a temperature of 125° F.

The dissolution reaction is exothermic and can accelerate above the desired upper temperature limit if temperature is not adequately controlled. It also produces hydrogen gas as a byproduct, and the production rate will increase with increasing temperature. This is more of a problem at the start of the reaction when sulfamic acid concentration is at its peak. In any case, the solution temperature must be controlled, and a potentially dangerous byproduct must be handled safely.

The basic operation of the system is a simple acid spray loop, where acid is transferred from the slab vessel by a small centrifugal pump and passes through a steam heat exchanger and an in-line cartridge filter before it is sprayed onto the metal. This liquid drains out of the spray chamber through an always open overflow line into the slab vessel. The 7-liter spray chamber has an always open vent line to the vessel vent system and a fail high temperature detector. A hydrogen detector samples the offgas to the vessel vent system, and a flame arrester is provided in the vent line before it exits the glovebox. The temperature detector provides signals to a high-temperature alarm if the temperature of the spray chamber outlet overflow exceeds 148° F and an interlock turns off the centrifugal pump if temperature exceeds 155° F. If hydrogen offgas concentration exceeds 2.5% (lower flammability limit in air is 4.0%), the pump is also automatically turned off. Without additional

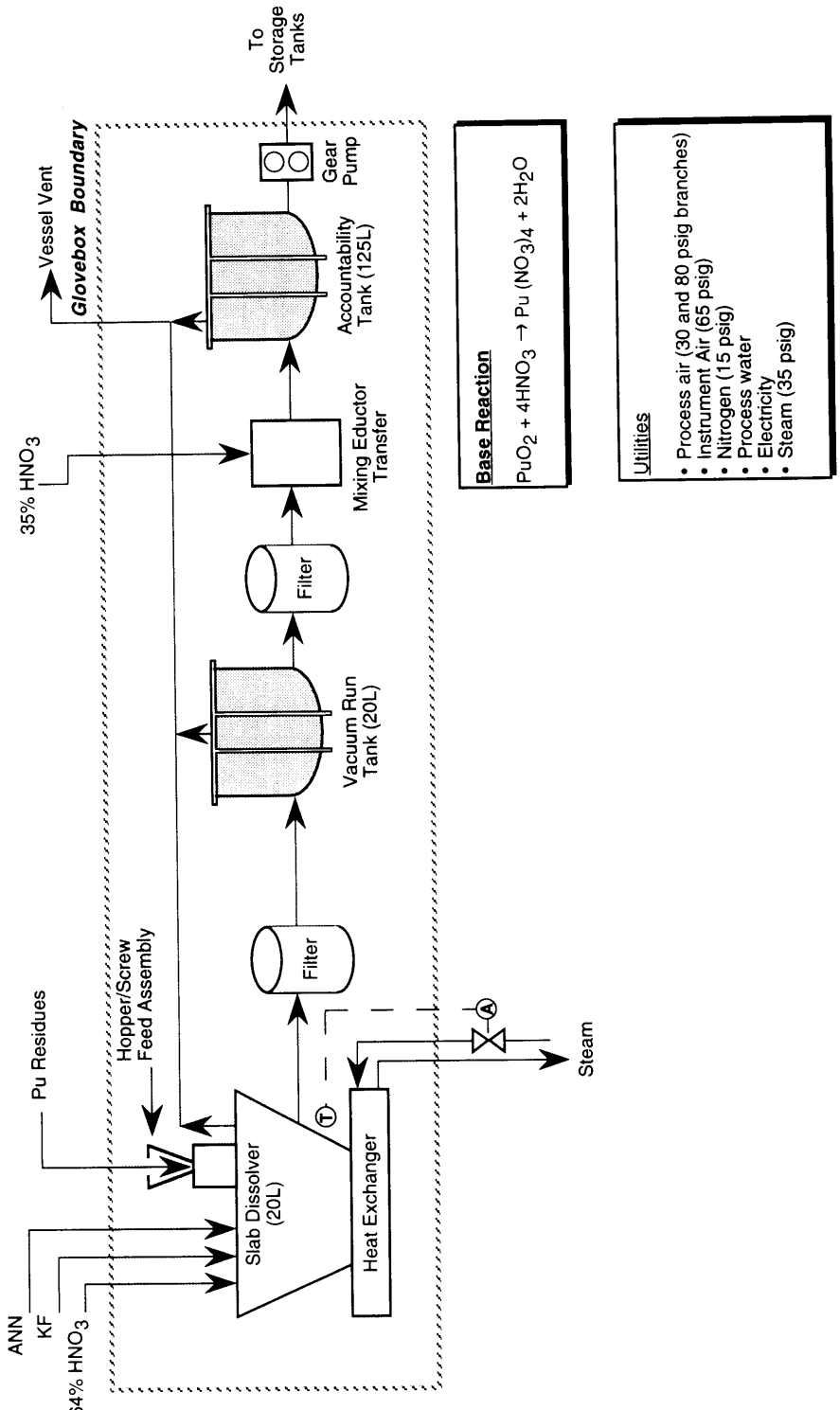


Figure B.7. Residue Dissolution Line

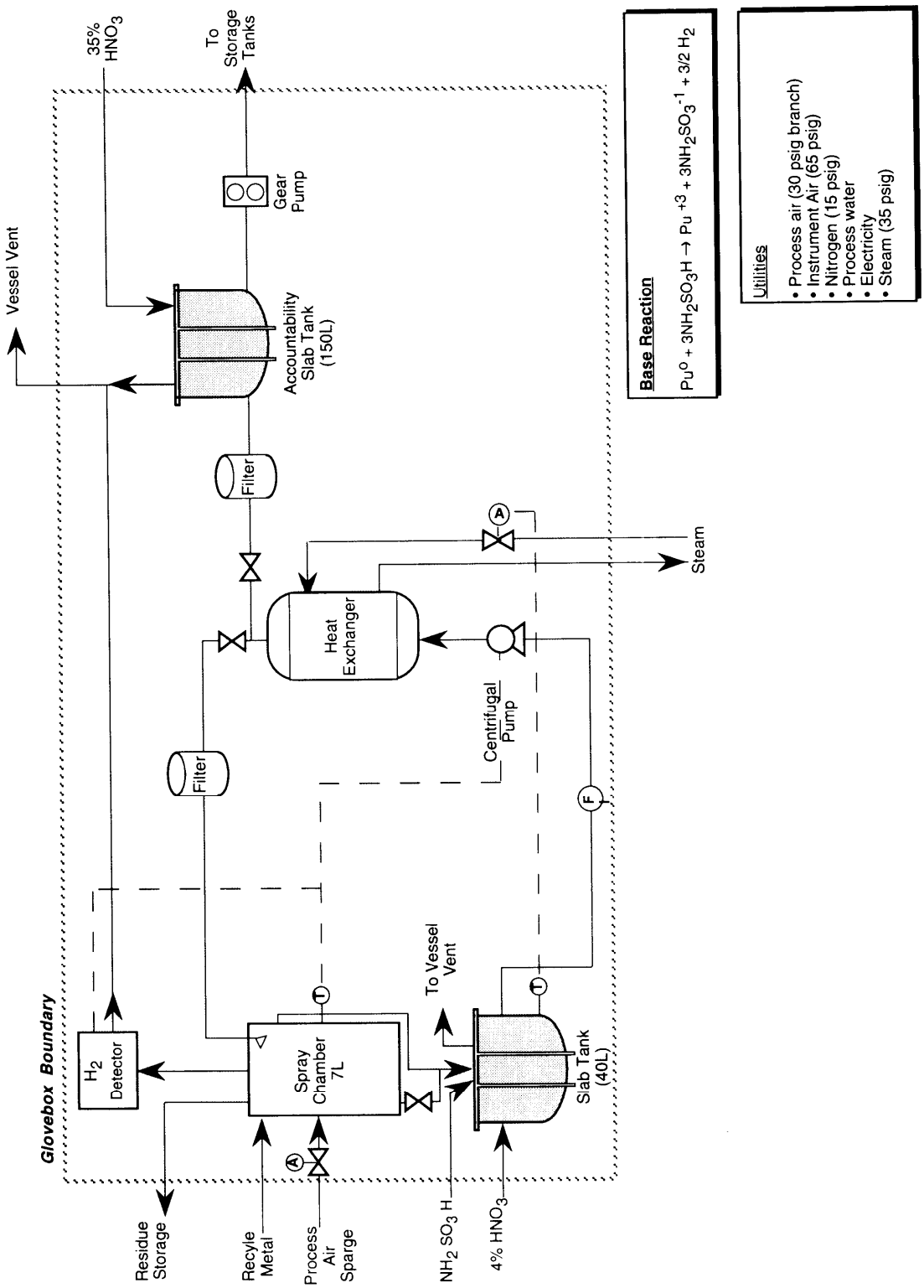


Figure B.8. Metal Dissolution Line

flow of heated acid, the reaction rate in the spray chamber, and thus the rate of hydrogen production, will decrease rapidly.

When dissolution is complete, the product solution is diverted into a 150-liter accountability slab tank. The spray chamber slab tank is then filled with 4% nitric acid that is recirculated through the spray chamber to passivate hydride if any is formed due to errors or unforeseen circumstances. This solution is then diverted to the accountability tank as well. Residue material is removed from the spray chamber and packaged for transfer from the facility. If any hydride is found, it is placed in a small milliliter plastic bottle with 4% nitric acid to keep it wet and passivated. A small portion of this material is transferred to the lab annex for assay and then returned to the oxide dissolution line, where it is added to the dissolver along with a special reduced oxide charge.

Before sampling and transfer out of the glovebox, 35% nitric acid is added to the accountability tank for additional cooling and to raise the acid concentration. An in-glovebox sampling system is used, and a gear pump is again used to transfer the product solution to tank #5 or #6 in the tank farm. There, 35% nitric acid and a limited amount of 64% nitric acid are added to reduce plutonium concentration to the range of 5 to 7 g/l and increase acid concentration.

The slab tanks have mechanical agitators, purge and chemical addition lines, always open vessel vent lines, and blowout plugs. Temperature and level indication are provided for both vessels, and pressure indication is provided for the spray chamber slab vessel. Installed detectors monitor plutonium holdup in both lines. Temperature indication for the steam heat exchanger is available as well. The sump level interlock stops major chemical addition to the glovebox as in all liquid processing gloveboxes.

2.2.2.3 Tank Farm

The tank farm consists of three separate enclosures containing annular storage tanks for process plutonium solutions and waste. There are a total of 21 tanks in the tank farm, which is located on the maintenance side of the wet processing line. It is placed there so the potential for tank leaks exists in only one maintenance room as opposed to multiple rooms or operating rooms. An additional advantage of placement in this room is immediate proximity to the sample glovebox, which minimizes the length of sample piping runs.

The tank farm enclosures are stainless steel rooms designed for ease of cleaning in the event of contamination from leaks. These enclosures are equipped with small exhausters leading to the room exhaust header to maintain them at a slight negative pressure with respect to the

maintenance room itself. The tanks themselves have support braces and mounts extending through the steel floor into the facility concrete floor below. In doing so, the braces pass through a shallow sump filled with borated raschig rings, which lies below an elevated steel grating upon which personnel walk. This sump is designed to ensure a criticality will not occur even if multiple tanks void their contents into this sump.

The tanks in this system are equipped with ever open vents to the vessel vent system and pressure relief valves that direct flow to the raschig ring sump. Level indication is available for each tank. High- and low-level alarms are provided locally and in the facility control room. Supply piping to and transfer piping from each tank goes to common headers to minimize the number of piping runs outside gloveboxes in the facility. Flow can be initiated to or from a given tank by remotely operated air-operated valves on individual tank piping leading to the headers. This capability was added to the system after initial construction to minimize the need for personnel to be in the actual tank farm area. Actuation of the air-operated valves is done at the appropriate local operating room control panel.

Lines going to and from the sample glovebox have identical air-operated isolation valves, but three separate headers with three separate sampling systems are used to minimize contamination and sampling error. The three systems are for pre-ion exchange dissolver solutions, post-ion exchange product solutions, and low-level waste solutions.

The tanks located in the three tank farm enclosures and their principal functions and capacities are listed below:

Enclosure #1

#1	-	Oxide dissolution storage tank	250 liters
#2	-	Oxide dissolution storage tank	250 liters
#3	-	Residue dissolution storage tank	250 liters
#4	-	Residue dissolution storage tank	250 liters
#5	-	Metal dissolution storage tank	250 liters
#6	-	Metal dissolution storage tank	250 liters
#9	-	Ion exchange effluent tank	400 liters
#10	-	Ion exchange effluent tank	400 liters
#11	-	Ion exchange effluent tank	400 liters
#12	-	Ion exchange effluent tank	400 liters

Enclosure #2

#7	-	Ion exchange eluate tank	235 liters
#8	-	Ion exchange eluate tank	235 liters
#13	-	Precipitator feed tank	190 liters
#14	-	Precipitator feed tank	190 liters
#15	-	Sump spill receipt storage tank	235 liters
#16	-	Spare non-waste tank	235 liters

Enclosure #3

#17	-	Distillate waste tank	400 liters
#18	-	Distillate waste tank	400 liters
#19	-	Distillate waste tank	400 liters
#20	-	HF scrubbing waste tank	400 liters
#21	-	HF scrubbing waste tank	400 liters

In actual practice, the tanks are not filled to their maximum capacity due to requirements to maintain a minimum level of freeboard.

2.2.2.4 Sampling

The sampling glovebox line is located directly north of tank farm enclosure #1 between the maintenance sides of the dissolving line and the wet processing line. It consists of three distinct sampling systems of the type previously described in section 2.1.5.7 and a slab vessel. The principal function of this glovebox is to draw liquid samples in 20-ml sample vials. Liquid is recirculated from the tank selected through a pump in the glovebox and back to the source tank. When sufficient recirculation or mixing occurs, the sample vial is inserted into the system and a sample drawn. A secondary purpose of this glovebox is to recirculate tanks if necessary for mixing.

The three sampling systems provided in the glovebox are completely independent and do not share pumps or piping. The first system samples the dissolver solution tanks (#1 through #6) before the ion exchange process has occurred. If a spill has occurred in a glovebox sump, necessitating the need to collect the solution in tank #15, the first sample system is used to sample this tank. The spare tank, #16, is normally jumpered into this system as well if it is being used. The second system samples the ion exchange eluate and precipitator feed tanks (#7, #8, #13, and #14). The third system samples the waste holding tanks (#9 - #12, #17 - #21).

The sampling glovebox also serves as the entry point for recycling sample solutions for recovery. Excess sample solutions are collected in 2-liter plastic bottles in the H-7 analytical lab. When one of these bottles is full, it is capped, bagged out of a glovebox, and placed inside a steel can that is locked shut. It is then hand-carried to the maintenance side of the sampling glovebox. The bottle is entered into the glovebox via an airlock and its contents are manually poured into a 100-liter slab tank identical in description to those found in the dissolving lines. Periodically, this tank is sampled and sent to the ion exchange feed tanks where any necessary chemistry adjustments are conducted.

2.2.2.5 Wet Processing Line

The wet processing line encompasses three gloveboxes that handle plutonium solutions to produce solid plutonium peroxide precipitate. These gloveboxes are the ion exchange line, the peroxide precipitation line, and the evaporation line. As with the dissolving line, the three gloveboxes are distinct but joined together structurally.

2.2.2.5.1 Ion Exchange

The ion exchange process is presented schematically as Figure B.9. It consists of three ion exchange columns in series with support equipment and piping. The columns themselves are 6-inch-diameter, 5.5-feet-tall Pyrex cylinders with flanged heads on top and bottom. Each column holds approximately 24 liters of Dowex 21-K anion resin or equivalent. The system is designed so that the plutonium processed in a given cycle will normally be absorbed on the first two columns, with the last column serving only as a safeguard against breakthrough.

The contents of four or five dissolving tanks are passed through the ion exchange columns in a complete extraction cycle. As noted in discussing the dissolving line, ion exchange feed concentration is adjusted to decrease the plutonium concentration to the range of 5 to 7 g/l. This prevents plutonium sulfates from forming and also assists in minimizing the chances of plutonium existing in the wrong valence in solution. Plutonium is loaded on the resin by pumping the dissolver solutions through the columns (upflow) after any additional chemical adjustments have been performed. Suction is taken on the appropriate tank by a gear pump in the ion exchange glovebox which directs flow through a filter and a steam-heated heat exchanger. The heat exchanger serves to raise solution temperature initially to approximately 120° F to decrease the loading time. The effluent from the ion exchange columns is transferred to effluent storage tanks #9 through #12 in the tank farm.

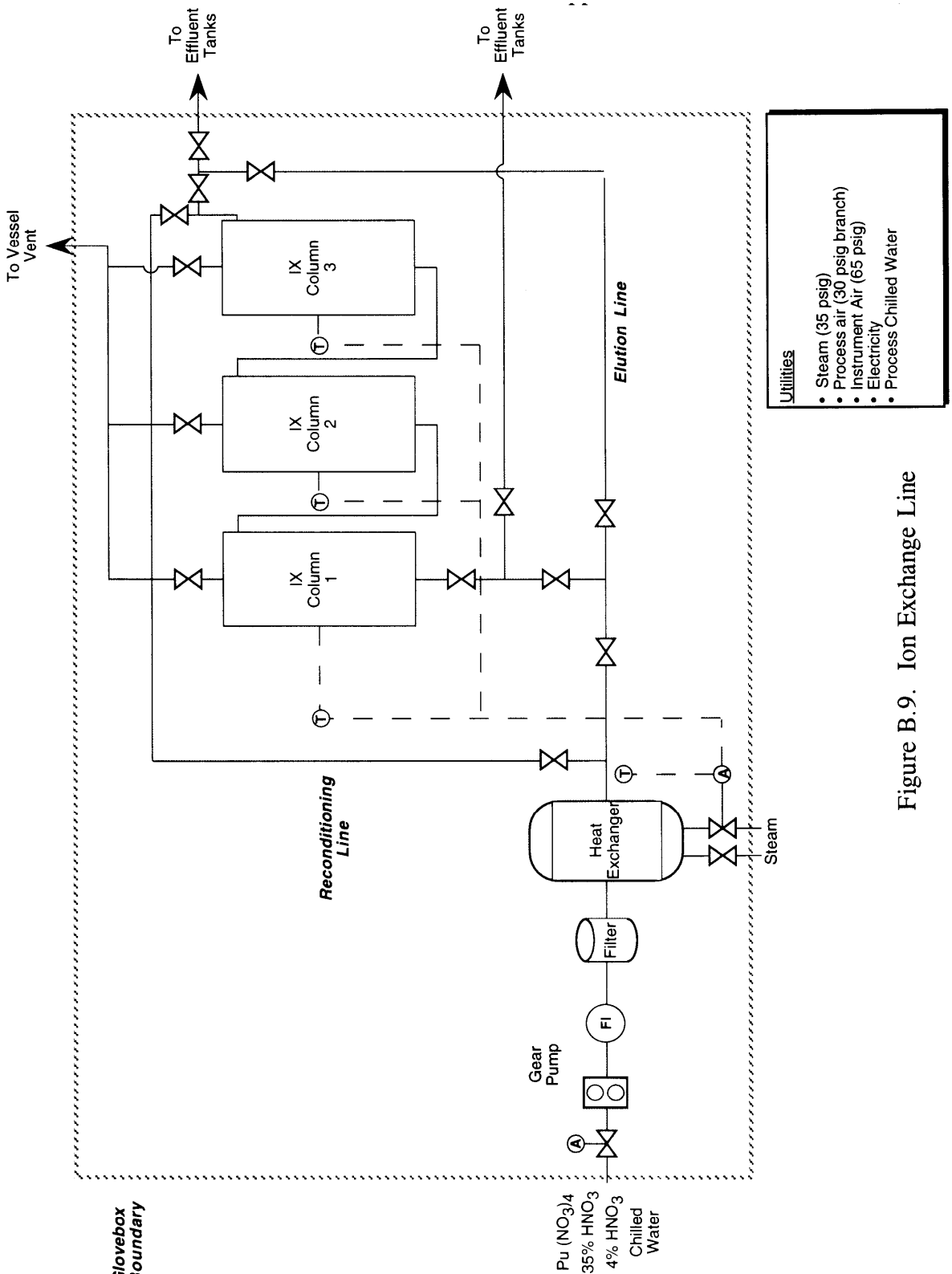


Figure B.9. Ion Exchange Line

After loading, the resin is washed with 35% nitric acid to remove impurities absorbed on the resin. This wash cycle is directed to the effluent storage tanks as well. The columns are then eluted (downflow) with 4% nitric acid, which produces a purified plutonium nitrate solution that is directed to eluate tanks #7 and #8 in the tank farm. The final portion of the cycle consists of providing a reconditioning flow of 35% nitric acid through the columns. These cycles are also conducted at approximately 120° F to shorten cycle time. All of the flow alignments associated with this cycle are conducted by operator repositioning of manual valves. Temperature sensors on the columns or on the outlet of the heat exchanger provide an alarm at 128° F and will shut the air-operated steam inlet valve if temperatures reach 135° F. Vent lines are also provided on the ion exchange columns, which go to the vessel vent system. Temperature, flow, and pressure indications for the system are provided locally and in the facility control room. The sump level interlock stops major chemical addition to the glovebox as in all liquid processing gloveboxes.

2.2.2.5.2 Eluate Evaporation

It is necessary to evaporate a portion of the eluate solution to provide peroxide precipitation feed concentrated enough for efficient product formation. This is accomplished in the evaporation line, which has two virtually identical evaporation systems. One is used for evaporation of ion exchange eluate, and the second is used for evaporation of precipitation filtrate. A simple schematic of the eluate evaporation system is provided as Figure B.10.

The evaporator unit itself is constructed of steel mesh reinforced Pyrex and consists of three critically safe cylinders joined by critically safe tubes. The system draws solution to the center, or evaporator portion of the unit, by gravity flow from a small slab head tank mounted in the overhead of the glovebox. This head tank is filled from eluate storage tanks #7 and #8 via a gear pump in the glovebox. Sloping lines lead to a reboiler that is heated by process steam in sheathed heating coils. Bottoms are drawn off to provide precipitation feed via a manually set throttle valve. A condenser cooled by chilled water is used to liquify the distillate from the unit, which is then pumped to tank farm vessels #17 through #19. Bottoms leaving the evaporator are driven by gravity and evaporator pressure through a cartridge filter and a chilled water heat exchanger to one of two pencil tanks in the glovebox. These tanks are critically safe because bottoms concentration cannot be known exactly, and the potential for excessive concentration exists. The bottoms are sampled via a small in-glovebox sampling line to verify plutonium concentration before pumping to tank farm vessels #13 and #14.

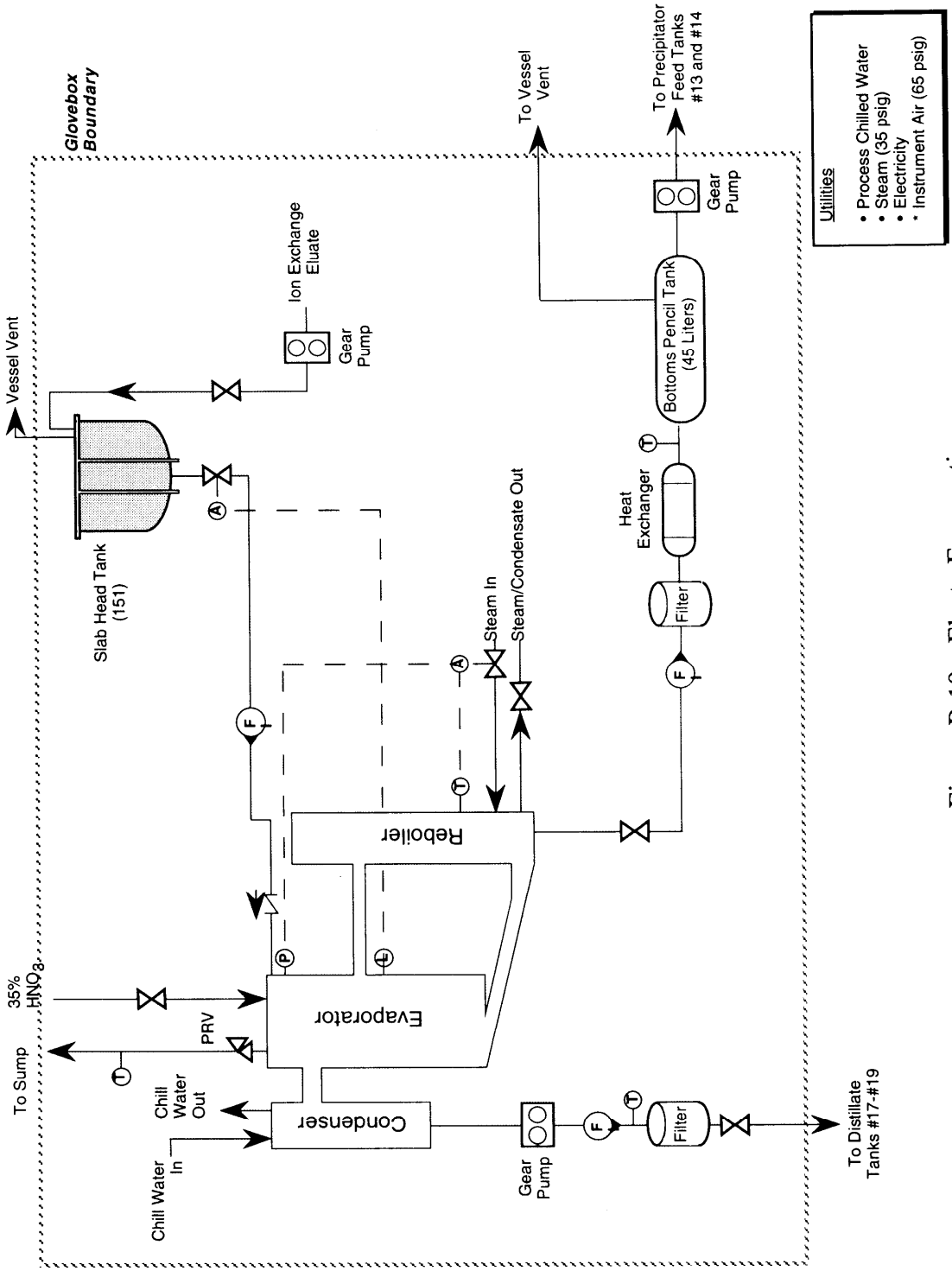


Figure B.10. Eluate Evaporation

The evaporators are equipped with a level, temperature, and pressure indication. Flow indication is available for all streams, as is temperature indication for exiting streams. Level indication is used to automatically control the feed inlet valve. Temperature indication controls the steam inlet valve, and is backed up by an automatic shutoff of the valve for high pressure. The evaporator column is also equipped with a pressure relief valve that lifts at 10 psig and leads to the glovebox sump. It initiates an alarm upon lifting. The pencil tanks are also equipped with relief valves leading to the glovebox sump. As in other liquid lines, the sump level interlock stops major chemical and feed addition to the glovebox.

2.2.2.5.3 Peroxide Precipitation

A simple schematic of the peroxide precipitation system is provided as Figure B.11. After chemical adjustment as required, the precipitate feed is drawn from tank farm vessels #13 and #14 by a gear pump and sent to the peroxide precipitation vessel. Initially, the solution transfer to the precipitation vessel is as a single batch. A commercial packaged refrigeration unit provides a source of chilled water that circulates through coils located within the vessel. The precipitation vessels are constructed of Pyrex and maintained at approximately 60° F to suppress peroxide decomposition.

When the desired temperature has been obtained, a batch addition of 35% hydrogen peroxide is made to the precipitation vessel. As the peroxide precipitate forms, a slurry develops that cascades over into a digestion vessel that is also maintained at approximately 60° F. Hydrogen peroxide is added to the digestion vessel almost to the point at which liquid will overflow from the digester to the rotary drum filter. When a distinct separation has occurred between liquid and precipitate in the digester, indicating a stable condition, the liquid is vacuum-drawn through the drum filter, and nitrate solution and peroxide addition begins at a continuous rate.

The reaction is completed in the digestion vessel, and the final slurry cascades over into the vacuum drum filter. Liquid is drawn through the filter media to the drum center by a vacuum, leaving the peroxide precipitate cake on the filter media. As the drum revolves, the cake is washed by a dilute nitric acid spray and then cut off the media by a fixed horizontal knife known as a doctor blade. The peroxide cake falls off into a storage container mounted on a load cell. When full, the container is replaced on the load cell, sealed, and sent by chainveyor to the calcination line.

Filtrate from the drum is collected in a slab tank and transferred to the evaporation line. The slab tank and the precipitation vessels are steel mesh, reinforced Pyrex

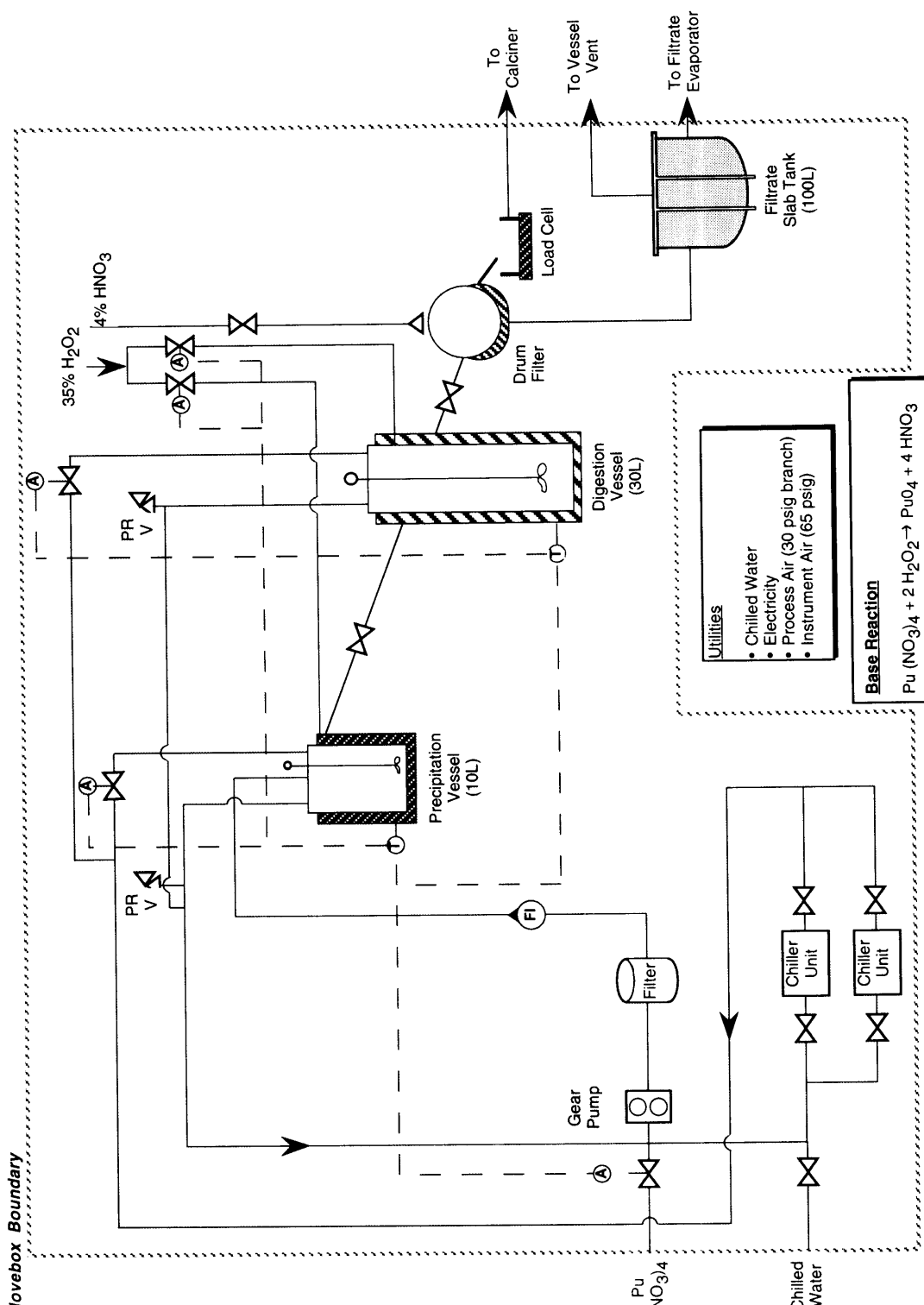


Figure B.11. H_2O_2 Precipitation Line

vessels. They are equipped with constant rpm, motor-driven agitators that are designed to prevent formation of fine precipitate. The lid over the vessel is fitted with a blow-out plug in the event of overpressurization of the vessel. Temperature control is provided by chilled water flowing through coils in the vessels. This water is continuously recirculated through package chillers mounted in the bottom of the glovebox. Make-up water to these chillers is provided by process water.

The filtrate slab vessel is made of Pyrex reinforced with stainless steel. It is equipped with level indication, an always open line to the vessel vent system, and a blow-out plug. Temperature indication controls chilled water flow rate and, on high temperature indication, shuts hydrogen peroxide and plutonium feed supply valves and turns off the plutonium feed gear pump. The load cell is equipped with both local and remote weight readouts, and an alarm. As in other liquid lines, the sump level interlock stops major chemical and feed addition to the glovebox.

2.2.2.5.4 Filtrate Evaporation

This system is identical to the eluate evaporation system previously described. It concentrates the filtrate, which contains greater than discard limits of plutonium. The bottoms from the unit are sampled to verify concentration and then transferred to the dissolver solution storage tanks as recycle material. The distillate is discharged to waste storage vessels #20 and #21 in the tank farm.

2.2.2.6 Dry Processing Line

The dry processing line consists of three distinct but structurally joined gloveboxes that turn peroxide cake into plutonium fluoride. These gloveboxes are the calcination line, the hydrofluorination line, and the HF scrubbing line. The dry processing line does not draw room air in for ventilation as previous lines did. It is supplied dry air via ducting, and is equipped with humidity alarms. Dry air is needed to ensure material is not contaminated with water. Such contamination could prevent formation of an acceptable product.

2.2.2.6.1 Calcination

The calcination line turns plutonium peroxide cake into plutonium oxide for feed to the hydrofluorination line. A simple schematic of the line is provided as Figure B.12. Temporary storage racks for plutonium peroxide containers are available in the calcination line to allow feed to accumulate for a calciner run. This material is initially placed in a drying vessel that pulls air through at ambient temperature for the first cycle and elevates the temperature to approximately 130° F for the second cycle.

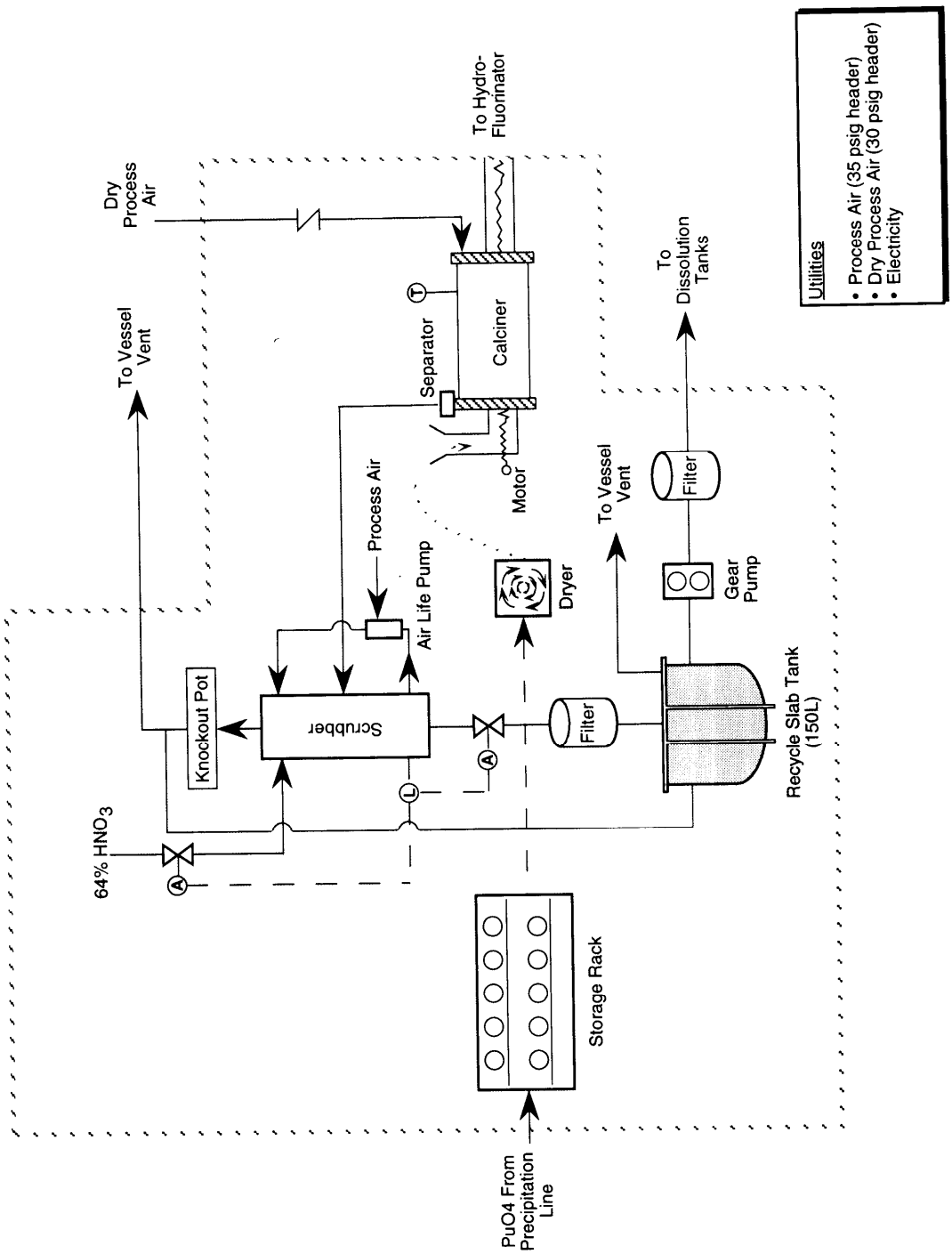


Figure B.12. Calcination Line

This initial drying cycle allows the use of lower temperatures in the actual calciner, thereby producing an oxide that is easier to fluorinate.

Upon completion of the initial drying cycle, the cake is manually placed in the calciner feed hopper where a screw auger drives it into the cylindrical calcining vessel. Dry air is passed countercurrently through the calciner, which operates at approximately 700° F. The internal sheath of the calciner rotates during operation to ensure even heating. This rotation is driven by a hydraulic unit mounted in the floor of the glovebox. The auger drives the product plutonium oxide out of the calciner and through the glovebox wall into the hydrofluorination line.

Due to the flaky nature of the peroxide cake and design difficulties with the air flowpath within the calciner, the offgas from the unit normally has recoverable quantities of plutonium even after passing through a baffle separator. Therefore, a scrubbing column is installed in the line as well. It is a 6-inch-diameter stainless steel pipe containing 64% nitric acid. The acid is recirculated via an airlift pump and cooled as necessary via a chilled water heat exchanger. The acid, containing the dissolved plutonium oxide, is periodically bled from the tank manually. New acid can be added manually as well.

The acid bled from the scrubber is collected in two stainless steel pencil tanks in the glovebox. These tanks are equipped with level instrumentation and relief valves that discharge to a sump in the vessel. A gear pump in the glovebox discharges the vessel contents to one of the dissolver solution storage tanks through a cartridge filter after a sample has been drawn from the interior glovebox sampling system to verify plutonium concentration. The air exhausting from the scrubber goes through a knockout pot and to the vessel vent system.

The glovebox sump is alarmed, but there is no interlock because liquid enters the glovebox only by manual opening of valves. The drying unit and the calciner are both electrically heated and are equipped with high temperature shutdown interlocks.

2.2.2.6.2 Hydrofluorination

As noted above, the hydrofluorination unit is physically joined to the calcining unit by common piping. The auger that drives material through the calcining unit stops at a dropoff point. At this point, the plutonium oxide is scooped up by a paddle wheel machined to maintain a physical isolation barrier between the calciner and the hydrofluorinator. This wheel drops the oxide into a 6-inch-diameter cylinder with a slow moving stirrer to prevent clumping. The feed auger for the hydrofluorinator is

located at the bottom of this cylinder. The cylinder is sized sufficiently to allow for holdup during a product run to account for the shorter residence time of the calciner. Normally, however, a significant portion of the lag space is not used as the calciner is simply fed at less than its full capacity rate.

A drawing of the hydrofluorination system is provided as Figure B.13. The rotary tube hydrofluorinator provides high temperature contact between the plutonium oxide generated in the calciner and a counter-current stream of hydrogen fluoride gas in dry air to generate plutonium fluoride. The reaction occurs in two zones within the unit, the first of which is heated to approximately 750° F and the second to approximately 1100° F. Fluorinated product passes through a breech seal and is deposited via high temperature isolation valves into a 6-inch-diameter metal product chamber. The chamber is isolated from the hydrofluorinator, and an outlet valve to the metal chamber is opened. Product flows out with the assistance of a dry air purge and is deposited in a container on a load cell. The container is manually placed in a chainveyor for transfer to the button reduction line.

The offgas from the hydrofluorinator contains sufficient HF gas that, if left untreated, it could cause a severe corrosion problem in ducting. As a result, the offgas from the unit passes into the final glovebox in the dry line where a caustic scrubbing system neutralizes the offgas before passing it on to the vessel vent system.

The hydrofluorination line is heavily shielded due to the high-neutron density associated with the interaction between alpha particles from the plutonium and fluorine. The dry line operating and maintenance rooms are segregated into two halves by shielding walls, which separate the calciner from the hydrofluorinator. The hydrofluorination glovebox itself is covered by a Benelex wall with sliding cabinet doors over the windows and gloveports. A second Benelex wall several feet from the cabinet further compartmentalizes the operating room. Operators normally enter the inner compartment and access the glovebox windows only to load product containers and place them into the chainveyor.

The hydrofluorinator system is designed to run with minimal operator supervision. The valves for loading product are remote-controlled air-operated valves, and a remote readout for the load cell is provided as well. The rotary unit in the hydrofluorinator is motor driven instead of hydraulically driven to reduce maintenance requirements. Fluorine detectors in the exhaust ventilation and in the operating rooms are designed to shut the air-operated HF inlet line and turn off the hydrofluorinator if 2 ppm of HF is detected.

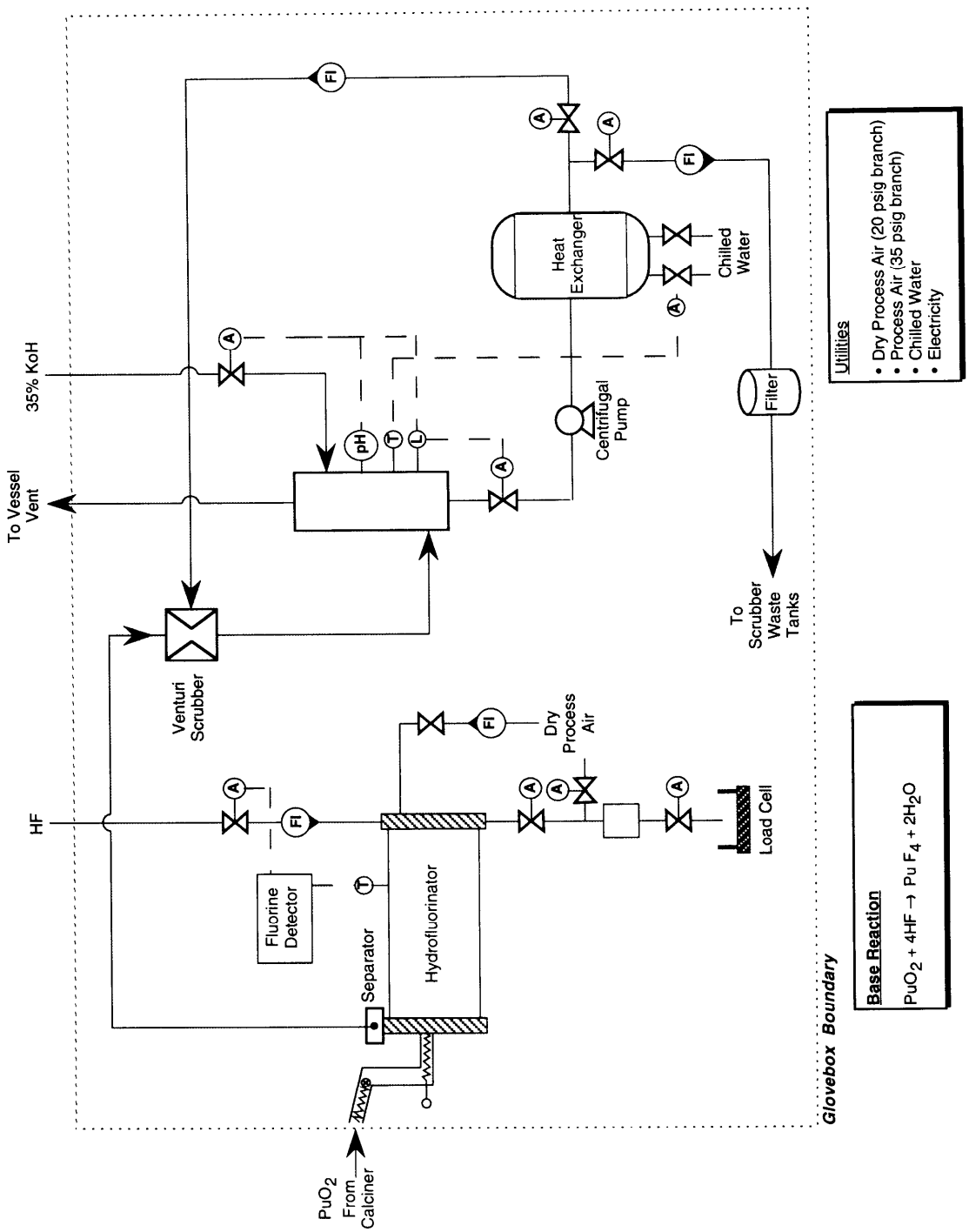


Figure B.13. Hydrofluorination Line

2.2.2.6.3 HF Scrubbing System

As noted above, the last glovebox in the dry line scrubs the hydrofluorinator offgas. In this system, 35% KOH is circulated by a small centrifugal pump into a venturi scrubber, where it is intermixed with the hydrofluorinator offgas. The scrubbed mixture than passes into a 6-inch-diameter tank, where the offgas bubbles up through 35% KOH and passes on to the vessel vent system.The centrifugal pump takes suction on this small KOH tank and sends the solution through a chilled water heat exchanger to remove the heat generated by the neutralization reaction. This liquid then goes back to the venturi scrubber. Periodically, liquid from the system can be blown down to scrubber waste tanks #20 and #21 via an air-operated valve.

A pH detector provides remote readout, a low pH alarm, and a low-low signal that automatically opens the 35% KOH supply line. The level detector that controls the liquid outlet line from the collection tank will also override the PH signal to the supply line if tank level is too high. A temperature sensor in the collection tank also provides control input to the chilled water inlet valve on the heat exchanger. This glovebox is the only one in the dry line equipped with a sump and associated level alarms and interlocks.

2.2.2.7 Reduction Line

Plutonium fluoride powder is received in the reduction line via a chainveyor from the hydrofluorination glovebox. There is a limited storage area with two storage spaces available in a rack, but the normal practice is to begin the reduction procedure as soon as plutonium fluoride is received for two main reasons. The first is, again, the desire to keep plutonium fluorides in line for as limited a time as possible from an ALARA perspective. The second is to keep the material dry so that moisture-induced pressure rises do not occur in the actual metal formation step. The reduction line is inerted, but standard procedure is that plutonium fluoride cannot be left cumulatively standing in the hydrofluorinator glovebox and the reduction line more than 24 hours and then used in the process. It must be heated in an argon atmosphere in a small muffle furnace in the reduction line and resampled before it can be used in the process.

The reduction process is schematically represented in Figure B.14. The first step in the reduction procedure is to use one of the two balances in the line to prepare a plutonium fluoride charge. The load cell, like all of the load cells used in H-Plant, is a basic pressure-sensitive transducer with digital readout of weight in grams. The plutonium fluoride charge container is then placed in a slightly recessed well in the glovebox floor near the preparation station.

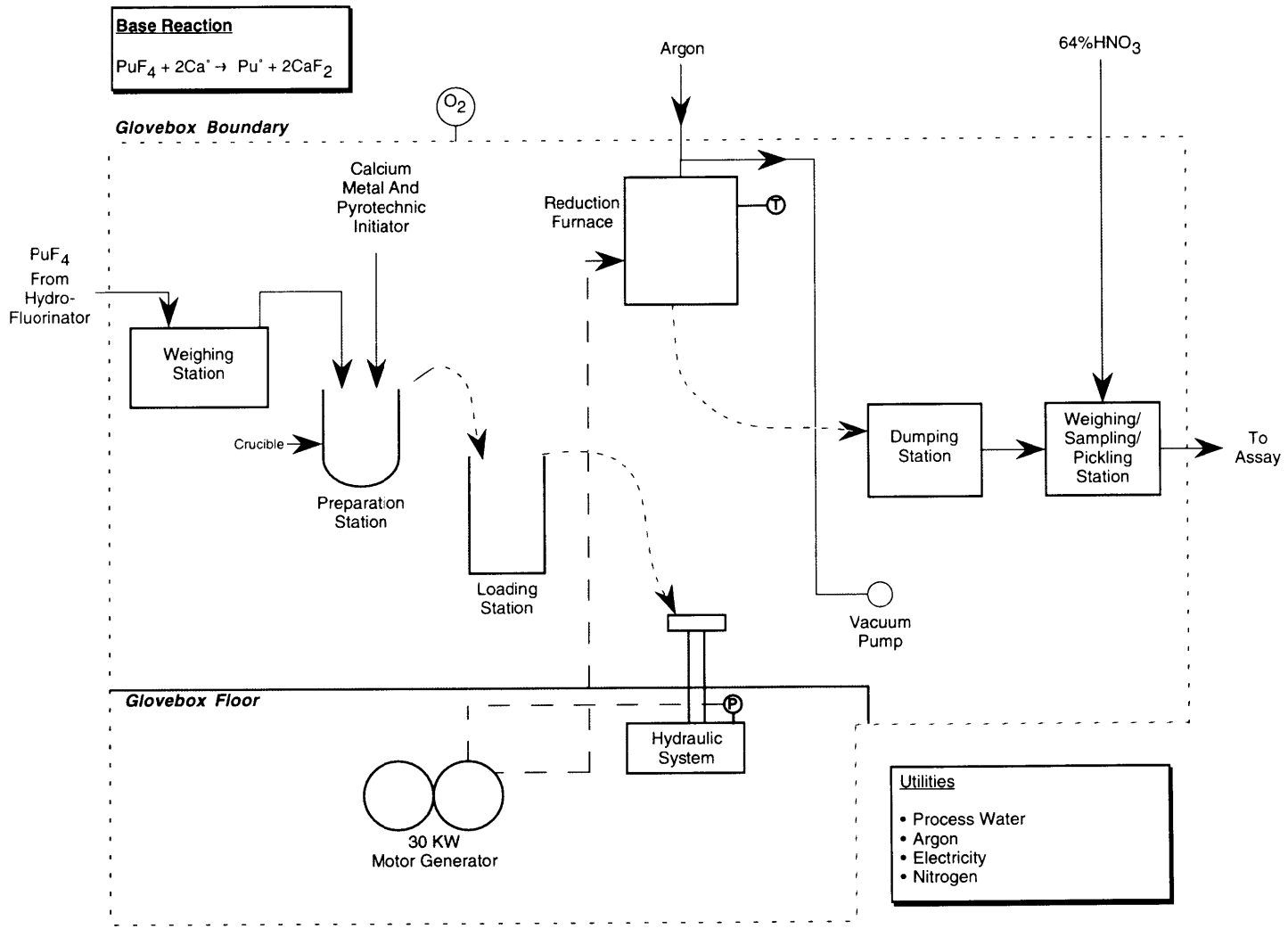


Figure B.14. Reduction Line

Calcium and pyrotechnic charges are brought into the line via an airlock on the back wall of the glovebox. In-line storage of these materials is prohibited, and only the quantities needed for a given charge are brought into the glovebox. The weight of the calcium charge is reverified, and then the plutonium fluoride, calcium, and two pyrotechnic initiators are loaded into a magnesium oxide crucible. The initiators reduce the ignition temperature required for commencing the reduction reaction, thus reducing the ultimate reduction pressure.

The crucible is then moved to the loading station, where it is placed inside a stainless steel reduction vessel packed with sand. The reduction vessel is mechanically a simple steel can of sufficient dimensions to withstand an internal pressure of 700 psig at 3100° F. It serves as the pressure vessel for the reduction reaction, while the inner magnesium oxide crucible prevents intermetallic reactions that would ruin the product from occurring between molten plutonium and the walls of the can. After loading, the pressure vessel is covered with a stainless steel lid that will be sealed to the reduction furnace head by a copper gasket designed to fit machined grooves on the lid.

The reduction vessel is then placed in the recessed portion of the hydraulic piston face. There are two pistons in the line, one for each furnace. They lift the reduction vessel up and seal it against the top of the furnace shell. Each furnace is a cylindrical stainless steel vessel with interior water-cooled induction coils, with power supplied by a common 30-kW, 10-kHz motor generator set. The piston raises the pressure vessel until it is inside the induction coils and seals the furnace with approximately 24,000 pounds total force. Interlocks prevent energizing the heating coils and deenergize them if the hydraulic pressure is at any value below its normal full rating or if the piston is not raised to its full stroke height.

The reduction furnace is evacuated by one of two small vacuum pumps, and the chamber is then pressurized to 5 psig with argon. An opening is provided in the furnace head for a manifold inlet that allows evacuating and inerting the furnace. Inerting is required because oxygen in the furnace would cause plutonium oxide formation, thus reducing product yield. Argon is used instead of nitrogen for the same reason, with plutonium nitride being the contaminant of concern.

The reduction process begins with a gradual heating of the pressure vessel. At a temperature in the range of 60° C to 150° C the pyrotechnic initiator will fire and the highly exothermic reduction reaction will commence, as noted by a sharp increase in temperature indication on the outer wall of the pressure vessel. Temperatures within the pressure vessel will rise to levels sufficient to melt the reaction products and ensure that the calcium/fluoride residue slags will remain molten long enough to allow the elemental plutonium to coalesce in the bottom of the pressure vessel. The control system has a timing unit that will secure heat to

the furnace if the reduction reaction does not begin within a set time period. The same control circuit will initiate another timing cycle that will not allow lowering of the piston and retrieval of the pressure vessel until a 6-hour cooling period has been completed.

After the reduction reaction has occurred, the induction coils are deenergized and a small argon purge is initiated while the furnace cools for 3 hours. The piston is then lowered, dropping the pressure vessel out of the reduction furnace. The pressure vessel is removed, undisturbed, and placed in one of six recessed wells, where it is allowed to cool for an additional 4 hours. At the end of this time, the pressure vessel is placed in a dumper. This simple mechanical device merely inverts the chamber, dumping the plutonium button, and the sand, slag, and crucible onto a stainless steel pan. At this point, the maximum temperature of the material should be no more than 100° F.

A hammer is used if necessary to break up the crucible, and the finished button is moved to the pickling station. This station and the remaining equipment, though structurally part of the same glovebox, are separated from the rest of the reduction line by an airlock. The button is moved through this airlock and dipped in a small (2 liters) bath of 35% nitric acid to dissolve any slag adhering to the button. The acid is then washed off the button by immersion in an identical water bath.

The button then moves to the sampling station where a 3/8" drill is used to obtain a small turning sample for analysis. The sample is placed in a small glass vial and transported to the H-7 analytical lab. The button moves on to a weighing station, where it is independently weighed twice. The weight of the button is recorded and assigned a tracking number on the accountability computer. Then it is placed in a steel can that is crimp-sealed. The steel can is bagged out of the glovebox and sealed by an electrically heated portable bag sealer. The complete package is then sealed inside a second steel can.

Historically, this unit has experienced failure of the furnace pressure seal on four occasions in the early to mid-1970's. In two of these instances, small fireballs travelling the length of the glovebox were observed as the inerting system was not routinely used at that time. In these cases, minor damage to glovebox gloves occurred and contamination was released to the operating room. However, there was no indication of major plutonium losses from the reduction crucible. The cause of the multiple pressure seal failures was traced to improper gasket design or use and, on one occasion, bypassing of piston interlocks. The last instance in 1976 involved reuse of a deformed gasket. No such incidents have occurred since the concluding investigation in 1976, which also resulted in the decision to use pyrotechnic initiators to reduce ultimate reduction pressure.

2.2.2.8 Vessel Vent

The vessel vent room is essentially the utility room for the plutonium processing line. It houses the vessel vent system, the process steam condensate tanks, and the process chilled water compressor.

A drawing of the vessel vent system is provided as Figure B.15. It consists of a typical packed column scrubbing system with the flow-driving equipment contained in small gloveboxes. The purpose of the system is to draw acidic vapors from the tanks to pass them through a weak caustic solution for neutralization. The scrubbed vapors can then be sent to the main exhaust plenums without creating potential concerns relating to chemical interaction with filters.

The vessel vent header in each glovebox is sloped to drain any liquid entering the header into small knock-out pots. The drain line entering each knock-out pot has its end submerged in a liquid seal in order to maintain negative pressure in the vessel vent system. Vapors passing into the header pass through a cyclone separator in the vessel vent room, which disengages any residual liquid into a 2-foot-diameter knock-out tank filled with borated raschig rings. The vapor then enters the bottom of a packed bed scrubber, bubbling up through a liquid sump containing borated raschig rings, and then passes through the main bed of raschig rings. 15% KOH is flowing downward through the packed bed as the neutralizing medium. Vapors exit the scrubber through a series of demister pads and are then drawn into the small blower glovebox where one of two centrifugal blowers sends them to join the main exhaust ventilation upstream of HEPA filtration.

KOH solution at the bottom of the scrubber is drawn by one of two on-line pumps through a heat exchanger to the top of the scrubber tower where it is sprayed onto the packed bed. The small centrifugal pumps used in this system are, like the air blowers, housed in a small glovebox. The heat exchanger uses process chilled water to prevent heat buildup due to the exothermic nature of the neutralization reaction. The flow in this loop is periodically directed to a raschig ring blowdown tank to remove depleted caustic and water generated by neutralization. This tank and the knock-out tank can be recirculated for sampling or directed to the liquid waste header leading to the H-8 treatment facility by a small centrifugal pump located in the pumping glovebox.

Level indication is available for all of the tanks in this system. Temperature indication is provided for the heat exchanger outlet and the scrubber tower sump. A pH measurement device is also used to control the rate of blowdown and fresh caustic addition. Although the drawing provided shows only one system, there are actually two of each tank to allow maintenance on one tank while the other continues to support operation.

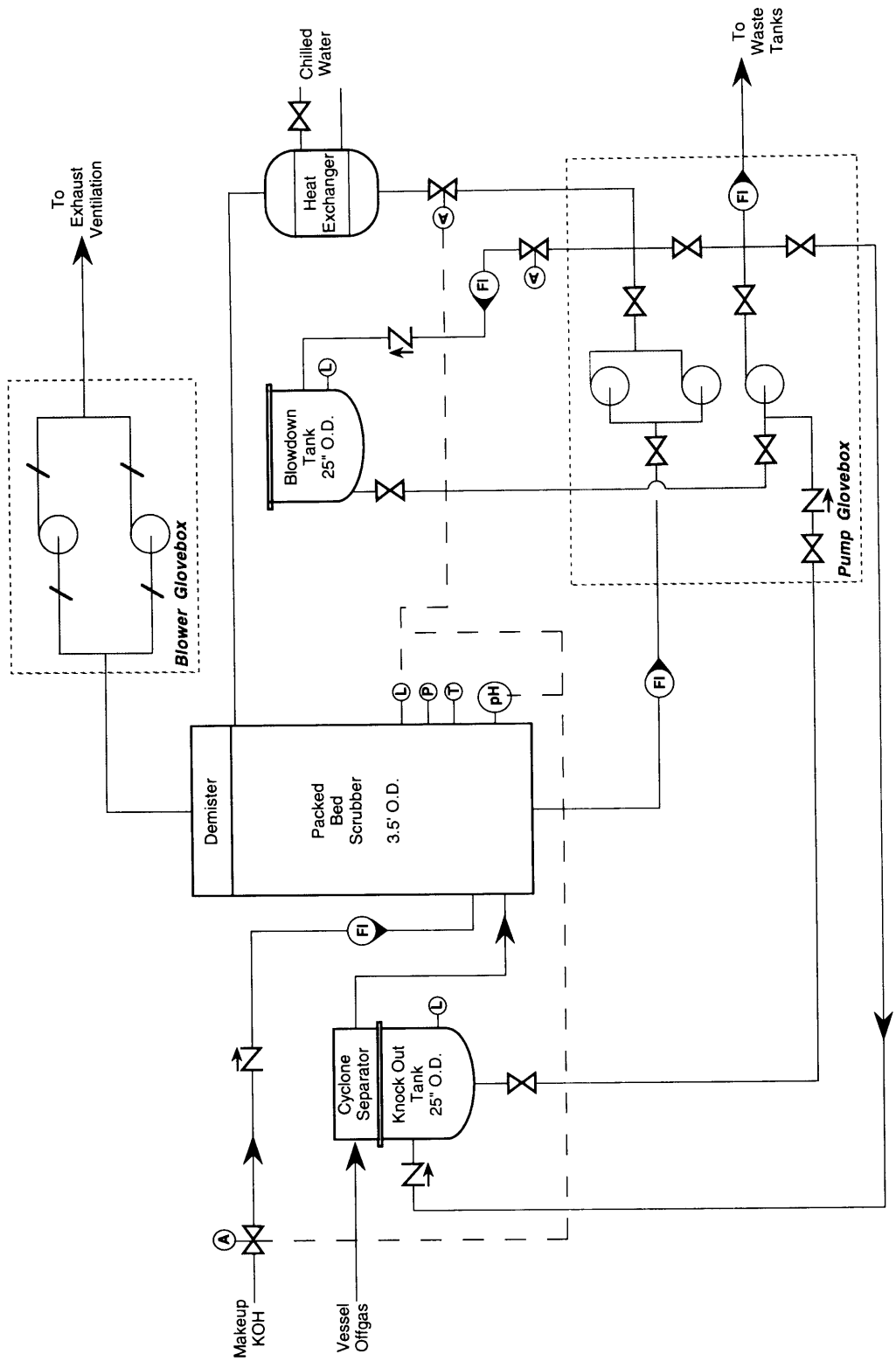


Figure B.15. Vessel Vent

Two raschig ring-filled process steam condensate tanks are located in the vessel vent room. They receive condensate from steam heat exchangers in the process. Recirculation, sampling, and transfer lines are provided along with a centrifugal pump not located in the pumping glovebox. Condensate is periodically sampled to verify it is not contaminated and then returned to the reboiler in the facility utility room.

The final major system, housed in the vessel vent room, is the process chilled water system. It consists of a raschig ring-filled chilled water supply tank, a package commercial refrigeration unit, and a centrifugal driving pump that is also not located in the pumping glovebox. The purpose of this system is to provide a source of process cooling water that is not directly tied into the plant water mains. This tank is periodically sampled as well and flushed to the sanitary sewers upon verification that the water is not contaminated.

2.2.3 Process Associated or Byproduct Operations

To provide a complete description of the operation of H-Plant, it is necessary to discuss some operations that are not a distinct process and/or are not conducted in the glovebox lines. The four major items in this category are (1) button closeout and storage, (2) solid waste/residue handling, (3) chemical preparation and storage, and (4) hydrogen fluoride storage and supply.

2.2.3.1 Button Closeout and Storage

Double-canned buttons are removed from the reduction line maintenance room and taken to the assay room where the package is weighed again followed by calorimetric assay to generate confirmatory readings. The accountability computer system then generates a bar code that is affixed to the outer can. Depending on available space and whether or not loading operations are occurring in the Plutonium Vault Facility (PVF, H-17), the can is then either placed in the local storage vault or transferred to the PVF to be placed in a shipping container and stored.

The local storage vault is located on the first floor in the northeast corner of the H-1 building. The walls of the vault are 14-inch reinforced concrete, and a steel cage is placed over the entry door to the vault and over the vault ceiling. There are three storage racks along the walls of the vault and three smaller storage racks mounted on the vault interior floorspace. The storage racks along the walls are bolted to the floor and the walls, while the interior racks are bolted to both the floor and to stiffening rods mounted in the floor that run up the backside of the racks.

The racks are four positions high and provide a total of 114 storage positions. The vault is reserved for storing buttons (nominally 78 positions) or selected high assay wastes that are to be processed for recovery (nominally 36 positions). The buttons are double canned, while the residues will be double wrapped in plastic and contained in sealed, hard plastic pails. The shelving design maintains a safe separation between the stored units for criticality limits larger than the administrative/design flowsheet limits for buttons or high assay residues.

2.2.3.2 Solid Waste/Residue Handling

Glovebox waste is removed through airlocks or bagports in a 12-mil PVC bag sealed with plastic tape. The waste is placed inside another plastic bag that is sealed with tape, and the entire package is placed in a 5-gallon pail that is sealed with tape. Readings are taken with a portable monitor at the generation point to verify limits have not been exceeded in the package, in which case it would have to be reintroduced into the glovebox and broken down into several waste packages.

Lag storage for waste pails that have not been assayed is available in the drumming area. A small room is equipped with two high storage racks along the wall with a maximum storage capacity of 25 pails. An adjacent room has two 3 high racks with 40 spaces for lag storage of assayed pails. Up to 20 additional pails can be stored if necessary in marked positions along unused walls in corridors within the regulated area.

The waste drumming room contains a pulsed high analyzer (PHA) that is used for assay measurement of waste pails. This room also contains a ventilated waste hut where workers in protective suits remove assayed waste bags from the plastic pails and place them in DOT-approved 55-gallon drums. These drums are then sealed and subsequently smeared to verify no surface contamination is present on the drum. They are then moved to the drum counting station for confirmatory measurement of plutonium content.

The drum counting room makes use of two separate NDA instruments. A control computer for the two devices combines the results via an operator-selected algorithm based on type of waste assayed to produce a single value estimate. About 20 drums can be temporarily stored in the floorspace of the drum assay room, but normal practice is to move the drums to the TRU waste storage building soon after completion of assay.

Low-level solid waste that is generated largely outside the gloveboxes or in maintenance activities is either placed in drums or in fire retardant treated wooden boxes. The boxes are generally reserved for waste activities that can be expected to fill a complete box. These materials are temporarily stored in the hallways of the TRU waste storage building until they are removed for disposal.

Residues for recovery are generally handled in a manner very similar to TRU waste except that storage must occur in the button vault or in the PVF.

2.2.3.3 Chemical Preparation and Storage

Chemical preparation and storage is carried out in the outside chemical tank farm and on the second floor of the H-1 building. The outside chemical tank farm contains the following large storage tanks:

1.	64% Nitric Acid	-	4000 gallons
2.	35% Nitric Acid	-	8000 gallons
3.	35% Nitric Acid	-	8000 gallons
4.	35% Potassium Hydroxide	-	5500 gallons
5.	100% Hydrofluoric Acid	-	1500 gallons
6.	Liquid Nitrogen	-	3500 gallons
7.	Liquid Nitrogen	-	3500 gallons

From the storage tank, -380° F liquid nitrogen is vaporized in an evaporator that is part of the package unit. Nitrogen gas is generated at 90 psig and enters the plant supply manifold. One header takes 90 psig nitrogen to pressurize chemical storage tanks for transfer to the H-1 building. Another branch reduces pressure to 15 psig for transfer of nitrogen into the H-1 building. This branch enters the building in the utility room where it passes through one of two dryer units before entering the building header.

All of the process chemical storage tanks are transferred into the H-1 building by nitrogen overpressure. The tanks are equipped with level and pressure indicators, overflow lines, relief valves, and are surrounded by dikes designed to hold the majority of the material in each tank. The HF storage system will be discussed in greater detail in the next section.

A diagram of the second floor of the H-1 building is presented again as Figure B.16. The individual storage tanks located on the second floor are noted on the diagram and listed below:

Tank Farm	Volume (l)	Transfer Method
Tank Farm #1		
N-1 64% Nitric Acid Storage -	1500	Pump
N-2 35% Nitric Acid Storage -	4000	Pump
N-3 4% Nitric Acid Storage -	1500	Pump

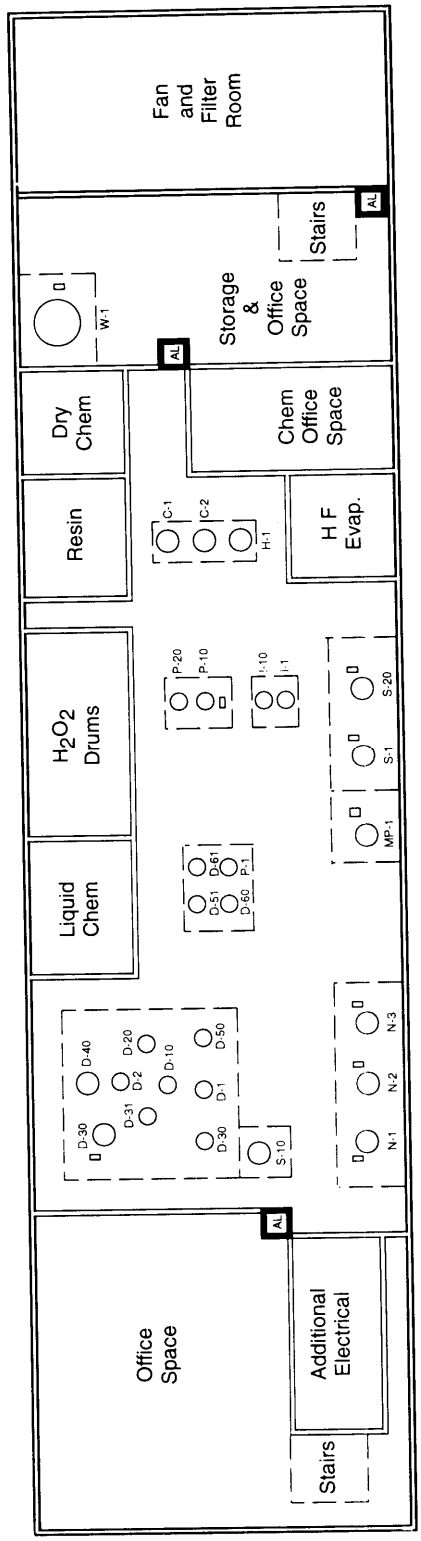


Figure B.16. Plutionium Recovery Facility Second Level Floor Plan

Appendix B; Plutonium Recovery Facility

Tank Farm	Volume (l)	Transfer Method
Tank Farm #2		
D-1 64% HNO_3 Oxide Dissolver Head Tank -	30	Gravity
D-2 64% HNO_3 Residue Dissolver Head Tank -	20	Gravity
D-10 35% HNO_3 Dissolver Dilution Head Tank -	1000	Vacuum
D-20 20% Potassium Fluoride Batch Tank -	50	Gravity
D-30 35% Aluminum Nitrate Storage Tank -	100	Pump
D-31 35% Aluminum Nitrate Head Tank -	20	Gravity
D-40 14% Sulfamic Acid Batch Tank -	250	Gravity
D-50 4% HNO_3 Flush/Dilution Head Tank -	150	Gravity
S-10 15% Caustic Scrubbing Head Tank -	1000	Pump
Tank Farm #3		
D-51 64% HNO_3 Concentration Tank -	75	Gravity
D-60 Sodium Nitrate Batch Tank -	50	Gravity
D-61 Ferrous Sulfamate Batch Tank -	50	Gravity
P-1 HNO_3 Multi-Purpose Tank -	50	Gravity
Tank Farm #4		
I-1 35% HNO_3 Wash/Recondition Tank -	1500	Pump suction
I-10 4% HNO_3 Elution Head Tank -	250	Pump suction
P-10 35% H_2O_2 Feed Tank -	400	Pump
P-20 4% HNO_3 Precipitate Wash Head Tank -	200	Pump
Tank Farm #5		
C-1 64% HNO_3 Offgas Scrubbing Head Tank -	100	Pump
C-2 4% HNO_3 Dilution Tank -	100	Gravity
H-1 35% KOH Head Tank -	1000	Pump
Tank Farm #6		
MP-1 Multi-Purpose Drain Tank -	2000	Pump
S-1 35% KOH Storage Tank -	2000	Pump
S-2 15% KOH Storage Tank -	2000	Pump

The tank farm groupings are based on placing tanks approximately over the process they feed, except for the main interior storage tanks. Each tank farm grouping is surrounded by a dike to contain spilled liquid.

All tanks have sightglass level indication, which is monitored hourly and during filling operations. Certain tanks are also equipped with alarming level indication. These alarms are for the purpose of informing operators so as to maintain operational continuity, not to prevent imminent hazards. Internal bulk storage tanks N-1, N-2, N-3, S-1, and S-2 are provided with low level alarms to alert operators that the sources of makeup feed for process head tanks need to be refilled. These tanks are also equipped with high level alarm indication as they are filled from the large outside storage tanks in the H-3 chemical feed area. Ion exchange head tanks I-1 and I-10 and precipitator head tanks P-10 and P-20 are provided with low level alarms to avoid needless interruption of the process cycle that would trigger lengthy procedural requirements for restoration. Scrubbing system tanks S-10, C-1, and H-1 are alarmed to avoid interrupting scrubbing operations that would require shutdown of vessel vent, calcination, or hydrofluorination processes. A master alarm sounds at three locations in the tank farm area and at an individual alarm panel on the north wall of the area. The master alarm also sounds in the facility control room. All tanks in which mixing occurs and those that contain chemicals prone to stratification are equipped with agitation impellers.

There are four chemical storage rooms on the second floor. The first houses bottles of liquid chemicals, which are manually mixed with water in small tanks. These bottles are kept in storage cabinets. The only other source of bottled chemicals on the second floor is the flammable liquids storage cabinet, which contains cleaning supplies. It is located against the outer south wall of the liquid chemical storage room.

The H_2O_2 storage room holds up to 11 55-gallon drums of 35% hydrogen peroxide at a time. A portable pump and tubing is used to empty these drums into the hydrogen peroxide feed tank. The resin storage room contains up to five drums of Dowex 21-K resin at a time. Various equipment used in the tank farm is stored both in this room and the hydrogen peroxide drum storage room. The dry chemical storage room contains calcium metal in one storage cabinet, pre-weighed reduction charges of calcium in a second cabinet, various dry chemicals in small bottles in a third cabinet, and pyrotechnic initiators in a fourth cabinet. A small storage bin for 12 calcium charges and one for 12 initiators are also located in the maintenance room of the reduction line.

2.2.3.4 Hydrogen Fluoride Storage and Supply

The HF storage and supply system for H-Plant consists of two major parts. The first is the storage tank and associated vessels in the external chemical tank farm. The second is the HF evaporator located on the second floor of the H-1 building.

2.2.3.4.1 HF Storage Tank

A drawing of the HF storage system is provided as Figure B.17. The HF storage tank is a heavily insulated monel vessel equipped with a level detection system and temperature and pressure indication. Liquid hydrogen fluoride is transferred out of the tank by applying a nitrogen overpressure of 75 psig to the system. Double-walled pipes deliver the liquid to the second floor of the H-1 building.

Nitrogen lines penetrate the vessel in three other locations to provide for tank purging as necessary. The purge exhaust line ties off the tank relief valve line. It directs purge flow to a knock-out tank and then into a scrubber filled with 35% KOH. The plant air main is used to drive a jet pump that accelerates purge flow and provides good intermixing between the air flow and the scrubbing solution. This simple scrubber vents directly to the atmosphere.

The tank relief valve is set to lift at 150 psig, a pressure that is not considered attainable absent a major fire. A pressure sensor in the relief outlet line sounds an alarm in the H-1 control room when the relief lifts. The gas released when the relief valve lifts is directed to the main exhaust stack.

2.2.3.4.2 HF Evaporator

The HF evaporator, represented in Figure B.18, is located in a dedicated room on the south side of the chemical tank farm area. The location allows the unit to be directly over the dry processing line, which allows gaseous HF to be piped directly to the hydrofluorinator without having to pass through intervening rooms or corridors.

Liquid HF is piped through the exterior wall of the evaporator room. The evaporator is a 15-inch diameter cylinder sitting in a water bath on a scale. The scale has been calibrated both for the weight of the bath and the evaporator vessel so that the weight of HF can be directly read at all times. The water bath is equipped with a standard heating element that maintains the bath at approximately 70° F to boil HF. The bath is recirculated by a small centrifugal pump that directs the water through a heat exchanger and back to the bath. The chilled water inlet valve to the heat exchanger is

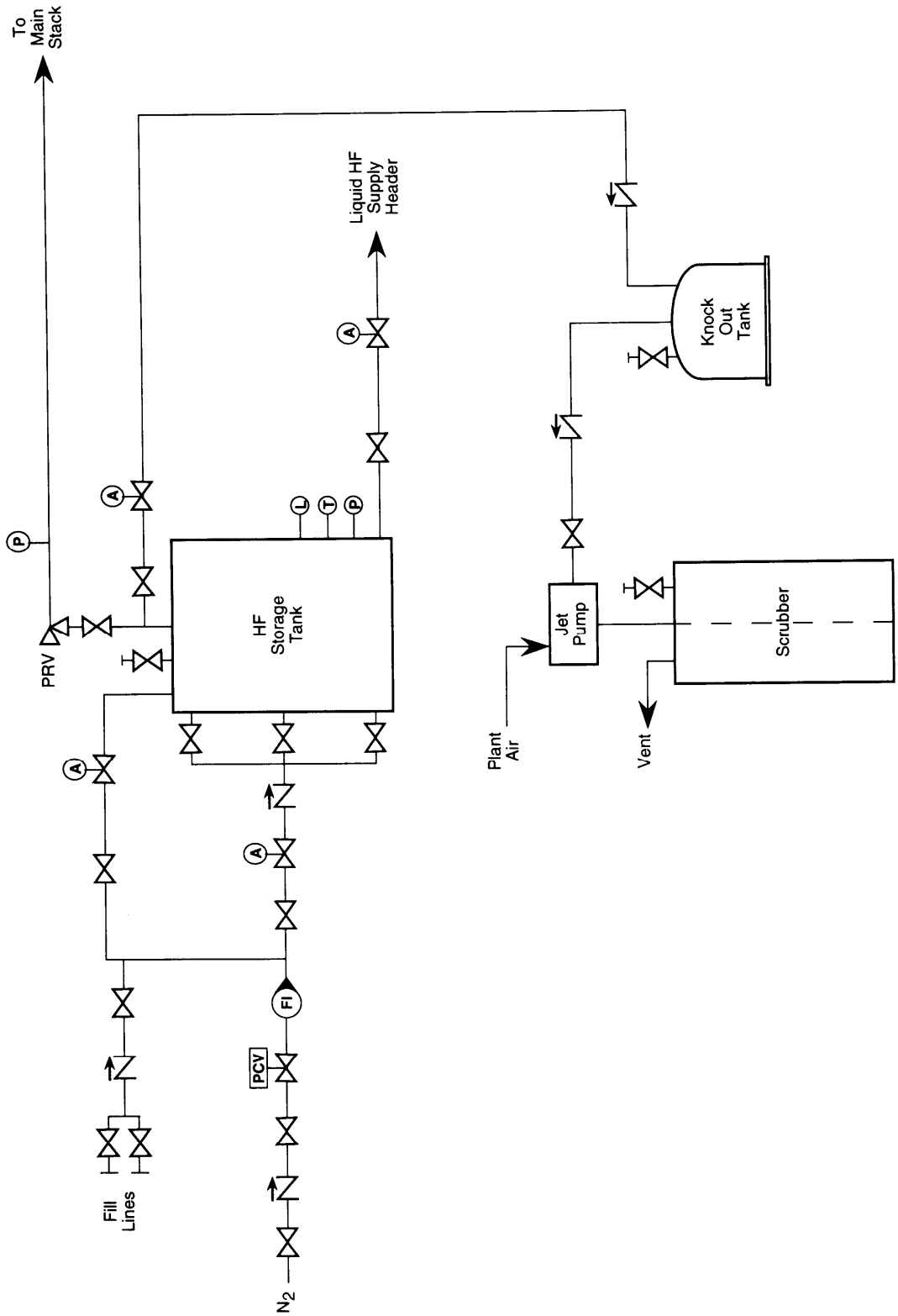


Figure B.17. HF Supply

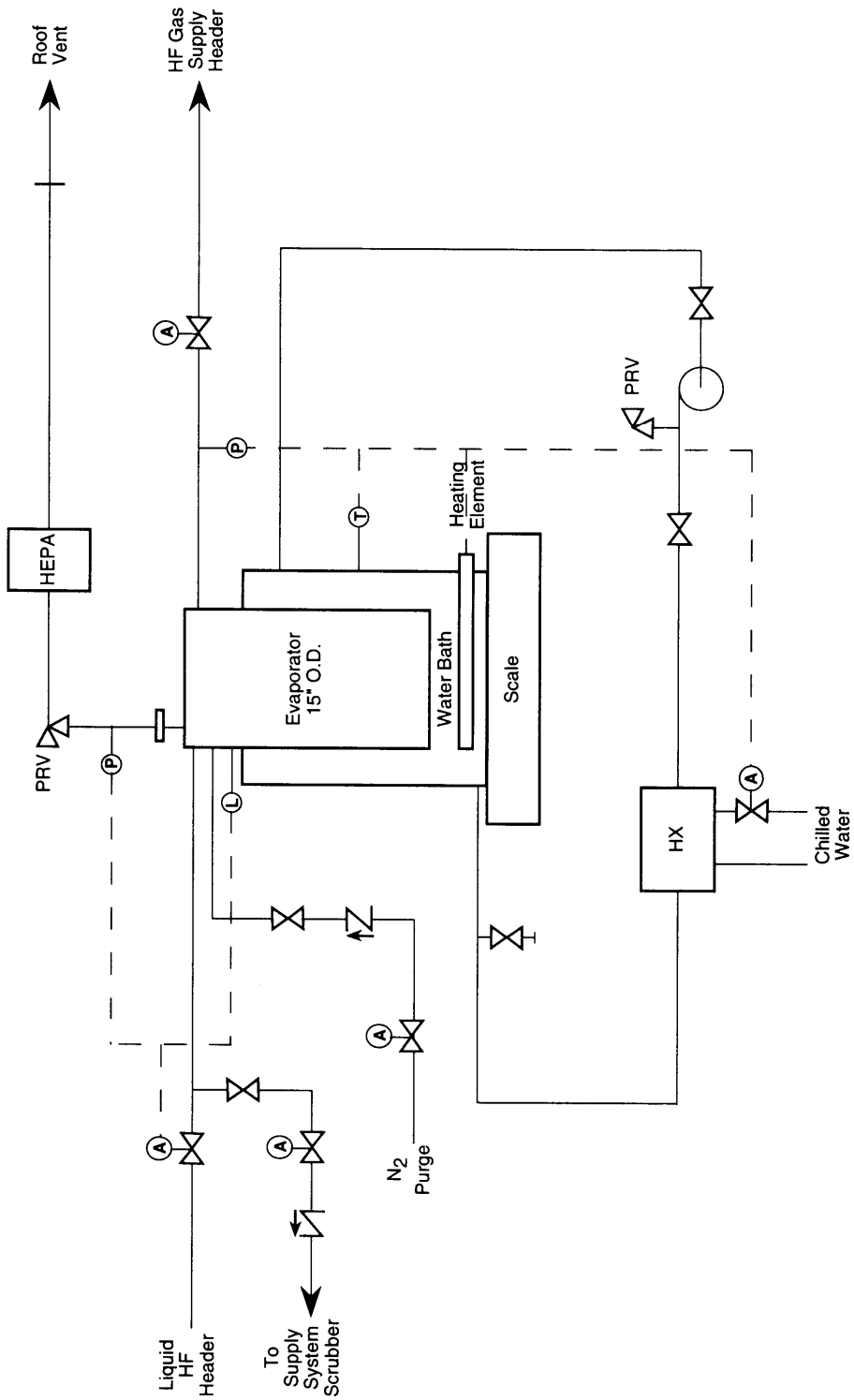


Figure B.18. HF Evaporator

normally open only enough to maintain a small flow through the heat exchanger. A temperature detector on the bath controls the position of the inlet valve to allow for quick compensation of temperature fluctuations. The bath heating element is controlled by a thermostat, but the bath temperature signal provides an alarm and deenergizes the element if temperature exceeds 76° F. The pressure sensor on the gaseous HF outlet line will also shut off the heater if pressure begins to rise continuously.

A level sensor on the evaporator controls the position of the liquid HF inlet valve. Nitrogen purge lines are provided on the system as well. They exhaust to the HF storage tank scrubbing system. The final major feature of the evaporation system is the installed rupture disc and relief valve. The rupture disc is designed to fail at 14 psig. The resultant pressurization of the piping between the rupture disc and the relief valve will cause the installed pressure sensor to trigger an alarm locally, in the dry line operating room and in the main control room. The sensor's signal will also cause the liquid HF supply valve to the evaporator to shut.

The evaporator relief valve will lift at approximately 20 psig. The relief line will pass through a single HEPA filter installed to preserve the integrity of the radiological envelope within airlock areas. The line then passes through the ceiling of the room to a roof vent elevated 15 feet above the actual roof of the building. This release will be accompanied by an audible alarm on the roof triggered by the evaporator pressure sensor. The limited flowrate needed to relieve pressure from the evaporator will not create a significant personnel hazard due to the elevation of the roof vent.

The evaporator room itself is equipped with fluorine detectors, which are also in the ventilation exhaust header. These units alarm in the same locations as the pressure relief alarms.

2.3 HAZARD IDENTIFICATION

This document presents in tabular form the hazards identified by the team evaluating the H-1 Plutonium Recovery Facility. It follows the process flow of the facility as it would occur, and then identifies potential hazards in supporting activities in accordance with the building layout. The two general types of hazards identified are as follows:

A - Material of concern for release or a potential hazard in direct contact with a material of concern.

B - Hazard in the vicinity of material of concern that could be relevant to an event affecting material of concern.

Standard industrial hazards are not included unless they represent a potential hazard type B. In that case, the focus of identification is on basic parameters to support examining the potential affect on materials of concern, not standard worker safety issues. This practice is in keeping with the definitions of both hazard and standard industrial hazard in DOE-STD-3009-94.

The initial effort has largely relied upon procedural and flowsheet limits to produce an initial definition of facility hazards that reflects actual conditions anticipated. This is generally adequate for the overall examination envisioned, but it is essential for the initial effort as a minimum. Unreal numbers based on mathematical dose or high criticality limit considerations should not be used without appreciation of the actual conditions underlying those constructs. Blindly applying such numbers can result in significant confusion in the hazard analysis process. Evaluations can become distorted, resulting in the utility of subsequent results obtained being questionable. For example, consider the case where a criticality limit exceeds by an order of magnitude what a given process can actually handle based on concerns about stability of other process materials, such as ion exchange resin, in radiation fields. Pretending the criticality limit is the amount of material actually present is interfering with objective assessment of what may be a more significant safety issue than that for which the unrealistic material quantity is being postulated.

Table B-1 - Plutonium Recovery Facility Hazard Identification

Location	Type	Hazard	Quantity
PVF Transfer Corridor	A	1. Plutonium solid	1. A maximum of 2000 g of Pu can be transferred as a unit (either metal, oxide, or residue) through the corridor by procedure. The actual procedural limits for dissolution are 1200 g of metal, 1500 g of oxide, and 1000 g Pu in residue.
	B	1. Standard industrial	1. Low combustible loading.
Feed Preparation Glovebox	A	1. Plutonium solid 2. Thermal Energy 3. Chemical energy	1. Procedures limit total Pu at all stations in glovebox to maximum of 20,000 g. A maximum of 2000 grams of Pu is allowed at each station as oxide or residue. A 6-position charge can storage rack can hold ≈ 8000 g of Pu as 6 oxide charges for dissolver or 12,000 g at theoretical loading of 2000 g per can. 2. Oxide burning furnace (1200 °F). 3. Pyrophoric plutonium metal fines in oxide. General maximum is 100 g to 200 g quantities at most.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC in electrical wiring; 440 VAC outlet for impactor. - 30 psig source air line - 15 psig source nitrogen line 2. Rotational Impactor
Feed Preparation Operating Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading.
Feed Preparation Maintenance Room	A	1. Plutonium solid 2. Plutonium in bagged waste.	1. Hood airlock station used for entering material into the glovebox can have 2000 g of Pu based on procedural issues previously noted. 2. Up to 100 g of Pu solid are allowed to be entrained with waste in a single bag. Actual average values are on the order of 1 to 2 grams.
	B	1. Standard industrial	1. Low combustible loading.
Oxide Dissolution Glovebox	A	1. Plutonium oxide 2. Plutonium nitrate 3. 35% and 64% nitric acid	1. One charge can containing 1500 g of oxide (1322 g Pu) is allowed by procedure and flowsheet. 2. 1322 grams of Pu in nitrate solution based on a single charge. 3. The operational flowsheet uses 23 l of 64% nitric acid and 102 l of 35% nitric acid in glovebox vessels.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Oxide Dissolution Glovebox (cont.)	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Steam supplied to dissolver heat exchanger at 280 °F. 2. - Ventilation - 115 VAC - 30, 65, and 80 psig source air lines. - 15 psig source nitrogen line. 3. Small gear pump (12 psi).
Residue Dissolution Glovebox	A	1. Plutonium in residue 2. Plutonium nitrate 3. 35% and 64% nitric acid	1. A single charge of 1000 g of Pu in up to 2000 g residue is allowed into the glovebox. 2. 1000 g of Pu in nitrate solution is allowed in the line based on the limit that only one charge is processed at a time. 3. The operational flowsheet for the process uses 15 l of 64% nitric acid and 85 l of 35% nitric acid.
	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Steam supplied to dissolver heat exchanger at 280 °F. 2. - Ventilation - 115 VAC - 30, 65, and 80 psig source air lines - 15 psig source nitrogen line. 3. Small gear pump (12 psi).
Metal Dissolution Glovebox	A	1. Plutonium metal 2. Plutonium hydride 3. Plutonium in solution 4. 35% nitric acid 5. 14% sulfamic acid 6. Chemical energy	1. A single charge of 1200 g of plutonium metal is allowed into the glovebox. 2. A small hydride sludge may form during the reaction. Historical values range from 1 to 60 g, with 100 g considered a practical limit based on reaction kinetics. 3. 1200 g of Pu in sulfamic and nitrate solution based on a single charge. 4. The operational flowsheet uses 45 l of 35% nitric acid. 5. The operational flowsheet uses 30 l of 14% sulfamic acid. 6. Hydride sludge is pyrophoric when dried.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Metal Dissolution Glovebox (cont.)	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Steam supplied to dissolver heat exchanger at 280 °F. 2. - Ventilation - 115 VAC - 30 and 65 psig source air lines - 15 psig source nitrogen line. 3. Small gear pump (12 psi).
Dissolution Line Operating Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading.
Dissolution Line Maintenance Room	A	1. Plutonium metal 2. Plutonium hydride 3. Plutonium in bagged waste 4. Plutonium nitrate solution	1. 1200 g of metal are allowed in the airlock entry hood on the back of the metal dissolution glovebox. 2. Up to 10 g of plutonium hydride in a sample vial can be removed in a CRC to be sent to the lab for analysis. A theoretical maximum of 100 g can be transferred by CRC from the metal dissolution glovebox to the oxide dissolution glovebox by CRC. 3. Up to 100 g of Pu solid can be entrained in a waste bag, although average values are 1 - 2 g per bag. 4. 1 to 2 g in sample vials removed via CRCs mounted on the back wall of each of the gloveboxes.
	B	1. Standard industrial	1. Low combustible loading.
Sample Glovebox	A	1. Plutonium nitrate solutions in piping. 2. Plutonium nitrate solution in sample recovery tank. 3. Plutonium nitrate solution in sample storage rack.	1. Nitrate solutions ranging in concentration from 0.01 g/l to 90 g/l are circulated through glovebox piping. 2. Unused portions of analytical samples sent to the lab are stored for recovery in a 100 l slab vessel. Nominal concentration of sample mixture is 30 g/l for a total of 3000 g of Pu. Maximum allowed is 5000 g to conform to flowsheet parameters. 3. 30 sample storage rack. 100 g maximum total allowed in storage.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Sample Glovebox (cont.)	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC - 30, 65, and 80 psig source air lines - 15 psig source nitrogen line. 2. 3 small centrifugal pumps (20 psi).
Sample Line Operating Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading.
Sample Line Maintenance Room	A	1. Plutonium nitrate 2. Plutonium oxide	1. 2 liter bottle allowed in airlock entry hood on back of glovebox. Procedure limits each bottle to a maximum of 100 g Pu. 30 sample vials (30 ml) can be removed via the airlock at a time. Approximately 10 to 40 g Pu depending on breakdown of tanks sampled. There are three plutonium piping headers on the floor and three plutonium piping headers in the overhead. Solution concentration run from 0.01 g/l to 90 g/l. 2. 100 grams of Pu solid can be entrained in a waste bag, but average values are 1 to 2 grams.
	B	1. Standard industrial	1. Low combustible loading.
Ion Exchange Glovebox	A	1. Plutonium 2. 35% Nitric acid 3. Chemical energy	1. Procedural limit is 6500 g Pu in nitrate feed solution into the box ($\approx$ 5 - 6 g/l) or sorbed on resin. Average run would load $\approx$ 5800 grams. 2. 1330 l flow through glovebox during the course of a load/wash/elute/recond. cycle. $\approx$ 920 l are plutonium feed solution. 3. $\approx$ 45,000 grams of Dowel 21-K anion resin (strong base) in 3 columns. Resin decomposition reactions can be explosive under certain circumstances. Relevant factors include drying resin, exposing to temperatures in excess of 60 °C, excess radiation, stagnation, and confinement.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Ion Exchange Glovebox (cont.)	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Steam supplied to heat exchanger at 280°F. 2. - Ventilation - 115 VAC - 30 and 65 psig source air lines 3. Small gear pump (12 psi).
Peroxide Precipitation Glovebox	A	1. Plutonium nitrate solution 2. Plutonium peroxide cake 3. Plutonium filtrate solution 4. 35% hydrogen peroxide 5. Chemical energy	1. ≈ 23,300 g of Pu in solution fed to the box in a complete production run at inlet feed concentration ≈ 90 g/l. Based on precip. vessel sizes, ≈ 2000 g cumulative total of Pu can be in vessels during normal operation (i.e., vessels 1/2 full of feed and 1/2 full of 35% H_2O_2). 2. ≈ 2900 g of peroxide cake (2300 g Pu) are collected in the load cell before its contents are sent to the calcining line. 3. ≈ 100 g of Pu in solution are collected in the filtrate slab tank for transfer to the evaporation line for recycle. ≈ 500 - 600 g of Pu will pass through the filtrate slab tank in a complete production run. 4. ≈ 180 l of H_2O_2 fed into the line during a complete production run. 5. 35% H_2O_2 can decompose explosively from pressure buildup (i.e. not propagating detonation) under certain circumstances such as excessive temperature or mixture with organic or ferrous contaminants. 52% or greater solutions pose the greatest hazard and require special handling. Reaction of such high strength solutions with certain organic contaminants can result in detonations. During normal operations, precip. vessels hold 7 and 14 l of 35% H_2O_2 diluted with Pu feed, and the filtrate slab tank holds 100 l of solution containing depleted peroxide.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC - 30 and 65 source psig air lines 2. - 1 small gear pump (12 psi) and 2 small compressor units - Motor driven agitators in the precipitation vessels

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Evaporation Glovebox	A	1. Plutonium nitrate solution 2. Hydrogen peroxide 3. Chemical energy	1. Eluate evaporator processes ≈ 6000 g of Pu per run. Feed is ≈ 25 - 30 g/l and exiting bottoms are ≈ 90 g/l. ≈ 2000 g can be in the evaporation vessel during operation, and all 6000 g are collected in the pencil tanks during a run. Filtrate evaporator processes ≈ 600 g per run. Feed is ≈ 1 g/l and exiting bottoms are ≈ 10 g/l. ≈ 200 g can be in the evaporation vessel and all 600 g are collected in the pencil tanks during a run. 2. Depleted H_2O_2 is in filtrate solution (< 10% H_2O_2). 3. As noted, H_2O_2 can decompose explosively under certain circumstances.
	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Steam supplied to evaporator heat exchangers at 280 °F. 2. - Ventilation - 115 VAC - 65 psig source air lines 3. 3 small gear pumps (10 psi) per evaporator.
Wet Line Operating Room	A	1. Plutonium nitrate solution 2. Plutonium waste solutions	1. Pu recycle header from calcining line in overhead at concentration ≈ 4 g/l. 2. Pu in spent caustic header from hydrofluorinator scrubber runs in overhead. Concentration is 0.01 g/l.
	B	1. Standard industrial	1. Low combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Wet Line Maintenance Room	A	1. Plutonium nitrate solution 2. Plutonium waste solutions 3. Plutonium solids 3. Plutonium solid in waste	1. All process tanks in the tank farm, if full, hold ≈ 42 kg of Pu at flowsheet parameters. Maximum loadings per tank are: 1,2 - 1322 g, 3, 4 - 1000 g, 5,6 - 1200 g, 7,8 - 5800 g, 13,14 - 11,650 g, 15,16 - Spares. There are piping runs in the overhead. Concentrations range from 0.01 g/l to 90 g/l. CRCs on back of precipitation and evaporation boxes can hold a sample vial (30 ml) drawn for analysis. 10 vials, holding a cumulative Pu total of 0.02 and 20 g depending on breakdown of vessels sampled, can be moved at a time. 2. All the waste tanks in the tank farm (9-12, 17-21) hold ≈ 30 g at flowsheet parameters. There are piping runs in the overhead at concentrations ≈ 0.01 g/l. 3. The CRC on the back of the precipitation glovebox can hold up to 5 sample vials (50 g) of solid plutonium peroxide. 4. 100 g of Pu solid in a waste bag. Average values are 1 to 2 grams per bag.
	B	1. Standard industrial	1. Low combustible loading.
Calcination Glovebox	A	1. Plutonium peroxide 2. Plutonium oxide 3. Plutonium nitrate solution 4. 64% nitric acid 5. Thermal energy 6. Chemical energy	1. Storage space is available for ≈ 29,000 g plutonium peroxide (23,000 g Pu). 2. 2 - 4 kg Pu inside calciner during operation. 3. Maximum of ≈ 1 kg Pu in solution in recycle slab tank at end of complete calciner run per flowsheet parameters. 4. 60 l are used in a complete calciner run. 5. Calciner operates at 700 °F. 6. 1 - 2 liters of low combustibility hydraulic oil.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Calcination Glovebox (cont.)	B	1. Thermal energy 2. Potential energy 3. Kinetic energy	1. Dryer unit operates at 130 °F. 2. - Ventilation - 115 and 440 VAC - 35 psig source air lines, 30 psig dry air supplies ventilation 3. - Calciner auger - Small gear pump (12 psi)
Hydrofluorination Glovebox and Scrubber Glovebox	A	1. Plutonium oxide 2. Plutonium fluoride 3. Plutonium in waste scrubber solution 4. Hydrogen fluoride gas 5. 35% KOH 6. Thermal energy 7. Chemical energy	1. 2.5 kg Pu in the hydrofluorinator. 2. 4600 g (3500 g Pu). Two containers with 2300 g fluoride apiece. 3. ≈ 10 g in total waste for one complete run. 4. 170 pounds is used in a complete run, with flow in fixed at 1 scfm. 5. 470 l used in a production run. 6. Hydrofluorinator operates at up to 1100 °F. 7. Neutralization of HF by KOH is an exothermic reaction.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 and 440 VAC - 35 psig source air line, 20 psig dry air supplies ventilation. 2. A small centrifugal pump (20 psi) for recirculating the scrubber solution.
Dry Line Operating Room	A	-	-
	B	1. Standard industrial	1. High combustible loading, especially for hydrofluorinator glovebox line.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Dry Line Maintenance Room	A	1. Pu nitrate solution 2. Plutonium solid 3. Pu waste solution 4. Plutonium solid as waste	1. There is a recycle line in the overhead at concentration 5 -10 g/l. A CRC on the back of the calcining line holds a sample vial (20 ml containing 0.2 g Pu). 2. 5 sample vials (≈ cumulative 50 g of Pu compounds) can be carried in a CRC. 3. There is a caustic waste header in the overhead. Concentration is 0.01 g/l. 4. 100 grams of Pu can be entrained in waste bag. Average values are 1 - 2 g.
	B	1. Standard industrial	1. Relatively high combustible loading in front of hydrofluorinator glovebox line.
Reduction Glovebox	A	1. Plutonium fluoride 2. Plutonium metal 3. Calcium 4. Thermal energy 5. Chemical energy 6. Potential energy	1. 4600 g (3500 g Pu) storage capacity available. 1300 - 2600 g (1000 - 2000g Pu) can loaded in charge crucibles just prior to initiating a reduction operation. 2. 6 crucibles that have undergone reduction can be stored in recessed wells, holding 6 kg to 12 kg Pu if fully loaded (an atypical condition). Another 4 kg to 8 kg can be in downstream finishing activities (i.e., pickling, weighing, sampling). 3. One reduction charge (typically 700 - 800 g) allowed in the glovebox at a time. 4. Reduction vessel can reach 3000 °F, although overall furnace does not. 5. Calcium can react with moisture to produce heat and hydrogen gas. Two pyrotechnic initiators are allowed in the glovebox at a time. 6. A 30 kw/10 kHz motor generator set is installed in the glovebox.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 and 440 VAC, - 15 psig source argon and nitrogen for purging and inerting 2. - Hydraulic piston (24,000 pounds-force) - Hammer used to break crucibles and 3/8" drill
Reduction Operating Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Reduction Maintenance Room	A	1. Calcium 2. Chemical energy 3. Pu solid in waste	1. 9 kg, amount needed to reduce a complete hydrofluorinator output cycle. 2. Calcium can react with water. 25 pyrotechnic initiators in a cabinet. 3. 100 grams of Pu can be entrained in a waste bag (1 - 2 grams average).
	B	1. Standard industrial	Low combustible loading. Water from sprinkler system could react with calcium.
Vessel Vent Recirculation	A	Pu waste solution	Trace quantities of plutonium exist in scrubber solution. Approximately 0.01 g/l.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC 2. Two small centrifugal pumps (30 psi).
Vessel Vent Blower Glovebox	A	1. Plutonium in air	Trace plutonium in vessel vent exhaust.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC 2. Two centrifugal blowers.
Vessel Vent Room	A	1. Plutonium in air 2. Plutonium in waste solution 3. 15% KOH 4. Chemical energy	1. Trace plutonium in vessel vent airstream. 2. Knock-out tank contains acidic waste with trace plutonium (0.01 g/l). Blowdown tank and scrubber sump contain caustic waste with trace plutonium (0.01 g/l). Approximately 10 g Pu conservatively estimated in liquid in all tanks. Small holdup of 5 to 20 g Pu solid conservatively estimated in each tank. Steam condensate tanks and chilled water head tank are normally clean and normally will be less than 0.01 g/l if any contamination is present. 3. 850 liters 4. Neutralization reaction between acid and base is exothermic.
	B	1. Standard industrial	1. Compressor unit for chilled water system. Low combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Pre-Assay Waste Pail Storage Room	A	1. Plutonium in waste 2. Chemical energy	1. 25 pails at a maximum of 100 g Pu per pail = 2500 g. Historical record average is 2 g per pail. 2. Nitrated cellulose material in waste can spontaneously ignite.
	B	1. Standard industrial	1. Medium to high combustible loading.
Post-Assay Waste Pail Storage	A	1. Plutonium in waste 2. Chemical energy	1. 40 pails at a maximum of 100 g Pu per pail = 4000 g Pu. Historical record average is 2 g per pail. 2. Nitrated cellulose material in waste can spontaneously ignite.
	B	1. Standard industrial	1. Medium to high combustible loading.
Pail Assay Room	A	1. Plutonium in waste 2. Chemical energy	1. 5 pails can be stored awaiting assay. At maximum loading of 100 g Pu per pail = 500 g Pu. Historical record average is 2 g per pail. 2. Nitrated cellulose material in waste can spontaneously ignite.
	B	1. Standard industrial	1. Low to medium combustible loading. Liquid nitrogen used for pulsed height analyzer.
Drumming Room	A	1. Plutonium in waste 2. Chemical energy	1. 20 pails can be stored awaiting drumming. At maximum loading of 100 g Pu per pail = 2000 g Pu. Historical record average is 2 g per pail. There is storage space for ten 55 gallon drums awaiting assay or just finished being assayed. The maximum limit for each drum is 200 g for a maximum total of 2000 g. The historical record average is 30 g per drum. 2. Nitrated cellulose in waste can ignite spontaneously.
	B	1. Standard industrial	1. Medium to high combustible loading.
Process Office Space	A	-	-
	B	1. Standard industrial	1. Low to medium combustible loading.
Storage/Maint. Shops	A	-	-
	B	1. Standard industrial	1. Low combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Drum Assay Room	A	1. Plutonium in waste 2. Chemical energy	1. Temporary storage for 2 drums awaiting or just completed assay is available. Maximum Pu based on procedural limit is 200 g. 2. Nitrated cellulose in waste can ignite spontaneously.
	B	1. Standard industrial	1. Low combustible loading.
Pu Button Calorimetry	A	1. Plutonium metal	1. 4 calorimeters with four wells apiece could hold 16 kg to 32 kg of Pu.
	B	1. Standard industrial	1. Low combustible loading.
Pu Button Vault	A	1. Plutonium metal 2. Plutonium in waste	1. 78 kg to 156 kg of Pu metal can be stored in available positions. 2. 36 positions for high assay recoverable residues. Maximum limit is 1000 grams for total of 36,000 grams. Historical average is between 50 - 300 g depending on waste specifics.
	B	1. Standard industrial	1. No combustible loading other than residue pails.
Process Area Hallways	A	1. Plutonium in waste 2. Plutonium liquid samples 3. Plutonium metal samples 4. Chemical energy	1. Storage space for 20 pails in the hallways for 2000 g Pu at maximum loading. 2. One container with at most 30 samples can be transferred at a time. Loading 1 to 40 g of Pu depending on sample distribution. 3. One container with 5 samples can be transferred at a time for a maximum of 50 grams of Pu or Pu compounds. 4. Nitrated cellulose in waste can ignite spontaneously.
	B	1. Standard industrial	1. Generally low combustible loading.
Utility Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading. UPS with potential H_2 generation during charging.
Second Floor Office Space and Electronics Room	A	-	-
	B	1. Standard industrial	1. Low to medium combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Second Floor Chemical Tank Farm	A	1. 64% nitric acid	1. 1725 liter capacity.
		2. 35% nitric acid	2. 6900 liter capacity.
		3. 14% sulfamic acid	3. 250 liter capacity
		4. 35% hydrogen peroxide	4. 400 liter capacity.
			5. 3000 liter capacity.
		5. 35% potassium hydroxide	6. 3000 liter capacity.
		6. 15% potassium hydroxide	7. Acid-base neutralization reactions generate heat. 35% H_2O_2 can decompose explosively. The 50 liters of ferrous sulfamate present would likely cause a peroxide degradation reaction if mixing occurred (free Fe^+ ions)
		7. Chemical energy	8. Ferrous sulfamate or sodium nitrate mixing with nitric acid would quickly liberate NO_x fumes. The evaporation of nitric acid generates NO_x as well.
		8. Toxic potential	
	B	1. Standard industrial	1. Low combustible loading. A number of small centrifugal pumps are used in the tank farm as are impellers for tank mixing. Flammable liquid storage cabinet contains cleaning supplies.
Second Floor Liquid Chemical Storage Room	A	1. Sulfamic acid	1. 10 liters of reagent for minor tank chemistry adjustment.
		2. Potassium fluoride	2. 200 liters in prepared commercial reagent bottles.
		3. Sodium nitrate	3. 10 liters of reagent for minor tank chemistry adjustment.
		4. Aluminum nitrate	4. 600 liters in prepared commercial reagent drums.
		5. Ferrous sulfamate	5. 600 liters in prepared commercial reagent drums.
	B	1. Standard industrial	1. Low combustible loading.
Hydrogen Peroxide Storage Room	A	1. 35% H_2O_2 2. Chemical energy	1. 1500 l in drums. 2. Hydrogen peroxide can decompose explosively under certain conditions.
	B	1. Standard industrial	1. No combustible loading.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Resin Storage Room	A	1. Dowex 21-K resin 2. Chemical energy 3. Toxic potential	1. 500 pounds. 2. Resin can decompose explosively under certain circumstances. 3. Resin fires produce heavy clouds of toxic smoke.
	B	1. Standard industrial	1. Low combustible loading other than resin.
Dry Chemical Storage Room	A	1. Aluminum nitrate 2. Sulfamic acid 3. Calcium metal 4. Pyrotechnical initiators 5. Chemical energy	1. 400 pounds. 2. 500 pounds. 3. 250 pounds. 4. 200 units. 5. Calcium reacts with water to generate hydrogen.
	B	1. Standard industrial	1. Low combustible loading. Sprinkler can provide water to react with calcium.
HF Evaporator Room	A	1. HF liquid 2. HF gas	1. Flowsheet parameter is 170 pounds. Vessel could physically hold 300 pounds. 2. Supply piping designed to transmit 1 scfm. Relief valve piping designed to release 18 scfm.
	B	1. Thermal energy	2 kw heater installed in unit. Overall combustible loading low.
Fan and Filter Room	A	1. Plutonium	Historical records indicate the following plutonium contents as bounds for specific plenums: A - 2 g, B - 20 g, C - 400 g, D - 30 g.
	B	1. Standard industrial	2 flammable liquid storage cabinets for general cleaners. Overall combustible loading low.

Table B-1 - Plutonium Recovery Facility Hazard Identification (cont.)

Location	Type	Hazard	Quantity
H-3 Outside Chemical Tank Farm	A	1. 64% nitric acid 2. 35% nitric acid 3. Anhydrous hydrogen fluoride liquid 4. 35% potassium hydroxide 5. Nitrogen	1. 4000 gallons. 2. 16,000 gallons. 3. 12,500 pounds. 4. 5500 gallons. 5. 600,000 scf.
	B	1. Standard industrial	1. Almost no combustible loading. Motive force for transfer into building is nitrogen blanket.
H-5 Diesel Generator Room	A	1. Diesel fuel	1. Day tank holds 100 gallons. Underground storage tank holds 5000 gallons.
	B	1. Standard industrial.	1. Low combustible loading excluding diesel fuel.

Appendix B

3.0 H-7 PRODUCTION SUPPORT LAB

3.1 FACILITY DESCRIPTION

3.1.1 Overview

The H-7 Production Support Lab was built as a research lab in 1962 and modified to adjoin with and support H Plant operations. It provides analytical support to the plutonium recovery facility (H-1). Its main purposes are (1) to analyze process samples to verify flowsheet expectations and (2) to analyze finished product material to verify product specifications are met. All operations are on a laboratory as opposed to a process scale.

3.1.2 Facility Structure

The H-7 lab is a single-story concrete structure. The foundations of the building are horizontal reinforced concrete footings varying from 2 to 5 feet square and approximately 1-foot thick. The ground floor is a 6-inch-thick reinforced concrete slab. The main support columns are 18-inch-diameter reinforced concrete cylinders tied to both the floor slab and the exterior walls.

The exterior walls are 8-inch-thick reinforced concrete block walls. Several main dividing walls in the interior of the building are non-reinforced concrete block, with the other process interior walls being double gypsum board over metal studs. The interior walls in office space are single gypsum board over metal studs.

Precast concrete beams resting on the main columns support the roof, which is composed of 2-hour fire-rated prestressed, precast concrete twin-tee panels covered with a 3-inch-thick lightweight concrete topping. All roof surfaces are covered with metal decking overlayed by a rigid buildup four-ply incombustible insulation, covered by coal-tar pitch and gravel. The roof is flat with downspouts to facilitate drainage.

3.1.3 Confinement Systems

The principal sources of confinement are gloveboxes and hoods, airlocks, the HVAC systems, and the facility structure itself. This section will concentrate on the first three items.

3.1.3.1 Gloveboxes and Hoods

Gloveboxes used in the H Plant are typical 304L stainless steel units machined to a smooth surface inside. The gloveboxes are mounted on stantions anchored to and grouted into the concrete floors of the facility. The windows are 0.5-inch plate glass with 0.25 inches of lexan mounted over them on the external glovebox frame. All gloveboxes in the analytical laboratory are equipped with plexiglass and lexan end hood units that have airlock doors to allow entry and exit of samples from the glovebox. Many sampling gloveboxes consist of several small units bolted together in a line with airlock doors separating each major section.

The typical steel hood is 4.5-feet tall, 3.5-feet wide, and 2.5-feet deep. A vertically sliding pane of 0.25 inch thick safety glass moves on track mounting equipped with limiting stops for upward motion. These stops ensure that for normal operation the hood will be pulling a minimum of 150 cfm of room air to prevent any potential contamination backflow. Only aliquots of samples, as opposed to the full concentration sample material, are handled in the hoods.

3.1.3.2 Airlocks

The lab is divided up into airlock zones to minimize the chance of spreading contamination. One set of airlocks separates those rooms containing radionuclide-handling equipment from the rest of the processing enclosure. A second set of airlocks separates the processing enclosure and HEPA filtration plenums from the general use areas of the building. One individual airlock separates the H-7 building from the H-1 building at the sample transfer location.

The primary airlocks isolate the eight analysis rooms from the rest of the operating area. Unlike the processing line rooms, the analytical line rooms are not separated into maintenance and operating sides so that one airlock can serve as an entry point to the complete room.

The primary airlocks consist of an enclosure defined by two doors. One set leads to a glovebox room (or one of the other areas noted above), while the other set leads out into a corridor. Both the outer and inner doors have a combination lock for entry. A hand and shoe monitor is installed in the airlock for use when exiting the potentially contaminated area.

The secondary airlocks separate the facility utility room, change room, and office space from the primary processing enclosure. There are four of these units in the building, and they

function exactly like the primary airlocks. The location of the airlocks in the facility is designated by an AL on the floorplan of the facility provided as Figure B.19.

3.1.3.3 HVAC System

The ventilation system, depicted in Figure B.20, consists of two independent once-through airflow systems. All exhaust goes through High Efficiency Air Particulate (HEPA) filters before entering an underground tunnel, where it is joined by exhaust from other nearby facilities and exits from the H Plant stack.

There are four ventilation supply fans for the building. These centrifugal fans operate as sets of two, with one always serving as an automatic start standby fan in the event of failure of the running fan. Two of the fans serve the "clean" areas (System A), which are general access, and two of the fans serve the remainder of the analytical and HEPA plenum areas (System B). The "clean" areas are designed to have 6 air changes per hour, while the production areas are designed to have 10 air changes per hour. Overall, the system is designed to keep temperature at 75° F and 50% humidity in the summer, 70° F in the winter, and to keep all glovebox temperatures below a maximum of 100° F.

All supply air is prefiltered, filtered, and heated or cooled as appropriate before entry into the building environment. Fail shut, tornado-proof supply air dampers are provided at each inlet as well. All ductwork in the building is constructed of galvanized steel.

System A sends all of its exhaust through plenum A, which has two HEPA filter banks in series. It is basically a straight through system. System B directs air to the production areas and rooms. Air can then discharge via any one of three paths. Exhaust air from analytical area corridors and the HEPA plenum area are bled off by one set of exhaust fans via a two-stage HEPA filter plenum. Room air filtering in from the corridors is drawn through hoods by another set of exhaust fans and passes through four stages of HEPA filtration. Other room air is drawn into the gloveboxes via glovebox-mounted HEPA filters. It then passes through the glovebox and is drawn by the final set of exhaust fans though the glovebox mounted exhaust HEPA filters into a four-stage HEPA filter plenum. All exhaust air eventually passes into an underground tunnel leading to the H plant stack.

For the analytical areas, negative pressure at specific supply and exhaust inlet points is controlled by pneumatically operated dampers. These units respond to signals from differential pressure detectors. Typical differential pressures between areas and atmosphere maintained are listed below:

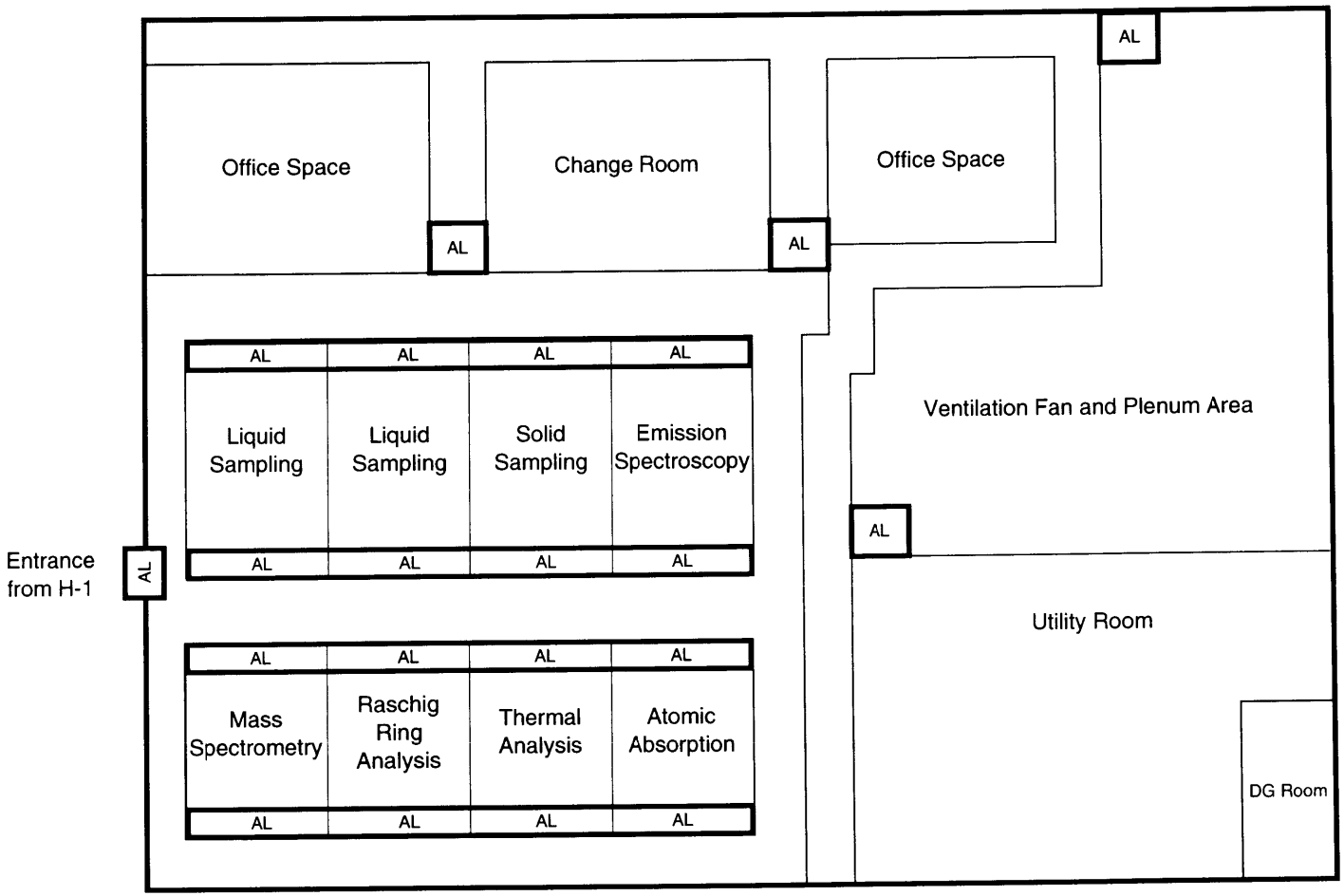


Figure B.19. H-7 Production Support Lab Floor Plan

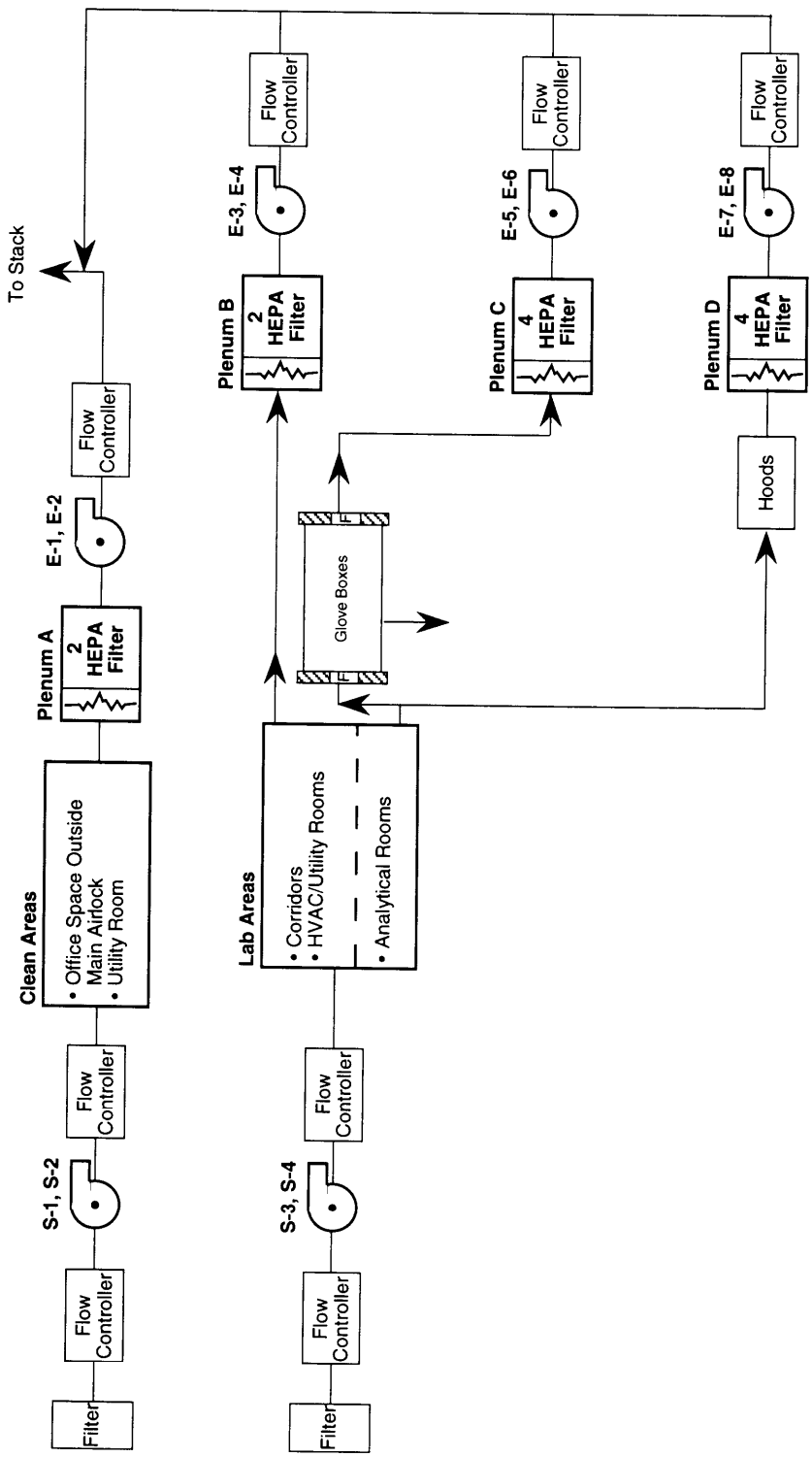


Figure B.20. Production Support Lab Ventilation System

Clean Areas	- 0.1" WG
Secondary Air Locks	- 0.15" WG
Regulated Analytical Areas	- 0.2" WG
Primary Air Locks	- 0.25" WG
Analytical Rooms	- 0.3" WG
Gloveboxes	- 0.9" WG

Differential pressure readout and low-level alarms are available in the facility utility room. Local indications of differential pressure are available at each glovebox as well. An automatic mechanical sequencer controls restart of fans following loss of ventilation to prevent overpressurizing the facility. This unit will also trip supply fans if an exhaust fan fails and the standby unit does not come on.

3.1.4 Existing Structural Studies

The H-7 building was not built in accordance with any one set of identifiable contractor standards. The site study "Building H-7 Design Criteria" identifies what criteria the building construction is believed to correlate with and notes modifications made in accordance with the changed mission to support H-Plant operations.

An independent study of the facility was performed by Brown and Associates in 1987. This study relied on extensive facility walk-throughs and review of available documentation. The study concluded that the H-7 facility is structurally sound and would withstand the design basis equivalent tornado of 119 mph from UCRL-15910 without significant damage. The seismic resistance of the facility, however, is substantially weaker than that of H-Plant.

Site-specific response spectra used in the evaluation were defined in an independent study conducted by Lawrence Livermore National Laboratory. These response spectra provided surface accelerations at an average soil depth. For return periods of one in 1000 years and one in 10,000 years, acceleration levels are 0.13g and 0.25g. The 1987 structural assessment reached the following conclusions about expected seismic damage:

g-Level	Probable Damage
0.1	Threshold of serious effects. Exterior walls are overstressed and experience minor cracking. Interior gypsum board walls begin to fail. Interior unreinforced concrete block walls intact but show signs of distress. Connection points between girders and support columns experience some weldment failure. Generically supported piping fails due to differential displacement.

g-Level	Probable Damage
0.12	Onset of potential for utility equipment failures. Highest value at which continued supply of electrical power can be assumed. Represents threshold of ventilation unavailability due to loss of power. Interior unreinforced concrete block wall cracking and possible localized failures. General failure of non-concrete walls.
0.13	Major cracking in external walls. Onset of external glovebox connection pipe and wiring failure. Excessive slippage due to failed weldments between girders and columns on the south wall of the building causes partial collapse of roof in the ventilation and HEPA plenum area (i.e., southeast quadrant, ≈ 25% of room).
≥ 0.15	General building collapse.

3.1.5 Facility Support Systems

3.1.5.1 Nuclear Incident Monitors

Four sets of two nuclear criticality incident monitors each detect and alarm in excessive radiation fields. These detectors are spaced so as to provide overlapping coverage by a minimum of three monitors at any point in the facility. They provide flashing light and bell ringing indications when activated. The units are designed to alarm on any internal failure and receive power via an uninterruptable power supply.

3.1.5.2 Nuclear Criticality Design Mitigation and Control Systems

There are only two major contaminated liquid holding tanks in the H-7 building. These are the plenum deluge catch tank and the waste holding tank, each of which are equipped with borated raschig rings to prevent criticality during abnormal conditions. During normal operation, there is no reason to believe critical accumulations of plutonium in the tanks can occur.

All transfers of material, whether samples, sample recycle, or waste pails, are limited to one defined critically safe unit at a time.

3.1.5.3 Fire Mitigation Design and Practices

Whenever possible, construction materials are noncombustible or fire resistant. The exterior walls and roof of the building have a minimum 2-hour fire rating while the concrete interior walls and gypsum board over steel stud walls have minimum 2- and 1-hour fire ratings respectively. Major structural components of the gloveboxes and process material are made of noncombustible material.

Combustible liquids are not allowed in gloveboxes as part of the combustible loading control program in effect, except for one 50-ml bottle of a hexone-based solvent used for sample extractions. Potentially combustible wipes are limited by this program as well to approximately six in line at any one time. In normal operation, non-installed combustibles in the operating areas consist of desks, chairs, papers and books, electrical insulation, and flammable liquid storage cabinets. The latter normally contain several liter bottles of a hexone-based extraction solvent and/or several bottles of flammable chemicals such as ether, as well as miscellaneous cleaning chemicals.

A reasonable amount of clutter, largely in the form of empty sample vials (glass or impact-resistant plastic), tools, and glassware, can be found in analytical gloveboxes. However, the major sources of combustible material in lab gloveboxes are electrical wiring, glovebox gloves, sample label paper, and possibly sample vials if temperatures become hot enough. Wiring is installed in accordance with codes and housed in conduits or sealed raceways. Wiring penetrates gloveboxes through pave connectors to prevent an insulation fire from progressing into gloveboxes. The glovebox gloves are made of materials such as Hypalon and will melt and burn at elevated temperatures. However, the number of gloves is limited, and storage of used gloves in a line after removal is forbidden by procedure.

3.1.5.4 Fire Detection and Alarm System

The lab has three types of fire detectors available: ionization, photoelectric, and thermal. All three are used in individual rooms, while only thermal detectors are used in gloveboxes and ventilation plenums. Exceeding the setpoint on any detector will initiate an alarm in the operating area, the facility control room, and the site fire department. Failure of a detector and interruption of signal flowpath by such means as a wire break will initiate an alarm as well.

3.1.5.5 Fire Suppression System

All analytical areas of the lab are equipped with automatic wet-pipe sprinklers in the overhead, which actuate at temperatures slightly higher (approximately 155° F) than the fire

detection alarm setpoints. A dedicated set of thermal detectors in gloveboxes and rooms are used to provide initiation input to the sprinkler system, which is equipped with fusible links in the process areas as a backup means of initiation. Nozzle arrangement in the system is in accordance with NFPA standards and will blanket a room as well as directing spray to glovebox walls.

A thermal detector-activated deluge system is available for all HEPA plenums as well. This system actuates when air temperature coming to the plenum is above 180° F, providing a continual spray of firemain water upstream of the HEPA plenums. Series demisters are available to protect the plenum from a large flow of water drops. This system and any of the sprinkler systems can be activated manually as well.

3.1.5.6 Air Sampling Systems

There are two air sampling systems in the lab, a high- and a low-volume system. The high-volume system has 16 units in the analytical rooms themselves and an additional 10 exhaust duct samplers. Each of these units draws 30 cfm. There are also 25 low-volume air samplers designed to detect airborne contamination in airlocks, regulated corridors, utility areas, etc. These units draw 5 cfm. Both systems use impaction collection and photomultiplier tube detection and provide local audio and visual alarms. Only the high-volume system, however, provides remote alarm capability to the data logger in the facility utility control room. The motive force for both the low- and high-volume air samplers is one of two centrifugal exhausters located in the HEPA plenum room. These units discharge into the central facility exhaust duct downstream of the main exhaust fans.

There are also two low-volume air samplers downstream of the HEPA filters for each plenum. These units have remote alarm capability in the utility room as well. Continuously on-line filter media particulate samplers are provided for stack exhaust as well. These media are manually collected and sampled at prescribed intervals.

3.1.5.7 Cold Chemical Storage and Supply

Cold (i.e., not radioactively contaminated) liquid feed chemicals are kept in storage compartments in the analytical rooms themselves. The compartments are normally cabinets with locking doors except for the flammable liquid storage cabinets, which are constructed in accordance with NFPA and RCRA requirements.

3.1.5.8 Facility Control Room

The H-7 facility does not have a designated control room. Remote alarms for the air sampling system, fire detection and suppression, ventilation pressure, etc. are available in the utility room, which has designated shift operators to detect an alarm at the panel or via the remote indicator horns spaced throughout the utility room. Ventilation system controller status readout and remote controls are available by the alarm panel as well and are logged hourly.

3.1.5.9 Electrical Power Distribution

The H-7 facility is provided with split bus redundant normal power, auxiliary power from the facility diesel, and critical indication power from uninterruptable power supplies (UPS). Normal power is received from two separate public utilities. Utility A provides power to one main bus via the 32 substation, while Utility B provides power to the other main bus via the 33 substation. Automatic transfer switches will connect a given bus to the other substation upon loss of power from one supplier.

Auxiliary power is provided to the facility by a 250-kw diesel generator located in its own compartment in the utility area. Loss of power from both normal sources will automatically start the diesel and commence a timing sequence that will transfer emergency busses to the diesel once it is running at rated speed. Typical time for power restoration is on the order of 10 seconds. Upon restoration of power, the ventilation fans will automatically restart in the appropriate sequence.

There are two separate UPS in the H-7 facility. The first is dedicated to the criticality alarm systems and provides operational power for up to 3 hours. The second UPS provides power to the air sampling system and the ventilation readout panel for approximately 1.5 hours.

The building grounding system serves two functions. As the building electrical ground, it offers a path to ground for electrical faults, providing additional protection along with breakers and fuse blocks and allowing "bleedoff" of static electrical charges. Its second function is to provide a "bleedoff" path to ground in the event lightening strikes the building.

3.1.5.10 Instrument Air

Instrument air is generated by a small compressor unit in the utility room. It provides air for a variety of small users, the most significant being the automatically controlled dampers on the ventilation system. These units fail in their current position upon loss of instrument air.

Filtered air is drawn into one of two air compressors (on-line and standby units) rated for 200 scfm and 100 psig discharge pressure. The compressor outlet passes through drying towers to one of two surge receivers. Downstream of the receivers, reducing valves are used to provide two independent 60 psig instrument air lines.

3.1.5.11 Breathing Air

As in the case of process and instrument air, filtered breathing air is drawn into one of two redundant compressors and discharged to receiving tanks. Maximum flowrates and pressures are 450 scfm and 115 psig. A low-pressure alarm is provided on the receiving tank which allows 5 minutes of breathing air for eight people to exit from any ongoing jobs.

Downstream of the receiving tanks, supplied breathing air passes through two stages of cellulose fiber filters that remove particles greater than 20 μm in diameter. Reducing valves maintain a pressure of 30 psig on the system, which serves sets of manifolds in all of the operating and maintenance areas. A monitoring system is provided inline with the main header, which measures temperature, pressure, and O_2, CO_2, and H_2O concentration levels. An alarm is provided when one of these parameters goes out of a specified band. All alarms on the system are received in the control room and at individual manifold stations.

3.1.5.12 Steam and Condensate System

Steam is received from the site boilerhouse via a 150-psig main. Before entry into the building, it is reduced in pressure to 60 psig. Steam branch lines for use in the facility are reduced to a nominal pressure of 35 psig.

Steam is used as an energy supply for the hot water and building heating systems. General building use steam condensate is collected in tanks in the utility area and pumped back to the boilerhouse.

3.1.5.13 Domestic Water

The domestic cold water main is supplied from site utilities and is equipped with multiple redundant backflow preventers at various points in the system. One branch serves general building needs, a second serves utility needs, and a third serves process needs. The first two branches are disposed of through the sewage system.

The process water branch consists of three separate headers. The first provides water to safety showers in the operating and maintenance rooms. The second provides water to analytical room sinks. The third provides cooling water needed by analytical instruments.

Discharge from these lines is drained to a raschig ring waste water tank in the ventilation fan and plenum area, where it is ultimately disposed of to the H-8 liquid waste treatment facility.

3.1.5.14 Chilled Water Systems

There chilled water vendor package units are located in the facility utility room and serve as the chilled water supply for general use.

3.1.5.15 Sanitary Sewer System

The sanitary sewer system accepts effluent from washrooms, showers, clean utility system drainage or blowdown, etc. It serves as a conduit to deliver waste water to the site sewage plant.

3.1.5.16 Diesel Fuel Oil System

The fuel oil supply source for the backup power diesel generator is an 800 gallon underground storage tank immediately outside the building. The currently installed tank does not meet all regulatory requirements and is the subject of investigation for potential soil contamination remediation. A project for a replacement tank is currently underway. The tank is not equipped with automatic pumps, and the diesel fuel day tank is filled by a manually operated pump.

3.2 PROCESS DESCRIPTION

3.2.1 Overview

There is no systematic flow of material through the H-7 laboratory facility. Liquid and solid samples are received in maximum transfer quantities of 30- and 5-sample vials, respectively. Liquid samples are normally received in one of the two liquid sampling lines. Metal, oxide, peroxide, or fluoride samples are delivered directly to the solid sampling line. These lines then prepare smaller samples for other analytical gloveboxes.

In general, samples are introduced into lines via hood units located at either end of a line. Samples are then prepared and analyzed in the gloveboxes or prepared and removed from the gloveboxes for counting. The principle outputs of the gloveboxes are normal solid waste, unused sample material for recycle to the process, and low level-liquid waste generated by dilution of samples for counting.

Gloveboxes handling high-plutonium content solutions collect the unused sample portions of these solutions in two-liter plastic jugs. When these jugs become full, they are removed from the glovebox, placed inside a metal pail, and transferred back to the H-1 sampling line for recycle into the process. In a similar manner, solids are collected in individual vials until a preset limit is reached. The old limit was 10 sample vials, which has been adjusted down to 5 due to changes in transfer procedures in the Plutonium Recovery Facility. The vials are placed inside a metal can, which is sealed and removed from the glovebox for transfer to the H-1 feed preparation line to be burned to oxide for recycle into the process.

Solid waste is normally removed from the gloveboxes via bagports. Low-level liquid waste generated during the formation of aliquots is fed to a drain, which leads to a 200-gallon liquid waste collection tank in the ventilation fan and plenum room. When this tank becomes full, it is sampled and sent to the H-8 liquid waste treatment facility.

Minimum critical quantities of plutonium are not handled in any one glovebox, and all analytical gloveboxes are generically limited to 400 grams of plutonium. This limit is not reached when gloveboxes are operating. The procedures of the lab are currently being reviewed to determine if operating inventories can be reduced sufficiently to make the lab a Hazard Category 3 facility.

3.2.2 Liquid Sampling Lines

There are two identical liquid sampling lines due to the larger number of liquid samples processed as compared to solid samples. Each sampling line contains a storage rack that can hold up to 30 20-ml sample vials at a time. The glovebox consists of three major stations: (1) the densitometer station, (2) the aliquotting station, and (3) the extraction and drying station.

The densitometer station serves to allow density measurements of plutonium solutions if desired. The aliquotting station has a small water supply station that also houses the low-level waste drain. At this station, a small portion of the sample can be diluted by several orders of magnitude to allow for later counting.

The extraction and drying station contains a 50-ml bottle of a hexone-based solvent, which is used to extract plutonium from americium for a small portion of a sample. The plutonium transfers to the organic layer, an aliquot of which is then pipetted to a stainless steel disc and evaporated under an infrared lamp. The disc is then sealed with a thin coating and removed from the glovebox for counting. Americium aliquots are prepared from the aqueous layer and either dried or transferred to a small vial for counting.

Several types of counting devices are available in the liquid sample line rooms. The most significant are the simple alpha and gamma scintillation detectors used for measuring plutonium and americium respectively, and the x-ray fluorescence unit. This unit is contained in a shielded enclosure in the corner of the room. The unit is constructed so that it is not physically possible for an operator to get his hands into the path of the primary or secondary beams, and warning lights are activated in the room and the outside corridor when the unit is activated. The unit is operated in accordance with ANSI standards in the NBS 111 publication.

3.2.3 Solid Sampling Line

The solid sampling line contains one rack that can hold up to 10 sample vials awaiting analysis, and 1 metal storage container that can hold up to 5 sample vials awaiting return to H-1 for recycle into the main process. The glovebox consists of five major stations: (1) the densitometer station, (2) the preparation/dissolution station, (3) the aliquotting station, (4) the extraction and drying station, and (5) the titration station.

The densitometer station and the aliquotting station are essentially the same as their counterparts in the liquid lines. The preparation/dissolution station is the first unique feature of the solid sampling box. It is necessary because all solids must pass through a liquid phase before final analysis. Small metal samples are easily dissolved in hydrochloric or nitric acids. Plutonium fluoride is dissolved in nitric acid with an aluminum complexing agent, and plutonium peroxide is dissolved in acid containing an oxidizing or reducing agent (i.e., permanganate or iodide). Plutonium oxide is normally mixed with potassium pyrosulfate and fused in a small muffle furnace provided at the station. The resulting solid is easily dissolved in nitric acid.

The extraction and drying station performs the same operations as the same section does in the liquid lines as well as one additional major operation. This operation is the extraction of neptunium from the aqueous americium layer by use of small ion exchange columns made of laboratory glassware. This operation is conducted on solutions obtained from product metal samples, with the neptunium obtained being plated out on a stainless steel disc in the same manner as plutonium.

The titration station is used to dissolve small metal samples of plutonium in hydrochloric acid. The resulting solution is reduced by the addition of titanium chloride and titrated to an endpoint with cerric ammonium nitrate solution. This operation is used to determine the relative purity of the original sample.

The same types of counting devices found in the liquid sample line rooms are found in the metal sample line rooms.

3.2.4 Emission Spectroscopy Line

The emission spectrometer is used primarily to measure impurities in plutonium metal. It is also used to prepare samples for the x-ray diffraction analysis unit installed in the room. The line consists of three major stations: (1) the diffraction sample preparation station, (2) the spectrometer sample preparation station, and (3) the emission spectrometer station.

The diffraction sample preparation station has a storage rack capable of holding 10 sample vials. A metal storage container that can hold up to five sample vials awaiting return to H-1 for recycle into the main process is located at this station as well. A mortar and pestle are provided in the station to grind non-metallic samples into fine powder. The sample obtained is sealed in a plastic pipe cap by Teflon or Mylar film before being removed from the glovebox via the hood box on the entry end of the line. It is examined for contamination in a separate laboratory hood and then taken to the diffractometer sample chamber. The x-ray unit is operated in accordance with ANSI standards and is equipped with warning lights that activate in the room and in the hallway when the unit is on. Respirators are worn whenever the sealed sample is in transit in the room, and a contamination check is made before removing the respirator after transfer.

The spectrometer sample preparation station also has a storage rack capable of holding 10 sample vials. The first step in preparation is to dissolve the sample in acid and then precipitate the sample in a slurry form. The slurry is dried under an infrared lamp and converted to oxide in a small muffle furnace. In the final step of sample preparation, the oxide obtained is pelletized in a sodium fluoride matrix.

Individual pellets are introduced into the emission spectrometer station and inserted in the unit's electrode rod. The pellet is vaporized once it is in place, and impurities are detected from their spectral emissions. The emission spectrometer itself is built into the glovebox, with the physical bulk of the unit outside the box.

3.2.5 Mass Spectrometry Line

Like the emission spectrometer, the mass spectrometer is built into the mass spectrometry glovebox with the bulk of the unit outside the glovebox. The line receives small liquid samples from the liquid or solid sampling lines and is equipped with a 20-position storage rack. Analysis is performed on small samples dried and oxidized with a heated filament. These samples are transferred through a vacuum lock into the automated mass spectrometer.

Computer readouts from the instrument provide estimates of isotope quantities for specific elements.

3.2.6 Raschig Ring Line

New and used raschig rings are examined in this room, with used rings being examined in a small glovebox. The major tests are: (1) neutron absorption test using a packaged source and absorption instrument, (2) chemical stability test performed by immersion in a heated nitric acid bath, and (3) physical strength test performed by rotating in a tumbler.

3.2.7 Thermal Analysis Line

This line serves to allow thermal characterization of samples, including metallic plutonium. A 10-position storage rack is provided for sample vials, and a storage can for up to 5 leftover sample vials awaiting recycle to the process. Differential thermal analysis measures the endothermic or exothermic response of sample material to heating over a selected temperature range. Thermogravimetric analysis determines the weight change of sample material over a selected temperature range. A small arc welding unit is provided in the box for sealing sample holders prior to measurement.

3.2.8 Atomic Absorption Line

This small line receives samples generated in the liquid or solid handling lines. An automated atomic absorption unit integral to the glovebox receives a supply of acetylene gas from a vendor-supplied bottle stored in the room. This gas provides a small flame into which the sample is aspirated. Differences in light transmission as the sample passes through the flame are used to determine quantities of selected impurities in the original sample. The line is equipped with a 20-position sample vial storage rack.

3.2.9 Solid Waste and Residue Handling

All solid waste is taken to the Plutonium Recovery Facility pail assay area upon generation.

3.3 HAZARD IDENTIFICATION

This document presents in tabular form the hazards identified by the team evaluating the H-7 Production Support Lab. It examines each of the major activities and areas of the facility. The two general types of hazards identified are as follows:

A - Material of concern for release or a potential hazard in direct contact with a material of concern.

B - Hazard in the vicinity of material of concern that could be relevant to an event affecting material of concern.

Standard industrial hazards are not included unless they represent a potential hazard type B. In that case, the focus of identification is on basic parameters to support examining the potential affect on materials of concern, not standard worker safety issues. This practice is in keeping with the definitions of both hazard and standard industrial hazard in DOE-STD-3009-94.

The initial effort has largely relied upon procedural and activity limits to produce an initial definition of facility hazards that reflects actual conditions anticipated. This is generally adequate for the overall examination envisioned, but it is essential for the initial effort as a minimum. Unreal numbers based on mathematical dose or high criticality limit considerations should not be used without appreciation of the actual conditions underlying those constructs, as blind application of such numbers can distort evaluation results.

Table B-2 - Production Support Lab Facility Hazard Identification

Location	Type	Hazard	Quantity
Lab Corridors	A	1. Plutonium solutions 2. Plutonium solids 3. Plutonium in waste	1. Procedure limits any one sample transfer into the facility to 30 sample vials (600 ml) based on the maximum storage capacity of any one liquid line. This would correspond to between 0.3 and 50 g of Pu depending on where the samples were drawn, with a typical loading between 1 and 20 g Pu. 2 liter bottles of excess sample material are transferred to the sampling line for recovery. Procedural and accountability requirements limit bottle contents to a maximum of 100 g of Pu. 2. Five sample vials can be transferred at a time. Inlet quantity of 10 grams/vial gives total of 50 g Pu or Pu compound. The same limit applies for transferring leftover sample material back to the process. 3. Up to 20 grams of plutonium are allowed to be entrained in a waste pail from the lab.
	B	1. Standard Industrial	1. Low combustible loading.
Liquid Sampling Gloveboxes (2 identical units - values are for one)	A	1. Plutonium solution 2. Plutonium residues	1. Storage rack will hold 30 sample vials. This is 0.3 - 50 grams of Pu. One 2 liter sample recycle bottle is allowed in the box. The bottle is allowed to hold 100 grams of Pu. A 30 position storage rack is available for aliquot vials. Total plutonium present would be less than 1E-5 grams. 2. Sample aliquots are boiled dry in planchettes. They are removed from B-boxes at the end of the glovebox for counting. Each planchette will have less than 1E-6 grams.
	B	1. Potential energy 2. Thermal energy 3. Chemical energy	1. - Ventilation - 115 VAC 2. Open-faced hot-plate used to boil counting samples. 3. 50 ml of a hexone based organic solvent is allowed in the glovebox for extractive sampling.
Liquid Sampling Line Room (2 identical rooms - values are for one)	A	1. Plutonium residues 2. Plutonium solutions	1. Sealed prepared planchette samples are handled in the room for counting. Up to 20 grams of plutonium can be entrained with bagged waste. 2. Samples are brought into the room for transfer into and out of the glovebox. Aliquot vials are handled in the room for counting. Each vial contains less than 1E-5 grams. One sample recycle bottle (maximum of 100 grams) can be transferred out of the room at a time.

Table B-2 - Production Support Lab Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Liquid Sampling Line Room (cont.)	B	1. Standard industrial 2. Potential energy	1. Low to medium combustible loading. Lab quantities of chemicals used and stored in accordance with 29 CFR 1910.1450. 5 liters of hexone based solvent and various cleaning agents stored in flammable liquid cabinet. 2. X-ray source for x-ray fluorescence detector.
Solid Sampling Line	A	1. Plutonium solids 2. Plutonium solutions 3. Plutonium residues	1. Storage rack will hold 10 sample vials. At 10 g/vial limit, this is 100 g Pu or Pu compounds. Leftover sample material is stored in vials in additional 5 position rack (50 g total). 2. Solids are dissolved in 30 ml of acid for analysis. A storage rack for 20 sample solutions is provided. If full, rack would typically hold ≈ 20 g Pu in solution. One 2 liter sample recycle bottles is allowed in the box (100 g Pu max.). A 30 position storage rack is available for aliquot vials. Total plutonium present would be less than 1E-5 grams. 3. Sample aliquots are boiled dry in planchettes. They are removed from B-boxes at the end of the glovebox for counting. Each planchette will have less than 1E-6 grams.
	B	1. Potential energy 2. Thermal energy 3. Chemical energy	1. - Ventilation - 115 VAC 2. Open-faced hot-plate used to boil counting samples. 3. 50 ml of a hexone based organic solvent is allowed in the glovebox for extractive sampling.
Solid Sampling Line Room	A	1. Plutonium residues 2. Plutonium solutions	1. Sealed prepared planchette samples are handled in the room for counting. Up to 20 grams of plutonium can be entrained with bagged waste. 2. Samples are brought into the room for transfer into and out of the glovebox. Aliquot vials are handled in the room for counting. Each vial contains less than 1 E-5 grams. One sample recycle bottle can be transferred from the room at a time. Maximum plutonium content is 100 grams.
	B	1. Standard industrial 2. Potential energy	1. Low to medium combustible loading. Lab quantities of chemicals used and stored in accordance with 29 CFR 1910.1450. 5 liters of hexone based solvent and various cleaning agents stored in flammable liquid cabinet. 2. X-ray source for x-ray fluorescence detector
Emission Spectroscopy Glovebox	A	1. Plutonium solids 2. Plutonium oxide	1. There are two 10 position storage racks for samples (maximum of 200 g). One 5 sample storage box for return to H-1 is available (maximum of 50 g). 2. Gram or less samples of plutonium oxide are generated for pellet making. Only one pellet at a time is in the box.

Table B-2 - Production Support Lab Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Emission Spectroscopy Glovebox (cont.)	B	1. Potential energy 2. Thermal energy	1. - Ventilation - 480 VAC 2. A small muffle furnace is provided for converting oxalic precipitate to oxide.
Emission Spectroscopy Room	A	1. Plutonium solids 2. Plutonium residues.	1. Samples are brought into the room for transfer into the box. Maximum transfer is 5, which can hold as much as 50 g of Pu or Pu compounds. 2. Up to 20 g Pu can be entrained with a bag of waste.
	B	1. Standard industrial	1. Low combustible loading. Lab quantities of chemicals are used in accordance with 29 CFR 1910.1450.
Mass Spectrometry Glovebox	A	1. Plutonium solutions	1. A storage rack with room for 20 samples from the liquid or solid sampling line is provided. Typical inventory if the rack full is ≈ 20 g Pu or less. One 2 liter bottle for excess sample solution is allowed. The administrative limit is 100 g Pu.
	B	1. Potential energy	1. - Ventilation - 480 VAC
Mass Spectrometery Room	A	1. Plutonium solutions 2. Plutonium residue	1. Plutonium solutions enter the room for transfer into the glovebox. A maximum of 10 vials may be transferred into the room at a time (≈ 10 g Pu or less). One 2 liter bottle of excess sample material may be transferred from the line at a time. 2. Up to 20 grams of plutonium may be entrained in a waste bag.
	B	1. Standard industrial	1. Low combustible loading.
Raschig Ring Analysis Glovebox	A	1. Plutonium as trace contaminant on raschig ring.	1. Only one sample batch is allowed into the glovebox at a time. Typical inventory would be fractions of a gram.
	B	1. Potential energy 2. Kinetic energy	1. - Ventilation - 115 VAC 2. Small tumbler unit tests strength of rings.
Raschig Ring Analysis Room	A	1. Plutonium as trace contaminant on raschig rings. 2. Plutonium in waste.	1. Samples are transferred through the room to the glovebox. 2. Up to 20 grams of plutonium may be entrained in a bag of waste.
	B	1. Standard industrial	1. Low combustible loading.

Table B-2 - Production Support Lab Hazard Identification (cont.)

Location	Type	Hazard	Quantity
Thermal Analysis Glovebox	A	1. Plutonium solid	1. Storage rack will hold 10 sample vials. At 10 g/vial, max. of 100 g. Leftover sample material is stored in vials in additional 5 position can (50 g total).
	B	1. Potential energy	1. - Ventilation - 480 VAC 2. Small arc welding unit
Thermal Analysis Room	A	1. Plutonium solid. 2. Plutonium residues.	1. Samples are brought into the room for transfer into the box. Maximum transfer is 5, which can hold as much as 50 g of Pu or Pu compounds. 2. Up to 20 grams of Pu can be entrained in solid waste.
	B	1. Standard industrial	1. Low combustible loading. Lab quantities of chemicals used in accordance with 29 CFR 1910.1450.
Atomic Absorption Glovebox	A	1. Plutonium liquid 2. Chemical energy	1. A storage rack with room for 20 samples from the liquid or solid sampling line is provided. Typical inventory if the rack is full would be less than 20 grams Pu. 2. Small flow of acetylene in absorption unit.
	B	1. Potential energy	1. - Ventilation - 115 VAC
Atomic Absorption Room	A	1. Plutonium solutions 2. Plutonium residues 3. Chemical energy	1. Samples are brought into the room for transfer into the box. A maximum of 10 vials may be transferred into the room at a time ($\approx$ 10 g Pu or less). 2. Up to 20 grams of Pu can be entrained in solid waste. 3. 125 scf of acetylene in vendor supplied cylinder.
	B	1. Standard industrial.	1. Other than acetylene bottle, low combustible loading.
Utility Room	A	-	-
	B	1. Standard industrial	1. Low combustible loading. One flammable liquid storage cabinet with cleaning agents.
Fan and Filter Room	A	1. Plutonium	1. Historical records indicate the following plutonium contents as bounds for specific plenums: A - 1 g, B - 2 g, C - 10 g, D - 5 g. Wastewater collection tank holds less than 10 grams plutonium total. Holdup measurements are less than 10 grams (i.e., in range of uncertainty).
	B	1. Standard industrial	1. Low combustible loading.
Diesel Generator Room	A	1. Diesel fuel	1. Day tank holds 50 gallons. Underground storage tank holds 800 gallons.
	B	1. Standard industrial.	1. Other than day tank, low combustible loading.

Appendix B

4.0 H-21 TRU-WASTE FACILITY

4.1 FACILITY DESCRIPTION

4.1.1 Overview

The H-21 TRU-Waste Facility is used to store and ship transuranic waste generated as a result of operations in the H-Plant Area. The building consists of four areas; the storage bay, the loading dock, the real-time radiography (RTR) room and employee office space. The storage bay provides short-term storage of 55-gallon transuranic waste drums. It has a capacity of 320 waste drums, with an additional capacity for up to 12 rejected drums awaiting return. Limited space away from drum storage is also provided for short-term storage of several large waste crates. The maximum inventory of radioactivity allowed in the H-21 facility is 10,000 grams of weapons-grade plutonium. A single drum of TRU waste may contain up to 200 grams of weapons-grade plutonium. Material handling equipment used in this facility consists of common industrial stock items, such as electrical forklifts, barrel huggers, and slings. The layout of the H-21 facility is presented in Figure B.21.

4.1.2 Facility Structure

The H-21 facility is a 4,000 ft^2 Butler style building. It is a single story, metal frame, metal panel building with reinforced concrete footings, foundation an floors. The building frame is constructed of welded plate and wide flange columns and beams. The roof and walls consist of ribbed interlocking steel panels that provide shelter from normal atmospheric phenomena.

4.1.3 Facility Support Systems

4.1.3.1 HVAC System

Heating and ventilation is provided by a ceiling mounted heater and blower system supplied by a single intake duct on the roof. Air is introduced into the office area, from which it flows through the storage bay to the loading bay. Exhaust is through one-way outlets in both the storage bay and the loading bay, as well as through gaps in the loading bay door openings. A single air conditioning unit is located outside and adjacent to the facility, providing cool air to the building.

Appendix B; H-21 TRU Waste Facility

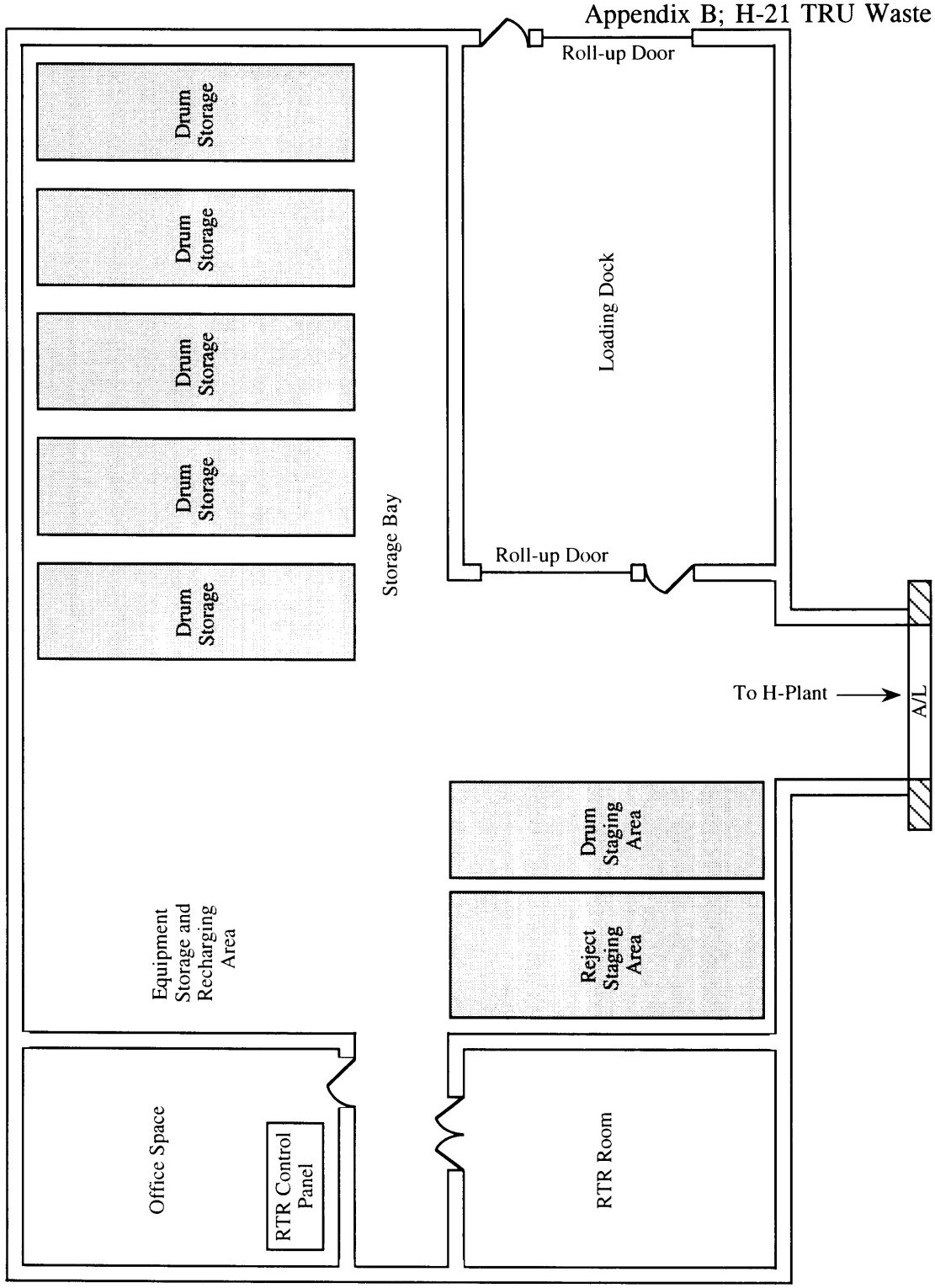


Figure B.21. H-21 TRU-Waste Facility Floor Plan

4.1.3.2 Fire Suppression System

The H-21 fire protection system is a wet-pipe sprinkler system employing automatic heat-activated sprinklers in the overhead designed to actuate at 100° C. Activation of the sprinkler sounds a building-wide audible alarm and also triggers an alarm at the local fire station. The H-21 facility fire protection system is not seismically qualified.

4.1.3.3 Electrical Power Distribution

The H-21 facility is provided with normal power received from a local utility. No backup or redundant power is available. The building grounding system serves two functions. As the building electrical ground, it provides a path to ground for electrical faults, affording additional protection along with breakers and fuse blocks and allowing "bleedoff" of static electrical charges. Its second function is to provide a conducting path to ground in the event of lightning strike.

4.1.3.4 Domestic Water

Domestic, industrial, and fire-fighting water is drawn from a 30.5 cm cast iron water main extending from the south. Effluent from this system is disposed of through the sewage system.

4.1.4 Real-Time Radiography Unit

The RTR unit is a filmless radiography machine operating at approximately 420 kV and 10 mA. Trained RTR personnel view the real-time X-rays which are displayed on a television monitor. RTR personnel look for wave motion on the X-ray display which is the indicator of free liquids within the waste drums. The X-ray images are videotaped to create a permanent record as drums are scanned.

Drums undergoing RTR examination are placed on a cart and positioned inside a shielded room. The X-ray tube and imaging system are located on opposite sides of the shielded room and are positioned to scan the drum. The tube and imaging system remain fixed in position while the cart is mechanically jostled. Safety interlocks prevent the X-ray tube from operating if a shielded door is open. The unit is operated remotely from the RTR control panel located in the facility office area.

4.2 DESCRIPTION OF OPERATIONS

The H-21 TRU-Waste Facility serves as a radioactive and hazardous waste and shipping facility and prepares new certified waste drums for plant-wide use. The building is in operation 24 hours per day for five days each week. The real-time radiography unit is used to evaluate the contents of waste drums.

4.2.1 Receiving and Inspection of Waste Drums

The H-21 facility receives drums of waste produced by the adjacent H-Plant. Drums of waste are inspected according to the procedures titled "Waste Drum Inspection Process" and "Dock Area Inspection Process." The received waste is moved into the staging area where drums are inspected for dents or other damage. Waste drum identification is verified by the Tamper Indicating Device (TID) number. Drums can be rejected for any reason, such as bulges, dents, loose bolts, holes, loose packaging, incomplete paperwork, exceeding weight limit, or liquids in the drum. The H-Plant is notified of the intent to return the rejected drum, and the material is moved to the reject staging area prior to return.

TRU-Waste drums are examined through RTR by non-destructive testing (NDT) personnel prior to storage or staging for shipment to verify compliance with drum requirements, mixture requirements, and that no free liquids are present. The Shipping Operations Manager is immediately notified if free liquids are suspected to be present. During RTR examination the drum is mechanically jostled and passed in front of the X-ray tube and imaging system. RTR acceptance criteria include the following:

- Drums require a rigid liner and a minimum of one sealed poly liner inside the rigid liner. The rigid liner is secured with a retaining clamp and bolt.
- No free liquid can be present in the waste.
- Metal or glass wastes may contain up to 10% combustibles by volume as estimated by RTR examination.
- All pressurized containers in drums must show clear evidence that container integrity has been destroyed, removing the potential for residual container pressurization. Examples include aerosol cans and pressurized-gas bottles.

After RTR inspection the drum is moved back to the staging area. Drums containing free liquids are placed inside a catch pan for secondary containment should the drum leak or rupture.

4.2.2 Storage of Waste Drums

The TWF has a total storage of 90 cubic yards of TRU-waste. Rejected drums awaiting return are included in the allowed inventory, although they are not stacked and therefore the number staged is limited. The maximum permitted dose rate of a single drum is 200 mrem per hour, although normally observed dose rates are far below the limit. Drum storage cannot exceed 4 layers and a lateral spacing cannot be less than 18 inches between drums. All banding and palletting of drums is performed at floor level. Drums are placed on pallets, where they are coated with fire retardant and separated by sheets of plywood. Banding is required on the fourth tier of drums. Main egress routes between stacks are at least 44 inches greater than the width of the widest load.

4.2.3 Radiation Monitoring

Contamination surveys are performed at each shift change (every 8 hours) using swipes and an alpha particle instrument. Smears are taken form the walking area, routinely used equipment, miscellaneous drums, and pallets. Smear readings above 20 dpm require decontamination. A weekly radiation exposure survey monitors gamma and neutron radiation activity. Instruments are used to survey gamma and neutron activity near the outside of the drums. All waste drums to be shipped receive a final survey.

4.2.4 Shipping

TRU-Waste drums are shipped out of the H-21 facility via truck trailer to the onsite storage location. Truck trailers are inspected and surveyed prior to backing up to the H-21 loading dock. Once in place, the trailer wheels are chocked, and a visual inspection is conducted to verify that the trailer is in place and secure.

TRU-Waste drums are loaded onto the trailer one at a time using an electric forklift equipped with a barrel hugger. Cardboard is placed between barrel tiers when more than one layer of drums is configured on the trailer. Drum are placed so as to ensure proper weight distribution over the trailer axles. Each tier of drums is then banded.

After loading, trailers are surveyed for gamma and neutron radiation. The loading document is reviewed for accuracy, and if no discrepancies are found the paperwork is signed. The loaded trailer then receives a final inspection. The trailer is closed and sealed, the chocks are removed, and the truck pulls away from the H-21 loading dock.

CONCLUDING MATERIAL

Review Activities:

DOE	Field Offices	National Laboratories	Area Offices
DP	AL	ANL	Argonne
EH	CH	BNL	Brookhaven
EM	ID	INEL	Golden
ER	NV	LANL	Kirtland
NE	OR	LLNL	Los Alamos
NS	RFO	ORNL	Rocky Flats
	RL	PNL	
	SR	SNL	
	SF		
	SRO		

Preparing Activity:

DOE DP-31

Project Number:

SAFT-0013