TABLE G-2 (cont'd)

COMPOSITION OF COMBUSTION GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VCG-1	VCG-2	VCG-3	VCG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	2.7	0.7	Samples not submitted by EHL/M for analysis.		4.2
Aliphatic hydrocarbons (2)	2.5	0.3			4.2
Chlorinated aromatic hydrocarbons (3)	ND	ND			4.2
Chlorinated aliphatic hydrocarbons (4)	ND	ND			4.2
Chlorophenol	ND	ND			5.0
Dichlorophenol	ND	ND			5.0
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND			3.7
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND			3.5
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND			3.8
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND			3.5
Ionol	5.6	1.7			4.2
Didecylphthlate	7.2	2.9			4.2
Biphenyl	ND	ND			4.2
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND			3.7
Total volume of solution (ml)	576	312			

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-2 (cont'd)

COMPOSITION OF COMBUSTION GAS SAMPLING TRAIN
IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VICG-1	VICG-2	VICG-3	VICG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	29.0	0.4	0.3	0.1	0.15
Aliphatic hydrocarbons (2)	2.6	0.3	0.3	0.2	0.15
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.15
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.15
Chlorophenol	ND	ND	ND	ND	0.18
Dichlorophenol	ND	ND	ND	ND	0.18
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.13
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.13
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.14
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.13
Ionol	27.1	3.6	1.3	2.1	0.15
Didecylphthlate	21.7	2.9	2.2	0.8	0.15
Biphenyl	ND	ND	ND	ND	0.15
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.13
Total volume of solution (ml)	570	325	315	295	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-2 (cont'd)

COMPOSITION OF COMBUSTION GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VECG-1	VECG-2	VECG-3	VECG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	7.0	1.3	0.6	0.3	0.22
Aliphatic hydrocarbons (2)	1.9	0.7	0.5	0.2	0.22
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.22
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.22
Chlorophenol	ND	ND	ND	ND	0.27
Dichlorophenol	ND	ND	ND	ND	0.27
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.20
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.19
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.21
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.19
Ionol	19.5	1.0	1.1	0.4	0.22
Didecylphthlate	0.5	1.4	0.4	0.3	0.22
Biphenyl	ND	ND	ND	ND	0.22
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.20
Total volume of solution (ml)	635	315	310	295	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-2 (cont'd)

COMPOSITION OF COMBUSTION GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VIIICG-1	VIIICG-2	VIIICG-3	VIIICG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	19.2	1.0	0.3	0.2	0.20
Aliphatic hydrocarbons (2)	10.8	2.3	0.7	0.3	0.20
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.20
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.20
Chlorophenol	ND	ND	ND	ND	0.23
Dichlorophenol	ND	ND	ND	ND	0.23
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.17
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.16
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.18
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.16
Ionol	72.8	13.6	1.3	1.8	0.20
Didecylphthlate	495.	8.6	1.0	0.3	0.20
Biphenyl	ND	ND	ND	ND	0.20
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.17
Total volume of solution (ml)	490	290	285	285	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	ISG-1	ISG-2	ISG-3	ISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	2.7	1.2	1.1	0.9	0.23
Aliphatic hydrocarbons (2)	1.6	1.1	0.9	0.5	0.23
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.23
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.23
Chlorophenol	ND	ND	ND	ND	0.28
Dichlorophenol	ND	ND	ND	ND	0.28
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.21
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.20
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.22
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.20
Ionol	5.4	3.0	0.6	0.6	0.23
Didecylphthlate	35.2	2.4	0.7	0.3	0.23
Biphenyl	0.25	0.21	0.81	0.50	0.23
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.21
Total volume of solution (ml)	448	361	350	276	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

(TABLE G-3 cont'd on following seven pages)

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	IISG-1	IISG-2	IISG-3	IISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	0.5	0.5	1.2	2.1	0.21
Aliphatic hydrocarbons (2)	1.1	0.8	1.0	1.5	0.21
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.21
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.21
Chlorophenol	ND	ND	ND	ND	0.25
Dichlorophenol	ND	ND	ND	ND	0.25
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.18
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.17
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.19
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.17
Ionol	2.8	1.5	8.2	17.9	0.21
Didecylphthlate	5.7	6.0	3.5	2.4	0.21
Biphenyl	0.69	0.39	0.41	0.56	0.21
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.18
Total volume of solution (ml)	626	342	394	380	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	IIISG-1	IIISG-2	IIISG-3	IIISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	9.9	1.7	2.2	1.9	0.26
Aliphatic hydrocarbons (2)	6.7	4.1	1.2	1.1	0.26
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.26
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.26
Chlorophenol	ND	ND	ND	ND	0.31
Dichlorophenol	ND	ND	ND	ND	0.31
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.23
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.21
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.24
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.21
Ionol	11.6	2.1	1.3	0.4	0.26
Didecylphthlate	19.5	1.5	0.4	0.3	0.26
Biphenyl	0.63	0.10	0.07	0.12	0.26
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.23
Total volume of solution (ml)	534	468	362	340	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	IVSG-1	IVSG-2	IVSG-3	IVSG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	6.1	1.7	0.3	0.2	0.19
Aliphatic hydrocarbons (2)	3.2	1.9	0.7	0.6	0.19
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.19
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.19
Chlorophenol	ND	ND	ND	ND	0.22
Dichlorophenol	ND	ND	ND	ND	0.22
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.16
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.16
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.17
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.16
Ionol	53.4	3.1	2.9	3.2	0.19
Didecylphthlate	50.3	29.7	3.8	16.4	0.19
Biphenyl	0.80	0.07	ND	ND	0.19
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.16
Total volume of solution (ml)	492	406	354	324	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VSG-1	VSG-2	VSG-3	VSG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	1.1	0.4	0.6	0.6	0.23
Aliphatic hydrocarbons (2)	2.3	0.7	0.7	0.6	0.23
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.23
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.23
Chlorophenol	ND	ND	ND	ND	0.27
Dichlorophenol	ND	ND	ND	ND	0.27
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.20
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.19
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.21
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.19
Ionol	2.7	5.2	4.9	5.8	0.23
Didecylphthlate	15.3	33.9	4.5	8.5	0.23
Biphenyl	4.18	0.90	0.30	ND	0.23
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.20
Total volume of solution (ml)	610	250	424	330	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VISG-1	VISG-2	VISG-3	VISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	2.3	1.9	0.8	0.7	0.69
Aliphatic hydrocarbons (2)	4.2	3.7	2.0	1.2	0.69
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.69
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.69
Chlorophenol	ND	ND	ND	ND	0.83
Dichlorophenol	ND	ND	ND	ND	0.83
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.61
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.58
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.63
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.58
Ionol	5.7	7.3	1.7	6.2	0.69
Didecylphthlate	11.0	39.4	1.5	2.9	0.69
Biphenyl	0.98	2.17	1.67	1.29	0.69
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.61
Total volume of solution (ml)	520	335	335	285	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VIISG-1	VIISG-2	VIISG-3	VIISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	1.1	1.3	1.0	0.2	0.30
Aliphatic hydrocarbons (2)	1.1	0.8	1.1	0.7	0.30
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.30
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.30
Chlorophenol	ND	ND	ND	ND	0.36
Dichlorophenol	ND	ND	ND	ND	0.36
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.27
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.25
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.29
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.25
Ionol	0.6	1.9	0.5	0.5	0.30
Didecylphthlate	0.4	0.8	0.5	0.1	0.30
Biphenyl	2.05	0.42	0.04	0.03	0.30
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.27
Total volume of solution (ml)	450	395	410	295	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G–3 (cont'd)

COMPOSITION OF SCRUBBED EFFLUENT GAS SAMPLING TRAIN IMPINGER SAMPLES

(micrograms per total sample as compound except as noted)

	VIIISG-1	VIIISG-2	VIIISG-3	VIIISG-4	Detection Limits* nanograms/liter
Aromatic hydrocarbons (1)	7.0	1.3	0.5	0.5	0.28
Aliphatic hydrocarbons (2)	2.2	0.7	0.2	0.2	0.28
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.28
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.28
Chlorophenol	ND	ND	ND	ND	0.33
Dichlorophenol	ND	ND	ND	ND	0.33
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.24
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.23
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.25
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.23
Ionol	4.9	2.5	0.5	0.9	0.28
Didecylphthlate	2.2	1.1	0.4	0.4	0.28
Biphenyl	4.37	1.21	0.87	0.02	0.28
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.24
Total volume of solution (ml)	470	350	400	320	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Based on flow data furnished by EHL/M

WEST COAST TECHNICAL SERVICE INC.

TABLE G-4

TOTAL QUANTITY OF MATERIAL PRESENT ON PARTICULATE SAMPLING FILTERS

(micrograms per total sample as compound except as noted)

	I-P	II-P	III-P	IV-P	Detection Limits micrograms
Aromatic hydrocarbons (1)	ND	ND	ND	Sample lost in transit.	0.025
Aliphatic hydrocarbons (2)	11.3	4.2	3.1		0.025
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND		0.025
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND		0.025
Chlorophenol	ND	ND	ND		0.030
Dichlorophenol	ND	ND	ND		0.030
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND		0.022
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND		0.021
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND		0.023
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND		0.021
Ionol	ND	ND	ND		0.025
Didecylphthlate	0.5	0.3	0.1		0.025
Biphenyl	ND	ND	ND		0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND		0.022
Iron	786.	669.	1016.		N/A
Total particulate mass (x 10^3) (data furnished by EHL/M)	79.6	44.9	51.1	92.9	N/A

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

(TABLE G-4 cont'd next page)

TABLE G-4 (cont'd)

TOTAL QUANTITY OF MATERIAL PRESENT ON PARTICULATE SAMPLING FILTERS

(micrograms per total sample as compound except as noted)

	V-P	VI-P	VII-P	VIII-P	Detection Limits micrograms
Aromatic hydrocarbons (1)	ND	ND	ND	ND	0.025
Aliphatic hydrocarbons (2)	1.3	9.3	3.7	6.2	0.025
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND	ND	0.025
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	0.025
Chlorophenol	ND	ND	ND	ND	0.030
Dichlorophenol	ND	ND	ND	ND	0.030
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.022
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	0.021
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.023
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	0.021
Ionol	ND	ND	ND	ND	0.025
Didecylphthlate	0.1	0.6	1.1	1.2	0.025
Biphenyl	ND	ND	ND	ND	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND	ND	0.022
Iron	1720.	400.	659.	1070.	N/A
Total particulate mass (x 10^3) (data furnished by EHL/M)	167.8	88.4	114.4	191.0	N/A

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

TABLE G-5

COMPOSITION OF GAS SAMPLING PROBE RINSES

(micrograms per total sample as compound except as noted)

	ICG-ACP	IICG-ACP	IIICG-ACP	IVCG-ACP	Detection Limits micrograms
Aromatic hydrocarbons (1)		1.7	2.8	Sample rinsed into IVCG-1.	0.025
Aliphatic hydrocarbons (2)	66.7*	1.3	1.7		0.025
Chlorinated aromatic hydrocarbons (3)		ND	ND		0.025
Chlorinated aliphatic hydrocarbons (4)		ND	ND		0.025
Chlorophenol		ND	ND		0.030
Dichlorophenol		1.38	0.7		0.030
2,4-dichlorophenoxy acetic acid (methylester)		ND	ND		0.022
2,4,5-trichlorophenoxy acetic acid (methylester)		ND	ND		0.021
2,4,-dichlorophenoxy acetic acid - butylester		ND	ND		0.023
2,4,5-trichlorophenoxy acetic acid - butylester		ND	ND		0.021
Ionol		ND	ND		0.025
Didecylphthlate		ND	ND		0.025
Biphenyl		ND	ND		0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin		ND	ND		0.022
Total volume of solution (ml)	265	242	280		

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

* Light lubrication oil; material masked other possible compounds present.

WEST COAST TECHNICAL SERVICE INC.

(TABLE G-5 cont'd next page)

TABLE G-5 (cont'd)

COMPOSITION OF GAS SAMPLING PROBE RINSES
(micrograms per total sample as compound except as noted)

	VCG-ACP	VICG-WCP	VIICG-WCP	VIIICG-WCP	Detection Limits micrograms
Aromatic hydrocarbons (1)	Sample	Sample	0.40	1.8	0.025
Aliphatic hydrocarbons (2)	not	rinsed into	0.26	0.73	0.025
Chlorinated aromatic hydrocarbons (3)	submitted by EHL/M	VICG-1.	ND	ND	0.025
Chlorinated aliphatic hydrocarbons (4)			ND	ND	0.025
Chlorophenol			ND	ND	0.030
Dichlorophenol			ND	ND	0.030
2,4-dichlorophenoxy acetic acid (methylester)			ND	ND	0.022
2,4,5-trichlorophenoxy acetic acid (methylester)			ND	ND	0.021
2,4,-dichlorophenoxy acetic acid - butylester			ND	ND	0.023
2,4,5-trichlorophenoxy acetic acid - butylester			ND	ND	0.021
Ionol			ND	ND	0.025
Didecylphthlate			ND	ND	0.025
Biphenyl			ND	ND	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin			ND	ND	0.022
Total volume of solution (ml)			118	415	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

TABLE G-6

COMPOSITION OF MISCELLANEOUS SAMPLES RELATED TO GAS SAMPLING

(micrograms per total sample as compound except as noted)

	IP-1&2	IIP-1&2	IIIP-1&2	IVP-1&2	Detection Limits micrograms
Aromatic hydrocarbons (1)	Samples not submitted		72.1	51.2	0.025
Aliphatic hydrocarbons (2)			7.4	45.6	0.025
Chlorinated aromatic hydrocarbons (3)			ND	ND	0.025
Chlorinated aliphatic hydrocarbons (4)			ND	ND	0.025
Chlorophenol			ND	ND	0.030
Dichlorophenol			ND	1.3	0.030
2,4-dichlorophenoxy acetic acid (methylester)			ND	ND	0.022
2,4,5-trichlorophenoxy acetic acid (methylester)			ND	ND	0.021
2,4,-dichlorophenoxy acetic acid - butylester			ND	ND	0.023
2,4,5-trichlorophenoxy acetic acid - butylester			ND	ND	0.021
Ionol			ND	ND	0.025
Didecylphthlate			ND	ND	0.025
Biphenyl			ND	ND	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin			ND	ND	0.022
Total volume of solution (ml)			65	400	

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

(TABLE G-6 cont'd next two pages)

TABLE G-6 (cont'd)

COMPOSITION OF MISCELLANEOUS SAMPLES RELATED TO GAS SAMPLING

(micrograms per total sample as compound except as noted)

	VP-1&2	VIP-1&2	VIIP-1&2	VIIIP-1&2	Detection Limits micrograms
Aromatic hydrocarbons (1)	34.7	16.2	Samples not submitted.		0.025
Aliphatic hydrocarbons (2)	32.1	1.7			0.025
Chlorinated aromatic hydrocarbons (3)	ND	ND			0.025
Chlorinated aliphatic hydrocarbons (4)	ND	ND			0.025
Chlorophenol	ND	ND			0.030
Dichlorophenol	ND	0.10			0.030
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND			0.022
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND			0.021
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND			0.023
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND			0.021
Ionol	ND	ND			0.025
Didecylphthlate	ND	ND			0.025
Biphenyl	ND	ND			0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND			0.022
Total volume of solution (ml)	475	280			

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

TABLE G-6 (cont'd)

COMPOSITION OF MISCELLANEOUS SAMPLES RELATED TO GAS SAMPLING

(micrograms per total sample as compound except as noted)

	ICG-CT	IICG-CT	IIICG-CT	IVCG-CT through VIIICG-CT	Detection Limits micrograms
Aromatic hydrocarbons (1)	12.6	0.9	16.0	Samples not submitted	0.025
Aliphatic hydrocarbons (2)	0.3	1.8	32.0		0.025
Chlorinated aromatic hydrocarbons (3)	ND	ND	ND		0.025
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND		0.025
Chlorophenol	ND	ND	ND		0.030
Dichlorophenol	1.2	0.1	0.1		0.030
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND		0.022
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND		0.021
2,4,-dichlorophenoxy acetic acid - butylester	0.70	ND	ND		0.023
2,4,5-trichlorophenoxy acetic acid - butylester	6.5	ND	ND		0.021
Ionol	ND	ND	ND		0.025
Didecylphthlate	ND	ND	ND		0.025
Biphenyl	ND	ND	ND		0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	ND		0.022
Total volume of solution (ml)	640	705	637		

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

TABLE G-7

EXTRACTABLES FROM FRESH AND SPENT SCRUBBER WATER
(micrograms/liter of compound except as noted)

	ISSW-TBC	IISSW-TBC	IIISSW-TBC	IVSSW-TBC	VSSW-TBC	VIISSW-TBC	VIIISSW-TBC	Detection Limits µg/l
Aromatic hydrocarbons (1)	191.5	121.0	56.4	5.1	1.2	7.8	6.2	0.05
Aliphatic hydrocarbons (2)	107.6	97.2	112.5	6.2	9.6	9.7	9.8	0.05
Chlorinated aromatic hydrocarbons (3)	524.1	465.1	32.3	7.2	3.2	1.1	2.2	0.05
Chlorinated aliphatic hydrocarbons (4)	ND	ND	ND	ND	ND	ND	ND	0.05
Chlorophenol	52.7	14.1	0.2	0.2	0.1	0.1	0.1	0.08
Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	0.08
2,4-dichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	ND	ND	ND	0.048
2,4,5-trichlorophenoxy acetic acid (methylester)	ND	ND	ND	ND	ND	ND	ND	0.046
2,4,-dichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	ND	ND	ND	0.048
2,4,5-trichlorophenoxy acetic acid - butylester	ND	ND	ND	ND	ND	ND	ND	0.043
Ionol	6.3	2.6	3.8	2.2	0.5	1.2	0.3	0.05
Didecylphthlate	16.9	7.2	7.1	6.3	4.1	3.6	7.2	0.05
Biphenyl	ND	ND	ND	ND	ND	ND	ND	0.05
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND	0.25	ND	ND	ND	ND	0.047
Butylalcohol	ND	ND	ND	ND	ND	ND	ND	0.05

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

NOTE: A VI-SSW-TBC sample was not prepared or submitted by EHL/K.

(TABLE G-7 cont'd next page)

TABLE G-7 (cont'd)

EXTRACTABLES FROM FRESH AND SPENT SCRUBBER WATER

(micrograms/liter of compound except as noted)

	IFSW-A	IIFSW-A	IIISSW-C1	IVSSW-C1	VSSW-C1	VISSW-C1	VISSW-C2	Detection Limits µg/l
Aromatic hydrocarbons (1)	13.5	*	1.7	0.6	15.0	5.3	1.4	0.05
Aliphatic hydrocarbons (2)	4.0		3.6	0.5	0.7	2.0	1.9	0.05
Chlorinated aromatic hydrocarbons (3)	ND		0.8	0.9	1.0	0.6	0.2	0.05
Chlorinated aliphatic hydrocarbons (4)	ND		ND	ND	ND	ND	ND	0.05
Chlorophenol	ND		0.2	0.1	0.1	0.1	0.1	0.08
Dichlorophenol	ND		ND	ND	ND	ND	ND	0.08
2,4-dichlorophenoxy acetic acid (methylester)	ND		ND	ND	ND	ND	ND	0.048
2,4,5-trichlorophenoxy acetic acid (methylester)	ND		ND	ND	ND	ND	ND	0.046
2,4,-dichlorophenoxy acetic acid - butylester	ND		ND	ND	ND	ND	ND	0.048
2,4,5-trichlorophenoxy acetic acid - butylester	ND		ND	ND	ND	ND	ND	0.043
Ionol	ND		0.5	3.4	11.4	8.4	2.7	0.05
Didecylphthlate	ND		9.6	3.5	10.5	8.5	7.1	0.05
Biphenyl	ND		ND	ND	ND	ND	ND	0.05
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND		ND	ND	ND	ND	ND	0.047
Butylalcohol	ND		ND	ND	ND	ND	ND	0.05

* Sample not analyzed by agreement between WCTS & EHL/K due to aluminum contamination.

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

NOTE: No I/II/VII/ or VIII SSW-C1 samples were submitted by EHL/K.

TABLE G-8

COMPOSITION OF SEDIMENT FROM SPENT SCRUBBER WATER HOLDING TANK

(micrograms as compound except as noted)

	ISSW-HT-2	IISSW-HT-2	IIISSW-HT-2	IVSSW-HT-2	VSSW-HT-2	VI/VII SSW-HT-2	VIIISSW-HT-2	Detection Limit-μg
Aromatic hydrocarbons (1)	Sample apparently lost.	Sample not submitted.	ND	ND	Sample not submitted.	ND	ND	0.025
Aliphatic hydrocarbons (2)			ND	ND		ND	ND	0.025
Chlorinated aromatic hydrocarbons (3)			ND	ND		ND	ND	0.025
Chlorinated aliphatic hydrocarbons (4)			ND	ND		ND	ND	0.025
Chlorophenol			ND	ND		ND	ND	0.030
Dichlorophenol			ND	ND		ND	ND	0.030
2,4-dichlorophenoxy acetic acid (methylester)			ND	ND		ND	ND	0.022
2,4,5-trichlorophenoxy acetic acid (methylester)			ND	ND		ND	ND	0.021
2,4,-dichlorophenoxy acetic acid - butylester			ND	ND		ND	ND	0.023
2,4,5-trichlorophenoxy acetic acid - butylester			ND	ND		ND	ND	0.021
Ionol			ND	ND		ND	ND	0.025
Didecylphthlate			ND	ND		ND	ND	0.025
Biphenyl			ND	ND		ND	ND	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin			ND	ND		ND	ND	0.022
Total residue (grams) of sample submitted			11.3	8.6		9.6	12.2	N/A
Iron (micrograms/gm. of residue)			80600.	99200.		55700.	44000.	N/A

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

TABLE G-9

COMPOSITION OF COMBUSTION CHAMBER RESIDUE

(micrograms of compound per 100 grams of residue)

	IRACC-2	IIRACC-1	IIRACC-2	IIIRACC-2	IVRACC-2	V/VIRACC-2	Detection Limits micrograms/100gms.
Aromatic hydrocarbons (1)	163.5	Samples not received at WCTS		2.7	512.6	33.9	0.025
Aliphatic hydrocarbons (2)	86.8			16.2	7.6	31.4	0.025
Chlorinated aromatic hydrocarbons (3)	ND			ND	ND	ND	0.025
Chlorinated aliphatic hydrocarbons (4)	ND			0.5	ND	ND	0.025
Chlorophenol	ND			ND	ND	ND	0.030
Dichlorophenol	ND			6.8	5.6	ND	0.030
2,4-dichlorophenoxy acetic acid (methylester)	ND			2.5	ND	ND	0.022
2,4,5-trichlorophenoxy acetic acid (methylester)	ND			2.4	ND	ND	0.021
2,4,-dichlorophenoxy acetic acid - butylester	ND			551	ND	ND	0.023
2,4,5-trichlorophenoxy acetic acid - butylester	ND			542	ND	ND	0.021
Ionol	ND			ND	ND	ND	0.025
Didecylphthlate	ND			ND	ND	ND	0.025
Biphenyl	9.5			6.2	17.1	1.6	0.025
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND			ND	ND	ND	0.022
2,4-dichlorophenoxy acetic acid-octylester	ND			0.2	ND	ND	0.020
2,4,5-trichlorophenoxy acetic acid-octylester	ND			0.6	ND	ND	0.020
Iron	103			127	12.5	25.0	N/A
Ash (%)	Not requested			0.05	0.04	0.06	N/A
Phenoxyacetic acid	ND			1.5	ND	ND	0.025

(1) calculated as butylbenzene
(2) calculated as decane
(3) calculated as dichlorobenzene
(4) calculated as $C_2H_4Cl_2$

WEST COAST TECHNICAL SERVICE INC.

NOTE: No VIII RACC-1 sample was submitted by EML/K.

APPENDIX H

(TO APPENDIX E)

SAFETY AND HANDLING

1.0 GENERAL

Due to the potential health hazard related to handling and incineration of "Orange" Herbicide, special safety requirements were established per the contract and TMC safety standards. In general, the items discussed in the following paragraphs were established to insure that:

- Personnel were protected against any contact with the herbicide or its possible hazardous combustion products.
- No herbicide was released to the environment.
- Medical surveillance of applicable personnel was provided.

As applicable, many of these same safety precautions were also observed in the handling of caustic solution.

2.0 DRUM MONITORING

An Inspection Log Sheet was established for each drum of "Orange" Herbicide received from the Air Force. This sheet was maintained by a TMC Safety Engineer and all information regarding the drum during its stay was recorded. Information included initial receipt data, receipt condition, results of daily inspection, transfer data, cleaning operations, and final disposal. All drums were received in good condition and no redrumming was required. These records are available at TMC.

3.0 PHYSICAL EXAMINATIONS

Complete physical examinations were performed on all TMC personnel directly involved in herbicide operations of unloading, transfer, incineration, operations and drum cleaning. Examinations were performed just prior to TMC receipt of the "Orange" Herbicide, and repeated after the program was completed. Although intermediate examinations were authorized if warranted by exposure problems, none were required. Examinations included a routine history and physical, chext x-ray, and special attention directed to skin and liver. Laboratory procedures included complete hemogram including hematocrit and platelet count, prothrombin time, serium lipids, S-GOT, S-GPT, serium bilirubin, blood glucose, and complete urinalysis. Examinations were conducted at the Van Nuys Medical Clinic, Panorama City, California and the records will be maintained at TMC until at least November, 1976.

4.0 EQUIPMENT AND FACILITIES

4.1 Personnel Protective Gear

The following gear was worn by personnel during transfer or other operations where direct contact with the herbicide was possible:

- MSA Cyralon Gloves
- MSA Yellow Plastic Suits
- Tingley 10" Neoprene Boots
- MSA Face Shields

Personnel requiring gas masks (including AF) were issued MSA Rocket Propellant Masks No. EF-86847 with Cannisters, Type GMC-S, P/N 05-84908, suitable for use with "Orange" Herbicide, phosgene, or HCl. MSA hard hats were also issued and required in the test area.

4.2 Special Equipment

In addition to the normal equipment used in this type of facility operations, the following special items were provided:

- "Orange" Herbicide drums were transported with a fork lift drum handling fixture. This fixture was securely attached around the drum's entire circumference, and allowed the drum to be rotated for draining.
- Barrel pumping was performed with a pneumatic device which forced the fluid through a hose assembly. This device removed all but about two quarts of "Orange" Herbicide from the drum while the drum was in its normal upright position.
- A specially constructed funnel was placed in the run tank for receiving the "Orange" Herbicide from the drum pump hose. This funnel had a closed top to prevent splash or spray and included a filtering screen.
- Steam cleaned 55-gallon drums were available for possible redrumming of any leaking drums.
- Drums of JP-4 were stored in the drum storage area and in the test cell area for use to wash down any spillages.
- Sealable cardboard drums were available for storing any accumulated contaminated materials.
- The Aero Thermo Laboratory and the drum storage area were equipped with fire protection equipment and emergency eye baths and showers.

5.0 GENERAL SAFETY PROCEDURES

The following paragraphs present other general safety requirements employed during this program:

- Only authorized personnel (TMC personnel with physical examinations or required AF personnel) were permitted to conduct test program operations and be present in the test area during actual testing.
- The test area was bounded by safety ropes during operations. Access to the area was strictly controlled by the Test Engineer.
- All personnel within the test area during tests were required to have an approved gas mask and cannister attached to their person and available for immediate use.
- Warning signals were prearranged to notify personnel to don gas masks and evacuate the test area during the testing.
- During testing the test area was monitored for the presence of phosgene gas with an MSA Model 1 kit, Universal tester (P/N 08-83500) using MSA phosgene gas sampling tubes (P/N 89890). Monitoring was conducted in the control room, on the scrubber stack sampling platform, and within a 100-foot radius of the test area.
- Visual contact between operators and the test system was maintained at all times.
- All "Orange" Herbicide transfer and cleaning operations were performed within diked areas. Drums were placed on a grounding plate during transfer.
- The protective clothing described in paragraph 4.1 were required to be worn by personnel involved in all operations which directly exposed them to the herbicide or caustic solution.
- All spills or drips were immediately mopped up with JP-4 soaked rags.
- All utensils (funnels, hoses, beakers, etc.) contacted by the herbicide were rinsed in JP-4 after each use and stored in covered containers.
- All materials contaminated with "Orange" Herbicide were stored in sealed containers and disposed of by the Air Force.

6.0 INDOCTRINATION

A meeting was held prior to initiating the test program to acquaint all TMC and USAF personnel with the operations to be conducted and the applicable safety requirements and hazards. Facility safety procedures were defined. Gas Masks, face shields, and hard hats were issued and their operations demonstrated.

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USAF ENVIRONMENTAL HEALTH LABORATORIES

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APPENDIX I

(TO APPENDIX E)

EVALUATION AND DISCUSSION OF ORGANIC ANALYSES OF BLENDED HERBICIDE, SCRUBBER WATER, COMBUSTION GAS, SCRUBBED EFFLUENT GAS, AND RESIDUES

E(H-5)

APPENDIX I

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APPENDIX I

EVALUATION AND DISCUSSION OF ORGANIC ANALYSES OF BLENDED HERBICIDE, SCRUBBER WATER, COMBUSTION GAS, SCRUBBED EFFLUENT GAS, AND RESIDUES

1. INTRODUCTION: This appendix contains an evaluation and discussion of all organic analyses of EHL samples; see Appendix G for data. Relationships were established between:

a. Measured and theoretical combustion gas volumes.

b. Sample data from replicate burns.

c. Combustion and scrubbed effluent gas hydrocarbon mass concentration.

d. Penetration and collection of hydrocarbon mass in the caustic scrubber.

e. Beckman 109A hydrocarbon data and TCDD sampling train hydrocarbon data.

f. Hydrocarbon mass collected in the TCDD sampling train and hydrocarbon mass incinerated. This relationship was used to calculate relative pyrolysis efficiencies (RPE) for each burn. These RPE's were used in various comparisons.

2. ANALYSES OF "ORANGE" HERBICIDE INCINERATED DURING THIS PROGRAM

a. The twenty-eight 55-gallon drums of "Orange" herbicide incinerated during this program were from the USAF stocks at Gulfport MS. The drums were all from FSN 6840-926-9095, original Air Force Transportation Control Number of FY9461-7165-0001AA, and Air Force Analysis Sequence Number 18.

b. Blended samples of herbicide were taken from the fuel feed tank prior to each burn. WCTS's analyses of each sample are presented in Table G-1, Appendix G, with reference to the EHL/K drums from which the fuel feed tank was filled. Composition of each sample was consistent with no significant variations. The 2,4-D acetic acid-butyl ester content averaged 50.90% by weight and met Air Force procurement specifications for this compound. The 2,4,5-T acetic acid-butyl ester content, however, averaged only 43.78% by weight and was 10% below its Air Force procurement specification. The average weight percent of "contaminant" compounds were, in decending order, as follows:

(1) Dichlorophenol - 1.46% plus trichlorophenol of 0.66% to yield total phenolic contaminants of 2.12%.

(2) 2,4-D, 2,4,5-T, and monochloro octyl esters had a total average of 1.44%.

(3) Acids of 2,4-D and 2,4,5-T were 0.73% and 0.52%, respectively, for total acids of 1.25%.

(4) TCDD concentration averaged 13 mg/kg (ppm) of total herbicide weight (s=2 mg/kg). This composition of TCDD was in very close agreement with other laboratories' TCDD analyses of other herbicide samples taken from drums of Analysis Sequence Number 18.

(5) Iron concentration averaged 9.0 mg/kg of total herbicide weight (s=2.9). Iron was considered a minor and insignificant "contaminant" which was slowly leached from the drum walls or from materials during the manufacturing process.

c. Neither ionol nor didecylphthlate was detected in the blended herbicide samples even though these compounds consistently appeared as microgram quantities in nearly all EHL gas and liquid samples. Their presence in these samples is discussed in paragraph 3, this appendix.

3. IONOL AND DIDECYLPHTHLATE IN EHL SAMPLES

a. Ionol (2,6-di-tert-butyl-4-methyl phenol) and didecylphthlate [$C_6H_4(COOC_{10}H_{21})_2$] were not considered products of "Orange" herbicide incineration. Both compounds are associated with tygon tubing and plastics (plasticizers and antioxidants) which had been extensively used in the laboratory areas where gas and water sample containers were prepared for sampling.

b. These compounds were not found in the blended herbicide samples, fresh scrubber water, combustion chamber coke deposits, holding tank sediment samples, the miscellaneous gas sample probe and cold trap rinses, or the "blank" benzene and acetone used in filling or cleaning the impingers. However, the compounds appeared in nearly all the gas sampling impinger liquids and spent scrubber water liquids. Their concentrations were random and could not be related between impingers in a series, applied caustic strength, or incineration parameters.

c. Based upon factors in paragraphs 3a and b and the lack of a likely precursor mechanism for these compounds in the "Orange" herbicide incineration process, it was concluded that these compounds were contaminants not associated with "Orange" herbicide pyrolysis; see Paragraph V, Appendix G.

4. COMBUSTION AND SCRUBBED EFFLUENT GAS VOLUMES PER BURN

a. The scrubbed effluent gas velocity pressures were too low (0.008 to 0.010 inches of water pressure) to be measured accurately. The error in the velocity pressure measurement was estimated by calculating carbon mass balances for burns IV, V, VI, and VII. The calculated carbon masses were 102 to 136% greater than the carbon feed into the system. (See Tables D-6 and I-1.) This carbon imbalance indicated that the measured effluent gas velocity pressures were inaccurate and could not be reliably used to calculate the total effluent gas volumes for each burn.

b. Consequently, an alternative method for determining the total burn combustion gas volumes was to evaluate Marquardt's computer predictions of combustion gas products and gas velocities through the incinerator. In this evaluation, a carbon mass balance could not be used for the combustion or scrubbed effluent gas because neither CO_2 nor CO were measured in the combustion gases, the scrubber absorbed various amounts of CO_2 per burn depending on the applied mass of NaOH, and the measured CO_2 and CO in the scrubbed effluent

TABLE I-1: CARBON MATERIAL BALANCE
"ORANGE" HERBICIDE PROGRAM
12-30 NOV 1973

Burn	INTO SYSTEM					OUT OF SYSTEM														Percent of Total Acc'ted For by Measure
	Total In	Into Combustor				Combustor Coke Deposit		Holding Tank				Scrubbed Effluent Stack								
		Herbicide		Air				Carbonate		Particles		Per Measurement				Per Calcul. Balance				
												CO_2		CO		CO_2*		CO*		
No.	lbs	lbs	%T	lbs	%T	lbs	%T	lbs	%T	lbs	%T	lbs	%T	lbs	%T	lbs	%T	lbs	%T	
I	736.74	754.33	99.68	2.41	0.32	7.9	1.04	112.8	14.9	2.49	0.33	-	-	-	-	589.27	77.87	44.35	5.86	-
†	289.94	289.01		0.92		3.03		43.22		0.94						225.77		17.00		
II	869.93	867.16	99.68	2.77	0.32	9.02	1.04	118.51	13.6	1.90	0.23	-	-	-	-	683.75	79.17	51.84	5.96	-
†	289.90	289.06		0.92		3.01		39.50		0.66						229.52		17.28		
III	1138.40	1135.42	99.74	2.98	0.26	12.9	1.13	109.358	9.61	2.59	0.23	-	-	-	-	942.57	82.80	70.95	6.23	-
†	289.77	289.01		0.76		3.28		27.84		0.66						239.92		18.06		
IV	1136.45	1133.46	99.74	2.99	0.26	11.01	0.97	100.96	8.88	2.45	0.22	1333.4	117.33	99.12	8.72	951.29	83.71	70.72	6.22	136.1
†	289.77	289.01		0.76		2.81		25.74		0.63		340.00		25.27		242.56		18.03		
V	1163.66	1160.96	99.77	2.70	0.23	3.00	0.26	117.37	10.09	2.59	0.22	1365.33	117.33	102.24	8.79	968.13	83.20	72.53	6.23	136.7
†	289.68	289.01		0.67		0.74		29.22		0.65		339.89		25.45		241.00		18.06		
VI/VII	1824.93	1820.51	99.76	4.43	0.24	3.50	0.19	152.53	8.36	3.70	0.20	1806.57	98.99	131.44	7.20	1552.73	85.08	112.52	6.17	115.0
†	289.62	289.01		0.70		0.56		24.22		0.58		286.80		20.87		246.50		17.86		
VIII	1293.18	1290.12	99.76	3.06	0.24	2.59	0.20	33.33	2.58	9.23	0.71	-	-	-	-	1160.68	89.75	87.36	6.76	-
	289.68	289.01		0.69		0.58		7.47		2.07						260.02		19.57		
Ave †	289.77	289.02	99.73	0.77	0.27	2.00	0.69	28.17	9.72	0.89	0.31	347.38	119.90	26.89	9.28	240.76	83.08	17.98	6.20	-
Std. † D.	0.11	0.32	0.04	0.11	0.04	1.29	0.45	11.59	3.99	0.54	0.18	62.46	21.57	2.65	0.92	11.25	3.90	0.82	0.29	

*Based on assumption that 93% of C in effluent gases was as CO_2 per Burns IV, V, VI, and VII

†Pounds per drum of herbicide incinerated during Burn.

NOTE: All carbon species expressed in pounds as carbon.

%T denotes that species carbon as a percent of total carbon into the system.

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gases could not be conveniently related to what may have been present in the combustion gases. Therefore, this evaluation was based on a chlorine mass balance of the system which considered that no chlorine as HCl, Cl_2, or (Cl) escaped in the effluent gases and that these chlorines in the combustion gases were completely absorbed into the scrubber water. This was a reasonable basis of evaluation since none of these chlorines were detected in the effluent gases--except for short periods during burns VI and VIII when slightly less than the required amount of NaOH was applied to the scrubber.

c. The total HCl, Cl_2 and (Cl) predicted by Marquardt's theoretical analyses never exceeded 0.03 mole fraction of the combustion gases and these gases had a calculated volume always exceeding a million liters per burn. Thus, if total calculated chlorine mass production per burn from Marquardt's theory was comparable to measured chlorine mass in the scrubber water, then volumes of combustion gas production per burn as calculated from Marquardt theory could be accepted. These volumes could then be used to calculate dry scrubbed effluent gas volumes which would be more accurate than those calculated from measured effluent gas velocity pressures. Table I-2 presents the calculated and measured chlorine mass balance for each burn. The ratio of measured to calculated chlorine mass for each burn averaged 0.947 over the eight burns and had a standard deviation of 0.057. These balances were acceptably close for all burns. Marquardt's theoretical data were therefore used to calculate total dry combustion and dry scrubbed effluent gas volumes for each burn. The mass of CO_2 removed in the caustic scrubber was calculated from the mass of carbonate alkalinity measured in the spent scrubber water. The mass of carbonate alkalinity was converted to the equivalent volume of CO_2, and this volume plus the volumes of HCl, (Cl), Cl_2 and H_2O were subtracted from the combustion gas volume to obtain dry scrubbed effluent gas volume. Table I-3 presents the measured and calculated dry scrubbed effluent gas volume for each burn. Excluding burn VIII, the ratio of measured/calculated dry scrubbed effluent gas volumes per burn averaged 1.15 and had a standard deviation of 0.14.

d. All gas volumes used in this report are dry volumes at standard conditions of 70°F and 29.92" of mercury pressure.

5. COMPARISON OF COLLECTED SAMPLE DATA FOR REPLICATE BURNS

a. A review of Table 2 showed that burns I and II could be considered a set of burns which were conducted with poppet nozzles under nearly identical operating parameters. Similarly, burns V and VII could be considered a different set of near-replicate burns which were conducted with radial slot nozzles under nearly identical operating parameters.

b. Each burn's datum in Table I-4 compared favorably and within accuracies of measurement with its respective replicate burn datum. The only exception to these comparable values was burn V's CGH of 0.90 versus burn VII's CGH of 0.10. This difference was attributed to Burn V's combustion gas sample volume of only six liters versus an average of 150 liters for other burns. This small sample volume was less representative and contained hydrocarbon mass near the analytical detection limit. Since all these burns operated with very minor fluctuations of operating parameters, the comparisons of Table I-4 data lend credence to the replicability of incineration products as determined by reproducible sample collections and analyses.

TABLE I-2

CHLORINE MASS BALANCE - MEASURED VERSUS THEORETICAL VALUES
"ORANGE" HERBICIDE PROGRAM
12-30 NOV 1973

BURN NUMBER	Pounds and Percent of Total							STATISTICS	
	I	II	III	IV	V	VI/VII	VIII	MEAN	STD D.
EHL(K) Measured									
Cl as HCl Pounds	451.7	520.1	655.6	570.5	668.5	1064.9	714.9		
% of Total	98.5	98.6	98.9	98.6	98.1	98.8	99.5	98.7	0.4
Cl as Cl_2 Pounds	7.1	7.4	35.0	116.8	35.5	39.0	67.5		
% of Total	1.5	1.4	1.1	1.4	2.0	1.2	0.5	1.3	0.4
Cl Total Pounds	458.8	527.5	690.6	687.3	704.0	1103.9	782.4		
EHL(M) Calculated*									
Cl as HCl Pounds	408.5	499.2	635.9	694.2	638.8	1001.1	706.5		
% of Total	93.0	91.5	86.8	85.9	85.1	86.4	84.0	87.5	3.4
Cl as Cl_2 & Cl Pounds	30.9	46.3	97.0	113.7	111.8	157.2	134.1		
% of Total	7.0	8.5	13.2	14.1	14.9	13.6	16.0	12.5	3.4
Cl Total Pounds	439.4	545.5	732.9	807.9	750.6	1158.3	840.6		
Measured/ Calculated Totals as Percent	104.4	96.7	94.2	85.1	93.8	95.3	93.1	94.7	5.7

*EHL(M) calculated based on Marquardt theoretical as predicted by computer program.

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TABLE I-3

SCRUBBED EFFLUENT GAS ($x10^6$ LITERS/BURN)*
MEASURED (M) VERSUS CALCULATED (C)**
"ORANGE" HERBICIDE PROGRAM
12-30 NOV 1973

BURN NUMBER	I	II	III	IV	V	VI	VII	VIII
MEASURED	8.38	9.04	9.14	10.12	10.36	4.71	8.72	16.02
CALCULATED	6.55	7.75	8.58	9.47	7.65	5.03	7.55	8.76
RATIO M/C ***	1.28	1.17	1.07	1.07	1.35	0.94	1.16	1.83

* Dry, at 70°F and 29.92" Hg pressure.

** Based on Marquardt's theoretical data.

*** $\bar{x} = 1.23$ $\delta = 0.27$ For burns I thru VIII

$\bar{x} = 1.15$ $\delta = 0.14$ excluding burn VIII

EHL(M)

TABLE I-4

COMPARISONS OF COMBUSTION SYSTEM PARAMETERS AND EHL SAMPLE DATA FOR REPLICATE BURNS "ORANGE" HERBICIDE PROGRAM 12-30 NOV 1973

BURN NO.	F/A	TCave (°F)	Stay Time (sec)	Fuel Temp °F (± 2)	CGH	SGH	SGBH	SSWH	SSWC	CCD/D	NOZZLE
I	0.086	2273	0.16	65	4.02	0.081	3.5	8.59	0.89	3.03	Poppet
II	0.086	2286	0.15	97	9.59	0.063	18.6	6.38	0.68	3.01	Poppet
Replicates											
V	0.120	2734	0.14	99	0.90	0.055	75.7	0.13	0.62	0.74	Slot
VII	0.120	2772	0.15	105	0.10	0.076	36.5	0.22	0.60	0.75	Slot
Replicates											

CGH - Sum of aliphatic and aromatic hydrocarbons as carbon mass per liter (μg/l) in sampled combustion gas, See Table I-6.

SGH - Sum of aliphatic and aromatic hydrocarbons as carbon mass per liter (μg/l) in sampled scrubbed effluent gas, See Table I-7.

SGHB - Beckman 109A hydrocarbon data (ppm) from scrubbed effluent gas, See Table I-9.

SSWH - Total aliphatic, aromatic, and phenolic hydrocarbons as carbon mass (gms) collected in the total volume of spent scrubber water, See Table I-8.

SSWC - Carbon particles in spent scrubber water, pounds per drum of herbicide burned.

CCD/D - Combustion coke deposit in combustion chamber, pounds per drum of herbicide burned.

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6. HYDROCARBON MASS PENETRATION THROUGH THE TCDD, nb-ESTER AND ACID (OF 2,4-D AND 2,4,5-T) SAMPLING TRAINS

a. The TCDD, nb-ester and acid sampling train (TCDD sampling train) was developed and tested specifically for the mass collection of the nb-esters and acids of 2,4-D and 2,4,5-T (See Appendix D.). The collection of TCDD in the sampling trains was not tested in the laboratory. However, TCDD's vapor pressure and solubility similarities to the nb-esters of 2,4-D and 2,4,5-T were sufficient to conclude that TCDD would be collected as effectively in the sampling train as the nb-esters. This same reasoning could not be applied to the mass collection of nonchlorinated aliphatic and nonchlorinated aromatic hydrocarbons. However, sufficient data were collected during the field sampling program so that an assessment of hydrocarbon mass penetration (collection) through the sampling trains could be made.

b. Table I-5 presents, for each burn, the hydrocarbon mass collected in all four impingers, the mass collected only in the last one of the four serial impingers, and the percent of the total mass that was collected in the last impinger. The combustion gas samples and the scrubbed effluent gas samples were grouped respectively as sets because the physical conditions (temperature, pressure, etc.) of these sampled gases were quite different.

(1) The following observations of the data in Table I-5 were made:

(a) The averages of the aliphatic and aromatic hydrocarbon masses collected in the last impinger were nearly equal in both sample sets.

(b) The averages of the total masses collected in all four impingers varied significantly between sample sets.

(c) The total mass collected in all four impingers varied significantly within each sample set.

(d) The mass collected in the last impinger did not vary significantly within each sample set (relative to the variance of mass collected in all four impingers).

(2) From these observations, it was concluded that hydrocarbon mass collection in the last impinger (in the series of four impingers) was independent of:

(a) Mass loading in the first three impingers.

(b) Hydrocarbon mass concentration in the sampled gas.

c. For nonchlorinated aliphatic and aromatic hydrocarbon mass collection in the last impinger of this serial impinger collection system to be independent of mass loading and independent of mass concentration in the sampled gas, the mass collection efficiency in the first three impingers necessarily was good for those hydrocarbons collected or it was near 0% in all impingers. Since collection efficiency was obviously not 0%, collection efficiency in the first three impingers was good (for those hydrocarbons collected). However, since hydrocarbon mass was found in the last impinger, collection efficiency in the impinger sampling train was not 100%.

TABLE I-5 HYDROCARBON MASS COLLECTION IN THE TCDD SAMPLING TRAINS "ORANGE" HERBICIDE PROGRAM 12-30 NOV 1973

BURN NO.	Total Mass (µ g) Collected in all 4 Impingers		Mass (µg) Collected in Last Impinger		% of Total Mass Collected in Last Impinger	
	Aliphatic $C_{10}H_{22}$	Aromatic C_6H_5 (C_4H_9)	Aliphatic $C_{10}H_{22}$	Aromatic C_6H_5 (C_4H_9)	Aliphatic $C_{10}H_{22}$	Aromatic C_6H_5 (C_4H_9)
COMBUSTION GAS SAMPLE SET						
I	91.9	440.0	2.7	2.9	3	1
II	37.7	329.0	1.0	0.6	3	0
III	245.6	110.4	5.9	2.5	2	2
IV	1.2	1.6	0.2	0.2	17	13
V	2.8	3.4	0.3	0.7	11	21
VI	3.4	29.8	0.2	0.1	6	0
VII	3.3	9.2	0.2	0.3	6	3
VIII	14.1	20.7	0.3	0.2	2	1
$\bar{x}$	50.0	118.0	1.3	0.9	6.2	5.1
δ	84.9	170.7	2.0	1.1	5.3	7.7
$\bar{x}$ *					3.7	1.2
δ *	*Excluding burns IV and V				1.9	1.2
SCRUBBED EFFLUENT GAS SAMPLE SET						
I	4.1	5.9	0.5	0.9	12	15
II	4.4	4.3	1.5	2.1	34	49
III	13.1	15.7	1.1	1.9	8	12
IV	6.4	8.3	0.6	0.2	9	2
V	4.3	2.7	0.6	0.6	14	22
VI	11.1	5.7	1.2	0.7	11	12
VII	3.7	3.6	0.7	0.2	19	6
VIII	3.3	9.3	0.2	0.5	6	5
$\bar{x}$	6.3	6.9	0.8	0.9	14	16
δ	3.7	4.2	0.4	0.7	9	15
$\bar{x}$ **					11.3	10.6
δ **	** Excluding Burn II				4.3	6.8

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d. Two potential causes for penetration of hydrocarbon mass to and through the last impinger were considered:

(1) A specific nonchlorinated aliphatic and aromatic hydrocarbon or a specific group of hydrocarbons was relatively insoluble in the benzene or,

(2) a specific hydrocarbon or group of hydrocarbons was bleeding (movement of the compound down the impinger series) due to high vapor pressure (volatility) and low concentration in the sampled gases.

e. Solubility was dismissed as the potential cause for penetration of hydrocarbons to the last impinger since nonchlorinated aliphatic and aromatic hydrocarbons are generally very soluble in benzene.

f. Bleeding of a specific hydrocarbon or group of specific hydrocarbons was considered the most probable cause of mass penetration to and through the last impinger. Discussion of this consideration is as follows:

(1) Since a gas confined (as in a bubble) in contact with a liquid will dissolve in the liquid (if soluble) until "...its partial pressure above the liquid is in equilibrium with the gas dissolved in the liquid..."[1] any hydrocarbons that existed in the sampled gas and had a significant vapor pressure at ~50°F (benzene temperature during sampling) would not have appreciably dissolved (absorbed) in the benzene at concentrations less than several 1000 $\text{ppm}_{v/v}$ and would have bled. Since aromatic hydrocarbons with molecular weights <132.2 have vapor pressures >0.0001 mm of mercury pressure at ~50°F (100 ppm at 760 mm of mercury pressure and at saturation), these hydrocarbons would have bled (penetrated the sampling system) substantially.

(2) However, nonchlorinated aromatic hydrocarbons with molecular weights greater than 200 generally have freezing points near ~50°F (temperature of benzene in the impingers during sampling) and the corresponding vapor pressures are extremely low (<0.00001 mm mercury pressure). Thus, these compounds would have been effectively collected in the TCDD sampling train. An exact number for the collection efficiency of these heavy hydrocarbons (>200) was impossible to determine objectively, however, a subjective evaluation based on previous laboratory work was made and the collection efficiency was considered ≧90% for hydrocarbons with molecular weights >200. For hydrocarbons with mw<200 the collection efficiency becomes a function of their vapor pressure and mass concentration in the sample gas. A similar argument was used for aliphatic hydrocarbons.

(3) At this point, two dependent conclusions were made that the hydrocarbon mass collected in the TCDD sampling trains:

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[1] Patty, Frank A., Industrial Hygiene and Toxicology, Volume I, 2nd Edition, page 153.

(a) did not include lightweight hydrocarbons (mw <132) and was thus not representative of a total hydrocarbon mass in the sampled gas, but

(b) was representative of the degree of "Orange" herbicide pyrolytic degradation to unchlorinated hydrocarbon compounds which were considered to have no significant herbicidal or toxic properties even though they were herbicide pyrolyzates.

(4) This latter conclusion, in conjunction with the fact that hydrocarbon collection efficiency in the TCDD sampling train remained equal for all burns, permitted the hydrocarbon mass data from the TCDD sampling systems to be used as an indicator of the relative degree of pyrolysis of Orange herbicide. Thus, relative pyrolysis efficiencies (RPEs) were calculated for each burn. The collection efficiency of specific hydrocarbons in the TCDD sampling trains did not vary between burns since the trains were operated in a consistent manner under similar sampling conditions. An RPE calculation was based on the mass of hydrocarbons as carbon collected in a TCDD sampling train at the reaction tailpipe versus the mass of Orange herbicide as carbon incinerated. Although these calculated efficiencies were relative to hydrocarbon mass collected rather than an absolute quantitation of all potentially existing combustion gas hydrocarbons, they provided a means of evaluating and comparing the different burns.

g. The existence of nearly the same hydrocarbon mass in the last impinger from all sample trains was probable due to a combination of factors:

(1) analytical accuracy decreased as the hydrocarbon mass in the sample volumes approached the detection limit,

(2) hydrocarbon gas chromatographic peaks were more susceptible to interferences, when hydrocarbon mass in the samples was lowest,

(3) potential production of intermediate weight Orange herbicide pyrolysis products (those hydrocarbons having molecular weights between 132 and 200 and being only partially collected) may have been produced in a relatively constant mass concentration during all burns,

h. Essentially the same hydrocarbon mass was collected in each burn's scrubbed effluent gas sampling train. This was probably caused by a relatively consistent mass of light and intermediate weight hydrocarbons (mw <200) which penetrated the scrubber and were collected by the scrubbed effluent gas sampling train.

7. RELATIVE PYROLYSIS EFFICIENCIES OF ORANGE HERBICIDE INCINERATION

a. Relative pyrolysis efficiencies (RPE) of Orange herbicide were calculated for burns I through VIII and are presented in Table I-6. Presented data are described as follows:

(1) Total combustion gas volume per burn (liters) as discussed in paragraph 4, this appendix.

(2) Total hydrocarbons detected in combustion gas samples, divided into two categories: the monochlorophenol and aliphatic hydrocarbons (nonchlorinated) and aromatic hydrocarbons (nonchlorinated), expressed as the:

(a) actual mass of each per liter of sampled combustion gas (μg/l),

(b) carbon mass of each per liter of sampled combustion gas (μg/l),

(c) actual mass as carbon for each in the total burn (g).

(3) Five herbicide compounds (2,4-D and 2,4,5-T nb-esters and acids and TCDD) that were undetected but could have existed without detection in a combustion gas sample -- expressed as the:

(a) mass of each compound as the compound per liter of sampled combustion gas (μg/l),

(b) mass of each compound as carbon per liter of sampled combustion gas (μg/l), and

(c) total masses for all five compounds as carbon for a total burn (g).

The undetected masses of these herbicide compounds were calculated based upon an average detection limit of 22×10^{-9} gms per total sample for all five compounds. This detection limit was divided by the burn's combustion gas sample volume to find the minimum combustion gas mass concentration that was necessary for detection of each of these compounds. This value was then multiplied by the total burn combustion gas volume, the average percent carbon content of these compounds, and five in order to determine the total possible undetected mass of these compounds in the combustion gas of each burn. This procedure assumed that the undetected total mass of these compounds and the detected masses of the other hydrocarbons existed evenly throughout the burn.

(4) Herbicide fuel feed mass expressed as carbon mass that was injected into the combustion chamber during a burn period.

(5) Ionol and didecylphthlate were not included in Table I-6 combustion gas sample masses since these compounds were not considered products of Orange herbicide incineration (see paragraph 3, this appendix).

(6) Relative pyrolysis efficiency (RPE) was based upon the analytical values presented for each burn. (See Appendix G for analytical values.)

b. One could double the total combustion gas hydrocarbon masses as carbon per burn and decrease the fuel feed herbicide carbon by 5% to test the significance of the digits of the RPE in Table I-6. These worst case conditions would represent pooling of errors for nonrepresentative sampling, errors of sample analyses, and errors in calculating total burn volumes. This exercise concluded that the second decimal place was significant for all burns and that the third decimal place was significant only for Burns IV through VIII.

8. EFFECTS OF INCINERATOR OPERATING PARAMETERS

a. Effects of various incineration operating parameters on the RPE's

TABLE I-6 RELATIVE "ORANGE" HERBICIDE PYROLYTIC DESTRUCTION
"ORANGE" HERBICIDE PROGRAM
12-30 NOV 1973

BURN NUMBER	I	II	III	IV	V	VI	VII	VIII
Combustion Gas Volume (Liters/Burn)[1]	6.79×10^6	8.02×10^6	8.89×10^6	9.79×10^6	7.98×10^6	5.21×10^6	7.87×10^6	9.03×10^6
Aliphatic HC[2] (Unchlorinated)								
µg/l as $C_{10}H_{22}$	0.67	1.11	1.10	<0.01*	0.47	0.02	0.03	0.09
µg/l as C	0.56	0.92	0.92	<0.01	0.39	0.02	0.03	0.09
g/Burn as C	3.80	7.38	8.18	<0.01	3.11	0.10	0.24	0.81
Aromatic HC[2] (Unchlorinated)**								
µg/l as C_6H_5 (C_4H_9)	4.26	9.68	0.49	<0.01	0.57	0.18	0.08	0.16
µg/l as C	3.46	8.67	0.44	<0.01	0.51	0.16	0.07	0.14
g/Burn as C	23.49	69.50	3.91	<0.01	4.07	0.83	0.55	1.26
Herbicide HC[3]								
µg/l as HC/compound	0.00016	0.00065	0.00009	0.00008	0.00366	0.00013	0.00019	0.00017
µg/l as C/compound	0.00008	0.00033	0.00005	0.00004	0.00180	0.00006	0.00009	0.00008
g/Burn as C/^{5}compounds	0.003	0.013	0.002	0.002	0.072	0.000	0.004	0.004
TOTAL CARBON								
g/Burn Combustion Gas	27.29	76.89	12.09	<0.01*	7.25	0.93	0.79	2.07
g/Burn Input	342466.	393670.	515480.	514590.	527076.	529992.	585776.	585714.
% Relative Pyrolysis Efficiency	99.99	99.98	99.99	>99.999	99.998	99.999	99.999	99.999

1. Based on Marquardt theoretical calculations (See Appendix A)
2. Calculated from hydrocarbon mass found in combustion gas impinger samples.
3. Based on the maximum mass that could have existed in the combustion gas without being detected (Sum of TCDD and the butyl esters and acids of 2,4-D and 2,4,5-T).

*See Discussion of Conflicting Data, page I-25.

**Includes monochlorophenol detected in Burn I.

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of Table I-6 were evaluated by comparing those burns that were replicate except for a change in only one operating parameter. Since the RPE's were almost identical in value, they were not used to assess effects of changed operating parameters. Instead, the following measured/calculated data are defined and were used in the comparisons:

(1) CGH - (See definition on Table I-4)

(2) SSWH - (See definition on Table I-4)

(3) CCD/D - (See definition on Table I-4)

(4) SGHB - (See definition on Table I-4)

(5) Contaminate mass of hydrocarbons found in the combustion coke deposit (CCH) expressed as µg/100 gms, see Table G-9, Appendix G.

b. As selected from Table 2 of this report, the following burns were compared in relation to their one different operating parameter.

(1) <u>"Orange" Herbicide Preheat - Burns III and IV</u>

(a) "Orange" herbicide fuel was preheated to 178°F (±2) in burn IV but only to 91°F(±1) in burn III. The CGH was two orders of magnitude greater in III than IV. The SSWH of III was 2.42 gms or about ten times (on order of magnitude) the SSWH of IV (burn duration of III and IV were about equal.) Additionally, the spent scrubber water of III contained 0.25 µg/l of TCDD which along with any of the other original herbicide compounds were undetected in any scrubber water samples. The CCD/D was 2.81 pounds for burn IV compared to 3.28 pounds for burn III. Burn III's CCH was 1132.6 and contained the methyl and butyl esters of 2,4-D and 2,4,5-T while burn IV's CCH weighed 542 and no methyl/butyl ester of 2,4-D or 2,4,5-T were detected.

(b) A small improvement of effluent quality due to herbicide preheating was also noted between replicate burns I and II, see Table I-6. Although comparisons of Table I-6 values did not show significant improvement, the trend toward better RPE's was evident.

(c) From these comparative observations it was concluded that:

<u>1</u>. Burn IV's RPE appeared at least one order of magnitude better than burn III's, and

<u>2</u>. Preheating of "Orange" herbicide to ~180°F was an important operating parameter which improved burn IV's RPE.

(2) <u>Central Poppet Nozzle Versus Radial Slot Nozzles - Burns III and VI</u>: Burns III and VI were identical in operating parameters except the central poppet nozzle was used in burn III while the radial slot nozzles were used in burn VI. Burn III's CGH was about one order of magnitude greater than burn VI's CGH. The SSWH for burn III was 2.42 while burn VI's SSWH would have been 0.06 for a total burn period equal to III's. Burn III's CCD/D was

3.28 pounds versus 0.85 pounds for burn VI. As previously cited, Burn III's CCH was 1132.6 and herbicidally contaiminated while burn VI's CCH was only 66.9. These data demonstrated that radial slot nozzles produced significantly better incineration results than poppet nozzles when both nozzles were operated under identical parameters and a medium range F/A of 0.106.

(3) Process Flow Rates - Burns VII and VIII: Burns VII and VIII were replicates except that the air and herbicide fuel feed mass flow rates of burn VIII were only 66% of burn VII's: 1.05 pps air/0.123 pps fuel for VIII and 1.55 pps air/0.186 pps fuel for VII. Burn VIII's CGH was about twice that of Burn VII's CGH; however, both concentrations were near the analytical detection limit and thus not sufficiently different to allow a definitive conclusion about which set of process flows was better. Compared to equal burn durations, the SSWH and CCD/D of burns VII and VIII were very nearly equal. Analyses of combustor coke deposit from these burns were not made but there was no reason to believe their qualities differed. These comparisons showed no differences in RPE or effluent quality between these identical burns which had different air and fuel mass flow rates but identical F/A ratios. Thus without any differences, the higher process flow rate could be chosen to minimize incineration time.

(4) Fuel to Air Mass Flow Ratios and Different Nozzles - Burns I and II Versus Burns V and VII

(a) As discussed in paragraph 5, this appendix, burns I and II were replicates of each other as were burns V and VII. As shown in Table I-4, the EHL sample data values of Burns V/VII were all at least ten percent less than those for burns I/II -- particularly noteworthy was that burns V/VII's CGH, SSWH, and CCD/D values were one order of magnitude less than burns I/II's values. The only exception was SBGH, and its inverse relationship to RPE is discussed in paragraph 10, this appendix.

(b) From these comparative observations it was concluded that the radial slot nozzle handled higher mass flow rates than the poppet nozzle and yet produced RPE's and incineration effluent quality generally one order of magnitude better.

(c) Effects of Temperature on RPE

1. The relative degree of "Orange" herbicide destruction in the combustion process was not expected to be a simple function of temperature (heat energy). Other parameters such as burn velocity (stay time), burner pressure, air and fuel preheat, process flow rates, and method of fuel injection were all expected to be interrelated parameters. The following analysis of the relationship of temperature and the relative degree of "Orange" herbicide pyrolysis indicated the complexity of these interrelationships.

2. For example, the average temperature (TC_{AVE} column 16, Table 2 and discussion, paragraph 7.2) for burns I and II was 2280° F and the TC_{AVE} for burns V and VII was 2753° F. The RPE's in burns V and VII were significantly better than in burns I and II, 99.999 vs 99.99%. However, burn VI had an RPE comparable to that in burns V and VII, but the TC_{AVE} was

2454°F, about 300°F less than in burns V and VII and only 174°F greater than the TC_{AVE} in burns I and II. In yet another case, burn IV had the highest RPE of all burns but the TC_{AVE} was only 2508°F, 245°F less than in burns V and VII and only 228°F greater than in burns I and II.

3. From these observations one might have concluded that the RPE was not improved by increasing TC_{AVE} above 2454°F. In these burns and from a temperature standpoint, this conclusion would be correct. However, other combustion parameters were changed in the burns and one could not conclude that destruction efficiency would not have improved with an increase in temperature had different operating parameters existed.

9. HYDROCARBON MASS PENETRATION THROUGH THE CAUSTIC SCRUBBER AND COLLECTION IN THE SCRUBBER

a. Table I-7 presents each burn's CGH and SGH data. Penetration of hydrocarbon mass through the caustic scrubber increased as the burn's RPE improved. Similar to the discussion in paragraph 6 of this appendix, hydrocarbon mass penetration through the caustic scrubber was expected to be a function of hydrocarbon vapor pressure (condensability) since the detected hydrocarbons were only slightly soluble in caustic solution. The hydrocarbon collection mechanism in the caustic scrubber was probably impaction (entrainment) rather than absorption. Heavier, less volatile hydrocarbons were expected to condense from the combustion gases in and downstream of the venturi since the venturi pressure drop and injected caustic solution provided very rapid cooling of the combustion gases. The degree of this rapid cooling was rather consistent between burns, i.e. from an average combustion gas temperature of 1990°F (s=158) exiting the reaction tailpipe, passing through the venturi at 400 ft/sec, and dropping to an average scrubbed effluent gas temperature of 163°F (s=8).

b. Once these condensed hydrocarbons were entrained in the caustic solution, they were either dissolved to their solubility limits and retained or desorbed and entered the scrubbed effluent gas if their vapor pressures were significant in the spent scrubber water's average temperature of 160°F. As the burn's RPE improved, the combustion gas contained less of these heavier hydrocarbon compounds. The hydrocarbon mass collected in the spent scrubber water decreased with the decreasing difference in hydrocarbon mass collected in the combustion and scrubbed effluent gas TCDD sampling trains. Scrubber water "efficiency" of total hydrocarbon collection decreased more rapidly than that of the TCDD sampling trains because of the much higher collection of low vapor pressure hydrocarbons in benzene at ~50°F.

c. Table I-8 presents the detected hydrocarbon (grams) in each burn's total spent scrubber water volume. As discussed in paragraph "b" above, the detected hydrocarbon masses decreased in proportion to increased RPE; i.e. one order of magnitude decrease when the third decimal of the RPE became significant. Except for burns I, II and III, which used poppet nozzles and had the lowest RPE's and TC_{AVE}'s, all detected hydrocarbons were less than 20 µg/l in the spent scrubber water. Of this total hydrocarbon mass per liter of SSW, less than 1.5% could have been the total undetectable TCDD and acids/esters of 2,4-D and 2,4,5-T listed in Table I-8.

TABLE I-7: HYDROCARBON MASS PENETRATION THROUGH THE CAUSTIC SCRUBBER (CGH vs SGH) "ORANGE" HERBICIDE PROGRAM 12-30 NOV 73

Burn Number	I	II	III	IV	V	VI	VII	VIII
Scrubbed Effluent Gas Volume (Liters)*	6.55×10^6	7.75×10^6	8.58×10^6	9.47×10^6	7.65×10^6	5.03×10^6	7.55×10^6	8.76×10^6
Aliphatic HC**								
µg/l as $C_{10}H_{22}$	0.038	0.037	0.135	0.048	0.039	0.306	0.045	0.037
µg/l as C	0.032	0.031	0.113	0.040	0.033	0.255	0.037	0.031
g/burn as C	0.210	0.240	0.969	0.379	0.252	1.283	0.279	0.272
Aromatic HC								
µg/l as $C_6H_5(C_4H_9)$	0.055	0.036	0.162	0.062	0.024	0.157	0.044	0.103
µg/l as C	0.049	0.032	0.145	0.056	0.022	0.141	0.039	0.092
g/burn as C	0.321	0.248	1.244	0.530	0.168	0.709	0.294	0.806
Biphenyl HC								
µg/l as $C_{12}H_{10}$	0.017	0.017	0.009	0.006	0.048	0.168	0.031	0.072
µg/l as C	0.016	0.016	0.009	0.006	0.046	0.158	0.029	0.067
g/burn as C	0.102	0.132	0.076	0.061	0.348	0.796	0.218	0.589
Herbicide HC								
µg/l as HC/compound	0.00021	0.00018	0.00023	0.00016	0.00020	0.00060	0.00026	0.00024
µg/l as C/compound	0.00010	0.00009	0.00011	0.00008	0.00010	0.00030	0.00013	0.00011
g/burn as C/5 compounds	0.003	0.004	0.005	0.004	0.004	0.007	0.004	0.005
Total Carbon								
g/burn Scrubbed Gas	0.636	0.624	2.289	0.974	0.772	2.795	0.79	1.672
g/burn Combustion Gas†	27.29	76.89	12.09	<0.01	7.25	0.93	0.79	2.07
Penetration, Percent	2.33	0.81	18.93	-	10.65	-	100	80.8
Relative Pyrolysis Efficiency, Percent	99.99	99.98	99.99	>99.999	99.998	99.999	99.999	99.999

*Dry, at 70°F and 29.92" Hg pressure. From Table I-3.

USAF EHL(M)

**HC - hydrocarbon

† From Table I-6

TABLE I-8: SUMMARY OF HYDROCARBON COMPOUNDS COLLECTED IN SPENT SCRUBBER WATER "ORANGE" HERBICIDE PROGRAM 12-30 NOV 1973

	Spent Scrubber Water Total Volume Per Burn (Liters)							
	15693	14996	15100	15916	13538	7185	14267	12124
BURN NUMBER →	I	II	III	IV	V	VI	VII	VIII
Detected Hydrocarbons (gms)								
Aliphatic Hydrocarbon as $C_{10}H_{22}$	1.689	1.458	1.699	0.099	0.130	0.014	0.138	0.119
" " as C	1.407	1.215	1.415	0.082	0.108	0.012	0.115	0.099
Aromatic Hydrocarbon as $C_6H_5C_4H_9$	3.005	1.815	0.852	0.081	0.001	0.024	0.111	0.075
" " as C	2.692	1.626	0.763	0.073	0.001	0.022	0.099	0.067
Dichlorobenzene as $C_6H_4Cl_2$	8.225	6.975	0.488	0.115	0.043	0.003	0.016	0.027
" " as C	4.030	3.418	0.239	0.056	0.021	0.001	0.008	0.013
Monochlorophenol as C_6H_4ClOH	0.827	0.211	0.003	0.003	0.001	0.001	0.001	0.001
" " as C	0.463	0.118	0.001	0.001	0.001	0.001	0.001	0.001
Total Weight of Above (gms)	13.744	10.459	3.042	0.298	0.175	0.042	0.266	0.222
" " " " as C (gms)	8.592	6.377	2.418	0.212	0.131	0.035	0.223	0.180
Maximal Undetected Components of Blended Herbicide Feed (mgm)								
TCDD	0.74	0.71	3.78*	0.75	0.64	0.34	0.68	0.58
TCDD as C	0.33	0.32	1.69	0.34	0.29	0.15	0.30	0.25
2,4-D acid (butyl ester)	0.75	0.72	0.72	0.76	0.65	0.34	0.68	0.58
" " " " as C	0.43	0.42	0.42	0.44	0.37	0.20	0.40	0.34
2,4,5-T acid (butyl ester)	0.63	0.60	0.60	0.63	0.54	0.29	0.58	0.49
" " " " as C	0.29	0.28	0.28	0.29	0.25	0.13	0.26	0.22
2,4-D acid (methyl ester)	0.75	0.72	0.72	0.76	0.65	0.34	0.68	0.58
" " " " as C	0.34	0.33	0.33	0.35	0.30	0.16	0.32	0.27
2,4,5-T acid (methyl ester)	0.67	0.64	0.64	0.67	0.57	0.30	0.60	0.51
" " " " as C	0.27	0.26	0.26	0.27	0.23	0.12	0.24	0.20
Total Undetected Weight of Above (mg)	3.54	3.39	6.46	3.57	3.05	1.62	3.22	2.74
" " " " as C (mg)	1.66	1.61	2.98	1.69	1.44	0.76	1.51	1.28
Grand Total of all Hydrocarbons (gms)	13.748	10.462	3.048	0.302	0.178	0.044	0.269	0.225
" " " " " as C (gms)	8.594	6.379	2.421	0.214	0.132	0.036	0.225	0.181

*Only one of these compounds detected in any spent scrubber water samples.

d. The unchlorinated aliphatic and aromatic hydrocarbons of Table I-8 were considered as pyrolyzates which were trapped and slightly dissolved in the scrubber water. The detected chlorinated hydrocarbons were considered hydrolyzates formed by reaction of the aromatic hydrocarbons and chlorine species in the combustion gases as they cooled and mixed with the caustic in the scrubber (see paragraph 11, this report). As the RPE's increased (burns IV through VIII), the mass of the chlorinated hydrocarbons in the SSW decreased faster than the mass of the aromatic hydrocarbons. This was because the mass of the former was dependent on the latter, and the latter decreased in the combustion gas as RPE increased.

e. Table I-8 also presents the maximal mass of components of blended herbicide (mgm) that could have existed undetected in each burn's total spent scrubber water volume. These values were based on the detection limits and analytical recovery efficiencies of each compound in 500 ml of collected SSW TBC that was analyzed. These calculated masses were therefore all relative to the total spent scrubber water volume except for TCDD in burn III. This TCDD was the only one of these herbicidal component compounds detected in any SSW-TBC or SSW-Cl samples, see discussion in paragraph 12 of this appendix.

f. Suspended matter in the SSW were analyzed from concentrated sediment samples collected after each burn from the bottom of the SSW holding tank. Analytical results presented in Table G-8, Appendix G, showed that no detectable hydrocarbons were extracted from any of the sediments. These sediments were thus considered as carbon with less than 9.0% iron content. The carbon was a pyrolytic product but the iron came from combustion gas acids leaching the metal of the scrubber tank.

10. BECKMAN 109A DATA COMPARED WITH RPE's

a. Table I-9 was presented to demonstrate that scrubbed effluent gas hydrocarbon data measured with the Beckman 109A total hydrocarbon analyzer (SGBH) was not an indicator of the relative pyrolysis efficiency (RPE) of "Orange" herbicide.

b. Burns I and II had the lowest SGBH of all burns. If SGBH was a good indicator of RPE, burns I and II would have had the best RPE in the set of eight burns. However, the CGH and SSWH was greater in burns I and II than in all other burns and the RPE of burns I and II was less than in all other burns.

c. Burns VII and VIII had a greater RPE than burns I and II, but their SGBH readings were greater than in burns I and II. In burns III through VI, the SGBH had no apparent inverse or direct relationship to RPE.

d. During the incineration of "Orange" herbicide, the CGH and SSWH were related. This was anticipated since the heavier, but not completely combusted hydrocarbons, (pyrolyzates) would be more effectively collected in both the TCDD sampling trains and the caustic scrubber than the light molecular weight pyrolyzates. In burns that had a poorer RPE (burns I and II) the heavy pyrolyzates were more effectively collected in the caustic scrubber and were not

TABLE I-9: COMPARISON OF HYDROCARBON DATA - BECKMAN 109A (SCRUBBED EFFLUENT GAS), CGH, AND SSWH "ORANGE" HERBICIDE PROGRAM 12-30 NOV 73

BurnNumber	I	II	III	IV	V	VI	VII	VIII
SGHB† $\bar{x}$	3.5	18.6	395*	1450.0	79.5*	151.7	75.7	36.5
(ppm) s	2.9	5.8		1258.9		22.6	23.1	17.1
CGH (µg/l)	4.02	9.59	1.36	-	0.90	0.18	0.10	0.23
SSWH (g/burn)	8.59	6.38	2.42	0.21	0.13	0.04	0.22	0.18

*Measured during the same time period of CGH sampling.

†Four (4) values used for $\bar{x}$.

For definition of SGBH, CGH, and SSWH, see Table I-4.

USAF EHL(M) and (K)

detected by the Beckman 109A. In burns that had better RPE's (burns IV through VIII) the light pyrolyzates were not collected in the scrubber but were detected by the Beckman 109A, and thus higher SGBH values were observed even though the RPE's were higher.

11. HERBICIDAL COMPOUNDS DETECTED IN GAS SAMPLES AND RELATED EQUIPMENT

a. The nb-esters of 2,4-D and 2,4,5-T were detected in the rinse from the Beckman 109A cold trap used in burn I Monochlorophenol was detected in the first impinger of the combustion gas sampling train from burn I. Dichlorophenol was detected in the rinses from the Beckman 109A cold traps used in burns I, II and III, in the air cooled sampling probe rinses from burns II and III, and in the mixed (one and two impingers) water of the particulate source sampling train impingers from burns IV and VI.

b. The butyl esters found in the cold trap rinse from record burn I could have been deposited during either of two checkout burns made before record burn I (see Marquardt Test 4 and 5). The first attempt at record burn I was aborted 16 minutes into the burn due to fuel injection problems caused by the high viscosity of "Orange" herbicide. Since the incineration of "Orange" herbicide during these checkout burns was not as carefully controlled as during all successful record burns, and since the cold trap was not rinsed after the two checkout burns it was concluded that the cold trap rinse from record burn I was not representative. No butyl esters were found in the cold trap rinses from record burns II and III. The cold traps used in burns IV through VIII were rinsed but not analyzed.

c. The dichlorophenol found in the Beckman 109A cold trap rinse from burn I was considered unrepresentative for reasons given in the previous paragraph.

d. Dichlorophenol was found in the Beckman 109A cold trap rinses from burns II and III and in the combustion gas air cooled sampling probe rinses from burns II and III. However, the compound was not detected in the combustion gas impinger samples that were downstream of the air cooled probes or in the spent scrubber water samples from these burns.

(1) Dichlorophenol has a high melting and boiling point (113°F and 403°F for 2,4). The caustic scrubber (caustic solution at 160°F in collector tank) was expected to collect a significant fraction of compounds as condensable as dichlorophenol (monochlorophenol was collected in the scrubber). Since dichlorophenol was not detected in the combustion gas impinger samples (detection level = 0.88×10^{-9} grams/liter) downstream from the air cooled probes or in the spent scrubber water (detection level = 0.08×10^{-6} grams/liter) from these burns, the existence of dichlorophenol in the combustion gas was doubted.

(2) Since no dichlorophenol was detected in the impingers downstream of the air cooled probe, it was supposed that the probe collected all of the dichlorophenol. Based on this conclusion, the apparent combustion gas concentration was 40×10^{-9} grams per liter (1.38 µg/34 liters). If this

concentration existed throughout the burn, the caustic scrubber was exposed to 320 mg over the total burn. The volume of the spent scrubber water from burn II was 14996 liters. Based on the detection limit of dichlorophenol in the spent scrubber water (0.08 µg/l), 1.2 mg of dichlorophenol in the spent scrubber water would have been detected. The 1.2 mg needed for detection was only 0.37% of the 320 mg available if the 40 x10^{-9} grams/liter existed throughout the burn. The caustic scrubber was expected to collect a significantly greater fraction of dichlorophenol than 0.37% (see Table I-7).

(3) From these observations, the following possibilities were considered. That,

(a) dichlorophenol did not exist at a mass concentration of 40 x10^{-9} grams/liter throughout burn II, and

(b) the dichlorophenol was formed in the air cooled sampling probes and in the Beckman 109A cold traps from reactions of Cl_2 and (Cl) with the nonchlorinated aromatic hydrocarbons detected in the combustion gas (these reactions are favorable between 500 and 700°C, slower at <500°C and almost nonexistent >700°C; the combustion gas was cooled from ~1040°C to 150°C rapidly in the air cooled probe; the environment was favorable to formation of dichlorophenol), or

(C) the dichlorophenol was chemically altered to the monochlorophenol in the caustic scrubber. Monochlorophenol and dichlorobenzene were detected in all spent scrubber water samples. The monochlorophenol-dichlorophenol equilibrium could have been shifted to monochlorophenol in the caustic scrubber.

e. The spent scrubber water from burns II and III contained 211 mg and 3 mg of monochlorophenol respectively. The (apparent) total burn production of dichlorophenol was 320 mg and 26.7 mg for burns II and III respectively. There appeared to be a relationship between (apparent) dichlorophenol in the combustion gas and monochlorophenol in the caustic scrubber. However, since dichlorophenol and monochlorophenol could have been formed in the venturi of the caustic scrubber (rapid cooling of combustion gas from ~1040°C to 72°C), to account for the monochlorophenol detected, and the existence of mono and dichlorophenol in the combustion gases was unfavorable (temperature), the conclusion was made that dichlorophenol did not exist in the combustion gas but was generated in the air cooled probe and in the cold trap. This conclusion was supported by the fact that dichlorophenol was not detected in these probes and traps of burns IV through VIII when the mass concentration of unchlorinated aromatic hydrocarbons was low.

f. The dichlorophenol found in the water impingers in the particulate sampling train sample from burns IV and VI was concluded to be contamination not associated with "Orange" herbicide incineration. This conclusion was based upon the following observations:

(1) In burn IV, the dichlorophenol mass concentration in the scrubbed effluent gas that was necessary to produce the mass collected in the particulate sampling train was greater than the detection limit in the TCDD sampling train, i.e., 1.3 µg was collected from a sample volume of 737.2 liters for an apparent mass concentration of 1.76 x10^{-9} grams/liter but the detection limit in the TCDD sampling train was 0.22 x10^{-9} grams/liter. Therefore, dichlorophenol should have been detected in the TCDD sampling train.

(2) In burn VI; 0.1 μg was collected from 444.0 liters for an apparent mass concentration of 0.22 x 10^{-9} grams/liter. However, the detection limit in the TCDD sampling train was only 0.83 x 10^{-9} grams/liter. The apparent mass concentration in the scrubbed effluent gas was below the detection limit of the TCDD sampling train if the collection efficiencies in the particulate and the TCDD sampling trains was assumed to be equal. However, dichlorophenol collection efficiency in the TCDD sampling train was greater than in the particulate train water impingers and dichlorophenol should have been differentially collected in the TCDD sampling train because:

(a) Dichlorophenol is soluble in benzene but only slightly soluble in water.

(b) Fritted impingers, as used in the TCDD system are more effective gas and aerosol collectors than modified impingers used in the particulate train.

(c) A series of four impingers was used in the TCDD sampling train but only two were used in the particulate train.

(3) The water impingers used in the particulate train were packed in sponge rubber and styrofoam for shipment. They had been used in numerous particulate source sampling projects prior to this work. Since it was not anticipated that they would be used for hydrocarbon collection, they were not properly washed for herbicide analysis but merely rinsed with distilled water. Contamination of these impingers with dichlorophenol could have occurred in numerous cases and rinsing with distilled water would not have removed contamination. Also two impinger sets were alternated and the same impinger set (potentially contaminated) was used in burn IV and VI while a different (uncontaminated) set was used in burn III and V.

(4) The water in the impingers and the particulate sampling train from burn III and V did not contain dichlorophenol even though burn III was less efficient in relative pyrolysis of "Orange" herbicide than burn IV and VI. Burn V had a comparable RPE to burn IV and VI. If dichlorophenol was being produced during "Orange" herbicide incineration it would have been produced and detected in burn III and V as well.

(5) Dichlorophenol was not detected in the spent scrubber water (detection limit ≤ equal to 0.08 x10^{-6} grams/liter) in any of the burns, and as discussed in paragraph 11d(1) the caustic scrubber was expected to collect a significant fraction of dichlorophenol. If dichlorophenol was being produced throughout the burn at the rate indicated by the water impinger samples in burn IV (1.76 x10^{-9} grams/liter) then (1.76 x10^{-9} grams/liter times 9.47 x 10^{6} liters) 16.67 milligrams would have been produced. If 1.27 milligrams (7.6% of 16.67 milligrams) of dichlorophenol had been collected by the caustic scrubbers it would have been detected.

g. Based upon the fact that dichlorophenol should have been differentially collected in the TCDD sampling train but was not, contamination of the water impingers with dichlorophenol was possible, and no dichlorophenol was detected in the caustic scrubber, the conclusion was made that dichlorophenol found in the water impingers in burn IV and VI was extraneous contamination.

12. HERBICIDE IN BURN III EHL SAMPLES

a. Only two of all the EHL samples contained any of the following nine herbicide compounds: nb 2,4-D and 2,4,5-T esters and acids, octyl 2,4-D and 2,4,5-T esters and acids, and TCDD. Both of these samples occurred in burn III. First, the combustion chamber coke deposit contained 1100.20 µg of these esters and acids per 100 gms of deposit; of which 551 µg was nb 2,4-D ester and 542 µg was nb 2,4,5-T ester. These esters produced the characteristic "Orange" herbicide odor which was detected in burn III's coke deposit. Neither this odor nor any of the aforementioned nine herbicide compounds were detected in coke deposits from any other burns. Second, the total burn scrubber water composite (SSW-TBC) sample contained 0.25 µg/l of TCDD but none of the other eight herbicide compounds. Suspended matter in burn III's SSW-TBC or from any of the other burns contained none of the nine herbicide compounds. None of these compounds were detected in burn III's first hour spent scrubber water composite (SSW-C1) or any other burn's SSW-TBC or SSW-C1.

b. The total TCDD mass in the spent scrubber water was calculated as 3775 µg for the total burn. If this TCDD mass had been evenly distributed throughout the burn's combustion gas, the sampled combustion gas would have contained about 4.5 times the TCDD mass concentration needed for TCDD detection. However, no TCDD was detected in the combustion gas sample which was initiated 51 minutes into the burn and continued for 64 minutes. Additionally, no TCDD was detected in the SSW-C1 which was initiated 54 minutes into the burn and completed 44 minutes later. Thus, the TCDD must have passed through the incinerator during the last 120 minutes of burn III. The TCDD probably passed through the incinerator in a relatively short period since no noticeable changes in burn III's operational parameters were ever observed.

c. Unlike any other burns, the appearance of burn III's coke deposit indicated very poor combustion and that lower temperatures occurred around the deposit. Although no TCDD was detected in the deposit, it could have been present in concentrations up to about 15 µg/100 grams of deposit. This value was calculated under the assumption that TCDD was present in the 1100.2 µg of esters and acids in the same proportion as it was in the blended herbicide. The 15 µg/100 grams of deposit would have been below the analytical detection limit for that size sample.

d. Earlier comparisons of CGH and SSWH showed no reason to believe that the overall RPE of burn III was significantly less than RPE's in burns I and II. However, burn III's quantity and quality of coke deposit, SGH quality, and TCDD in the SSW-TBC were significantly different than burn I, II, or any other burns. These comparative observations lead to the conclusion that combustor coke chips, 175 grams or more, broke loose from the combustion chamber deposit and, combusted well enough during incinerator dwell time to destruct the herbicide esters and acids but not the TCDD, and then intimately mixed and settled in the scrubber tank. Even though not appreciably soluble in water, enough TCDD must have leached from the coke to produce 250 nanograms per liter of collected SSW-TBC.

13. DISCUSSION OF CONFLICTING DATA

a. Burn IV:

(1) In burn IV, the scrubbed effluent gas hydrocarbon mass concentration (SGH) was greater than the combustion gas hydrocarbon mass concentration (see Table I-7). In all other burns, as expected, the reverse was true.

(2) The mass of hydrocarbons collected in the scrubber (SSWH) during burn IV was comparable to that collected in burns V, VI, VII and VIII. Since caustic scrubber characteristics were not significantly different in burn IV from those in burns V, VI, VII and VIII, one must consider that burn IV combustion gas contained hydrocarbon mass concentrations comparable to burns V, VI, VII, and VIII, or that a combination of two things occurred,

(a) a slug of pyrolyzates occurred during startup (before sampling to account for the hydrocarbon mass in the scrubber) and

(b) the combustion gas and scrubbed effluent gas samples were reversed in the recovery or analytical steps.

(3) Since gas chromatographic peak interferences were possible in the burn IV combustion gas samples, the first consideration was concluded to be the most probable. Therefore, the CGH in burn IV was considered equal to or greater than the CGH in burns V, VI, VII and VIII, but less than the CGH in burns I, II and III.

b. Burn VI: In burn VI, the SGH aliphatics were greater than the CGH aliphatics. This conflict was concluded to be due to:

(1) gas chromatography peak interferences, or

(2) analytical accuracy as the detection limit was being approached.

c. Biphenyls in SGH: Biphenyl (unchlorinated) was not detected in the CGH (Tables G-2 and G-3). Also, it was not detected in the SSWH (Table G-7). The conclusions were made that biphenyl was:

(1) present in the CGH but hidden by gas chromatographic peak interferences (Appendix G, paragraph V),

(2) not collected in the SSWH due to its relatively high vapor pressure (in the scrubber water temperature, 160-170°F) and low solubility in the caustic solution,

(3) detected in the SGH because of fewer gas chromatographic peak interferences.

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APPENDIX J

(TO APPENDIX E)

NOISE MONITORING

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APPENDIX J

NOISE MONITORING

1. Introduction

This appendix presents the noise measuring equipment used, octave band analyses of the noise produced by one incinerator, and the location where noise measurements were made. Data are discussed, particularly as regards the occupational hazards of the noise to exposed operators and estimates of noise intensities expected by more than one incinerator.

2. Results and Discussion

a. Octave band sound level measurements of the incinerator noise, equipment used, and environmental conditions are presented in Table J-1. Locations where noise measurements were made are shown in Figure J-1.

b. "A" weighted octave band sound levels could not be summed any closer than ± 2 decibels (db) of the overall dbA. These minor inaccuracies of measurement were acceptable for meeting the objectives of the study. The following unavoidable environmental conditions caused the measurement errors:

(1) Except for location "7", positions of equipment within the area required that all measurements be taken relatively close (10 - 15 feet) to the incinerator in order to get "line-of-sight" measurements. Consequently, the measurements were influenced by "near field" effects.

(2) Many metallic surfaces around the incinerator contributed reverberation noises.

(3) Background noises were present from a commercial airport 100 - 200 yards away as well as industrial noises from within the contractors facility. However, measurements were taken only when these background noises were at a minimum.

c. The incinerator was not considered a point source of noise. The noise was steady state. The overall sound level averaged 91 dbA and 91 dbC at points twelve feet around the incinerator. Such close values of overall dbA and dbC were in agreement because most of the noise level was produced in the higher frequencies, 2000 - 8000 Hertz. At twenty-four feet from the incinerator, overall average noise levels decreased to 85 dbA or 87 dbC because the

TABLE J-1: SUE® Burner Noise Survey-Octave Band Analyses

Location(1)	Angle	R (ft)	"A" Weighted Slow Response Octave Band Level (dB) Reference 0.0002ubars/M^2 for Octave-Band Center Frequency in Hertz										"A" All Pass	"C" All Pass
			31.5	63	125	250	500	1000	2000	4000	8000	16000		
1*	--	12	72	79	72	71	74	78	82	88	84	73	92	91.5
2*	--	12	76	80	72	74	79	82	84	89	85	74	93	92
3*	--	12	78	83	77	77	79	83	84	88	84	71	92	92
4* & 5*	--	12	75	85	79	77	80	84	83	86	80	65	91	92
6*	--	12	74	83	80	84	79	77	79	83	77	62	88	91
7*	--	24	68	74	69	68	69	76	80	84	78	65	87	86.5
8*	--	15	--	--	--	--	--	--	--	--	--	--	64	65
1**	--	12	71	81	71	73	74	77	81	85	81	72	88	89
2**	--	12	78	79	77	74	78	83	83	88	84	74	91	91
6**	--	12	--	--	--	--	--	--	--	--	--	--	84	87
7**	--	24	70	75	68	69	70	71	76	80	74	60	83	83
									$\overline{X}_{1,2,3,4,5}$				91.	91.
									$\overline{X}_{6,7}$				85.	87.

Intstruments Used: General Radio Octave Band Analyzer Type 1558-PB(Serial No. 2473) with General Radio Microphone 1560-P6 with wind shield (Serial No. 2680).Calibrated with General Radio Calibrator Type 1562-A (Serial No. 2579)

Date of Survey: *20Nov **29Nov Surveyor: Capt.C.W. Bullock Operational Mode of Burner: * Burn IV ** Burn VII

Dashed lines indicate that measurements were not taken.

(1) For location of measurement, see Figure J-1.

Wind conditions during survey: * FRom 120-160°, 9mph, Temp=62°F. ** Calm, 0mph, Temp=62°F.

USAF EHL(K)

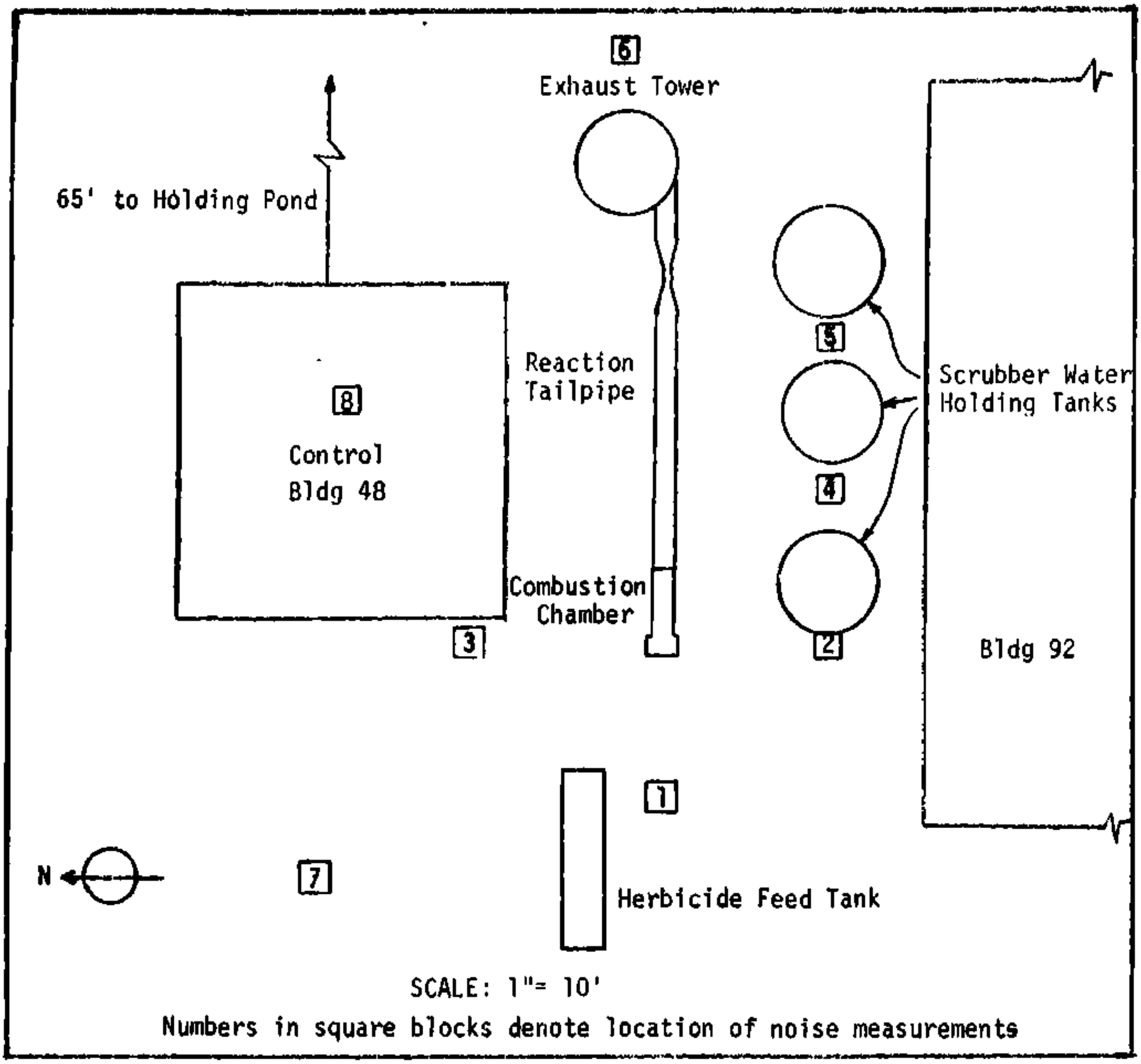

FIGURE J-1: LOCATIONS OF NOISE MEASUREMENTS DURING TEST BURNS

USAF EHL(K)

higher frequency noises had begun to dissipate and the lower frequency components were contributing more significantly to the overall noise level.

d. The control building effectively attenuated exterior incinerator noise to an overall level of 64 dbA. Although octave band analyses were not made, no speech interference was experienced inside the control building.

e. Operators occupationally exposed to the noise within a fifty foot radius of the incinerator should be provided ear muffs and be monitored via a hearing conservation program. The noise data can be used with various hearing protection criteria to determine limited exposure periods in which an unprotected operator could be exposed without risk of developing any hearing loss.

f. Table J-2 below presents estimated overall sound levels with increasing numbers of incinerator units. Appropriate adjustments of hearing conservation protection requirements around the incinerator(s) can be made depending on the number of incinerators and the distance from them to the workers.

TABLE J-2: ESTIMATES OF OVERALL SOUND LEVELS AT VARIOUS DISTANCES FROM ONE TO EIGHT INCINERATORS

Number of Incinerator Units	Overall Sound Level (Reference 0.0002 μ bars/M^2)		
	At Twelve Feet dbA or dbC	At Twenty-four Feet	
		dbA	dbC
1	91	85	87
2	94	88	90
4	97	91	93
8	100	94	96

APPENDIX K

(TO APPENDIX E)

REFERENCES

MAIN REPORT

(1) THERMAL DECOMPOSITION OF ORANGE HERBICIDES, Mississippi Agricultural and Forestry Experiment Station and Plant Science Research Division of the USDA, Cooperative Agreement No. 12-14-100-10, 673(34), to USAF, AFLC/SAAMA, Kelly AFB, Texas (1 June 1972).

(2) INCINERATION OF ORANGE HERBICIDE, USAF Environmental Health Laboratory Technical Report EHL(K) 72-7, USAF EHL(K), Kelly AFB, Texas (July 1972).

(3) REPORT ON THE FEASIBILITY OF DESTROYING HERBICIDE ORANGE BY INCINERATION USING THE MARQUARDT SUE® BURNER, Report S-1224, The Marquardt Company, Van Nuys, California. Prepared under Contract No. F04611-72-C-0087 for Air Force Rocket Propulsion Laboratory (AFRPL), Air Force Systems Command, Edwards, California (August 1972).

APPENDIX B

(4) Private Communication, The Marquardt Company, Van Nuys, California and Air Force Rocket Propulsion Laboratory (AFRPL), Edwards, California (1972).

APPENDIX D

(See References on Page D-27)

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APPENDIX F

THE ECOLOGICAL CONSEQUENCES OF MASSIVE QUANTITIES OF 2,4-D and 2,4,5-T HERBICIDES
SUMMARY OF A FIVE YEAR FIELD STUDY

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THE ECOLOGICAL CONSEQUENCES OF MASSIVE QUANTITIES OF 2,4-D and 2,4,5-T HERBICIDES

SUMMARY OF A FIVE YEAR FIELD STUDY*

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In support of programs testing aerial dissemination systems, a one square mile test grid on Test Area C-52A, Eglin AFB Reservation, Florida received massive quantities of military herbicides. The purpose of these test programs was to evaluate the capabilities of the equipment systems, not the biological effectiveness of the various herbicides. Hence, it was only after repetitive applications that test personnel began to express concern over the potential ecological and environmental hazards that might be associated with continuance of the Test Program. This concern led to the establishment of a research program in the fall of 1967 to measure the ecological effects produced by the various herbicides on the plant and animal communities of Test Area C-52A. This report documents six years of research (1967 - 1973) on Test Area C-52A and the immediately adjacent streams and forested areas.

This report attempts to answer the major questions concerned with the ecological consequences of applying massive quantities of herbicides (345,117 pounds), via repetitive applications, over a period of eight years, 1962 - 1970, to an area of approximately one square mile. Moreover, the report documents the persistence, degradation, and/or disappearance of the herbicides from the Test Area's soils and drainage waters and their subsequent effects (direct or indirect) upon the vegetative, faunal, and microbial communities.

The active ingredients of the four military herbicides (Orange, Purple, White, and Blue) sprayed on Test Area C-52A were 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), 4-amino-3,5,6-trichloropicolinic acid (picloram), and dimethylarsinic acid (cacodylic acid). It is probable that the 2,4,5-T herbicide contained the highly teratogenic (fetus deforming) contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Ninety-two acres of the test grid received 1,894 pounds 2,4-D, 2,4,5-T per acre in 1962 to 1964, while another 92 acres received 1,168 pounds per acre in 1964 to 1966. In the period from 1966 to 1970, a third distinct area of over 240 acres received 343 pounds per acre of 2,4-D and 2,4,5-T, 6 pounds per acre picloram, and in 1969 to 1970, 53 pounds per acre cacodylic acid (28 pounds per acre of arsenic as the organic pentavalent form; calculated on weight of Blue applied per acre).

From the rates of herbicides that were applied during the years of testing spray equipment, it was obvious that Test Area C-52A offered a unique opportunity to study herbicide persistence and soil leaching. Yet the problem of how best to assess the level of herbicide residue was

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*Presentation to the Weed Sciences Society of America, 14 February 1974, Las Vegas, Nevada. Abstract No. 164.

a difficult one. The herbicides could be chemically present but because of soil binding might not be biologically active. Thus, both bioassay techniques and analytical analyses were employed. The first major bioassay experiment was conducted in April 1970. By considering the flightpaths, the water sources, and the terracing effects, it was possible to divide the one-square mile test grid into 16 vegetation areas. These areas formed the basis for the random selection of 48 3-foot soil cores. Soybean bioassays indicated that 27 of the 48 cores were significantly different from control cores (95% probability level). The results indicated that soil leaching or penetration was much more prevalent along the dissemination flight paths than in other areas of the test grid. Efforts to quantitate (chemically) the bioassay were confined to only the top 6-inch increment because of within-core variations. By considering that all phytotoxic effects were from Orange (2,4-D and 2,4,5-T) the average value for the top 6 inches of soil core for the eight cores showing greatest herbicide concentration was 2.82 ppm (parts per million) herbicide. Chemical analyses of soil cores collected from the eight sites showing greatest phytotoxic concentrations were performed in December 1970. Results indicated that the maximum concentration of either 2,4-D or 2,4,5-T was 8.7 ppb (parts per billion). A 1970 analysis of soil cores for arsenic, from areas receiving greatest quantities of Blue, indicated maximum levels of 4.70, 1.30, and 0.90 ppm arsenic for the first three 6-inch increments of the soil profile, respectively. These same increments were again collected and analyzed in 1973: levels of arsenic were 0.85, 0.47, and 0.59 ppm for the three consecutive 6-inch increments. Leaching of the arsenical from the soils may have occurred. Picloram analysis in November 1969 of soil cores from areas receiving greatest quantities of White indicated that maximum levels of 2.8 ppm picloram were present in the 6 to 12-inch depth increment. Analysis of the same sites performed in 1971 indicated the picloram had leached further into the soil profile but concentrations were significantly less (ppb). Analysis of soil cores in 1971 showed no residue of TCDD at a minimum detection limit of less than 1 ppb, even in soil previously treated with 947 pounds 2,4,5-T per acre. However, data from soil analysis (via mass spectrometry) of four total samples collected in June and October 1973 indicated TCDD levels of <10, 11, 30, and 710 parts per trillion (ppt), respectively. These levels were found in the top six inches of soil core. The greatest concentration (710 ppt) was found in a sample from the area that received 947 pounds 2,4,5-T in the 1962 - 1964 test period.

A comparison of vegetative coverage and occurrence of plant species on the one-square mile grid between June 1971 and June 1973 has indicated that areas with 0 to 60% vegetative cover in 1971 had a coverage of 15 to 85% in June 1973. Those areas having 0 to 5% coverage in 1971 (areas adjacent to or under flightpaths used during herbicide-equipment testing) had 15 to 54% coverage. The rate of change in coverage seemed to be dependent upon soil type, soil moisture, and wind. There was no evidence to indicate that the existing vegetative coverage was in any way related to herbicide residue in the soil: dicotyledonous or broadleaf plants that are normally susceptible to damage from herbicide residues occurred throughout the entire one square mile grid. The square-foot transect method of determining vegetative cover indicated that the most dominant plants on the test area were the grasses, switchgrass (Panicum virgatum), woolly panicum (Panicum lanuginosum), and the broadleaf plants rough buttonweed (Diodia teres), poverty weed (Hypericum gentianoides), and common polypremum (polypremum procumbens). In 1971, 74 dicotyledonous species were collected on the one square mile grid; in 1973, 107 dicotyledonous species were found. All of the plant species collected were pressed, mounted, and placed in the Eglin AFB Herbarium.

An evaluation of the effects of the spray-equipment testing program on faunal communities was conducted from May 1970 to August 1973. The extent of any faunal ecological alterations was measured by assessing data on species variation, distribution patterns, habitat preference and its relationships to vegetative coverage, occurrence and incidence of developmental defects, as well as gross and histologic lesions in post mortem pathological examinations.

A total of 73 species of vertebrate animals (mammals, birds, reptiles, and amphibians) were observed on Test Area C-52A and in the surrounding area. Of these 73 species, 22 species were observed only off the grid, 11 species were observed only on the grid, and 40 species were observed to be common to both areas. During the early studies no attempts were made to quantitate animal populations in the areas surrounding the grid; however, in 1970, preliminary population studies by trap-retrap methods were performed on the beach mouse (Peromyscus polionotus) population for a 60 day period to confirm the hypothesis that it was the most prevalent species on the grid. The hypothesis was supported by the capture of 36 beach mice from widely distributed areas on the grid, except in areas with less than 5% vegetation. Eight pairs of eastern harvest mice were taken to the laboratory and allowed to breed. Six of the eight pairs had litters totalling 24 mice. These progeny were free from any gross external birth defects. During February - May 1971 population densities of the beach mouse were studied at eight different locations on the grid along with two different areas off the grid which served as controls. Populations were estimated on the basis of trap-retrap data. There was no difference in mouse population densitites in herbicide treated and control areas affording comparable habitats. All indications were that any population differences in other animal species between the test area and the surrounding area were due to differences caused by the elimination of certain plants and, therefore, certain ecological niches, rather than being due to any direct detrimental effect of the herbicides on the animal population present on TA C-52A.

During the last day of the 1971 study, 9 mice were captured and taken to the laboratory for post mortem pathological examination. There were no instances of cleft palate or other deformities. Histologically, liver, kidney and gonadal tissues from these animals appeared normal, In the 1973 study several different species of animals were caught, both on and off the test grid. These included beach mice, (*Peromyscus polionotus*), cotton mice, (*Peromyscus cossypinus*), eastern harvest mice, (*Reithrodontomys humulis*), hispid cotton rats, (*Signodon hispidus*), six-lined race-runners, (*Cnemidophorus sexlineatus*), a toad, (*Bufo americanus*), and a cottonmouth water moccasin, (*Ancistrocon piscivorus*). A total of 89 animals were submitted to The Armed Forces Institute of Pathology, Washington, D.C. for complete pathological examination including gross and microscopic studies. Liver and fat tissue from 70 rodents were forwarded to the Interpretive Analytical Services, Dow Chemical U.S.A., for TCDD analyses. The sex distribution of the trapped animals was relatively equal. The ages of the animals varied, but adults predominated in the sample. No gross or histological developmental defects were seen in any of the animals. Several of the rats and mice from both groups were pregnant at the time of autopsy. The stage of gestation varied considerably from early pregnancy to near term. The embryos and fetuses were examined grossly and microscopically, but no developmental defects or other lesions were observed. Gross necropsy lesions were relatively infrequent and consisted primarily of lung congestion in those animals that had died from heat exhaustion prior to being brought to the laboratory. The organ weights did not vary significantly between the test and control animals when an animal with lungs and kidneys showing inflammatory pathological lesions was removed from the sample. Histologically, the tissues of 13 of the 26 control animals and 40 of the 63 animals from the test grid, were considered normal. Microscopic lesions were noted in some animals from both groups. For the most part, these were minor changes of a type one expects to find in any animal population. One of the most common findings was parasites. A total of 11 controls and 9 grid animals were affected with one or more classes of parasites. Parasites may be observed in any wild species and those in this population were for the most part incidental findings that were apparently not harmful to the animals. There were exceptions however. Protozoan organisms had produced focal myositis in one rat, and were also responsible for hypertrophy of the bile duct epithelium in a six-lined racerunner.

Moderate to severe pulmonary conjestion and edema were seen in several rats and mice. All of these animals were found dead in the traps before reaching the laboratory, and the lung lesions were probably the results of heat exhaustion. The remainder of the lesions in both groups consisted principally of inflammatory cell infiltrates of various organs and tissues. They were usually mild in extent and although the etiology was not readily apparent, the cause was not interpreted as toxic. The analyses of TCDD from the rodents collected in June and October 1973 indicated that TCDD or a compound chemically similar to TCDD accumulated in the liver and fat of rodents collected from an area receiving massive quantities of 2,4,5-T. However, based on the pathological studies there was no evidence that the herbicides and/or contaminants produced any developmental defects or other specific lesions in the animals sampled or in the progeny of those that were pregnant. The lesions found were interpreted to be of a naturally occurring type and were not considered related to any specific chemical toxicity.

In 1970 beach mice were not found on the more barren sections of the grid (0-5% vegetative cover). There were, however, some areas of the grid which had population densities exceeding those of the species preferred habitat as reported in the literature. In an attempt to correlate distribution of the beach mouse with vegetative cover (i.e., habitat preferance) a trapping-retrapping program of 8 days duration was conducted in 1973. The majority of animals (63) were found in areas with 5% to 60% vegetative cover: Within this range, the greatest number of animals trapped (28) was from an area with 40% to 60% cover. A similar habitat preference has been observed along the beaches of the Gulf Coast. In this study, it appeared that the beach mouse used the seeds of switchgrass (Panicum virgatum) and wooly panicum (Panicum lanuginosum) as a food source.

Trapping data from 1971 was compared to trapping data collected in 1973 to determine whether an increase in the population of beach mice had occurred. The statistical evidence derived from that study showed that the 1.64 beach mice per acre population (based on the Lincoln Index for 1973) was slightly higher than the 0.8 and 1.4 mice per acre reported for a similar habitat. The population of beach mice was also higher in 1973 than in 1971 in the area of the test grid. The apparent increase in beach mouse population on the grid in 1973 over 1971 was probably due to the natural recovery phenomenon of a previously disturbed area (i.e., ecological succession). Some areas of the test grid have currently exceeded that preferred percentage of vegetative coverage of the beach mouse habitat, and other areas were either ideal or fast developing into an ideal habitat. If the test grid remains undisturbed and continues toward the climax species, a reduction in the number of beach mice will probably occur simply due to decline of preferred habitat.

A 1973 sweep net survey of the Arthropods of Test Area C-52A resulted in the collection of over 1,700 specimens belonging to 66 insect families and Arachnid orders. These totals represented only one of five paired sweeps taken over a one-mile section of the test grid. A similar study performed in 1971 produced 1,803 specimens and 74 families from five paired sweeps of the same area using the same basic sampling techniques. A much greater number of small to minute insects were taken in the 1973 survey. Vegetative coverage of the test area had increased since 1971. The two studies showed similarities in pattern of distribution of Arthropods in relation to the vegetation, number of Arthropod species, and Arthropod diversity. Generally, the 1973 study showed a reduction of the extremes found in the above parameters in the 1971 study. This trend was expected to continue as the test area stabilizes and develops further plant cover, thus allowing a succession of insect populations to invade the recovering habitat.

There are two classes of aquatic areas associated with the Test Area; ponds actually on the square mile area and streams which drain the area. Most of the ponds are primarily of the "wet weather" type, drying up once in the last five years, although one of the ponds is spring fed. Three major streams and two minor streams drain the test area. The combined annual flow of the five streams exceeds 24 billion gallons of water. Seventeen different species of fishes have been collected from the major streams while three species have been collected from the spring-fed pond on the grid. Statistical comparisons of 1969 and 1973 data of fish populations in the three major streams confirm a chronologically higher diversity in fish populations. However, the two control streams confirm a similar trend in diversity. Nevertheless, from examining all of the aquatic data, certain observations support the idea that a "recovery" phenomenon is occurring in the streams draining TA C-52A. These observations are difficult to document because of insufficient data. For example, in 1969, the Southern Brook Lamprey (Ichthyomyzon gagei) was never collected in one of the streams immediately adjacent to the area of the grid receiving the heaviest applications of herbicides; however, in 1973 it was taken in relatively large numbers. These observations may or may not reflect a change in habitat due to recovery from herbicide exposure. Residue analyses (1969 to 1971) of 558 water samples, 68 silt samples and 73 oyster samples from aquatic communitites associated with drainage of water from Test Area C-52A showed negligible arsenic levels. However, a maximum concentration of 11 ppb picloram was detected in one of the streams in June 1971 but dropped to less than 1 ppb when sampled in December 1971. TCDD analysis of biological organisms from streams draining Test Area C-52A or in the ponds on the test area were free from contamination at a detection limit of less than 10 parts per trillion.

In analyses performed 3 years after the last application of 2,4-D and 2,4,5-T herbicide the test grid exhibited population levels of soil microorganisms identical to that in adjacent control areas of similar soil and vegetative characteristics not exposed to herbicides. There were increases in Actinomycete and bacterial populations in some test site areas over levels recorded in 1970. This was possibly due to a general increase in vegetative cover for those sampling sites and for the entire test grid. No significant permanent effects could be attributed to exposure to herbicides.

Data on aquatic algal populations from ponds on the one square mile grid (previously exposed to repetitive applications of herbicides) indicated that the genera present were those expected in warm, acid (pH 5.5), seepage, or standing waters.

APPENDIX G

FIELD STUDIES ON THE SOIL PERSISTENCE AND MOVEMENT OF 2,4-D, 2,4,5-T, AND TCDD

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FIELD STUDIES ON THE SOIL PERSISTENCE AND MOVEMENT OF 2,4-D, 2,4,5-T, and TCDD*

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INTRODUCTION

Concern over the level of contamination of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) herbicide by the teratogen 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) may result in the disposal of selected inventories of this herbicide. A potential disposal method is that of soil incorporation. The soil incorporation method is based on the premise that high concentrations of phenoxy herbicide and TCDD will be degraded to innocuous products by the combined action of soil microorganisms and soil chemical hydrolysis.

It has been known for several years that the rate at which herbicides disappear from the soil is largely dependent upon their susceptibility to metabolism by soil microorganisms. Much of the information available on the biological breakdown of the phenoxy herbicides comes from laboratory studies and is very useful for predicting what might happen when relatively high concentrations of phenoxy herbicides are applied to a soil incorporation site. Conversely, a certain amount of caution must always be used when extrapolating laboratory data to a field situation. Data on the field persistence of TCDD is extremely limited primarily due to the low levels of contamination in commercial formulations, the rate of application of such formulation, and the lack of a sensitive analytical method for the detection of TCDD. This report documents current field research on the soil degradation of a TCDD-contaminated phenoxy formulation when incorporated in the soil at massive rates of application.

METHODS AND MATERIALS

In August 1972, a site for the soil incorporation of phenoxy herbicides was selected on the Air Force Logistics Command Test Range Complex, Hill Air Force Base, Utah. The potential site was characterized as being relatively flat and having a uniform surface without rock outcrops or areas of marked deflation or dunes. Sediments in this area are lacustrine in origin and were deposited when ancient Lake Bonneville covered this region of the Great Basin. Sediments consist of clays interlaced irregularly with sand lenses and remnant stream sands; the clays predominanting. The undifferentiated clays contain various amounts of dissolved salts. Table 1 shows an analysis of the top two

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TABLE 1. Soil analysis of the top two six-inch soil imcrements from the soil incorporated plots, Air Force Logistics Command Test Range Complex, Hill Air Force Base, Utah[a]

Inches	pH	Organic Carbon (%)	Electrical Conductivity (EC x 10^3)[b]	Ca/Mg	K	Na	Sand (%)	Silt (%)	Clay (%)	Moisture at Saturation (%)
				meq/100g soil)						
0-6	7.8	0.82	28.0	23.7	3.9	13.4	27	53	20	31.1
6-12	7.9	0.95	31.0	23.8	3.9	13.2	26	52	22	34.2

[a] Determined by Soils Laboratory, Utah State University, Logan, Utah, and the Soils Laboratory, Kansas Agricultural Experiment Station, Garden City, Kansas.

[b] Electrical conductivity in millimhos per cm at 25 C.

six-inch increments (0-6, 6-12 inches) of the soil profile. The annual rainfall of the area is less than ten inches taking into consideration the water equivalent of snowfall. Ground water of the area varies from 16 to 20 feet below the surface. It is supplied primarily by the precipitation falling on the nearby mountains. The small amount of water which percolates through the existing clays moves laterally westward towards the salt flats, picking up chemical matter from these clays. As a result, the ground water contains up to 1,000 parts per million (ppm) sodium chloride. The annual mean daily minimum temperature is 33.5 F and the annual mean daily maximum temperature is 64.7 F. The experimental area has a vegetative cover of 15 percent and is dominated by fourwing saltbush, Atriplex canescens (Pursh) Nutt,; halogeton, Halogeton glomeratus (M. Bieb.) C.A. Mey; and graymolly, Kochia vestita.

Six field plots, each 10 x 15 feet, were established on the Air Force Logistics Command Test Range Complex on 6 October 1972. To simulate subsurface injection (incorporation), three equally-spaced trenches, 6 inches wide and 10 feet in length were dug to a depth of 4-6 inches in each plot. The rates of herbicide selected for incorporation were 1,000, 2,000, and 4,000 pounds active ingredient per acre (lb ai/A) 2,4-D plus 2,4,5-T. Two replications (plots) per rate were included in the experiment. The quantity of herbicide required for each rate was divided into three equal parts and sprayed, as the concentrate, into each of the three trenches per plot, respectively. A hand sprayer with the nozzle removed was used to spray as uniformly as possible an approximate two-to-three-inch band of herbicide in the center of the 6-inch by 10-foot trench. The trenches in each plot were then covered by use of a handshovel, tamped, and levelled using a handrake.

The herbicide formulation used for these simulated incorporation experiments was an approximate 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T. One gallon of this formulation contains 4.21 pounds of the active ingredient of 2,4-D and 4.41 pounds of the active ingredient of 2,4,5-T. The formulation was originally specified to contain:

n-butyl ester of 2,4-D	49.40%
free acid of 2,4-D	0.13%
n-butyl ester of 2,4,5-T	48.75%
free acid of 2,4,5-T	1.00%
inert ingredients (e.g., butyl alcohol and ester moieties)	0.62%

Some of the physical, chemical, and toxicological properties of the herbicide formulation are:

Specific Density (25 C)	1.282
Viscosity, centipoise (23 C)	43
Molecular mass	618
Weight of Formulation (lbs/gal)	9.63
Soluble in water	no
Specific toxicity for female white rats (mg formulation/kg body weight)	566

A 200 ml sample of the formulation was removed from the container of herbicide used on these plots, placed in a hexane-acetone-rinsed glass jar and shipped to the Interpretive Analytical Services Laboratory, Dow Chemical U.S.A., Midland, Michigan, for analysis of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The results of the analysis indicated a concentration of 3.7 parts per million (ppm) TCDD.

The first initial soil samples were to be taken the following day after incorporation of the herbicide. However, because of adverse weather initial samples were not obtained. Beginning in January 1973 soil samples were collected routinely every 2-3 months. Sampling was done by using a 3-inch by 6-inch hand auger. Each row (trench) in each plot was sampled once by removing 6-inch increments to a depth of 36 inches. Each depth was uniformly mixed per plot (i.e., the three rows per plot were mixed for each depth), placed in sample containers, and shipped under dry ice to the laboratory for herbicide analysis. In all cases, the soil cores were obtained as accurately as possible from the center of the 6-inch wide row (trench). In the laboratory, each sample was analyzed for 2,4-D acid, 2,4,5-T acid, 2,4-D n-butyl ester, and 2,4,5-T n-butyl ester by the gas chromatographic procedure of Arnold and Young (in press, Analytical Chemistry, 1974).

RESULTS AND DISCUSSION

The results of the analysis of soil samples taken from the test plots are displayed in Tables 2-4. Table 2 illustrates the loss of total active herbicide from the upper 12 inches of soil increment over a period of 440 days (6 Oct 1972 - 14 Dec 1973). Assuming normal climatological conditions this period represents 7 months of relatively cold temperatures and 7 months of relative warmth. The percent loss of herbicide over just the 330 day sampling period (from 110 to 440 days) was 78.2%, 75.2% and 60.8% for the 1,000, 2,000, and 4,000 lb ai/A plots, respectively. If the theoretical values for herbicide concentration at day 0 are used, percent loss of herbicide during the entire experiment was 87.8%, 85.3% and 82.6%, respectively. These data tend to indicate a decreased degradation of herbicide with increased application rate. However, the unusually low rate calculated for 4,000 lb ai/A application over the 330-day period is likely a result of low value of herbicide measured in the first sample (110 days) rather than a difference in degradation rate. If a strict exponential decay curve is assumed, the half life for the total herbicide ranges from 146 to 155 days depending on application rate.

Tables 3 and 4 illustrate the individual loss of each of the herbicides (2,4-D and 2,4,5-T) contained in the original formulation. Except at the lowest rate of applicaton, no significant difference was seen in the rate of degradation of the individual components in this formulation. At the application rate of 1000 lbs/A, there was a 7.5% difference (rate, 2,4-D = 81.2%; 2,4,5-T = 73.7%) in degradation rates. It was originally thought that this was due to laboratory error, however, further sampling has tended to confirm this difference. It should be noted at this

TABLE 2. Soil concentration, part per million, of 2,4-D and 2,4,5-T herbicide at selected sampling periods, days, following soil incorporation.

Application Rate of Formulation (lb ai/A)[b]	Sampling Time After Incorporation (Days)[a]				
	0[c]	110	220	282	440
1,000	10,000	5,580	1,876	----	1,216
2,000	20,000	11,877	----	4,670	2,944
4,000	40,000	17,729	----	8,489	6,944

[a] Data represent an average of two replications with the duplicate samples of each replication: the total value for depths 0-6 and 6-12 inches of soil increment.

[b] Pounds active ingredient per acre.

[c] Theoretical concentration at time of application based on a two-inch spray swath at a depth of 4-6 inches within the soil profile.

TABLE 3. Soil concentration, parts per million, of 2,4-D herbicide at selected sampling periods, days, following soil incorporation.

Approximate[a] rate of 2,4-D (lb ai/A)	Sampling Time After Incorporation (Days)[b]				
	0[c]	110	220	282	440
500	5,000	3,280	976	----	616
1,000	10,000	7,261	----	2,370	1,844
2,000	20,000	10,545	4,829	----	4,112

[a] Rate of herbicide per acre was based on the original specification of the formulation (i.e., a 50:50 n-butyl formulation containing 8.63 pounds active ingredient per gallon).

[b] Data represent an average of two replications with two duplicate samples of each replication: the total for depths 0-6 and 6-12 inches of soil increment.

[c] Theoretical concentration at time of application based on two-inch spray swath at a depth of 4-6 inches within the soil profile.

TABLE 4. Soil concentration, parts per million, of 2,4,5-T herbicide at selected sampling periods, days, following soil incorporation.

Approximate[a] Rate of 2,4,5-T (lb ai/A)	Sampling Time After Incorporation (Days)[b]				
	0[c]	110	220	282	440
500	5,000	2,300	900	----	604
1,000	10,000	4,616	----	2,300	1,100
2,000	20,000	7,184	----	3,734	2,832

[a] Rate of herbicide per acre was based on the original specification of the formulation (i.e., a 50:50 n-butyl formulation containing 8.63 pounds active ingredient per gallon).

[b] Data represent an average of two replications with two duplicate samples of each replication: the total for depths 0-6 and 6-12 inches of soil increment.

[c] Theoretical concentration at time of application based on two-inch spray swath at a depth of 4-6 inches within the soil profile.

point that while it was originally assumed that the formulation which was applied contained equal amounts of each herbicide, data obtained from soil analysis tended to contradict this assumption. On the first sampling date the soils contained an average of 66.9% 2,4-D and only 33.1% 2,4,5-T. This ratio was approximately maintained throughout the study. A sample of the herbicide formulation was analyzed by gas chromatographic-mass spectrometry techniques and found to contain approximately 60% 2,4-D and 40% 2,4,5-T In addition to the butyl esters, the formulation also contained relatively large amounts of octyl and iso-octyl esters of both components.

A great deal of difficulty was encountered in our attempt to accurately measure the rate of herbicide loss in these field samples. Without averaging, loss rates calculated varied over a rather large range from sample to sample. Even with averaging a few samples which were analyzed were not included in the data due to extreme variations in herbicide concentration, i.e. much higher or lower than previous samples. We attribute these variations to a number of uncontrollable variables, the most significant of which was a variation in application rates within the test rows. When the test plots were established, the herbicide was sprayed into the rows with a hand sprayer and it appears likely that there were originally concentration differences at various points due to this method of application. A second source of error is attributable to the moisture content of the soil samples. On some of the sampling dates, the samples received were extremely wet due to snow drifts over the plots while others were relatively dry. This variation in moisture tended to change the consistency of the soil and in many cases made the obtaining of a uniform sample impossible. A third source of variation occurred due to the composition of the herbicide sample which was originally applied. As was previously mentioned in addition to the expected n-butyl esters of 2,4-D and 2,4,5-T, a portion of the formulation of the sample was made up of n-octyl and iso-octyl esters of the two herbicides. No attempt was made to analyze for these esters in the soil samples; consequently, the effect of these compounds on the overall degradation pattern would only be noted after they had been hydrolyzed to the free acid. Since the rates of hydrolysis of these compounds may be different than that of n-butyl esters, this is another possible source of variation in the data obtained on early sampling dates.

In order to minimize variations in the data, on February 1, 1973, small amounts of soil (200 g) from the field plots were analyzed and placed in glass stoppered bottles. These bottles were then placed in a constant temperature incubator at 83 F to be analyzed periodically at later dates. The analytical data from these samples are presented in Table 5. Average percent loss/day values calculated from these samples were 0.42%/day for 2,4-D and 0.48%/day for 2,4,5-T. Half lives for 2,4-D and 2,4,5-T calculated from these data are 119 days and 104 days, respectively. In these samples it appears that the rate of degradation decreases with time since, in most samples, the loss of herbicide was greater from day 0 to 82 than between days 82-156. Apparently initial concentration had little effect on the degradation rate. The average rates of loss for the 6 samples with the highest initial concentrations were .43 and .48 while those for the 6

TABLE 5. Loss of herbicide (ppm) from field samples incubated in the laboratory at 83 F.

Sample Number	0 Days		82 Days		156 Days		Total loss/ day (percent)	
	2,4-D[a]	2,4,5-T[b]	2,4-D	2,4,5-T	2,4-D	2,4,5-T	2,4-D	2,4,5-T
1	2740	1980	2300	1178	868	480	.44	.44
2	2440	1500	1412	695	680	320	.46	.50
3	3220	2380	1340	820	840	488	.47	.51
4	2360	1500	1260	750	784	440	.43	.45
5	5704	4220	3148	1640	2000	1124	.42	.47
6	5484	3388	2408	1350	1652	920	.43	.47
7	3260	2100	1540	760	1164	632	.41	.45
8	2980	2200	1162	547	1300	720	.36	.43
9	9680	7080	4584	2408	3552	1740	.41	.48
10	11000	7720	4644	2388	3590	1902	.43	.48
11	2820	1820	1500	700	1032	608	.41	.43
12	3320	2440	1448	895	1028	500	.44	.51
AVG.	4584	3194	2229	1178	1558	823	.42	.43
TOTAL	55,008	38,328	26,746	14,131	18,690	9,879		

[a] Total value for esters and acids of 2,4-D.

[b] Total value for esters and acids of 2,4,5-T.

samples of lowest concentration were .42 and .46, respectively, and are therefore not significantly different.

One observation that was apparent in all degradation studies which have been performed is the relatively rapid hydrolysis of the n-butyl esters of the herbicide due to contact with the alkaline Utah soils. Table 6 gives the percentage saponification of the n-butyl esters of 2,4-D and 2,4,5-T to the acids over a period of 282 days for two different application rates. It was found that in all samples, the rate of hydrolysis of n-butyl 2,4-D was greater than that of n-butyl 2,4,5-T. Moreover, it is likely that at the higher concentrations (e.g., 4,000 lb ai/A), the acid salts formed could not be removed at a sufficiently rapid rate (via degradation and/or penetration), causing the chemical equilibrium to shift to the left.

Data concerning herbicide penetration in Utah soils are shown in Table 7. Samples from lower soil increments were taken from those plots where it was expected that herbicide concentrations would be most likely to penetrate into the soils. With one exception, both 2,4-D and 2,4,5-T residues were found at all levels sampled. In all cases the total herbicide concentration in levels greater than 18 inches was made up entirely of the free acids. Butyl esters were not detected at depths greater than 12 inches for 2,4-D or 18 inches for 2,4,5-T. It is also interesting to note that the penetration of 2,4-D is greater than that of 2,4,5-T. Apparently this is due to the greater water solubility of the free acid of 2,4-D. This may also explain why 2,4-D appeared to degrade more slowly in laboratory samples where there was no loss from the sample due to penetration.

In June 1973, a composite soil core from one of the 4,000 lb ai/A plots was selected for TCDD analysis. The Interpretive Analytical Services Laboratory, Dow Chemical U.S.A. performed the analysis using a modification of the method developed by Baughman and Meselson (published in Environmental Health Perspectives, Experimental Issue No. 5, September 1973). The following data were obtained:

	2,3,7,8-tetrachlorodibenzo-p-dioxin	
Sample	parts per trillion	parts per billion
Control (0-6 inches)	<10	<10
Plot 5 (0-6 inches)	15,000	15.00
Plot 5 (6-12 inches)	3,000	3.00
Plot 5 (12-18 inches)	90	0.09
Plot 5 (18-24 inches)	120	0.12

Thus, within the four samples from the plot 5 core (4,000 lb ai/A) a total concentration of 18,210 ppt (18.21 parts per billion - ppb) was found. Undoubtedly the lower two depths (12-18 and 18-24 inches) represent contamination from the upper two increments, via the use of the hand auger.

TABLE 6. Percentage saponification of the n-butyl esters of 2,4-D and 2,4,5-T at selected time periods, days, following soil incorporation in alkaline soils.

Application Rate of Formulation	Days After Incorporation[a]			
	0	110	220	282
1,000 lb ai/A[b]				
Esters	100	24	13	3
Acids	0	76	87	97
4,000 lb ai/A				
Esters	100	77	40	32
Acid	0	23	60	68

[a] Data are the percent acid and esters of herbicides found in top 0-6 of soil profile.

[b] lb ai/A = pounds active ingredient per acre.

TABLE 7. Herbicide (2,4-D and 2,4,5-T) penetration (ppm) in the 4,000 lb ai/A plots 282 days after soil incorporation.

Depth (inches)	2,4-D[a] (ppm)	2,4,5-T[a] (ppm)	Percent of total Herbicide
0-5	4262	2982	72.4
6-12	1093	752	18.4
12-18	126	101	2.3
18-24	158	70	2.7
25-30	230	50	2.9
30-36	161	21	1.8

[a] Data are an average of two analyses and represents the total of both the ester and acid components.

Since the TCDD concentration of the formulation was known (see Methods), and since its determination in the soil core was performed by the same laboratory and instrumentation, an estimation of the degradation of TCDD can be obtained by comparison to the expected value based on the known concentration of herbicide at time of sampling. Subsamples of the soil core analyzed for TCDD were also analyzed for 2,4-D and 2,4,5-T. The total concentration of herbicide in the 0-6 and 6-12 inch increments was approximately 14,000 ppm. Therefore, the actual concentration should have been approximately 51.8 ppb TCDD ($14{,}000 \times 3.7 \times 10^{-3} = 51.8$) *if* degradation of the TCDD was at the same rate as 2,4-D and 2,4,5-T. If the theoretical values for herbicide concentration at day 0 (time of incorporation) are used, then the initial concentration of TCDD would have been 148 ppb ($40{,}000 \times 3.7 \times 10^{-3} = 148$ ppb). The percent loss of TCDD over a period of 265 days was 87.7% (18.21/148 = 12.3%; 100% - 12.3% = 87.7%). The value 87.7% would represent 3 half-lives for TCDD persistence. Therefore a rough estimate for the half-life of TCDD would be 88 days *in these alkaline soils, under desert conditions*, and *in the presence of massive quantities of 2,4-D and 2,4,5-T*.

These preliminary data suggest that TCDD degrades at a more rapid rate than 2,4-D or 2,4,5-T. Moreover, the movement of the TCDD to the 6-12 inch depth probably represents co-movement with the massive amounts of esterified herbicide, rather than independent penetration into the soil profile.

APPENDIX H

JOHNSTON ISLAND DATA

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1. BACKGROUND INFORMATION

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1. BACKGROUND INFORMATION

a. History of Johnston Island

(1) Johnston Atoll has had a varied history. It is one of the most isolated atolls in the entire Pacific Ocean. Originally it consisted of two small, insignificant islands, a partial coral reef to the west and northwest and a rather large, shallow lagoon to the east and south. This lagoon is dotted by numerous patch reefs and coral heads. It is now a large Department of Defense (DoD) complex. Johnston Atoll was originally discovered by the American brig "Sally" out of Boston on September 2, 1796 (Bryan, 1942)(Wetmore, 1963). However, no landing was made. On December 1, 1807 the HMS "Cornwallis" under the command of Captain Charles James Johnston visited the atoll (Marshall, 1825). Today the atoll bears this discoverer's name. Since 1858, Johnston Atoll has been the undisputed possession of the United States. Prior to that date it was claimed for short periods of time by the Kingdom of Hawaii (Bryan, 1942). In 1892, Great Britain filed a claim that Johnston Atoll was being considered as a possible relay station for a transoceanic communications cable (Bauer, 1973). Johnston Atoll is not now and never has been a part of the State of Hawaii. It is presently an unincorporated territory which is distinguished from an incorporated territory, i.e., it is a territory to which the constitution of the United States has not been fully and expressly extended (U.S. Department of State, 1965). Birds have in the past and continue at present to play an important part in the history of the atoll. Following passage of the Guano Act of 1856 by the United States Congress there were transient guano mining efforts in 1858-1860. The first scientific visit in July 1923 resulted largely from interest in the bird population (Wetmore, 1963). As a result of this visit, the atoll was made a Federal bird refuge on July 29, 1926 by Executive Order No. 4467 signed by President Calvin Coolidge. Initially the atoll was under the jurisdiction of the Department of Agriculture but in 1940 this responsibility was transferred to the Department of the Interior. This executive order remains in force although subsequent executive orders have given jurisdiction over the atoll to the Department of Defense, see Appendix B.

(2) Because of its strategic military location, President Franklin D. Roosevelt, on December 29, 1934, by Executive Order No. 6935, placed the atoll under the Department of the Navy. From 1934 to 1939 infrequent visits were made to Johnston Atoll by Pacific Fleet units. In the fall of 1939 the Navy awarded a contract for construction of a small naval base. A lagoon seaplane landing area with headquarters on Sand Island was initially constructed (Bauer, 1973). In February 1941, by Executive Order No. 8682, the airspace above and the water within the 3-mile marine boundary were designated as the Johnston Island Naval Airspace Reservation and the Johnston Island Naval Defense Sea Area, respectively, see Appendix B. On August 15, 1941, the Naval Air Station was commissioned. On December 15, 1941, eight days after the attack on Pearl Harbor, Johnston Island was shelled for a short time by Japanese surface vessels. Again on December 21, 22, and 29, 1941 both Johnston and Sand Islands were shelled; one Japanese submarine was reported sunk by American gunfire. There were no injuries to personnel but the shelling caused considerable damage to various facilities. Construction continued until April 1942. Channel approaches and a seaplane landing area were dredged. Other construction included bomb shelters, living quarters, runways, parking aprons, storage sheds and gun emplacements (Bauer, 1973).

(3) During early World War II, patrol submarines used the atoll as a refueling station. By 1944, and throughout the rest of the war, it became a major transport terminal for the Pacific area, servicing aircraft going to and from the Pacific battle fronts (Abend, 1942). After World War II, the Navy continued to operate the Naval Air Station at reduced strength. The status was later reduced to that of a Naval Air Facility. Sand Island was abandoned in 1946. By order of the Secretary of the Navy, operational cortrol of Johnston Atoll was transferred to the U.S. Air Force on July 1, 1948. The Navy retained technical jurisdiction. During the Korean airlift in 1951 and 1952, Johnston Island again assumed major military importance. The airstrip was enlarged by dredging and new buildings and improved utilities were added (Bauer, 1973).

(4) On January 25, 1957, the Treasury Department was granted a permit for the U.S. Coast Guard to operate a LORAN (Long Range Air to Navigation) transmitter on Johnston Island. On September 13, 1957, the Department of Commerce began operation of a Weather Bureau facility on the island. On April 22, 1958 operational control of Johnston Atoll was assumed by the commander of Joint Task Force Seven. As part of Operation Hardtack, two missiles carrying thermonuclear devices were fired from Johnston Island into the stratosphere to obtain information on the effects of nuclear detonations at high altitudes. These were the first megaton devices detonated in the stratosphere by the United States. The Pacific phase of Operation Hardtack lasted until August 19, 1958. Operational control of Johnston was assumed by Joint Task Force Eight and the Atomic Energy Commission on January 17, 1962 for the purpose of conducting additional high-altitude nuclear tests. The Secretary of Defense granted permission on December 10, 1959 to relocate the U.S. Coast Guard LORAN-A and -C Station to Sand Island. Completed in 1961, the U.S. Coast Guard facility presently maintains a staff of approximately 25 men. Sand Island is still a bird sanctuary under the jurisdicition of the Department of Interior (Bauer, 1973).

(5) By August 1960, Air Force retention of Johnston Island seemed assured, and a survey was made to ascertain the scope of work required to restore base facilities to minimum operational condition. Extensive engineering activity continued throughout 1961. Also, during this period the LORAN station on Sand Island and the U.S. Weather Station authorized by JCS Document 1910/10 were finished. Important contracts were let for modification and alteration, airfield pavement repair and emergency runway lighting. Repair of the old distillation system and installation of new equipment was accomplished. Several construction projects continued with a deadline of 15 March 1962, necessitated by 1962 Pacific Atomic Tests (USAF Hist, 1959-1963). Joint Task Force Eight and the Atomic Energy Commission entered into an operational agreement with the Department of the Air Force on 17 January 1962 to take control of Johnston Island. Additionally a memorandum of understanding was executed between Commander, Joint Task Force Eight and Commander in Chief, Pacific Air Forces on 18 January 1962. As part of this agreement, support of both the Coast Guard LORAN Station and the Weather Bureau Station, previously a commitment of Pacific Air Force Base Command, was undertaken by Commander, Joint Task Force Eight. Major construction projects in support of the test series were completed in May 1962; however, numerous minor projects continued throughout the test period. All existing facilities were augmented to the fullest extent possible, but were subject to the limitations imposed by useable estate and available time (Bauer, 1973).

(6) Commander, Joint Task Force Eight proposed in his message 26030Z of October 1962 to the Chairman, JCS, that steps be taken for preservation on the island of certain test assets there and to return operational control of the island to Commander in Chief, Pacific Air Forces providing there were no plans for additional nuclear tests prior to mid-1964. The JCS generally concurred; however, because of plans for possible use of Johnston Island during calendar year 1963, by their message 071837Z of November 1962, requested that the plan be reviewed in light of this development. While this review was being conducted, further direction by JCS message JCS 7654 011648Z of December 1962 was received. It directed Commander, Joint Task Force Eight to retain control of Johnston Island pending further guidance. On 16 January 1963, Commander, Joint Task Force Eight, proposed that the control and support arrangements for Johnston Island be maintained until at least 1 April 1963. Additional plans and guidance for the Task Force were received from the JCS through their Paper SM-373-63 of 19 March 1963. It was clear at this time that the most efficient procedure would be for Commander, Joint Task Force Eight to retain operational control of Johnston Island at least through the completion of the 1964 test plans. The proposal was affirmed by JCS Paper SM-758-63 of 11 June 1963. Later in 1963 the mission and the future of Johnston Atoll were to be guided by the national requirements for possible continuation of nuclear testing in the atmosphere. The significant influence for ratification of the Limited Test Ban Treaty of 1963 was President Kennedy's assurance to Congress that four safeguards would be established and maintained to keep the U.S. from falling behind in nuclear technology. One of the safeguards, Safeguard III, was the development of the ability to resume testing promptly in those environments prohibited by the treaty in the event of Russia's abrogating the treaty or if such test should be deemed essential to national security. Thus, by Safeguard III, the future of Johnston Atoll was established as an overseas nuclear test base. Plans for the 1964 tests were later cancelled; however, CJTF-8 continued to maintain Operations control of Johnston Atoll (until 1970) under the direction of the Director, Defense Atomic Support Agency (DASA), now the Defense Nuclear Agency (DNA) (Bauer, 1973).

(7) During the latter part of 1964 and early 1965, an advanced state of readiness was developed at Johnston Atoll in support of the National Nuclear Test Readiness Program (NNTRP), a prompt response testing program, prepared by both the Atomic Energy Commission (AEC) and DoD (DoD-AEC a., 1965) (DoD-AEC b., 1965) to satisfy the Safeguard III requirement. This readiness posture, which included an extensive building program on Johnston Atoll, was maintained until 1970. Annual exercises conducted by JTF-8, commencing in 1964, evaluated the capability of the AEC and DOD agencies to initiate nuclear testing within specified reaction times. These full scale exercises at Johnston Atoll commenced with Operation Crosscheck in 1964 and continued with Operation Roundup in 1965. Operation Windlass in 1966 and Operation Paddlewheel in 1967 (the last JTF-8 readiness-to-test exercise) included in addition to the previous years activities, a series of coordinated rocket firings from Johnston Atoll. The Department of the Interior approved the title "Johnston Atoll" to be used henceforth and forevermore as a fitting recognition of the importance of the Johnston Island complex and its environs. Further, it was proposed that the two man-made island, created within the surrounding barrier reef, be named Akau and Hikina, Hawaiian words meaning north and east. On 20 May 1965, these names were officially assigned to the two islands. Extensive building of testing and support facilities, including airfield improvements and the installation of the Pacific Missile Range tracking complex, continued during 1965 to 1967. An Air

Force Baker-Nunn space camera station was constructed on Sand Island and was functioning in 1965. It has continued to remain in full operational status. An agreement between AEC and DoD (AEC-DoD, 1971) in 1965 provided the basis for the necessary contractual arrangements for engineering, construction, maintenance, and operations services. The build-up program consisted of laboratories, shops, rocket launch pads, rocket assembly buildings, storage bunkers, control and monitoring facilities, sampling and tracking facilities, photo and optical stations, and weather facilities (AEC-DoD, n.d). A significant portion of the readiness-to-test capability is the THOR launch complex developed by the USAF which was used for launching nuclear payloads during the test series (Dominic/Fishbowl) of 1962. Since then this complex operated by Program 437, a USAF R&D space program, made 15 scheduled THOR launches from 1965 to 1970. Since that time only crew training (operations terminated short of actual launch) continues. Launch crews are provided by the 10th Aerospace Defense Squadron under the control of Aerospace Defense Command. Improvements to the communications system in 1965 included the installation of a submarine telephone cable from Johnston Atoll to Oahu with additional cables connecting Johnston Island to Sand, Akau and Hikina Islands (Bauer, 1973).

(8) During the years of the Vietnam conflict, Johnston Atoll continued to support the flow of air traffic enroute to and returning from Southeast Asia. Formations of tactical aircraft made use of Johnston Atoll's refueling facilities since they were dependent upon enroute stops and/or the use of inflight refueling tankers. Due to increasing demands for additional jet commercial routes to the various Pacific Islands, particularly to the Trust Territories, the Defense Department allowed the Civil Aeronautics Board to authorize commercial aircraft to make refueling stops at Johnston Atoll. This resulted in Air Micronesia service to Johnston Atoll on 17 May 1968 (Bauer, 1973).

(9) In late 1969, national decisions were made to reduce the level of support to the readiness program and to revise the NNTRP. These decisions included the inactivation of JTF-8 and the transfer of operational and funding responsibility for Johnston Atoll to the USAF (AEC-DoD, n.d). Effective 1 July 1970, operational control of Johnston Atoll was transferred to USAF, with continuing readiness planning responsibilities assumed by Director, DNA (Sec Def, 1969). The JTF-8 designator and records were retained by Director, DNA for utilizations as required. Operations and maintenance of Johnston Atoll was assumed by the 6486th Air Base Wing (PACAF), which was renamed the 15th Air Base Wing on 1 November 1971 with no change in mission. The population of Johnston Atoll, which had been approximately 1200, was reduced to approximately 600 by the end of 1970, with about one-half military and one-half civilian contract personnel. The responsibilities of Director, DNA concerning readiness facilities and the siting thereof at Johnston Atoll are defined in Dep Sec Def Memorandum for Director, DNA (Program/Budget, 1969). The relationships and responsibilities for the 15th Air Base Wing (PACAF) and the DNA (JTF-8) at Johnston Atoll concerning readiness matters were delineated in a support agreement (Sec Def b, 1970). Concurrently, the emphasis within the technical and experimental readiness related programs of the AEC and DoD laboratories was shifted to address high altitude phenomenology and effects. A high altitude development test, planned and funded prior to the decision to phase down, was carried forward to execution. In September 1970, the AEC/DNA development test was conducted at Johnston Atoll utilizing a THOR booster mated with an AEC developed non-nuclear high altitude test vehicle (HATV). The successful THOR/HATV launch was conducted by a JTF-8 organization developed for this particular test.

(10) The decision was made during 1970 to remove U.S. chemical munitions from Okinawa; however, their retention as part of the national stockpile was necessary. Political pressure which ultimately resulted in forbidding relocation of these munitions, designated RED HAT, to any point on CONUS or Alaska caused the selection of Johnston Atoll as the storage site. Movement of the RED HAT toxic chemicals (MUSTARD, GB and VX) by ships, from Okinawa to Johnston Atoll, started in early 1971 and was completed in mid-May 1971. On Johnston Atoll they were placed under the custody and control of the U.S. Army 267th Chemical Company. The construction of storage facilities for RED HAT in the southwest quadrant of Johnston Island occupies a 41-acre area. Just prior to movement of the chemical munitions to Johnston Atoll, the Surgeon General, Public Health Service, reviewed the shipment and the Johnston Atoll Storage plans and caused the Secretary of Defense in December 1970 (DNA-PACAF, 1971) to issue instructions restricting missile firings and all aircraft flights to the island except essential military flights to support the island's mission. As a result, Air Micronesia service was immediately discontinued and rocket missile firings suspended (Bauer, 1973). Again, early in 1972, another politically unpopular problem arose with the phasing down of the Vietnam conflict which necessitated the movement of herbicide Orange (a USAF defoliant spraying mixture)from Vietnam. As a result of Congressional and citizen interest in disposal problems, the Department of Defense (DoD) decided to move one and one-half million gallons (26,300 55-gallon drums) to Johnston Atoll for storage to await a means of future disposal. By April 1972, herbicide Orange was in storage at Johnston Atoll (Sec Def a, 1970) on the southwest peninsula. As a result of a DNA Joint Hazards Evaluation Group study (DNA, 1972) conducted in July 1972, concerning the hazards to both transient and island personnel from commercial aircraft use imposed by the storage of RED HAT, the commercial flight restrictions to Johnston Atoll were conditionally lifted. Air Micronesia was allowed to resume air service to Johnston Atoll on 29 April 1973.

(11) During mid-August 1972, a tropical storm, Celeste, located southeast of the Hawaiian Island, had blossomed into a full scale hurricane. Observation of Celeste's track for several days, it became apparent that Johnston ATоll woul be in the path of the hurricane. The decision was made to evacuate the island and by 18 August all personnel had been flown to Hickam AFB, HI. This was the first known time the island had been completely evacuated of personnel since the Navy commenced its construction program in 1939. On 19 August, Celeste struck Johnston Atoll at approximately 1400 hours local time. The atoll was subjected to sustained winds of 100 knots with gusts up to 130 knots. The heavy surf primarily affected the north, northeast, and south sides of the island. On 22 August a seaborne cadre, consisting of an Army RED HAT checkout team and an Air Force/H&N team, were put ashore at Johnston Atoll from the Navy destroyer USS Lloyd Thomas to initiate restoration of life support activities (Bauer, 1973).

(12) In June 1973, the Deputy Secretary of Defense approved a USAF plan for the transfer of host manager responsibility of Johnston Atoll to DNA which was formulated into a joint USAF/DNA agreement (Joint Hazards, 1972) with an effective date of transfer of 1 July 1973 (DAF-DNA, 1973).

(13) Remaining still in effect, down through the years, is the executive order which origianlly designated Johnston Atoll a bird sanctuary. The bird scene today, principally at Sand Island, shows little if any effect by the numerous activities which the atoll has been committed to during its years of development.

(14) A summary of ownership and control of Johnston Atoll is shown in Table H-1.

(15) Through the past decade Johnston Atoll (environment, flora, fauna) has been the subject of numerous studies and surveys. Periodically, the Smithsonian Institution has investigated the bird life of Sand Island (bird sanctuary), its most recent effort being in 1969 when a research biologist spent several months there. Earlier studies commenced in 1963 (Bauer, 1973) by the Hawaii Marine Laboratory of the University of Hawaii, to investigate the effects on marine growth from the extensive dredging and buildup of the atoll, have continued to this day. A land management plan (Support Agreement, 1973), prepared at the request of CJTF-8 in 1964, was used as a guide for developing plant life on the atoll and for control of erosion from wind and water. Surveys conducted in 1965 for the Naval Oceanographic Office (DNA-AEC, 1973) obtained detailed information about the water flow regime around the island. Another environmental program, continuous since 1966 by the Laboratory of Radiation Ecology, College of Fisheries, University of Washington, has been to obtain information for predicting and evaluating the biological consequences of a possible nuclear test series at Johnston Atoll. Reports on this program are submitted to the AEC annually.

(16) As a result of Executive Order numbers 4467 and 6935 and their effect on the possible disposal of herbicide Orange on Johnston Island, the opinion of the General Counsel, Department of the Air Force, was requested.

b. Location and Size (Land Surface)

(1) Located at latitude 16 degrees 45 minutes north and longitude 169 degrees 30 minutes west, Johnston Atoll is one of the most isolated atolls in the Pacific. The closest reef is French Frigate Shoals, approximately 450 miles to the north. Honolulu, Hawaii is approximately 717 miles to the northeast, while the nearest land to the southeast is Palmyra Island, about 750 miles away. The Marshall Island Group is the closest land mass to the west at a distance of about 1,300 miles, see Figures H-1 and H-2 (POBSP, 1964) (Thorp, 1960)(Navy Hydro a, 1959 and Navy Hydro b, 1959).

(2) Johnston Atoll consists of a pair of low sand and coral islands, Johnston and Sand Islands, plus two entirely man-made islets, Akau (North) and Hikina (East) Islands within a shallow lagoon partially enclosed by a semicircular reef to the north and west. The southern and eastern portions of the fringing reef, however, are made up of numerous discrete fragments spread over a large area to the south and east of the main lagoon. If one uses the 4-fathom line as indicating the outer boundaries of the atoll, Johnston Atoll has a circumference of somewhat more than 21 miles. This particular depth was used since it apparently correlates almost exactly with the outer limits of the exposed reefs, with the line lying only a few yards to the seaward of the most southerly of the reefs. The atoll is roughly lens-shaped, with the long axis running on

TABLE H-1

OWNERSHIP AND CONTROL OF JOHNSTON ATOLL

Period	"Owner"	Operational Control	Purpose of Document	Authority	Event/Use
1923	Dept of Agriculture	Agriculture	Plant and sealife surveys.	*Executive Order 4467	Bird refuge (Executive Order June 29, 1926)
1934	Dept of the Navy	USN	Pacific defense	*Executive Order 6935	
1941	" " " "	USN	Established Naval Defense Sea Area for military sea and air operations	*Executive Order 8682	Became Johnston Island Naval Air Station
1944	" " " "	USN	---	---	Defense of area; Air Transport Command operations; Oceanic Air Traffic Control
1947	" " " "	USN	---	Secretary of the Navy	Became a Naval Air Facility
1948 Jul 1	" " " "	USAF	Transfer of operational control to USAF	Agreement	Pacific Air Command (MATS, ARS, AACS, AWS Dets) (SecNav ordered transfer to USAF)
1949 Jun 1	" " " "	USAF	---	---	Pacific Air Command inactivated; Pacific Division MATS took over.

*Executive Orders are still in effect; have not been amended or rescinded so as to affect "ownership."

TABLE H-1 (Cont'd)

Period	"Owner"	Operational Control	Purpose of Document	Authority	Event/Use
1951-52	Dept of the Navy	USAF	---	---	Korean airlift support
1957 Jan 25	" " " "	USAF	---	---	USAF granted Treasury Department five year use for USCG Loran Station
1957 Sep 13	" " " "	USAF	---	---	USAF granted Department of Commerce five year use for U. S. Weather Bureau
1958 Apr 22	" " " "	CJTF-7	---	Agreement	Atomic tests in Pacific area until August 19, 1958; then roll-up.
1959 Jul 24	" " " "	USAF	---	---	Formal meeting in Hawaii to propose transfer of operational control to Army for the Nike-Zeus test program.
1959 Sep 23	" " " "	USAF	To transfer operational control to Army	---	Proposed agreement sent to higher headquarters
1959 Jun 30	" " " "	USAF	---	---	Secretary of the Treasury asked Secretary of Defense for Sand Island as Loran Station, to be under operational control of Commander in Chief, Pacific.

TABLE H-1 (Cont'd)

Period	"Owner	Operational Control	Purpose of Document	Authority	Event/Use
1962 Jan 17	Dept of the Navy	CTJF-8/AEC	---	Agreement	USAF signed Operations Agreement for 1962 nuclear tests.
1962 Jan 18	" " " "	CJTF-8/AEC	---	Agreement	Commander in Chief, Pacific signed agreement with Commander Joint Task Force EIGHT.
1963 Jun 11	" " " "	CJTF-8/AEC	---	---	Joint Chiefs of Staff reaffirmed operation control of Joint Task Force EIGHT.
1970 Jul 1	" " " "	USAF	Transfer of operational control to USAF	---	JTF-8 inactivated. Deputy Secretary of Defense Memorandum to Secretary of Air Force for transfer of JA to USAF
1973 Jul 1	" " " "	DNA (FCDNA)	Transfer of operational control to DNA	Agreement	Department of the Air Force signed agreement with Defense Nuclear Agency

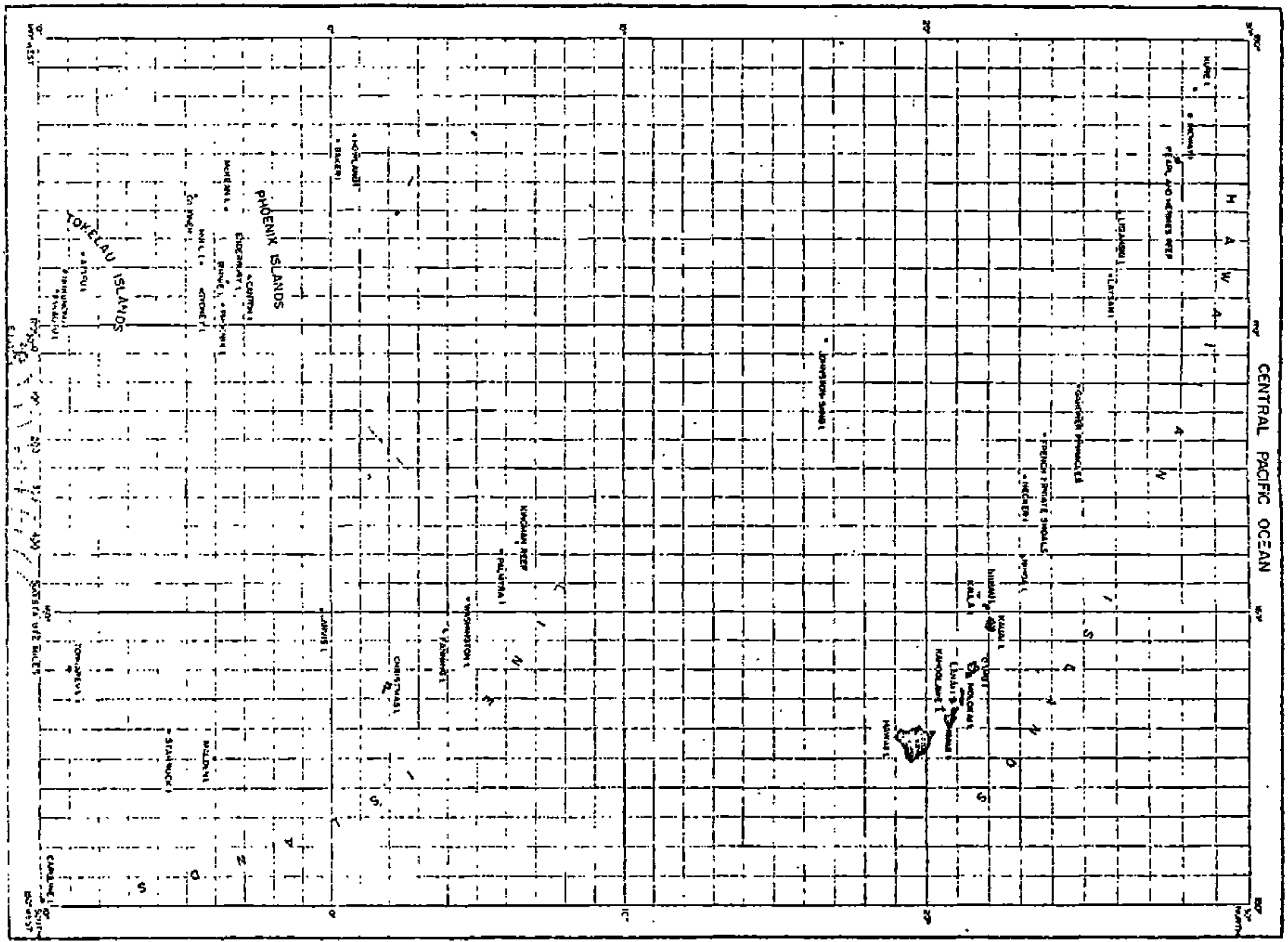


FIGURE H-1 TAKEN FROM THE PRELIMINARY BIOLOGICAL SURVEY OF SAND ISLAND - JOHNSTON ATOLL (POBSP, 1964)

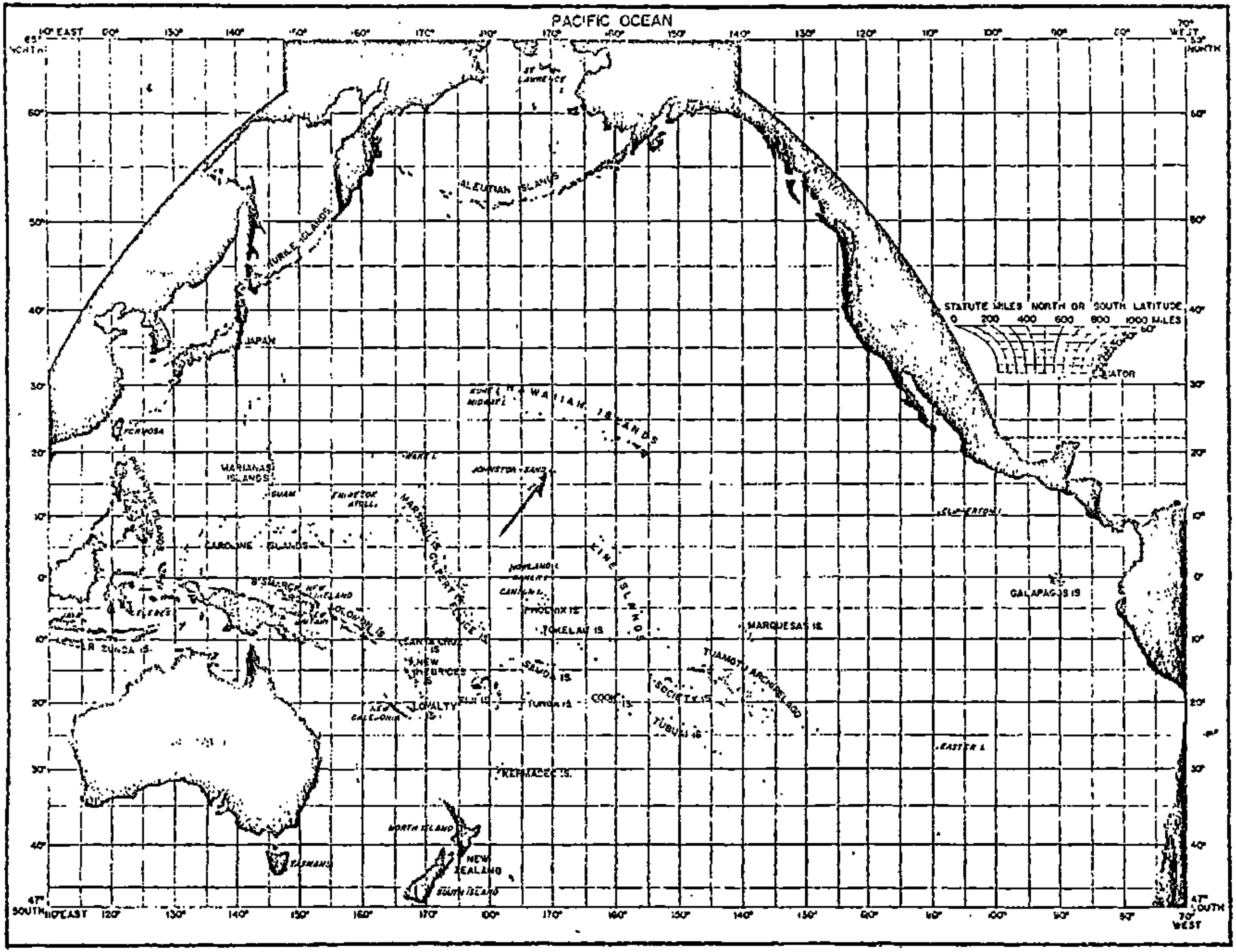


FIGURE H-2 MAP OF PACIFIC OCEAN

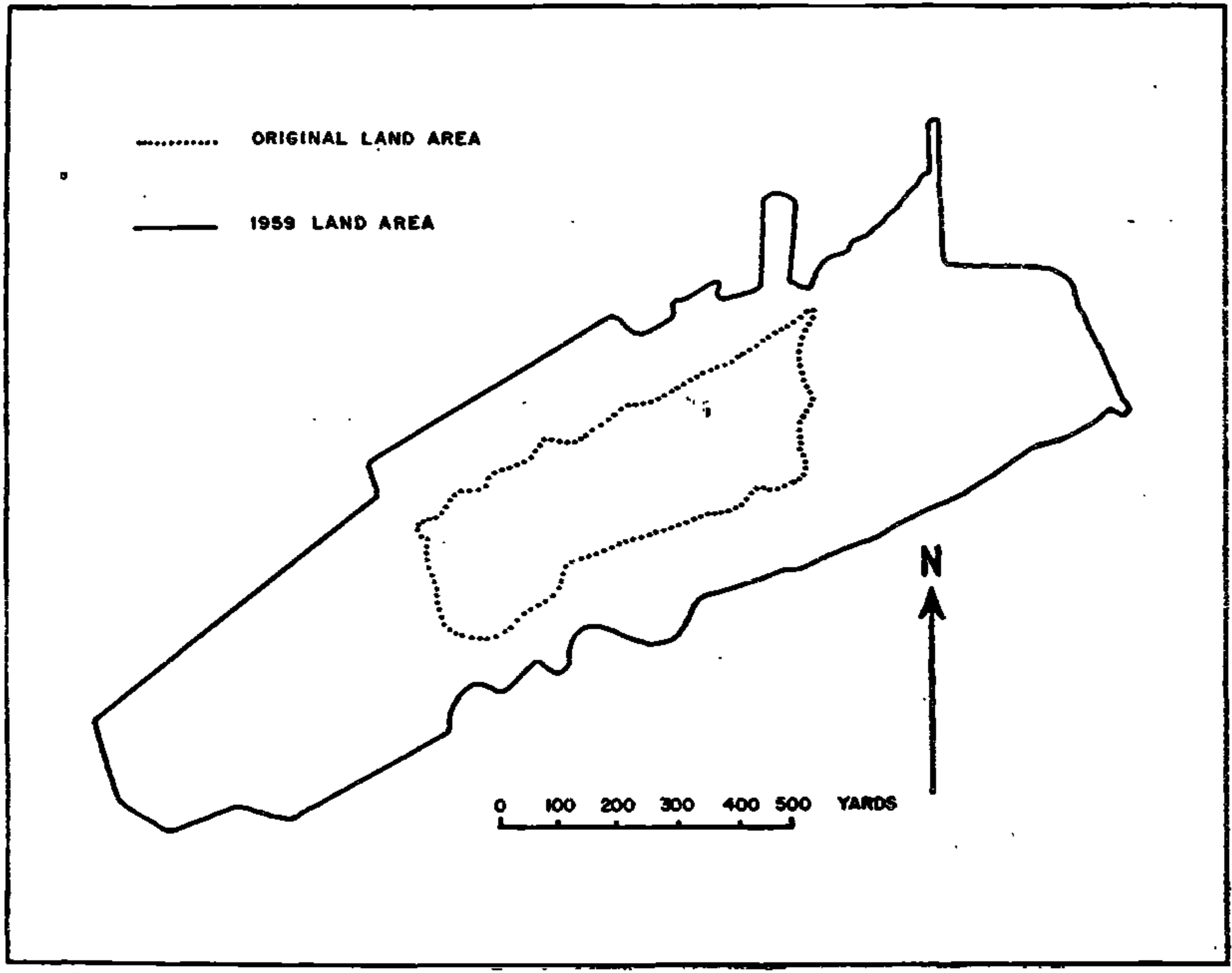


FIGURE II-3 CHANGES IN THE LAND AREA OF JOHNSTON ISLAND (Bryan, 1942) (Navy Hydro a, 1959)

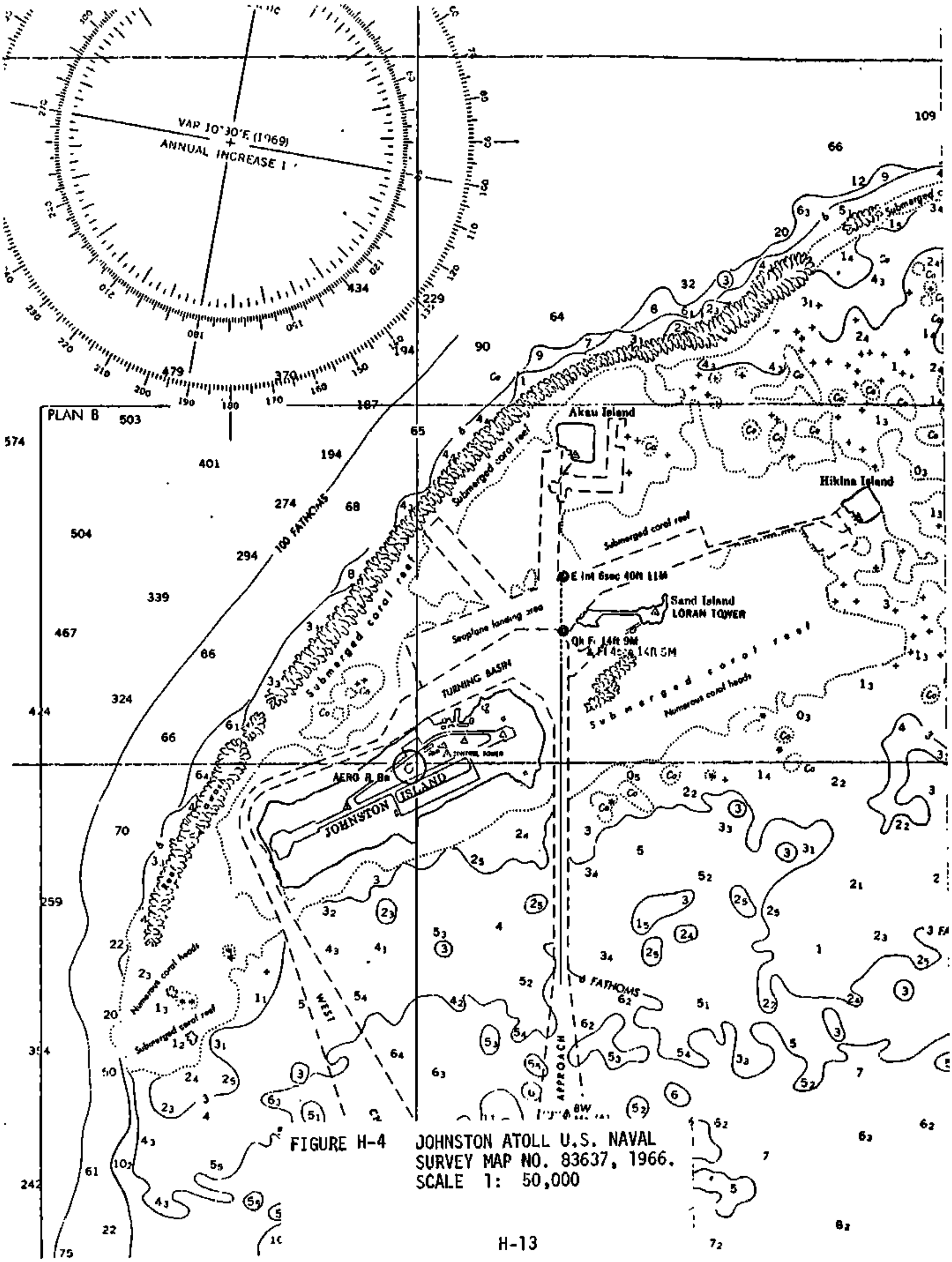


FIGURE H-4 JOHNSTON ATOLL U.S. NAVAL SURVEY MAP NO. 83637, 1966. SCALE 1: 50,000 a line almost exactly northeast to southwest (POBSP, 1964). Johnston Island, the larger of the two island, has had its area considerably modified by human activity. Figure H-3 reveals the original area of Johnston Island with the area in 1959. Originally the island was 2,850 feet long at its greatest extent. The width of the island varied from 500 to 800 feet. The original area of the island was about 40 acres or 0.06 square mile (Emery, 1956). Since 1949, however, Johnston Island has been more than tripled in size, as the lagoon was dredged with new land fills being developed at the periphery. At present (1959) the long axis of the island stretches 6,150 feet, with a greatest width of about 1,500 feet at the center of the island near the airstrip control tower. The total area of Johnston Island in August 1959, was about 0.33 square mile. None of the original shore line remains, and the addition of fill all around the original island has tended to produce an artifically smooth shore line except in the northeastern quarter where the quays and piers of the harbor area jut into the lagoon. The original rectangular orientation of Johnston has been retained, however, except for this northeastern portion of the island, see Table H-2 (Thorp, 1960)(Navy Hydro a, 1959)(Navy Hydro b, 1959). The following table depicts the major changes in the Johnston Atoll acreage as a result of the dredge and fill programs:

TABLE H-2 JOHNSTON ISLAND ACREAGE

	Acreage	
	1963	1973
Johnston and Sand	198	648
North (Akau)	0	25
East (Hikina)	0	18
TOTAL	198	691

(3) Sand Island (originally known as Agnes Island) is a small coral islet located 1,900 yards to the northeast of Johnston Island. It is roughly triangular in shape, and has not been greatly modified by man in its outline. The dimensions of Sand Island are about 600 feet by 1,500 feet, with an area of about 10 acres or about 0.016 square mile. A causeway has been built which runs about 500 yards west from Sand Island to a fill area of several acres which is adjacent to the seaplane landing area in the lagoon. The causeway, the fill area, and the original islet are locally thought of as being one unit, and "Sand Island" is used as a designation for the entire complex. Johnston Island is located a bit southwest of the center of the atoll. It is more than a mile south of the northern barrier reef, while almost abutting the first of the southern reefs. Sand Island is nearly at the center of the long axis of the atoll, but it is more than 2-1/2 miles south of the main barrier reef, while at the same time about 1-1/4 miles to the north of the first southern reefs, see Figure H-4 (Thorp, 1960).

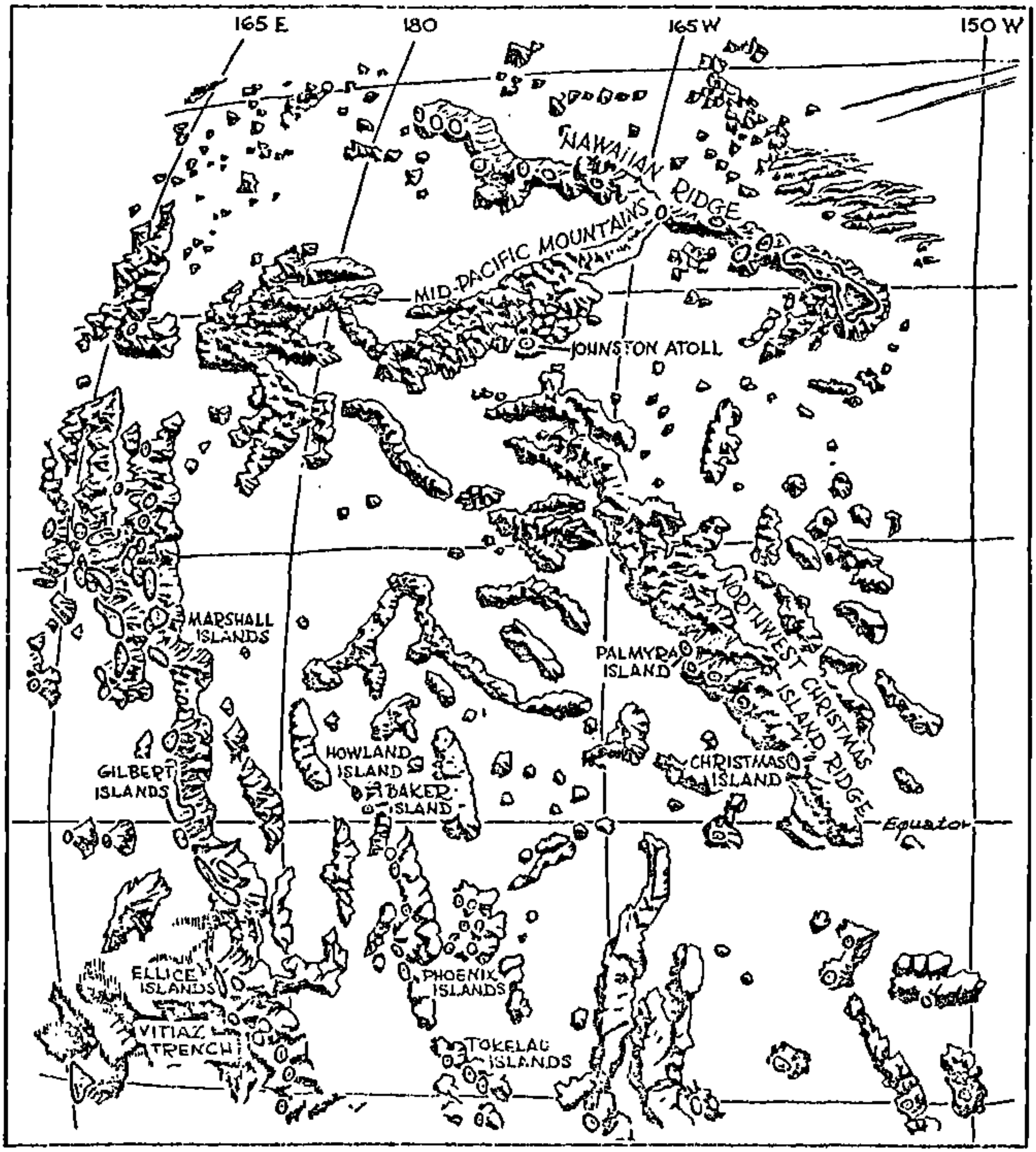


FIGURE H-5. CENTRAL PACIFIC SUBMERGED MOUNTAIN RANGES (POBSP, 1964)

c. Geology

(1) The original surface of Johnston Island was a mixture of sand, coral, and coral-derived rocks. The island rose from the southern beaches northward to a continuous sandy ridge (of an average height from 8 to 10 feet) extending along the northside of the island from end to end. This range connected Summit Peak, at the eastern end of Johnston Island, with an unnamed height of 13 feet at the western end of the island. Summit Peak, with an elevation of 44 feet, was the highest point in the atoll. At present the average height of the island is under eight feet, since both ridges and the two hills were leveled during the heavy construction which started in 1940 and changed the outline and surface of the island. Sand Island had no original height greater than eight feet, but it too has been leveled, since even a small relative relief such as that encountered on these two islands may produce a fairly rough and hummocky topography when the base material is sand under constant agitation by the prevailing winds (POBSP, 1964) (Thorp, 1960).

(2) The Central Pacific Ocean is dotted with a number of island groups, most of which are products of coral construction on worn-off volcanic upheavals. The Hawaiian Ridge stretches for a distance of some 1500 nautical miles from 20° N at 155°W to 30°N. The Mid-Pacific mountains intercept this chain from the west but support only one small coral atoll, namely Johnston Atoll. South of the Hawaiian Ridge and Johnston Atoll are located the Line Islands, also known as the Northwest Christmas Island Ridge and the Phoenix Islands, see Figure H -5. There is indirect evidence that Johnston Atoll is intermediate in age between the Line and Hawaiian Islands, rather than between the older Mid-Pacific Mountains and the Line Islands, between which Johnston Atoll lies physically (Thorp, 1960). If this is the case, then Johnston Atoll probably has existed for slightly more than the 24-million years which is thought to be the minimum age of the Hawaiian Islands, or somewhat less than the 60 to 70-million years since the Mesozoic-Cenozoic boundary when the Line Islands were thought to have formed. If, however, Johnston is more closely allied geologically with the Mid-Pacific Mountains, it could be older, perhaps dating from the middle Cretaceous Age or approximately 100-million years ago (Amerson, 1973). Ashmore (1973) considers Johnston Atoll as a northernmost extension of the Christmas Ridge and suggests that "the terraces at Johnston Atoll probably were formed with falling sea levels at the end of the Sangamon Interglacial, or with rising levels at the end of the Wisconsin Glaciation..." If the terraces formed at the end of the Sangamon Interglacial Age they have been exposed to approximately 65,000 years of subaerial weathering and erosion. The terraces.... appear to be much too well preserved to have withstood erosion and solution for that length of time. A more recent formation would seem indicated. If the possibility of Wisconsin interstadials is neglected the time of formation would be within the last 10 to 12 thousand years, Holocene period. Ashmore (1973) believes that the tilting hypothesis explains the northwestern reef and the submerged rim, but fails to explain many of the other atoll features. He favors a sea-level-change, which assumes that lowered sea levels during some glacial period allowed portions of the original atoll to be removed. He presents evidence that this hypothesis accounts for the -60 foot terrace and -30 foot level with its sinkholes. He does acknowledge the possibility of a combination of the tilting and sea-level-change hypothesis to explain the present day configuration of the atoll.

(3) The surface of Johnston Island is mainly coral sand, with an admixture of fine coral fragments. The original shoreline of the island had several outcrops of massive beach rock. The beach rock occurred especially on the northwestern tip of the island and on the south central shore. These outcrops have been covered over by the fill which was used to expand the area of the island. However, beach rock of the same type may still be seen in some places around the shore of the island. The beach rock is composed of coral sand and coral gravel loosely cemented together by calcium carbonate. Originally it was exposed in the form of smooth platforms, but with age, its surface has been eroded biochemically to form a series of irregular solution basins and smooth water-level terraces (Thorp, 1960). Records from the Corps of Engineers have been kept of 56 borings, with a maximum depth of 36 feet, that were made for the heavy construction foundations of 12 buildings on the central and northeastern parts of Johnston Island. In addition, drill logs were kept of six deep wells which ranged from 86 to 191 feet below mean sea level. In general, a fairly thin layer (or layers) of beach rock was found a few feet below the surface under a pure sand layer. Below this sandstone (or beach rock layer) was another area of pure sand alternating with sand mixed with coral fragments. These layers ranged from 10 to 50 feet in thickness and were usually followed by the solid coral bedrock of the island which extends below drilling depths. In view of the results obtained from deep drilling on other low islands in the Pacific, it seems probable to assume that the noncalcareous bedrock may be encountered as deep as 700 to 1,000 feet (Thorp, 1960). Under parts of the island there is apparently a narrow second layer of beach rock, according to the recordings in the drill logs. In 18 of the holes, the driller hit beach rock which was between 1 and 2½ feet above mean low water, and which extended to an average of 0.7 foot below mean low water. This strata apparently correlated with the beach rock still exposed on Sand Island. It is thought that the upper layer may be correlated with the widespread occurrence of beach rock in the wave-washed zone between high and low tides on most of the low coral islands of the Pacific. The origin of the deeper layer is more complex, but samples of beach rock were collected eight feet below sea level along the bases of the fragmented reef which extends from Johnston Island to Sand Island. Emery (1956) hypothesized that the unusual straightness of the patch reefs is the result of the various types of coralline algae atop the outcropping edges of this recently submerged beach rock. The deeper parts of the wells show alternating sand, loose coral, and sand and coral with no possibility of correlation from well to well. There were several small inclusions of mud in the wells from unknown origns.

(4) There is no noncalcareous rock found on Johnston Island other than that brought by man, with the exception of pumice stone found on the beaches and one erratic piece of fine-grained rhyolite about 10 inches in diameter which was found in situ in the beach rock on Sand Island. The pumice which floated onto the beaches, especially in 1953, was thought to have come from the volcanic eruptions at San Benedicto Island near Mexico. Emery (1955) stated that this was probably the result of driftwood transport, since large individual pieces such as this one could be more readily carried by floating trees than by other plants or animals, while transport by icebergs or kelp is ruled out by the tropical location. The coral bedrock weathers down to a fairly coarse-grained white sand. There is no solid soil cover on Johnston Island, nor was any reported prior to the alterations of the environment by man. Since, as noted above, bedrock does not crop out on the surface of the two islets, it is necessary to build foundations to extra depths for any buildings which have a heavy bearing load.

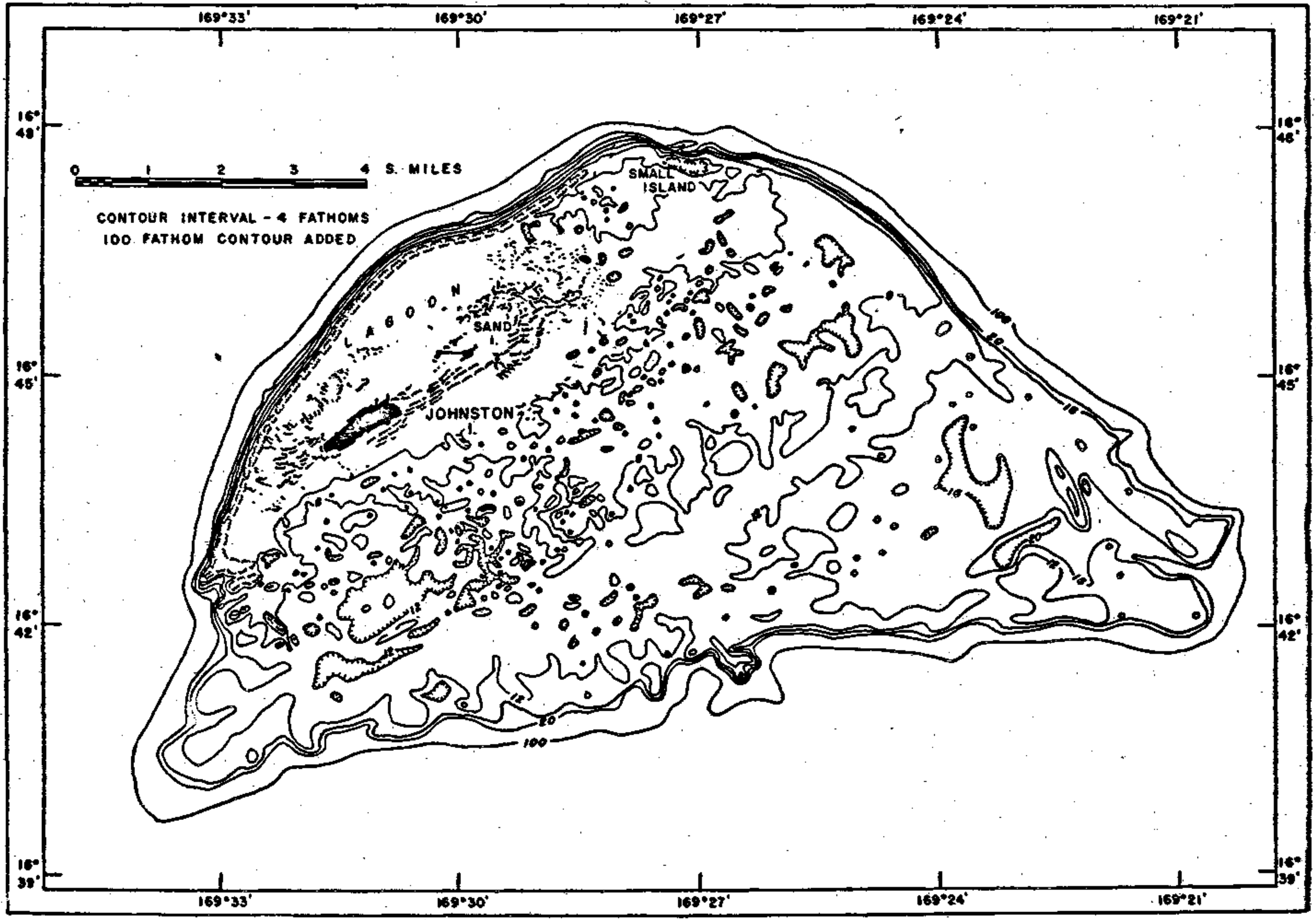
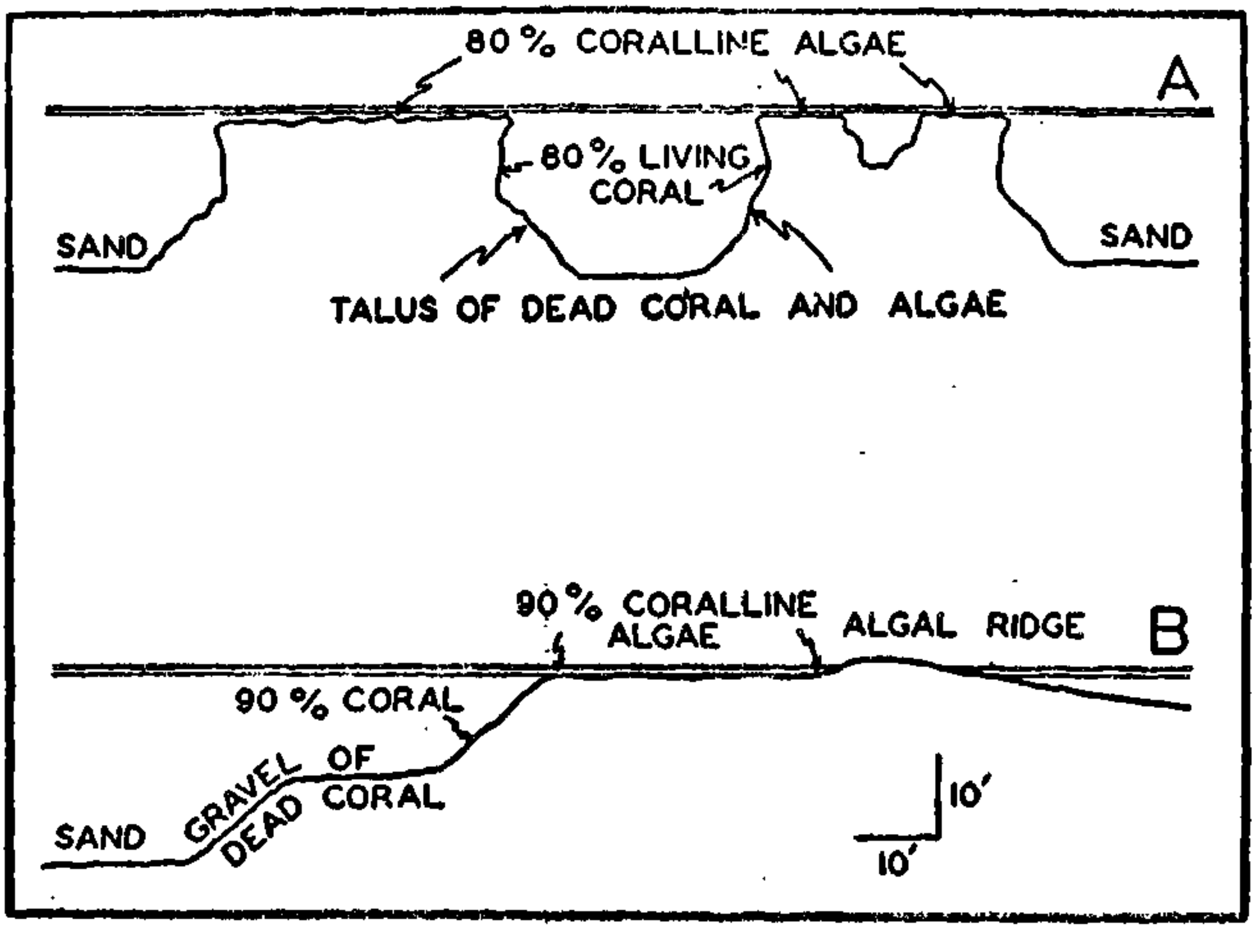


FIGURE H-6. JOHNSTON ATOLL SHOWING REEFS AND DEPTHS (AFTER EMERY, 1955)

The 56 borings for foundation piers (mentioned previously) averaged 10 feet in depth, of which the extreme depth was 36 feet. Another difficulty encountered in heavy construction work results from the porosity and toughness of the coral, which makes it hard to remove in large quantities either by blasting or bulldozing.

(5) The original shore lines of Johnston and Sand Islands were about evenly divided between sandy beaches and exposed coral formations which were usually the "beach rock." The beaches were between 50 feet and 100 feet wide generally, and they had a sand or beach rock cover. But they have all been modified, except for parts of Sand Island, with the result that the present shore lines tend to end abruptly in the water with little or no beach remaining (Thorp,1960). It is estimated that the total area of these reefs which are exposed at low tide is about two square miles, but because of the numerous small patch reefs no exact measurements have ever been made. If it were necessary to compute their area, an air photo taken at low tide could provide a fairly accurate base from which to compute the total expanse of reef exposed. Probably more than one-half of the total area of reef which lies above sea level at slack water is in the main northwestern reef, which forms an arc almost 11 miles long if one includes the break of about one mile near the northeastern end of the reef and its northeastern outlier which continues for another half mile. This latter section of reef is known locally as Small Island, although this name does not appear on the official charts.

(6) The depth in the shallow "lagoon" area to the south of the main reef ranges from 3 to 40 feet. It is in this area that the elongated and subcircular patch reefs attain their greatest concentration. To the south of Johnston Island these patch reefs serve to define the southeastern boundaries of the lagoon area (Thorp, 1960). Profiles of the two reef types are shown in Figure H -7. The main outer reef has a gentle slope to the seaward (at least for the first few hundred feet) cut by narrow surge channels. An algal ridge forms the outer edge of the reef about one to three feet above mean sea level. However, this area is periodically inundated by waves or high tides especially during storms. On the lagoon side, there is a reef flat from 100 to 500 feet wide composed chiefly of coralline algae and small corals of various species. This reef flat has numerous potholes and narrow channels left behind as the reef migrated seaward. The lagoon edge of the reef is a fairly steep slope consisting of mainly living coral to a depth of about 15 feet. Below this, dead coral and fragments of dead coral ("coral gravel") form a more gentle slope to the fairly flat sand bottom which reaches its greatest development at from 20 to 25 feet below the surface. This flat expanse of bottom is broken repeatedly by coral heads, a few yards in diameter, which rise just as abruptly but may be several hundred feet long. Characteristically, these patch reefs are topped by an irregular, overhanging surface of coralline algae just below the low-tide level. On the sides and locally are irregular masses of branching coral, mostly composed of different species of Acropora. The lower slopes are mainly a talus of loose pieces of dark dead coral and coralline algae which extends to the sandy bottom at about a 45 angle. There were no natural bays or harbors at Johnston Atoll, since none of the entrances into the lagoon area originally had a safe depth of more than three or four feet. There were no features on the interior of either Johnston Island or Sand Island.



A.—Isolated patch reef about 1 mile northwest of Johnston Island.
B.—Outer reef at Small Island.

FIGURE H-7. PROFILES OF TWO REEF TYPES (EMERY, 1955)

(7) Topography appears to be no particular problem for the installation of any type of equipment which does not require a large area. At the present time most of the surface of Johnston Island is completely utilized by existing facilities. It is necessary to spend considerable time in the construction of foundations because of the shift from sand to bedrock, and any underground installations required special water-proofing treatment because of the high water table and the permeability of the porous coral bedrock.

d. Hydrography

(1) There are no natural permanent freshwater bodies on Johnston Atoll. This lack of surface water is primarily due to the coarse texture and extreme permeability of the coral sand and rubble which make up the first few feet of the regolith, as well as to the porous nature of the coral bedrock. Other factors contributing to the absence of any fresh water on Johnston Island are the small size of the land area, the geographic location and the narrowness of the two islets as compared to the total length (Thorp, 1960).

(2) The lagoon inside the main atoll is about 14,000 yards long at its axis, which runs southwest from Small Island through the centre of both Sand and Johnston Islands. At its widest point, just east of Sand Island, the lagoon extends about 3,500 yards from northwest to southeast. West of Johnston Island the lagoon narrows to a few hundred yards in width before coming almost to a point at the extreme southwestern corner of the atoll. East of Sand Island, as mentioned above, the boundaries of the lagoon are indistinct, as the main reef breaks down into an intricate series of linear reefs and numerous isolated patch reefs, which are usually awash at high water. The total area of the lagoon within the reef is approximately 13 square statute miles. An exact measurement is impossible unless one uses a depth curve for the boundary of the lagoon because of the difficulty of measuring the exact line of demarcation between the lagoon proper and the extensive coral flats which form the southeastern part of the atoll (Thorp, 1960) (Navy Hydro a, 1959) (Navy Hydro b, 1959). The natural depths within the lagoon (except for the dredged portions) vary from a few inches to about 40 feet, because of the presence of coral heads and patch reefs. The greatest area lies between 15 and 25 feet underwater at mean sea level. At the extreme northeastern corner of the lagoon, south of the opening between the main reef and Small Island, there is an area of deeper water in which average depths of more than 40 feet have been reported, but the bottom still has many irregularities and numerous coral heads which almost broach the surface. Artificial dredging in the lagoon has left the seaplane landing area with a depth of eight feet cleared of obstructions, while the harbor and the entrance channel were originally dredged to 23 feet and have been swept to 14-1/2 feet (Thorp, 1960).

e. Tides and Currents

(1) The tidal range at Johnston Island, in common with other mid-Pacific islands, is relatively small, and the effects of the tides upon the atoll are correspondingly minor. The absolute tidal range during the year (the difference between the lowest and highest tides of the year) is only 3.4 feet. The lowest low is minus 0.5 foot in June, while the highest high is plus 2.9 feet, also in June. The mean spring high tides are plus 2.2 feet while the mean spring low tides are minus 0.2 foot. The mean neap tides are plus 1.6 feet, while the mean neap low tides are plus 0.4 foot (Thorp, 1960) (Navy Hydro, 1959) (Wennekens, 1969). The time of the tidal crests and troughs is only slightly later than those of Honolulu, the nearest point for which a full tide table is available. High tides are 29 minutes later at Johnston Island than at Honolulu, while the low tides are 23 minutes later. The high-water interval from full tide to the change of tide is three hours and 15 minutes. Inside the lagoon, the tides have a range only slightly less than in the open waters outside the lagoon, since the structure of the reefs permit water to flow through them as well as over them. The permeability of the coral bedrock is shown by the fact that the water level in all six of the deep wells on Johnston Island rises and falls with the tides (Thorp, 1960) (Wennekens, 1969).

(2) Ocean currents in the vicinity of Johnston Island run from the east to the west at a speed of about 1/2 knot or from 10 to 15 miles per day. Johnston Island is approximately in the center of the North Equatorial Current which extends in breadth several hundred miles both to the north and to the south of the island and has a fairly constant velocity. The tidal currents at Johnston Island, within the lagoon, show a variation. The normal current flows with average velocities of 1/2 knot to the northwest. However, usually for a short time at high tide the current flows at one knot to the southeast. According to Emery (1955) the current pattern influences the distribution of sand to the south of the lagoon: "These patch reefs block the current, causing the sand to be deposited against the currentward side and leaving a depression where the water speeds through the gaps between the patch reefs. Examination of several such areas showed depths in the gaps to be about half a fathom deeper and floored with coarser sediment than that of the adjoining areas."

(3) The underwater platform on which Johnston Island is located is similar to those connected with many Pacific atolls. Like most other low islands in the Pacific the main outer reef has a typical cross section, which includes surge channels, an algal ridge, and a reef flat, with coral heads rising abruptly in the deeper waters to the south and east of the main reefs. Between 16 and 100 fathoms the outer slope is quite steep, usually less than one-half mile in linear distance, with an average slope of 19°. The platform on which Johnston Atoll rests stops fairly abruptly at about the 16 fathom line at most points around the circumference of the atoll as the bottom begins to slope steeply down (Thorp, 1960) (Navy Hydro b, 1959) (Wennekens, 1969).

(4) The shallow lagoon area and its bordering reefs together form roughly the northwester quarter of the triangular-shaped platform on which the atoll rests. At the deeper eastern end of the platform the submerged contours suggest the outline of earlier peripheral reefs. It has been suggested by Emery (1955) that some early reefs may have been submerged as a result of the tilting of the whole base structure of the atoll to the southeast. Since the reef-forming corals grow slowly, and since they will not grow at all in water

below approximately 25 fathoms, a fairly rapid tilting might "drown" the coral ridges faster than they could build up. The main difference between Johnston Atoll and other Pacific islands is the lack of continuous reef around the atoll. The main outer reef extends around less than one-fourth of the circumference of the platform. In addition, there is an extensive zone of shallows to the south of the main reef which is also an unusual feature. As noted previously, it is this zone of shallows which contains most of the patch reefs, Johnston and Sand Islands and the two islets which make up the land area of Johnston Atoll. This suggested tilting of the whole atoll would account for this area of shallows to the northwest, since this area of the atoll would be raised as the opposite side, and most of the main reef sank. This theory has been moderately received, with the result that Johnston is considered one of the "raised" atolls, even though it does not have the typical outward features of one (cliffed beaches, dry center depression, comparatively good water supply, etc.) (Thorp, 1960) (Ashmore, 1973). An alternate theory, which would account for the unusual reef formation at Johnston Atoll is the early removal of the windward reef by wave erosion, is not generally accepted. According to this theory the original outer ridge to the east was the most exposed to waves and hence eroded away, probably at some time when a climatic change or a lowering in sea level had temporarily halted the growth of the reef. The main objection to this theory is the fact that, today, the most vigorous growth of a reef is to be found on the side of an atoll because the agitation of the water provides a greater supply of nutrients for the coral-buildings organisms. It would seem that a temporary interruption in reef building would be compensated for, once conditions reverted to normal (Ashmore, 1973). It has been hypothesized that Johnston Atoll may be structurally related to the Line Islands (Christmas Island, Palmyra Island, Jarvis Island, etc.). Although they are mainly raised islands also, this theory has yet to receive any confirmation (Emery, 1956).

(5) The waters around Johnston Island have not been completely surveyed, but the deepest point on H.O. Chart 5356 (Navy Hydro a, 1959) is 1,051 fathoms, which is located about 14 nautical miles southeast of the center of Johnston Island and about five miles south of the 100-fathom line. This indicates a descent of one foot in every 4-1/2 feet horizontally.

(6) The Japanese word "tsunami" is the term used to describe long gravity waves in the central and western Pacific Ocean areas. These waves are more commonly known as tidal or seismic waves and are caused by submarine earthquakes, landslides and plutonic activity and spread annularly from an epicenter. They are "shallow water waves," i.e., a wave in which the length of the wave is long when compared to the water depth. The velocity of the Pacific Tsunami ranges between 375 and 490 nautical miles per hour. The Tsunami Research Center of ESSA and the Institute of Geophysics of the University of Hawaii maintain historical records of tsunami events in the Pacific. The largest amplitude wave recorded appears to have been about 3.4 feet as a result of the Chilean earthquake generated tsunami on May 23-24, 1960. The second highest, slightly over three feet, followed the Alaskan earthquake of March 28-29, 1964. Past records reveal that the crest of a tsunami at Johnston Atoll resembles a progressive rise in sea level with the maximum depth being reached in about 25 to 30 minutes. The period of tsunami waves at Johnston Atoll is between 45 and 60 minutes. "Historical records indicate that, so far, no large breaking waves or bases have been experienced at the island from a tsunami."

The steep off-shore slope does not enhance incoming tsunami waves and the island is partially protected by an awash fringing reef along the western and northern periphery and by numerous coral patches scattered along the southern and eastern sectors of the island platform. "Historical records and the analysis of certain unusual environmental factors indicate that the effects of a tsunami at Johnston Island should be minimal, consisting of transient rise in water levels, occasional breakers to higher than normal levels, and local flooding of low areas. Backup of water in storm sewers and drainage ditches can be expected, and some erosion of the fill material can take place when the water drains out..." (Wennekens, 1969). Past history indicates that no large breaking wave is likely to occur on the island.

f. Climatology

(1) Climate

(a) The climate of Johnston Atoll is marine and tropical in nature. Weather records are available from about 1931; however, standardized data are available only since 1952. These latter records show a climate with little variation in temperature and wind speed, but great variability in rainfall. Weather data are from Joint Task Force Seven (1959), U.S. Dept of Commerce (1972), and Shelton (ms. in prep), USAF Environmental Technical Applications Center Report 7057. Because Johnston Atoll has a maximum elevation of less than 10 feet, a land area of about one square mile, and is surrounded by shallow waters in all directions, there is little difference in climate conditions from one part of the atoll to another (Amerson, 1973).

(b) Johnston Island is under the influence of tradewind weather 98% of the time. The normal weather during this period is scattered to broken Cumulus bases normally 2000 ft, tops 7000 to 9000 ft. Scattered showers in the area will occasionally drift over the island causing light precipitation to fall. This can be expected any time during the day or night as there is no apparent diurnal variation in the showers. Occasionally cloud tops will build to 11,000 feet, seldom exceeding 15,000 feet due to easterly perturbations in the area. Scattered Altostratus are in the area during this time and an increased amount of shower activity occurs until this perturbation passes. Due to the size of the island, which is about two miles long and approximately one-half mile wide, convective type clouds due to heating do not build. Even if they were influenced by the warm land they would be far off shore before they reached shower producing proportions.

(c) Severe storms in the area are limited to thunderstorms, tropical storms and hurricanes. Thunderstorms occur infrequently in the area. The mean number of days during which thunderstorms occurred over a 26 year interval (1945-1970) are listed in Table H-3 . The + indicates less than one-half day.

(2) <u>Temperature</u>: The mean annual temperature is 79.3°F. Temperatures are slightly higher from June through November (80°-80°F) than from December through May (77°-79°F) (Fig H-8). Daily ranges are normally only 7° or 8°F, and the daily maximum and minimum temperatures vary only a few

TABLE H-3

MEAN NUMBER OF DAYS OF THUNDERSTORMS
JOHNSTON ISLAND

MONTH	JOHNSTON ISLAND	MONTH	JOHNSTON ISLAND
JAN	+	JUL	+
FEB	+	AUG	+
MAR	+	SEP	+
APR	+	OCT	+
MAY	+	NOV	+
JUN	+	DEC	1
		YEAR	1

Note: Plus indicates less than one-half day.

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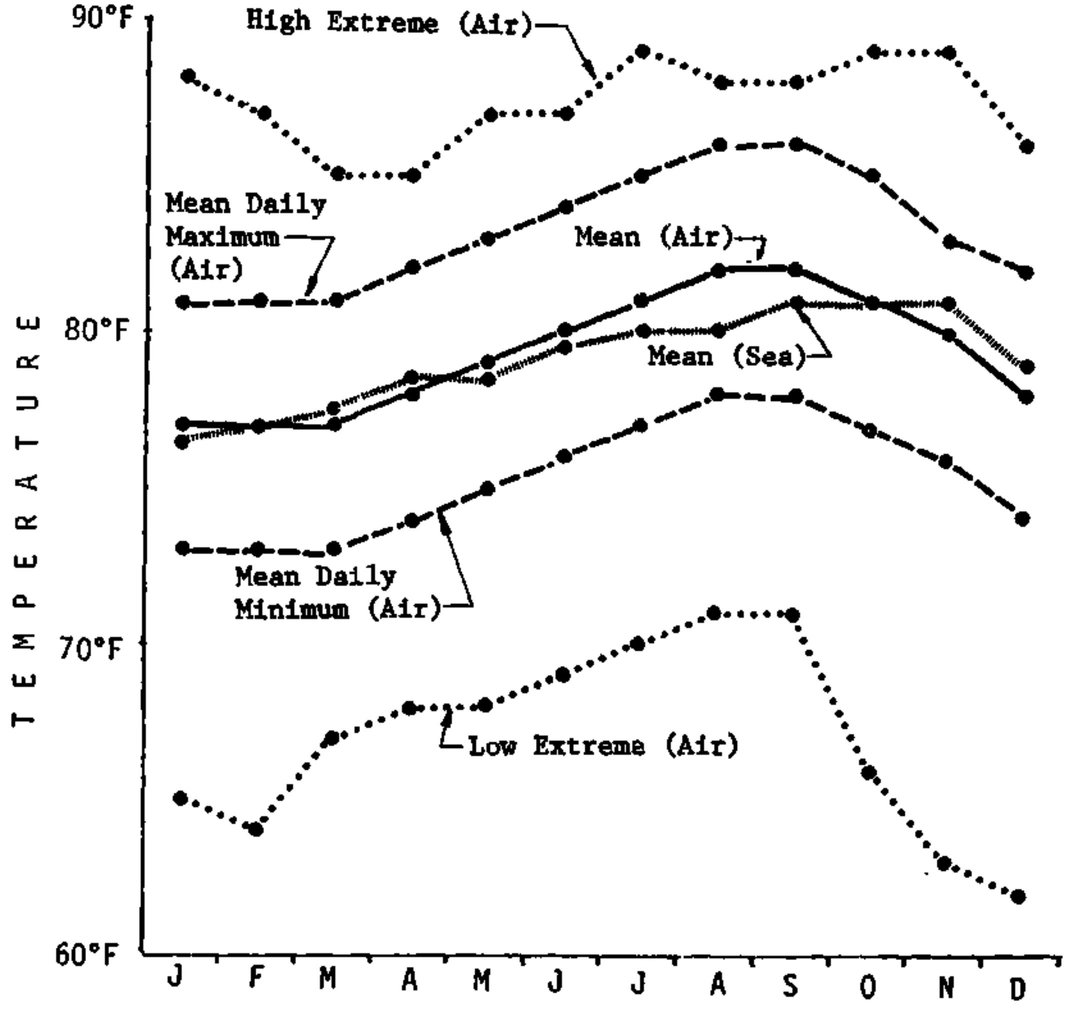

FIGURE.H-8. MEAN MONTHLY AIR AND SEA TEMPERATURES, JOHNSTON ATOLL, ADAPTED FROM SECKEL (1962) and U.S. DEPARTMENT OF COMMERCE (1972).

degrees throughout the year. The extremes range from a low of 62°F (December 1964) to a high of 89°F (October 1968, July and November 1969). This is lower than the daily range frequently encountered in continental areas. This constancy of temperature results from the fact that air masses passing over the atoll having been modified by close contact with the ocean for thousands of miles. Thus the air temperature is near that of the water temperature. Sea surface temperatures vary little from day to day and change only slowly with the seasons (Amerson, 1973).

(3) Precipitation: Precipitation of 0.01 inch or more occurs 162 mean number of days each year. The mean annual rainfall is 26.11 inches, but year-to-year variation is great. For example, the total for 1968 was 42.27 - the wettest year on record - while 1969 was only 17.11, next to the lowest yearly total recorded (12.86 inches in 1953). There is little monthly mean rainfall variation (Fig H-9); rainfall averages 2.75 inches monthly from December through March and 1.87 inches monthly from April through November. Year-to-year monthly variation is, however, great (Amerson, 1973).

(4) Relative Humidity: The annual mean relative humidity is 75 percent, being highest at 0100 hours (78 percent) and lowest at 1300 hours (69 percent). Monthly mean relative humidity values vary little throughout the year, but January and February values are definitely lower (Amerson, 1973).

(5) Surface Winds: The mean annual wind speed is 15.1 miles per hour with very little variation throughout the year (Fig H-10) (monthly means = 13.6 to 16.0 mph). Monthly extremes (excluding 1972) range from 35 mph in July to a high of 49 mph in March and November (mean monthly extremes = 43 mph). On 19 August 1972, however, the wind speed hit an all time high of 104 mph when hurricane Celeste, which spawned off the southern coast of Mexico some 3,000 nautical miles to the east nearly two weeks earlier, passed only about 25 miles to the northeast of Johnston Atoll. Damage to the island was minor. Observations from weather satellites indicate that tropical storms in the Johnston Atoll area, although infrequent, may not be as unusual as was once supposed. Surface trade winds are dominant at all times of the year (Fig H-11). Winds from between NE and E are experienced 62 percent or more of the time in every month, with the annual average being 85 percent, see Fig H-10 and H-11, (Amerson, 1973) (Bauer, 1973). Basically, two seasons can be distinguished. The first extends from December through March when the wind is from trade directions (NE through E) only 20 percent, or less, of the time. During this period, light, variable winds and westerlies occur, occasionally, as organized disturbances. These disturbances bring in cooler, less humid, less stable air, which results in more cumulus buildup and heavier, more frequent precipitation. From April through November, winds are from trade directions 80 percent, or more of the time (Amerson, 1973).

(6) Trophospheric Circulation: The trophospheric winds are readily divided into two distinct currents -- the Trade Winds and the Upper Westerlies -- by the lower zero isopleth of zonal components. The Trades are largely zonal and quite persistent all months of the year and are at a maximum in depth, speed, and steadiness during the summer. The Upper Westerlies occupy the remainder of the trophosphere and are separated from the stratospheric easterlies by the second zero isopleth at approximately 55-60,000 feet. They are also quite persistent during all months of the year, but reach a

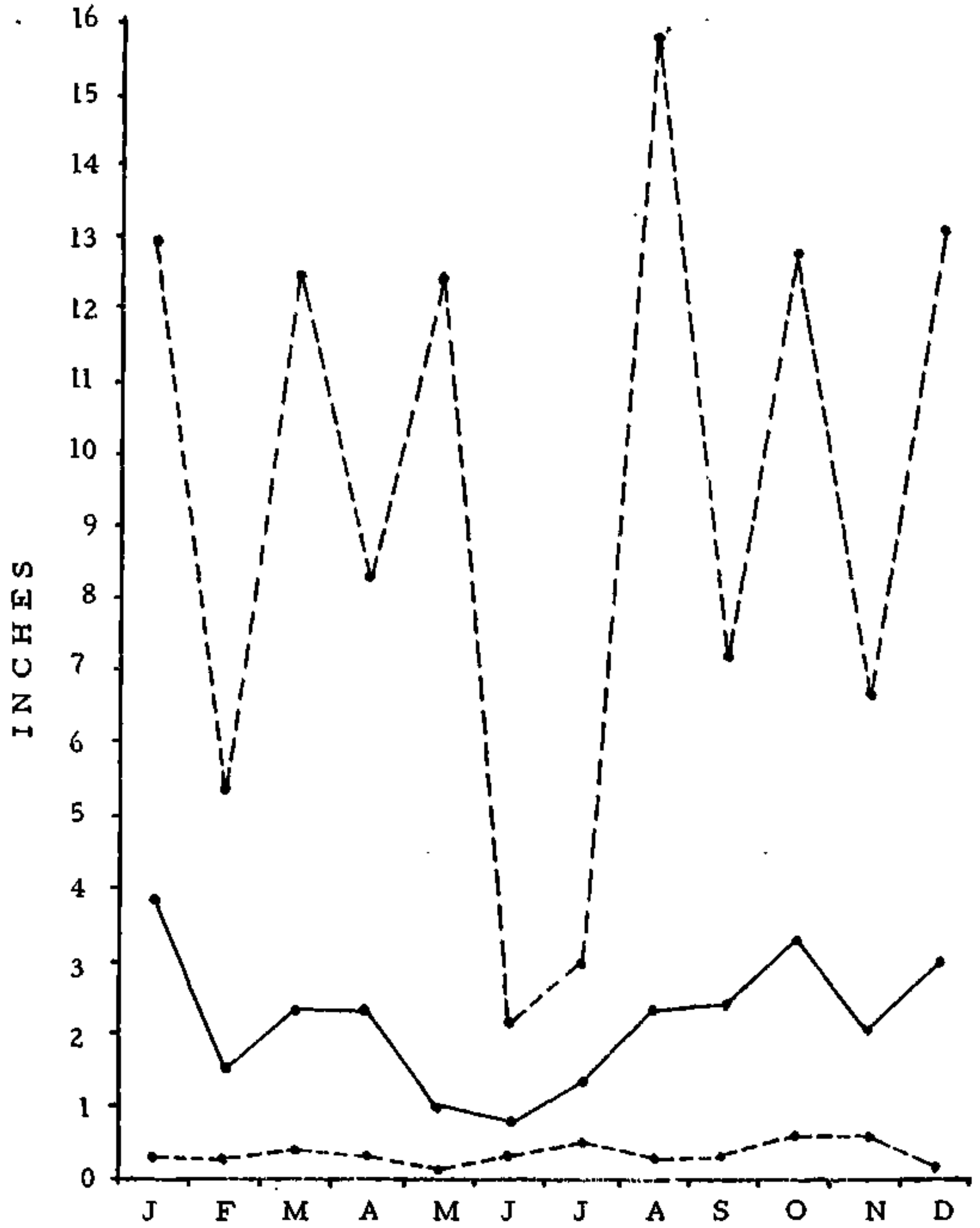

Figure H-9 Mean monthly precipitation, Johnston Atoll, 1931 - 1972; means (solid line), extremes (dashes). Adapted from U.S. Department of Commerce (1972).

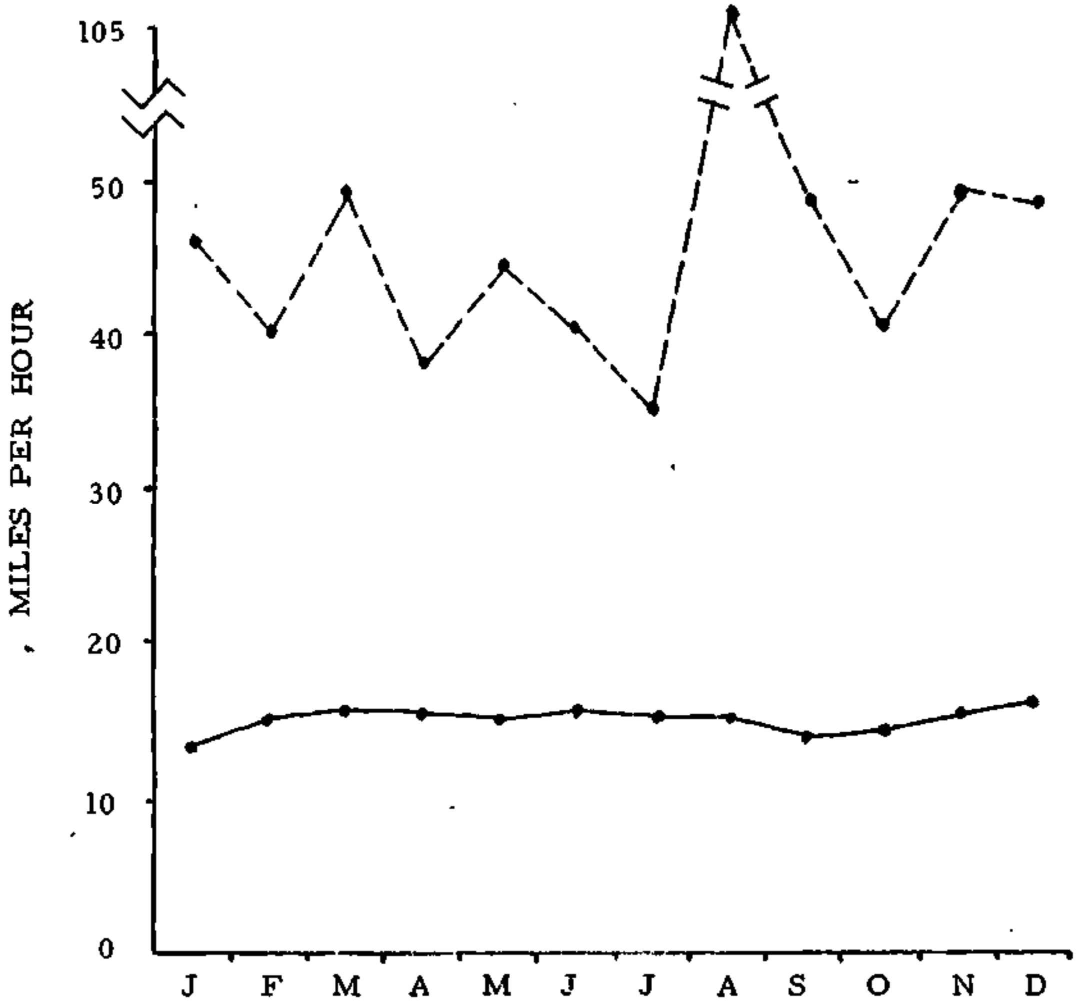

Figure H-10 Mean monthly wind speed, Johnston Atoll, 1931 - 1972; means (solid line) upper extremes (dashes). Adapted from U.S. Department of Commerce (1972).

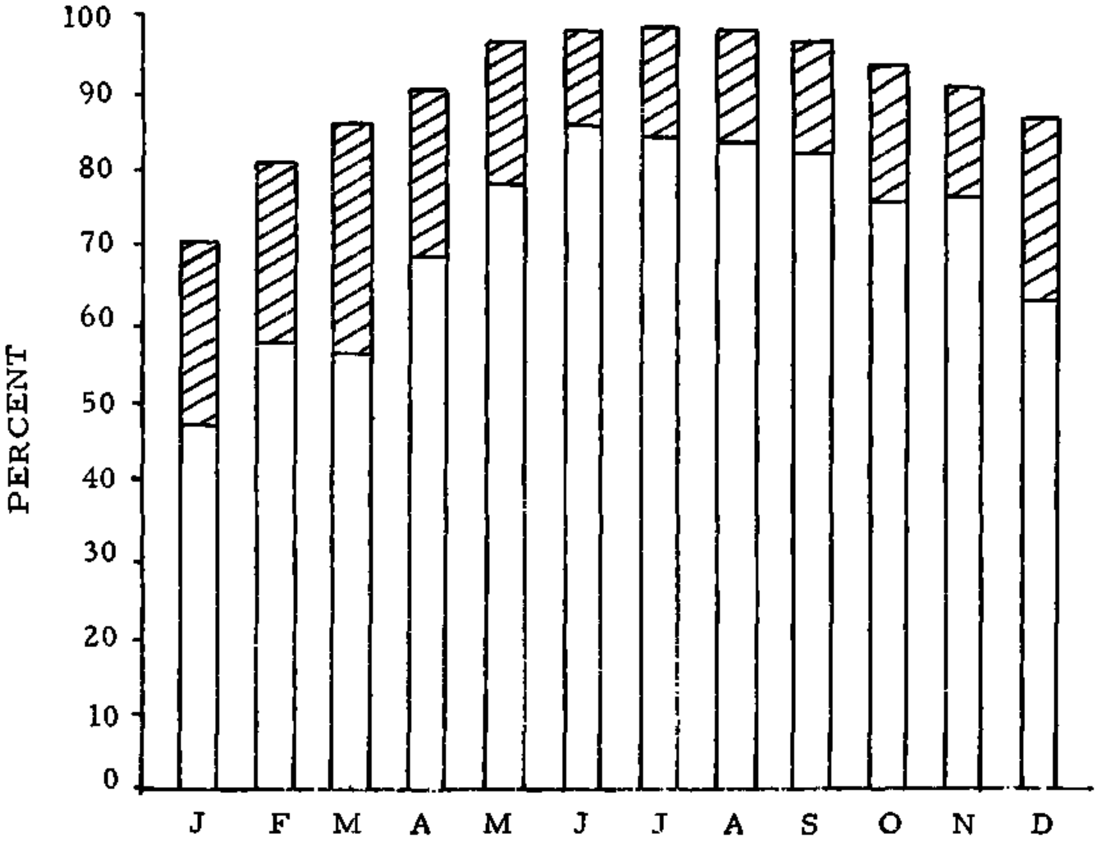

Figure H-11 Percent frequency of wind from E and ENE (open bar) and ESE and NE (striped bar), Johnston Atoll. (AMERSON, 1973) definite maximum in speed, steadiness, and depth during March and April. The November winds are much lighter in general and westerlies and the easterlies tend to cancel each other out leaving only a small south component in the mean, while in the winter there is a fairly strong northerly component reaching a maximum in February (Amerson, 1973).

(7) Stratospheric Circulation: The mean stratospheric circulation over Johnston Atoll is dominated by the Krakatoa Easterlies, but surprisingly shows greater seasonal variability than the tropospheric circulation. The winter is characterized by relatively light winds generally with east predominatin in the lower stratosphere, west in the mid-regions, and east again at levels above 110,000 feet. A fairly rapid transition occurs in spring to strong steady easterlies reaching a maximum in July and August. There is a sharp transition in the fall back to light and variable winds (Amerson, 1973).

(8) Sky Cover: Mean monthly sky cover, sunrise to sunset only, averages 6.0 on a scale of 0 to 10. There is little variation throughout the year. During an average year (again, sunrise to sunset) there are 75 mean clear days, 172 mean partly cloudy days, and 118 mean days (Amerson, 1973).

(9) Historical Data: Table H-4 shows a climatic brief for the period 1945-1970; Table H-5 shows the frequency of occurrence of different stability classes from 1949 to 1958, 86,190 observations; Table H-6 shows the frequency of stability vs wind direction for the period of Table H-5

g. Surrounding Land and Water Use and Ownership:

NOTE: THE FOLLOWING INFORMATION WAS PROVIDED LARGELY BY THE LOGISTICS PLANNING GROUP, HOLMES AND NARVER, INC., LAS VEGAS, NEVADA 89114.

(1) There are no cities or incorporated communities on Johnston Atoll. There are approximately 600 personnel currently living on the atoll. These consist for the most part of employees of Holmes and Narver, Inc., Pacific Test Division, P.O. Box 9186, Honolulu, Hawaii, 96820. This firm, operating under contract AT(29-2)-20 with the AEC, provides for general construction, maintenance and general operations on and around the atoll. The atoll is under the control of the Field Command, DNA and is currently under the command control of the USAF. There are a limited number of Holmes and Narver, Inc., subcontractor personnel. The United States AEC; U.S. Weather Bureau; 10th Aerospace Defense Squadron, Det 1; 18th Surveillance Squadron, Det 2; 2675th Chemical Company, USA; 2194th Communications Squadron; and USAF Logistics Command (SMAMA) maintain small detachments. At times a very limited number of personnel from other organizations such as the Smithsonian Institution, Sandia Corporation, USAF Space and Missile Organization, The University of Hawaii, etc., may be present on the atoll.

(2) A bird sanctuary still exists on Sand Island under the provisions of Executive Order No. 4467, dated July 29, 1926. (For detailed information regarding the present day bird population see Appendix A)

TABLE H-4

CLIMATIC BRIEF-JOHNSTON ISLAND

Month	Temperature (°F)				Precip (IN)		Wind (KT)			Mean				
	Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	Mean Total	Maximum in 24 hours	Prevailing Direction	Mean Speed	Extreme Speed (Peak Gust)	Relative Humidity (%)		Dew Point (°F)	Vapor Pressure (in Hg)	Clouds (Tenths)
										0400	1300			
JAN	88	81	73	63	3.9	9.8	ENE	14	55	79	71	68	.69	5
FEB	87	81	73	64	1.5	4.2	ENE	14	46	79	70	68	.69	5
MAR	86	81	73	67	2.3	3.8	ENE	15	54	79	71	68	.69	5
APR	87	82	74	67	2.3	3.9	ENE	15	46	81	72	70	.74	6
MAY	87	83	75	68	1.0	4.6	ENE	14	47	81	72	71	.76	6
JUN	88	84	76	69	0.8	1.1	ENE	15	46	80	70	71	.76	5
JUL	89	85	77	70	1.3	2.0	ENE	14	43	80	70	72	.79	5
AUG	88	86	78	70	2.3	8.0	ENE	14	46	80	70	73	.82	6
SEP	88	86	78	71	2.4	4.0	ENE	14	48	79	70	73	.82	6
OCT	89	85	77	66	3.3	9.5	ENE	14	43	80	71	73	.82	6
NOV	89	83	76	63	2.1	2.8	ENE	15	48	80	72	71	.76	5
DEC	88	82	74	62	3.0	9.2	ENE	15	58	79	72	70	.74	5
ANN	89	83	75	62	26.2	9.8	ENE	14	58	80	71	71	.76	5

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TABLE H-5

FREQUENCY OF OCCURRENCE - ATMOSPHERIC STABILITY CLASSES- JOHNSTON ISLAND

Stability	A	B	C	D	E	F
JAN	.0033	.0254	.0748	.7272	.1142	.0551
FEB	.0029	.0253	.0775	.7656	.0907	.0380
MAR	.0026	.0257	.1121	.7703	.0692	.0200
APR	.0023	.0195	.1097	.8009	.0527	.0150
MAY	.0019	.0137	.1258	.8095	.0399	.0093
JUN	.0014	.0157	.1470	.7596	.0611	.0150
JUL	.0033	.0174	.1423	.7653	.0624	.0093
AUG	.0017	.0109	.1481	.7719	.0611	.0064
SEP	.0024	.0205	.1352	.7306	.0944	.0168
OCT	.0044	.0195	.1017	.7688	.0857	.0199
NOV	.0000	.0038	.0370	.8962	.0455	.0175
DEC	.0021	.0113	.0477	.8377	.0842	.0170
ANN	.0024	.0175	.1062	.7821	.0718	.0199
ANNCALM	.0012	.0009	.0004	.0002	.0000	.0048

A - Extremely Unstable
B - Moderately Unstable
C - Slightly Unstable
D - Neutral
E - Slightly Stable
F - Moderately Stable

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TABLE H-6

FREQUENCY OF OCCURRENCE
WIND DIRECTION
JOHNSTON ISLAND

N	.0097	S	.0038
NNE	.0247	SSW	.0030
NE	.1244	SW	.0030
ENE	.3665	WSW	.0024
E	.3625	W	.0031
ESE	.0661	WNW	.0019
SE	.0159	NW	.0032
SSE	.0066	NNW	.0033

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(3) There is no commercial fishing in the immediate area of Johnston Atoll. Recreational fishing is extensive and is, in fact, one of the principal forms of recreation. A wide variety of species are present within the lagoon but extreme caution is advisable since some are hazardous on physical contact (sharks, barracuda, moray eel, turkey fish, stone fish, etc.) and others are very poisonous if ingested. Other forms of recreation include scuba diving, swimming, boating, basketball, bowling, golf, tennis, softball, pool, movies, library, hobby shops, clubs and gymnasium.

h. Facilities

(1) Transportation

(a) Sea Transport: Johnston Atoll is under the administrative control of the DoD, DNA and is a Naval Defense Sea Area and Airspace Reservation. All private vessels must apply for entrance prior to their arrival except in emergencies. Unauthorized landing or the violation of other regulations governing admission to the island are grounds for Federal prosecution. Johnston Atoll is accessible from all directions, although it is distant from all supply ports except Honolulu, Hawaii. This presents a problem since any supplies not brought in from Hawaii must be scheduled sufficiently in advance to allow for extra travel time for mainland supply ports. Otherwise a smooth flow of supplies is not maintained, and this often results in the use of expensive "airlifts" of bulk supplies which could be handled more economically by ship. There is no commercial shipping which makes Johnston Atoll a port of call. All supplies brought by ship are handled by the Military Sea Transport Service. Johnston Harbor (Fig H-12) is an artificially dredged turning basin and harbor area inside the lagoon and located to the north of Johnston and Sand Islands. The navigable width of the channel is from 170 feet to 190 feet, and it has a minimum charted depth of 35 feet and is 400 feet wide. The harbor and turning basin vary in width from 1200 to 2000 feet, 35 feet deep and about 1.2 miles long. A 300 foot wide, 17 foot deep channel around the west end of the island continues to deep water. Separate channels 120 feet wide and 8 feet deep connect Akau and Hikina Islands to the harbor area. At one point H.O. Chart 5356 (Navy Hydro a, 1959) shows a least depth of 13 feet. Vessels which are too large for the entrance channel may anchor in the channel approach area south of the channel entrance between the southernmost channel buoy, which is moored in 62 feet of water about 2,750 yards bearing 148° from the Johnston Island Aviation Light, and the 100-fathom line, about four miles to the south of the Island (Bauer, 1973) (Navy Hydro a, 1959) (Navy Hydro b, 1959). All channels are outlined with boundary lights, and pile dolphins are located within the harbor for ship moorage. LCM boats are available to assist with docking. Two ship-to-shore radio communications channels are provided. These are Harbor Common on 2716 KH$_Z$ and Local Boat Control on 32.8 KH$_Z$. A bulkhead wharf, a 360-foot long wooden pier, and a small boat pier with an adjoining wharf (approximately 450 feet long) are located on the north side of Johnston Island. These facilities are served with freshwater lines,a saltwater fire protection System, fuel lines, power, and lighting. The bulkhead wharf provides over 180,000 square feet of dock area. There is also a bulkhead wharf at the west end of the island with 14,000 square feet of dock area, but its usefulness is impared by silting in the channel. Small boat piers and wharves are located on the smaller islands. All the wharves and piers are equipped with

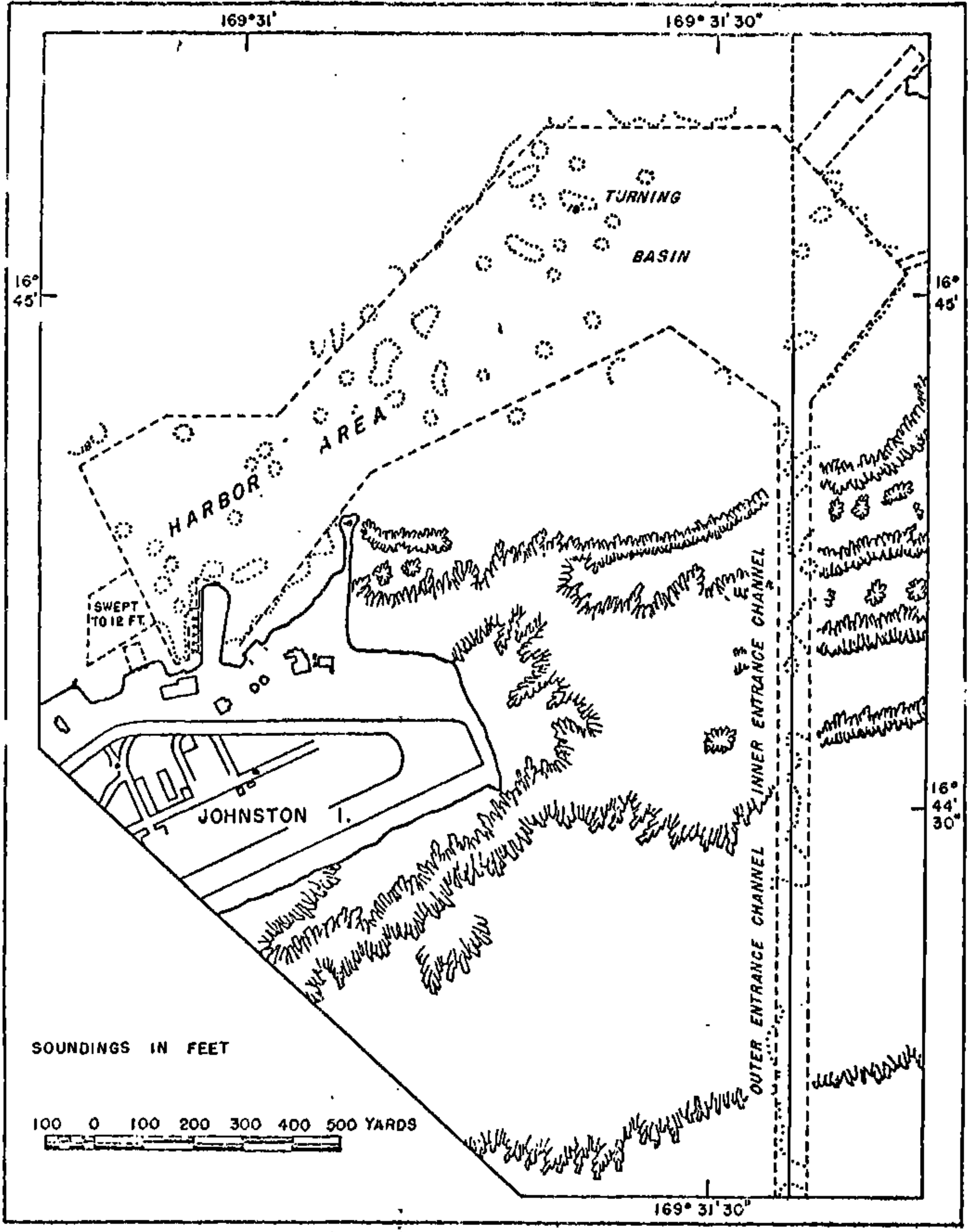

FIGURE H-12. PORT FACILITIES AT JOHNSTON ISLAND (Navy Hydro a, 1959) protective fenders (Bauer, 1973) (Navy Hydro b, 1959). Other facilities associated with the harbor are a repair shop (Bldg 126), transformer building (Bldg 128), harbor control (Bldg 110), and marine shop (Bldg 127).

(b) Air Transport: A major activity on Johnston Island is in connection with the airstrip which is operated by the United States Air Force. There is one commercial airline providing services to Johnston Atoll. A runway on Johnston Island is oriented in a northeast-southwest direction (true bearing of 65° 13' 30") along the southern side of the island. It is approximately 9,000 feet long and 150 feet wide and has shoulders 150 feet wide on each side. The first 500 feet of the west end is concrete, and the remainder is paved with asphaltic concrete. The runway weight bearing capacity for aircraft with twin wheel type landing gear is 200,000 pounds, and for aircraft with twin tandem wheel type landing gear is 350,000 pounds. Turnaround areas, blast pads and overruns adjoin each end of the runway. The north taxiway and parking area are closed; however, there are small parking areas north and south of the west end of the runway and a large parking area (140,000 square yards) south of the middle of the runway. The runway is equipped with standard frangible type lights and with visual guide indicators for approaches from the west. Traffic signals on the island's perimeter road control the movement of vehicles across flight paths. Runway lighting control equipment is housed in Building 501 which has a 75-KW standby generator for emergency power. AGE, personal equipment, and parking areas are also lighted. Air/ground communications facilities include a control tower (Bldg 505) located north of the runway near its midpoint, air/ground tactical communications (Bldg 507), antenna tower (Bldg 506), and a generator shed (Bldg 508). Airfield navigational aids are a base beacon tower (Bldg 635), a low frequency base beacon (Bldg 901), several aircraft obstruction lights, and a Tactical Air Navigation (TACAN) unit. The tower and UHF/DF are normally operational 30 minutes prior to and after all departures, and 30 minutes prior to an ETA until landing and parking of all arrivals. A newly constructed air passenger and freight terminal (Bldg 285) is located east of the aircraft parking area on the south side of the island. It is 14,000 square feet in Area, and contains a freight handling area, waiting area, baggage and ticket offices, lounges, restrooms, and a security briefing area. The island is currently serviced by both commercial and Military Airlift Command flights on a regularly scheduled basis. Since 1966, Johnston Atoll has adhered to USAF safety regulations, and approved waivers thereto, pertaining to airfields and their surrounding airspace. Current and future planning of new facilities will conform to the dimensions, clearances, and transitional slopes stipulated in these regulations. The seaplane base at Johnston Island has landing aprons and ramps on the north side of the island; a dredged landing area in the lagoon north of the boat turning basin and harbor area. The longest runway in the lagoon is 11,000 feet, running from the northeast to the southwest. There are also two shorter runways running north and south and northwest and southeast, with lengths of 6,000 and 4,000 feet respectively. The entire seaplane landing area has been swept to a minimum depth of eight feet. The first facility on Johnston Atoll was originally based on Sand Island; the causeway and fill to the west of Sand Island were constructed for this original seaplane base in the late 30's. The seaplane base is little used today, since, with the coming of the long-range land plane to the Pacific, the flying boat lost much of its utility and is at present being used mainly for air-sea rescue operations (Bauer, 1973). In the interest of completeness and to provide information not contained in the Holmes and Narver report, Change 12, U.S. Naval Oceanographic Office Publication, H.O. Pub. 80 (formerly No. 166) "Sailing Directions for the Pacific Islands" Vol. III, pages 354a - 375, 6th Ed., 1952 is included in Appendix C.

(c) Ground Transport: There are several miles of roads on Johnston Island including a perimeter road which varies from 20 to 26 feet in width. Some sections are paved with asphaltic concrete and others are compacted coral. The road network is excellent and allows easy access to all major facilities (Bauer, 1973).

(2) Communications: In addition to those discussed previously under Sea and Air Transport, there are numerous other communications facilities. A 1080 automatic dial telephone exchange provides on-atoll administrative telephone service, and off-island dialing to Oahu through a submarine cable. The Defense Communications Agency furnishes worldwide tele-communications services on a 24-hour, seven-day week, again through the submarine cable, and there is a backup communication link provided by a long haul radio trunk to Hickam AFB,HI. On-island there is a non-tactical VHF/FM mobile radio system with enough stations activated to meet local requirements. There are also from one to three civilian amateur radio stations, an Armed Forces Radio Station, a television station, a MARS station, a public address system, a disaster control system, and a fire alarm system (Bauer, 1973).

(3) Utilities

(a) Water Supply System: Johnston Atoll's Water system uses both fresh and salt water. Raw sea water is pumped from the lagoon through a traveling screen to the Salt Water Pump House (Bldg. 3). From there it is pumped to the Distillation Plant (Bldg. 45), and also into the salt water distribution system where it is used for sanitary purposes, fire protection, air conditioning condenser units, power plant waste heat dissipation, distillation Plant (Bldg. 45) which houses twelve distillation units and related equipment; the Freshwater Treatment Plant (Bldg. 44) with a pump station, soda-ash treatment area, and a chlorination room; the Freshwater Pump House (Bldg. 650); an Auxiliary Freshwater Pump House (Bldg. 649); and, storage facilities for approximately 740,000 gallons. The fresh water system is designed to support a population of approximately 4,500. Its total rated capacity is 318,000 gpd, but, allowing for maintenance and miscellaneous downtime, about 240,000 gpd can be expected. Fresh water for Akau, Hikina and Sand Islands is barged there in tank trucks (Bauer, 1973).

(b) Electrical Power System: The Power Plant (Bldg. 48) contains seven diesel-driven generators, each rated at 1400 kw with an 80 percent power factor. Outgoing power of 4160 volts is distributed through thirteen feeders. Two feeders serve the power plant's auxiliary equipment and utility load, two serve the smaller islands, one serves the LOX plant, and the remainder serve Johnston Island through approximately eighty substations. The distribution system consists of a network of underground duct banks in a modified loop radial configuration, and submarine cables which carry power to Akau, Hikina and Sand Islands. Although a loop tie-in arrangement provides 100 percent power back-up for the small islands, each also has one or more standby generators.

(c) Sanitary Sewerage System: Johnston Island has insufficient relief to permit use of a gravity sewage collection system; therefore, a forced system employing pumps and lift stations is used. The force main is a series of 3" to 16" cast iron and asbestos cement pipes in parallel runs along the north and south shores with connecting laterals. Raw effluent is discharged on the ocean bottom at a depth of 25.6 feet through a 10" pressure outfall pipeline which extends approximately 520 feet out from the southwest peninsula of the island. Sewage on the three smaller islands is collected in septic tanks, and the effluent from the septic tanks drains by gravity into the sea (Bauer, 1973).

(d) Storm Drainage System: The drainage system consists of inlets, french drains, and ditches which discharge into the lagoon. It is separate from the sewage system and does not use piping of any kind except for culverts under roads, runway, and taxiways and where ditches drain through outfalls into the ocean. Drainage is adequate for normal conditions, but problems may arise after heavy prolonged rainfall or severe storms (Bauer, 1973).

(4) Housekeeping

(a) Housing: Johnston Atoll housing can be classified as enlisted men's, officer/professional, and VIP. Dependents are not authorized; therefore, there is no dependent housing. Enlisted men's quarters are provided by six 4-story reinforced concrete barracks and two 3-story concrete block barracks. The former contain dormitory type accommodations (two-man cubicles) with a centrally located latrine on each floor. Each has a recreation lounge on the first floor and storage, janitorial,and equipment space. Each floor of the latter has twenty-four two-man rooms, a centrally located latrine, or recreational lounge, and laundry facilities. Each barrack also has storage, janitorial and equipment space. Total design capacity for the eight EM barracks is 1808. Two 4-story reinforced concrete professional barracks and twelve 2-story concrete block apartment buildings provide accommodations for officers and professional type personnel. The barracks have two-man bedrooms with each room accessible from an outside balcony. Each two bedrooms are connected by a latrine and closet area. Space is provided for storage, janitorial supplies, and equipment, and a recreational lounge is located on the first floor. Each apartment building contains six apartments with three bedrooms, a kitchen, combination living/dining area, and a bathroom. Total design capacity for officer/professional personnel is 824. There are four small cottages on Johnston Atoll which are reserved for use by the Commander and other VIPs. These contain kitchens, bathrooms, living and dining areas, and three bedrooms. Total capacity of the VIP quarters is 12 (Bauer, 1973).

(b) Messing: There are two mess halls on Johnston Atoll, Building 519 (Mess Hall No. 1) and Building 4 (Mess Hall No. 2). Mess Hall No. 1 is of concrete block construction with a built-up roof and a concrete floor. It can seat 1000 men for either family or cafeteria style meals and can be turned three times during each dining period for a serving capacity of 3000. Mess Hall No. 2 is constructed of concrete blocks with a precast roof. It was designed to seat 500 men, but it is not operational at the present time. One dining wing is now serving as a chapel and the other as the Officer's Club (Bauer, 1973).

(c) Recreation: Because of the remoteness of Johnston Atoll, its physical characteristics, and its use, emphasis has been given to providing excellent and varied recreation facilities. Indoor facilities include a bowling alley, gymnasium, hobby shops, library, pool and NCO, Officers and civilian clubs. Outdoor sports available are basketball, boating, fishing, golf, scuba diving, softball, swimming, tennis and volleyball. There is also an outdoor theater which seats approximately 1,000 men (Bauer, 1973).

(d) Dispensary: Medical facilities similar to those of a clinic or small hospital are located in Building 405, an underground structure of reinforced concrete with approximately 6,600 square feet of useable floor space. Included are rooms for minor and/or emergency surgery, examination and treatment, x-ray and associated darkroom equipment, isolation, 20-bed ward, offices, laboratory,storage, waiting room, library, latrine, and a dental operating room and laboratory. Two medical doctors and one dentist are normally on the island; however, treatment is generally confined to minor or emergency type ailments while patients with major problems are air-evacuated to Hawaii (Bauer, 1973). Facilities associated with the dispensary but located in separate structures are a decontamination station (Bldg 404), air conditioning equipment (Bldg 407), oxygen storage (Bldg 409), and emergency power (Bldg 416).

(e) Miscellaneous: In addition to the above, there is a post office, base exchange, barber shop, tailor shop, laundry, and fire station. All of these are adequate to support an island population of 4,500 personnel, if necessary.

(5) Storage

(a) Warehouses: Twelve steel frame buildings on the north side of Johnston Island, two similar structures near the south aircraft parking area, and Building 400, a wood frame structure with metal siding, provide a total of over 74,000 square feet of warehouse space. However, the latter (Bldg 400) was severely damaged during a recent hurricane and replacement facilities are being planned. There are also numerous storage facilities throughout the island designed and used for the storage of various types of munitions, and there are facilities reserved for special useage which are now used for storage.

(b) Open Storage: Open storage areas are located east of the north aircraft parking area, north of Bldg 390, and along the northwest shore of Johnston Island. Because of corrosion caused by the high humidity and blowing coral, the type of supplies which can be placed in outdoor storage is limited unless such supplies are enclosed in weather resistant packaging or coatings.

(c) POL/LOX: Petroleum, oil and lubricants (POL) stored in bulk include aviation gasoline (AVGAS), jet fuel (JP-4), motor gasoline (MOGAS), and diesel fuel. There are also storage facilities associated with the liquid oxygen (LOX) plant. MOGAS and diesel fuel facilities are located in the northeast portion of the island. Tanker-delivered fuels are conveyed to a 13,500 gallon diesel fuel tank near the power plant, and to six 25,000 gallon tanks (two for diesel and four for MOGAS) near the distillation plant. Associated facilities are a tank truck loading area and a vehicle fuel pumping station. The aircraft POL installation is located in an isolated area in the southeastern part of the island. It includes a 13,500-barrel storage tank and a 1,500-barrel ready tank for AVGAS, and the same for JP-4. This complex also has a tank truck loading assembly area, an electrical equipment shop, a pump complex, and a propellant and lube storage area (Bauer, 1973). The LOX plant, located on the northwest corner of the island, has two 28,000-gallon tanks for liquid oxygen storage, and a 28,000-gallon tank and 13,500-gallon tank for liquid nitrogen storage.

(6) Construction: Construction of new facilities and modification of existing facilities is normally accomplished by the support contractor under a Cost-Plus-Fixed Fee contract with the Atomic Energy Commission. However, special projects are sometimes awarded by competitive bidding. An assortment of construction equipment including trucks, tractors, cranes, etc., is available on the island, but all construction materials, with the exception of coral aggregate and salt water, must be imported.

i. Terrestrial and Marine Flora and Fauna

NOTE: The following sections were extracted from a document entitled "Preliminary Biological Survey of Sand Island - Johnston Atoll" (PCBSP, 1964). The work was accomplished under DoD Contract No. DA-18-064-AMC-56-A. For a more detailed discussion of Johnston Atoll, its history, terrestrial and aquatic flora and fauna, see Appendix A.

(1) Vegetation: The low-lying coral islands of the central Pacific are characterized by flora that contain few species. Plants are dominantly wide-ranging tropical species along with a few endemics (Fosberg, 1949). Only three plant species occurred on the original Johnston and Sand Islands. One hundred and twenty-four terrestrial plants have been introduced by man. In general, the indigenous flora of the atolls increases in number of species as one proceeds westward in the Pacific. This would be expected from the closer proximity of western islands to larger islands and land masses with their complex floras. Rainfall plays a particularly decisive role in the plant life of the coral atolls. Those with little rainfall, such as Sand - Johnston Atoll, have a very low, sparse vegetation consisting of a few grasses, herbs, and dwarf shrubs. This contrasts strikingly with the luxuriant growth and many trees to be found on atolls with high rainfall.

(2) General Animal Life: The animals of the Pacific show an increase in number of species from east to west as is true of plants. Central Pacific Atolls, like Johnston-Sand, with their small size, sparse and relatively uniform vegetation, and dry climates cannot support a large variety of species. With increasing size, diversity of habitat, and increased rainfall the number of species increases. Proximity to large land areas is a factor that is of great importance in causing an increase in the number of species. Many species, however, that reach the islands cannot find habitat suited to their survival.

(a) Mammals: The first men to visit the north central Pacific islands probably found only one mammal present, the Hawaiian Monk seal. The various tribes, however, probably brought along semi-domestic dogs and unintentionally the Polynesian rat (Rattus exulans). With the arrival of whalers, guano diggers, and traders, almost every island received by accident or intention one or more mammals. Most of these either brought about their own destruction, rabbits (Oryctolagus) on Laysan Island ate all available food (Bailey, 1956), or were destroyed by other introduced species, e.g., rats usually were exterminated by cats. Domestic animals, such as dogs, horses, sheep, goats, pigs, etc., generally cannot survive without human care. In some areas, cats and Polynesian rats occur on many uninhabited islands, and rabbits (Oryctolagus) occur on Phoenix Island, while Rattus rattus, Rattus norvegicus, and Mus musculus occur only on islands inhabited by man. These last three always occur in fairly close proximity to human activities and are probably dependent upon man for their large populations if not their existence. Several dogs are kept as pets on various islands and a monkey has existed for several years in a wild state on Kure Island.

(b) Birds: The bird population with few exceptions is composed entirely of oceanic birds or transient shorebirds. The total number of breeding sea birds in the central Pacific is twenty-four with the maximum number occurring at the present time on any one island is seventeen. The number of species which breed on any one island is dependent primarily on mammals present and secondarily on suitable nesting sites. A few individuals will usually nest on an island even if good nesting sites are absent, but the presence of cats will prevent nesting by some three to seven species. Fifty-six bird species have been recorded on the atoll. Twelve seabird species nest on the islands and six migratory shorebirds have been regularly observed in recent years. Endemic land birds (excluding the main Hawaiian forms) are represented only by the Laysan Finch of Laysan Island, a finch on Nihoa, and a parakeete and warbler in the Line Islands. An endemic duck is present on Laysan Island and a considerable variety of migrant ducks and small land birds have been recorded on the various islands. Finally wild populations of canaries and domestic pigeons occur on Midway.

(c) Reptiles: The reptile fauna usually consists of one skink, one gecko, and the Green turtle. Wetter islands support several species of geckos and skinks.

(d) Amphibians: None are present in the Johnston Atoll area and no suitable habitat is present to permit their survival.

(e) Fish: This group is still very poorly known and most authorities feel that the fish fauna of the various atolls will be very similar once complete collections have been made. Occasionally, sea turtles and porpoises are present in the lagoon. There are at least 94 species of inshore fish known and additional species probably exist.

(f) Insects and Other Arthropods: This is another group that has been incompletely studied. In general, the terrestrial invertebrate fauna consists of 68 species, many of them introduced. This is to be expected in view of small land areas, little variety of habitat, and long distances from land masses. Man has been instrumental in introducing many new species to inhabited atolls, however, where this has happened insect faunas can be expected to be more varied.

(g) Land Crustaceans and Mollusks: Several types of crabs are found on most Pacific coral atoll islands; land crabs, coconut crabs, and hermit crabs. Their occurrence in the central Pacific varies. Hermit crabs are not presently found north of the Line Islands. Terrestrial mollusks are not common on central Pacific atolls. Some, however, are found in close association with the sea. These are called "shore-zone" mollusks (Wiens, 1962).

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APPENDIX I

TRANSPORTATION REQUIREMENT

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1. INTRODUCTION: Transportation of the Orange herbicide presently stocked at the NCBC, Gulfport, Mississippi to Johnston Island, Central Pacific Ocean will be dependent on whether the proposed action, incineration at sea, or the principal alternative, incineration on Johnston Island, is selected. For incineration at sea, approximately 860,000 gallons would be removed from the drums and transferred by rail to the incinerator ship. For incineration on Johnston Island the drums of Orange will be transported to Johnston Island by ship from Gulfport. Shipment overland to a West Coast Port and then by vessel to Johnston Island or shipment via air flight only were also considered. Both of these alternatives are considered impractical because of higher cost, increased risk of product loss traversing the country overland, and the huge consumption of fuel connected with an air delivery of this magnitude.

2. CLASSIFICATION: Under the "Hazardous Materials Regulations" of the Department of Transportation (DOT), Code of Federal Regulations 49, Parts 100-199, Orange herbicide is not hazardous. Extensive experience over a number of years in the mid-1960's substantiates the adequacy of the shipping procedures which were then employed.

a. Flammable Classification: The DOT Transportation Regulation Section 173.115 defines a flammable liquid as one which gives off flammable vapors (as determined by flash point from Tagliabue's open-cup tester as used for test of burning oils, ASTM Test D1310) at or below a temperature of 80°F. Orange herbicide has a flash point of 295°F and vapor pressure less than 1 mm of mercury at 35°C. Therefore, it is not a flammable liquid.

b. Poisons-B-Classification: Code of Federal Regulations Title 49 - Transportation, Chapter 1 - Hazardous Materials Regulations Board, 173.343. Less dangerous poisons, Class 3, liquid or solid, poison label are described below:

(1) For the purposes of Parts 170-189 of this chapter and except as otherwise provided in this part, Class B poisons are those substances, liquid or solid (including pastes and semisolids), other than Class A or Class C poisons, which are known to be so toxic to man as to afford a hazard to health during transportation; or which in the absence of adequate data on human toxicity, are presumed to be toxic to man because they fall within any one of the following categories when tested on laboratory animals.

(a) Oral Toxicity: Those which produce death within 48 hours in half or more than half of a group of ten or more white laboratory rats weighing 200 to 300 grams at a single dose of 50 milligrams or less per kilogram of body weight, when administered orally.

(b) Toxicity on Inhalation: Those which produce death within 48 hours in half or more than half of a group of ten or more white laboratory rats weighing 200 to 300 grams, when inhaled continuously for a period of one hour or less at a concentration of two milligrams or less per liter of vapor, mist, or dust, provided such concentration is likely to be encountered by man when the chemical product is used in any reasonable foreseeable manner.

(c) Toxicity by Skin Absorption: Those which produce death within 48 hours in half or more than half of a group of ten or more rabbits tested at a dosage of 200 milligrams or less per kilogram body weight, when administered by continuous contact with the bare skin for 24 hours or less.

(2) The foregoing categories shall not apply if the physical characteristics or the probable hazards to humans as shown by experience indicate that the substances will not cause serious sickness or death. Neither the display of danger or warning labels pertaining to use nor the toxicity tests set forth above shall prejudice or prohibit the exemption of any substances from the provisions of Parts 170-189 of this chapter.

c. For Truck Shipment: National Motor Freight Classification (NMFC) 50320 compounds, tree or weed killing (herbicides), not otherwise indexed (NOI) or 2,4-D (dichlorophenoxyacetic acid) or 2,4-D formulations.

d. For Rail Shipment: Uniform Freight Classification (UFC) 96465 weed killing compounds, not otherwise indexed by name (NOIBN).

3. PROPOSED METHODS OF SHIPMENT:

a. General: Overland shipment from NCBC, Gulfport, Mississippi to the Port of Gulfport will move by rail, a distance of 2 1/2 to 3 miles. While not classified as hazardous under Hazardous Materials Regulations, the uncontrolled release of Orange herbicide can have a harmful effect on crops and aquatic life. For these reasons the precautions listed below will be enforced. These precautions are deemed reasonable and adequate for the situation. Some of these actions are routinely accomplished regardless of the product being shipped. In addition to the basic precautions discussed in the following paragraphs, an Operations Plan will be written to describe the transportation aspects with an emphasis on personnel and environmental safety. All parties who come into possession of the product will be instructed in writing of actions to be taken in the event of an accident.

b. Bulk Shipment: For incineration at sea as the disposal method, the Orange stored at NCBC, Gulfport, Mississippi would be transferred from drums to tank cars for rail shipment to the Port of Gulfport. The Orange would then be loaded aboard the incinerator ship for transport to the incineration location. Necessary precautions will be taken during all phases of this operation.

c. Shipment in Drums: For incineration on Johnston Island as the disposal method it would be transported to Johnston Island in drums. The product will be packaged in drums of 16 gauge steel or 18 gauge steel. This action satisfies Department of Transportation (DOT) requirements for Class B poison container, as defined in Code of Federal Regulations, Title 49 - Transportation, Chapter 1 - Hazardous Materials Regulation Board, 173.346(a)(2). Drums will be inspected prior to shipment to determine that no leakage exists. Any leaks detected during inspection will be positively corrected by tightening of closures, replacement of gaskets, or by drum replacement. Product in drums of questionable condition for safe and leak free transit will be redrummed. Shipment will be made in gondola cars with steel floors. These are open top cars with sides of 5 1/2 to 6 feet high. Use of this type car will permit overhead loading and unloading of drums with cranes, thus reducing time and cost in the loading and unloading operation. Lading will be blocked and braced in accorcance with rules of the Association of American Railroads (AAR rules). Prior to loading rail cars, the floor of the cars will be covered with plastic sheeting of sufficient width and length to allow sheeting to be folded up 10 to 12 inches along sides and ends of each car. This lining would serve to contain any product leakage while cars are loaded. Lifting of product from port will be scheduled aboard one vessel. Consideration will be given to lining the floor of the cargo holds with plastic sheeting prior to herbicide loading. Also to be considered will be the shipment of absorbent material in sufficient quantity to absorb minor product leakage. This absorbent material would be discharged with the product at Johnston Island either for use or disposal.

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APPENDIX J

ANALYTICAL METHODS

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I THE DETERMINATION OF 2,4-D AND 2,4,5-T HERBICIDES IN WATER

A. REAGENTS

1. Benzene distilled in glass, pesticide analysis grade
2. Ether distilled in glass, pesticide analysis grade
3. Concentrated H_2SO_4
4. Concentrated H_3PO_4
5. Acid washed anhydrous Na_2SO_4 or (5% solution of anhydrous Na_2SO_4 pH <5) anhydrous Na_2SO_4
6. Anhydrous Na_2SO_4
7. Florisil activated at 650°C and kept at 130°C
8. N-methyl-N'-nitro-N-nitrosoquanidine
9. Potassium Hydroxide
10. Sodium Bicarbonate

B. MATERIALS

1. Pyrex glass tubing, 1/8 inch O.D.
2. Glass wool
3. Gas-chrom[1] Q 60/80 mesh
4. 9" Disposable pipet

C. EQUIPMENT AND GLASSWARE

1. Varian Aerograph HY-FI III Model 1200 with a proportional temperature programmer, or similar instrument with electron capture detector.
2. Varian Aerograph Model 30 Recorder, 0-1 MV, half inch per minute or equivalent.
3. Dohrmann Microcoulometric Halide Titrating System/G.C.
4. A small oven, maximum temperature 150°C.

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[1] Applied Science Laboratories, Inc., State College, Pa.

5. Prepurified nitrogen with pressure regulator

6. Fluidized sand bath

7. Kuderna-Danish evaporator, 125 ml with various size concentrator tubes

8. One-liter separatory flask

9. Two-liter separatory flask

10. 125 ml and 250 ml Erlenmeyer flask

11. Various size volumetric flasks

12. Quart mason jars with teflon lined covers

13. Ultra pure oxygen with pressure regulator

D. COLUMN PREPARATION

1. DC-200 silicone grease is coated 2.5 percent by weight on 60/80 mesh Gas-chrom Q. The material is also coated with 0.25 percent carbowax 20M, and packed into 1.5 mm - ID, 3 mm - OD heat resistant glass column 6 feet long.

2. OV-17 1.5 percent by weight, QF1 - fluorinated silicone 1.95 percent by weight, carbowax 20M 0.25 percent by weight are coated on 60/80 mesh Gas-chrom Q and packed into 1.5 mm - ID, 3 mm - OD heat resistant glass column, 6 feet long.

3. EGSS-X is coated 3 percent by weight on 100/120 mesh Gas-chrome Q and packed into a 2 mm - ID, 4 mm - OD, glass column, 6 feet long.

E. PREPARATION OF STANDARDS

Herbicide standards are prepared from their methyl esters to contain from 2×10^{-9} g to 5×10^{-12}g per µl (microliter) in hexane or benzene in a volumetric flask.

F. PROCEDURE

1. <u>Sample Collection of Herbicides</u>: The water sample is collected, using a precleaned quart mason jar with a teflon lined cover. The jar is submerged directly into water source to collect sample. One-inch air space is left on top in the container.

2. Cleaning of glassware

a. All glassware, except volumetric glassware, is heated to 300°C for eight hours to eliminate organic contamination after detergent washing and rinsing in acid water pH <2 and rinsing clean of the acid with organic free water.

b. Volumetric glassware is cleaned with sodium dichromate in concertrated sulfuric acid cleaning solution, rinsed clean of sodium dichromate with organic free water and final rinse with acetone nanograde distilled in glass and dried in oven.

3. <u>Operating Parameters of the Gas Chromatograph</u>

a. Oven temperature: 170°C

b. Electron-capture detector, concentric tube design, D.C. mode, 90 volts temperature: 210°C.

c. Injection port temperature: 210°C.

d. Nitrogen (prepurified) carrier gas: 40 ml per minute.

e. Injection volume: 5 µl (microliter).

4. <u>Herbicide in Water</u>

a. Total phenoxy acid herbicides and its esters.

(1) Acidify (pH 2.0) the one-liter water sample with concentrated sulfuric acid.

(2) Pour the sample into a two-liter separatory funnel. Add 50 ml diethyl ether to the sample bottle, rinsing the sides, and pour the solvent into the separatory funnel. Shake the mixture vigorously for one minute. Repeat three times. Since ether is highly soluble in water, the sample must be saturated with ether before extraction. Dissolve 5 grams of Na_2SO_4 to water before extraction.

(3) Pour ether extract into a Ŧ joint 250 ml Erlenmeyer flask containing 2 ml of 37 percent aqueous potassium hydroxide. Add 15 ml H_2O and insert a one-ball Snyder column. Evaporate the ether on a steam bath; reflux for approximately 90 minutes.

(4) Transfer the concentrate to a 60 ml separatory funnel. Extract the basic solution three times with 20 ml ether and discard the ether layer. Acidify the aqueous layer with 2 ml of cold 4:1 aqueous sulfuric acid to pH 2 and extract the herbicides with 20 ml ether three times. Transfer the ether layer to a 125 ml Erlenmeyer flask containing about 0.5 gram acid washed anhydrous Na_2SO_4 in an explosion proof refrigerator for two hours or overnight.

(5) Transfer the ether solution into a Kuderna-Danish evaporator-concentrator apparatus with a 5 ml volumetric flask and add 0.5 ml benzene. Concentrate the extract to about 0.5 ml, using a fluidized sand bath at 70°C or lower. During the ether transfer, it is necessary to crush the caked Na_2SO_4 to obtain a quantitative transfer.

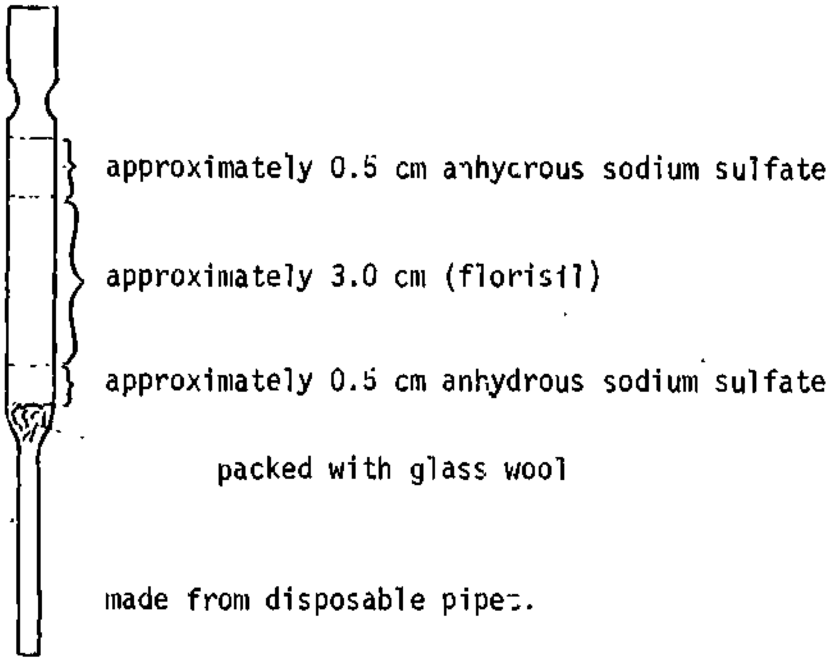
(6) When the concentrated extract is cool, add 0.5 ml of 14 percent BF_3-methanol reagent. Heat the contents at 50°C for 30 minutes in a sand bath or water bath.

(7) Cool and add 4.5 ml of 5 percent aqueous Na_2SO_4 solution to the reaction mixture, shake for one minute, allow to stand for approximately three minutes for phase separation.

(8) The benzene layer is pipetted from the receiver and passed through a micro cleanup column of florisil with more benzene to a volume of 5 ml. Then concentrate down to 0.5 ml for analysis.

(9) Gas chromatograph the methyl ester of chlorinated phenoxy acid through the same chromatographic columns as chlorinated pesticides.

(10) Compare with known quantities of prepared herbicide standards.



b. Butyl and Isooctyl Esters of 2,4-D and 2,4,5-T

(1) To a 1-liter water sample, add 1 N.NaOH to bring the pH to 8 or higher. (Caution: immediately start extraction; hydrolysis of the ester will take place if left standing).

(2) Pour the water sample into a two-liter separatory funnel. Add approximately 50 ml diethyl ether to the sample bottle, rinsing the sides, and pour the solvent into the separatory funnel. Shake the mixture vigorously for one minute. Repeat three times. Since ether is quite soluble in water, the sample must be saturated with ether before extraction. Total extracted ether volume is 150 mls. Dissolve 5 grams of Na_2SO_4 in water before extraction. Save the water sample for extraction of the chlorinated phenoxyacids and chlorinated phenols.

(3) Pour the ether extract into a $\overline{\text{S}}$ joint 250 ml Erlenmeyer flask containing sufficient anhydrous acidified Na_2SO_4 to remove the water and store in an explosion proof refrigerator for two hours or overnight.

(4) Transfer the ether solution into a Kuderna-Danish evaporator-concentrator apparatus with a 1 ml volumetric flask and add 0.5 ml benzene. Concentrate the extract to 0.5 ml, using a fluidized sand bath at 70° C or lower. During the ether transfer, it is necessary to crush the caked Na_2SO_4 to obtain a quantitative transfer.

(5) Cool the concentrate overnight.

(6) The benzene layer is pipetted from the receiver and passed through a micro cleanup column of florisil with more benzene to a volume of 5 ml. Concentrate to 0.5 ml for analysis using the columns normally used for chlorinated herbicides.

(7) Gas chromatograph the esters of chlorinated phenoxyacid. The 3 percent EGSS-X coated column has a better ester separation for e-c detection.

(8) Compare with known quantities of prepared herbicide standards.

(9) Proceed with the extraction of the chlorinated phenoxyacid and chlorinated phenols from step "(2)" by acidifying the water to pH 2 with concentrated sulfuric acid.

(10) Pour the sample into a two-liter separatory funnel. Saturate the sample with ether. Add 50 ml diethyl ether to the sample bottle, rinsing the sides and pour the ether into the separatory funnel. Shake the mixture vigorously for one minute. Repeat three times. Total extracted volume: 150 mls.

(11) Pour the ether extract into a $\overline{\text{S}}$ joint 250 ml Erlenmeyer flask containing anhydrous acidified Na_2SO_4 in an explosion proof refrigerator. Allow to stand for two hours or overnight.

(12) Transfer the ether solutions into a Kuderna-Danish evaporator-concentration apparatus with a 5 ml volumetric flask and add 0.5 ml benzene. Concentrate the extract to about 0.5 ml, using a fluidized sand bath at 70 C or lower. During the ether transfer, it is necessary to crush the caked Na_2SO_4 to obtain a quantitative transfer.

(13) When the concentrated extract is cool, add 0.5 ml of 14 percent BF_3-methanol reagent. Heat the contents at 50°C for 30 minutes in a sand bath or water bath. When chlorinated phenols are determined with the chlorinated phenoxyacids, add diazomethane dropwise until a yellow color persists.

(14) After methylation with the BF_3-methanol reagent sample, cool and add 4.5 ml of 5 percent aqueous Na_2SO_4 solution to the reaction mixture, shake for one minute, allow to stand for approximately three minutes for phase separation. After methylation with diazomethane, slowly warm the sample in a sand bath or water bath to 50°C for one-half hour; then use filtered air to evaporate the diazomethane.

(15) The benzene layer is pipetted from the receiver and passed through a micro cleanup column of florisil with more benzene to a volume of 5 ml. Then concentrate down to 0.5 ml for analysis.

(16) Gas chromatograph the methyl ether of chlorinated phenoxyacid and the methyl ethers of chlorinated phenols through the gas chromatographic columns.

(17) Compare with known quantities of prepared chlorinated herbicide and phenol standards.

(18) Confirmation of the chlorinated herbicides and the chlorinated phenols by Dohrmann Microcoulometric Titrating System.

(a) The left over sample from the electron capture detection analysis is further concentrated down to approximately 0.100 ml, and the whole sample is injected into the gas chromatograph and detected by the microcoulometric system for halogens.

c. Extraction or Partition of Chlorinated Phenoxy Acids and Chlorinated Phenols

(1) Pour the ether extract from Step b. of the total phenoxyacid herbicides and its esters into another 250 ml separatory funnel with 50 ml of 5 percent $NaHCO_3$ solution. Shake and wait for a few minutes for the two layers to separate. Repeat twice. Save both layers. The aqueous layer will contain the chlorinated phenoxy acid and chlorinated phenols. The ether layer will contain the esters.

(2) Dry the ether layer over anhydrous Na_2SO_4 and add 0.5 ml benzene. Transfer to a Kuderna-Danish evaporator-concentrator apparatus with 1 ml volumetric flask. Concentrate the extract to about 0.5 ml, using a fluidized sand bath at 70°C or lower. During the ether transfer, it is necessary to crush the caked $NaSO_4$ to obtain a quantitative transfer.

(3) The benzene layer is pipetted from the receiver and passed through a micro cleanup column of florisil with more benzene to a volume of 5 ml, then concentrated down to 0.5 ml for gas chromatography.

(4) Transfer the aqueous layer containing the chlorinated phenoxy acid and chlorinated phenols from Step a. to a separatory funnel and acidify with H_2SO_4 acid. Saturate the aqueous layer with ether and extract with 50 mls diethyl ether three times. Dry the ether layer over anhydrous acidic Na_2SO_4. Discard aqueous layer. Allow the extract to remain in contact with Na_2SO_4 in an explosion-proof refrigerator for two hours or overnight.

(5) Transfer the ether solution into a Kuderna-Danish evaporator-concentrator apparatus with a 5 ml volumetric flask and add 0.5 ml benzene. Concentrate the extract to about 0.5 ml, using a fluidized sand bath at 70°C or lower. During the ether transfer, it is necessary to crush the caked Na_2SO_4 to obtain a quantitative transfer.

(6) When the concentrated extract is cool, add 0.5 ml of 14 percent BF_3-methanol reagent for phenoxy acid. When chlorinated phenols are analyzed together with phenoxy acid, then use diazomethane (dropwise until yellow color persists). Heat the contents at 50°C for 30 minutes in a sand bath or water bath).

(7) Cool the methylated sample and add 4.5 ml of 5 percent aqueous Na_2SO_4 solution to the reaction mixture, shake for one minute, allow to stand for approximately three minutes for phase separation. Cool the sample which has been methylated with diazomethane and completely destroy the diazomethane.

(8) The benzene layer is pipetted from the receiver and passed through a micro cleanup column of florisil with more benzene to a volume of 5 ml. It is then concentrated down to 0.5 ml for analysis.

(9) Gas chromatograph the methyl ester of chlorinated phenoxy acid through the same gas chromatographic columns as chlorinated pesticides.

(10) Compare with known quantities of prepared herbicide standards.

G. ACCURACY AND COMMENTS

1. Minimum Measureable Concentration of Herbicide in the Water Sample

2,4-D	200 ppt
2,4,5-T	20 ppt

2. Discussion of the above minimum measurable concentration of herbicide:

a. Using the procedure, accurate analysis of most water samples can be routinely accomplished. Amounts less than the above detectable limits can be detected by analyzing a larger sample volume or reducing the volume of extract to less than 5 ml. Not all extracts, however, can be reduced to such a low volume without an accompanying buildup of excessive interferences.

b. Ultramicro analytical techniques must be used to determine nanogram concentrations of pesticides found in the environment. For analytical results to be meaningful, glassware should be properly washed and heat treated at 300°C. Extensive cleanup is required because interfering impurities are greater than pesticide found. Recovery of pesticides from the environment averages from 85 percent to 114 percent.

c. All glassware and reagents used should be free of interfering compounds. A blank and standard should be analyzed with the samples until the analyst becomes proficient.

"It was found that prompt handling of samples is necessary if the results of the analysis are to be representative of the condition of the water at the time of sampling. A water sample was selected from an area which had been sprayed for about 1-1/2 years with 2,4-D. Added 2,4-D almost completely disappeared after the spiked sample was allowed to stand at 72° - 74°F. in a stoppered bottle for 10 days. Apparently, in water courses and soils which are regularly exposed to 2,4-D, certain organisms may develop the capability to degrade the chemical. Shipping samples from the collection point to the laboratory may take too long and means for resolving this problem must be found. Perhaps 'icing' or chemical fixing' and air shipment may be required."[1]

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[1] Determination of Phenoxy Acid Herbicides in Water by Electron Capture and Microcoulometric Gas-Chromatography, by D.F. Goelitz and W.L. Lamar, U.S.G.S. WSP-1817-C. Draft copy from authors.

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II. GENERAL METHOD FOR CHLOROPHENOXY ACIDS FOR BIOLOGICAL MATERIAL

A. REAGENTS

1. Benzene, Pesticide Grade Quality
2. Hexane, Pesticide Grade Quality
3. Ethyl Ether, Pesticide Grade Quality
4. Petroleum Ether, Pesticide Grade Quality
5. Concentrated Sulfuric Acid
6. Anhydrous Sodium Sulfate
7. Florisil, Calcined at 650°C and stored at 130°C
8. BF_3-Methanol Reagent
9. Acetonitrite, Pesticide Grade Quality
10. Methanol, Pesticide Grade Quality

B. GLASSWARE

1. Liquid Chromatography Column, 22 mm ID
2. Separatory Funnels
3. Kuderna-Danish Evaporator
4. Erlenmeyer flasks
5. Beakers

C. EQUIPMENT

1. Gas Chromatograph, Tracor, Model 220, Dual Column, with two Ni^{63} Electron capture detectors and a digital integrator, VIDAR 6300, Autolab, with teletype attachment.

a. A 6 ft U-tube, glass column packed with 1.5% OV-17/1.95% QF-1 on 80/100 mesh Gas Chrom Q was connected to detector No. 1.

b. A 6 ft U-tube, glass column packed with 4% SE-30/6% QF-1 on 80/100 mesh Gas Chrom Q connected to detector No. 2.

c. Oven Temperature - 190°C.

d. Detector Temperature - 350°C.

e. Injector Temperature - 225°C.

f. Carrier Gas - Nitrogen (prepurified) 80 ml per min.

2. Gas Chromatograph/Mass Spectrometer, Finnigan Model 3000D interfaced with a system/150 data handling system.

a. Gas Chromatograph

(1) Column - 5 ft U-Tube, glass, packed with 3% OV-1 on 80/100 mesh Gas Chrom Q.

(2) Column Oven Temp. - 160°C.

(3) Injector Temperature - 225°C.

(4) Carrier Gas - Helium 25 ml per min.

(5) Sample injection - 5 μl.

(6) Transfer line - 180°C.

b. Mass Spectrometer

(1) Electron Energy - 70 eV

(2) Mass Range - 50-300 amu

(3) Pressure - 3×10^{-5} Torr.

(4) Sensitivity - 10^{-7} amp per volt

D. PREPARATION OF STANDARDS: Herbicide standards were prepared from the methyl esters, of 2,4-D and 2,4,5-T. Concentration of the standard solution for Gas Chromatography was 10 picograms (10×10^{-12}g) per microliter (μl) of each ester, in hexane. Concentration of standard for GC/MS was 0.1 nanograms (0.1×10^{-9}g) per microliter (μl) of each ester, in benzene.

E. PROCEDURE

1. Extraction of Acids

a. Biological Material

(1) One third of total sample material is placed in a blender and homogenized with anhydrous Na_2SO_4 until a uniform mixture is obtained.

(2) Transfer mixture to a beaker, add 25 ml of 10% H_2SO_4 in methanol and then enough ethanol to cover entire sample by 1 inch. Stir for 20 min.

(3) Pour into Erlenmeyer flask and evaporate on steam bath with a jet of air until about 35 ml ethanol remains.

(4) Transfer to 500 ml separatory funnel with 200 ml 50% ethyl ether in petroleum ether, add 50 ml 4% $NaHCO_3$ and shake carefully.

(5) Extract by isolation of acids procedure.

b. Non-biological Material

(1) Sediment Material

(a) Weigh 2g of dry sample material into a screw cap tube about 15 cm in length.

(b) Add 10 ml of 1:3 benzene-propanol mixture and rotate on a Fisher "Roto-Rack" at 40 rpm for 2 hours.

(c) Filter suspension thru a hexane washed Whatman #2 filter paper and collect the filtrate in a clean test tube.

(d) Evaporate to about 0.5 ml.

(e) Sample ready for methylation.

(2) Coral Material

(a) 100 g of coral are broken up into small pieces and placed in a 400 ml beaker.

(b) Add sufficient slightly acidified benzene to cover the coral.

(c) Stir mixture for about 30 minutes using a magnetic stirrer. Decant benzene and save. Repeat extraction two additional times. Collect benzene in same container.

(d) Evaporate benzene to almost dryness using gentle heat with a slow air current.

(e) Sample ready for methylation.

2. Isolation of Acids (Biological Material)

a. After releasing pressure in the separatory funnel several times, shake vigorously for 1 minute. Let layers separate.

b. Drain bottom aqueous layer into another 500 ml separatory funnel. Repeat extraction twice using 15 ml ethanol and 40 ml $NaHCO_3$ solution each time.

c. Combine the aqueous phases and discard the organic phase. Extract the combined aqueous phase twice using 25 ml $CHCL_3$ each time. Drain off the $CHCL_3$ and discard.

d. Carefully acidify the aqueous solution with 25 ml 10% aq. H_2SO_4. Extract acidified solution three times, using 30 ml benzene each time. Drain each benzene extract through a plug of cotton into a beaker.

e. Rinse cotton plug with benzene after the third benzene extract has filtered through. Remove cotton and replace funnel in beaker.

f. Evaporate sample just to dryness on a steam bath.

g. Sample ready for methylation.

3. Methylation of Acids

a. Make sample to a volume of 0.5 ml with benzene. Add 1 ml of BF_3/methanol reagent and mix.

b. Place on steam bath and boil for approximately two minutes.

c. Cool and add about 4.5 ml of 5% aqueous Na_2SO_4 solution, shake and allow to stand for phase separation.

d. Benzene layer is ready for clean-up.

4. Clean-up of Methylated Acids

a. Acetonitrite Partitioning: Only fatty samples were partitioned with petroleum ether - acetonitrite prior to florisil clean-up. The non-fatty samples were passed through florisil column for clean-up without partition.

(1) Add petroleum ether to the sample extract so that total volume in a 125 ml separatory funnel is 15 ml.

(2) Add 30 ml of acetonitrite saturated with petroleum ether. Shake vigorously 1 min. and let layers separate.

(3) Drain acetonitrite into a 1 liter separatory funnel containing 650 ml H_2O, 40 ml saturated N_aC_1 solution and 100 ml petroleum ether.

(4) Extract petroleum ether solution in the 125 ml separator with three additional 30 ml portions of acetonitrite saturated with petroleum ether, shaking vigorously for 1 min each time. Combine all extracts in the 1-liter separator.

(5) Mix 1 liter separator thoroughly 30-45 seconds. Let layers separate and drain aqueous layer into second 1-liter separator.

(6) Add 100 ml petroleum ether to second separator, shake vigorously 15 seconds, and let layers separate.

(7) Discard aqueous layer, combine petroleum ether with the petroleum ether in original separator and wash with two, 100 ml portions H_2O.

(8) Discard washings and drain petroleum ether layer through column of anhydrous Na_2SO_4. Rinse column with three (about 10 ml) portions of petroleum ether.

(9) Evaporate combined extract and rinses to 5-10 ml in Kuderna-Danish concentrator for transfer to florisil column.

b. Florisil Column

(1) Prepare 22 mm ID column that contains approximately four inches of activated florisil topped with about 1/2 in. anhydrous Na_2SO_4.

(2) Pre-wet column with 40-50 ml petroleum ether. Place Erlenmeyer flask under column to receive eluate.

(3) Transfer sample extract to column letting it pass through at about 5 ml/min.

(4) Rinse extract container and transfer rinses to column, and rinse walls of chromatographic column with additional small portions of petroleum ether.

(5) Elute column at about 5 ml/min. with 200 ml 10% ethyl ether/petroleum ether eluant.

(6) Concentrate eluate to appropriate volume for analysis.

c. Gas Chromatography - Electron Capture Detector (EC): 5 microliters of the eluate are injected into each of the two columns. Chromatograms are analyzed for peaks which have the same retention time as that of the methyl ester standards of 2,4-D and 2,4,5-T. The practical sensitivity of the Electron Capture to standard solutions of methyl esters of 2,4-D and 2,4,5-T is 50 picograms (50×10^{-12} grams) of each.

d. Gas Chromatography/Mass Spectrometry (GC/MS): Samples which have peaks of the same retention times as the methyl esters of 2,4-D and 2,4,5-T are analyzed by GC/MS. 5 μl of sample are injected into the injector part of the GC/MS systems. The methyl esters of 2,4-D and 2,4,5-T can be confined by using the data handling system of the GC/MS by comparing the fragmentation patterns of the suspected compounds with those of the standards. The practical sensitivity of the GC/MS to standard solutions of the methyl esters of 2,4-D and 2,4,5-T is 0.5 nanograms (0.5×10^{-9} grams) of each.

III. TCDD ANALYSIS: The TCDD analyses reported in the Environmental Statement Part III were accomplished by the EPA Pesticide Laboratory at Bay St Louis MS and the Perrine Laboratory, Perrine FL; therefore, the analytical procedures are not included in this appendix.

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APPENDIX K

DISPERSION MODEL STUDY

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1. GENERAL: The main effort, in attempting to define the effects of burning Orange herbicide on the air quality at and around Johnston Island, was directed toward the use of diffusion equations to predict the ground level concentrations.

2. DIFFUSION MODEL AND INPUT PARAMETERS:

a. The concentration, C, of gas or aerosols (particles less than about 20 microns diameter) at the coordinate points x, y, z, from a continuous source with an effective emission height, H, is given by equation (1). The notation used to depict this concentration is C (x, y, z, H). H is the height of the plume center line when it becomes essentially level, and is the sum of the physical stack height, h, and the plume rise, ΔH. The following assumptions are made: the plume spread has a Gaussian distribution in both the horizontal and vertical planes, with standard deviations of plume concentration distribution in the horizontal and vertical of σy and σz, respectively; the mean wind speed affecting the plume is u; the uniform emission rate of pollutants is Q; and total reflection of the plume takes place at the earth's surface, i. e., there is no deposition or reaction at the surface.

$$C\ (x, y, z; H) = \frac{Q}{2\pi\sigma z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma y}\right)^2\right] \left\{ \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma z}\right)^2\right] \right\} \quad (1)$$

For concentrations calculated at ground level (z=o), the equation simplifies to:

$$C\ (x, y, o; H) = \frac{Q}{\pi\sigma y\, \sigma z\, u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma y}\right)^2\right] \quad (2)$$

Where the concentration is to be calculated along the center line of the plume (y=o):

$$C\ (x, o, o; H) = \frac{Q}{\pi\, \sigma y \sigma z\, u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma z}\right)^2\right] \quad (3)$$

At distance equal to or greater than 2 x_L:

$$C\ (x, o, o; H) = \frac{Q}{\sqrt{2\pi}\,\sigma y\, L\, u} \quad (4)$$

X_L is the distance downwind where the vertical diffusion starts being affected by the inversion.

The Holland Plume Rise equations was used to determine H:

$$\Delta h = \frac{Vsd}{u} \left[1.5 + 2.68 \times 10^{-3} p \left(\frac{Ts - Ta}{Ts}\right) d\right] \qquad (5)$$

This is modified for atmospheric stability so the result is:

$$H = h + \Delta h \, (1.4 - .1\, P) \qquad (6)$$

The mixing depth, L:

$$L = (6 - P)\,(121)\,(T - T_d)\,/\,6 + \frac{(P)\,(0.087)\,(u_z + 0.5)}{12\, f \ln(z/zo)} \qquad (7)$$

The mixing depth of the atmosphere (thickness of the boundary layer) can be defined as that layer where vigorous mixing takes place due to thermal and mechanical turbulence.

TABLE K - 1

INPUT PARAMETERS

	J. I.	Ship
Stack height (m)	15.24	12
Stack diameter (m)	1.5	3
Stack temperature (^{o}F)	1600	1625
Stack velocity (m/sec)	18.17	20
Air temperature (^{o}F)	76.5	76.5
Air pressure (mbs)	1024	1024
Mixing depth (m)	719	719

3. RESULTS:

a. In order to determine a conservative estimate of the ground level concentration, the following parameters and considerations were used: the highest ground level concentration will occur with high winds and an unstable atmosphere; no deposition or reaction at the surface; no rain-out of the plume; the ship standing still in the water; and using the Holland Plume Rise Eq.

b. Figure K-1 shows the center line ground level concentration for a HCl plume at Johnston Island. The emission rate is 37,000 lbs/day. The maximum (1.85 ppm) concentration occures at 0.2 km downwind and decreases to 0.007 ppm at 10 km downwind. Figure K-2

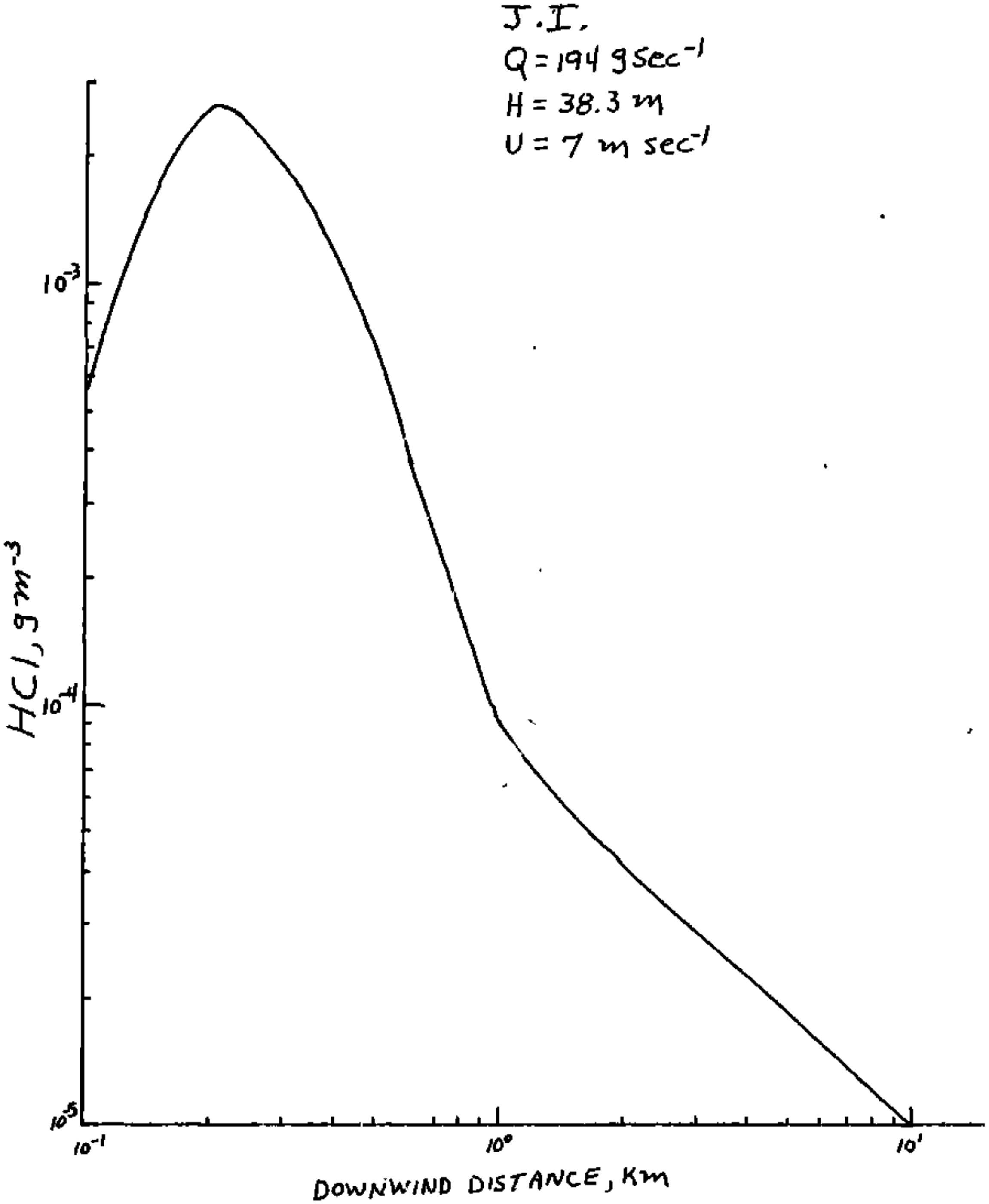

Figure K-1. Center line ground level HCl concentration, Johnston Island.

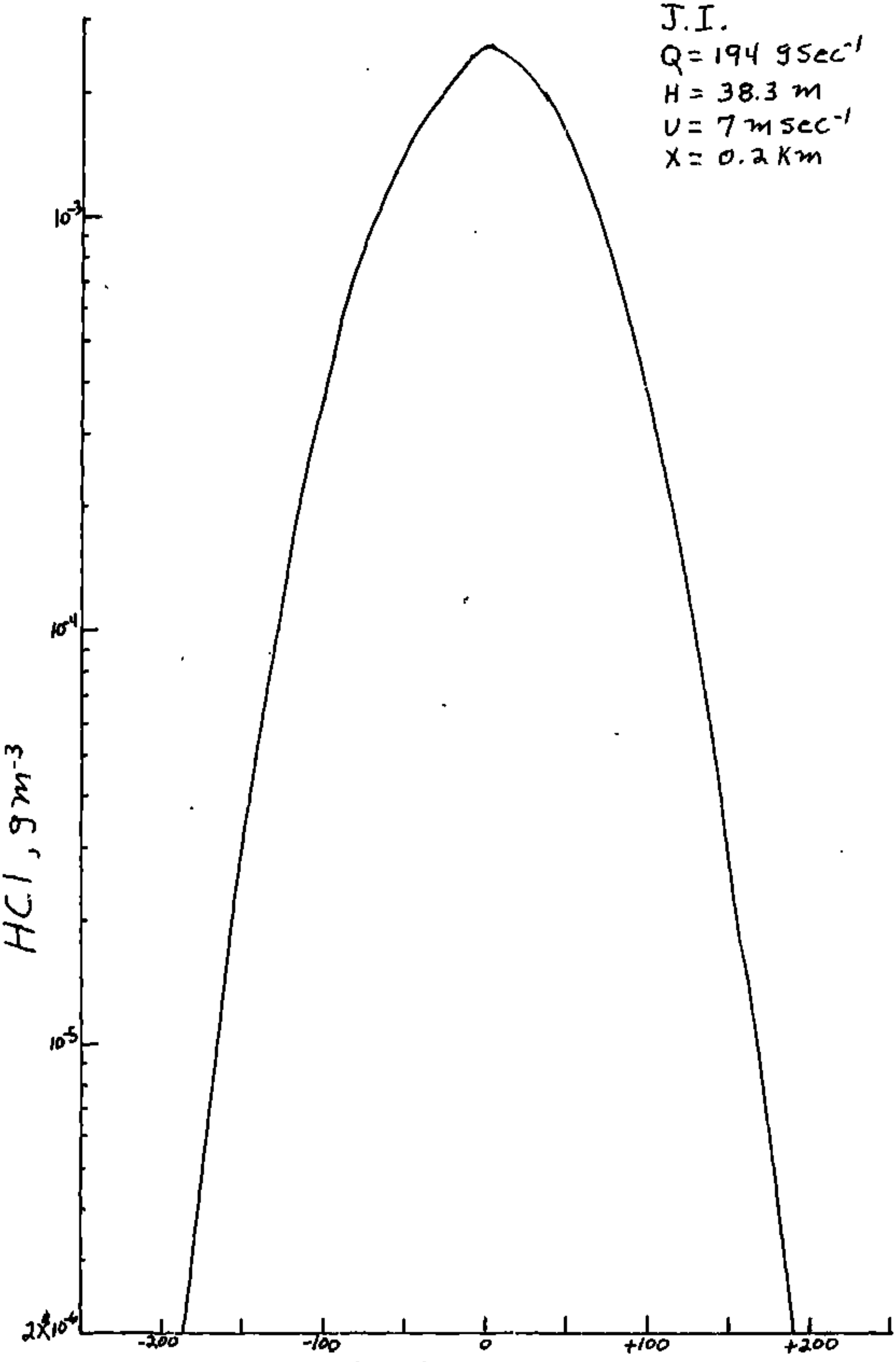

Figure K-2. Horizontal HCl concentration at 0.2 km downwind, Johnston Island.

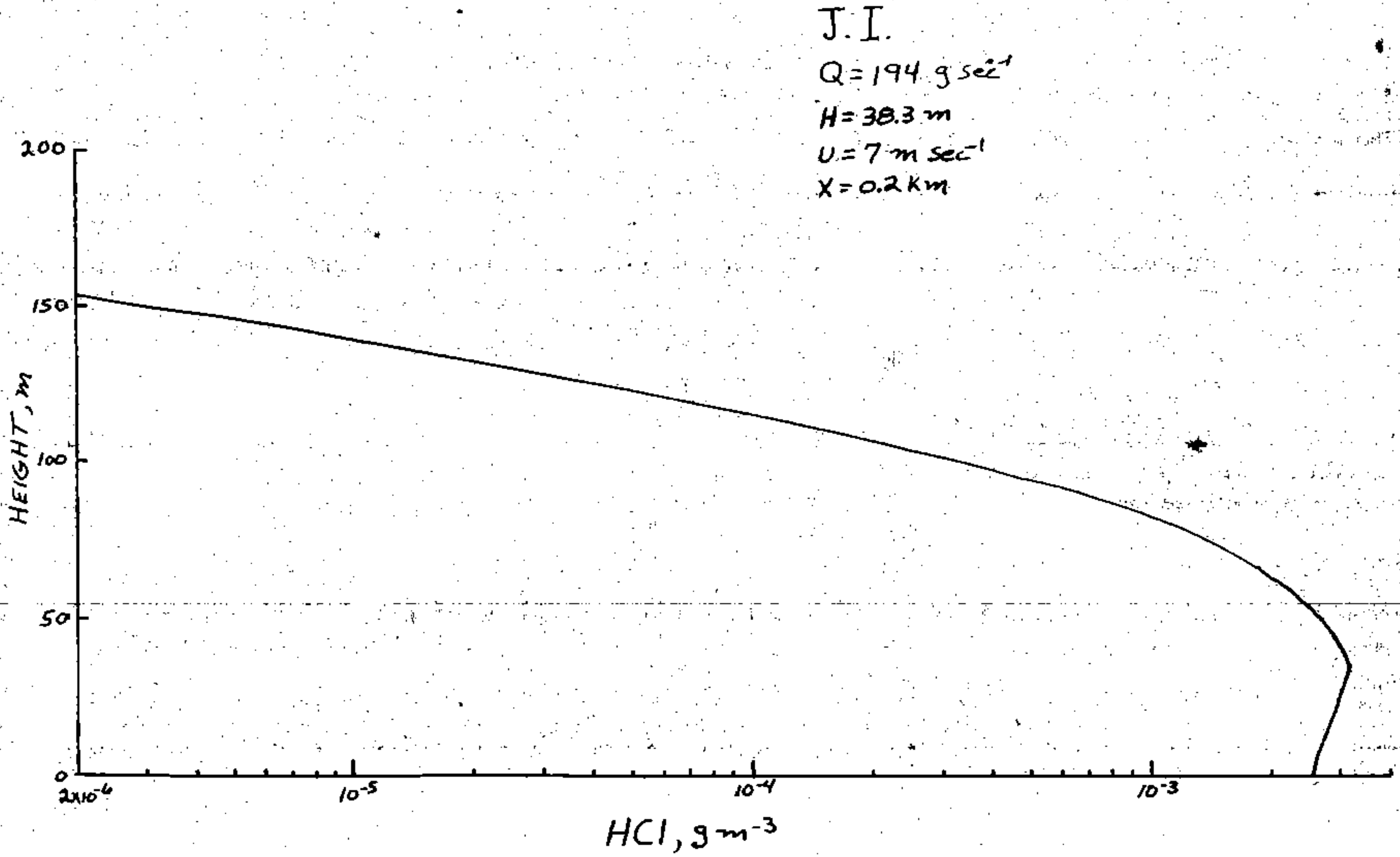

Figure K-3. Vertical HCl concentration at 0.2 km downwind, Johnston Island.

shows the horizontal extent of the concentration at 0.2 km downwind. Figure K-3 shows the vertical extent of the plume. Figure K-4 shows the ground level isopleths and area, A, enclosed by the isopleths.

Figures K-5 through K-10 are for a ship operating west of Johnston Island. Emission rates of 170 tons /day of Orange herbicide were used. Figure K-5 and K-8 show the center line ground level concentrations. The maximum 2.28 ppm (HCl) and 0.81 ppb (Orange) occur at 0.47 km downwind. At 10 km downwind the concentrations are 50.0 ppb (HCl) and 19.4 ppt (Orange). Figures K-6 and K-9 show the horizontal concentration, while figure K-7 and K-10 show the vertical.

4. ENVIRONMENTAL IMPLICATIONS:

a. It is very difficult to extrapolate these results to the actual situation at and around Johnston Island. The parameters used for the study are not necessarily those which will exist when the incineration takes place. These parameters were used in order to provide a conservative estimate (worst case) and these conditions are never expected to be reached.

b. Factors that will decrease the ground level concentration shown in this study for the ship are: the ship will be moving during incineration; the atmosphere is more towards neutral or stable, than unstable; the mixing depth will be higher; and there will be a certain amount of deposition and reaction with the surface and rain-out of the plume. For Johnston Island incineration, all of these factors, except movement of incinerator, also apply.

c. Another fact evident is that under all conditions studied, a majority of the time, the concentrations of interest will exist over the ocean, due to the prevailing wind direction at Johnston Island.

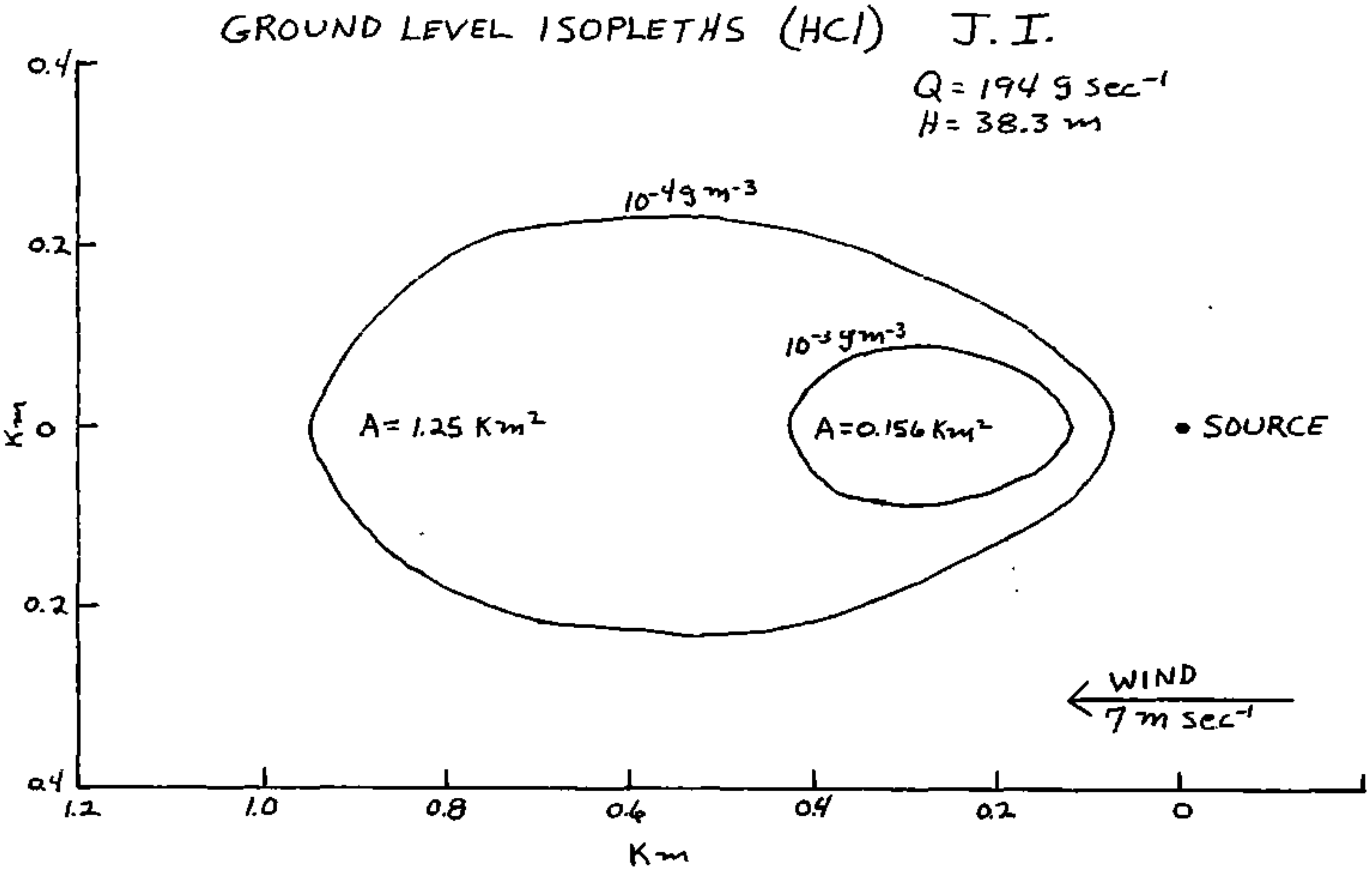

Figure K-4. Ground level isoplethes, Johnston Island.

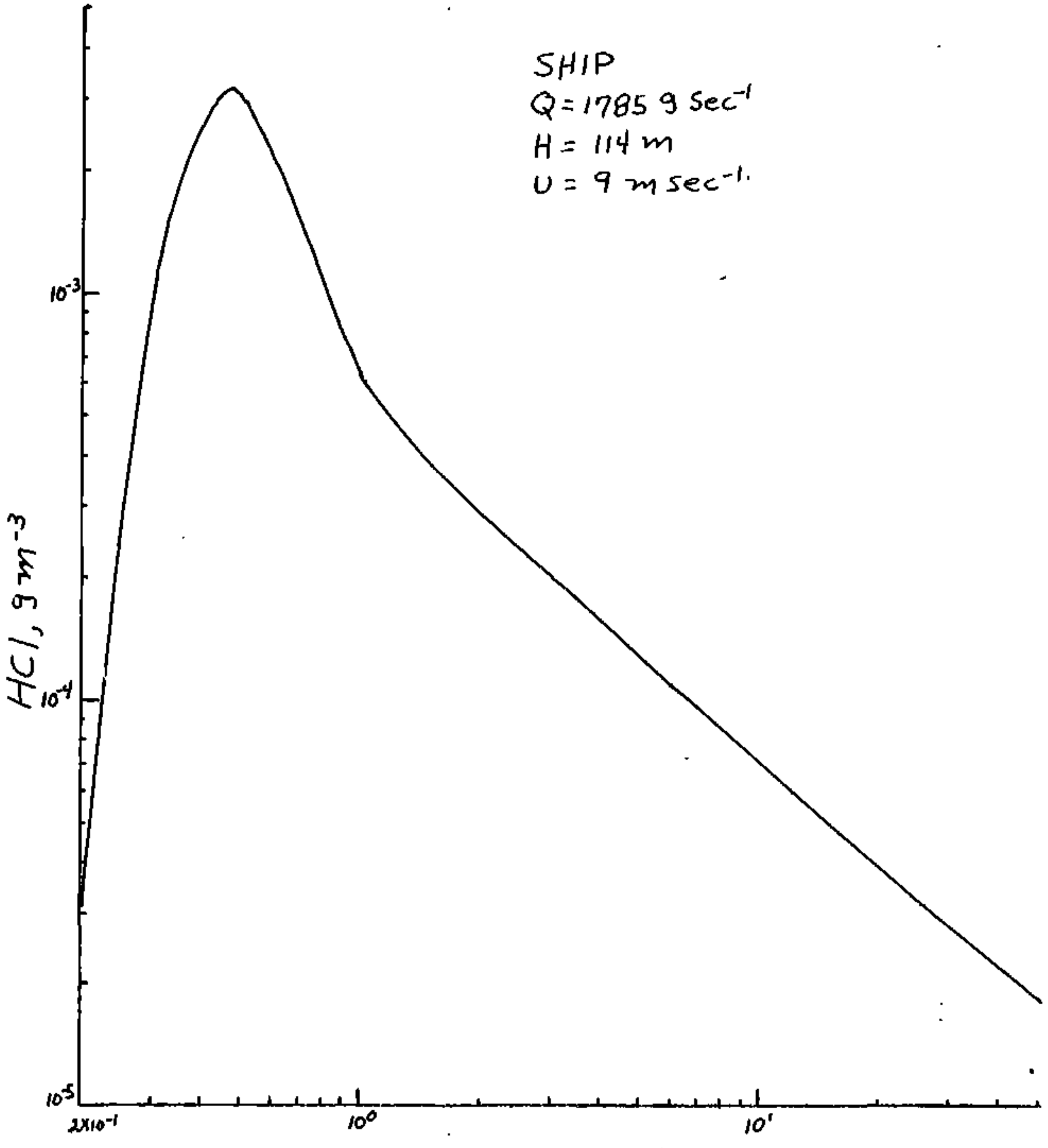

Figure K-5. Center line ground level HCl concentration, ship incinerator.

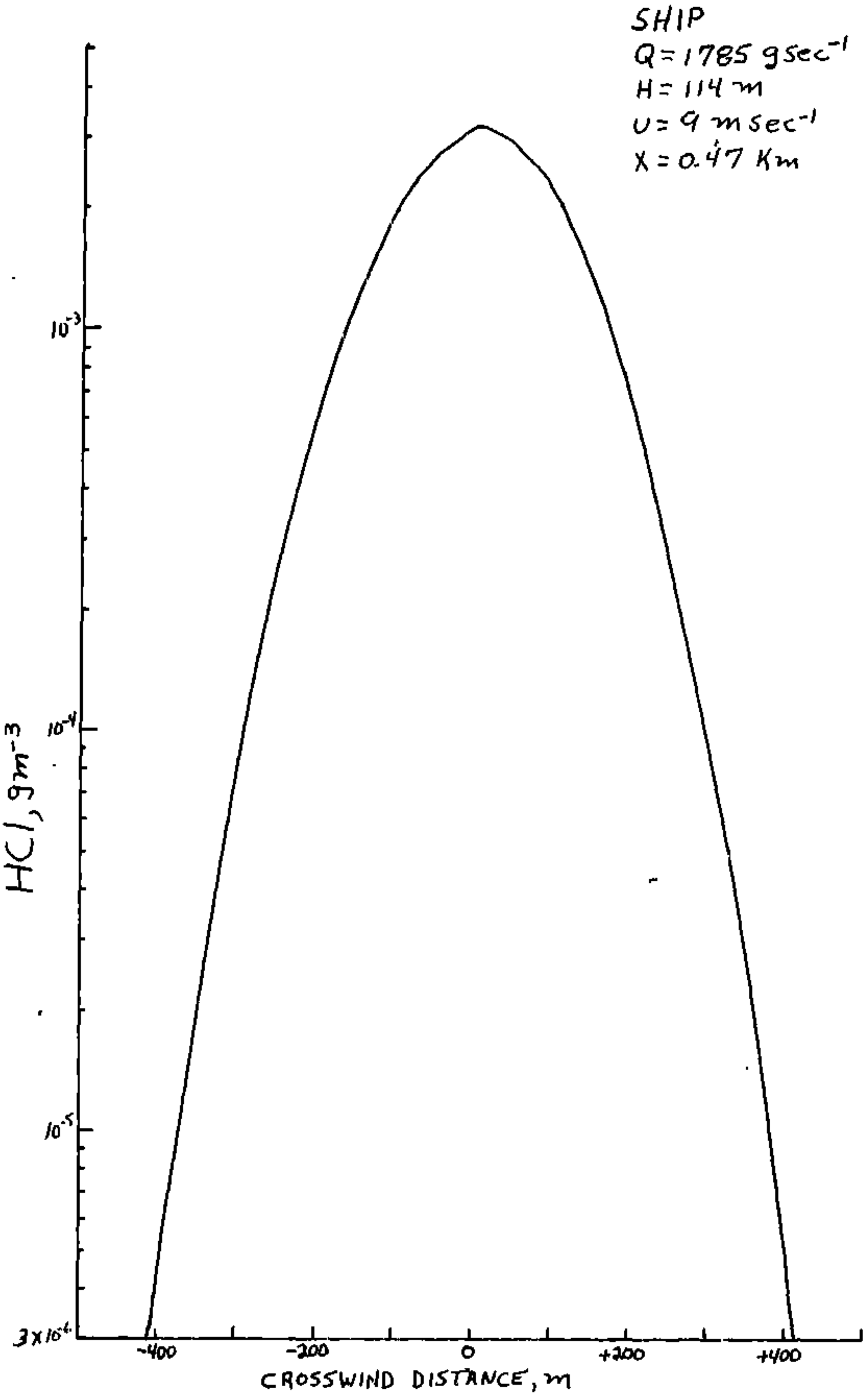

Figure K-6. Horizontal HCl concentration 0.47 km downwind, ship incinerator.

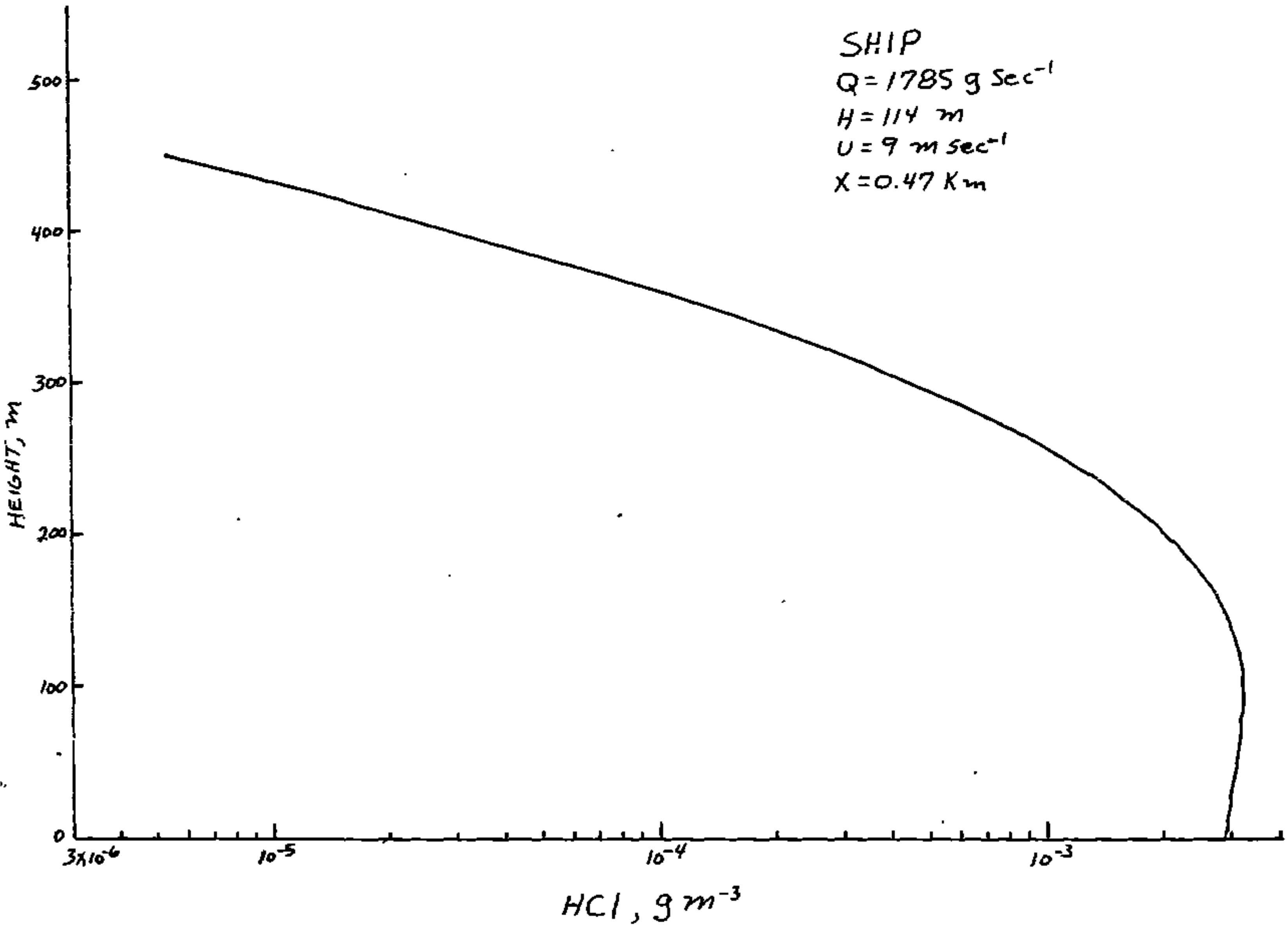

Figure K-7. Vertical HCl concentration at 0.47 km downwind, ship incinerator.

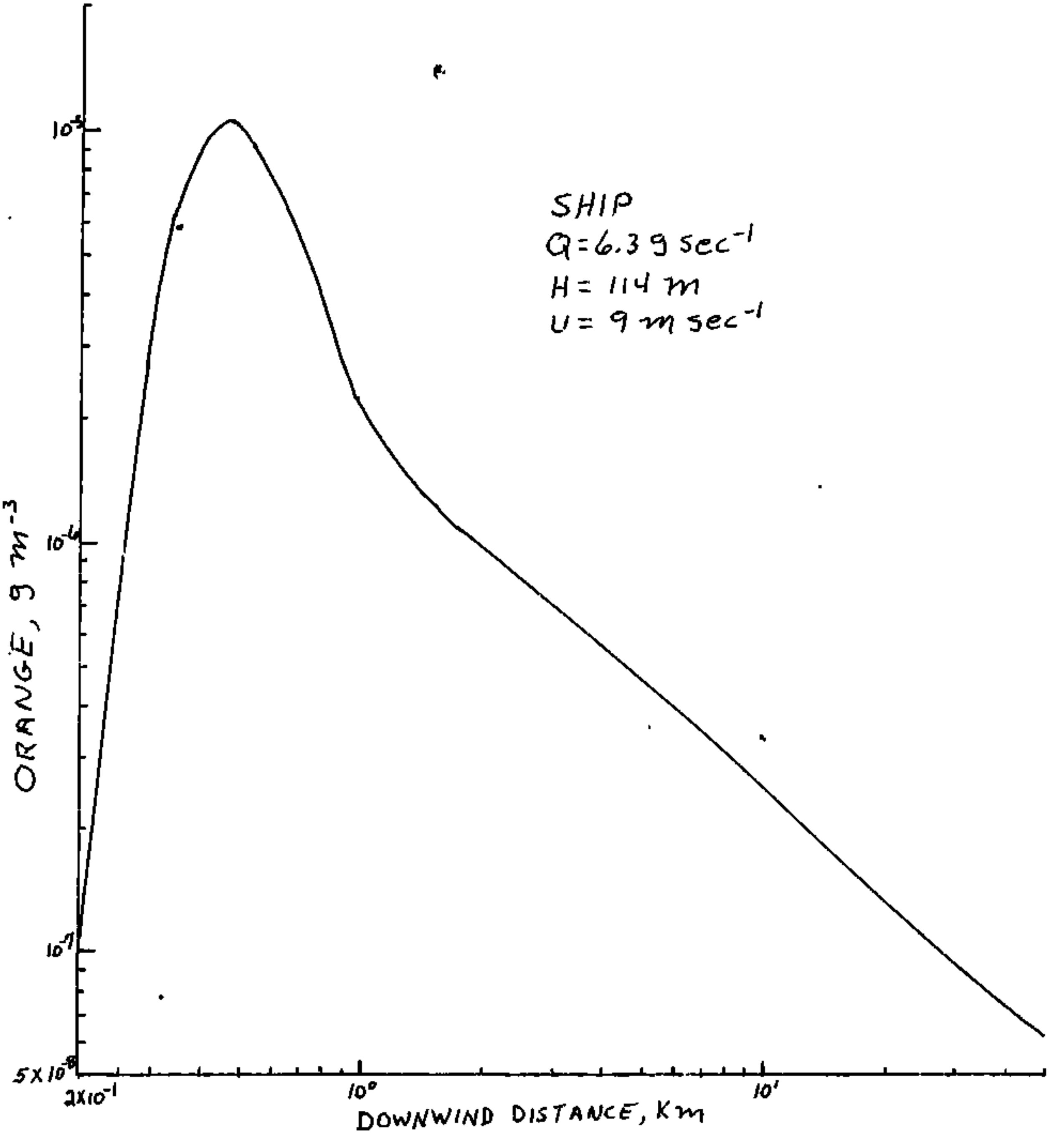

Figure K-8. Center line ground lever Orange herbicide concentration, ship incinerator.

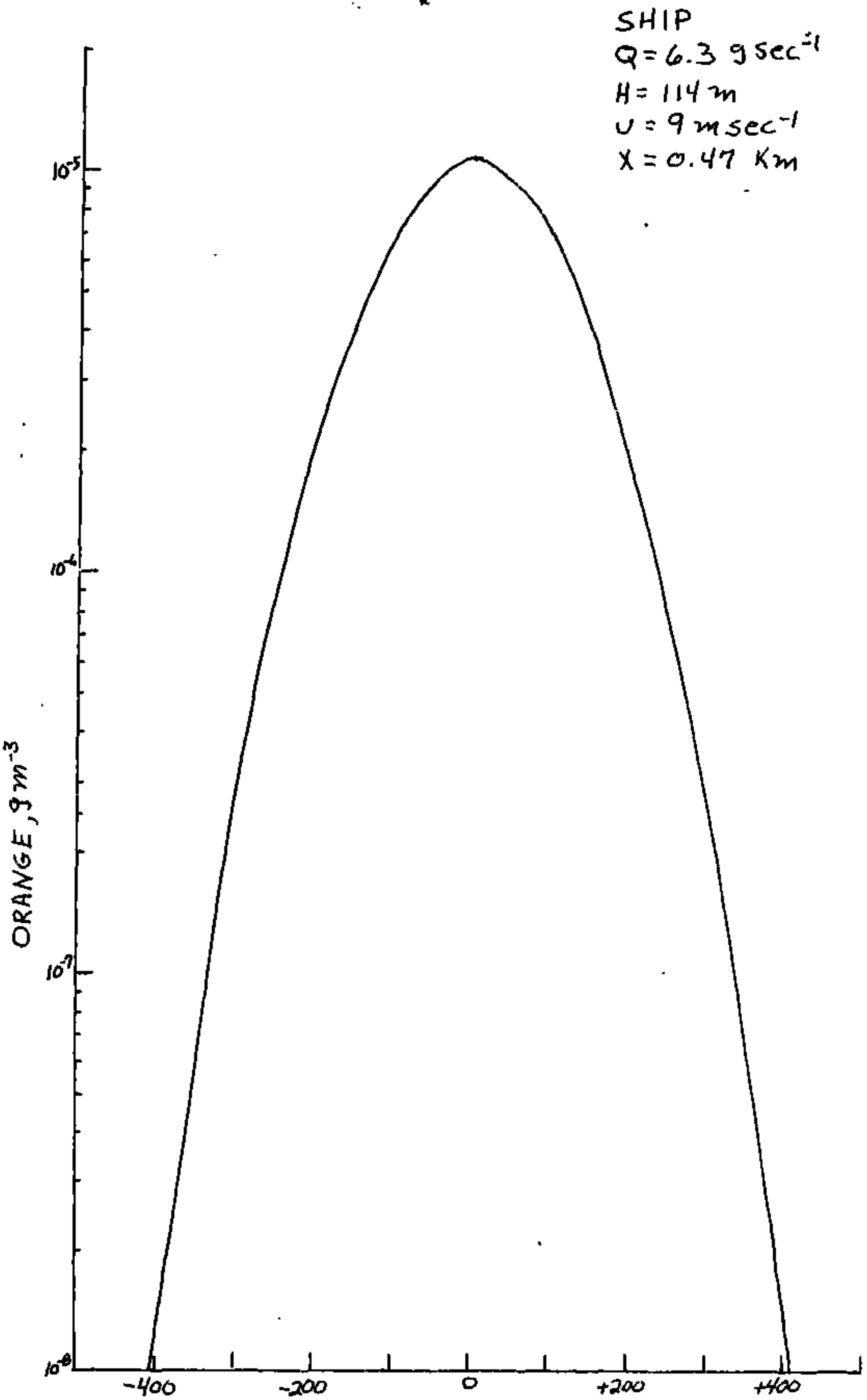

Figure K-9. Horizontal Orange herbicide concentration at 0.47 km downwind, ship incinerator.

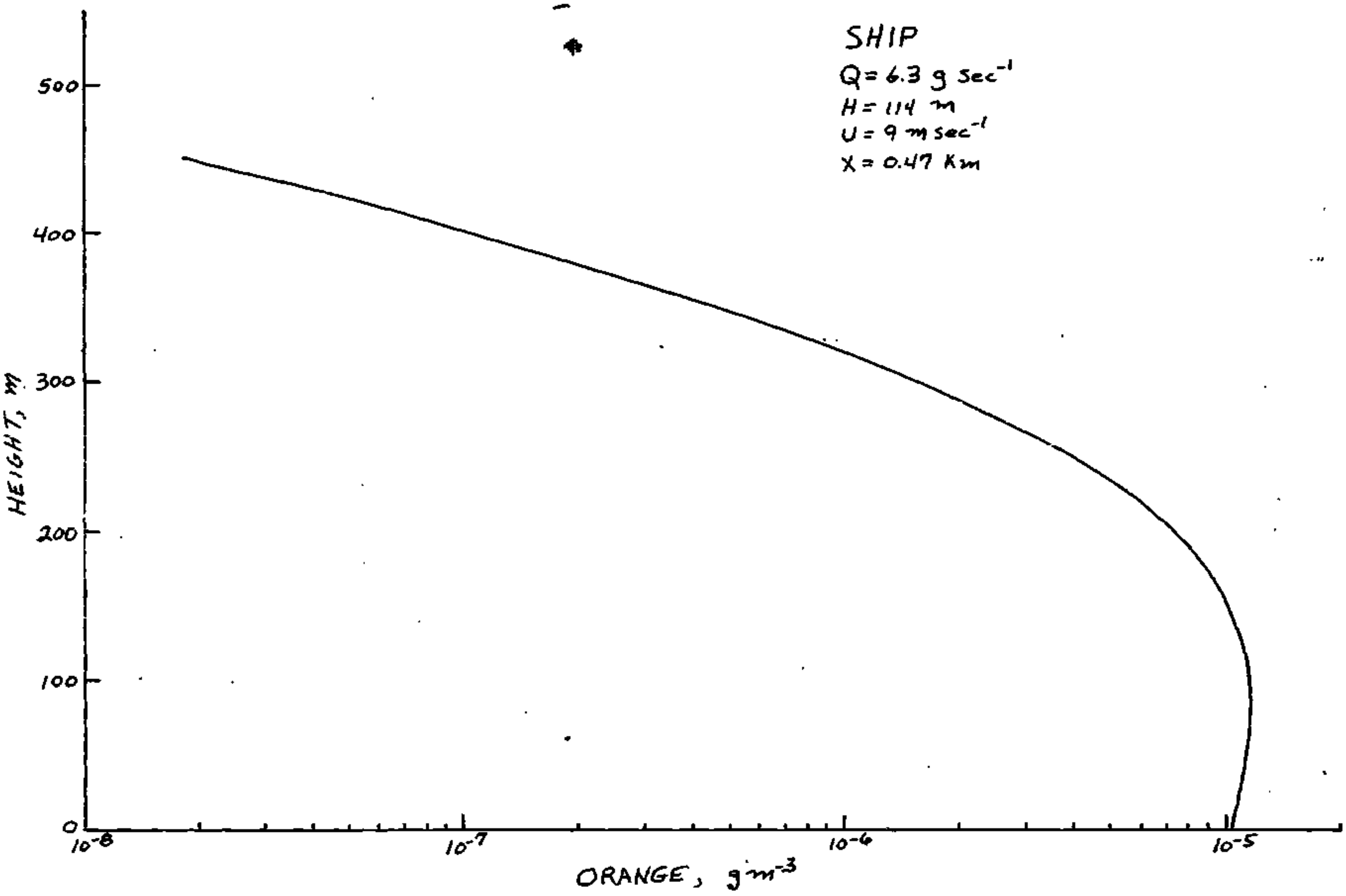

Figure K-10. Vertical Orange herbicide concentration at 0.47 km downwind, ship incinerator.

5. REFERENCES:

. Beals, G. A., "Guide to Local Diffusion of Air Pollutants," Air Weather Service Technical Report 214, (1971).

Lydon, D., _Plume Rise,_ USAF Environmental Technical Applications Center Report No 6611, (1973).

Nozaki, K. Y., _Mixing Depth Model Using Hourly Surface Observations,_ USAF Environmental Technical Applications Center Report No 7053 (1973).

Turner, D. B. "Workbook for Atmospheric Dispersion Estimates." US Department of Health, Education and Welfare, Cincinnati, OH, Revised 1969.

"Meteorology and Atomic Energy 1968" United States Atomic Energy Commission.

APPENDIX L

COMMENTS TO:

DRAFT ENVIRONMENTAL STATEMENT - DISPOSITION OF ORANGE HERBICIDE BY INCINERATION

January 1972--AF-ES-72-2D

(This Appendix consists of comments received from 9 agencies resulting from their review of the above Draft Statement)

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STATE OF MISSISSIPPI
EXECUTIVE CHAMBER
JACKSON

WILLIAM LOWE WALLER
GOVERNOR

February 11, 1972

Honorable Aaron J. Racusin
Acting Assistant Secretary of the Air Force
Installation and Logistics
Office of the Secretary
Department of the Air Force
Washington, D. C. 20330

Re: Draft Environmental Statement-Disposition of Orange Herbicide by Incineration - January 1972--AF-ES-72-2D

Dear Mr. Racusin:

In compliance with applicable regulations, the above captioned environmental statement has been reviewed by appropriate State agencies concerned with various aspects of the disposition. Comments from State agencies are summarized in the latter prepared by the Air and Water Pollution Control Commission, and are enclosed herewith.

It is my opinion that the attached environmental statement is satisfactory.

I recommend that full consideration be given to the comments of our agencies in the final review.

Sincerely,

Bill Waller
BILL WALLER
GOVERNOR

Air & Water Pollution Control Commission

STATE OF MISSISSIPPI

OMMISSIONERS
AMES W. CARRAWAY, CHAIRMAN
ASSFIELD
TATE PLANT BOARD
. T. GUICE, JR., VICE CHAIRMAN
IL & GAS BOARD
. F. BORTHWICK
OARD OF HEALTH
OE D. BROWN
IARINE CONSERVATION
OMMISSION
. J. DEMORAN
. E. GUPTON
ACKSON
'ERMIT A. JONES
ANTON

Glen Wood, Jr.
EXECUTIVE DIRECTOR
POST OFFICE BOX 827 TELEPHONE 354-6783
SIXTH FLOOR ROBERT E. LEE BUILDING
JACKSON, MISSISSIPPI 39205

COMMISSIONERS
GAME & FISH COMMISSION
BILLY JOE CROSS
BOARD OF WATER
COMMISSIONERS
JACK PEPPER
CHARLES W. ELSE
YAZOO CITY

ASSOCIATE MEMBERS
STATE PARK SYSTEM
SPENCER E. MEDLIN
A & I BOARD
PAUL BURT
GEOLOGICAL SURVEY
W. H. MOORE

February 8, 1972

Mr. Edward A. May, Jr.
Assistant to the Coordinator
Federal-State Programs
Office of the Governor
510 Lamar Life Building
Jackson, Mississippi

Dear Mr. May:

This letter is in reference to yours of January 26, concerning the draft environmental impact statement entitled "Disposition of Orange Herbicide by Incineration". A meeting was held in our office with concerned agencies of the State on February 3, to conduct a technical review of this statement and to coordinate the state's position in this matter. Copies of the impact statement had previously been forwarded to these agencies.

The consensus of this meeting is enumerated below:

1. Department of the Air Force should explore further possibilities for use of the material under adequate control measures, preferably by the federal government, as in national and state forests or by returning to commercial use through some acceptable channel. Apparently the alternative of giving this material away was not explored. It is felt that destruction of the material would be a needless waste and would create further expense. It is recognized that such action as suggested might require some emergency authority from Environmental Protection Agency but this should pose no great difficulty since a similar material is in everyday use.

2. In the event incineration is taken as the alternative, it is requested that the federal government assume the responsibility for all transportion of the material to the point of incineration and provide all necessary safety measures, such as, but not limited to, shipping materials in small quantities and providing the necessary absorbents at the convenient locations if shipped by rail.

3. It is requested that the material be removed from its present location at Keesler Air Force Base beginning immediately and without regard to the final disposition of the material. It is felt this is absolutely essential because of the proximity of the material to recreational and shellfish waters, as well as large densely populated areas, and further because of the history of hurricanes and tornadoes in that particular section of the country. It is our feeling there are many other areas in the continental United States which would provide a much safer depository for this material.

4. The Mississippi Air and Water Pollution Control Commission should be notified in advance of any proposed movement of the material, of the routes to be taken, and of the safety precautions.

Copies of this statement are being forwarded to all of the involved agencies, as noted on the attached sheet.

Yours very truly,

Glen Wood Jr.

Glen Wood, Jr.
Executive Director

GWjr:js

Copies furnished:

Mr. Billy Joe Cross, Director
Mississippi Game & Fish Commission
Post Office Box 451
Jackson, Mississippi

Mr. Joe D. Brown, Director
Division of Sanitary Engineering
State Board of Health
Post Office Box 1700
Jackson, Mississippi 39205

Mr. Jack W. Pepper, Water Engineer
Mississippi Board of Water Commissioners
416 North State Street
Jackson, Mississippi 39201

Dr. R. A. McLemore, Director
Mississippi Department of Archives and History
Post Office Box 571
Jackson, Mississippi 39205

Attention: Mr. Elbert Hilliard

Colonel Wendell D. Lack, State Forester
Mississippi Forestry Commission
1106 Woolfolk State Office Building
Jackson, Mississippi 39205

Mr. O. T. Guice, Jr., Director
Division of Plant Industry
P. O. Box 5207
State College, Mississippi 39762

Mr. William H. Moore
Director and State Geologist
Mississippi Geological Survey
Post Office Box 4915
Jackson, Mississippi 39216

Mr. Spencer E. Medlin, Comptroller
Mississippi Park System
717 Robert E. Lee Building
Jackson, Mississippi

Mr. William J. Demoran
Marine Biologist
Gulf Coast Research Lab
Post Office Box AG
Ocean Springs, Miss. 39654

Mr. Bobby R. Tramel
Bureau of Sport Fisheries
and Wildlife
Post Office Drawer FW
State College, Miss. 39762

THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

February 18, 1972

Department of the Air Force
HQ USAF/PREV
Washington, D. C. 20330

Dear Sir:

The draft environmental statement titled "Disposition of Orange Herbicide by Incineration," was received by the Department of Commerce for review and comment.

The Department of Commerce has reviewed the draft environmental statement and has the following comments to offer for consideration.

The key question is the completeness of combustion - i.e., the fraction not exidized but carried up the stack. Once this can be estimated, then there is the atmospheric transport and diffusion problem to a point at the nearest habitation or unrestricted area around the disposal plant. There is a 100 foot stack. Combustion temperature is 2500°F (1400°C) for 3 second dwell (p. 11).

Tentative data show orange decomposes at 900° C. (but how long does it take at this temperature? e.g., water boils at 100° C, but a large pot of water must remain at this temperature for sometime before it boils away). See page 15 - the Illinois plant would release 5% of the HCl as a stack effluent.

The combustion of gasoline in an auto engine is only partially complete - and hydrocarbons are emitted as wastes; i.e. unburnt gasoline. The combustion temperature of an auto is undetermined and the dwell time is about 4 millisec, so the analogy may be poor.

The safety of this operation will also depend on how continuously reliable and constant are thb actual temperature/pressure/dwell conditions inside the burner - because it will take more than a year of continuous burning to complete the job. The constancy, uniformity and reliability of the contractors' facility are therefore important questions which probably should be treated in the statement.

We hope these comments will be of assistance to you in the preparation of the final impact statement.

Sincerely yours,

Sidney R Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

FEB 22 1972

Mr. Aaron J. Racusin
Acting Assistant Secretary
of the Air Force
Washington, D.C. 20330

Dear Mr. Racusin:

We have reviewed the Draft Environmental Statement on "Disposition of Orange Herbicide by Incineration". Several questions have arisen that you may wish to consider.

The environmental statement does not contain data to show that effluent emissions would not contain biologically active dioxins. Data to show that dioxins are not emitted into the atmosphere must be provided. The statement does not provide for monitoring stack flume emissions from either of the proposed incinerators.

Information should be provided to assure that the orange herbicide remaining in the emptied containers does not have a higher concentration of dioxin than was present in the lot as a whole. Such a situation would arise if the dioxin settles to the bottom of a drum. If that happens, much of the dioxin would go into the soil instead of being combusted.

Damage to vegetation can occur from 2,4-D and 2,4,5-T in the vapor phase. Shipment of orange to the incineration site should be geared to incineration capacity so that large stocks are not kept in storage at the incineration site.

We believe the environmental impact statement must contain data on temperatures required for total combustion. The statement must also identify the effluent gases, and intermediate breakdown products. For example, incomplete combustion may occur when the incinerator is shut down. Intermediate combustion products may be potentially hazardous.

[illegible]

The biological activity of the effluent gases must be documented and a scrubbing system specified that will assure safety.

The volume of water into which the sodium chloride is discharged and the rate and volume of fresh water inflow should be specified so that the increased salt content of the water can be determined.

We hope these comments are helpful to you.

Sincerely,

T C Byerly

T. C. BYERLY
Assistant Director
Science & Education

Enclosure:
1 copy of Environmental
Statement

EXECUTIVE DEPARTMENT
DIVISION OF PLANNING COORDINATION
BOX 12428, CAPITOL STATION
AUSTIN, TEXAS 78711
PHONE 512 475-2427

IESTON SMITH
GOVERNOR

ED GRISHAM
DIRECTOR

February 25, 1972

Mr. Aaron T. Racusin
Acting Assistant Secretary
of the Air Force
Headquarters USAF/PREV
Washington, D.C. 20330

Dear Mr. Racusin:

The Office of the Governor, Division of Planning Coordination (State Planning and Development Clearinghouse), and affected Texas State agencies have reviewed the draft environmental impact statement for the disposition of Orange herbicide by incineration in Deer Park, Texas.

The Texas Air Control Board presently objects to the proposed project for several reasons which include insufficient technical information in the draft environmental statement and the possible harmful effects to the area by adding additional air pollutants to the atmosphere. The Texas Air Control Board (TACB) has statutory responsibility and authority in matters of air contamination.

The comments received from State agencies are enclosed.

Thank you for the opportunity to review this draft environmental impact statement.

Sincerely,

Ed Grisham

Ed Grisham
Director

EG:gtt

Encl. (4)

cc: Mr. Charles R. Barden, TACB
Mr. Hugh C. Yantis, Jr., TWQB
Mr. James U. Cross, TP&WD
Dr. James E. Peavy, TSDH
Mr. A. T. Traynor, USAF

PARKS AND WILDLIFE DEPARTMENT

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JOHN H. REAGAN BUILDING
AUSTIN, TEXAS 78701

February 14, 1972

Mr. Ed Coker
Division of Planning Coordination
Executive Department
Capitol Station
Austin, Texas 78711

Dear Mr. Coker:

We have reviewed the draft environmental impact statement for the disposal of Orange Herbicide by incineration, and are in general agreement with the method of disposal and the draft statement.

We would recommend that stack gases be monitored for 2,4-D; 2,4,5-T and dioxin to prevent any escape to the atmosphere. If other precautions are taken to prevent loss or spillage of the barrels and if the empty barrels are disposed of properly, the Parks and Wildlife Department would not object to the incineration of Orange Herbicide.

We appreciate having had the opportunity to comment on this draft statement.

Sincerely,

James U. Cross
JAMES U. CROSS
Executive Director

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FEB 15 1972
Div. of Plan. Coord

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EXECUTIVE DIRECTOR
PH. 475-2651
A.C. 512

314 WEST 11TH STREET 78701
P.O. BOX 13246 CAPITOL STATION 78711
AUSTIN, TEXAS

February 1, 1972

Mr. Ed Grisham, Director
Division of Planning Coordination
Office of the Governor
Capitol Station
Austin, Texas 78711

Dear Mr. Grisham:

In response to your memorandum of January 26, 1972, I would like to restate the comments of our letter of November 10, 1971, a copy of which is included in the Draft Environmental Statement for the Disposition of Orange Herbicide by Incineration by the Department of the Air Force.

In restating our previous opinion, I would like to suggest that insofar as water quality is concerned, no environmental statement or special permission is required so long as the disposal by Rollins Purle is carried out within the conditions of waste control order No. 01429 and so long as the solid waste disposal of decontaminated drums is carried out pursuant to state statute. It should be understood that if the disposal of either the Orange herbicide or the drums was proposed to be carried out contrary to state statutes, then this office would decline to authorize the disposal.

Very truly yours,

Hugh C. Yantis, Jr.
Executive Director

HCYjr:go

ccs: All Board Members - Texas Water Quality Board
Mr. Josiah Wheat, Legal Counsel, TWQB

RECEIVED
FEB 3 1972
Div. of Plan Coord

Texas State Department of Health

JAMES E. PEAVY, M.D., M.P.H.
COMMISSIONER OF HEALTH

J. B. COPELAND, M.D.
DEPUTY COMMISSIONER

AUSTIN, TEXAS

February 15, 1972

Honorable Preston Smith
Governor of Texas
State Capitol
Austin, Texas. 78701

ATTENTION: Mr. Ed Grisham

Dear Governor Smith:

The Draft Environmental Statement for the "Disposition of Orange Herbicide by Incineration," prepared by the Department of the Air Force has been reviewed by this Department.

In considering the proposal with regards to possible pollution of the waters of the State, we are in accord with the viewpoints expressed by Mr. Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, in his letter of February 1, 1972, to Mr. Ed Grisham, Director of your Division of Planning Coordination. Mr. Yantis stated that if the project is carried out in such a manner as to control the discharge so that the limitations set forth in Waste Control Order Number 01429 are not exceeded, no conditions will exist which will require special or extra permission.

However, when disposal by incineration is viewed from the standpoint of potential adverse air pollution conditions, we concur with the statements and recommendations offered by Mr. Charles R. Barden, Deputy Commissioner of the Air Control Section of this Department, who also serves as Executive Secretary of the Texas Air Control Board.

Respectfully,

J. E. Peavy

J. E. Peavy, M.D.
Commissioner of Health

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TEXAS AIR CONTROL BOARD

1100 WEST 49th STREET
AUSTIN, TEXAS – 78756

CHARLES R. BARDEN, P. E.
EXECUTIVE SECRETARY

February 14, 1972

Mr. Ed Grisham, Director
Division of Planning Coordination
Office of the Governor
Capitol Station
Austin, Texas 78711

Dear Ed:

Following are our comments on the Draft Environmental Impact Statement for Disposition of Orange Herbicide by Incineration, prepared by the Department of the Air Force in January, 1972:

"Information received since the draft environmental statement on the incineration of Orange herbicide from Kelly Air Force Base was written in October of 1971 makes it inadvisable to allow this operation to be conducted in the State of Texas at this time.

The following factors were considered in evaluating the proposal to incinerate the Orange herbicide in the Rollins Purle incinerator in Deer Park, Texas:

1. The information submitted in the impact statement does not indicate that alternate methods of disposing of the herbicide have been thoroughly explored, or that these methods will be more harmful to the environment than burning the herbicide would be.

2. Technical information submitted with the impact statement is insufficient to determine the feasibility of destroying great quantities of Orange herbicide by incineration. Although the impact statement indicates

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that Rollins Purle, Incorporated will comply with air pollution control regulations, methods of compliance and technical data are lacking; and no mention is made of laboratory facilities or the analytical capability of the Rollins Purle facility. On page twelve of the impact statement, the gravity of the problem is indicated by reference to the need for complete destruction of the Orange material in order to avoid contamination of the environment with hazardous combustion materials or unburned herbicide chemicals. The next sentence reveals that combustion stack emissions and liquid effluent monitoring systems and test methods have not yet been developed. The ultimate responsibility for technical errors and accidents is not clear.

3. The area around the proposed site of incineration, Air Quality Region VII, is a highly industrialized area which has relatively high concentration of air pollutants. The addition of combustion products from the incineration of over two million gallons of Orange herbicide into the atmosphere of this area over a prolonged period could compound an existing problem and might very well prove harmful. It might be desirable to explore the possibility of incinerating the Orange in a federally-owned facility located in a relatively unpopulated area.

In view of the factors enumerated above, we feel that the destruction of Orange herbicide in the State of Texas, as outlined in the Air Force impact statement, would be imprudent at this time."

We appreciate the opportunity to comment on this project. If I may be of further service to you, please let me know.

Sincerely yours,

Charles R. Barden, P.E.
Executive Secretary
Texas Air Control Board

cc: Mr. Jim Menke, Regional Supervisor, Baytown Regional Office

Robert Seamans
Secretary of the Air Force
Washington, D.C.

1 March 1972 MAR 6 [illegible]

Dear Mr Seamans: Subject: DISPOSITION OF ORANGE BY INCINERATION

A letter from John J Shaughnessy, Colonel, USAF, Chief Plans Group, Office of Legislative Liaison, to the US Congressman James W Symington on 11 February 1972, did invite comments from the citizens regarding the above subject as outlined within AF-ES-72-2D January 1972.

I take the following exceptions to the basic study:

1. The basic "SUMMARY SHEET", page 1, paragraph 3, in part; the description of the size and location of one incineration plant, located on a 200 acre site just Southeast of Houston, in a city called Deer Park, Texas, and then describes a second incineration plant located at Sauget, Illinois.

(a) This would infer that the plant described at Deer Park, Texas is just Southeast of Houston, Texas, a well known city, and it also infers the second plant is located at Sauget, Illinois and where is Sauget, Illinois?

(b) If you start searching for this city of Sauget, Illinois, you will not find it on any road map of the state of Illinois, but if you should find a blow-up map of the St Louis, Missouri and its metropolitan area, you might notice a small city located across the Mississippi River from the Corps of Engineers, whose mooring and base depot is located at the foot of Arsenal Street and only one block further, the Headquarters of one of the major USAF Agencies, The Aeronautical Chart and Information Center, located at Second and Arsenal Street, St Louis, Missouri.

(c) I invite you to read through the basic report, on pages 10, 11 and 12, you will notice the Deer Park, Texas incinerator stastics:

(1) A COMMERCIAL INCINERATION Plant, capable of burning ORANGE Herbicide.
(2) Located Near Houston, Texas, in a city called Deer Park.
(3) Presently burning liquid waste from the surrounding industrial complex consisting of oil refineries and chemical plants.
(4) The INCINERATOR is located on a 200 acre site, 15 miles from the center of Houston and 4 miles from the nearest population center of Deer Park, that lies to the Southwest of the incinerator.
(5) There is a prevailing wind from the Southeast.
(6) There are 35 people working at this incinerator.
(7) Natural gas is available for fuel, however, the natural combustion properties of the herbicide will provide the fuel required.
(8) ORANGE would normally be mixed with other waste combustible liquids during the incineration operation.
(9) The incinerator is equipped with caustic scrubbers which convert the hydrogen chloride into sodium chloride (salt).
(10) The incineration of the 2.3 million gallons of herbicide will produce approximately 44.6 million pounds of carbon dioxide and 12.4 million pounds of salt to be discharged into the surrounding environment.
(11) The daily rate of discharge would be for about 460 days, based on the incineration of 5000 gallons of ORANGE per every 24 hour day.

Subject: DISPOSITION OF ORANGE BY INCINERATION,
AF-ES-72-2D January 1972

(d) I invite you to read further through the basic report, on pages 13, 14 and 15 you will notice the Sauget, Illinois Monsanto Company Chemical Plant's incinerator stastics, the description of the before undescribed facility located within an unknown city!

(1) A Commercial FACTORY that has an incinerator capable of burning ORANGE and its ingredient materials.
(2) Located just across the Mississippi River from St Louis, Missouri, within the city of Sauget, Illinois.
(3) Presently is used to burn in-house and customer-returned contaminated polychorinated byphenols.
(4) The Factory is located on a 134 Acre site, 1.5 miles from the downtown center of St Louis, Missouri, the company has approximately 10 acres of stor age area available.
(5) There is a prevailing wind from the Southeast.
(6) There are 1303 employees working at this manufacturing factory.
(7) The basic report makes no mention of natural gas availability for incineration. (Ed.comment: Natural gas in excess quanities is available to the local gas company for underground storage only during the non cold months, for recycling into their system for cold month residential heating needs).
(8) ORANGE would not be mixed with other waste combustible liquids, during the incineration operation.
(9) The incinerator is not equipped with a caustic scrubber which would convert the hydrogen chloride into sodium chloride (salt), but it has only a system for processing the incinerated products stack exhaust gas through a water wash system including a venturi scrubber which diffuses the gases with water, to wash out 95% of the hydrogen chloride as a liquid effluent and discharges this into a municipal waste plant, then into the Mississippi River about 1 mile away.
(10) The incineration of the 2.3 million gallons of ORANGE will produce approximately the same 44.6 million pounds of carbon dioxide, but without caustic scrubbers and processed only through a water wash system, followed by the use of a venturi scrubber, this will release the unrecovered 5% of the hydrogen chloride along with a voluminous amount of water vapor to condense into varied concentrations of Hydrochloric Acid Mist fallout. The amounts to be considered is not referenced in the report, but is dismissed by:"This liquid effluent and stack discharge is within the existing permit limits".
(11) The daily rate of discharge would depend upon the industrial factory need to dispose of their own waste material in an incinerator whose capicity is only 2880 gallons every 24 hour period, and if this capicity is used only to incinerate ORANGE, it would take over 800 days.

(e) My exception to this basic paragraph is, why didn't the SUMMARY SHEET state this, instead of trying to leave the insinuation that Sauget, Illinois is just some small place, where no one has ever heard of, and probably would assure it is located out in the back country. If you would consider a 15 mile radius circle drawn about Sauget, Illinois, you would discover a metropolitan area with a population of much more than 1 million people. At Deer Park you would discover this same 15 mile circle encloses a much smaller population due to the location of Deer Park 15 Miles from Houston, and the incinerator plant falls within the area of the "Tideland Oil Area", where a large concentration of oil wells m may be found, as well as the surrounding area is semi-salt marsh flat, that is sparsely populated.

Subject: DISPOSITION OF ORANGE BY INCINERATION.
AF-ES-72-2D January 1972.

2. The basic study's request for comment from the Governmental Agencies: Why was not the State of Missouri, The County of St Louis and/or The City of St Louis requested to comment on the effect of this incineration of the ORANGE would have on their enviroment, especially since they have a pollution code more restrictive that that of the State of Illinois or the U.S.Government.

3. The question of water dilution of the 95% of the Hydrogen Chloride into the waste treatment plant in the form of Hydrochloric Acid, and then passed on into the Mississippi River? What effect would this have on the fish, the water fowl, the people downstream who depend on the water from the Mississippi River for the water they drink? What effect would this have on the National Goal of reaching the secondary sewage treatment system by 1975.

4. If the Sauget, Illinois Monsanto Company Plant's incinerator would be selected to dispose of this ORANGE, what security could be given that a 100% destruction of this herbicide could be accomplished? If an almost impossible 99% destruction was obtained, this would release 23,389 gallons of pure ORANGE in a vaporous state being discharged into the atmosphere, along with the 5% of the Hydrogen Chloride reported volume that could not be recovered which would also be air discharged along with a tremendous quanity of water vapor to be dispersed over the metropolitan area of St Louis, where this 1 million plus human persons reside and are employed. One of my concerns is: What would happen if a malfuntion of equipment would result in less than total destruction of this ORANGE, how long of a time span before the reaction in operations to bring to a halt the discharge and remedy would be made available to undo the damage created by such a malfuntion?

5. The alternate methods suggested to dispose of this dangerous materisl. I would offer the following additional methods be considered:

(a) Burial in abandoned salt or sulphur mines, in the same fashion and method used to dispose of hot radioactive waste material.

(b) Burial at sea, in an obsolete ship within an submarine trench, the same method the U.S. Army used to dispose of the unwanted Nerve Gas.

(c) Atomic incineration within an underground cavern with a small atomic energy device, that would produce the necessary destructive heat for the incineration instananeously.

(d) Pumping into either an abandoned or dry oil well drilled to a minimum depth of below 10,000 feet. In a legal sense belongs to the Government since either depletion of oil reserve or dry hole status payments have been allowed for tax purposes to the drilling company.

Mr Seamens, to quote the U.S. Government's stand on envioromental pollution, that pollution is a condition that knows no boundaries, either National, State, Regional or community.

(a) A recent meeting of the NATO Country representatives at Scott AFB, Illinois within 15 Miles of the Downtown St Louis, did discuss, world envioromental pollution problems. It was indicated at that time that the metropolitan St. Louis was the third dirtest, foulest and/or polluted city within the NATO Countries, exceeded only by a city in Turkey and by a city in Northern Europe.

Subject: DISPOSITION OF ORANGE BY INCINERATION.
AF-ES-72-2D January 1972

(b) A recent enviromental study of St Louis Metropolitan area indicated that Sauget, Illinois was located within one of the two heaviest chemically polluted areas within the region under study. Have you read the recent magazine article: A tree grows in Sauget? Where it describes the last lone surving tree within the city, how the shrubs if they grow at all, enter a early dormant period with leaves turning yellow by early summer, how the grass has died completely or is a sick yellow brown depending on how far they may be located from the source of the airbourne pollution, a disaster at its very best, the Monsanto Chemical Company and its incinerator.

(c) For the location of the second polluted area within the St Louis Metropolitan area, I refer you to the USAF ENVIRONMENTAL HEALTH LABORATORY, McClellan AFB, California, Report No. 69M-10 (Proljeot No. E68-69) July 1969 entitled: Air Pollution Study Aeronautical Chart and Information Center, South Annex, located at 8900 South Broadway, St Louis, Missouri.

In conclusion, I implore you to reconsider some other method of destroying this monster other than by incineration and releasing the contaminating chemicals into the environment.

Sincerely yours,

Douglas D Thornberry

Douglas D Thornberry
10414 Melvich Drive
St Louis, Missouri
63137

City of
HOUSTON
LOUIE WELCH, MAYOR
HOUSTON, TEXAS 77001

CITY COUNCILMEN
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LEONEL J. CASTILLO

DEPARTMENT OF PUBLIC HEALTH
1115 N. MACGREGOR
HOUSTON, TEXAS 77025

March 8, 1972

Cliff M. Whitehead, Colonel, USAF
Chief, Environmental Protection Group
Directorate of Civil Engineering
Department of the Air Force
Headquarters United States Air Force
Washington, D. C.

Dear Colonel Whitehead:

The environmental impact statement "Disposition of Orange Herbicide by Incineration, January, 1972" has been carefully reviewed by members of the City of Houston Pollution Control Division. However, we do wish to point out that this facility is not within our jurisdiction. According to the information in this impact statement, the Orange herbicide can be incinerated at 1908° F resulting in the formulation of hydrogen chloride and carbon dioxide. However, this information is based on tentative combustion data awaiting detailed results of a combustion analysis program to be completed by the Department of Agriculture by July, 1972.

In addition the impact statement listed the normal stack discharges for the Rollins Purle plant as carbon dioxide and steam. According to visual observations by our agency smoke discharges from the incinerator indicated that complete combustion is not always attained.

Considering these factors, it is the opinion of this agency that the final combustion data is needed before a decision is made to incinerate the Orange herbicide. Also a complete efficiency study is needed for the Rollins Purle incinerator plant before a decision is made on whether or not it can be incinerated at this facility.

We appreciate the opportunity to comment on this project. If additional information is needed from this agency, please contact our office.

Sincerely,

Victor N. Howard

Victor N. Howard, P. E.
Director
Pollution Control Division

VNH/fh

Read and Approved:

Albert G. Randall

Albert G. Randall, M. D.
Director of Public Health

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DCS/P&R
Asst DCS
Executive
Asst Exec
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Susp
Info

MAR 8 1972

Mr. Aaron J. Racusin
Acting Assistant Secretary
of the Air Force
Office of the Secretary
Headquarters USAF/PREV
Washington, D.C. 20330

Dear Mr. Racusin:

We have reviewed the U.S. Air Force draft environmental impact statement on the disposal of Orange herbicide by incineration.

The proposed action calls for the incineration of 2,338,900 gallons of Orange (including Orange II) herbicide over a 468-day period at either Deer Park, Texas or Sauget, Illinois.

We concur that the process of incineration if properly carried out under the appropriate conditions can effectively reduce the components of Orange to carbon dioxide and hydrochloric acid. However, these two gaseous effluents must be disposed of in such a way that they pose essentially no hazard to the environment. The final impact statement must provide additional information if we are to determine whether or not this project will be carried out in a way which is protective of public health and the environment.

We offer the following specific comments to assist you in the preparation of the final statement:

1. Special precautions should be taken to assure that efficient combustion conditions (product intake, temperature, and retention time) are maintained throughout the operation. These precautions are necessary to insure that the original material plus any intermediate pyrolysis products are burned completely and are not present in the stack effluent. Since the natural combustion properties of the herbicide will provide the fuel required, there should be no mixing of this herbicide with other combustible wastes as suggested for the incinerator in Deer Park, Texas.

2. The estimate of 468 days for the complete incineration is based on a feed rate of 5,000 gallons a day. If incineration is carried out at Sauget, Illinois, this time period must be increased to over 810 days since the incinerator capacity is only 2,880 gallons per day. No calculations were presented for the total volume of the wash from 42,483 barrels and the time for incineration of that wash.

3. Proper disposition of the hydrochloric acid is necessary if there is to be no adverse effect on the environment. At the Sauget, Illinois, incinerator, the daily volume of hydrochloric acid discharge is not given. Consequently we cannot calculate the concentration of the acid and the pH of the waste water. To assess the ability of the municipal sewer system to handle such a discharge over a long period of time, consideration should be given to the disposal of this waste dilute acid by sale, or free of charge, to companies who have need for such acid rather than disposing of it by sewer system discharge.

On the basis of the documented calculation of 12.4×10^6 lbs. of sodium chloride produced in Texas, it was calculated for these comments that there will be 7.7×10^6 lbs. of hydrogen chloride carried off in the liquid effluent at Sauget. For each of the 810 days of operation, this is approximately 9500 lbs. of hydrogen chloride.

The document indicates that approximately 95% of the total hydrogen chloride evolved in the incineration will be scrubbed from the effluent gas, the remaining 5% being exhausted to the atmosphere. Based on the same calculations as were used in the preceding paragraph, this is approximately 500 lbs. per day hydrogen chloride emission. Since the Sauget source is slightly east of a line drawn directly south from downtown St. Louis, and because the document indicates a prevailing southeast wind, it appears likely that this daily emission of 500 lbs. would fall into the area of downtown St. Louis most of the time. Because the draft environmental impact statement has not provided enough operating data on the incinerator at the Illinois site to calculate the concentrations of the hydrogen chloride emissions, it is impossible to accurately determine the effect of this amount of emissions on the surrounding community. It is safe to say however, that such an amount of emissions over such a long period of time could present a potentially serious condition.

It is felt that a correctly sized and operated sodium hydroxide scrubber added to the Sauget system would eliminate the hydrogen chloride problem completely. The sodium chloride and sodium carbonate produced by the scrubber could be disposed of by controlled discharge into the sanitary sewer system or directly into the river. In Deer Park, Texas, the absorption solution will be discharged into Tucker Bayou. There is not enough information to compute the expected plant effluent concentration of salt or sodium carbonate produced by the reaction of sodium hydroxide and carbon dioxide. This is important because salt equilibrium can affect the biota of estuarine systems and especially that of Tucker Bayou which has a variable rate of flow. The release of carbon dioxide into the atmosphere should pose no danger to the environment. We emphasize the necessity and the importance of compliance with Federal, State, and local air and water pollution control regulations.

4. Proper monitoring of the incineration process must be put into effect by both the contractor and the U.S. Air Force. Frequent periodic analyses of the stack gases and liquid effluent for unburned Orange pyrolyses products, hydrogen chloride, carbon dioxide, and ash (if any) must be made to assure that complete combustion is taking place. A technical representative should be present at the incinerator facility throughout the operation to assure that all combustion controls and scrubbers are functioning properly and to check on the monitoring operation and proper operational practices. Any breakdown in control measures or devices must be cause for stoppage of the operation until the problem is corrected.

5. The empty drums should be decontaminated with kerosene and an alkaline detergent and should be allowed to dry before being handled further. The preferred treatment of the drums should be either salvaging for further shipping uses or for smelting as scrap metal. Their disposal in landfill is the least acceptable alternative. If, however, this method of disposal must be used, the landfill site should be located on property so that there is no chance of runoff into streams, lakes, or groundwater systems.