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HW-44974

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ORGANIC CONTINUOUS CARTRIDGE FOR THE PUREX 2D COLUMN

AEC RESEARCH AND DEVELOPMENT REPORT

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August 16, 1956

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Richland, Washington

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ORGANIC CONTINUOUS CARTRIDGE FOR THE PUREX 2D COLUMN

INTRODUCTION

The performance of the Purex Plant since its startup has been characterized by a variable uranium decontamination. The fission product activity in the uranium product has varied from within to many times above process specifications. This document covers work done in 3- and 4-inch-diameter glass columns directed toward the development of improved cartridges for the Purex Plant final uranium cycle extraction column, the 2D column.

The present Purex Plant 2D column has a stainless steel sieve plate cartridge which operates with the aqueous phase continuous. Uranium recovery with this column has been satisfactory, but the uranium decontamination has been generally poor. The development work was directed at two of the many postulated mechanisms which might be responsible for the unsatisfactory decontamination.

The interface of a solvent extraction column always accumulates foreign solid materials. It has been found in the Redox and Uranium Recovery Plants and in 3- and 1-inch-diameter column studies that this accumulation builds up a high level of radioactivity. When the 2D column is operated with the aqueous phase continuous, the interface with its high level activity is at the top of the column, i.e., the product end. This high activity material in contact with the product effluent stream is believed to be at least partially responsible for the poor decontamination. The obvious solution is to move the interface to the bottom or waste end of the column and the primary effort of the program was to effect this.

A second objective was to develop a scrub cartridge which would be a more efficient solvent extraction contactor and would, therefore, achieve a higher degree of scrubbing of the fission products.

SUMMARY

A nozzle plate cartridge for the extraction section and a mixed plate cartridge containing both stainless steel and fluorothene sieve plates for the scrub section were developed. In 3- and 4-inch-diameter glass columns these cartridges have a uranium extraction efficiency as good as or better than the present cartridge; and a scrubbing efficiency, based on the transfer of chloride ion, about the same as the present cartridge.

EXPERIMENTAL RESULTS

The experimental program was broken into three phases: (1) investigation of simple scrub sections; (2) investigation of simple extraction sections; and (3) investigation of a dual-purpose column. For the simple column studies, 3-inch-diameter, 9-foot-high glass extraction and scrub sections were used which were physically separated so that each could be studied independently.

For the dual-purpose studies, a 3-inch-diameter, 9-foot-high extraction section surmounted by a 4-inch-diameter, 8-foot-high scrub section was used.

Chloride ion was used to measure the scrub section scrubbing efficiency. The HAF was made 0.5 M in NaCl. This resulted in a chloride ion concentration in the organic entering the scrub section of approximately one gram per liter. The distribution ratio (E_A^o) of the chloride ion in the scrub section was found to be constant at 0.115, about the same order of magnitude as might be expected of some of the fission product distribution ratios.

Simple Scrub Section Results

The program was started with a study of the standard cartridge of the type used in the present 2D column operated with the aqueous phase continuous to give a reference with which to compare new cartridges. Following this, several cartridges were investigated with the organic phase continuous. Of these, mixed cartridges containing alternate pairs of fluorothene and stainless steel sieve plates were the most promising. The cartridge chosen for potential Purex Plant 2D column use was one for which both the stainless steel and the fluorothene plates were available at H.A.P.O. The details of the cartridge and the experimental results are presented in Table V.

The mixed cartridge has flooding pulse frequencies of 125 and 105 cycles per minute at equivalent uranium processing rates of 10 and 20 tons per day, respectively. For comparison, the standard cartridge flooding frequencies at these rates are 125 and 85 cycles per minute.

The standard scrub section cartridge efficiency was found to be sharply frequency sensitive, the H.T.U.'s ranging from 3.2 feet at pulse frequencies of 60 to 70 cycles per minute down to 1.6 feet at pulse frequencies of 100 to 110 cycles per minute. The efficiency was found to be closely related to the dispersed phase holdup and the best efficiencies were obtained when the column was maintained at a flooded condition by a continuous adjustment of the pulse frequency.

As shown in Table I, the mixed cartridge had efficiencies considerably better than the standard cartridge.

TABLE I

COMPARISON OF STANDARD AND MIXED SCRUB CARTRIDGE SCRUBBING EFFICIENCIES

Pulse Frequency, Cyc./Min.	H.T.U., Ft.[a] Mixed Cartridge RR[b] = 10	Mixed Cartridge RR = 20	Standard Cartridge RR = 10	Standard Cartridge RR = 20
50		2.9		
60			3.2	
70	1.5	2.1		3.2
80			2.6	2.8
90	1.5	1.6		2.3
100	1.2		1.8	1.8[c]

(a) Height of a transfer unit, over-all organic-film basis, based on Cl^- transfer.
(b) RR defined as equivalent uranium processing rate in tons per day.
(c) Column was operated in a flooded condition.

The good efficiencies attained by the mixed cartridge are due to the coalescence of the dispersed aqueous phase at the stainless steel plates. The optimum condition was that in which the coalescence had reached a point of complete inversion in the region of the stainless steel plates and the column consisted of alternate layers of organic phase continuous and aqueous phase continuous.

The efficiencies of both the standard and mixed cartridges are adversely affected by dirty plates. In both cases the unfavorable effects arose from the fact that dirty stainless steel plates are partially wetted by the organic phase. In the case of the standard cartridge this resulted in an increased organic drop size, a looser dispersion and a lower dispersed phase holdup with a consequent loss of efficiency. With the mixed cartridge, the partially preferentially organic wet plates decrease the degree of inversion attained which results in a loss of efficiency. The studies made with the simple column were made with thoroughly cleaned plates.

Simple Extraction Section Results

Three cartridges were investigated for organic continuous behavior. Of these, a 23 percent free area stainless steel nozzle plate cartridge was the most promising. The details of the cartridge and experimental results are presented in Tables VI and VII. The flooding frequencies of the nozzle plate cartridge are 105 and 95 cycles per minute at uranium processing rates of 10 and 20 tons per day, respectively. The graded plate cartridge of the type presently in use in the 2D column has flooding frequencies of 115 and 105 cycles per minute at the above throughputs.

A comparison of the extraction efficiencies of the nozzle plate cartridge and the graded plate cartridge is presented in Table II.

TABLE II

COMPARISON OF EXTRACTION EFFICIENCIES OF NOZZLE PLATE AND GRADED PLATE CARTRIDGES

Pulse Frequency, Cyc./Min.	H.T.U., Ft.(a) Nozzle Plate Cartridge RR(b) = 10	Nozzle Plate Cartridge RR = 20	Graded Plate Cartridge RR = 10	Graded Plate Cartridge RR = 20
60				0.9
70				
80	1.0			0.8
90		0.8		
100	0.9		0.7	

(a) Height of a transfer unit, over-all aqueous-film basis.
(b) Defined at the equivalent uranium processing rate in tons/day.

The nozzle plates were also investigated under conditions of the "High Capacity Purex Study Flowsheet", HW-42978. The uranium waste losses ranged from 0.0001 to 0.0048 percent at pulse frequencies of from 60 to 115 cycles per minute and throughputs of from 500 to 1800 gallons per hour per square foot, sum of both phases.

Dual-Purpose Column Results

A dual-purpose column using a mixed cartridge scrub section and a 23 percent free area nozzle plate cartridge was investigated with the organic phase continuous under 2D column conditions prescribed by both Purex HW No. 3 Flowsheet and Purex Plant Flowsheet No. 2 For comparison, a column using a standard cartridge scrub section and a graded plate cartridge extraction section operated with the aqueous phase continuous was also studied. The details of the cartridges and the experimental results are presented in Tables VIII, IX, and X.

The plates were cleaned prior to the start of the investigation. However, in order to more nearly simulate plant conditions, the columns were operated until the plates had reached a steady-state degree of dirtiness before the efficiencies were determined.

The extraction section controlled the flooding of the organic phase continuous column at all throughputs studied. The extraction section controlled the flooding of the aqueous phase continuous column only at the lower throughputs. A comparison of the flooding frequencies is presented in Table III.

TABLE III

COMPARISON OF FLOODING FREQUENCIES

	Flooding Frequency, Cyc./Min.			
	Organic Continuous Column		Aqueous Continuous Column	
RR[a]	Extraction Section	Scrub Section	Extraction Section	Scrub Section
10	105	125	115	125
20	95	105	105	85

(a) RR defined as equivalent processing rate in tons uranium per day.

Under conditions of Purex HW No. 3 Flowsheet the uranium extraction behavior of the two columns is quite similar. The organic phase continuous column had uranium waste losses ranging from 0.0001 to 0.02 percent and the standard cartridge columns had uranium waste losses ranging from 0.0007 to 0.005 percent at pulse frequencies from 60 to 100 cycles per minute ~~and at~~ processing rates of 10 and 20 tons uranium per day.

Under Purex Plant Flowsheet No. 2 2D column conditions, the organic phase continuous cartridge exhibited a better uranium extraction behavior than did the extraction cartridge. Both cartridges were investigated at a processing rate of 10 tons uranium per day for an extended period of time, the standard cartridge column for 16 hours and the organic phase continuous column for 30 hours. The standard cartridge column had erratic waste losses varying from

0.12 to 12 percent. No noticeable change in the column appearance was noted to occur in conjunction with the changing waste losses. The organic phase continuous column became unstable at a pulse frequency of 90 cycles per minute after approximately 6 hours of operation. During this time, waste losses were erratic, varying from 0.08 to 6 percent. The last 12 hours were made at a pulse frequency of 80 cycles per minute and the waste losses were consistent at approximately 0.025 percent.

The chloride decontamination attained in the scrub section was estimated by assuming that the organic entering the scrub section contained one gram per liter chloride ion. The chloride decontaminations attained in the scrub section of the dual-purpose column were considerably lower than those reached in the simple column studies. Possible reasons for this include: (1) the dual-purpose scrub section was 8 feet high, one foot less than the simple column; (2) the dual-purpose column was made of standard bore glass and had a larger diametrical clearance between the plates and column wall than had the precision bore simple column; (3) backmixing occurred in the dual-purpose column; and (4) the plates of the dual-purpose column were allowed to reach the degree of dirtiness arising from several days operation before efficiency studies were made. Of these the wettability of the plates as determined by the degree of dirtiness is believed to be the prime cause.

Although the adverse effect is more pronounced with the mixed cartridge than with the standard cartridge, the chloride decontaminations achieved with the mixed cartridge in the dual-purpose column were approximately the same as those of the standard cartridge. Table IV compares the two cartridges.

TABLE IV

COMPARISON OF STANDARD AND MIXED SCRUB CARTRIDGES IN A DUAL-PURPOSE COLUMN

Pulse Frequency, Cyc./Min.	Chloride Decontamination[a]			
	Mixed Cartridge		Standard Cartridge	
	RR[b] = 10	RR = 20	RR = 10	RR = 20
60		3.5		3.3
70		4.5	2.8	3.8
80	2.8	5.1	2.7	8.3
90				
100	13.8		5.7	

(a) Defined as $\frac{1}{\text{Chloride concentration in effluent organic}}$.

(b) Defined as uranium processing rate in tons per day.

On the basis of this work done in 3- and 4-inch-diameter columns, the organic phase continuous nozzle plate extraction cartridge efficiency is better than, and the organic phase continuous mixed plate cartridge efficiency is about the same as, the cartridges currently in use in the Purex Plant 2D column. On this basis, these cartridges have been recommended as a replacement for the Purex Plant 2D column to permit operation with the interface at the waste end of the column.

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TABLE V

PUREX 3-IN. A-TYPE SCRUB SECTION STUDIES

Flowsheet: Purex HW No. 3, Pu and F.P.'s omitted, NaCl added to HAF. Diluent: Shell E-2342.
Equipment: 3-in.-diameter precision bore glass column with a 9-ft.-high cartridge as described in notes.
Pulse Amplitude: 0.6 in.

Flooding Studies

Run No.	Cartridge[a]	Continuous Phase	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	Flooding Frequency, Cyc./Min.
3-35c-ASH	A	Aqueous	240	125 ± 5
3-36-ASH	A	Aqueous	480	85 ± 5
3-37b-ASH	A	Organic	480	<40[e]
3-37c-ASH	A	Organic	240	75 ± 5 <80[e] 115 ± 5
3-93-ASH	B	Organic	240	125 ± 5
3-94-ASH	B	Organic	480	105 ± 5
3-97-ASH	B	Aqueous	240	125 ± 5
3-98-ASH	B	Aqueous	480	105 ± 5

TABLE V (Continued)

Efficiency Studies

Run No.	Cartridge[a]	Continuous Phase	Pulse Frequency, Cyc./Min.	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	Cl^- D.F.[b]	H.T.U., Ft.[c]
3-37b-ASH	A	organic	60	480	7.5	2.8
3-37c-ASH	A	Organic	110	240	10.6	2.4
3-38b-ASH	A	Aqueous	80	480	10.0	2.2
3-38-ASH	A	Aqueous	60	480	6.4	3.0
3-67a-ASH	A	Aqueous	70	480	6.4	3.2
3-67b-ASH	A	Aqueous	80	490	7.4	2.8
3-67c-ASH	A	Aqueous	90	480	11.1	2.3
3-67d-ASH	A	Aqueous	102	490	19.8	1.7
3-69a-ASH	A	Organic	40	480	4.9	3.9
3-69b-ASH	A	Organic	70	490	6.1	3.3
3-69c-ASH	A	Organic	100	490	12.7	2.1
3-70a-ASH	A	Aqueous	100	250	35.9	1.5
3-70b-ASH	A	Aqueous	110	250	22.3	1.7
3-70c-ASH	A	Aqueous	(f)	250	21.8	1.7
3-95a-ASH	B	Organic	50	490	7.5	2.9
3-95b-ASH	B	Organic	70	470	11.5	2.1
3-95c-ASH	B	Organic	90	480	18.8	1.6
3-96-ASH	B	Organic	90	240	22.1	1.5
3-99-ASH	B	Aqueous	80	490	6.4	3.3
3-100-ASH	B	Aqueous	90	240	6.5	3.0
3-101-ASH	B	(d)	80	480	5.4	3.8
3-102-ASH	B	Aqueous	90	470	5.6	3.6
3-103a-ASH	B	Aqueous	100	240	6.0	3.2
3-103b-ASH	B	Aqueous	70	240	4.1	4.4
3-104a-ASH	B	Organic	70	250	20	1.5
3-104b-ASH	B	Organic	100	350	50	1.2
3-108-ASH	A	Aqueous	60	240	5.7	3.2
3-109-ASH	A	Aqueous	80	250	7.3	2.6
3-110-ASH	A	Aqueous	100	240	14.8	1.8

Notes:

(a) Cartridge A: Stainless steel sieve plates, 1/8-in.-diameter holes, 23% free area, 2-in. plate spacing.

Cartridge B: Alternate pairs of 2 stainless steel sieve plates and fluorothene sieve plates; 1-in. spacing throughout. Stainless steel plates - 0.08-in.-diameter holes, 21% free area. Fluorothene plates - 3/16-in.-diameter holes, 23% free area.

(b) Defined as $\frac{Cl^- \text{ concentration in influent organic}}{Cl^- \text{ concentration in effluent organic}}$.

(c) Height of a transfer unit, over-all organic-film basis.

(d) The interface was maintained in the cartridge 2 to 3 ft. from the top of the column.

(e) Cyclic local flooding frequency.

(f) Frequency was varied from 120 to 140 cycles per minute to maintain the column in a flooded condition.

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TABLE VI

PUREX 3-IN. A-TYPE EXTRACTION SECTION STUDIES

Flowsheet: Purex HW No. 3, Pu and F.P.'s omitted. NaCl added to HAF. Shell E-2342 diluent.

Equipment: 3-in.-diameter precision bore glass column with a 9-ft.-high cartridge of stainless steel nozzle plates, 1/8-in.-diameter holes, 23% free area on 2-in. plate spacing. Nozzles pointed down.

Pulse Amplitude: 1.0 in.

Flooding Studies

Run No.	Continuous Phase	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	Flood Freq.,[a] Cyc./Min.
3-240-AH	Organic	500	105 ± 5
3-241-AH	Organic	1000	95 ± 5
3-246-AH	Aqueous	1000	55 ± 5[b]
			85 ± 5
3-247-AH	Aqueous	500	65 ± 5[b]
			95 ± 5

Efficiency Studies

Continuous Phase: Organic

Run No.	Freq., Cyc./Min.	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	% U Loss	H.T.U.,[c] Ft.
3-242-AH	100	530	0.004	0.87
3-243-AH	90	1040	0.003	0.84
3-244-AH	80	520	0.032	1.00

(a) Complete flooding threshold unless otherwise noted.
(b) Cyclic local flooding threshold.
(c) Height of a transfer unit, over-all aqueous-film basis.

TABLE VII

PUREX 3-INCH HA EXTRACTION SECTION STUDIES

Flowsheet: "High Capacity Purex Study Flowsheet", HW-42978,[a] Pu and F.P.'s omitted. Shell E-2342 diluent.

Equipment: 3-in.-diameter precision bore glass column containing 9 ft. of stainless steel nozzle plates with 1/8-in. holes, 23% free area, 0.04-in.-deep nozzles pointed down on 2-in. plate spacing.

Pulse Amplitude: 1.0 in.

Flooding Studies
Complete Flooding Threshold

Run No.	Continuous Phase	Freq., Cyc./Min.	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Flows	L/V Aq./Org., Volume Ratio
3-254-AH	Organic	105 ± 5	490	0.401
3-255-AH	Organic	95 ± 5	1000	0.327
3-256-AH	Organic	95 ± 5	960	0.309
3-262-AH	Organic	80	>1940	0.387
3-263-AH	Aqueous	95 ± 5	510	0.394[b]
3-264-AH	Aqueous	96 ± 5	1000	0.392[b]

Efficiency Studies

Run No.	Continuous Phase	Freq., Cyc./Min.	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Flows	L/V Aq./Org., Volume Ratio	% U Loss
3-257-AH	Organic	90	510	0.388	0.0003
3-258-AH	Organic	70	500	0.367	0.0002
3-259-AH	Organic	80	950	0.385	0.0003
3-260-AH	Organic	60	930	0.421	0.005
3-261-AH	Organic	70	530	0.394	0.0003
3-265-AH	Aqueous	70	490	0.405	0.0004
3-266-AH	Aqueous	50	490	0.412	0.0048
3-267-AH	Aqueous	70	1030	0.388	0.0004
3-268-AH	Aqueous	50	1010	0.395	0.0048
3-269-AH	Organic	60	1000	0.396	0.0043
3-270-AH	Organic	40	1000	0.384	0.024
3-271-AH	Organic	60	1480	0.398	0.0021
3-272-AH	Organic	70	1790	0.385	0.0008
3-273-AH	Organic	60	1750	0.360	0.0019
3-274-AH	Organic	110	240	0.398	0.0025
3-275-AH	Organic	80	500	0.384	0.0004
3-276-AH	Organic	60	500	0.384	0.0011
3-277-AH	Organic	50	490	0.385	0.0083

Notes:

(a) HAFS composition unless otherwise noted: 1.0 M U, 1.9 M HNO_3, 0.28 M ANN.

(b) Instability threshold noted at ca. 80 cycles/minute.

TABLE VIII

PUREX 3-IN. A-TYPE EXTRACTION SECTION EFFICIENCY STUDIES

Flowsheet: Purex HW No. 3. Pu and F.P.'s omitted. NaCl added to HAF Shell E-2342 diluent.
Equipment: 3-in.-diameter precision bore glass extraction column 9-ft.-high surmounted with a 4-in.-diameter standard bore glass scrub column 8-ft. high.
Pulse Amplitude: 1.0 in. in extraction section.

Run No.	Cartridge [a]	Continuous Phase	Pulse Frequency	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	H.T.U.,[b] Ft.	% U Loss
4-3-ASH	A	Organic	100	520	0.64	0.0001
4-4-ASH	A	Organic	80	1070	0.71	0.0004
4-5-ASH	A	Organic	60	1070	0.86	0.0057
4-6-ASH	A	Organic	80	540	0.89	0.0033
4-7-ASH	A	Aqueous	60	1080	0.86	0.0041
4-8-ASH	A	Aqueous	80	530	0.76	0.0011
4-9-ASH	A	Organic	80	1050	0.62	0.0001
4-10-ASH	A	Organic	100	520	0.67	0.0002
4-11-ASH	A	Organic	60	1040	0.73	0.021
4-12-ASH	A	Organic	80	1010	0.66	0.0007
4-13-ASH	A	Organic	70	1060	0.67	0.0006
4-17-ASH	B	Aqueous	80	1080	0.60	0.0046
4-18-ASH	B	Aqueous	80	520	0.64	0.0017
4-19-ASH	B	Aqueous	70	1050	0.63	0.0009
4-20-ASH	B	Aqueous	60	1060	0.62	0.0086
4-21-ASH	B	Aqueous	70	530	0.67	0.0025
4-22-ASH	B	Aqueous	90	530	0.72	0.0043

Notes:

(a) A: Extraction section cartridge of stainless steel nozzle plates, 1/8-in.-diameter holes, 23% free area on 2-in. plate spacing. Nozzles pointed down.
B: Extraction section cartridge - graded plate cartridge of the type used in the Purex Plant A-type columns.

(b) Height of a transfer unit, over-all aqueous-film basis.

TABLE IX

PUREX 3-IN. 2D EXTRACTION COLUMN EFFICIENCY STUDIES

Flowsheet: Purex Plant Flowsheet #2. Pu and F.P.'s omitted. Shell E-2342 diluent.
Equipment: Dual-purpose column with a 3-in.-diameter, 9-ft.-high precision bore glass extraction section and a 4-in.-diameter, 8-ft.-high standard bore scrub section. Cartridges are specified in the notes.
Pulse Amplitude: 1.0 in. in the extraction section.
Volume Velocity: 500 ± 10 gal./(hr.)(sq.ft.), sum of both phases.

Run No.	Cartridge[a]	Time From Start of Run, Hrs.	Pulse Frequency Cyc./Min.	L/V, Aq./Org. Flow Ratio	% U Loss
4-14-ASH	A	4	100	0.482	0.24
		8	100	0.475	6.45[b]
		12	100	0.456	0.12
		14	100	0.435	0.039[b]
		18	90	0.501	12.7 [c]
		22	90	0.425	0.025
		26	90	0.428	0.018
		30	90	0.455	0.025
4-15-ASH	B	4	80	0.471	0.12
		8	80	0.470	0.13
		12	80	0.445	6.20[d]
		16	80	0.471	1.49

Notes:

(a) See note (a) of Table VII.
(b) Approximately 6 hours after the start of the run, the column dispersion in the extraction section tightened and a cyclic coalescence started which continued until the frequency was reduced from 100 to 90 cycles per minute 14 hours after the start of the run.
(c) The 2DX rate fell off to approximately 20% of flowsheet value, one-half to three-quarters of an hour before these samples were taken.
(d) The dispersion loosened sharply approximately 9 hours after the run was started and the color line disappeared. Throughout the rest of the run the color line was gradually rising. This is an average waste loss over 4 hours. The peak waste loss was approximately 12%.

TABLE X

PUREX 4-IN. HA SCRUB COLUMN EFFICIENCY STUDIES

Flowsheet: Purex HW #3, Pu and F.P.'s omitted. NaCl added to HAF. Shell E-2342 diluent.

Equipment: Dual-purpose column with a 3-in.-diameter, 9-ft.-high precision bore glass extraction section and a 4-in.-diameter, 8-ft.-high standard bore glass scrub section. Cartridges are specified in the notes.

Pulse Amplitude: 0.6 in. in the scrub section.

Run No.	Cartridge[a]	Continuous Phase	Pulse Frequency, Cyc./Min.	Volume Velocity, Gal./(Hr.)(Sq.Ft.), Sum of Both Phases	L/V, Aq./Org. Flow Ratio	Cl DF.[b]
4-3-ASH	A	Organic	100	240	0.175	14.9
4-4-ASH	A	Organic	80	490	0.174	4.5
4-5-ASH	A	Organic	60	490	0.185	3.4
4-6-ASH	A	Organic	80	250	0.176	2.8
4-7-ASH	A	Aqueous	60	500	0.182	3.2
4-8-ASH	A	Aqueous	80	240	0.173	2.9
4-9-ASH	A	Organic	80	480	0.189	5.9
4-10-ASH	A	Organic	100	240	0.182	12.8
4-11-ASH	A	Organic	60	470	0.190	3.6
4-12-ASH	A	Organic	80	460	0.191	5.0
4-13-ASH	A	Organic	70	480	0.183	4.5
4-16a-ASH	B	Aqueous	95	230	0.157	5.0
4-16b-ASH	B	Aqueous	90	240	0.196	8.0
4-17-ASH	B	Aqueous	80	490	0.181	8.3
4-18-ASH	B	Aqueous	80	240	0.187	2.7
4-19-ASH	B	Aqueous	70	470	0.182	3.8
4-20-ASH	B	Aqueous	60	480	0.185	3.3
4-21-ASH	B	Aqueous	70	240	0.178	2.8
4-22-ASH	B	Aqueous	90	240	0.176	3.1

Notes:

(a) Cartridge A: Extraction section; stainless steel nozzle plates, 1/8-in.-diameter holes, 23% free area on 2-in. plate spacing. Scrub section; alternate sets of 2 stainless steel and 2 fluorothene sieve plates on 1-in. plate spacing. Stainless steel plates - 0.08-in.-diameter holes, 21% free area. Fluorothene plates - 1/8-in.-diameter holes, 23% free area.

Cartridge B: Extraction section; graded plate cartridge. Scrub section; stainless steel sieve plates, 1/8-in.-diameter holes, 23% free area on 2-in. plate spacing.

(b) Defined as $\frac{\text{Cl concentration in scrub section influent organic}}{\text{Cl concentration in scrub section effluent organic}}$.

The scrub section influent organic chloride concentration was assumed to be 1 g./l.