

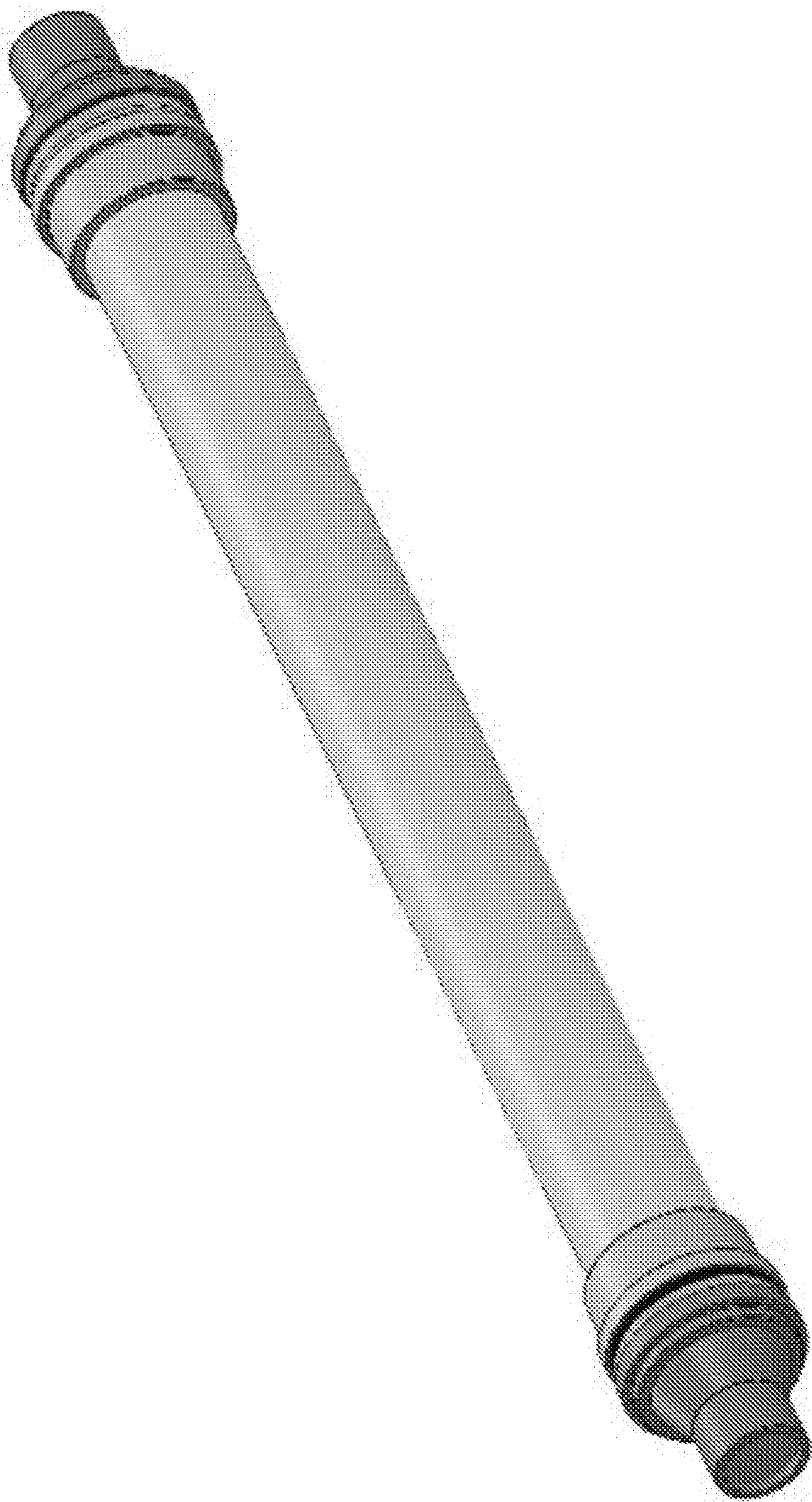


FIG. 1A

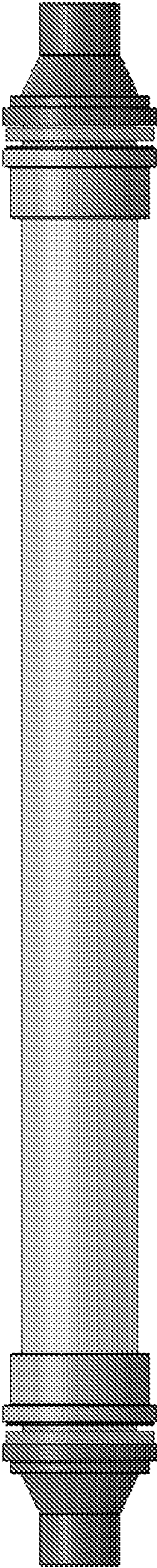


FIG. 1B

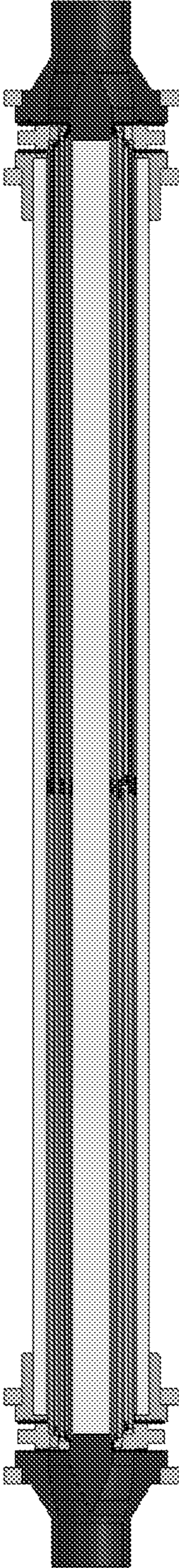


FIG. 1C

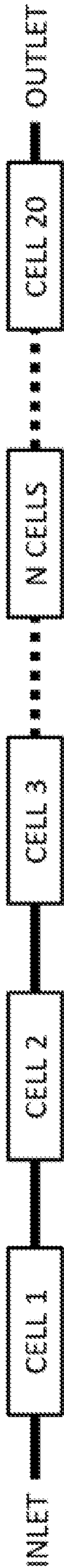


FIG. 2

<i>Constant</i>	<i>Value</i>	<i>Unit</i>
Cell Half Length	0.6	m
Current Density	1800	A/m ²
Electrode Area	0.91	m ² /cell
Electrolyzer Size	20	cells
Flow Rate	22	m ³ /hr
1 Faraday	26.81	A/hr
Molar Mass Cl ₂	70.91	g/mol
Molar Mass H ₂	2.02	g/mol
Molar Mass OH ⁻	17.01	g/mol
1 g/hr Cl ₂	0.76	A
1g/hr H ₂	26.59	A
1 g/hr OH ⁻	1.58	A

<i>Flow Rate (m³/hr)</i>
22
<i>Cell Output (kg/hr)</i>
2.2
<i>Pump Discharge Pressure (Barg)</i>
8
<i>Pressure Loss from Pump (Barg)</i>
0.25
<i>Hydrogen Generation/kg Hypo (m³/hr)</i>
0.45
<i>H₂ Solubility in Water (m³/hr @ 1 BarA)</i>
0.44

FIG. 3A

	Total Hardness		Value	Units
	Na ⁺ TDS		10,750	ppm
	Cl ⁻ TDS		19,350	ppm
	Mg ²⁺ TDS		1,290	ppm
	Ca ²⁺ TDS		410	ppm
Na ⁺	Cl ⁻	Mg ²⁺	Ca ²⁺	
kg/hr	kg/hr	kg/hr	kg/hr	
236.5	425.7	28.38	9.02	

FIG. 3B

Cell No.	Cell Inlet Pressure Barg	Pressure Drop Thru Cell Barg	Cell Outlet Pressure Barg	Hydrogen Generation m³/hr (atmos)	Hydrogen Volume at Line Pressure m³/hr	Dissolvable Hydrogen m³/hr	Hydrogen in Cell m³/hr	Hydrogen in the Cell %
1	7.75	0.28	7.48	0.99	0.12	3.85	-3.73	-17%
2	7.48	0.28	7.19	1.98	0.24	3.73	-3.49	-16%
3	7.19	0.28	6.91	2.97	0.38	3.61	-3.23	-15%
4	6.91	0.29	6.62	3.96	0.52	3.48	-2.96	-13%
5	6.62	0.29	6.33	4.95	0.68	3.35	-2.68	-12%
6	6.33	0.30	6.03	5.94	0.84	3.22	-2.38	-11%
7	6.03	0.30	5.73	6.93	1.03	3.09	-2.06	-9%
8	5.73	0.31	5.42	7.92	1.23	2.96	-1.73	-8%
9	5.42	0.31	5.11	8.91	1.46	2.83	-1.37	-6%
10	5.11	0.32	4.79	9.9	1.71	2.69	-0.98	-4%
11	4.79	0.32	4.47	10.89	1.99	2.55	-0.56	-3%
12	4.47	0.33	4.15	11.88	2.31	2.41	-0.10	0%
13	4.15	0.33	3.82	12.87	2.67	2.26	0.41	2%
14	3.82	0.34	3.48	13.86	3.09	2.12	0.97	4%
15	3.48	0.34	3.14	14.85	3.59	1.97	1.61	7%
16	3.14	0.35	2.80	15.84	4.17	1.82	2.35	11%
17	2.80	0.35	2.4	16.83	4.89	1.67	3.22	15%
18	2.44	0.36	2.09	17.82	5.77	1.52	4.25	19%
19	2.09	0.36	1.73	18.81	6.90	1.36	5.54	25%
20	1.73	0.37	1.36	19.8	8.39	1.20	7.19	33%

FIG. 3C

Unit Generation Rates:						
	Cl ₂	Cl ₂	H ₂	H ₂	OH ⁻	OH ⁻
Cell#	kg/hr	ppm	kg/hr	ppm	kg/hr	ppm
1	2.2	98.7	0.06	2.8	1.04	47.4
2	4.3	197.4	0.12	5.6	2.08	94.7
3	6.5	296.2	0.19	8.4	3.13	142.1
4	8.7	394.9	0.25	11.2	4.17	189.4
5	10.9	493.6	0.31	14.0	5.21	236.8
6	13.0	592.3	0.37	16.8	6.25	284.2
7	15.2	691.1	0.43	19.6	7.29	331.5
8	17.4	789.8	0.49	22.5	8.34	378.9
9	19.5	888.5	0.56	25.3	9.38	426.3
10	21.7	987.2	0.62	28.1	10.42	473.6
11	23.9	1086.0	0.68	30.9	11.46	521.0
12	26.1	1184.7	0.74	33.7	12.50	568.3
13	28.2	1283.4	0.80	36.5	13.55	615.7
14	30.4	1382.1	0.86	39.3	14.59	663.1
15	32.6	1480.9	0.93	42.1	15.63	710.4
16	34.8	1579.6	0.99	44.9	16.67	757.8
17	36.9	1678.3	1.05	47.7	17.71	805.1
18	39.1	1777.0	1.11	50.5	18.76	852.5
19	41.3	1875.8	1.17	53.3	19.80	899.9
20	43.4	1974.5	1.23	56.1	20.84	947.2

FIG. 3D

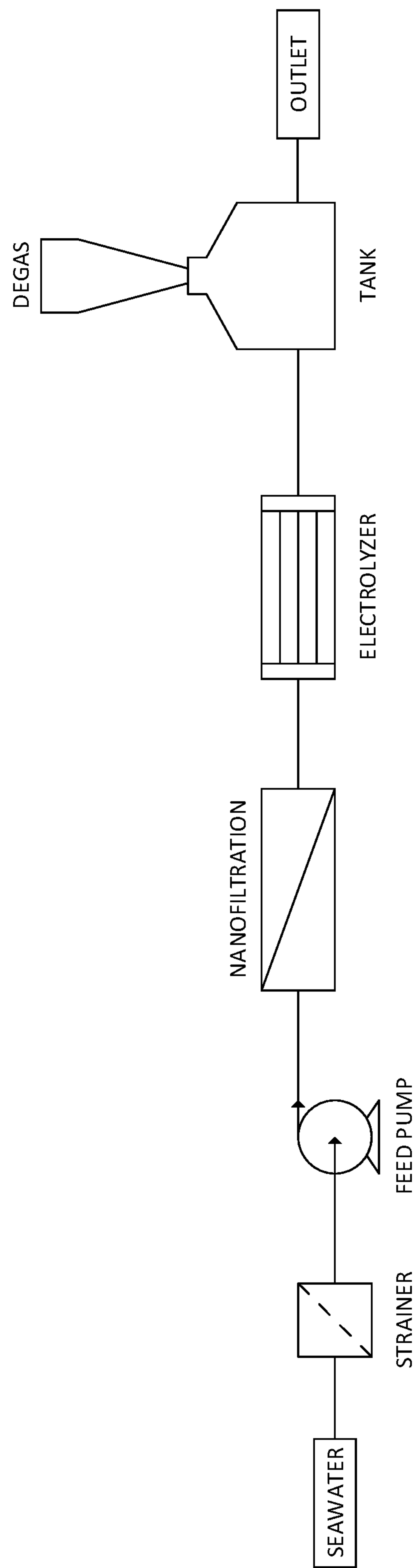


FIG. 4

Rejection values recorded for the main seawater ions, as a function of the recovery (membrane type: DS-5 DL, pressure: 14 bars, feed flow rate: 60 l/h m²; temperature range: 25–27 °C; permeate flux range: 19.2–18.0 l/h m²).

Recovery (%)	Cl(-)(%)	Na(I)(%)	Ca(II)(%)	Mg(II)(%)	K(I)(%)	HCO ₃ (-)(%)
10	28.4 ± 4.0	4.3 ± 2.6	100.0 ± 0	100.0 ± 0	32.7 ± 12.5	37.7 ± 0.9
40	14.2 ± 0.1	2.0 ± 1.5	60.7 ± 5.1	98.2 ± 2.5	9.1 ± 7.1	37.7 ± 0.5
50	11.7 ± 0	2.6 ± 1.4	58.3 ± 1.1	98.2 ± 0.2	4.8 ± 0.5	36.4 ± 2.2
55	10.6 ± 0	1.6 ± 0.6	58.2 ± 6.1	92.6 ± 3.8	4.7 ± 2.3	35.6 ± 1.8
60	10.2 ± 0.4	3.1 ± 1.5	54.6 ± 0	92.9 ± 0.2	6.1 ± 1.9	33.8 ± 1.6
63	9.6 ± 0.3	1.8 ± 0.3	49.7 ± 0.8	95.0 ± 7.1	5.7 ± 1.3	33.7 ± 1.5
66	9.3 ± 0.2	1.3 ± 0.7	46.4 ± 3.7	89.5 ± 1.3	5.6 ± 1.0	32.6 ± 0.1
69	9.1 ± 0.5	1.4 ± 0.1	47.0 ± 0.5	91.4 ± 8.7	4.9 ± 1.5	30.0 ± 1.5
72	8.5 ± 1.3	1.1 ± 0.3	45.1 ± 1.3	89.2 ± 4.0	4.4 ± 1.2	30.2 ± 1.9
75	8.3 ± 0.6	0.4 ± 0.8	41.8 ± 1.3	83.4 ± 5.4	4.1 ± 2.2	31.2 ± 5.9
78	6.5	0.8	38.8	71.5	3.1	21.6

FIG. 5

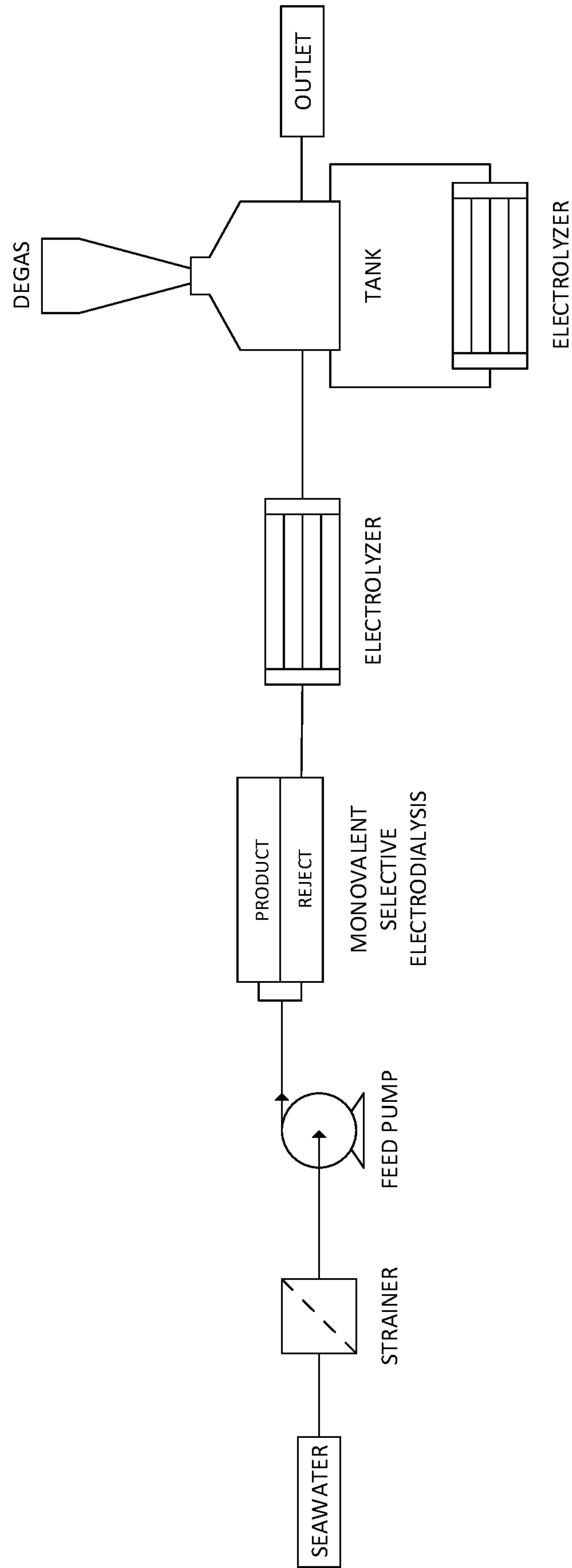


FIG. 6

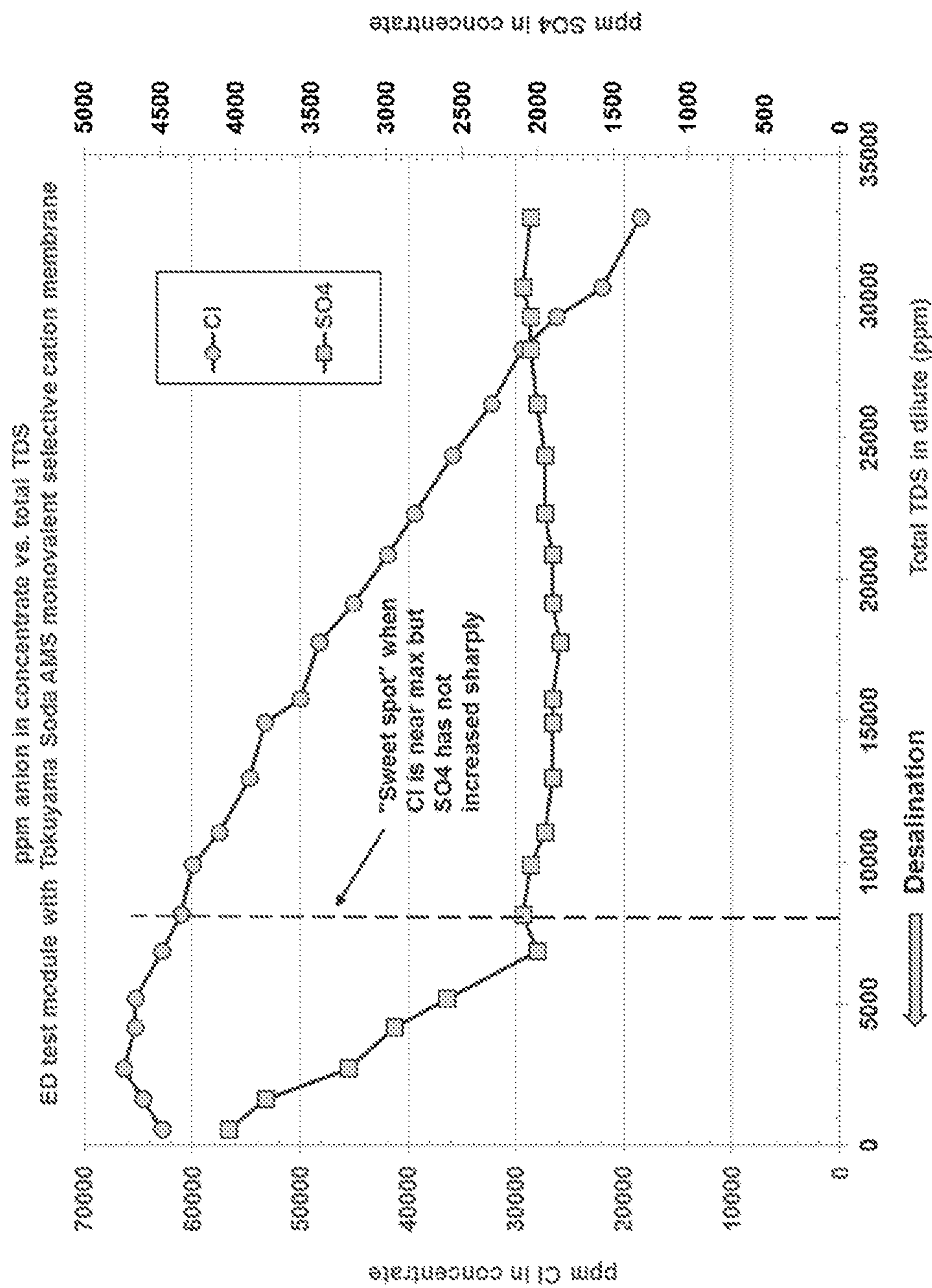


FIG. 7A

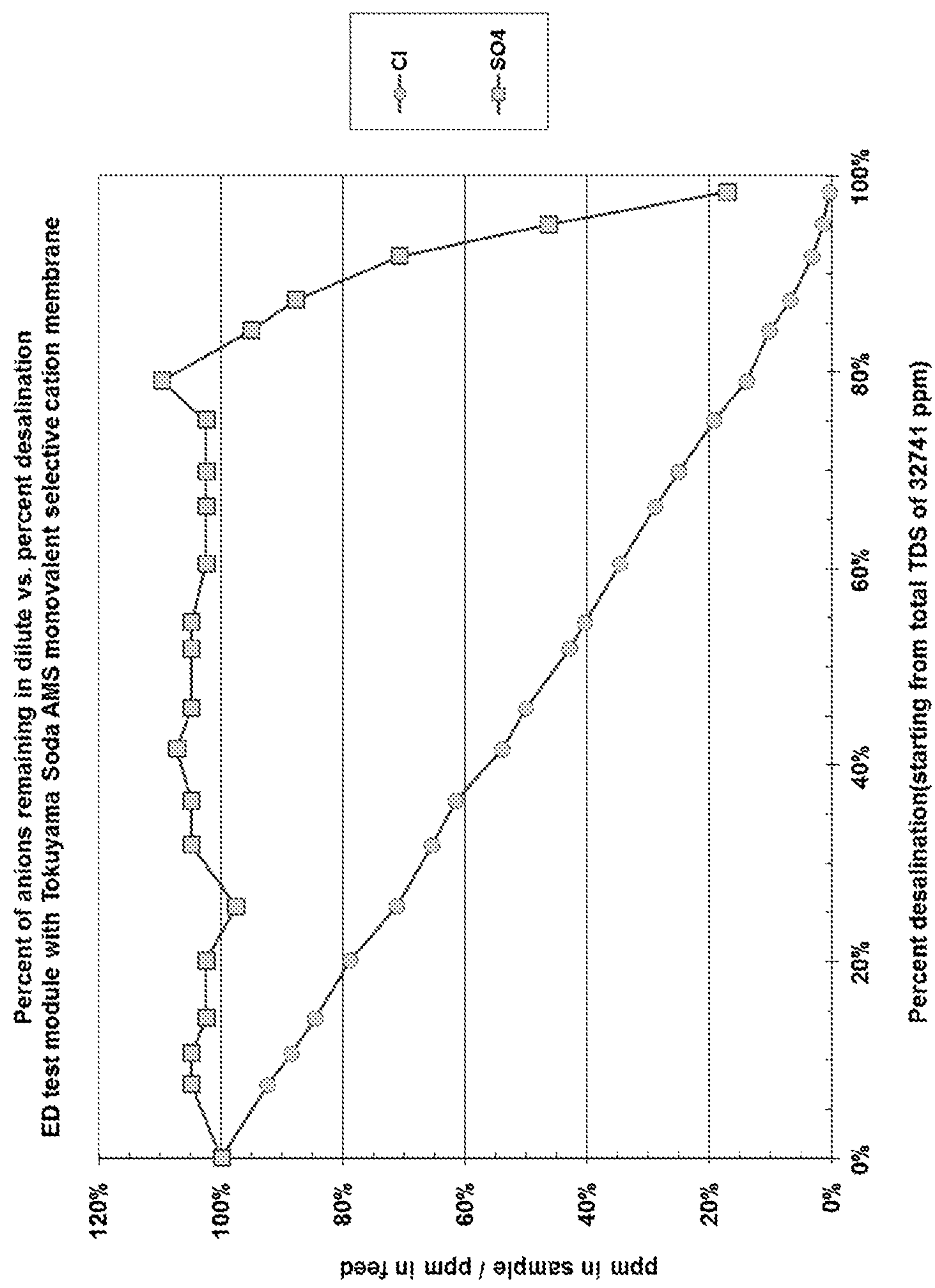


FIG. 7B

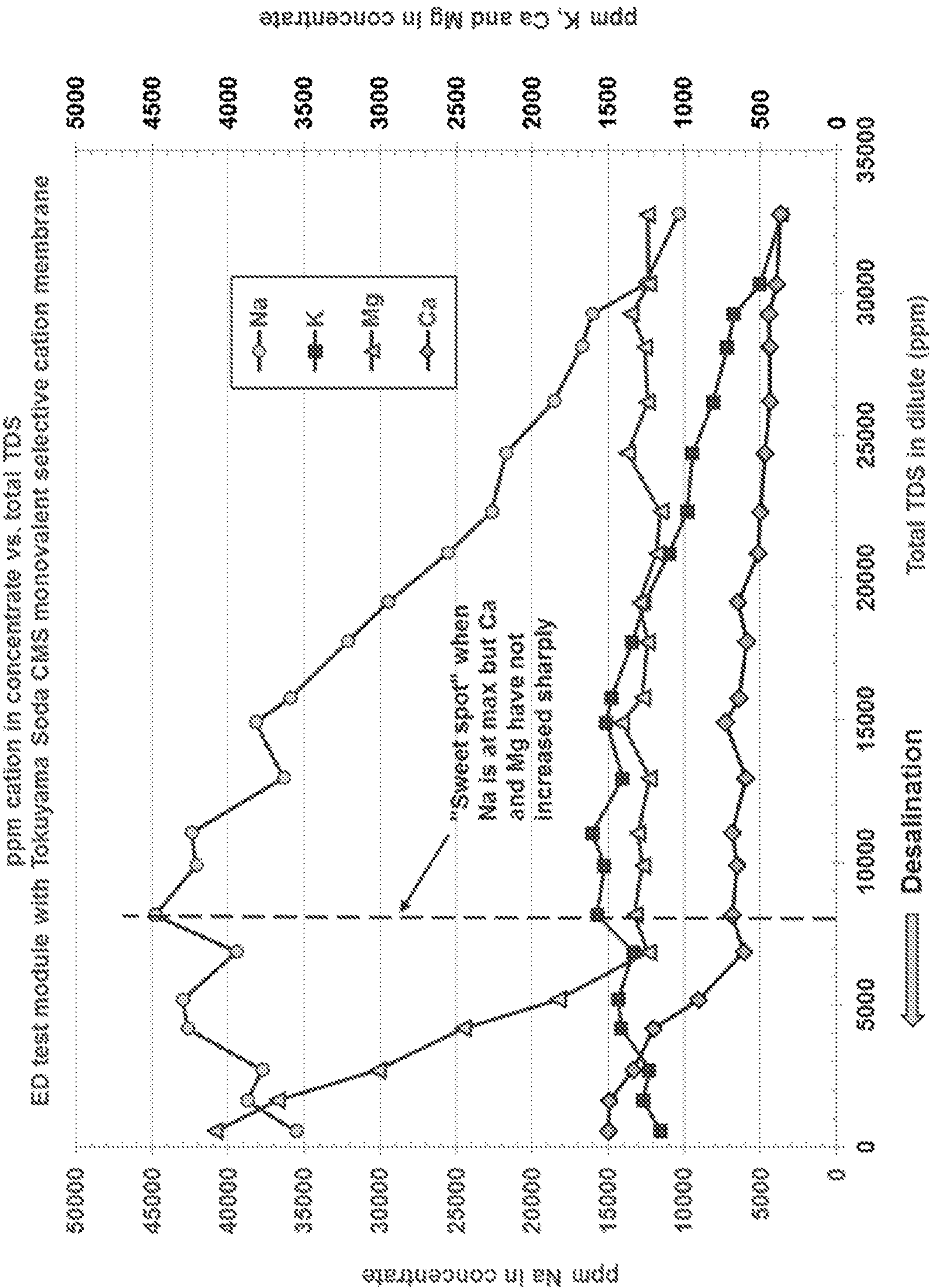


FIG. 8A

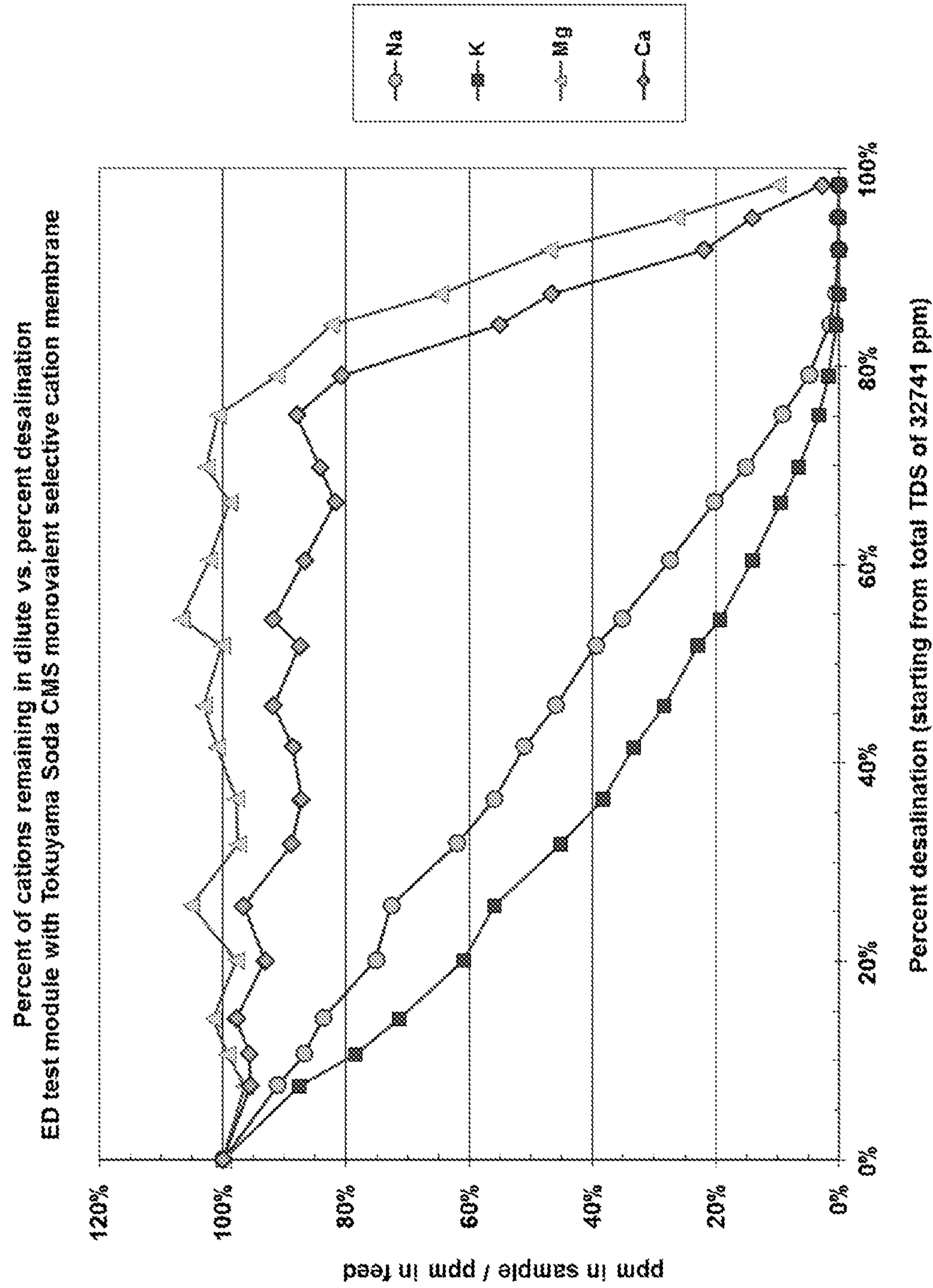


FIG. 8B

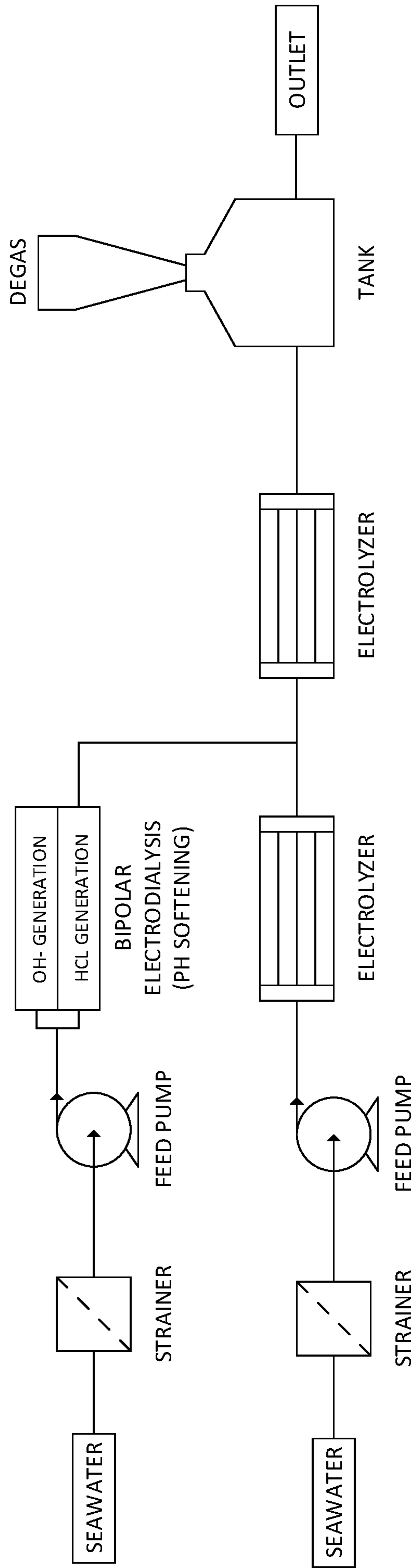


FIG. 9A

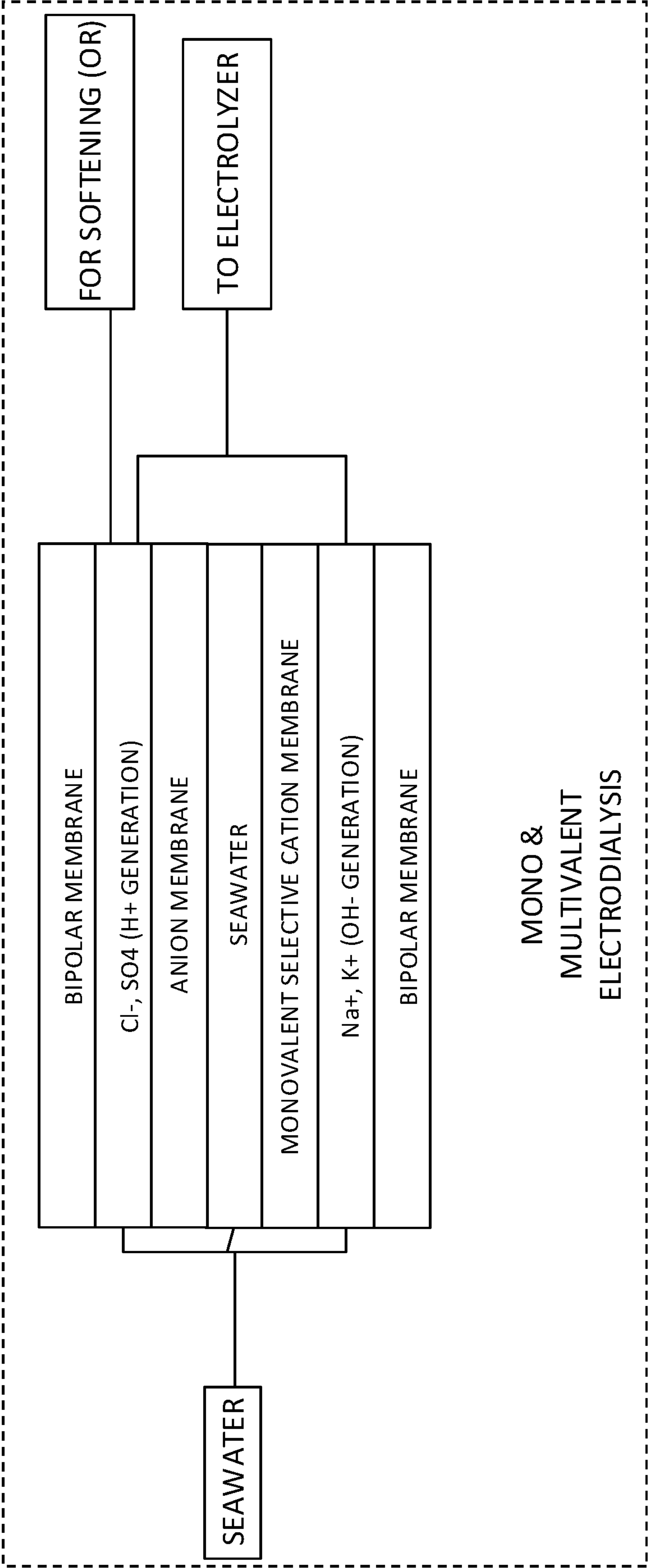


FIG. 9B

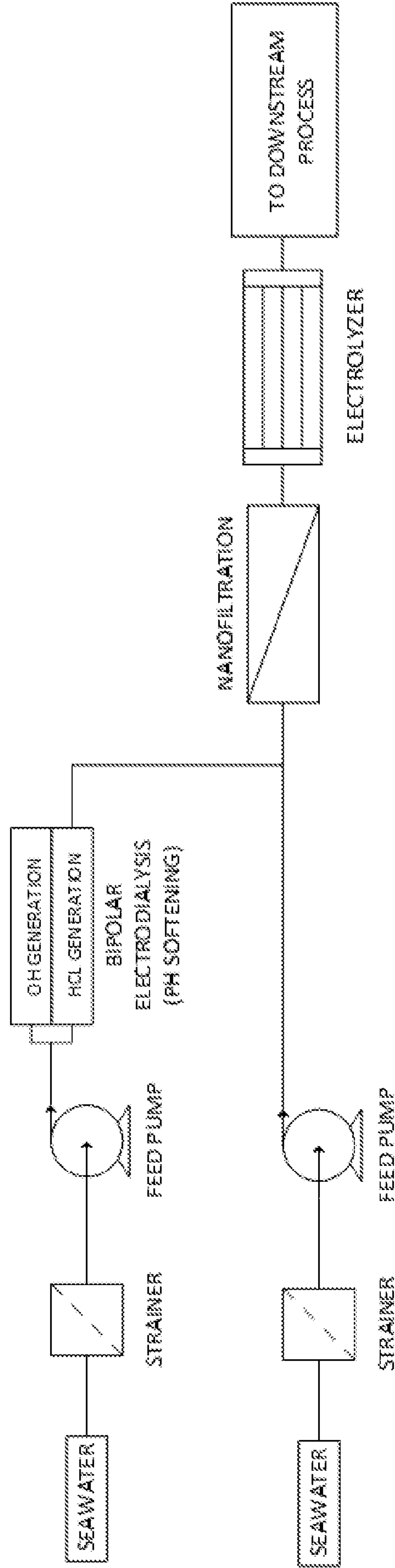


FIG. 10

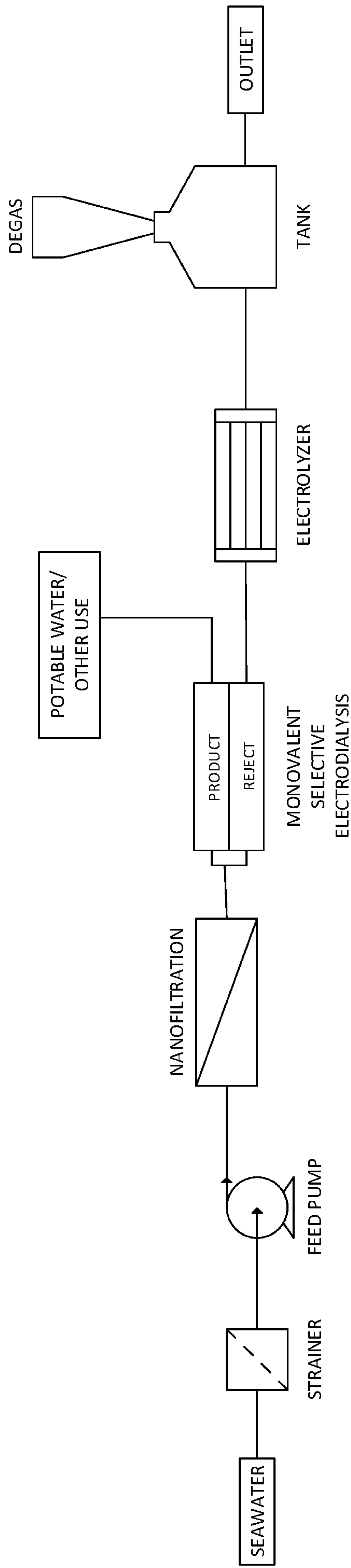


FIG. 11A

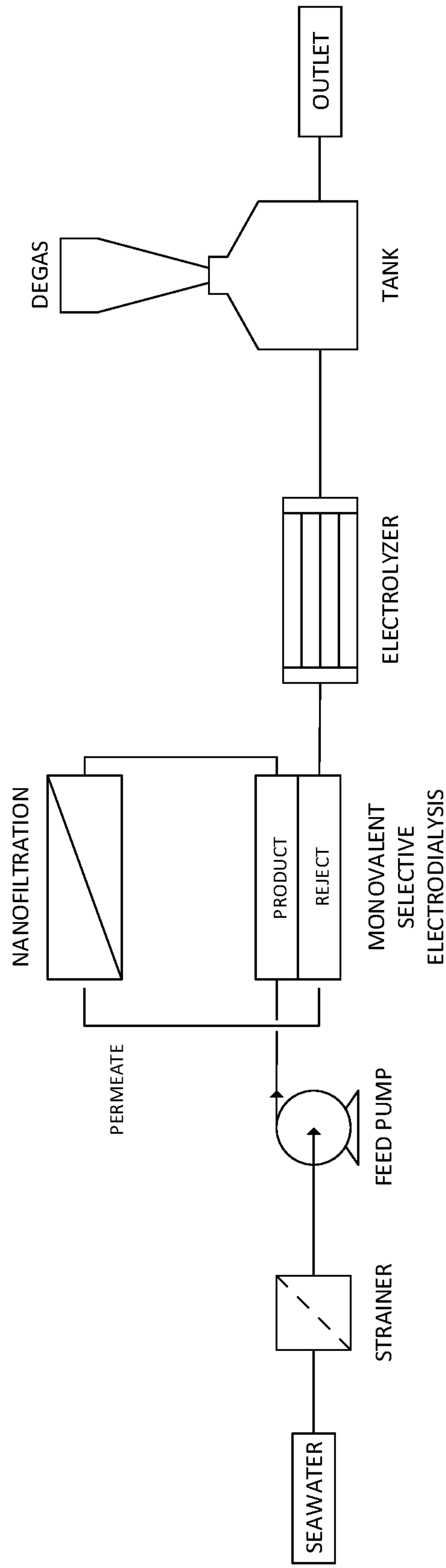


FIG. 11B

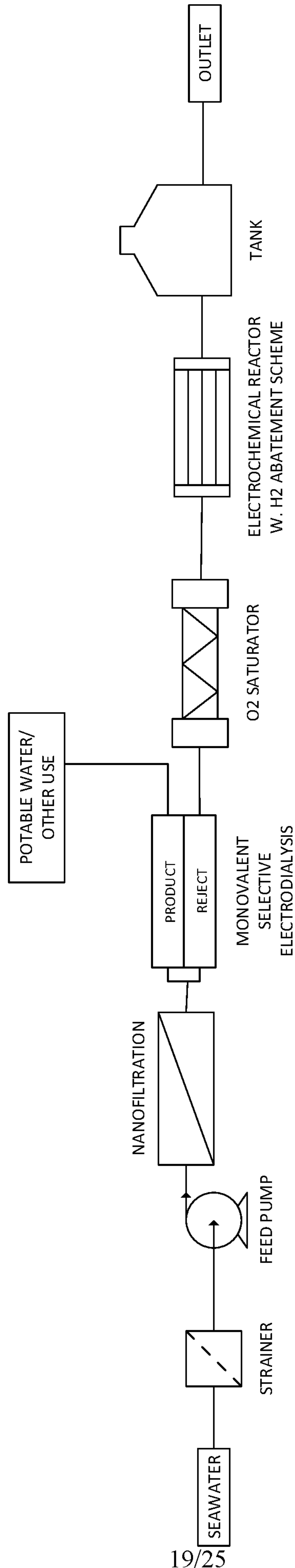


FIG. 12A

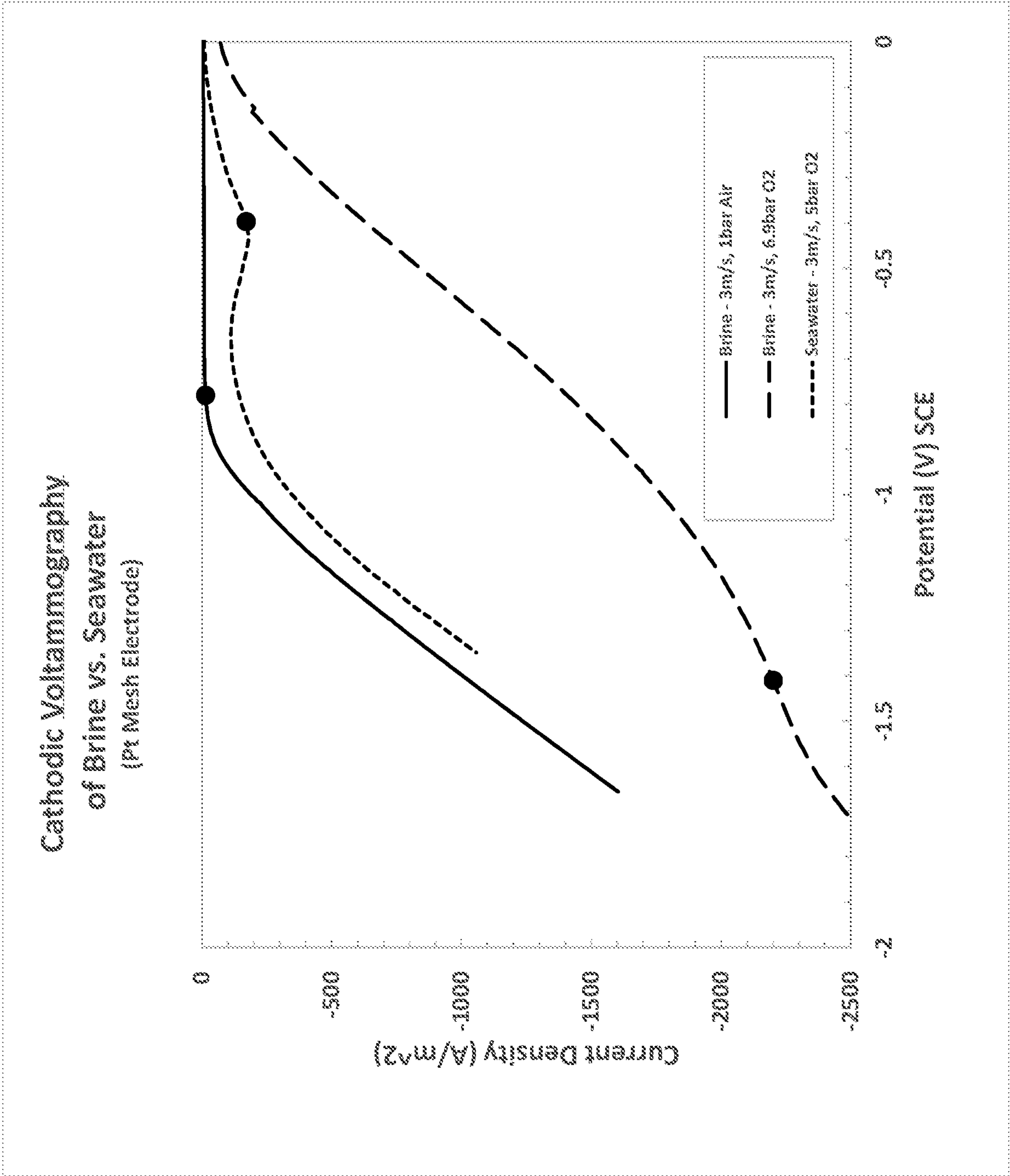


FIG. 12B

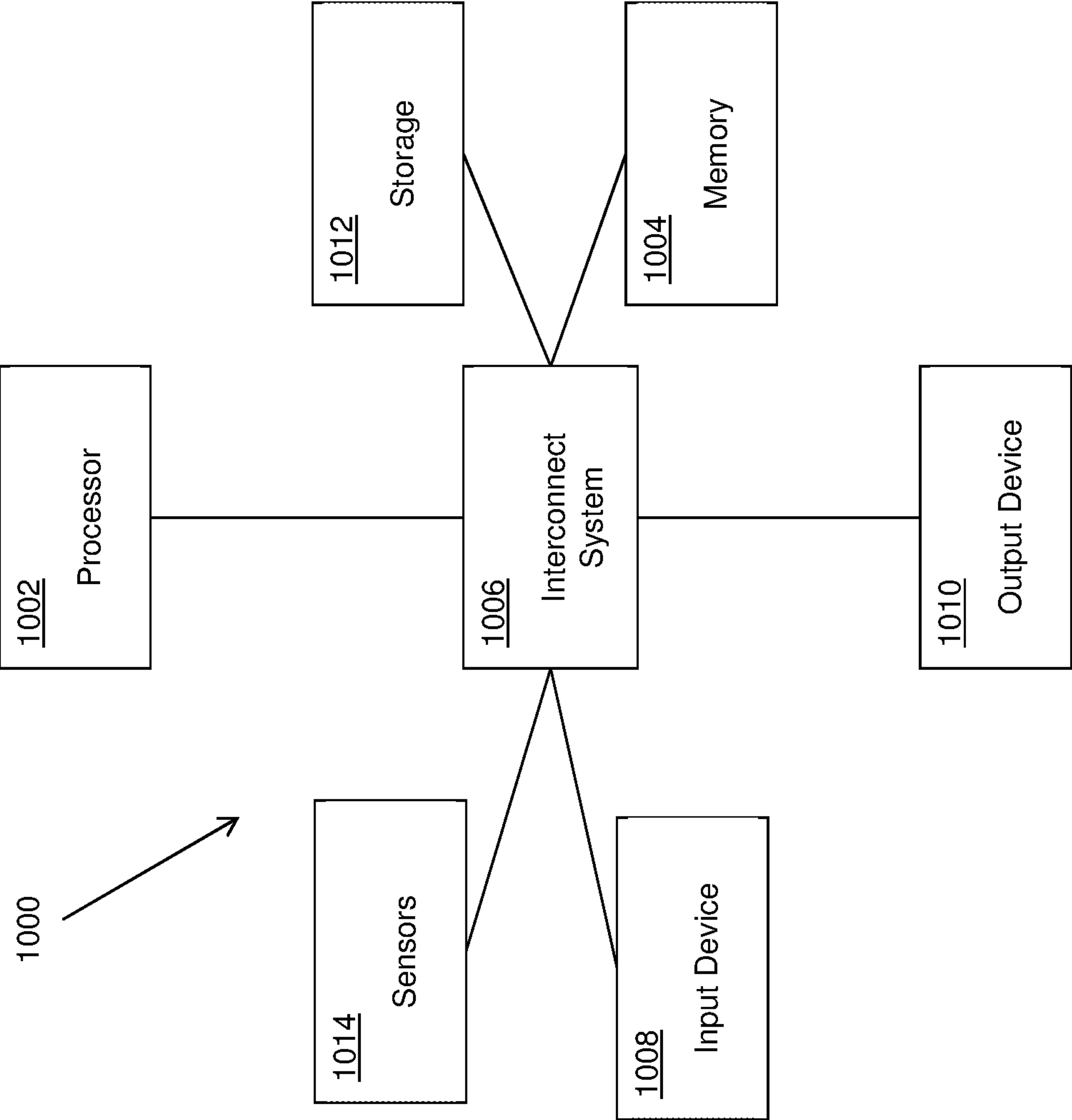


FIG. 13

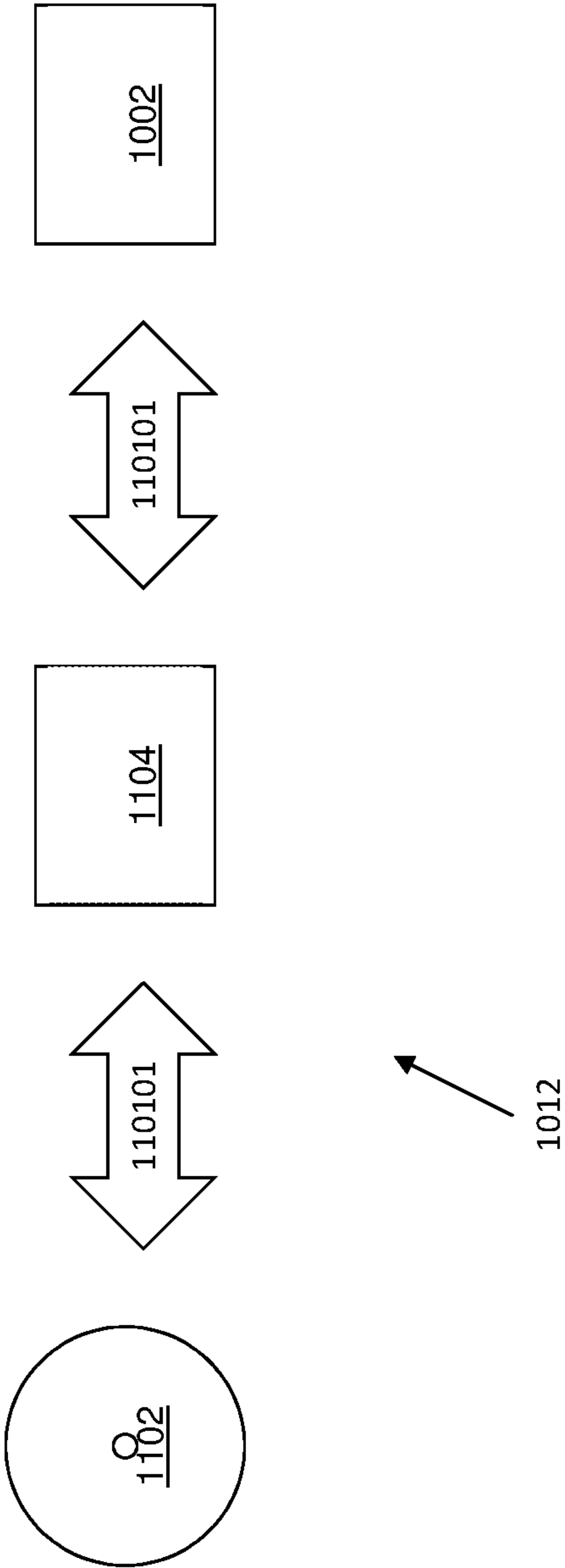


FIG. 14

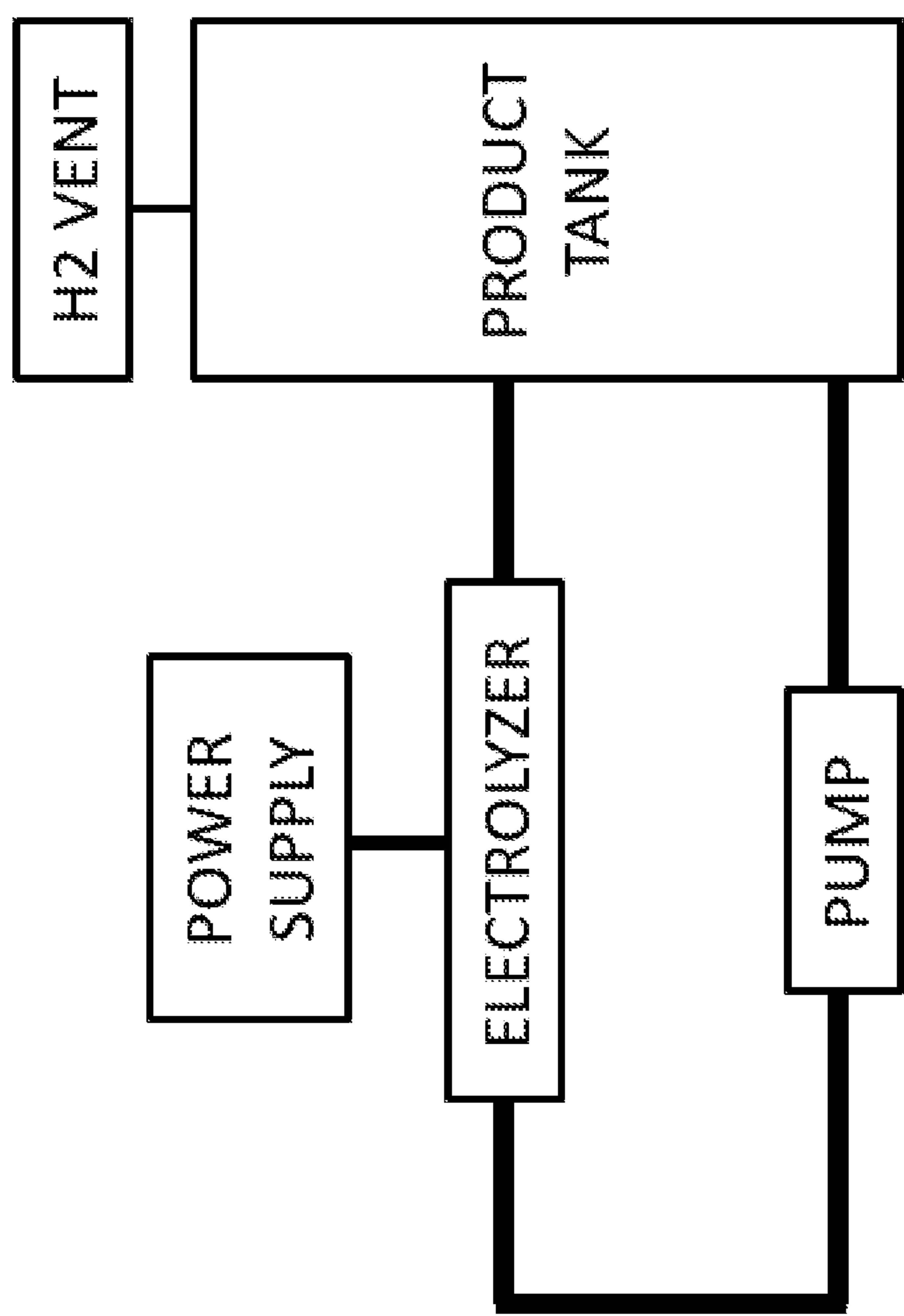


FIG. 15A

Mean Concentration of major ions in Instant Ocean® synthetic seawater at approximate salinity of 35 ppt	
Ion	Concentration (ppm)
Chloride	19,290
Sodium	10,780
Magnesium	1,320
Potassium	420
Calcium	400
Carbonate/bicarbonate	200
Bromide	56
Strontium	8.8
Fluoride	1
Iodide	0.24

FIG. 15B

RECIRCULATING HYPOCHLORITE GENERATION									
EXPERIMENTAL PARAMETERS									
Temperature (C)	20	20	20	20	20	20	20	20	20
Flow Rate (L/min)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Time of Operation (hrs)	2.08	1.18	0.83	0.83	0.42	0.12			
V DC	11.62	11.8	9.81	9.5	9.5	9.5			
A DC	12	12	8.3	8.3	8.3	8.3			
Feed Conductivity (mS)	45.8	45.1	45.3	45.25	45.06				
Volume (L)	6	8	8	8	8	8			
Titration #1 (mL)	8.65	4.94	3.09	7.2	4.45				
Titration #2 (mL)	8.69	4.96	3.02	7.2	4.43				

EXPERIMENTAL NOTES
3.5% Instant Ocean (I.O.) solution prepared with RO water
1mol NaClO equivalent to 1mol Cl ₂ (MW=70.91g/mol)
Na ₂ S ₂ O ₃ Conc. = 0.1M

HYPOCHLORITE CONC. (VIA TITRATION)							
Conc. Theoretical (ppm)	8000	4000	2000	1000	300		
Conc. Det.#1 (mg/L)	6134	3503	2191	1276	789		
Conc. Det.#2 (mg/L)	6162	3517	2141	1276	785		
Conc. Average (mg/L)	6148	3510	2166	1276	787		
Titration Volume (mL)	5	5	5	20	20		
Deviation %	-23.2	-12.2	8.3	27.6	162.4		

HYPOCHLORITE CONC. (VIA ABSORBANCE)							
385 nm	0.233	0.161	0.122	0.099	0.088		
390 nm	0.166	0.117	0.091	0.075	0.067		
395 nm	0.123	0.089	0.069	0.058	0.053		
pH	8.79	8.79	8.76	8.67	8.74		

3.5% I.O. (ABSORBANCE)	
385 nm	0.02
390 nm	0.019
395 nm	0.018

FIG. 15C