

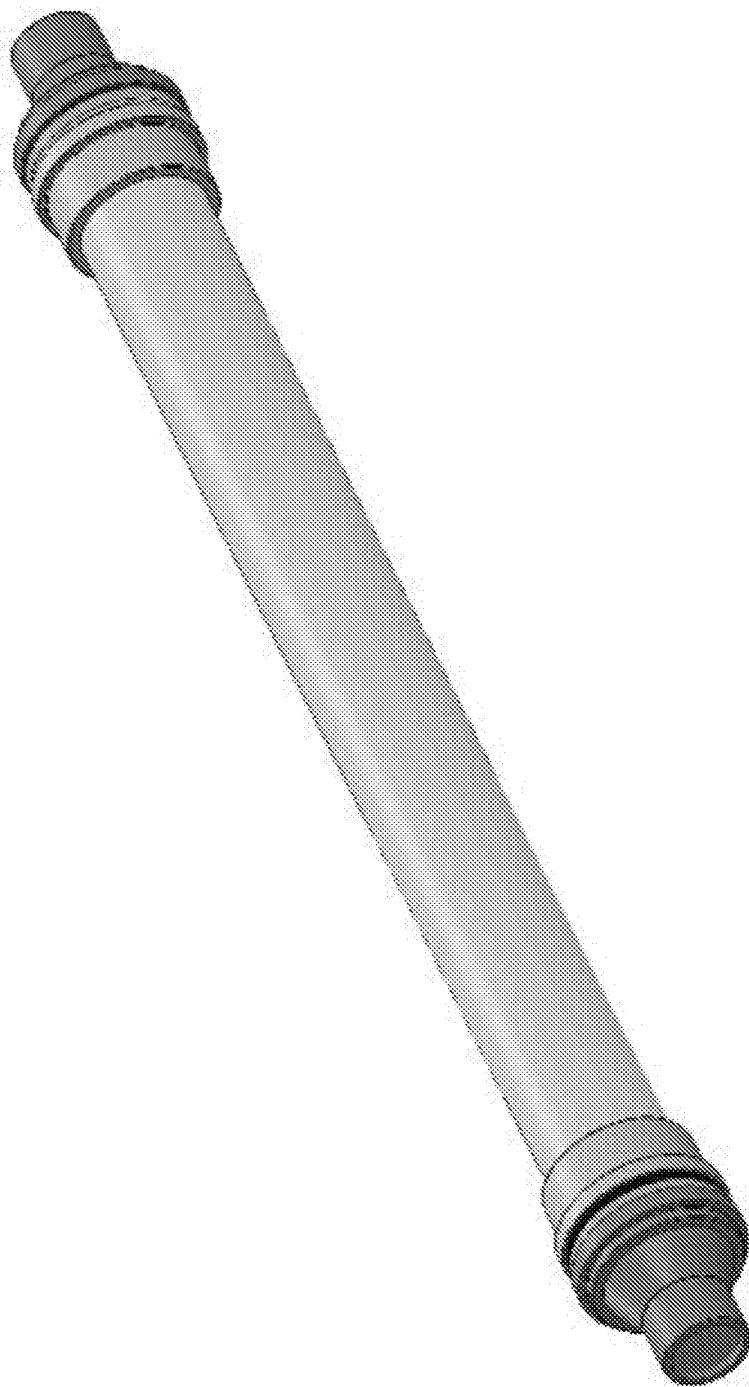


FIG. 1A

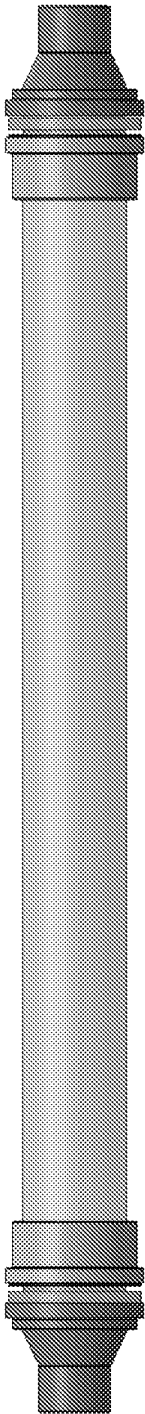


FIG. 1B

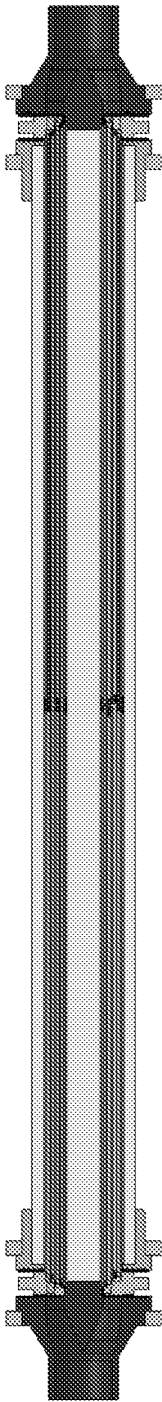


FIG. 1C



FIG. 2

Flow Rate (m^3/hr)
22
Cell Output (kg/hr)
2.2
Pump Discharge Pressure (Barg)
8
Pressure Loss from Pump (Barg)
0.25
Hydrogen Generation/kg Hypo (m^3/hr)
0.45
H₂ Solubility in Water (m^3/hr @ 1 BarA)
0.44

Constant	Value	Unit
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

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 m ³ /hr (atmos)	Hydrogen Volume at Line Pressure m ³ /hr	Dissolvable Hydrogen m ³ /hr	Hydrogen in Cell m ³ /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:						
Cell#	Cl ₂ kg/hr	Cl ₂ ppm	H ₂ kg/hr	H ₂ ppm	OH ⁻ kg/hr	OH ⁻ 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

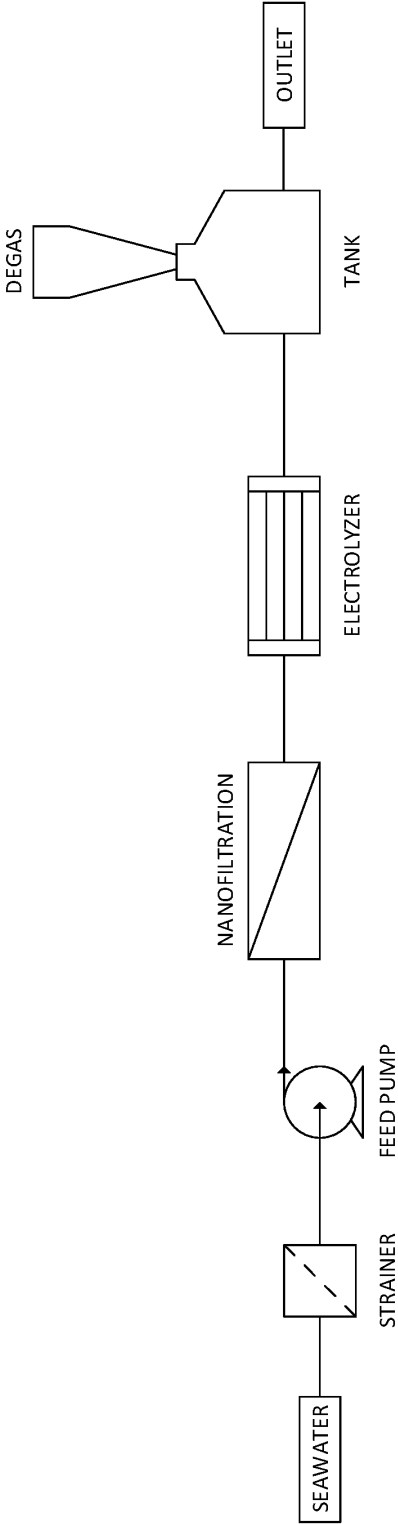


FIG. 4

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 ⁺ (+)(%)	Ca ²⁺ (+)(%)	Mg ²⁺ (+)(%)	K ⁺ (+)(%)	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

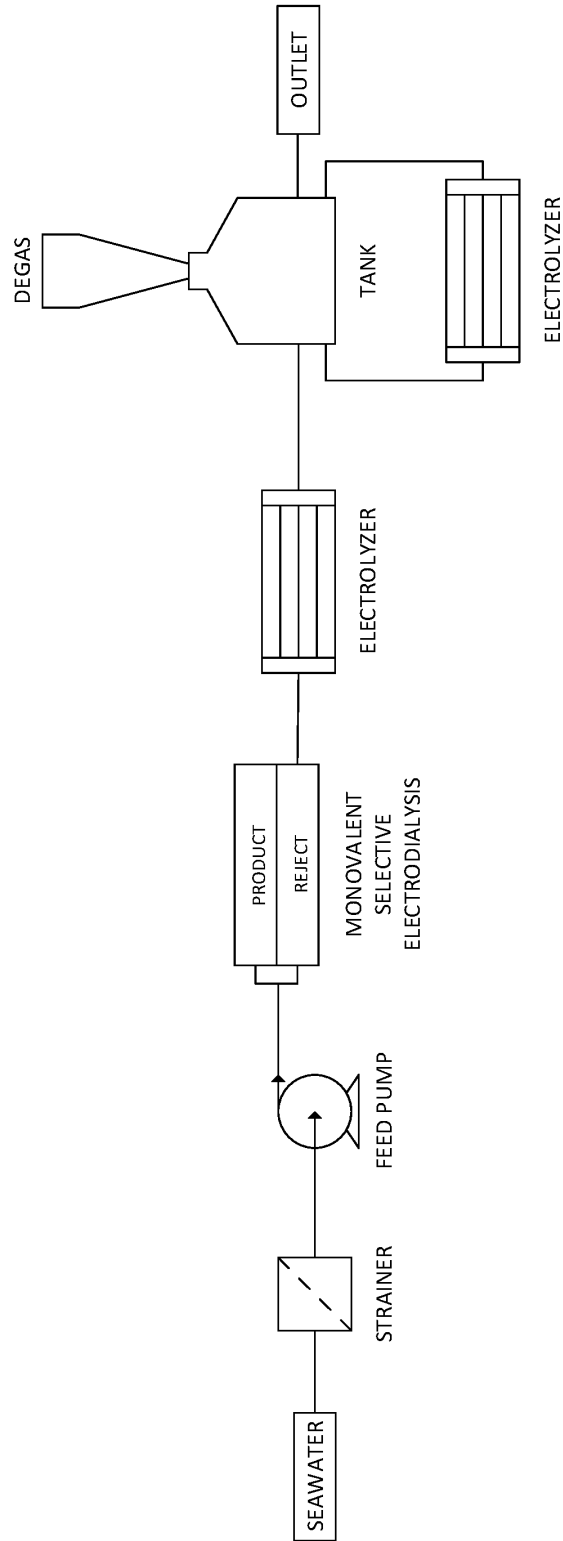


FIG. 6

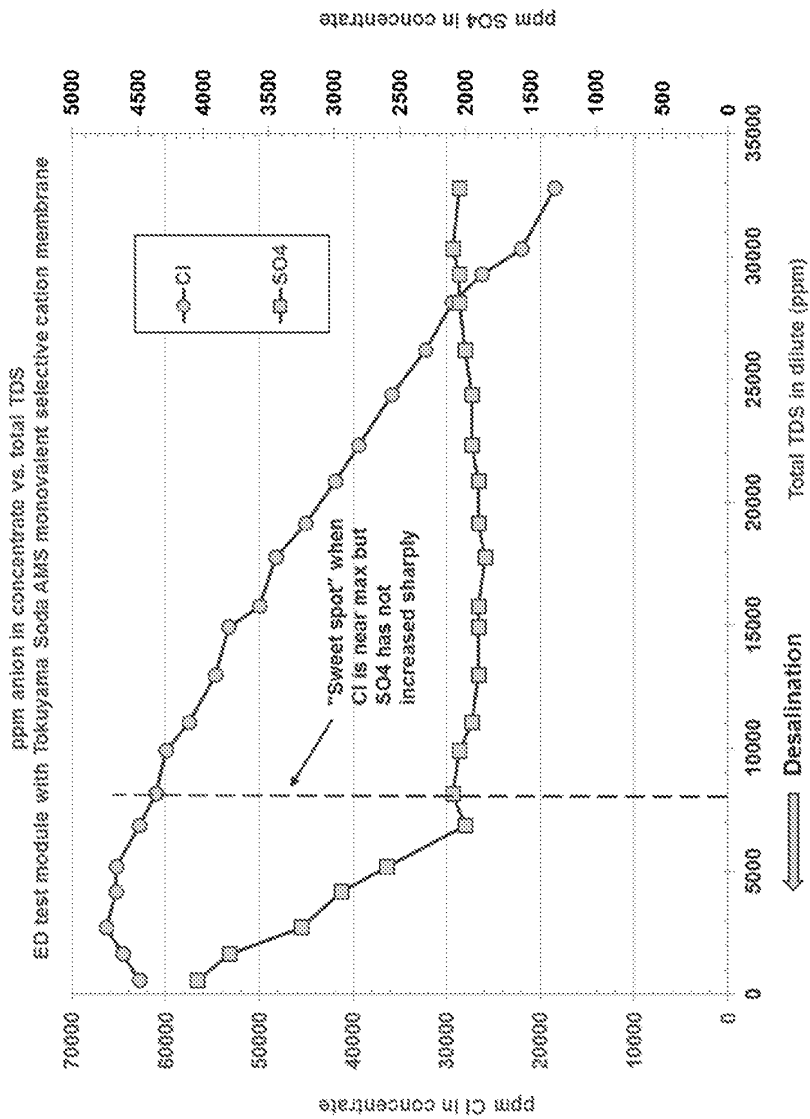


FIG. 7A

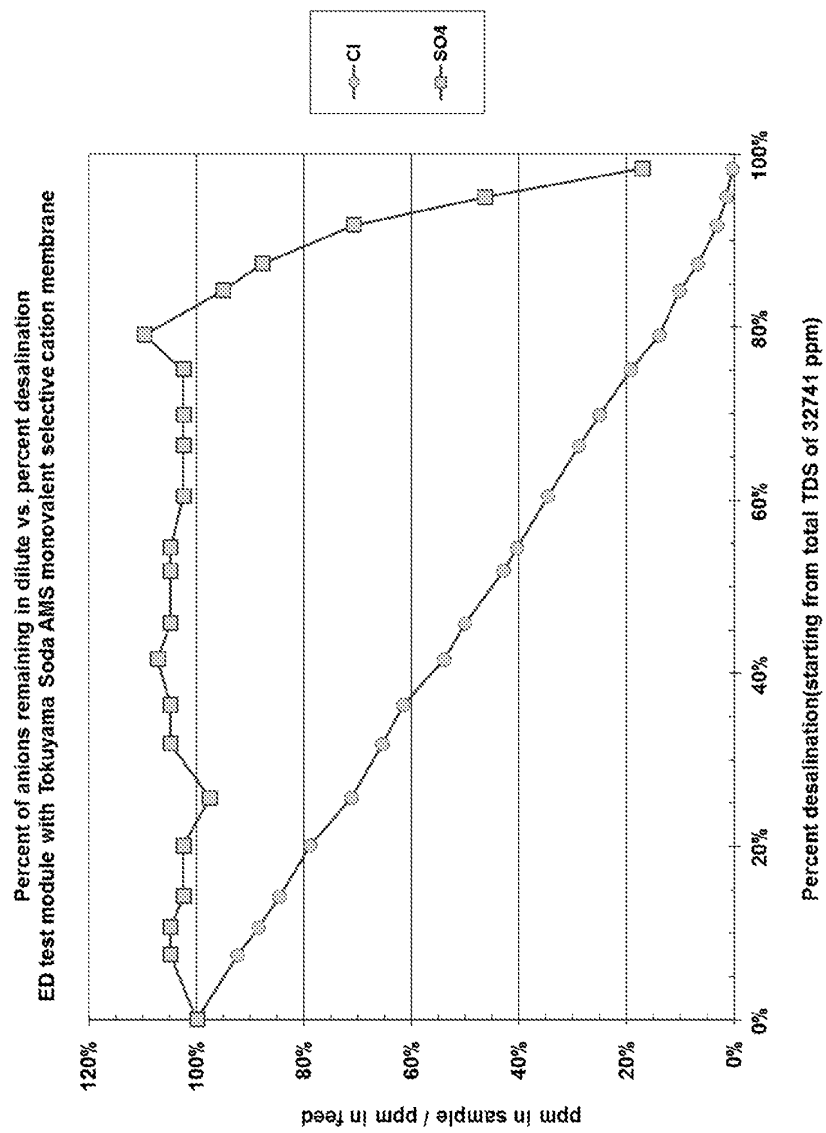


FIG. 7B

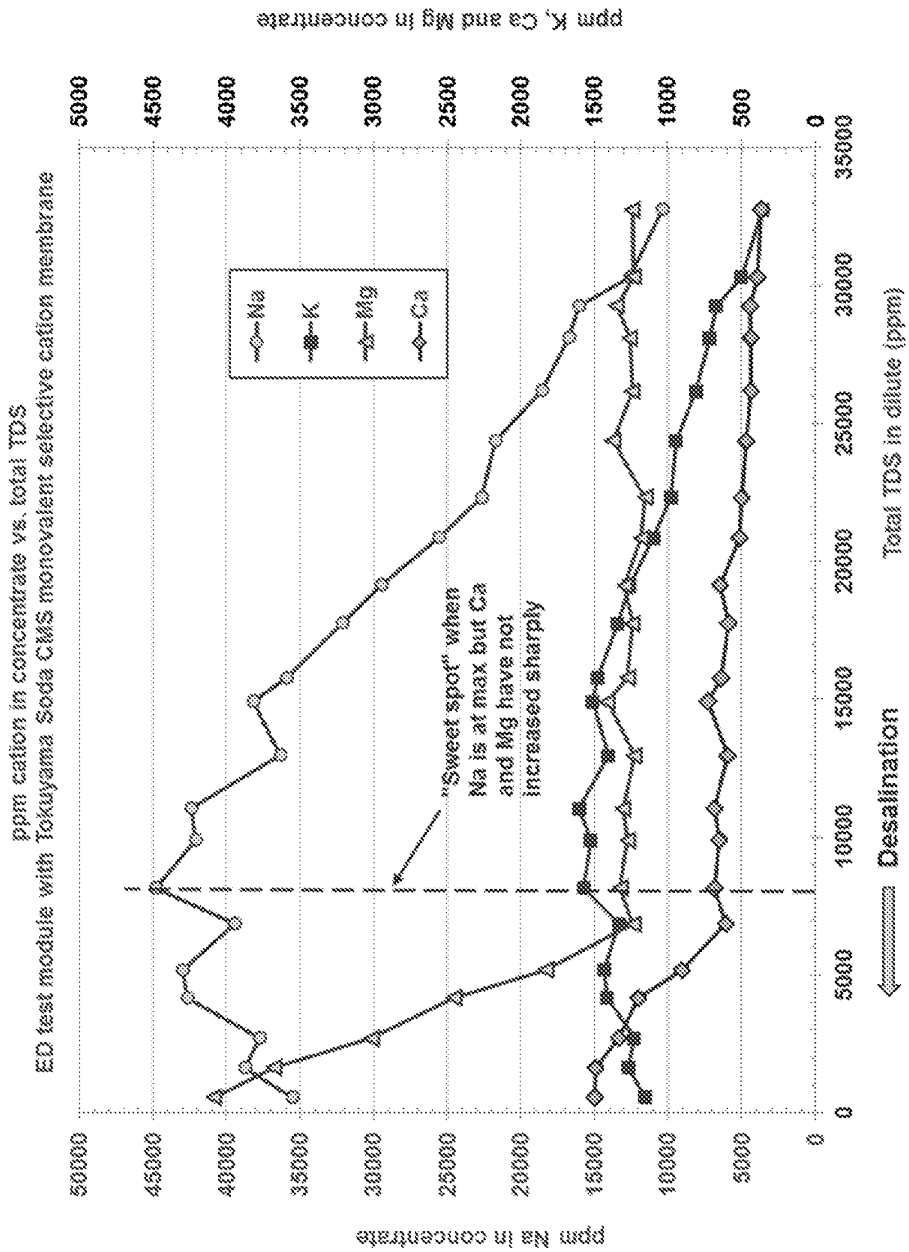


FIG. 8A

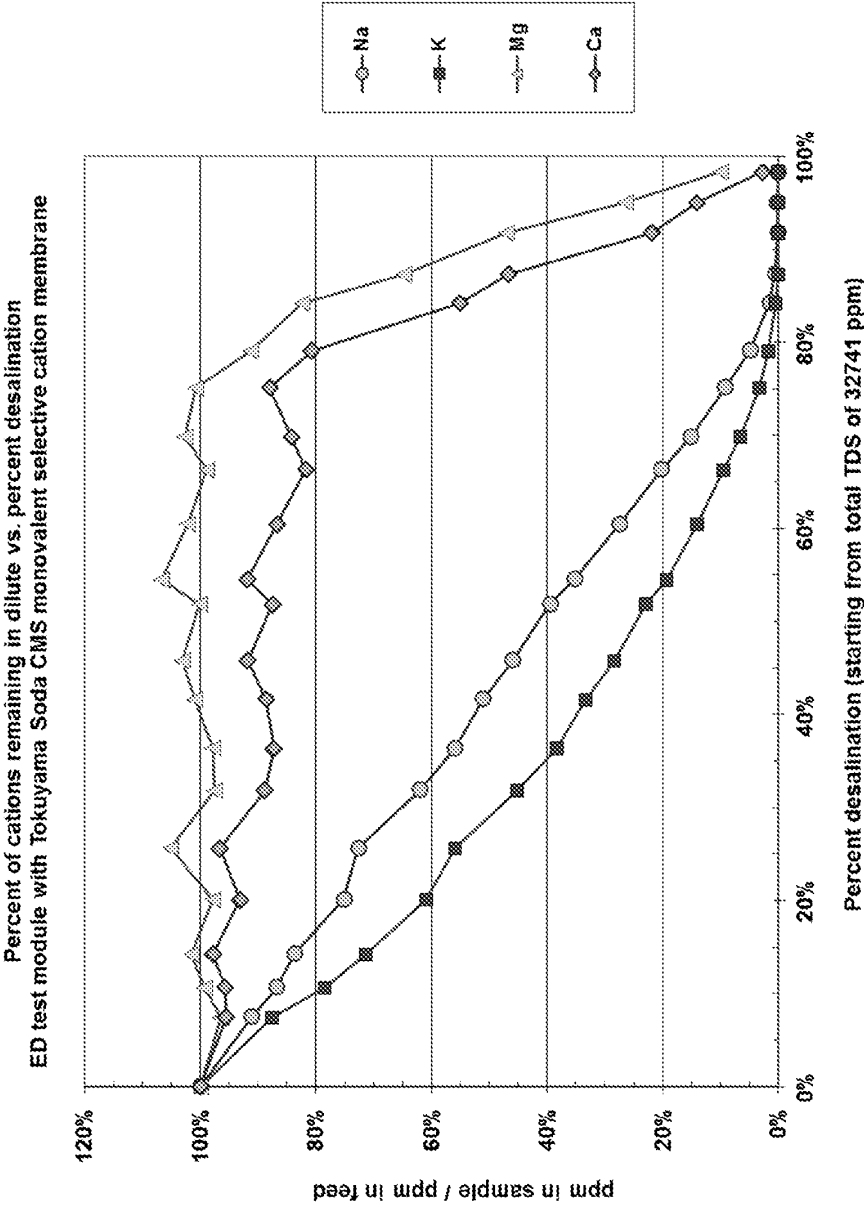


FIG. 8B

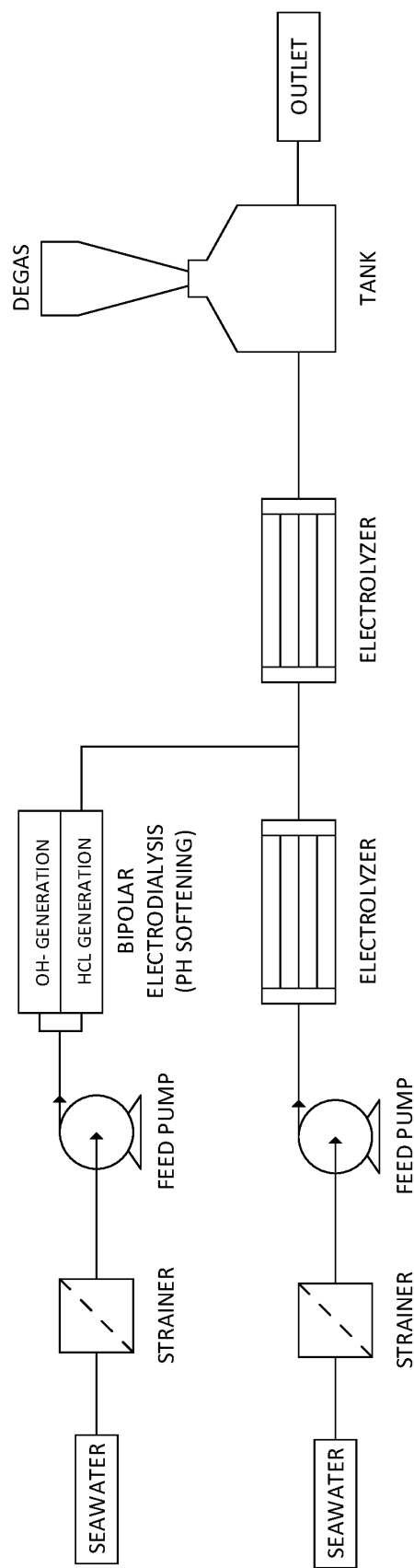


FIG. 9A

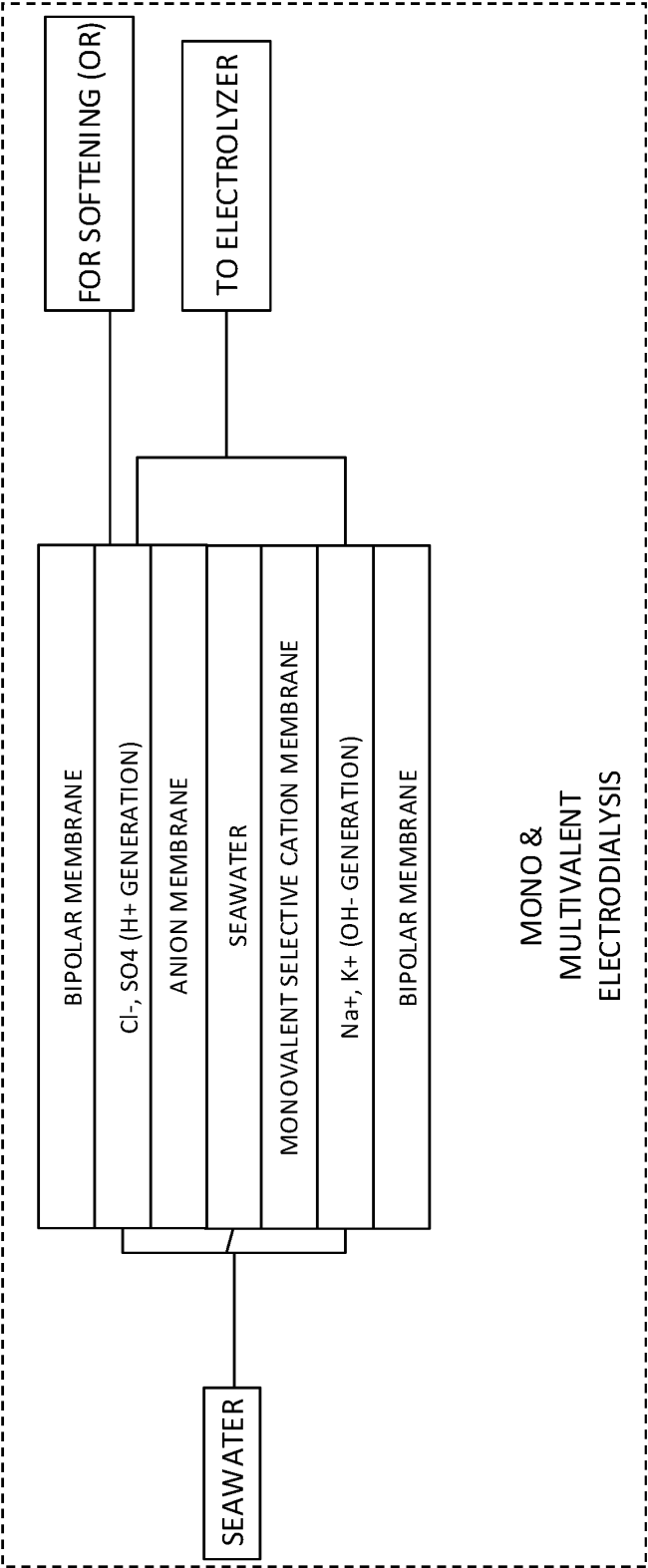


FIG. 9B

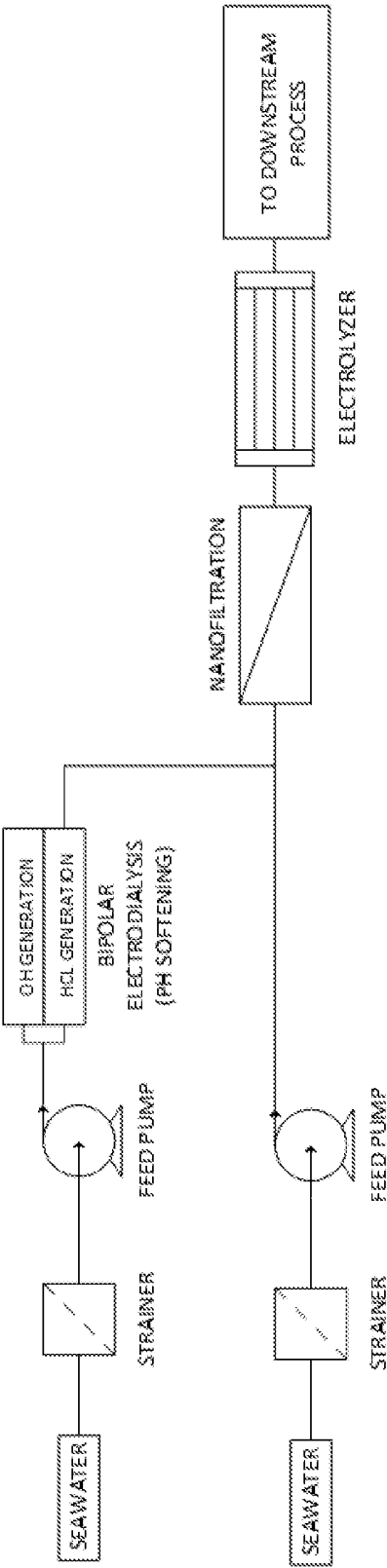


FIG. 10

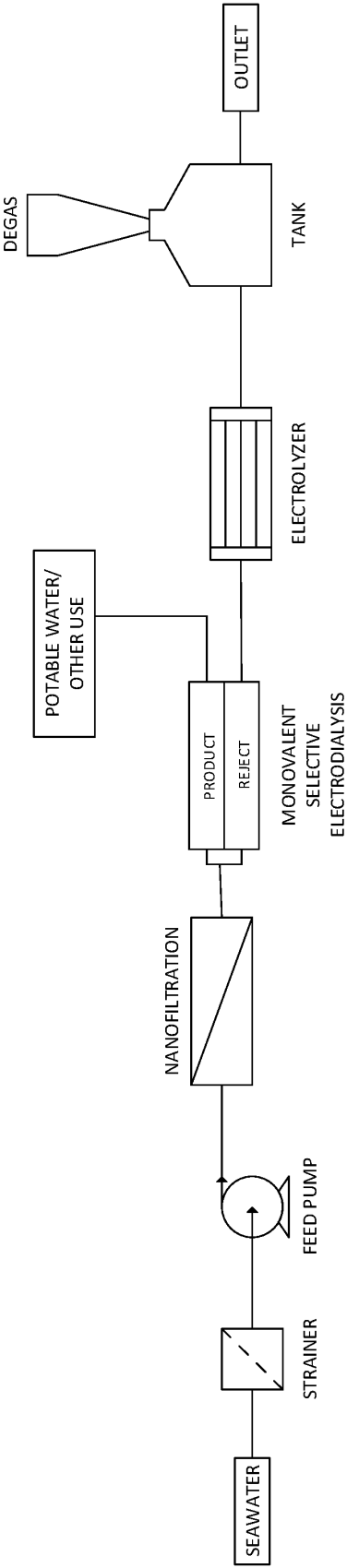


FIG. 11A

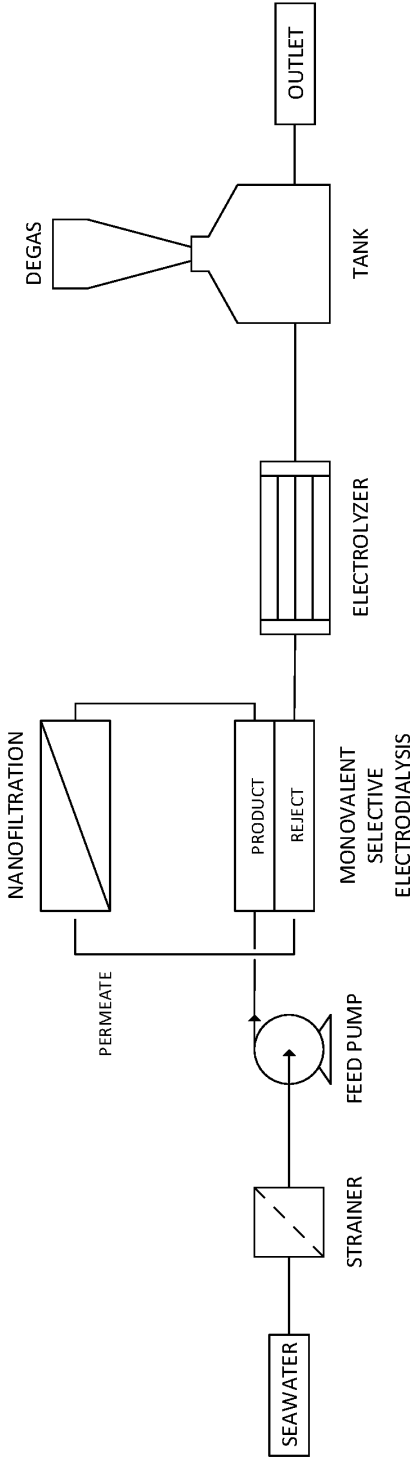


FIG. 11B

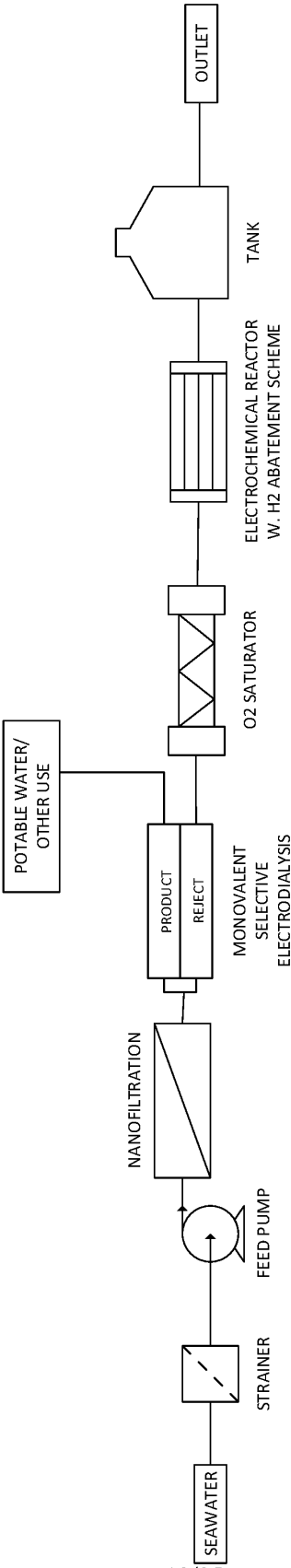


FIG. 12A

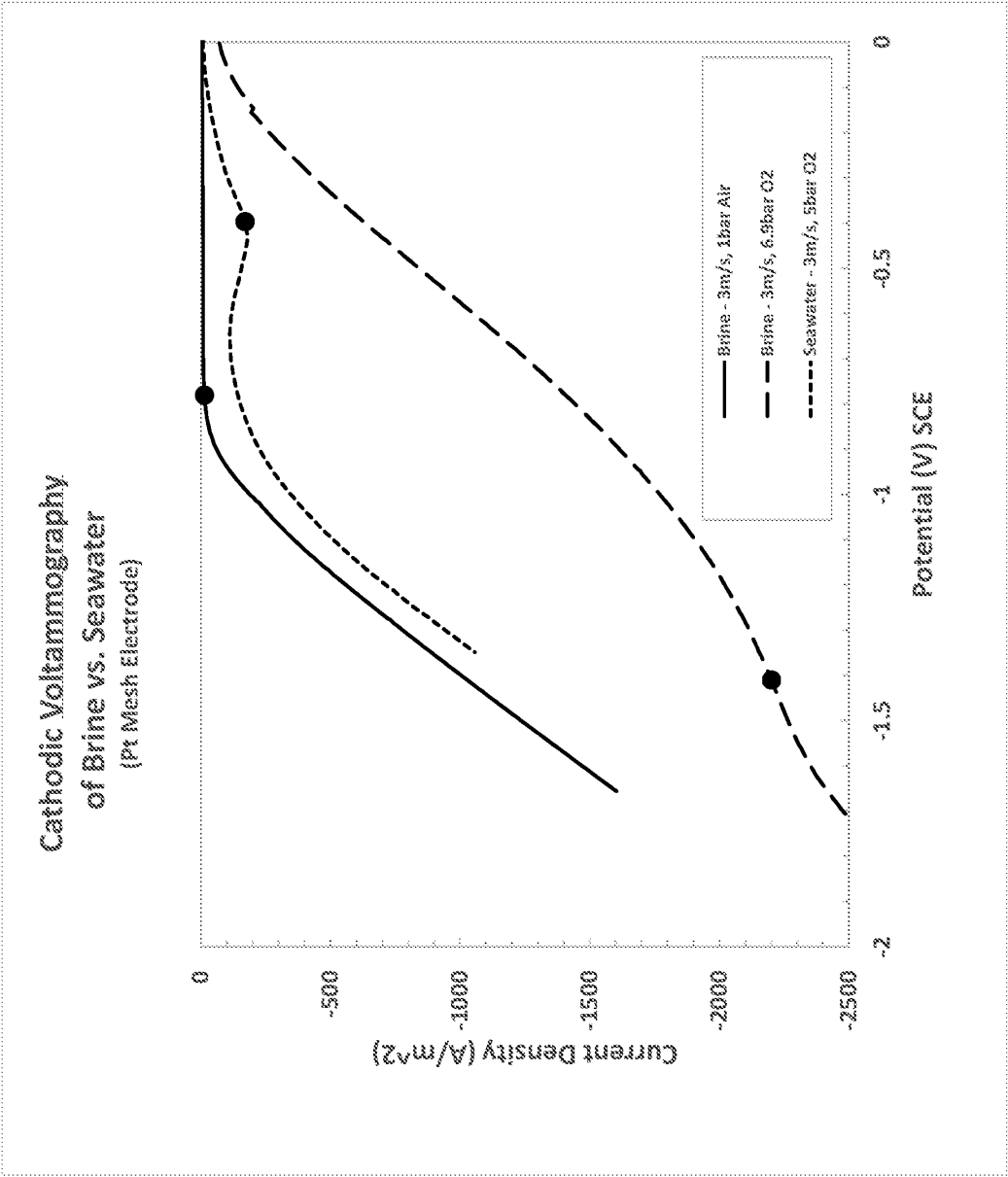


FIG. 12B

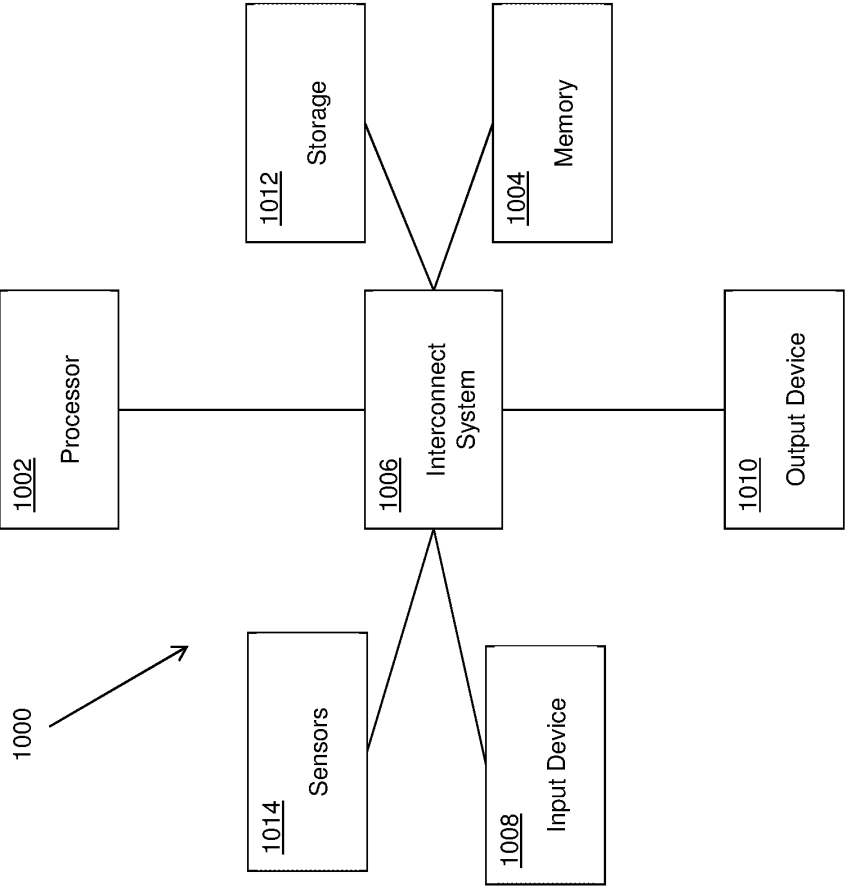


FIG. 13

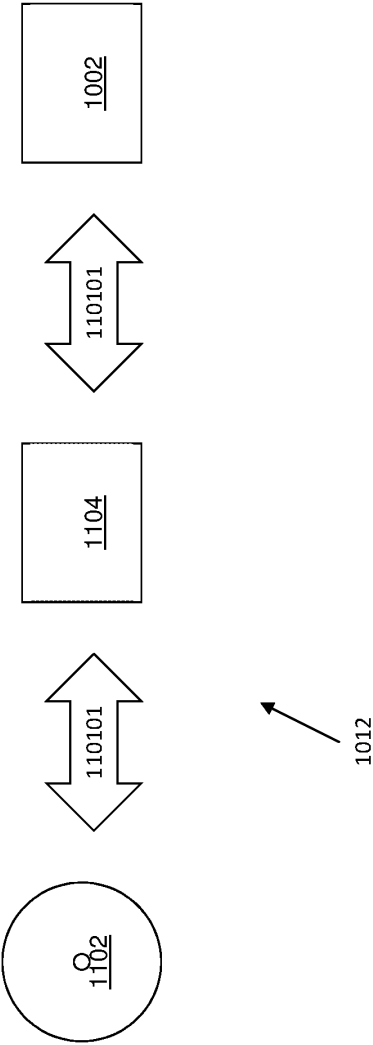


FIG. 14

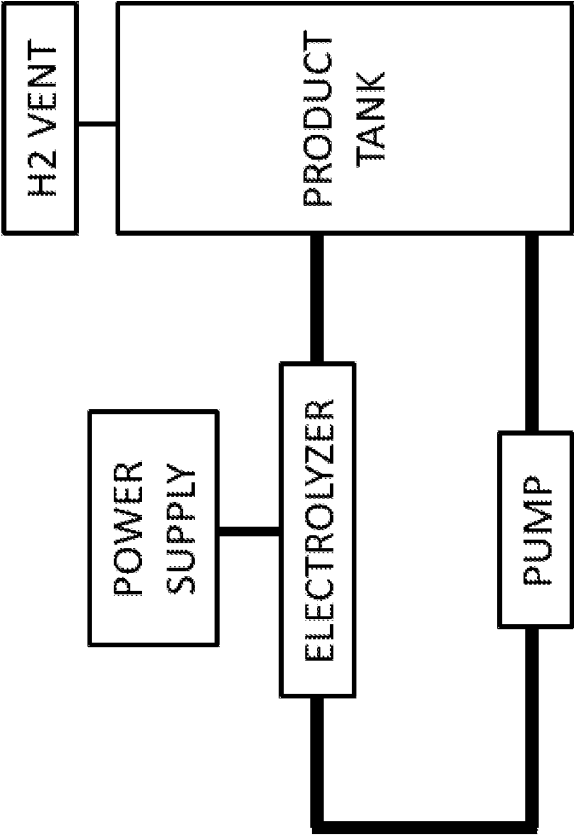


FIG. 15A

<i>Mean Concentration of major ions in Instant Ocean® synthetic seawater at approximate salinity of 35 ppt</i>	
<i>Ion</i>	<i>Concentration (ppm)</i>
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			
VDC	11.62	11.8	9.81	9.5	9.5	9.5			
ADC	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				

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

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	

FIG. 15C