APPENDIX A

AEROGEL QAULITY CONTROL AND INDUSTRIAL CDT™ PROTOTYPE TEST RUN DATA

Aerogel QAQC Test Procedure

The attached data file show a typical QAQC test procedure that was conducted by the researcher on each batch of carbon aerogel produced during the industrial module development phase.

- Two pieces of aerogel { 7.62 cm (3-inch) x 5.08 cm (2-inch) } was cut from a randomly selected aerogel sheet.
- The two pieces were then electrically connected in a 10 000 ppm NaCl solution as a capacitor.
- Computer measurements were taken of the applied voltage and current to the capacitor during a charge and discharge cycle. Three test runs was done per QAQC test.
- Voltage and current data was then used to calculate total energy used to charge the capacitor per test run and the total energy discharged by the capacitor, as measured through a shunt resistor.
- A summary sheet was then generated, via a macro program written by the researcher.
- The amount of energy stored by the mini aerogel capacitor is a direct link to the amount of ion storage to be expected by the industrial unit. Therefore a batch of produced aerogel was passed or failed by this procedure, before the aerogel was inserted into an industrial module.

Aerogel QAQC Test Data Run 1

Time (sec)	Voltage	Current	Energy J	Power W
0	0	0	0	0
10	0	0	0	0
20	1.42578	0.238525	3.400842	0.340084
30	1.31592	0.286621	7.172545	0.37717
40	1.30859	0.251953	10.46958	0.329703
50	1.30615	0.226318	13.42563	0.295605
60	1.30371	0.204102	16.08653	0.26609
70	1.30371	0.185791	18.5087	0.242218
80	1.30371	0.170654	20.73354	0.222483
90	1.30127	0.157715	22.78583	0.20523
100	1.30371	0.146484	24.69556	0.190973
110	1.30127	0.136475	26.47147	0.177591
120	1.30127	0.127686	28.13301	0.166154
130	1.30127	0.120117	29.69606	0.156305
140	1.30127	0.113037	31.16697	0.147092
150	1.30127	0.106689	32.55528	0.138831
160	1.30127	0.101563	33.87689	0.132161
170	1.30127	0.0964355	35.13178	0.125489
180	1.30127	0.0917969	36.3263	0.119453
190	1.29883	0.0876465	37.46468	0.113838
200	1.29883	0.0837402	38.55233	0.108764
210	1.30127	0.079834	39.59118	0.103886
220	1.29883	0.0766602	40.58687	0.099569
230	1.30127	0.0737305	41.5463	0.095943
240	1.30127	0.0710449	42.47079	0.092449
250	1.29883	0.0688477	43.365	0.089421
260	1.30127	0.065918	44.22277	0.085777
270	1.29883	0.0637207	45.0504	0.082762
280	1.29883	0.0612793	45.84631	0.079591
290	1.30127	0.0593262	46.6183	0.077199
300	1.29883	0.057373	47.36348	0.074518
310	1.29883	0.0556641	48.08646	0.072298
320	1.29883	0.0537109	48.78408	0.069761
330	1.30127	0.0522461	49.46394	0.067986
340	1.30127	0.0505371	50.12156	0.065762
350	1.30127	0.0493164	50.7633	0.064174
360	1.30127	0.0480957	51.38916	0.062585
370	1.30127	0.0463867	51.99277	0.060362
380	1.29883	0.045166	52.5794	0.058663
390	1.29883	0.0444336	53.15652	0.057712
400	1.30127	0.0432129	53.71884	0.056232
410	1.30127	0.0419922	54.26527	0.054643
420	1.29883	0.0412598	54.80116	0.053589
430	1.30127	0.0397949	55.319	0.051784
440	1.29883	0.0390625	55.82636	0.050736
450	1.29883	0.0380859	56.32103	0.049467
460	1.30127	0.0371094	56.80392	0.048289
470	1.29883	0.036377	57.2764	0.047248
480	1.30127	0.0356445	57.74023	0.046383
490	1.29883	0.034668	58.19051	0.045028
500	1.30127	0.0336914	58.62892	0.043842
510	1.29883	0.0332031	59.06018	0.043125
520	1.29883	0.0324707	59.48192	0.042174
530	1.30127	0.0322266	59.90127	0.041936
540	1.29883	0.0314941	60.31033	0.040905
550	1.30127	0.0307617	60.71062	0.040029
560	1.30127	0.0305176	61.10773	0.039712
570	1.30127	0.0297852	61.49532	0.038759
580	1.29883	0.0292969	61.87584	0.038052

590	1.29883	0.0285645	62.24684	0.0371
600	1.29883	0.0280762	62.6115	0.036466
610	1.29883	0.027832	62.97299	0.036149
620	1.29883	0.0273438	63.32814	0.035515
630	1.29883	0.0268555	63.67695	0.034881
640	1.29883	0.0266113	64.02259	0.034564
650	1.30127	0.0258789	64.35934	0.033675
660	1.30127	0.0256348	64.69292	0.033358
670	1.30127	0.0253906	65.02332	0.03304
680	1.30127	0.0249023	65.34737	0.032405
690	1.29883	0.0244141	65.66446	0.03171
700	1.29883	0.0244141	65.98156	0.03171
710	1.29883	0.0239258	66.29232	0.031076
720	1.30127	0.0234375	66.5973	0.030499
730	1.29883	0.0231934	66.89854	0.030124
740	1.29883	0.0229492	67.19661	0.029807
750	1.29883	0.0224609	67.48834	0.029173
760	1.29883	0.0224609	67.78007	0.029173
770	1.29883	0.0219727	68.06546	0.028539
780	1.30127	0.0214844	68.34503	0.027957
790	1.29883	0.0217285	68.62725	0.028222
800	1.29883	0.0212402	68.90312	0.027587
810	1.29883	0.0212402	69.179	0.027587
820	1.30127	0.0205078	69.44586	0.026686
830	1.29883	0.0205078	69.71222	0.026636
840	1.30127	0.0205078	69.97908	0.026686
850	1.30127	0.0202637	70.24277	0.026369
860	1.30127	0.0197754	70.5001	0.025733
870	1.30127	0.0197754	70.75743	0.025733
880	1.30127	0.0192871	71.00841	0.025098
890	1.30127	0.0192871	71.25938	0.025098
900	1.29883	0.0192871	71.50989	0.025051
910	0	0	0	0
920	0.866699	-0.0866699	0.751167	0.075117
930	0.839844	-0.0839844	1.456505	0.070534
940	0.817871	-0.0817871	2.125418	0.066891
950	0.795898	-0.0795898	2.758872	0.063345
960	0.773926	-0.0773926	3.357833	0.059896
970	0.751953	-0.0751953	3.923266	0.056543
980	0.732422	-0.0732422	4.459708	0.053644
990	0.715332	-0.0715332	4.971408	0.05117
1000	0.695801	-0.0695801	5.455547	0.048414
1010	0.67627	-0.067627	5.912888	0.045734
1020	0.656738	-0.0656738	6.344193	0.04313
1030	0.639648	-0.0639648	6.753343	0.040915
1040	0.622559	-0.0622559	7.140923	0.038758
1050	0.605469	-0.0605469	7.507515	0.036659
1060	0.588379	-0.0588379	7.853705	0.034619
1070	0.57373	-0.057373	8.182871	0.032917
1080	0.556641	-0.0556641	8.49272	0.030985
1090	0.541992	-0.0541992	8.786476	0.029376
1100	0.527344	-0.0527344	9.064567	0.027809
1110	0.512695	-0.0512695	9.327424	0.026286
1120	0.498047	-0.0498047	9.575474	0.024805
1130	0.48584	-0.048584	9.811515	0.023604
1140	0.471191	-0.0471191	10.03354	0.022202
1150	0.456543	-0.0456543	10.24197	0.020843
1160	0.444336	-0.0444336	10.4394	0.019743
1170	0.432129	-0.0432129	10.62614	0.018674
1180	0.41748	-0.041748	10.80043	0.017429
1190	0.405273	-0.0405273	10.96467	0.016425
1200	0.393066	-0.0393066	11.11917	0.01545
1210	0.383301	-0.0383301	11.26609	0.014692
1220	0.371094	-0.0371094	11.4038	0.013771

1230	0.358887	-0.0358887	11.5326	0.01288
1240	0.349121	-0.0349121	11.65449	0.012189
1250	0.339355	-0.0339355	11.76965	0.011516
1260	0.32959	-0.032959	11.87828	0.010863
1270	0.319824	-0.0319824	11.98057	0.010229
1280	0.310059	-0.0310059	12.07671	0.009614
1290	0.300293	-0.0300293	12.16688	0.009018
1300	0.290527	-0.0290527	12.25129	0.008441
1310	0.283203	-0.0283203	12.33149	0.00802
1320	0.273438	-0.0273438	12.40626	0.007477
1330	0.263672	-0.0263672	12.47578	0.006952
1340	0.256348	-0.0256348	12.5415	0.006571
1350	0.249023	-0.0249023	12.60351	0.006201
1360	0.239258	-0.0239258	12.66075	0.005724
1370	0.234375	-0.0234375	12.71568	0.005493
1380	0.227051	-0.0227051	12.76724	0.005155
1390	0.219727	-0.0219727	12.81552	0.004828
1400	0.212402	-0.0212402	12.86063	0.004511
1410	0.205078	-0.0205078	12.90269	0.004206
1420	0.197754	-0.0197754	12.9418	0.003911
1430	0.192871	-0.0192871	12.97899	0.00372
1440	0.185547	-0.0185547	13.01342	0.003443
1450	0.180664	-0.0180664	13.04606	0.003264
1460	0.17334	-0.017334	13.07611	0.003005
1470	0.168457	-0.0168457	13.10449	0.002838
1480	0.163574	-0.0163574	13.13124	0.002676
1490	0.15625	-0.015625	13.15566	0.002441
1500	0.153809	-0.0153809	13.17931	0.002366
1510	0.148926	-0.0148926	13.20149	0.002218
1520	0.144043	-0.0144043	13.22224	0.002075
1530	0.136719	-0.0136719	13.24093	0.001869
1540	0.134277	-0.0134277	13.25896	0.001803
1550	0.129395	-0.0129395	13.27571	0.001674
1560	0.126953	-0.0126953	13.29182	0.001612
1570	0.12207	-0.012207	13.30672	0.00149
1580	0.117188	-0.0117188	13.32046	0.001373
1590	0.114746	-0.0114746	13.33362	0.001317
1600	0.109863	-0.0109863	13.34569	0.001207
1610	0.107422	-0.0107422	13.35723	0.001154
1620	0.102539	-0.0102539	13.36775	0.001051
1630	0.100098	-0.0100098	13.37777	0.001002
1640	0.0976563	-0.00976563	13.3873	0.000954
1650	0.0927734	-0.00927734	13.39591	0.000861
1660	0.090332	-0.0090332	13.40407	0.000816
1670	0.0878906	-0.00878906	13.4118	0.000772
1680	0.0854492	-0.00854492	13.4191	0.00073
1690	0.0830078	-0.00830078	13.42599	0.000689
1700	0.078125	-0.0078125	13.43209	0.00061
1710	0.0756836	-0.00756836	13.43782	0.000573
1720	0.0756836	-0.00756836	13.44355	0.000573
1730	0.0732422	-0.00732422	13.44891	0.000536
1740	0.0708008	-0.00708008	13.45392	0.000501
1750	0.0683594	-0.00683594	13.4586	0.000467
1760	0.065918	-0.0065918	13.46294	0.000435
1770	0.0634766	-0.00634766	13.46697	0.000403
1780	0.0610352	-0.00610352	13.4707	0.000373
1790	0.0610352	-0.00610352	13.47442	0.000373
1800	0.0585938	-0.00585938	13.47786	0.000343
1810	0.0561523	-0.00561523	13.48101	0.000315

Aerogel QAQC Test Data Run 2

Time (sec)	Voltage	Current	Energy J	Power W
0	0	0	0	0
10	0	0	0	0
20	1.31592	0.389893	5.13068	0.513068
30	1.31104	0.326172	9.406925	0.427625
40	1.30859	0.284424	13.12887	0.372194
50	1.30615	0.252686	16.42933	0.330046
60	1.30371	0.227783	19.39896	0.296963
70	1.30371	0.207764	22.1076	0.270864
80	1.30371	0.190918	24.59661	0.248902
90	1.30371	0.176025	26.89147	0.229486
100	1.30127	0.163818	29.02318	0.213171
110	1.30371	0.151855	31.00293	0.197975
120	1.30371	0.14209	32.85537	0.185244
130	1.30127	0.133545	34.59316	0.173778
140	1.30127	0.125244	36.22292	0.162976
150	1.30127	0.118164	37.76055	0.153763
160	1.29883	0.111572	39.20968	0.144913
170	1.30127	0.105957	40.58847	0.137879
180	1.30127	0.100586	41.89736	0.13089
190	1.29883	0.0961914	43.14673	0.124936
200	1.29883	0.0913086	44.33267	0.118594
210	1.30127	0.0871582	45.46683	0.113416
220	1.30127	0.0834961	46.55334	0.108651
230	1.30127	0.079834	47.5922	0.103886
240	1.29883	0.0766602	48.58788	0.099569
250	1.29883	0.0734863	49.54235	0.095446
260	1.30127	0.0710449	50.46683	0.092449
270	1.30127	0.0678711	51.35002	0.088319
280	1.30127	0.0656738	52.20461	0.085459
290	1.29883	0.0639648	53.03541	0.083079
300	1.29883	0.0617676	53.83766	0.080226
310	1.29883	0.0600586	54.61772	0.078006
320	1.29883	0.0578613	55.36924	0.075152
330	1.29883	0.0559082	56.09539	0.072615
340	1.30127	0.0541992	56.80067	0.070528
350	1.29883	0.0527344	57.4856	0.068493
360	1.30127	0.0505371	58.14323	0.065762
370	1.29883	0.0495605	58.78693	0.064371
380	1.30127	0.0480957	59.41279	0.062585
390	1.29883	0.046875	60.02161	0.060883
400	1.30127	0.0456543	60.6157	0.059409
410	1.29883	0.0444336	61.19282	0.057712
420	1.29883	0.0437012	61.76042	0.05676
430	1.29883	0.0429688	62.31851	0.055809
440	1.30127	0.0412598	62.85541	0.05369
450	1.29883	0.0407715	63.38497	0.052955
460	1.29883	0.0397949	63.90184	0.051687
470	1.29883	0.0388184	64.40602	0.050419
480	1.30127	0.0378418	64.89844	0.049242
490	1.30127	0.0368652	65.37816	0.047972
500	1.29883	0.036377	65.85064	0.047248
510	1.29883	0.0356445	66.3136	0.046296
520	1.30127	0.034668	66.76472	0.045112
530	1.30127	0.0344238	67.21267	0.044795
540	1.29883	0.0339355	67.65343	0.044076
550	1.30127	0.0332031	68.08549	0.043206
560	1.30127	0.0327148	68.5112	0.042571
570	1.30127	0.0322266	68.93056	0.041936
580	1.30127	0.0317383	69.34356	0.0413

590	1.29883	0.03125	69.74944	0.040588
600	1.30127	0.0305176	70.14656	0.039712
610	1.30127	0.0300293	70.53732	0.039076
620	1.30127	0.029541	70.92173	0.038441
630	1.29883	0.029541	71.30542	0.038369
640	1.29883	0.0288086	71.67959	0.037417
650	1.29883	0.0288086	72.05377	0.037417
660	1.29883	0.0283203	72.4216	0.036783
670	1.30127	0.027832	72.78377	0.036217
680	1.29883	0.0273438	73.13892	0.035515
690	1.30127	0.0270996	73.49156	0.035264
700	1.30127	0.0266113	73.83784	0.034628
710	1.30127	0.026123	74.17777	0.033993
720	1.30127	0.0258789	74.51453	0.033675
730	1.29883	0.0256348	74.84748	0.033295
740	1.30127	0.0251465	75.1747	0.032722
750	1.30127	0.0251465	75.50193	0.032722
760	1.30127	0.0246582	75.8228	0.032087
770	1.30127	0.0244141	76.14049	0.031769
780	1.29883	0.0244141	76.45759	0.03171
790	1.29883	0.0241699	76.77151	0.031393
800	1.30127	0.0236816	77.07968	0.030816
810	1.29883	0.0236816	77.38726	0.030758
820	1.29883	0.0236816	77.69484	0.030758
830	1.30127	0.0231934	77.99665	0.030181
840	1.29883	0.0229492	78.29472	0.029807
850	1.30127	0.0224609	78.587	0.029228
860	1.30127	0.0222168	78.8761	0.02891
870	1.30127	0.0224609	79.16838	0.029228
880	1.30127	0.0224609	79.46065	0.029228
890	1.30127	0.0217285	79.7434	0.028275
900	1.30127	0.0214844	80.02297	0.027957
910	0	0	0	0
920	0.9375	-0.09375	0.878906	0.087891
930	0.908203	-0.0908203	1.703739	0.082483
940	0.878906	-0.0878906	2.476215	0.077248
950	0.856934	-0.0856934	3.210551	0.073434
960	0.830078	-0.0830078	3.89958	0.068903
970	0.808105	-0.0808105	4.552614	0.065303
980	0.783691	-0.0783691	5.166785	0.061417
990	0.761719	-0.0761719	5.747001	0.058022
1000	0.742188	-0.0742188	6.297844	0.055084
1010	0.717773	-0.0717773	6.813042	0.05152
1020	0.698242	-0.0698242	7.300584	0.048754
1030	0.678711	-0.0678711	7.761233	0.046065
1040	0.65918	-0.065918	8.195751	0.043452
1050	0.637207	-0.0637207	8.601784	0.040603
1060	0.620117	-0.0620117	8.986329	0.038455
1070	0.600586	-0.0600586	9.347032	0.03607
1080	0.583496	-0.0583496	9.6875	0.034047
1090	0.566406	-0.0566406	10.00832	0.032082
1100	0.549316	-0.0549316	10.31006	0.030175
1110	0.532227	-0.0532227	10.59333	0.028327
1120	0.515137	-0.0515137	10.8587	0.026537
1130	0.500488	-0.0500488	11.10918	0.025049
1140	0.483398	-0.0483398	11.34286	0.023367
1150	0.46875	-0.046875	11.56258	0.021973
1160	0.456543	-0.0456543	11.77102	0.020843
1170	0.441895	-0.0441895	11.96629	0.019527
1180	0.427246	-0.0427246	12.14883	0.018254
1190	0.415039	-0.0415039	12.32108	0.017226
1200	0.400391	-0.0400391	12.4814	0.016031
1210	0.388184	-0.0388184	12.63208	0.015069
1220	0.375977	-0.0375977	12.77344	0.014136

1230	0.36377	-0.036377	12.90577	0.013233
1240	0.354004	-0.0354004	13.03109	0.012532
1250	0.341797	-0.0341797	13.14791	0.011683
1260	0.332031	-0.0332031	13.25816	0.011024
1270	0.319824	-0.0319824	13.36045	0.010229
1280	0.310059	-0.0310059	13.45658	0.009614
1290	0.300293	-0.0300293	13.54676	0.009018
1300	0.290527	-0.0290527	13.63116	0.008441
1310	0.283203	-0.0283203	13.71137	0.00802
1320	0.270996	-0.0270996	13.78481	0.007344
1330	0.263672	-0.0263672	13.85433	0.006952
1340	0.253906	-0.0253906	13.9188	0.006447
1350	0.244141	-0.0244141	13.9784	0.00596
1360	0.236816	-0.0236816	14.03449	0.005608
1370	0.229492	-0.0229492	14.08715	0.005267
1380	0.219727	-0.0219727	14.13543	0.004828
1390	0.212402	-0.0212402	14.18055	0.004511
1400	0.205078	-0.0205078	14.2226	0.004206
1410	0.197754	-0.0197754	14.26171	0.003911
1420	0.192871	-0.0192871	14.29891	0.00372
1430	0.185547	-0.0185547	14.33334	0.003443
1440	0.178223	-0.0178223	14.3651	0.003176
1450	0.17334	-0.017334	14.39515	0.003005
1460	0.168457	-0.0168457	14.42352	0.002838
1470	0.161133	-0.0161133	14.44949	0.002596
1480	0.15625	-0.015625	14.4739	0.002441
1490	0.151367	-0.0151367	14.49681	0.002291
1500	0.144043	-0.0144043	14.51756	0.002075
1510	0.13916	-0.013916	14.53693	0.001937
1520	0.136719	-0.0136719	14.55562	0.001869
1530	0.131836	-0.0131836	14.573	0.001738
1540	0.126953	-0.0126953	14.58912	0.001612
1550	0.12207	-0.012207	14.60402	0.00149
1560	0.117188	-0.0117188	14.61775	0.001373
1570	0.114746	-0.0114746	14.63092	0.001317
1580	0.112305	-0.0112305	14.64353	0.001261
1590	0.107422	-0.0107422	14.65507	0.001154
1600	0.10498	-0.010498	14.66609	0.001102
1610	0.100098	-0.0100098	14.67611	0.001002
1620	0.0976563	-0.00976563	14.68565	0.000954
1630	0.0952148	-0.00952148	14.69471	0.000907
1640	0.0927734	-0.00927734	14.70332	0.000861
1650	0.0878906	-0.00878906	14.71105	0.000772
1660	0.0854492	-0.00854492	14.71835	0.00073
1670	0.0830078	-0.00830078	14.72524	0.000689
1680	0.0805664	-0.00805664	14.73173	0.000649
1690	0.078125	-0.0078125	14.73783	0.00061
1700	0.0732422	-0.00732422	14.7432	0.000536
1710	0.0732422	-0.00732422	14.74856	0.000536
1720	0.0708008	-0.00708008	14.75357	0.000501
1730	0.0683594	-0.00683594	14.75825	0.000467
1740	0.065918	-0.0065918	14.76259	0.000435
1750	0.0634766	-0.00634766	14.76662	0.000403
1760	0.0634766	-0.00634766	14.77065	0.000403
1770	0.0610352	-0.00610352	14.77438	0.000373
1780	0.0585938	-0.00585938	14.77781	0.000343
1790	0.0561523	-0.00561523	14.78096	0.000315
1800	0.0561523	-0.00561523	14.78412	0.000315
1810	0.0537109	-0.00537109	14.787	0.000288

Aerogel QAQC Test Data Run 3

Time (sec)	Voltage	Current	Energy J	Power W
0	0	0	0	0
10	0	0	0	0
20	1.30127	0.227295	2.957722	0.295772
30	1.30371	0.208496	5.675905	0.271818
40	1.30127	0.205322	8.347698	0.267179
50	1.30127	0.200684	10.95914	0.261144
60	1.30371	0.192627	13.47044	0.25113
70	1.30127	0.184082	15.86584	0.23954
80	1.30371	0.17334	18.12569	0.225985
90	1.30127	0.164307	20.26377	0.213808
100	1.30127	0.153809	22.26524	0.200147
110	1.30127	0.145752	24.16187	0.189663
120	1.30127	0.137207	25.9473	0.178543
130	1.30127	0.128906	27.62472	0.167742
140	1.30371	0.121582	29.20979	0.158508
150	1.30127	0.115723	30.71566	0.150587
160	1.30127	0.109375	32.13892	0.142326
170	1.30127	0.104492	33.49865	0.135972
180	1.30127	0.0991211	34.78848	0.128983
190	1.30127	0.0952148	36.02748	0.1239
200	1.30127	0.0910645	37.21248	0.1185
210	1.30127	0.0871582	38.34664	0.113416
220	1.29883	0.0837402	39.43428	0.108764
230	1.30127	0.0800781	40.47632	0.104203
240	1.30127	0.0773926	41.4834	0.100709
250	1.29883	0.074707	42.45372	0.097032
260	1.30127	0.0720215	43.39091	0.093719
270	1.29883	0.0693359	44.29147	0.090056
280	1.30127	0.0668945	45.16195	0.087048
290	1.30127	0.0646973	46.00383	0.084189
300	1.30127	0.0629883	46.82348	0.081965
310	1.29883	0.0603027	47.60671	0.078323
320	1.30127	0.0585938	48.36917	0.076246
330	1.30127	0.0568848	49.1094	0.074022
340	1.29883	0.0554199	49.82921	0.071981
350	1.30127	0.0537109	50.52813	0.069892
360	1.30127	0.0524902	51.21117	0.068304
370	1.29883	0.0517578	51.88342	0.067225
380	1.29883	0.0505371	52.53981	0.065639
390	1.30127	0.0490723	53.17837	0.063856
400	1.29883	0.0473633	53.79354	0.061517
410	1.30127	0.0458984	54.3908	0.059726
420	1.29883	0.045166	54.97743	0.058663
430	1.30127	0.0446777	55.55881	0.058138
440	1.30127	0.0437012	56.12748	0.056867
450	1.30127	0.0424805	56.68027	0.055279
460	1.30127	0.0419922	57.2267	0.054643
470	1.30127	0.0407715	57.75725	0.053055
480	1.30127	0.0402832	58.28144	0.052419
490	1.30127	0.0400391	58.80246	0.052102
500	1.30127	0.0388184	59.30759	0.050513
510	1.29883	0.0378418	59.79909	0.04915
520	1.30127	0.0375977	60.28834	0.048925
530	1.30127	0.0366211	60.76488	0.047654
540	1.29883	0.0358887	61.23101	0.046613
550	1.29883	0.0354004	61.6908	0.045979
560	1.29883	0.0349121	62.14425	0.045345
570	1.30127	0.0344238	62.5922	0.044795
580	1.29883	0.0339355	63.03296	0.044076

590	1.29883	0.0334473	63.46738	0.043442
600	1.30127	0.0327148	63.89309	0.042571
610	1.29883	0.0319824	64.30849	0.04154
620	1.29883	0.0319824	64.72389	0.04154
630	1.29883	0.0314941	65.13294	0.040905
640	1.29883	0.0310059	65.53565	0.040271
650	1.30127	0.0305176	65.93277	0.039712
660	1.30127	0.0300293	66.32353	0.039076
670	1.30127	0.029541	66.70794	0.038441
680	1.29883	0.0292969	67.08846	0.038052
690	1.30127	0.0285645	67.46016	0.03717
700	1.30127	0.0283203	67.82868	0.036852
710	1.30127	0.0283203	68.19721	0.036852
720	1.30127	0.027832	68.55938	0.036217
730	1.30127	0.0275879	68.91837	0.035899
740	1.30127	0.0273438	69.27419	0.035582
750	1.30127	0.0270996	69.62683	0.035264
760	1.30127	0.0266113	69.97311	0.034628
770	1.29883	0.0263672	70.31558	0.034247
780	1.30127	0.0256348	70.64915	0.033358
790	1.29883	0.0256348	70.98211	0.033295
800	1.30127	0.0251465	71.30933	0.032722
810	1.30127	0.0251465	71.63655	0.032722
820	1.29883	0.0251465	71.96316	0.032661
830	1.29883	0.0249023	72.2866	0.032344
840	1.29883	0.0244141	72.6037	0.03171
850	1.29883	0.0244141	72.9208	0.03171
860	1.29883	0.0244141	73.2379	0.03171
870	1.29883	0.0239258	73.54865	0.031076
880	1.30127	0.0236816	73.85681	0.030816
890	1.29883	0.0236816	74.1644	0.030758
900	1.29883	0.0231934	74.46564	0.030124
910	0	0	0	0
920	0.83252	-0.083252	0.69309	0.069309
930	0.78125	-0.078125	1.303441	0.061035
940	0.756836	-0.0756836	1.876242	0.05728
950	0.737305	-0.0737305	2.419861	0.054362
960	0.722656	-0.0722656	2.942092	0.052223
970	0.708008	-0.0708008	3.443368	0.050128
980	0.693359	-0.0693359	3.924114	0.048075
990	0.673828	-0.0673828	4.378158	0.045404
1000	0.65918	-0.065918	4.812677	0.043452
1010	0.64209	-0.064209	5.224956	0.041228
1020	0.622559	-0.0622559	5.612536	0.038758
1030	0.60791	-0.060791	5.982091	0.036955
1040	0.593262	-0.0593262	6.33405	0.035196
1050	0.578613	-0.0578613	6.668843	0.033479
1060	0.561523	-0.0561523	6.984151	0.031531
1070	0.541992	-0.0541992	7.277907	0.029376
1080	0.534668	-0.0534668	7.563777	0.028587
1090	0.517578	-0.0517578	7.831664	0.026789
1100	0.505371	-0.0505371	8.087063	0.02554
1110	0.490723	-0.0490723	8.327873	0.024081
1120	0.478516	-0.0478516	8.55685	0.022898
1130	0.466309	-0.0466309	8.774294	0.021744
1140	0.45166	-0.045166	8.978291	0.0204
1150	0.437012	-0.0437012	9.16927	0.019098
1160	0.424805	-0.0424805	9.34973	0.018046
1170	0.415039	-0.0415039	9.521987	0.017226
1180	0.405273	-0.0405273	9.686233	0.016425
1190	0.393066	-0.0393066	9.840734	0.01545
1200	0.383301	-0.0383301	9.987654	0.014692
1210	0.371094	-0.0371094	10.12536	0.013771
1220	0.361328	-0.0361328	10.25592	0.013056

1230	0.351563	-0.0351563	10.37952	0.01236
1240	0.339355	-0.0339355	10.49468	0.011516
1250	0.332031	-0.0332031	10.60493	0.011024
1260	0.322266	-0.0322266	10.70878	0.010386
1270	0.3125	-0.03125	10.80644	0.009766
1280	0.302734	-0.0302734	10.89808	0.009165
1290	0.29541	-0.029541	10.98535	0.008727
1300	0.285645	-0.0285645	11.06695	0.008159
1310	0.275879	-0.0275879	11.14305	0.007611
1320	0.266113	-0.0266113	11.21387	0.007082
1330	0.258789	-0.0258789	11.28084	0.006697
1340	0.249023	-0.0249023	11.34285	0.006201
1350	0.244141	-0.0244141	11.40246	0.00596
1360	0.236816	-0.0236816	11.45854	0.005608
1370	0.229492	-0.0229492	11.51121	0.005267
1380	0.222168	-0.0222168	11.56057	0.004936
1390	0.214844	-0.0214844	11.60672	0.004616
1400	0.209961	-0.0209961	11.65081	0.004408
1410	0.205078	-0.0205078	11.69286	0.004206
1420	0.200195	-0.0200195	11.73294	0.004008
1430	0.192871	-0.0192871	11.77014	0.00372
1440	0.187988	-0.0187988	11.80548	0.003534
1450	0.183105	-0.0183105	11.83901	0.003353
1460	0.175781	-0.0175781	11.86991	0.00309
1470	0.170898	-0.0170898	11.89911	0.002921
1480	0.166016	-0.0166016	11.92668	0.002756
1490	0.161133	-0.0161133	11.95264	0.002596
1500	0.153809	-0.0153809	11.9763	0.002366
1510	0.148926	-0.0148926	11.99848	0.002218
1520	0.144043	-0.0144043	12.01922	0.002075
1530	0.144043	-0.0144043	12.03997	0.002075
1540	0.13916	-0.013916	12.05934	0.001937
1550	0.136719	-0.0136719	12.07803	0.001869
1560	0.131836	-0.0131836	12.09541	0.001738
1570	0.126953	-0.0126953	12.11153	0.001612
1580	0.124512	-0.0124512	12.12703	0.00155
1590	0.119629	-0.0119629	12.14134	0.001431
1600	0.114746	-0.0114746	12.15451	0.001317
1610	0.112305	-0.0112305	12.16712	0.001261
1620	0.109863	-0.0109863	12.17919	0.001207
1630	0.107422	-0.0107422	12.19073	0.001154
1640	0.10498	-0.010498	12.20175	0.001102
1650	0.100098	-0.0100098	12.21177	0.001002
1660	0.0976563	-0.00976563	12.22131	0.000954
1670	0.0952148	-0.00952148	12.23037	0.000907
1680	0.090332	-0.0090332	12.23853	0.000816
1690	0.0878906	-0.00878906	12.24626	0.000772
1700	0.0854492	-0.00854492	12.25356	0.00073
1710	0.0830078	-0.00830078	12.26045	0.000689
1720	0.078125	-0.0078125	12.26655	0.00061
1730	0.078125	-0.0078125	12.27266	0.00061
1740	0.0756836	-0.00756836	12.27839	0.000573
1750	0.0732422	-0.00732422	12.28375	0.000536
1760	0.0683594	-0.00683594	12.28842	0.000467
1770	0.065918	-0.0065918	12.29277	0.000435
1780	0.065918	-0.0065918	12.29711	0.000435
1790	0.0634766	-0.00634766	12.30114	0.000403
1800	0.0610352	-0.00610352	12.30487	0.000373
1810	0.0610352	-0.00610352	12.30859	0.000373

Energy Data Used for Graph

Time s	Run 1 - Energy J	Run 2 - Energy J	Run 3 - Energy J
0	0	0	0
10	0	0	0
20	3.400841745	5.130679966	2.957721647
30	7.172544808	9.406925354	5.675904848
40	10.46957657	13.12886938	8.347698438
50	13.42562913	16.42932757	10.95913912
60	16.08652731	19.39895731	13.47043659
70	18.50870316	22.10759736	15.86584043
80	20.73353642	24.59661442	18.12569134
90	22.7858344	26.89146994	20.26376904
100	24.69556096	29.02318443	22.26523941
110	26.47146919	31.00293325	24.16186647
120	28.1330088	32.85537479	25.94729999
130	29.69605529	34.59315581	27.6247151
140	31.16697186	36.22291841	29.20979179
150	32.55528381	37.7605511	30.71566047
160	33.87689266	39.2096817	32.13892454
170	35.13177889	40.58846836	33.49864759
180	36.32630441	41.8973638	34.78848072
190	37.46468345	43.14672656	36.02748235
200	38.55232629	44.33267005	37.21247737
210	39.59118218	45.46683356	38.34664088
220	40.58686785	46.55334326	39.43428372
230	41.54630073	47.59219915	40.47631601
240	42.4707867	48.58788483	41.4834027
250	43.36500128	49.54234694	42.45371963
260	44.22277244	50.46683291	43.3909138
270	45.05039601	51.35001917	44.29146927
280	45.84630994	52.20461263	45.16194733
290	46.61830398	53.03540664	46.00383388
300	47.36348172	53.83766276	46.82348174
310	48.08646375	54.61772187	47.60671129
320	48.78407703	55.36924179	48.36917484
330	49.46393986	56.09539427	49.10939967
340	50.12156398	56.8006722	49.82920996
350	50.7633035	57.48560241	50.52813379
360	51.38915841	58.14322653	51.21117301
370	51.99277462	58.78693317	51.88341885
380	52.57940418	59.41278808	52.53980986
390	53.15652111	60.02161465	53.17837298
400	53.71883761	60.61570036	53.79354173
410	54.26526951	61.19281728	54.39080384
420	54.80116417	61.76042158	54.9774334
430	55.31900327	62.31851324	55.5588109
440	55.82635874	62.85541464	56.12748151
450	56.32102983	63.38496712	56.68026751
460	56.80392332	63.90183522	57.22669941
470	57.27639871	64.40602024	57.75724671
480	57.7402299	64.89844423	58.28143991
490	58.19050828	65.37816002	58.8024567
500	58.62892436	65.85063541	59.3075889
510	59.06017619	66.31359687	59.79908955
520	59.48191538	66.76472115	60.28833714
530	59.90127046	67.21266774	60.76487653
540	60.31032528	67.65343219	61.23100973
550	60.71061805	68.08549417	61.69080075
560	61.10773442	68.51120205	62.14424957
570	61.49532029	68.93055713	62.59219616
580	61.87583722	69.3435581	63.03296061

590	62.24684152	69.74944248	63.46738418
600	62.61150362	70.14655885	63.89309206
610	62.97299399	70.53732112	64.30848906
620	63.32814347	70.92172929	64.72388607
630	63.67695076	71.30541666	65.13294089
640	64.02258631	71.6795914	65.53565482
650	64.35934067	72.05376614	65.93277119
660	64.69291863	72.42159869	66.32353346
670	65.02331889	72.78376816	66.70794163
680	65.34736505	73.13891764	67.08845856
690	65.66446271	73.4915566	67.46015983
700	65.98156036	73.83784147	67.8286834
710	66.29231583	74.17777223	68.19720696
720	66.59730098	74.51452659	68.55937643
730	66.89854382	74.84747906	68.9183695
740	67.19661492	75.17470292	69.27418616
750	67.48834382	75.50192678	69.62682513
760	67.78007273	75.82279654	69.97310999
770	68.06546075	76.1404899	70.3155751
780	68.3450308	76.45758756	70.64915306
790	68.62724708	76.77151347	70.98210553
800	68.90312117	77.07967503	71.30932939
810	69.17899526	77.38725875	71.63655325
820	69.44585711	77.69484248	71.96316354
830	69.71221857	77.99665123	72.28660208
840	69.97908042	78.29472233	72.60369974
850	70.24276586	78.58699928	72.92079739
860	70.50009721	78.87609983	73.23789505
870	70.75742856	79.16837679	73.54865051
880	71.00840581	79.46065374	73.85681207
890	71.25938305	79.74340019	74.1643958
900	71.50988969	80.02297025	74.46563863
910	0	0	0
920	0.751167157	0.87890625	0.69308955
930	1.456505101	1.703738939	1.303441113
940	2.125418074	2.476214696	1.876241844
950	2.7588717	3.210550576	2.419860507
960	3.357833153	3.899580062	2.942092201
970	3.923266468	4.552613754	3.443367529
980	4.459708454	5.166785337	3.924114232
990	4.971408324	5.747001172	4.378158406
1000	5.455547356	6.297844199	4.812676678
1010	5.912888468	6.813042279	5.224956246
1020	6.344193269	7.300584169	5.612535955
1030	6.753342833	7.761232791	5.982090523
1040	7.140922542	8.195751063	6.334050323
1050	7.507515251	8.601783824	6.668843327
1060	7.853705099	8.986328918	6.984151407
1070	8.182871212	9.347032461	7.277906735
1080	8.492720415	9.687500043	7.563776605
1090	8.786475743	10.0083158	7.831663591
1100	9.064567437	10.31006387	8.087063439
1110	9.3274236	10.59332945	8.327872501
1120	9.575474415	10.85869558	8.556850064
1130	9.81151492	11.10918381	8.774294147
1140	10.03353588	11.34285744	8.978290903
1150	10.24196739	11.562584	9.169270391
1160	10.43940187	11.77101551	9.349729679
1170	10.62613734	11.96628671	9.52198705
1180	10.80042689	12.14882585	9.686233255
1190	10.9646731	12.32108322	9.840734135
1200	11.11917398	12.48139617	9.987653792

1210	11.26609363	12.63208299	10.12536455
1220	11.40380439	12.7734417	10.25592247
1230	11.53260427	12.90577031	10.37951902
1240	11.65448974	13.03108914	10.49468083
1250	11.76965156	13.14791433	10.60492542
1260	11.87828113	13.25815892	10.70878079
1270	11.98056852	13.36044631	10.80643704
1280	12.0767051	13.45658289	10.89808492
1290	12.16688099	13.54675878	10.98535198
1300	12.25128693	13.63116471	11.06694505
1310	12.33149086	13.71136865	11.14305427
1320	12.4062592	13.78480748	11.2138704
1330	12.47578213	13.85433041	11.28084215
1340	12.54149643	13.91879867	11.3428546
1350	12.60350888	13.97840349	11.40245943
1360	12.66075327	14.03448531	11.45854125
1370	12.71568491	14.08715189	11.51120783
1380	12.76723707	14.13543184	11.56056645
1390	12.81551702	14.18054645	11.60672439
1400	12.86063163	14.22260344	11.65080801
1410	12.90268862	14.26171008	11.692865
1420	12.94179526	14.29890931	11.73294304
1430	12.97899448	14.333337	11.77014226
1440	13.01342217	14.36510043	11.80548175
1450	13.04606165	14.39514719	11.83900919
1460	13.07610841	14.42352495	11.86990815
1470	13.10448617	14.44948879	11.89911427
1480	13.13124262	14.47390286	11.92667559
1490	13.15565669	14.49681482	11.95263943
1500	13.1793139	14.51756321	11.97629664
1510	13.20149285	14.53692872	11.99847559
1520	13.22224124	14.5556208	12.01922398
1530	13.24093332	14.57300153	12.03997236
1540	13.25896363	14.5891186	12.05933787
1550	13.2757067	14.60401968	12.07802995
1560	13.29182376	14.61775271	12.09541069
1570	13.30672485	14.63091935	12.11152775
1580	13.32045788	14.64353177	12.12703099
1590	13.33362452	14.65507125	12.14134209
1600	13.3456944	14.66609205	12.15450873
1610	13.35723388	14.67611166	12.16712114
1620	13.36774813	14.68564841	12.17919102
1630	13.37776774	14.69471427	12.19073051
1640	13.38730449	14.70332118	12.20175131
1650	13.3959114	14.71104593	12.21177092
1660	13.40407127	14.7183475	12.22130767
1670	13.41179603	14.7252378	12.23037353
1680	13.41909759	14.73172874	12.2385334
1690	13.42598789	14.73783226	12.24625816
1700	13.4320914	14.74319668	12.25355972
1710	13.43781941	14.7485611	12.26045002
1720	13.44354742	14.75357385	12.26655353
1730	13.44891184	14.75824686	12.27265705
1740	13.45392459	14.76259204	12.27838506
1750	13.4585976	14.76662132	12.28374948
1760	13.46294278	14.7706506	12.28842248
1770	13.46697206	14.77437589	12.29276767
1780	13.47069735	14.77780913	12.29711285
1790	13.47442265	14.78096221	12.30114213
1800	13.47785588	14.78411529	12.30486742
1810	13.48100896	14.78700015	12.30859272

SUMMARY SHEET

AEROGEL MANUFACTURING: QUALITY CONTROL TEST

Technician: T.Welgemoed

BATCH SERIAL NUMBER: QA071900edge

REMARK : Aerogel received from CCAT on 071900
Test Pieces from edge of sample sheet.

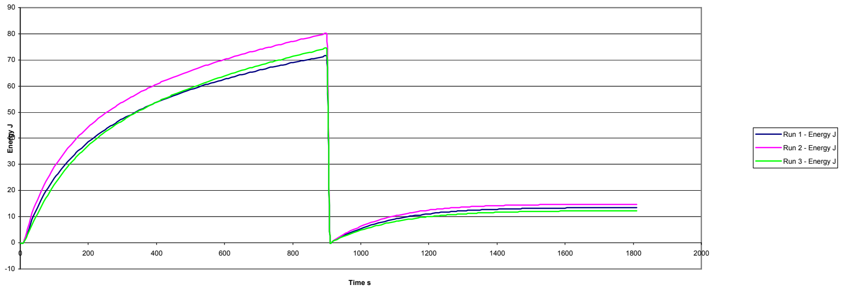
PHYSICAL PARAMETERS

	Length in inches "	Width in inches "	Thickness "x.001	Dry Mass in g	Length in cm	Width in cm	Thickness in cm	Density in g/cm3
Plate1	3	2	34	2.35	7.62	5.08	0.08636	0.703
Plate2	3	2	34	2.3	7.62	5.08	0.08636	0.688

CAPACITY TEST

	Datafile	Energy In - J	Energy Out - J	Ratio out/In	Energy out per g of Aerogel (J/g)	Energy out per cm^2 (J/cm^2)
Run 1	QAmini071900A	71.51	13.48	0.1885195	5.737	0.348
Run 2	QAmini071900B	80.02	14.79	0.18478445	6.292	0.382
Run 3	QAmini071900C	74.47	12.31	0.16529225	5.238	0.318
	Average	75.33	13.53	0.17953207	5.756	0.349

GRAPH FOR BATCH SERIAL NUMBER : **QA071900edge**



	YES/NO	Supervisor	Action Taken
Batch Approved For Manufacturing	Yes	TW	None

Preliminary Source Water Desalination Efficiency Test

Once an industrial module prototype was completed a basic desalination efficiency test was conducted for a specific source water. The attached sheet illustrates typical data collected during a basic desalination efficiency test.

DATA FOR ENCINA PILOT PLANT TESTING

Capacitive Deionization Technology: Encina Water Pollution Control Facility

2-Apr-01
Experimental setup: Recirculating Flow .
Objective: Determine Ion Storage Capacity of 1/4 scale Cell
Feed Water: Encina Brackish Groundwater
Technician: T.Welgemoed

Time	Flow (liters/min)	Cell Voltage (V)	Current (A)	Conductivity IN (uS/cm)	Conductivity OUT (uS/cm)
0	1.50	0.60	110.00	4591	5806
1	1.50	0.60	110.00	4620	5848
2	1.50	0.73	110.00	4614	5804
3	1.50	0.83	110.00	4611	5730
4	1.50	0.92	110.00	4598	5673
5	1.50	1.00	110.00	4567	5525
6	1.50	1.06	110.00	4539	5401
7	1.50	1.10	110.00	4480	5287
8	1.50	1.17	110.00	4424	5154
9	1.50	1.20	93.00	4355	5045
10	1.50	1.20	69.00	4286	4941
12	1.50	1.20	60.00	4215	4852
13	1.50	1.20	40.00	4058	4714
15	1.50	1.20	37.00	3925	4630
17	1.50	1.20	30.00	3798	4557
19	1.50	1.20	29.00	3711	4498
22	1.50	1.20	22.00	3640	4448
24	1.50	1.20	19.00	3501	4421
30	1.50	1.20	20.00	3467	4459
36	1.50	1.20	17.00	3384	4462
40	1.50	1.20	17.00	3348	4493
41	**1.50**	**0.00**	**0.00**	**3344**	**4489**
42	1.50	0.00	0.00	3340	4505
43	1.50	0.00	0.00	3332	4664
44	1.50	0.00	0.00	3328	4599
45	1.50	0.00	0.00	3332	4664
46	1.50	0.90	0.00	3342	4721
47	1.50	0.89	0.00	3353	4781
48	1.50	0.86	0.00	3385	4827
49	1.50	0.84	0.00	3409	4878
50	1.50	0.82	0.00	3429	4917
55	1.50	0.71	0.00	3571	5140
60	1.50	0.63	0.00	3665	5297
70	1.50	0.48	0.00	3832	5602
80	1.50	0.37	0.00	3932	5842
85	1.50	0.32	0.00	3955	5921
91	1.50	0.28	0.00	3988	5967
93	1.50	0.27	0.00	3971	5978
94	1.50	0.26	0.00	4004	5974
96	1.50	0.25	0.00	4005	5970
97	1.50	0.24	0.00	4008	5989
98	1.50	0.23	0.00	4009	6008
100	1.50	0.22	0.00	4015	6019
101	1.00	0.00	0.00	4015	6019
102	1.00	0.22	0.00	4022	6028
105	1.00	0.20	0.00	4044	6044

107	0.10	0.00	0.00	4058	6049
109	0.10	0.18	0.00	4072	6053
112	0.10	0.17	0.00	4072	6075

FARWEST GROUP, INC
Water Analysis Report
Client : CBMA
Date of Test Run: 21 June, 2000
Datafile: C:\Temp\cbma062100
Prepared by : T. Welgemoed

Sample No	Description	Conductivity in microsiemans/cm	Iron as mg/l Fe	Sodium as mg/l Na	Bicarbonate as mg/l CaCO3	Total Alk as mg/l CaCO3	Sulfate as mg/l SO4	pH
CBMA 1	Feed To Brick after 50 % dilution	1140.1	ND	280	520	520	ND	8.2
CBMA 2	After Physi-sorbsion	980	ND	230	370	410	5.1	8.5
CBMA 3	After 40 min Charge - Once Through Flow	285	ND	68	72	120	ND	9
CBMA 4	Rinse Water at Stabilization		ND	84	140	140	ND	8.2
	% Reduction of Component with regards to feed		NA	75.71%	86.15%	76.92%	NA	NA

ND = None Detected
NA = Not Applicable

Comments

Total Rinse volume was 6.15 liters from which a combined sample (CBMA 4) was taken.
The rinse cycle was started at the end of the 40 min charge cycle by changing polarity, shorting the brick and switching of the power. The feed water for the rinse cycle was as for CBMA 1 sample.

Conclusion

This source water is mostly contaminated by Na2HCO3 (Sodium Bicarbonate)
Raw Water Quality :
pH = 8.0
Conductivity = 2490 microsiemans/cm
Turbidity = 200 NTU (Must be filtered before entering CDT system)
DO = 1.33 mg/l
HCO3- = 1040 mg/l
Na+ = 560 mg/l
No iron was detected and very little sulfate
CDT would be able to treat this source water effectively to produce potable and or irrigation standard water.

APPENDIX B

INDUSTRIAL PROTOTYPE DEVELEPMENT PHASE: TECHNICAL BULLITENS

TECHNICAL BULLETIN

3/8/01

Graphite Bus - Mk-8A Brick

Initial Testing

FarWest Group, Inc
Engineering and Development Center
701 Palomar Airport Road, Suite 300
Carlsbad, CA 92009

Phone: (760)931-4784 Fax: (760)931-4850
Email: c_sheppard@msn.com

Introduction

Due to the high costs of experimental graphite components, the electrode internal electrical connections have been made via metallic bus elements. This has been adequate to obtain short term performance data but has never been the long term design objective.

A prototype brick incorporating a psuedo graphite bus has been construced using the same housings and electrode geometry as the Mk-8 brick. The electrical bus is constructed at each end by reaming and press fitting four 1/4 inch diameter graphite rods through a stack of aerogel electrodes and aerogel spacers at each end of the brick.

Redundant electrical connection is made by parallel connection to three of the graphite rods at each pole. The fourth is used to monitor electrode voltage.

Coupling to the graphite rods is made by wraping the post with stripped multistrand copper wire and installing a metal "P" clamp over the wire. The copper wire provides improved coupling between the clamp and rod.

The results of two single pass tests at different flow rates are presented here and compared with the previous Mk-8 brick containing metallic separators...

Objectives

1. Determine ion storage capacity.
2. Compare performance of the new Mk-8A graphite bus brick with the older Mk-8 metal bus brick.
3. Study effect of flow rate on ion adsorption and energy use.

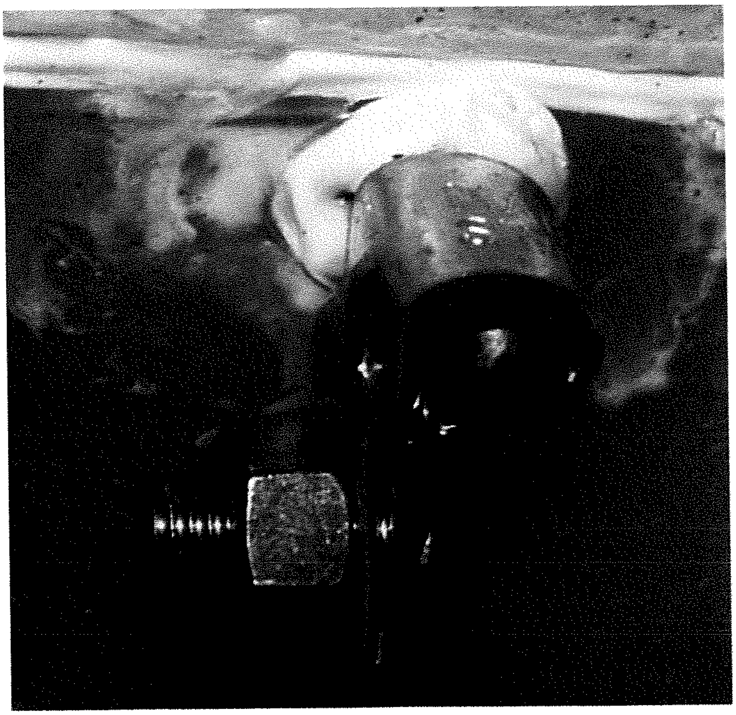


Figure 1 - Graphite rod connection. Metal clamp makes good electrical connection to graphite rod through stranded copper wires.

Test Equipment

1. Mk-8A brick serial number 3
2. Mk-8 brick serial number 1 (tested June 2000)
3. Pulsafeeder metering pumps set at 52.6 ml/min and 157.6 ml/min flow rates
4. Input reservoir containing 500 ppm NaCl
5. Signet conductivity probe K=1
6. Signet conductivity readout model 8850 - full scale 20mA output value set to 5000 uS/cm
7. Industrial computer ADIO interface board mounted in Compaq Presario 4880
8. FarWest test interface control box
9. Fluke 89 mk IV True RMS Multimeter
10. Ohaus 2610g triple beam balance
11. Plastic tubing and connectors

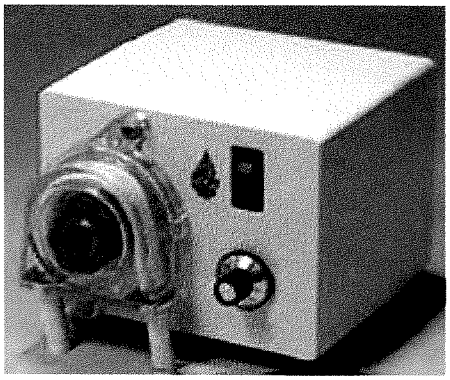


Figure 2 - Metering Pump

Figure 3 - Experimental setup - the fourth, non connected terminal at each end of the brick is used to measure the voltage in the bus. To reach the non connected terminals, current must flow through the internal bus.

Test Results

Variables and Constants

Aerogel electrode dimensions,

$l_{electrode} := 11.86 \cdot in$ $\quad w_{electrode} := 6.25 \cdot in$ $\quad t_{electrode} := .032 \cdot in$

Aerogel Density

$$\rho_{aerogel} := .78 \cdot \frac{gm}{cm^3}$$

Note: the density is adjusted for the aerogel sheets used in the MK8A brick which were more compressed than usual during pyrolization.

Water Density

$$\rho_{water} := 1 \cdot \frac{kg}{liter}$$

Number of electrodes,

$n_{electrodeMK8} := 20$ $\quad n_{electrodeMK8A} := 24$

Total electrode area,

$A_{totalelectrodeMK8} := w_{electrode} \cdot l_{electrode} \cdot n_{electrodeMK8}$ $\quad A_{totalelectrodeMK8} = 10.295\, ft^2$

$A_{totalelectrodeMK8A} := w_{electrode} \cdot l_{electrode} \cdot n_{electrodeMK8A}$ $\quad A_{totalelectrodeMK8A} = 12.354\, ft^2$

Brick scale compared to 1000 square foot version

$$Scale_{MK8} := \frac{A_{totalelectrodeMK8}}{1000 \cdot ft^2} \qquad Scale_{MK8} = 0.01$$

$$Scale_{MK8A} := \frac{A_{totalelectrodeMK8A}}{1000 \cdot ft^2} \qquad Scale_{MK8A} = 0.012$$

Flow rates,

$$Flow_{low} := 52.6 \cdot 10^{-3} \cdot \frac{liter}{min} \qquad Flow_{low} = 0.014 \frac{gal}{min}$$

$$Flow_{moderate} := 157.6 \cdot 10^{-3} \cdot \frac{liter}{min} \qquad Flow_{moderate} = 0.042 \frac{gal}{min}$$

TDS to Conductivity Ratio

$$TDS_{conversion} := \frac{500 \cdot 10^{-6}}{1032 \cdot 10^{-6} \cdot \frac{S}{cm}} \qquad TDS_{conversion} = 0.484 \frac{cm}{S}$$

Input conductivity

$$Conductivity_{Input} := 1032 \cdot 10^{-6} \cdot \frac{S}{cm} \qquad TDS_{Input} := Conductivity_{Input} \cdot TDS_{conversion}$$

$$TDS_{Input} = 5 \times 10^{-4}$$

Results Tables

Data is arranged in the following column order - Time(sec), Conductivity (uS/cm), PS Voltage(V), Current (A)

Low Flow Test - Mk-8A Brick

$\mathrm{Data}_{\mathrm{Mk8Asn3\_4}} :=$

	0	1	2	3
0	0	1004.77	0	0
1	10	997.82	0	0
2	20	1001.3	0	0
3	30	1008.25	0	0.05
4	40	1008.25	0	0
5	50	1008.25	0	0.05
6	60	56.31	0	0.05
7	70	164.01	0	0.05
8	80	191.8	0	0
9	90	125.79	0	0.05

$i := 0, 1 .. 779$

$j1 := 125, 126 .. 512$

$k1 := 120, 121 .. 475$

Table 1 - Mk-8A Graphite bus S/N 3 brick test 4 data, 52 ml/min flow (only 10 table entries visible).

Moderate Flow Results - Mk-8A Brick

$\mathrm{Data}_{\mathrm{Mk8Asn3\_5}} :=$

	0	1	2	3
0	0	35.46	0	0.05
1	10	31.99	0	0.05
2	20	28.51	0	0
3	30	25.04	0	0
4	40	1008.25	0	0.05
5	50	1015.19	0	0.05
6	60	98	0	0.05
7	70	139.69	0	0.05
8	80	35.46	0	0.05
9	90	18.09	0	0

Table 2 - Mk-8A Graphite bus S/N 3 brick test 5 data, 157 ml/min (only 10 table entries visible)

Time increment for integration

$$dT := \left(\mathrm{Data}_{\mathrm{Mk8Asn3\_5}_{1,0}} - \mathrm{Data}_{\mathrm{Mk8Asn3\_5}_{0,0}}\right)\cdot \mathrm{sec} \qquad dT = 10\,\mathrm{s}$$

Low Flow Test - Mk-8 Brick

This data for the Mk-8 brick with the metallic bus was collected May 9, 2000. The brick is now at Kurita.

$\mathrm{Data}_{\mathrm{Mk8sn1\_060900a}} :=$

	0	1	2	3
0	0	1088.15	0	0.07
1	10	1084.68	0	0.02
2	20	1091.63	0	0
3	30	1077.73	0	0.02
4	40	1088.15	-0	-0.02
5	50	1084.68	0	0.07
6	60	1254.92	0.01	0.05
7	70	-13.18	0.01	0
8	80	-2.75	0	0.05
9	90	1025.62	-0	0.05

Table 3 - Mk-8 metallic bus brick S/N 1 test data collected May 9, 2000, 157.6 ml/min (only 10 table entries visible)

Graphical Data

Data is collected at 10 second intervals using the Industrial Computer ADIO 1600 I/O board and stored in ASCII format delineated by commas. Tables 1,2 and 3 contain the raw data. Only 10 values are shown and the full data set can be viewed using Mathcad.
The graphs presented here compare the following;

- Effect of flow rates on output conductivity/ion adsorption and power requirements
- Effect of improved electrical connections on output conductivity/ion adsorption and power requirements

Offsets and Counters

For correct alignment of graphical data offsets should be applied,

- Time Offsets - adjust the ellapsed time to align the trigger event horizontally
- Measured Quantity Offsets - adjust the Y axis value to account for such things as measurement offset or summation starting point correction

Time counter offset for the Mk-8A graphite bus brick low flow test time axis

$dNT_{Mk8Asn3\_4} \equiv 70$ Moves data to left by 70 time increments 11.7 minutes.

Time counter offset for the Mk-8A graphite bus brick moderate flow test time axis

$dNT_{Mk8Asn3\_5} \equiv 0$

Time counter offset for the Mk-8 metal bus brick test results at 52.6 ml/min from 06/09/00

$dNT_{Mk8sn1\_060900a} := 20$

Ion mass offset for the Mk-8A graphite bus brick low flow test

$dIon_{Mk8Asn3\_4} \equiv -.35$

Ion mass offset for the Mk-8A graphite bus brick moderate flow test

$dIon_{Mk8Asn3\_5} \equiv -.35$

Ion mass offset for the Mk-8 metal bus brick test results at 52.6 ml/min from 06/09/00

$dIon_{Mk8sn1\_060900a} \equiv 0$

Effect of Flow Rate on Performance

The data presented here compares results from two tests performed on the Mk-8A brick containing the graphite bus. Slow flow results at 52.6 ml/min are shown in red and the moderate flow of 157 ml/min is shown in blue.

Conductivity Reduction

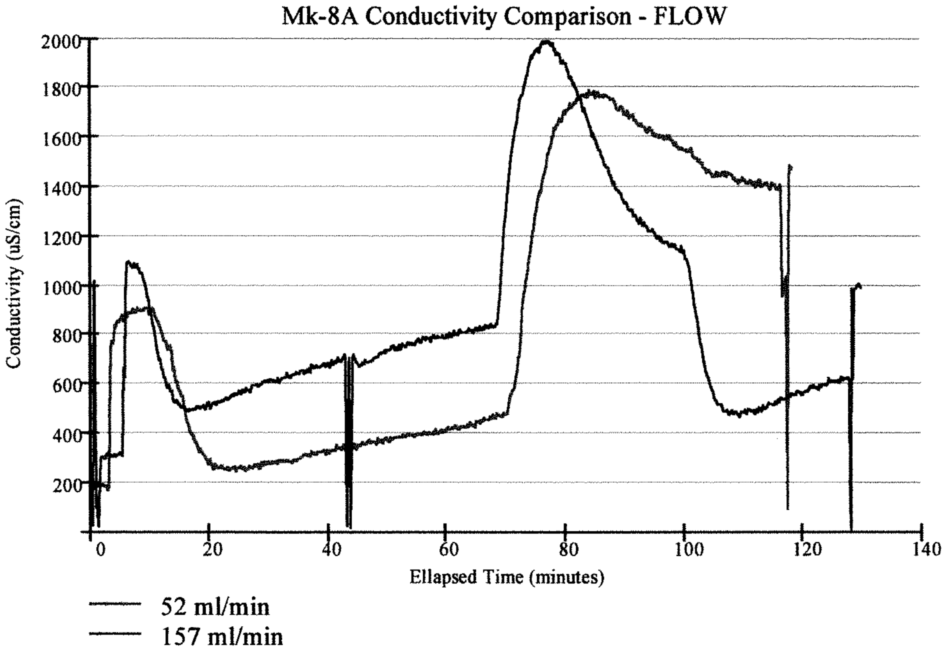


Figure 4 - Output conductivity of Mk-8A s/n 1 graphite bus brick for one charge/discharge cycle of single pass 1032 uS/cm NaCl. Two flow rates are presented.

Notes on Flow Comparison Conductivity Graph Above

- For the low flow rate test, conductivity at start is not at full level due to physisorbtion, longer stabilization would have brought it to the 1032 uS/cm level - does not significantly affect validity of results.
- At approximately 100 minutes the 157 ml/min flow conductivity starts to fall since a second cycle was initiated.
- The higher flow velocity produced more rapid removal of ions during rinse.

Power Use

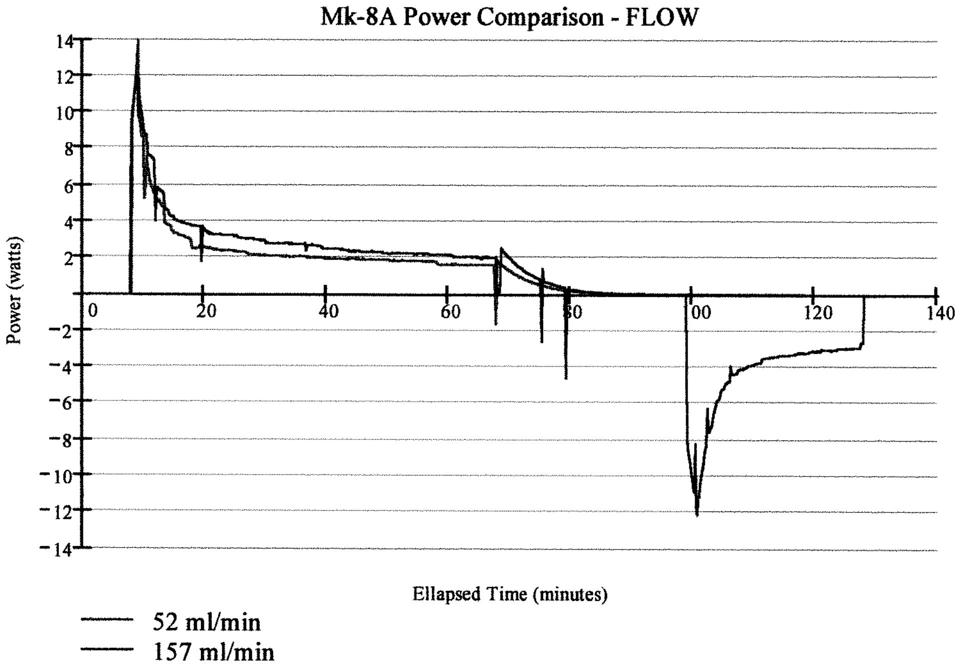


Figure 5 - Power use of Mk-8A s/n 1 graphite bus brick for one charge/discharge cycle of single pass 1032 uS/cm NaCl. Two flow rates presented

Notes on Flow Comparison Power Graph Above

- Power is obtained by multiplying voltage by current
- A second charge cycle of reversed polarity was started on the moderate flow test but not the low flow test
- Curves to the between the discontinuities at about 72.5 minutes and 100 minutes represent energy recovered from the shorted cell - discharge through the small shunt resistor may give an unrealistic value of recovered energy
- Both curves are of the type expected - capacitor charging

Ion Adsorption

Cummulative ion adsorption can be calculated by integrating the product of TDS reduction, water density, and flow rate over time.

$$\mathrm{IonMass}_{low}(i1) := dT \cdot \rho_{water} \cdot \mathrm{Flow}_{low} \cdot \mathrm{TDS}_{conversion} \cdot \sum_{j=0}^{i1} \left(\mathrm{Conductivity}_{Input} - \mathrm{Data}_{Mk8Asn3\_4_{j,1}} \cdot 10^{-6} \cdot \frac{S}{cm} \right)$$

$$\mathrm{IonMass}_{moderate}(i1) := dT \cdot \rho_{water} \cdot \mathrm{Flow}_{moderate} \cdot \mathrm{TDS}_{conversion} \cdot \sum_{j=0}^{i1} \left(\mathrm{Conductivity}_{Input} - \mathrm{Data}_{Mk8Asn3\_5_{j,1}} \cdot 10^{-6} \cdot \frac{S}{cm} \right)$$

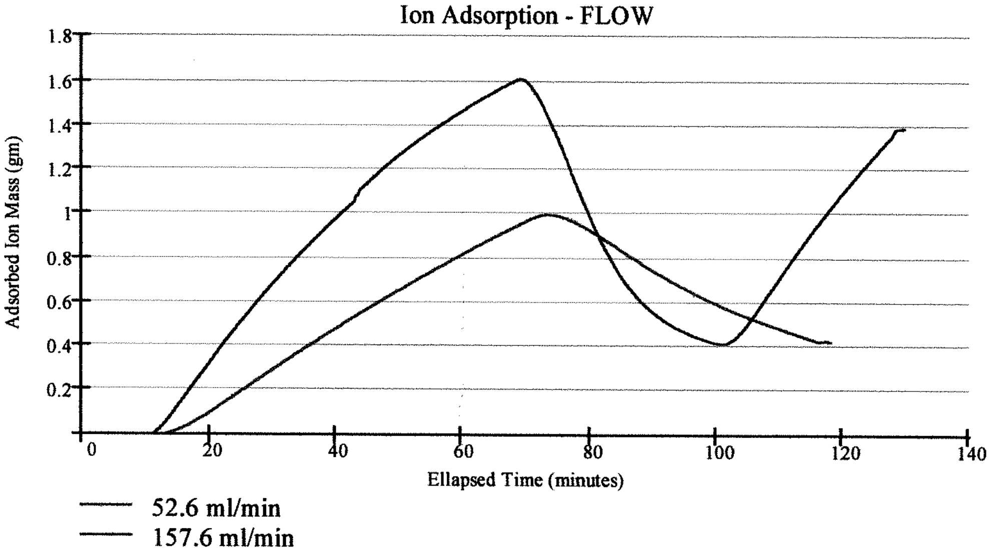


Figure 6 - Cummulative ion adsorption of Mk-8A s/n 1 graphite bus brick for one charge/discharge cycle of single pass 1032 uS/cm NaCl. Two flow rates are presented

Notes on Ion adsorption mass graph above

- Adsorbed mass was adjusted to be zero at the power on start time
- The release of ions during regeneration for the 157.6 ml/min flow case was incomplete when another cycle was started at 100 minutes.

Resistive Losses

At low voltages, resistive losses have been a significant problem resulting in low voltage at the aerogel electrode surface.
During the 52.6 ml/min flow experiment, voltages were measured at several points for evaluation of resistive losses through the system;

- Brick terminal posts on FarWest switch box - voltage going into the brick attachment cables.
- End of brick attachment cables after last brick attachment clip - this is the voltage reaching the clips attached to the graphite terminal rods on the brick.
- Vacant (unconnected) brick graphite terminal posts - current has travelled into and out of the bus to reach these points so this is the voltage on the aerogel at the bus end.

To determine the resistance of the control box to brick cables, the difference in potential at the control box and at the brick cable clamps is multiplied by the current. Simtoilarly the resistance of the bus is determined by comparing the potential differences between the cable clamps and vacant graphite post.

Five samples are used to improve accuracy.

$\mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}} :=$

	0	1	2	3
0	4.5	1.3	1.23	1.1
1	1.95	1.28	1.24	1.17
2	1.5	1.3	1.27	1.22
3	1.4	1.31	1.28	1.23
4	1.3	1.3	1.27	0

$n_{\mathrm{voltage}} := 0, 1 .. 4$

Table 4 - Voltage and current measurements at various points in the system. Columns represent Current(A), Control Box Voltage(V), Voltage at Cable Ends (V), Voltage Accross Vacant Posts (V)

Cable Resistance (total, both cables)

$$R_{\mathrm{cable}} := \sum_{n_{\mathrm{voltage}}} \frac{\left[\dfrac{\left(\mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},1}} - \mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},2}}\right)\cdot \mathrm{volt}}{\mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},0}}\cdot \mathrm{amp}}\right]}{5} \qquad R_{\mathrm{cable}} = 0.02\,\Omega$$

Bus Resistance (total, both poles)

$$R_{\mathrm{bus}} := \sum_{n_{\mathrm{voltage}}} \frac{\left[\dfrac{\left(\mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},2}} - \mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},3}}\right)\cdot \mathrm{volt}}{\mathrm{Voltages}_{\mathrm{Mk8Asn3\_4}_{n_{\mathrm{voltage}},0}}\cdot \mathrm{amp}}\right]}{5} \qquad R_{\mathrm{bus}} = 0.222\,\Omega$$

Performance Comparison to MK8 Metallic Bus Brick

To quantify improvements realized by the graphite bus system and multiple terminal connections, results obtained at 52.6 ml/min flow rate are compared to those obtained at the same flow from a Mk-8 brick containing metallic bus parts. Data for the Mk-8 metallic bus brick was collected on June 9, 2000.

Conductivity Reduction

The data presented here compares results from the tests performed on the Mk-8A brick containing the graphite bus and the Mk-8 brick containing a metal bus. Both tests were conducted at 52.6 ml/min. The Mk-8A graphite bus brick results are shown in red and the Mk-8 metallic bus brick results in green.

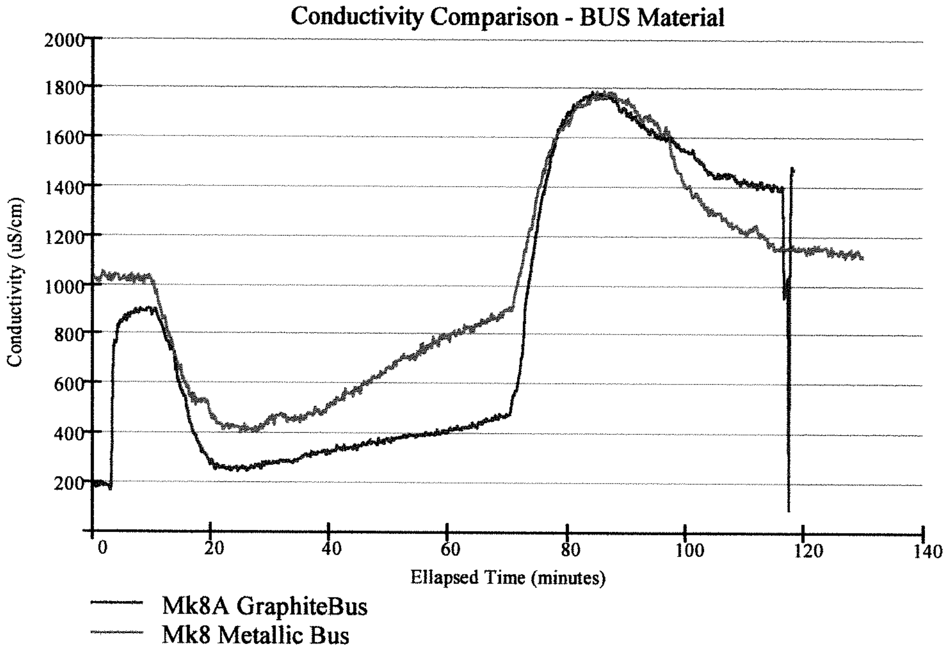


Figure 7 - Output conductivity for one charge/discharge cycle of single pass 1032 uS/cm NaCl at 52.6 ml/min. Data for the Mk-8A graphite bus brick (red) and Mk-8 metal bus brick (green) are presented.

Notes on Flow Comparison Conductivity Graph Above

- For the low flow rate test, conductivity at start is not at full level due to physisorbtion, longer stabilization would have brought it to the 1032 uS/cm level - does not significantly affect validity of results.
- Regeneration started at around 72.5 minutes.
- The Mk-8 metallic bus brick was almost saturated by the time regeneration began, the Mk-8A graphite bus brick was a long way from saturation.

Power Use

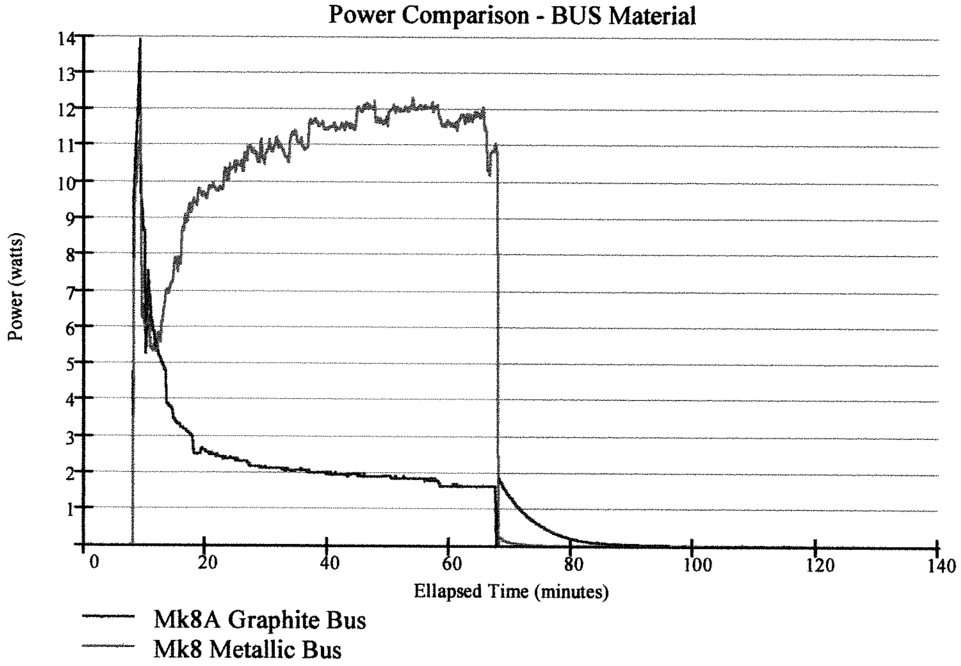


Figure 8 - Power use for one charge/discharge cycle of single pass 1032 uS/cm NaCl at 52.6 ml/min. Data for the Mk-8A graphite bus brick (red) and Mk-8 metal bus brick (green) are presented.

Notes on Flow Comparison Power Graph Above

- Power is obtained by multiplying voltage by current
- The Mk8 metallic bus brick developed an increased current draw at approximately 12 minutes - it is not a direct short since the voltage was maintained at 1.3 volts by the power supply.
- Power draw measurements for the Mk8 metallic bus brick should be viewed with caution, however other data should be considered reliable since voltage was maintained.

Ion Adsorption

Cummulative ion adsorption can be calculated bv intearatina the product of TDS reduction. water densitv. and flow

$$\text{IonMass}_{\text{metallic}}(i1) := dT\cdot\rho_{\text{water}}\cdot\text{Flow}_{\text{low}}\cdot\text{TDS}_{\text{conversion}}\cdot\sum_{j=0}^{i1}\left(\text{Conductivity}_{\text{Input}} - \text{Data}_{\text{Mk8sn1\_060900a}_{j,1}}\cdot 10^{-6}\cdot\frac{S}{cm}\right)$$

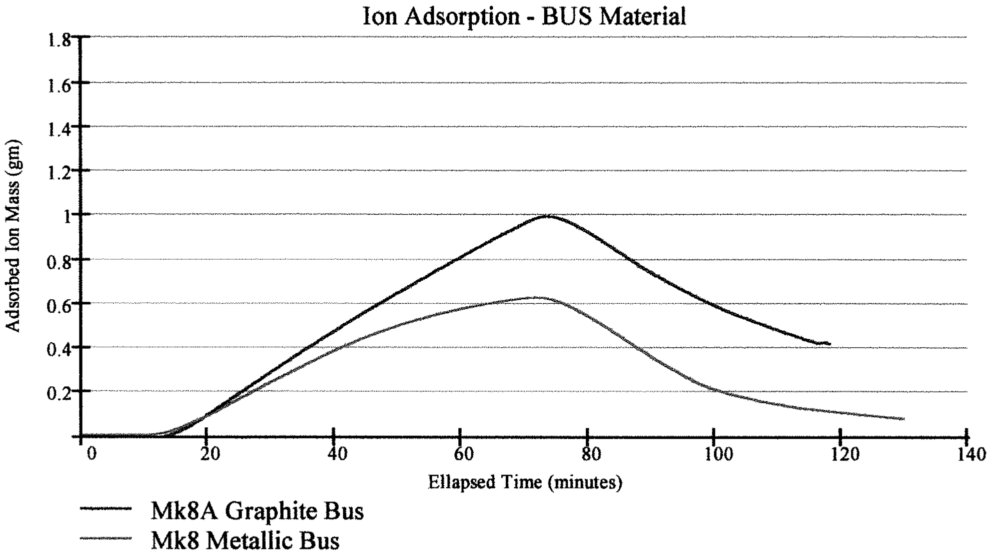


Figure 9 - Cummulative ion adsorption for one charge/discharge cycle of single pass 1032 uS/cm NaCl at 52.6 ml/min. Data for the Mk-8A graphite bus brick (red) and Mk-8 metal bus brick (green) are presented.

Notes on Ion adsorption mass graph above

- Adsorbed mass was adjusted to be zero at the power on start time
- The release of ions during regenerationwas not complete in either case
- The Mk8A Graphite bus brick clearly had greater ion adsorption capacity.

Conclusions

- Electrical losses in the new Mk-8A graphite bus based brick are lower.
- Increased flow rates improve ion adsorption
- The graphite bus configuration adsorbs 1.6 times the ions of the metallic configuration - probably more at the higher flow rate but no data is available for the metal bus brick.

Graphite Bus - Mk-8A Brick

2 Bricks in Series - Mountain Spring Water

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Introduction

A demonstration was prepared for two representatives from Hankook Jungsoo Industries of Korea to demonstrate suitability of CDT for water polishing. An application of interest to the company is production of high purity water for the electronics and other manufacturing industries.

As input, bottled mountain spring water with a conductivity of 282 micro Seimen/centimeters was chosen. We had no analytical data on the sample but felt it was a good random selection.

The test system chosen to demonstrate the process incorporated two Mk-8A connected in series. This setup had been configured earlier for determining maximum rinse concentration levels attainable when processing water from coal beds.

Arrangement of the system components was such that complete drainage of tubes and bricks could be accomplished through computer control between production and rinse cycles.

Objectives

1. Demonstrate ion removal at low TDS.
2. Determine effect of output conductivity on flow rate.
3. Evaluate efficiency of electrical series connection to bricks.

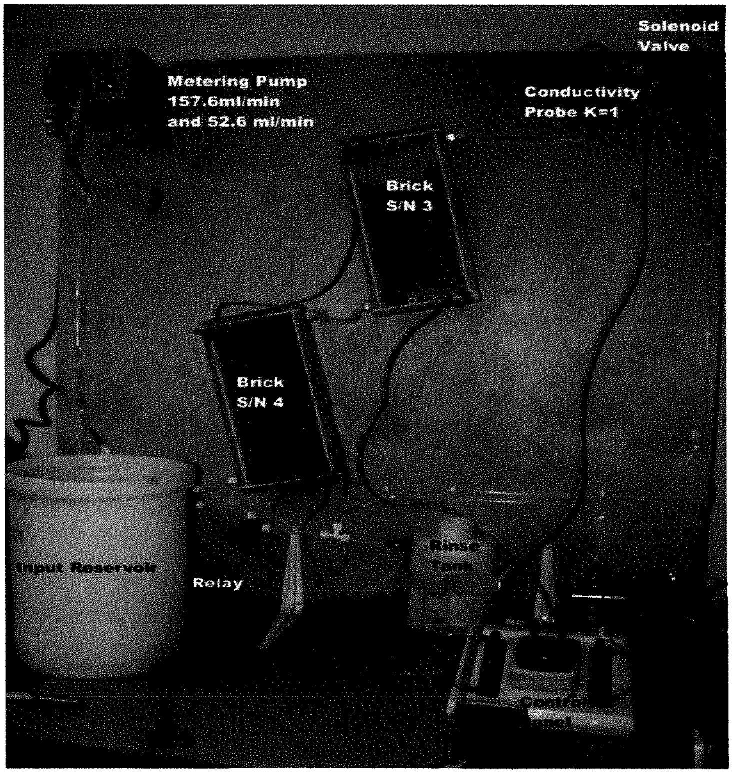

Figure 1 - Rinse concentration system setup incorporating 2 Mk-8A bricks.

Test Equipment

1. Mk-8A bricks serial numbers 3 and 4
2. Pulsafeeder metering pumps set at 52.6 ml/min and 157.6 ml/min flow rates
3. Input reservoir containing 9.46 litres of 282 uS/cm "Sparklets" mountain spring water
4. Additional 9.46 litres of mountain spring water for top up during experiment
5. Signet conductivity probe K=1
6. Signet conductivity readout model 8850 - full scale 20mA output value set to 5000 uS/cm
7. Industrial computer ADIO interface board mounted in Compaq Presario 4880
8. FarWest test interface control box
9. Fluke 89 mk IV True RMS Multimeter
10. Plastic tubing and connectors

Input Data

Variables and Constants

Aerogel electrode dimensions,

$l_{electrode} := 11.86 \cdot in$ $w_{electrode} := 6.25 \cdot in$ $t_{electrode} := .032 \cdot in$

Aerogel Density

$$\rho_{aerogel} := .78 \cdot \frac{gm}{cm^3}$$

Note: the density is adjusted for the aerogel sheets used in the MK8A brick which were more compressed than usual during pyrolization.

Water Density

$$\rho_{water} := 1 \cdot \frac{kg}{liter}$$

Number of electrodes per brick,

$n_{electrodeMK8} := 20$ $n_{electrodeMK8A} := 24$

Number of bricks in system,

$n_{bricks} := 2$

Total electrode area,

$A_{totalelectrodeMK8A} := w_{electrode} \cdot l_{electrode} \cdot n_{electrodeMK8A} \cdot n_{bricks}$ $A_{totalelectrodeMK8A} = 24.708\ ft^2$

Brick scale compared to 1000 square foot version

$$\text{Scale}_{\text{MK8A}} := \frac{A_{\text{totalelectrodeMK8A}}}{1000 \cdot \text{ft}^2} \qquad \text{Scale}_{\text{MK8A}} = 0.025$$

Flow rates,

$$\text{Flow}_{\text{low}} := 52.6 \cdot 10^{-3} \cdot \frac{\text{liter}}{\text{min}} \qquad \text{Flow}_{\text{low}} = 0.014 \frac{\text{gal}}{\text{min}}$$

$$\text{Flow}_{\text{moderate}} := 157.6 \cdot 10^{-3} \cdot \frac{\text{liter}}{\text{min}} \qquad \text{Flow}_{\text{moderate}} = 0.042 \frac{\text{gal}}{\text{min}}$$

TDS to Conductivity Ratio based on 500ppm NaCl Solution

$$\text{TDS}_{\text{conversion}} := \frac{500 \cdot 10^{-6}}{1032 \cdot 10^{-6} \cdot \frac{\text{S}}{\text{cm}}} \qquad \text{TDS}_{\text{conversion}} = 0.484 \frac{\text{cm}}{\text{S}}$$

Input conductivity

$$\text{Conductivity}_{\text{Input}} := 282 \cdot 10^{-6} \cdot \frac{\text{S}}{\text{cm}} \qquad \text{TDS}_{\text{Input}} := \text{Conductivity}_{\text{Input}} \cdot \text{TDS}_{\text{conversion}}$$

$$\text{TDS}_{\text{Input}} = 1.366 \times 10^{-4}$$

Results Tables

Initially the run time for the experiment was set at 1 hour so the data collection terminated after that time. Since the results were encouraging, a second data collection file was started and ran for an additional hour.
Both files were concatenated into a single file.
There was approximatey 5 minutes (300 seconds) between the last data point of the first file and the first data point of the second file.
Data is arranged in the following column order - Time(sec), Conductivity (uS/cm), PS Voltage(V), Current (A)

$\text{Data}_{\text{MSC}} :=$

	0	1	2	3
286	2860	-145.2	-3.18	1.12
287	2870	-134.77	-3.18	1.12
288	2880	-134.77	-3.03	0.93
289	2890	-6.23	-2.93	0.98
290	2900	31.99	-2.93	0.98
291	2910	18.09	-2.93	0.98
292	2920	28.51	-2.92	1.07
293	2930	31.99	-2.92	1.07
294	2940	14.62	-2.92	1.07
295	2950	35.46	-2.92	1.02

$$i := 0, 1 .. 720$$

Table 1 - Combined data from 2 files - only the first 10 out of 720 entries are shown.

Time increment for integration

$$dT := \left(\text{Data}_{\text{MSC}_{1,0}} - \text{Data}_{\text{MSC}_{0,0}}\right) \cdot \text{sec} \qquad dT = 10\,\text{s}$$

Graphical Data

Data is collected at 10 second intervals using the Industrial Computer ADIO 1600 I/O board and stored in ASCII format delineated by commas. The previous table was produced by concatenating two output files from the data collection system;

- MountainSpring.TXT - first 60 minutes of data collection
- MountainSpringContd1.TXT - second 60 minutes of data collection

The graphs presented here show the results obtained over the total 120 minutes data collection period;

- Output conductivity
- Instantaneous power consumptioin
- Cummulative ion storage

Output Conductivity

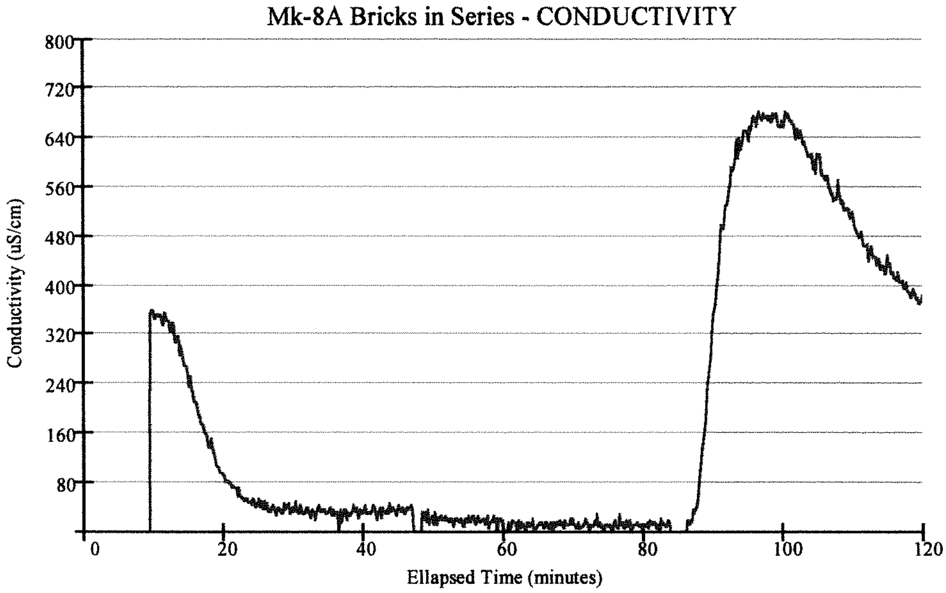

Figure 2 - Output conductivity of two Mk-8A s/n 3 and 4 graphite bus brick for one charge/partial discharge cycle of single pass of 282uS/cm "Sparklets Bottled Mountain Spring Water"

Notes on Graph Above

- Flow rate was 157.6 ml/min except between t=48 minutes and t=85 minutes when it was switched to 52.6 ml/min.
- Fluctuations of measurement are due to the computer recording sensitivity which was set to 5000 uS/cm full range with 8 bit full rrange. In other words, one count represented 19.5 uS/cm (looking at the conductivity meter during the last part of the production cycle it was stable at 20-25 uS/cm)

Power Consumption

The two bricks were wired in series and a voltage of 2.8 - 3.0 volts applied at the control panel end of the cables. Voltages were measured at several points in the system within a few minutes of start up.

- Power supply voltage at control panel end of cable: 3.0 volts
- Power supply voltage at brick end of cable: 2.9 volts
- Voltage drop across brick S/N 3 bus measured at vacant terminal posts: 1.22 volts
- Voltage drop across brick S/N 4 bus measured at vacant terminal posts: 1.03 volts

From the above measurements it can be assumed that an applied voltage of 3 volts yields the correct bus voltage in each brick. Further into the test, the difference in voltages between S/N 3 and S/N 4 increased but weren't recorded.

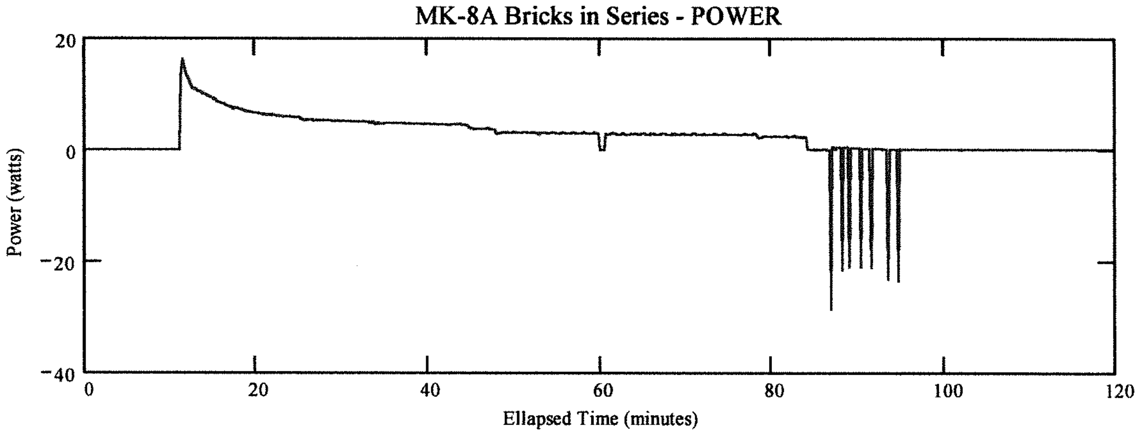

Figure 3 - Power use of two Mk-8A s/n 3 and 4 graphite bus brick for one charge/partial discharge cycle of single pass 232µS/cm "Sparklets Bottled Mountain Spring Water"

Notes on Power Graph Above

- Power is obtained by multiplying voltage by current
- Spikes at around 88 minutes are given during regeneration to force ions off electrodes (10A for 10 seconds)

Ion Adsorption

Cumulative ion adsorption can be calculated by integrating the product of TDS reduction, water density, and flow rate over time. Since there was a change in flow rate during the test, the equation is a little more complex than for a single flow rate.

The record number at which flow changed from 157.6 to 52.6 ml/min,

$$j_{low} := 283$$

Similarly, the record number at which flow reverted back to 157.6 ml/min is;

$$j_{moderate} := 505$$

The equation for the flow rate as a function of the record number is;

$$\mathrm{Flow}(i2) := \mathrm{if}\left(i2 < j_{low}, \mathrm{Flow}_{moderate}, \mathrm{if}\left(i2 < j_{moderate}, \mathrm{Flow}_{low}, \mathrm{Flow}_{moderate}\right)\right)$$

Cumulative ion adsorption is defined by the following equation;

$$\mathrm{IonMass}_{MSC}(i1) := dT \cdot \rho_{water} \cdot \mathrm{TDS}_{conversion} \cdot \sum_{j=0}^{i1} \left[\left(\mathrm{Conductivity}_{Input} - \mathrm{Data}_{MSC_{j,1}} \cdot 10^{-6} \cdot \frac{S}{cm}\right) \cdot \mathrm{Flow}(j)\right]$$

$$\mathrm{Offset}_{ionmass} := .3 \cdot gm$$

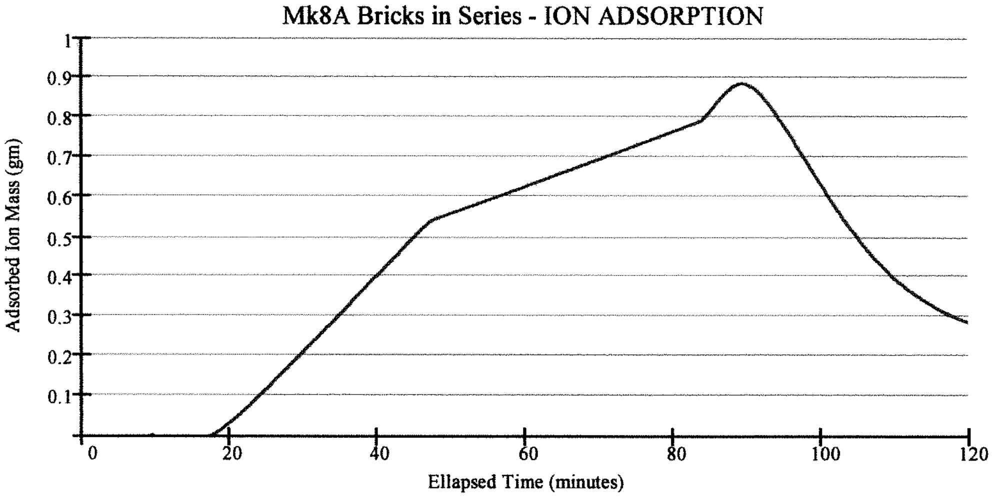

Figure 4 - Cummulative ion adsorption of Mk-8A s/n 3 and 4 graphite bus brick for one charge/discharge cycle of single pass 282 uS/cm "Sparklets Bottled Mountain Spring Water".

Notes on Ion adsorption mass graph above

- The first 18 minutes of integration were prior to output flow so the conductivity probe was at zero. This caused the integration to accumulate .3 g of ion adsorption during the period there was no output flow (filling). To correct for this .3g was subtracted from the ion adsorption mass values when plotted in figure 4.
- Change in slope at 47 minutes was due to the flow rate change from 157.6 to 52.6 ml/min.
- Regeneration was not completed and the bricks were not drained.

Conclusions

- the ion adsorption limit was not reached during this test since the input conductivity was low. If the production cycle had been extended, the output would have remained low for an hour or more (based on the knowledge that two bricks should adsorb a minimum of 3 g).
- series electrical connection produced unequal voltage drops accross the bricks due to variations in instantaneous resistance. Resistance variations arise from the capacitive nature of the device and the variations in water conductivity as is progresses through the system.

Dual Brick Concentrator

Coalbed Methane Application

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Introduction

For certain applications of CDT the goal is to produce a waste stream with the highest concentration of impurities and a product stream of adequate quality for reintroduction to the ground water system. Undoubtedly there is a reduction in the efficiency of the CDT system as rinse stream concentrations are increased due to residual impurities depositing themselves on the electrode surfaces between rinse and production cycles.

It is not adequate to demonstrate removal of ions from the product output but more importantly one must show the level of concentration that can be achieved in the waste stream. Depending on the regulations, it may be necessary to turn the contaminants into solid before storage in a long term closed landfill. Under this scenario, there will be an economic cutoff at which concentration is taken over by a secondary process such as distillation or other dewatering techniques.

A special series arrangement of two Mk-8A bricks was configured with elevations and flow paths oriented such that bricks and lines could be drained between cycles. This minimizes mixing between the product and rinse volumes thereby allowing the maximum concentrations to be achieved.

The Mk-8A fill volume is only 800ml which means that a rinse reservoir of 2 litres is sufficient to provide circulation for the two bricks.

Objectives

1. Produce sample of output with low TDS for lab testing - below 300 uS/cm to determine which, if any elements remain untouched by CDT
2. Produce rinse sample of high TDS for lab testing to ensure constituents removed by CDT are placed in rinse stream.
3. Determine limits of rinse concentration - economic and physical

Experimental Arrangement

To produce the highest concentration of rinse water with the lowest total sample use, a two brick system was constructed with plumbing arranged for complete drainage between cycles. Solenoid valves open the lines and allow them to be drained into either rinse or product tank.

1. Mk-8A bricks serial numbers 3 and 4
   Plumbed in series
   Wired in parallel
2. Pulsafeeder metering pumps
   52.6 ml/min for production
   157.6 ml/min for rinse
3. Input reservoir containing water sample from Wyoming Coal bed methane well Red13M 3190 - conductivity 2095 uS/cm
4. Additional water sample to top up input tank
5. 2 litre rinse reservoir
6. Signet conductivity probe K=1
7. Signet conductivity readout model 8850 - full scale 20mA output value set to 5000 uS/cm, increased further into test as TDS level of rinse increases
8. Industrial computer ADIO interface board mounted in Compaq Presario 4880
9. FarWest test interface control box
10. Fluke 89 mk IV True RMS Multimeter
11. Four Teqcom 3 way solenoid valves - M423W1ATS
12. Lambda regulated power supply - 9A, 0-30Vdc
13. 5 Crydom D1210 solid state relays - TTL control, 110Vac x 10A load

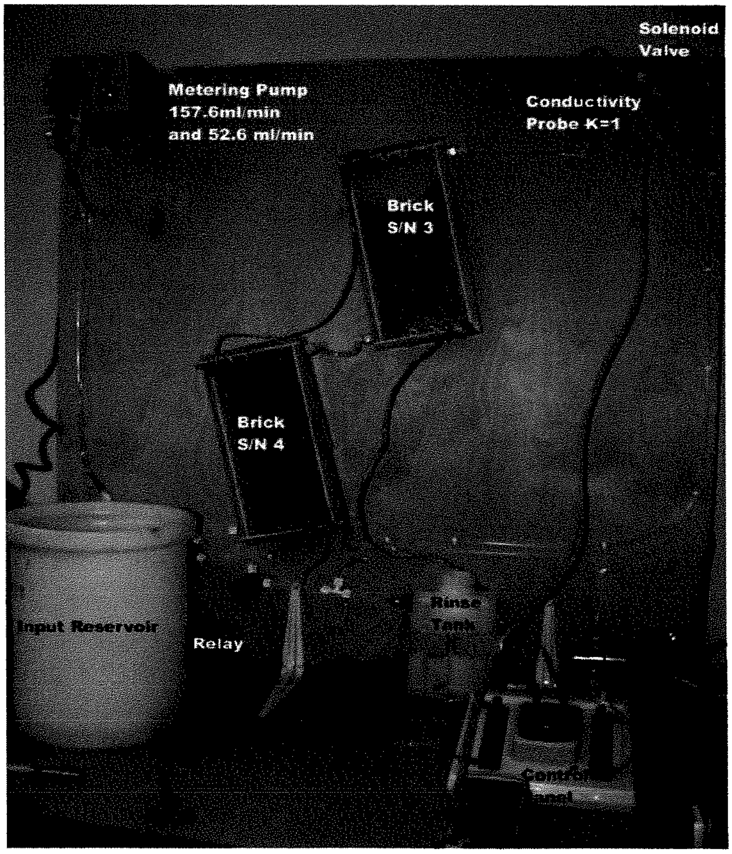
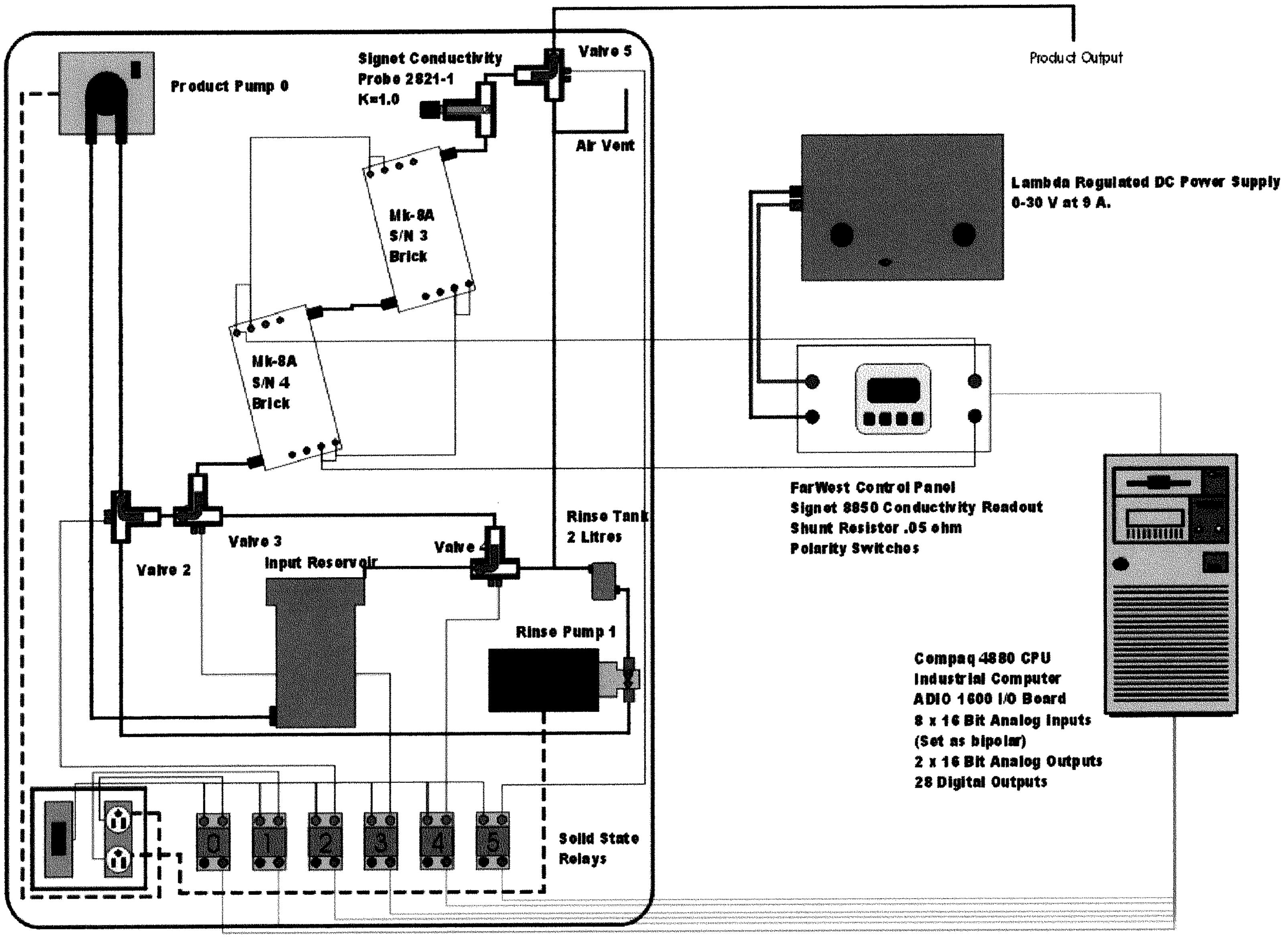


Figure 1: Dual brick concentrator setup. Note: wiring shown is series. It was changed to parallel for the tests since the capacitative nature of the load would not allow equal voltage distribution in a series connection.

System Diagram



Results

The system operation mode is still not optimized to produce the desired results, to date these are the items that were discovered during testing -

- During the early portion of the charge cycle 1.3V on the terminal input lines did not produce the required 1.2V on the bus. On later runs voltage was adjusted according to the voltage measured across the vacant bus terminals.
- The initial product water following a rinse cycle had a higher TDS than the input water due to residuals from the rinse. This got worse as the rinse TDS increased.

Data Files

A data file is collected for each cycle and given the name Red13M3190"x" where "x" is a letter representing the cycle.

Each record in the data file contains time (sec), conductivity (uS/cm), Voltage (V), and Current (A). The data is recorded at 10 second intervals and the record number at which power is turned off and the rinse started is different for each file.

The following table lists the first record at which power is turned off (column 0) and the total number of records in the file. The first row corresponds to file A, the second to B and so on.

The number of cycles in this study is $N_{cycles} := 7$ $n_{cycle} := 0, 1 .. N_{cycles} - 1$

$\mathrm{Nrecord} :=$

	0	1
0	252	720
1	264	720
2	562	720
3	592	900
4	560	900

$\mathrm{Data}_{Red13M3190} :=$

	0	1	2	3
0	0	167.48	0	0.05
1	10	160.53	0	0
2	20	160.53	0	0
3	30	157.06	0	0
4	40	160.53	0	0.05
5	50	164.01	0	0.05
6	60	167.48	0	0.05
7	70	160.53	0.18	0.93
8	80	174.43	0.22	0.93
9	90	167.48	0.23	11.44

$$N_{Records} := \sum_{i=0}^{(N_{cycles}-1)} \mathrm{Nrecord}_{i,1}$$

$N_{Records} = 5.76 \times 10^{3}$ $n := 0, 1 .. N_{Records}$

A second matrix can be constructed giving the starting record, power off, and ending record for each cycle from the table above

$$N_{Records} := \sum_{i=0}^{(N_{cycles}-1)} Nrecord_{i,1}$$

$$N_{Records} = 5.76 \times 10^3$$

$$n := 0,1 .. N_{Records}$$

A second matrix can be constructed giving the starting record, power off, and ending record for each cycle from the table above

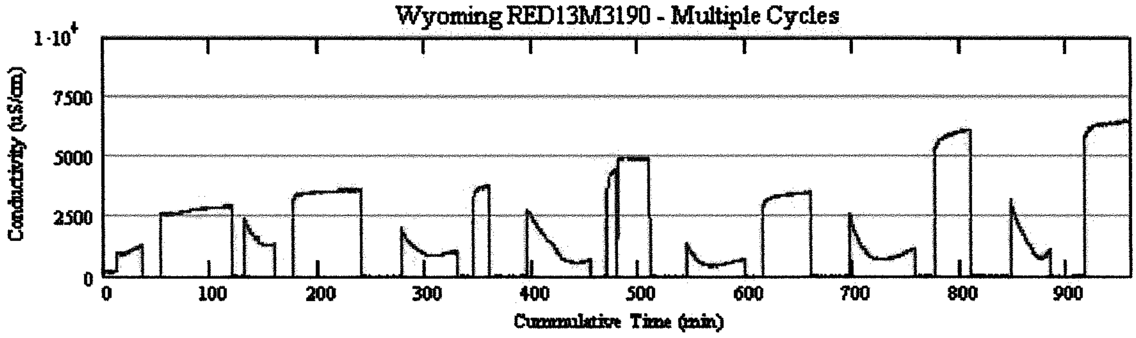
$$N_{Event_{n_{cycle},0}} := \mathrm{if}\left(n_{cycle} < 1, 0, \sum_{i=0}^{n_{cycle}-1} Nrecord_{i,1}\right)$$

$$N_{Event_{n_{cycle},1}} := N_{Event_{n_{cycle},0}} + Nrecord_{n_{cycle},0}$$

$$N_{Event_{n_{cycle},2}} := N_{Event_{n_{cycle},0}} + Nrecord_{n_{cycle},1}$$

$$N_{Event} = \begin{pmatrix} 0 & 252 & 720 \\ 720 & 984 & 1.44 \times 10^3 \\ 1.44 \times 10^3 & 2.002 \times 10^3 & 2.16 \times 10^3 \\ 2.16 \times 10^3 & 2.752 \times 10^3 & 3.06 \times 10^3 \\ 3.06 \times 10^3 & 3.62 \times 10^3 & 3.96 \times 10^3 \\ 3.96 \times 10^3 & 4.577 \times 10^3 & 4.86 \times 10^3 \\ 4.86 \times 10^3 & 5.416 \times 10^3 & 5.76 \times 10^3 \end{pmatrix}$$

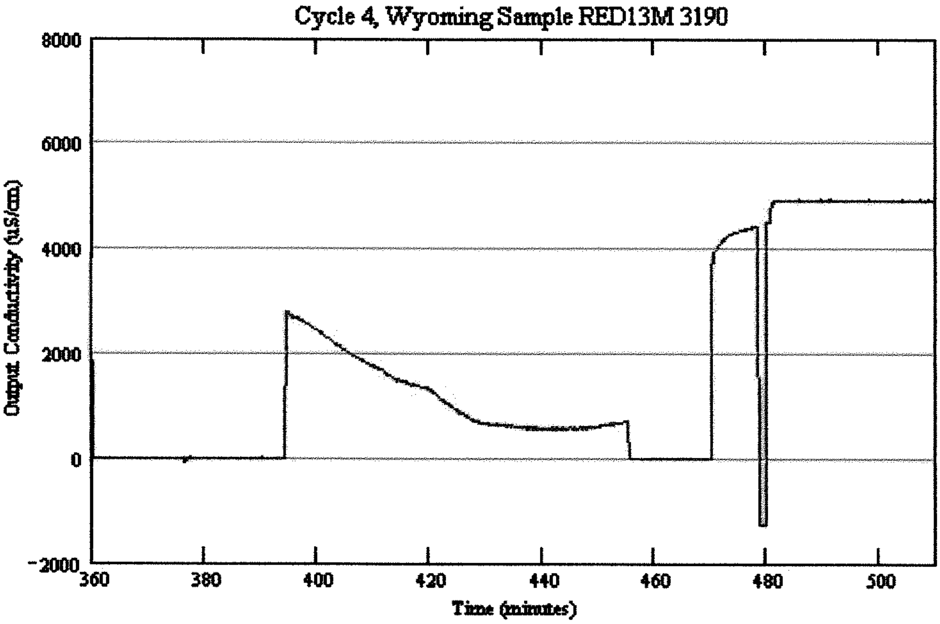
Multiple Cycle Conductivity Plot



Notes on graph above

1. First two cycles used low rinse velocity S/A production
2. Decreasing portions of curve are production
3. Rinse conductivity values increase with time as more ions are accumulated on subsequent runs
4. Time to remove residual rinse ions increases with rinse conductivity

Sample Plot From Cycle 4 Using 4078 uS/cm Rinse



Comments on the graph above

- During the period from 360 to roughly 390 minutes, the brick was filling so there was no output from the conductivity probe located on the brick output
- The input water conductivity was 2095 uS/cm at 20.5 C.
- The output conductivity at the start of the cycle was above the input value due to residual rinse water being pushed out the system
- The rinse began at roughly 470 minutes, the zero conductivity occurs during the fill time and is 1/3 the time of the production fill since the rinse flow rate is 3 times the production flow rate
- Rinse conductivity saturated at 5000 uS/cm since this was the maximum range set on the meter - it was increased for subsequent runs

Conclusion

Testing is still in progress and the system cycles are being optimized to produce the desired high TDS rinse.

- The system consistently reduced the input conductivity from 2095 uS/cm to below 800 uS/cm in a single pass.
  Surface area in the system is 1/80th that in a full size brick
- Rinse water residuals are a problem, the new aerogel without the cracks of the current material will help this. The cracks in the current aerogel account for 20-40% of the total aerogel volume.
- Product water should be recycled to bring TDS down further and increase ions available for transfer into the rinse water.

Technical Bulletin #4

Carlsbad Demonstrator

Preliminary Data - 1/4 Scale Bricks Fixed Volume Test 4.1.1

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Introduction

This document provides a sample of test results obtained from the Carlsbad demonstration system during testing of single 1/4 scale CDT bricks - MK-9 running in recirculating mode.

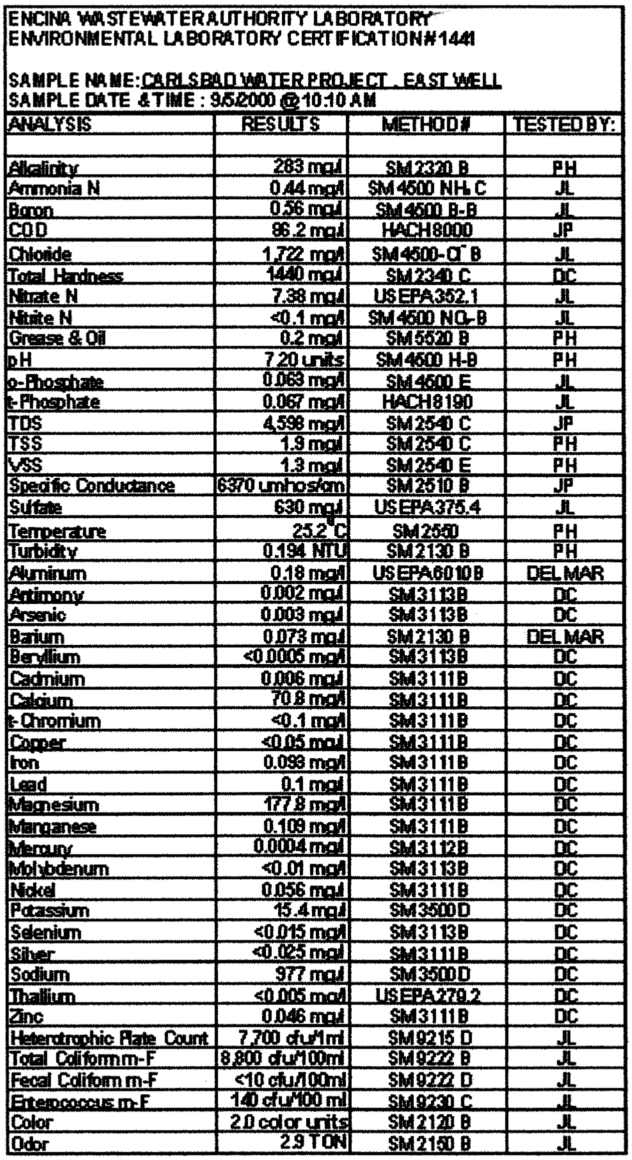
The purpose of the tests was to determine the ion storage limits for single 1/4 scale bricks using the ground water from the Encina wastewater site. This information will be used to predict performance of the system when multiple bricks are in operation.

These tests also provided insight into the operating scenarios best suited to the 1/4 scale bricks and Encina water source - shown right.

Objectives

The objectives for the test are in line with the test plan. Also included are some operation parameter experimentation as the performance of the brick on the ground water source is understood.

- Determine ion storage capacity of single 1/4 scale brick
- Determine optimum flow rates for ion adsorption and release (rinse)
- Determine effects of voltage on ion removal rates



ENCINA WASTEWATER AUTHORITY LABORATORY
ENVIRONMENTAL LABORATORY CERTIFICATION#1441

SAMPLE NAME: CARLSBAD WATER PROJECT , EAST WELL
SAMPLE DATE & TIME : 9/5/2000 @ 10:10 AM

ANALYSIS	RESULTS	METHOD#	TESTED BY:
Alkalinity	283 mg/l	SM 2320 B	PH
Ammonia N	0.44 mg/l	SM 4500 NH$_3$ C	JL
Boron	0.56 mg/l	SM 4500 B-B	JL
COD	86.2 mg/l	HACH 8000	JP
Chloride	1,722 mg/l	SM 4500-Cl$^-$ B	JL
Total Hardness	1440 mg/l	SM 2340 C	DC
Nitrate N	7.38 mg/l	USEPA 352.1	JL
Nitrite N	<0.1 mg/l	SM 4500 NO$_2$-B	JL
Grease & Oil	0.2 mg/l	SM 5520 B	PH
pH	7.20 units	SM 4500 H-B	PH
o-Phosphate	0.063 mg/l	SM 4500 E	JL
t-Phosphate	0.067 mg/l	HACH 8190	JL
TDS	4,598 mg/l	SM 2540 C	JP
TSS	1.9 mg/l	SM 2540 C	PH
VSS	1.3 mg/l	SM 2540 E	PH
Specific Conductance	6370 umhos/cm	SM 2510 B	JP
Sulfate	630 mg/l	USEPA 375.4	JL
Temperature	25.2 °C	SM 2550	PH
Turbidity	0.194 NTU	SM 2130 B	PH
Aluminum	0.18 mg/l	USEPA 6010 B	DEL MAR
Antimony	0.002 mg/l	SM3113B	DC
Arsenic	0.003 mg/l	SM3113B	DC
Barium	0.073 mg/l	SM 2130 B	DEL MAR
Beryllium	<0.0005 mg/l	SM3113B	DC
Cadmium	0.006 mg/l	SM3111B	DC
Calcium	70.8 mg/l	SM3111B	DC
t-Chromium	<0.1 mg/l	SM3111B	DC
Copper	<0.05 mg/l	SM3111B	DC
Iron	0.093 mg/l	SM3111B	DC
Lead	0.1 mg/l	SM3111B	DC
Magnesium	177.8 mg/l	SM3111B	DC
Manganese	0.109 mg/l	SM3111B	DC
Mercury	0.0004 mg/l	SM3112B	DC
Molybdenum	<0.01 mg/l	SM3113B	DC
Nickel	0.056 mg/l	SM3111B	DC
Potassium	15.4 mg/l	SM3500D	DC
Selenium	<0.015 mg/l	SM3113B	DC
Silver	<0.025 mg/l	SM3111B	DC
Sodium	977 mg/l	SM3500D	DC
Thallium	<0.005 mg/l	USEPA 279.2	DC
Zinc	0.046 mg/l	SM3111B	DC
Heterotrophic Plate Count	7,700 cfu/1ml	SM 9215 D	JL
Total Coliform m-F	8,800 cfu/100ml	SM 9222 B	JL
Fecal Coliform m-F	<10 cfu/100ml	SM 9222 D	JL
Enterococcus m-F	140 cfu/100 ml	SM 9230 C	JL
Color	2.0 color units	SM 2120 B	JL
Odor	2.9 TON	SM 2150 B	JL

Data Files

Each cycle is recorded in a separate data file. Each column from left to right represents Time (minutes), Flow (litres or litres/min), Voltage (V), Current (A), Probe 1 Conductivity (uS/cm), Probe 2 Conductivity (uS/cm)

$$\mathrm{Data}_{\mathrm{Sn2C}} := \begin{pmatrix}
0 & 2.20 & 1.30 & 0.00 & 6539 & 6333 \\
10 & 2.20 & 1.30 & 0.00 & 6487 & 6666 \\
21 & 2.20 & 1.30 & 100.00 & 6502 & 6677 \\
22 & 2.20 & 1.30 & 100.00 & 6499 & 6695 \\
23 & 2.20 & 1.30 & 100.00 & 6514 & 6717 \\
25 & 2.20 & 1.30 & 85.00 & 6047 & 6725 \\
26 & 2.20 & 1.30 & 80.00 & 6042 & 6719 \\
27 & 2.20 & 1.30 & 75.00 & 6037 & 6696 \\
28 & 2.20 & 1.30 & 70.00 & 6026 & 6661 \\
29 & 2.20 & 1.30 & 67.00 & 6026 & 6611 \\
30 & 2.20 & 1.30 & 55.00 & 6024 & 6592 \\
32 & 2.20 & 1.30 & 50.00 & 5988 & 6512 \\
34 & 2.20 & 1.30 & 50.00 & 5943 & 6432 \\
36 & 2.20 & 1.30 & 50.00 & 5723 & 6336 \\
38 & 2.20 & 1.30 & 50.00 & 5354 & 6307 \\
40 & 2.20 & 1.30 & 50.00 & 5282 & 6270 \\
48 & 2.20 & 1.30 & 38.00 & 4023 & 6083 \\
50 & 2.20 & 1.30 & 37.00 & 3987 & 6066 \\
60 & 1.00 & 1.30 & 32.00 & 3125 & 5931 \\
70 & 1.00 & 1.30 & 25.00 & 5193 & 5669 \\
80 & 2.00 & 1.30 & 25.00 & 5048 & 5663 \\
90 & 2.00 & 1.30 & 20.00 & 4956 & 5597 \\
100 & 2.00 & 1.30 & 20.00 & 4583 & 5541 \\
101 & 2 & 0 & 0 & 4575 & 5558 \\
107 & 2.00 & 0.00 & 0.00 & 4566 & 5675 \\
108 & 1.80 & 0.00 & 0.00 & 4573 & 5718 \\
109 & 1.80 & 0.00 & 0.00 & 4582 & 5763 \\
110 & 1.80 & 0.00 & 0.00 & 4598 & 5802 \\
111 & 1.80 & 0.00 & 0.00 & 4616 & 5841 \\
112 & 1.80 & 0.00 & 0.00 & 4626 & 5875 \\
113 & 1.80 & 0.00 & 0.00 & 4654 & 5903 \\
114 & 1.80 & 0.00 & 0.00 & 4679 & 5929 \\
115 & 1.80 & 0.00 & 0.00 & 4680 & 5953 \\
116 & 1.80 & 0.00 & 0.00 & 4709 & 5977 \\
117 & 1.80 & 0.00 & 0.00 & 4717 & 5997 \\
118 & 1.80 & 0.00 & 0.00 & 4744 & 6019 \\
119 & 1.80 & 0.00 & 0.00 & 4756 & 6034 \\
120 & 1.80 & 0.00 & 0.00 & 4746 & 6044 \\
121 & 1.80 & 0.00 & 0.00 & 4779 & 6038 \\
122 & 1.80 & 0.00 & 0.00 & 4799 & 6042 \\
123 & 1.80 & 0.00 & 0.00 & 4811 & 6042 \\
124 & 1.80 & 0.00 & 0.00 & 4825 & 6043 \\
125 & 1.80 & 0.00 & 0.00 & 4837 & 6048
\end{pmatrix}$$

$$\mathrm{Data}_{\mathrm{Sn4A}} := \begin{pmatrix}
0 & 1.00 & 1.30 & 0.00 & 5700 & 5788 \\
1 & 1.00 & 1.30 & 40.00 & 5692 & 5804 \\
2 & 1.00 & 1.30 & 40.00 & 5688 & 5812 \\
3 & 1.00 & 1.30 & 37.00 & 5688 & 5830 \\
4 & 1.00 & 1.30 & 35.00 & 5681 & 5832 \\
5 & 1.00 & 1.30 & 34.00 & 5680 & 5825 \\
6 & 1.00 & 1.30 & 32.00 & 5676 & 5816 \\
7 & 1.00 & 1.30 & 31.00 & 5671 & 5810 \\
8 & 1.00 & 1.30 & 30.00 & 5663 & 5795 \\
9 & 1.00 & 1.30 & 30.00 & 5665 & 5775 \\
10 & 1.00 & 1.30 & 29.00 & 5652 & 5753 \\
12 & 1.00 & 1.30 & 27.00 & 5632 & 5709 \\
14 & 1.00 & 1.30 & 25.00 & 5602 & 5663 \\
16 & 1.00 & 1.30 & 25.00 & 5581 & 5617 \\
18 & 1.00 & 1.30 & 24.00 & 5550 & 5569 \\
20 & 1.00 & 1.30 & 23.00 & 5517 & 5526 \\
25 & 1.00 & 1.30 & 21.00 & 5422 & 5426 \\
30 & 1.00 & 1.30 & 20.00 & 5333 & 5341 \\
35 & 1.00 & 1.30 & 19.00 & 5237 & 5271 \\
40 & 1.00 & 1.30 & 17.00 & 5141 & 5189 \\
45 & 1.00 & 1.30 & 16.00 & 5054 & 5174 \\
50 & 1.00 & 1.30 & 16.00 & 4983 & 5101 \\
55 & 1.00 & 1.30 & 15.00 & 4910 & 5054 \\
60 & 1.00 & 1.30 & 15.00 & 4841 & 5004 \\
65 & 1.00 & 1.30 & 15.00 & 4769 & 4958 \\
75 & 1.00 & 1.30 & 14.00 & 4653 & 4889 \\
80 & 1.00 & 1.30 & 12.00 & 4600 & 4863 \\
85 & 1.00 & 1.30 & 12.00 & 4549 & 4827 \\
100 & 1.00 & 1.30 & 11.00 & 4444 & 4753 \\
107 & 1.00 & 1.30 & 10.00 & 4420 & 4744 \\
108 & 1.00 & 0.00 & 0 & 4417 & 4760 \\
109 & 1.00 & 0.00 & 0.00 & 4414 & 4775 \\
110 & 1.00 & 0.00 & 0.00 & 4408 & 4812 \\
111 & 1.50 & 0.00 & 0.00 & 4406 & 4860 \\
112 & 1.50 & 0.00 & 0.00 & 4399 & 4897 \\
113 & 1.50 & 0.00 & 0.00 & 4401 & 4922 \\
114 & 1.50 & 0.00 & 0.00 & 4403 & 4947 \\
115 & 1.50 & 0.00 & 0.00 & 4410 & 4972 \\
120 & 1.50 & 0.00 & 0.00 & 4466 & 5123 \\
140 & 1.50 & 0.00 & 0.00 & 4673 & 5413 \\
168 & 1.50 & 0.00 & 0.00 & 4689 & 5582 \\
174 & 1.50 & 0.00 & 0.00 & 4660 & 5638 \\
178 & 1.50 & 0.00 & 0.00 & 4648 & 5652 \\
186 & 1.50 & 0.00 & 0.00 & 4604 & 5681
\end{pmatrix}$$

$$\mathrm{Data}_{\mathrm{Sn4B}} := \begin{pmatrix} 0 & 1.50 & 0.60 & 110.00 & 4591 & 5806 \\ 1 & 1.50 & 0.60 & 110.00 & 4620 & 5848 \\ 2 & 1.50 & 0.73 & 110.00 & 4614 & 5804 \\ 3 & 1.50 & 0.83 & 110.00 & 4611 & 5730 \\ 4 & 1.50 & 0.92 & 110.00 & 4598 & 5673 \\ 5 & 1.50 & 1.00 & 110.00 & 4567 & 5525 \\ 6 & 1.50 & 1.06 & 110.00 & 4539 & 5401 \\ 7 & 1.50 & 1.10 & 110.00 & 4480 & 5287 \\ 8 & 1.50 & 1.17 & 110.00 & 4424 & 5154 \\ 9 & 1.50 & 1.20 & 93.00 & 4355 & 5045 \\ 10 & 1.50 & 1.20 & 69.00 & 4286 & 4941 \\ 12 & 1.50 & 1.20 & 60.00 & 4215 & 4852 \\ 13 & 1.50 & 1.20 & 40.00 & 4058 & 4714 \\ 15 & 1.50 & 1.20 & 37.00 & 3925 & 4630 \\ 17 & 1.50 & 1.20 & 30.00 & 3798 & 4557 \\ 19 & 1.50 & 1.20 & 29.00 & 3711 & 4498 \\ 22 & 1.50 & 1.20 & 22.00 & 3640 & 4448 \\ 24 & 1.50 & 1.20 & 19.00 & 3501 & 4421 \\ 30 & 1.50 & 1.20 & 20.00 & 3467 & 4459 \\ 36 & 1.50 & 1.20 & 17.00 & 3384 & 4462 \\ 40 & 1.50 & 1.20 & 17.00 & 3348 & 4493 \\ 41 & 1.50 & 0.00 & 0.00 & 3344 & 4489 \\ 42 & 1.50 & 0.00 & 0.00 & 3340 & 4505 \\ 43 & 1.50 & 0.00 & 0.00 & 3331 & 4536 \\ 44 & 1.50 & 0.00 & 0.00 & 3328 & 4599 \\ 45 & 1.50 & 0.00 & 0.00 & 3332 & 4664 \\ 46 & 1.50 & 0.90 & 0.00 & 3342 & 4721 \\ 47 & 1.50 & 0.89 & 0.00 & 3353 & 4781 \\ 48 & 1.50 & 0.86 & 0.00 & 3385 & 4827 \\ 49 & 1.50 & 0.84 & 0.00 & 3409 & 4878 \\ 50 & 1.50 & 0.82 & 0.00 & 3429 & 4917 \\ 55 & 1.50 & 0.71 & 0.00 & 3571 & 5140 \\ 60 & 1.50 & 0.63 & 0.00 & 3665 & 5297 \\ 70 & 1.50 & 0.48 & 0.00 & 3832 & 5602 \\ 80 & 1.50 & 0.37 & 0.00 & 3932 & 5842 \\ 85 & 1.50 & 0.32 & 0.00 & 3955 & 5921 \\ 91 & 1.50 & 0.28 & 0.00 & 3988 & 5967 \\ 93 & 1.50 & 0.27 & 0.00 & 3971 & 5978 \\ 94 & 1.50 & 0.26 & 0.00 & 4004 & 5974 \\ 96 & 1.50 & 0.25 & 0.00 & 4005 & 5970 \\ 97 & 1.50 & 0.24 & 0.00 & 4008 & 5989 \\ 98 & 1.50 & 0.23 & 0.00 & 4009 & 6008 \\ 100 & 1.50 & 0.22 & 0.00 & 4015 & 6019 \\ 101 & 1.00 & 0.00 & 0.00 & 4019 & 6024 \\ 102 & 1.00 & 0.22 & 0.00 & 4022 & 6028 \\ 105 & 1.00 & 0.20 & 0.00 & 4044 & 6044 \\ 107 & 0.10 & 0.00 & 0.00 & 4058 & 6049 \\ 109 & 0.10 & 0.18 & 0.00 & 4072 & 6053 \\ 112 & 0.10 & 0.17 & 0.00 & 4072 & 6075 \end{pmatrix} \qquad \mathrm{Cond2Multiplier} := \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

Effects of Control Voltage and Flow Rate

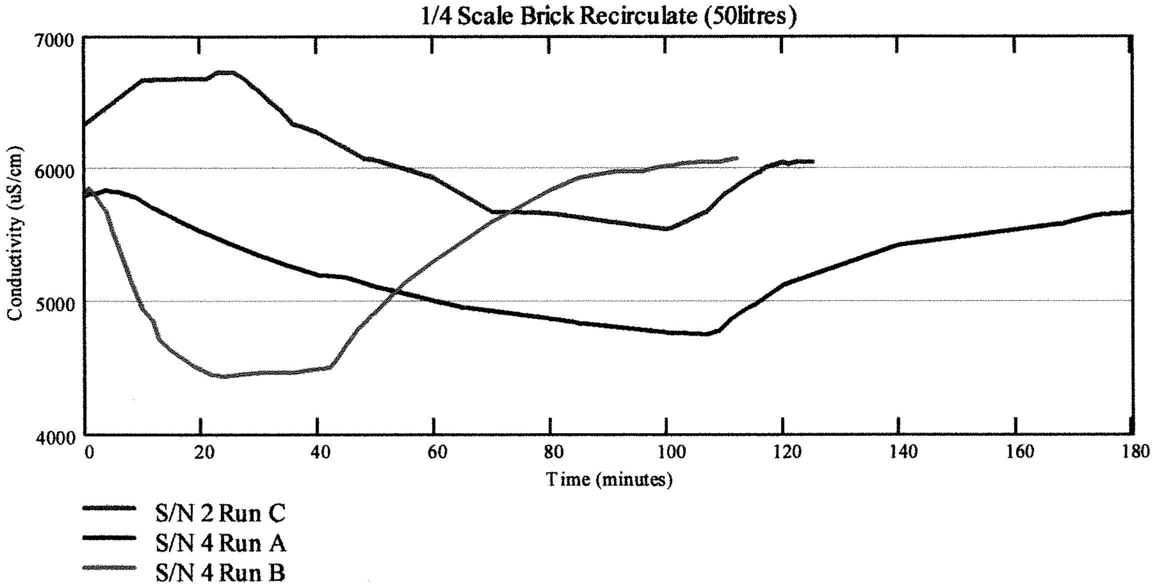
Early single brick tests were conducted with 1.3 vdc controlled at the power supply terminals.

Ion removal and removal levels were slow under this operating condition - electrical losses through the bus connections resulted in inadequate potential differences between aerogel electrode pairs.

For tests later than S/N 2D and S/N 4B, voltage control was implemented by sensing the voltage at two open terminals on the brick. The bricks have six terminals at each end alternating in polarity - 1,3,5 positive, 2,4,6 negative. Like terminals are connected internally through the aerogel electrodes. The supply cables were removed from terminals 5 and 6 at each end of the brick and they became the voltage sense points

The following graph demonstrates the dramatic performance accomplished by using bus feedback to regulate the applied voltage

$i := 0, 1 .. 50$

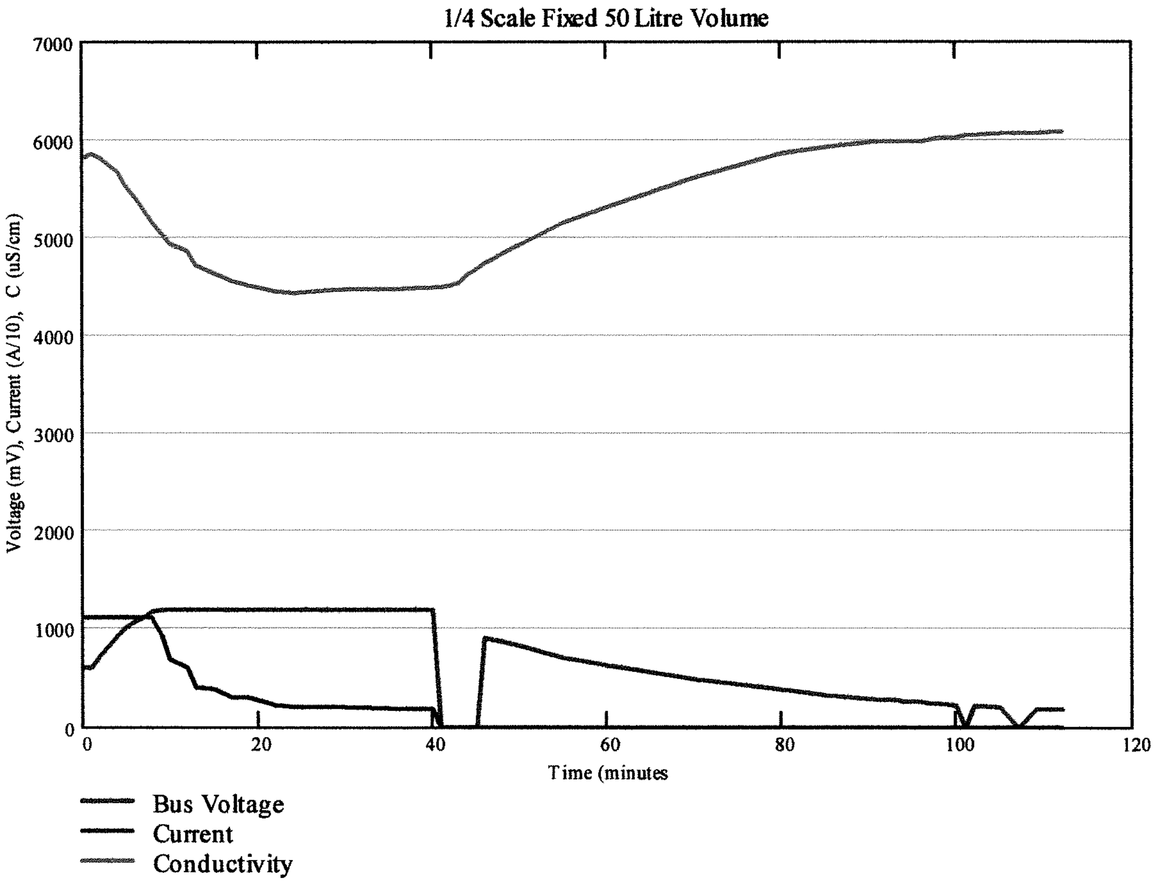


Comments on the previous graph

- Flow rates were 2, 1, and 1.5 litres/minute for runs S/N 2C, S/N 4A, and S/N 4B respectively
- Voltage control for run S/N 4B utilized feedback from vacant bus terminals on the brick, the other two runs controlled the voltage at the power supply.
- The S/N 2C brick was not completely rinsed on a prior rinse cycle and therefore increased conductivity of the water above input levels due to transfer of ions.
- Grounding occurred at 40 minutes for S/N 4B and approximately 100 minutes for the other two runs

Ion Storage Capacity

Using the conversion from conductivity to PPM given in the water analysis at the introduction, the mass of contaminants adsorbed and released can be predicted.



Notes on previous Graph

- Voltage not recorded from 41 to 46 minutes - hence dip in curve
- Discharge current not measured.
- System shorted at 40 minutes.
- Maximum current 110 A
- Maximum voltage 1.2 V

Water analysis conductivity, $C_{WaterAnal} := 6370 \cdot 10^{-6} \cdot \frac{S}{cm}$

Water analysis TDS, $TDS_{WaterAnal} := 4598 \cdot 10^{-6}$ (PPM expressed as a decimal)

Conversion factor - conductivity to TDS $Convert_{CondTDS} := \frac{TDS_{WaterAnal}}{C_{WaterAnal}}$ $Convert_{CondTDS} = 0.722 \frac{cm}{S}$

For S/N 4 run B the volume of water treated was $Vol_{Water} := 50 \cdot liter$

Water density, $\rho_{Water} := 1 \cdot \frac{kg}{liter}$

The approximate mass of ions adsorbed is calculated by looking at the change in conductivity accomplished

$MaxCond2 := max\left(Data_{Sn4B} \cdot Cond2Multiplier\right)$ $MaxCond2 = 6.075 \times 10^{3}$

$MinCond2 := min\left(Data_{Sn4B} \cdot Cond2Multiplier\right)$ $MinCond2 = 4.421 \times 10^{3}$

The absorbed ion mass is obtained thus,

$$M_{Ions} := (MaxCond2 - MinCond2) \cdot 10^{-6} \cdot \frac{S}{cm} \cdot Convert_{CondTDS} \cdot Vol_{Water} \cdot \rho_{Water}$$

$$M_{Ions} = 59.695\,gm$$

Benchmark

The goals for full scale CDT bricks are simple. A full size brick nominally contains 1000 square feet of aerogel and should accomplish a 1000 PPM TDS reduction at a flow rate of 1000 gallons per day.

This is considered the benchmark during development and brick performance is evaluated in terms of production gallons per day at 1000 ppm TDS reduction.

Initial results on the 1/4 scale brick S/N 4 suggest the following daily production at 1000 ppm TDS reduction

$CycleTime := 110 \cdot min$ $BrickScale := \frac{1}{4}$

$$ScaledDailyProduction_{Sn4B} := \frac{24 \cdot hr}{CycleTime} \cdot \frac{M_{Ions}}{10^{-3} \cdot \rho_{Water}} \cdot \frac{1}{BrickScale}$$

$$ScaledDailyProduction_{Sn4B} = 825.756\,gal$$

Conclusions

- Applied voltage must be controlled using feedback from the bus for best performance
- Single brick scaled performance seems to be better than 80% of the goal
- A cycle time of approximately 100 minutes (production and rinse) is effective

Ion storage and scaled daily production (based on 1000 ppm reduction per full sized brick) are as follows

$$M_{Ions} = 59.695\,\text{gm}$$

$$\text{ScaledDailyProduction}_{Sn4B} = 825.756\,\text{gal}$$

Electrode Performance Measurements

Sample S1 - Reduced Cost Material

FarWest Group, Inc
Engineering and Development Center
701 Palomar Airport Road, Suite 300
Carlsbad, CA 92009

Phone: (760)931-4784 Fax: (760)931-4850
Email: c_sheppard@msn.com

Introduction

There is ongoing development between FarWest and TDA to reduce the manufacturing costs of Aerogel and Aerogel type materials. As part of this development, materials are compared by charging and discharging a capacitor made of two 3" x 2" samples submerged in 10,000 ppm NaCl solution.

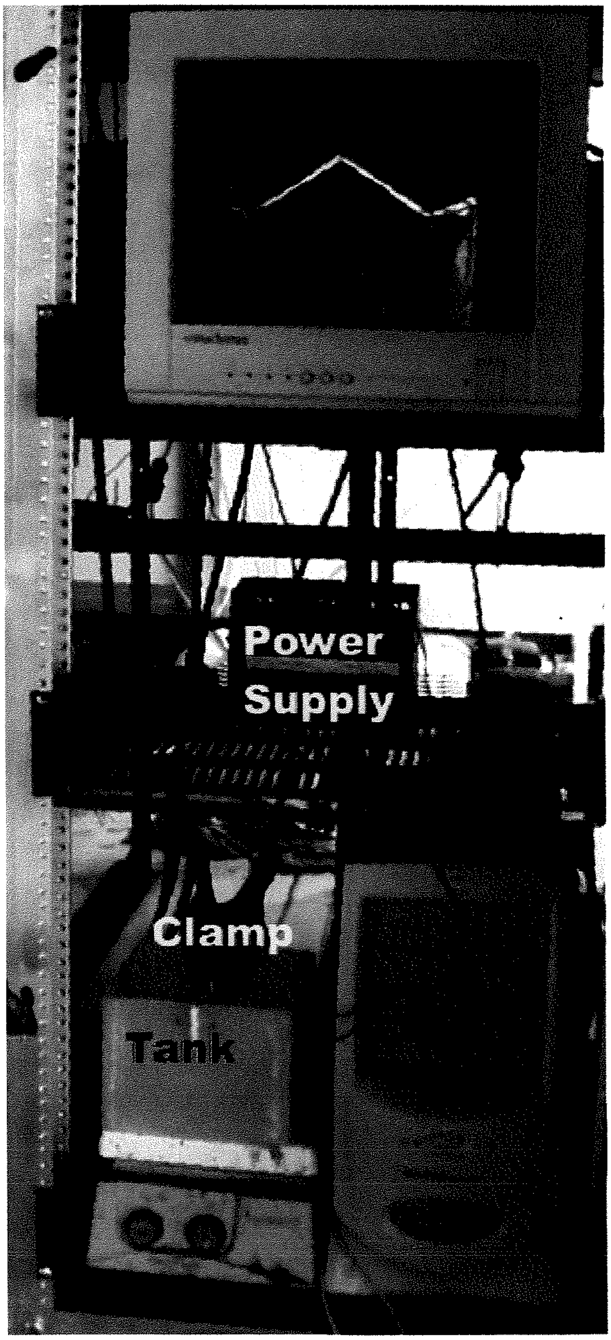
This document compares the following materials;

- Calibration run on same sample 071900Edge performed March 23, 2001
- Material P1 on Pan veil
- Material S1 on Carbon veil
- Material used in Mk-8A graphite bus bricks

Objectives

Objectives of these tests are two fold

- Quantify electrical conductivity improvement realized by changing from alligator connectors to spring loaded graphite rods for electrode coupling.
- Evaluate the P1 and S1 materials as a possible substitute for the current material due to their lower manufacturing cost.

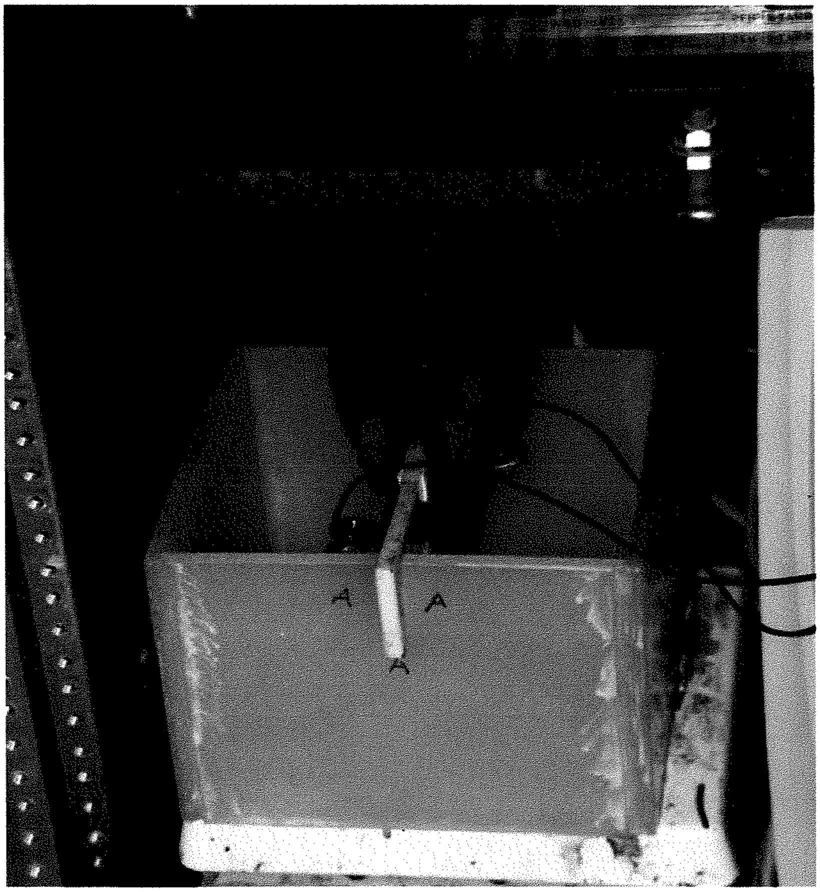


Test Equipment

1. Polypropylene reservoir - 2.0 litre fill level
2. 2 litres of 10,000 ppm NaCl solution
3. Plastic clamp with 1/4 diameter graphite rods bonded to tips for contact with electrode samples
4. Kepco power supply PAT 7-2 computer controlled 0-7 vdc at 0-2 A.
5. Industrial Computer ADIO 1600 I/O board mounted in Compaq 5304 computer
6. FarWest interface board containing relays and power supply control resistors.
   Relays are used to switch from power supply to discharge resistor during discharge portion of test cycle
7. Thermolyne Cimarec 2 hot plate/magnetic mixer
8. Various test electrode pairs measuring 2" x 3"
9. FarWest visual c++ control software "geltest"

Test Sequence

1. Mix 10,000 ppm NaCl solution and fill reservoir with 2.0 litres
2. Mount test samples in tank such that a 2" x 2" area remains under the water.
3. Set program for 15 minutes charge and 15 minutes discharge with an initial 10 second settling time
4. Assign filename
5. Start mixer
6. Start test
7. At end of test, record data.
8. Perform second cycle with new file name
9. Reverse clamp such that polarity is reversed relative to samples
10. Repeat two more cycles with new filenames



Test Data

Raw test data is presented in the same format for each run. The three columns represent Time (sec), Voltage Across Samples (V), Current (A).

Since this is a Mathcad document, the entire table of 181 entries is stored for each data set but only the first few are visible.

Old Test Results - Q/A 071900Edge

From the Q/A tests performed on 07-19-00, the average input and output energies for these samples was

- Average input energy = 75.33 J
- Average output energy = 13.53 J
- Ratio of output to input = 18%

$\text{AvEnergyIn}_{071900\text{Edge}} := 75.33\cdot\text{J}$

$\text{AvEnergyOut}_{071900\text{Edge}} := 13.53\cdot\text{J}$

Calibration Run 071900Edge Sample

These results have been obtained by performing the capacitor test on the same samples tested in Tucson immediately after production of the aerogel.

The only difference is the method of electrical connection to the electrode samples

$\text{Data}_{071900\text{EdgeCalA}} :=$

	0	1	2
0	10	0	0
1	20	1.22	0.38
2	30	1.21	0.3
3	40	1.21	0.25
4	50	1.21	0.21
5	60	1.2	0.18
6	70	1.2	0.16

$\text{Data}_{071900\text{EdgeCalB}} :=$

	0	1	2
0	10	0	0
1	20	1.23	0.39
2	30	1.21	0.31
3	40	1.21	0.25
4	50	1.21	0.21
5	60	1.2	0.18
6	70	1.2	0.16

Sample Physical Data

Plate 1

$t_{071900\text{Edge\_1}} := .034\cdot\text{in}$

$L_{071900\text{Edge\_1}} := 3\cdot\text{in}$

$w_{071900\text{Edge\_1}} := 2\cdot\text{in}$

$M_{071900\text{Edge\_1}} := 2.35\cdot\text{gm}$

Plate 2

$t_{071900\text{Edge\_2}} := .034\cdot\text{in}$

$L_{071900\text{Edge\_2}} := 3\cdot\text{in}$

$w_{071900\text{Edge\_2}} := 2\cdot\text{in}$

$M_{071900\text{Edge\_2}} := 2.3\cdot\text{gm}$

$\mathrm{Data}_{071900EdgeCalC} :=$

	0	1	2
0	10	0	0
1	20	1.23	0.41
2	30	1.21	0.32
3	40	1.21	0.26
4	50	1.2	0.23
5	60	1.21	0.2
6	70	1.2	0.17

$\mathrm{Data}_{071900EdgeCalD} :=$

	0	1	2
0	10	0	0
1	20	1.23	0.42
2	30	1.22	0.32
3	40	1.2	0.25
4	50	1.21	0.22
5	60	1.21	0.18
6	70	1.2	0.16

Material P1 on Carbon Veil

$\mathrm{Data}_{P1\_082800B} :=$

	0	1	2
0	10	0	0
1	20	1.21	0.3
2	30	1.21	0.27

$\mathrm{Data}_{P1\_082800C} :=$

	0	1	2
0	10	0	0
1	20	1.2	0.21
2	30	1.2	0.2

$\mathrm{Data}_{P1\_082800D} :=$

	0	1	2
0	10	0	0
1	20	1.2	0.31
2	30	1.21	0.29

Sample Physical Data

Plate 1

$t_{P1\_082800\_1} := .033 \cdot \mathrm{in}$

$L_{P1\_082800\_1} := 3. \cdot \mathrm{in}$

$w_{P1\_082800\_1} := 2 \cdot \mathrm{in}$

$M_{P1\_082800\_1} := 1.75 \cdot \mathrm{gm}$

$Data_{P1\_082800E} :=$

	0	1	2
0	10	0	0
1	20	1.21	0.27
2	30	1.2	0.25

$Data_{P1\_082800F} :=$

	0	1	2
0	10	0	0
1	20	1.2	0.3
2	30	1.2	0.28

Plate 2

$t_{P1\_082800\_2} := .033 \cdot in$

$L_{P1\_082800\_2} := 3 \cdot in$

$w_{P1\_082800\_2} := 2 \cdot in$

$M_{P1\_082800\_2} := 1.75 \cdot gm$

Material S1 on Carbon Veil

Four 2" x 3" samples were produced using the S1 formulation on carbon veil. These are the test results from the second pair tested.
The first pair gave almost identical results.

$Data_{S1\_032901A} :=$

	0	1	2
0	10	0.31	-0.01
1	20	1.21	0.24
2	30	1.2	0.21

$Data_{S1\_032901B} :=$

	0	1	2
0	10	0.22	-0.01
1	20	1.21	0.27
2	30	1.2	0.24

$Data_{S1\_032901C} :=$

	0	1	2
0	10	0.24	-0.01
1	20	1.21	0.26
2	30	1.2	0.24

Sample Physical Data

Plate 1

$t_{S1\_032901\_1} := .036 \cdot in$

$L_{S1\_032901\_1} := 3 \cdot in$

$w_{S1\_032901\_1} := 2 \cdot in$

$M_{S1\_032901\_1} := 1.59 \cdot gm$

$\mathrm{Data}_{S1\_032901D} :=$

	0	1	2
0	10	0	0
1	20	1.21	0.46
2	30	1.21	0.41

Plate 2

$t_{S1\_032901\_2} := .036 \cdot in$

$L_{S1\_032901\_2} := 3 \cdot in$

$w_{S1\_032901\_2} := 2 \cdot in$

$M_{S1\_032901\_2} := 1.59 \cdot gm$

$\mathrm{Data}_{S1\_032901E} :=$

	0	1	2
0	10	0.07	-0.01
1	20	1.21	0.35
2	30	1.21	0.31

$\mathrm{Data}_{S1\_032901F} :=$

	0	1	2
0	10	0.1	-0.01
1	20	1.21	0.34
2	30	1.21	0.3

MK 8A Graphite Bus Brick Samples

These samples were taken from material used in the construction of MK 8A serial number 6. They are from the same batch of material used to construct serial numbers 3, 4, and 5.

$\mathrm{Data}_{Mk8ASn6A} :=$

	0	1	2
0	10	0.89	-0.02
1	20	1.2	0.09
2	30	1.2	0.08

$\mathrm{Data}_{Mk8ASn6B} :=$

	0	1	2
0	10	0.07	-0.01
1	20	1.22	0.35
2	30	1.21	0.27

$\mathrm{Data}_{\mathrm{Mk8ASn6C}} :=$

	0	1	2
0	10	0.08	-0.01
1	20	1.22	0.36
2	30	1.21	0.28

$\mathrm{Data}_{\mathrm{Mk8ASn6D}} :=$

	0	1	2
0	10	0	0
1	20	1.23	0.47
2	30	1.22	0.37

$\mathrm{Data}_{\mathrm{Mk8ASn6E}} :=$

	0	1	2
0	10	0.06	-0.01
1	20	1.23	0.38
2	30	1.21	0.3

$\mathrm{Data}_{\mathrm{Mk8ASn6F}} :=$

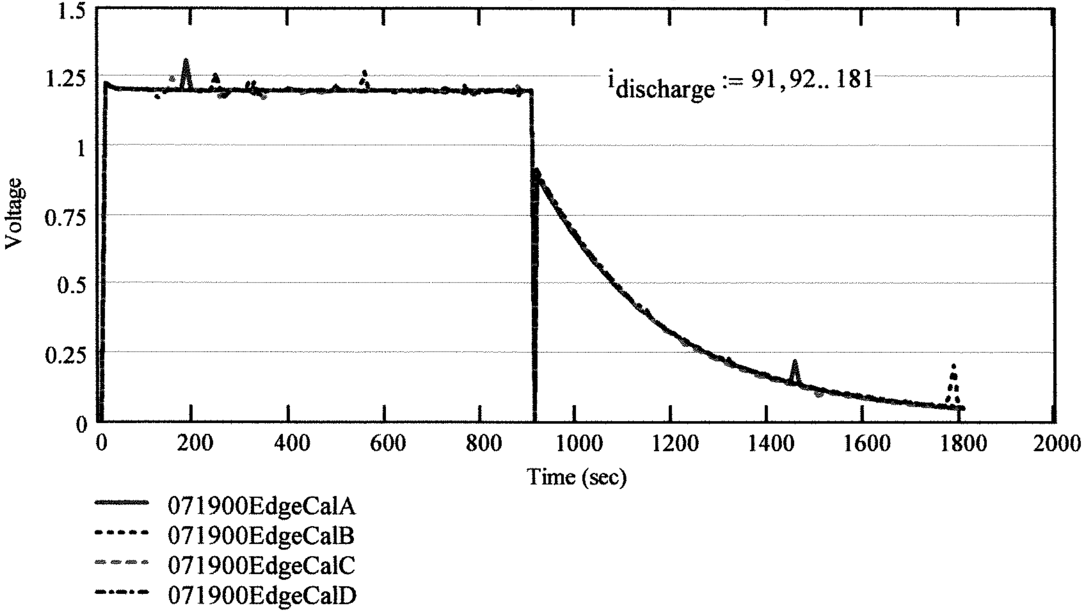
	0	1	2
0	10	0.08	-0.01
1	20	1.22	0.38
2	30	1.21	0.29

Graphical Results

Calibration Sample

$i := 0, 1 .. 181$ $\qquad$ $i_{charge} := 0, 1 .. 90$

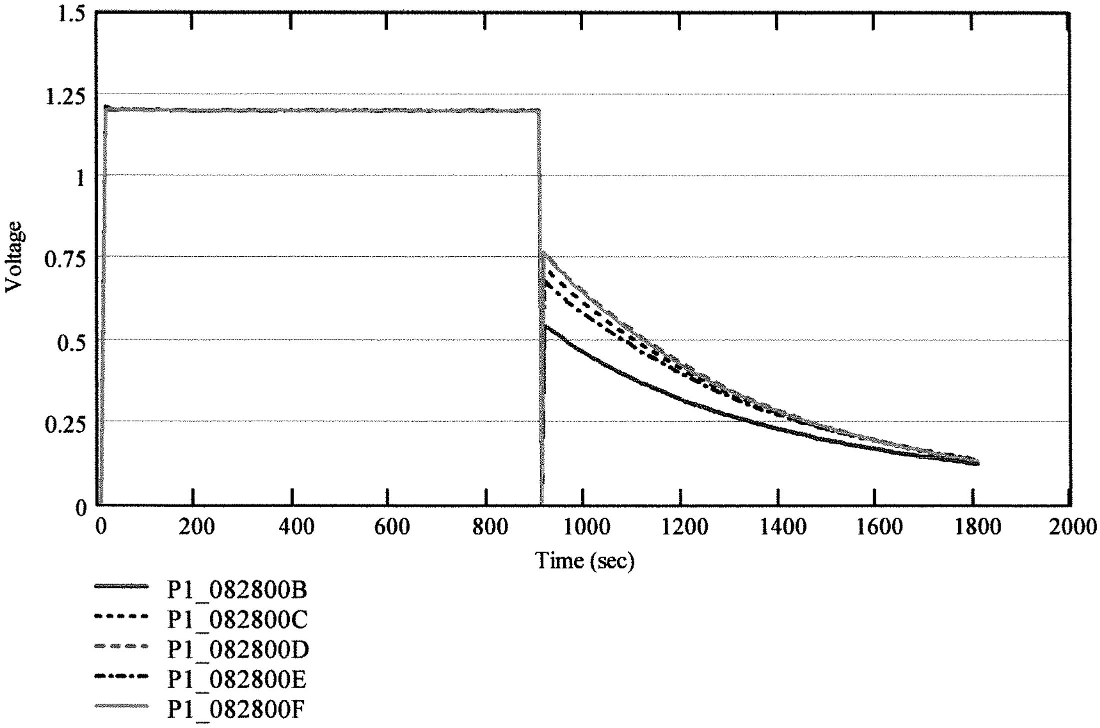
Calibration Sample Run - Graphite Clamp



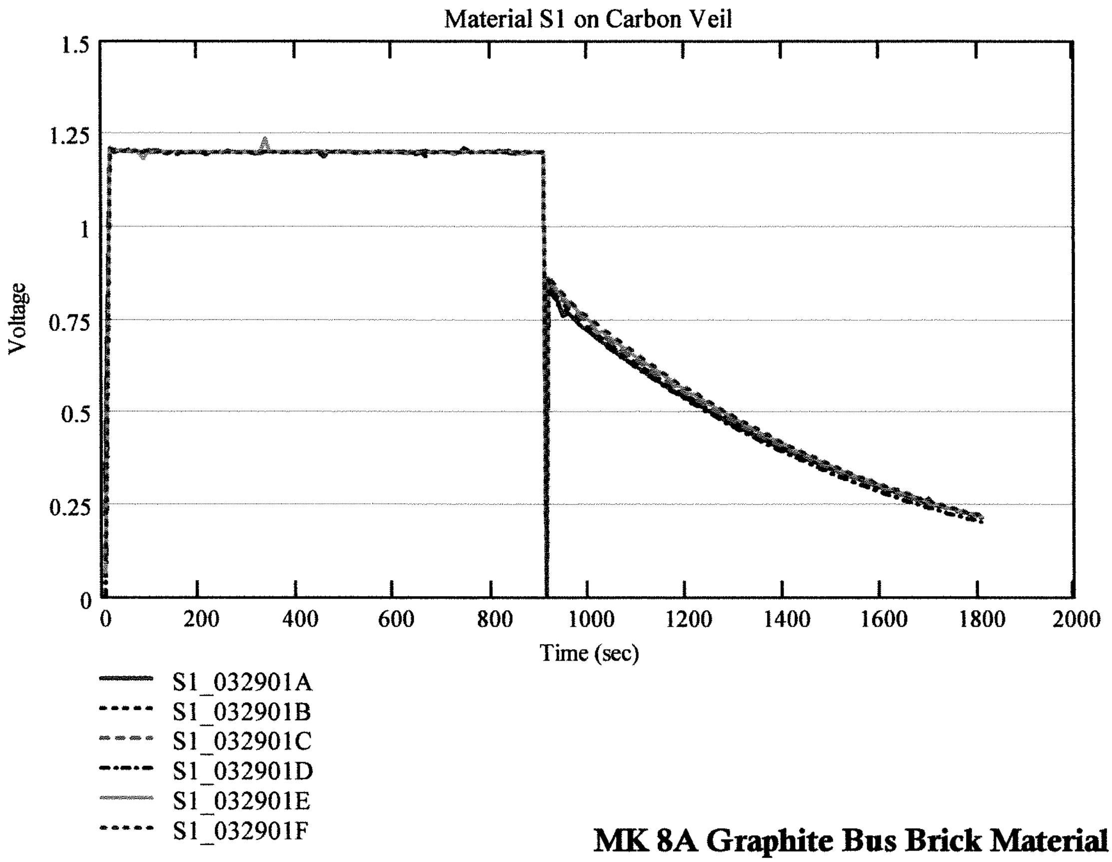
$i_{discharge} := 91, 92 .. 181$

Material P1 on Carbon Veil

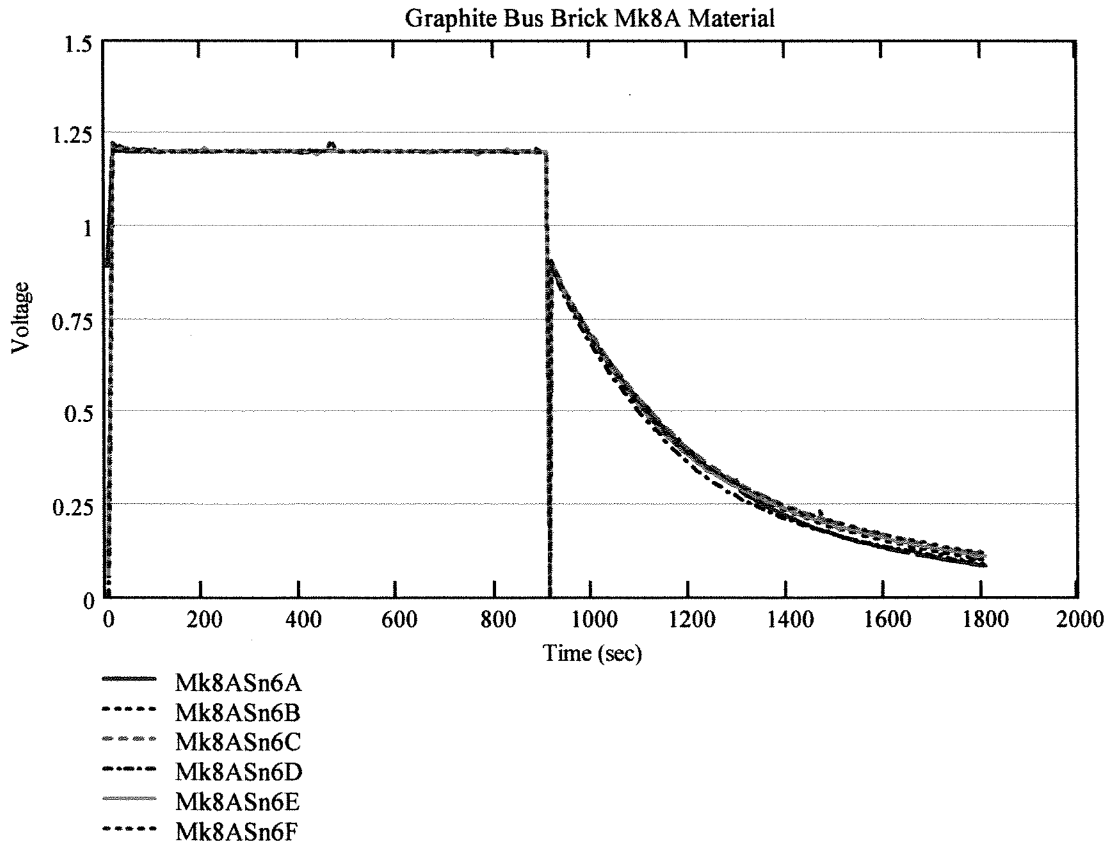
Material P1 on Carbon Veil



Material S1 on Carbon Veil


Material S1 on Carbon Veil

MK 8A Graphite Bus Brick Material


Graphite Bus Brick Mk8A Material

Energy Calculations

Before the energy input and output can be determined from the data tables (matrices), the tables must be split into two sub matrices - input and output

$\text{Input}_{071900EdgeCalA} := \text{submatrix}\left(\text{Data}_{071900EdgeCalA}, 0, 90, 0, 2\right)$

$\text{Input}_{071900EdgeCalB} := \text{submatrix}\left(\text{Data}_{071900EdgeCalB}, 0, 90, 0, 2\right)$

$\text{Input}_{071900EdgeCalC} := \text{submatrix}\left(\text{Data}_{071900EdgeCalC}, 0, 90, 0, 2\right)$

$\text{Input}_{071900EdgeCalD} := \text{submatrix}\left(\text{Data}_{071900EdgeCalD}, 0, 90, 0, 2\right)$

$\text{Output}_{071900EdgeCalA} := \text{submatrix}\left(\text{Data}_{071900EdgeCalA}, 91, 181, 0, 2\right)$

$\text{Output}_{071900EdgeCalB} := \text{submatrix}\left(\text{Data}_{071900EdgeCalB}, 91, 181, 0, 2\right)$

$\text{Output}_{071900EdgeCalC} := \text{submatrix}\left(\text{Data}_{071900EdgeCalC}, 91, 181, 0, 2\right)$

$\text{Output}_{071900EdgeCalD} := \text{submatrix}\left(\text{Data}_{071900EdgeCalD}, 91, 181, 0, 2\right)$

$\text{Input}_{P1\_082800B} := \text{submatrix}\left(\text{Data}_{P1\_082800B}, 0, 90, 0, 2\right)$

$\text{Input}_{P1\_082800C} := \text{submatrix}\left(\text{Data}_{P1\_082800C}, 0, 90, 0, 2\right)$

$\text{Input}_{P1\_082800D} := \text{submatrix}\left(\text{Data}_{P1\_082800D}, 0, 90, 0, 2\right)$

$\text{Input}_{P1\_082800E} := \text{submatrix}\left(\text{Data}_{P1\_082800E}, 0, 90, 0, 2\right)$

$\text{Input}_{P1\_082800F} := \text{submatrix}\left(\text{Data}_{P1\_082800F}, 0, 90, 0, 2\right)$

$\text{Output}_{P1\_082800B} := \text{submatrix}\left(\text{Data}_{P1\_082800B}, 91, 181, 0, 2\right)$

$\text{Output}_{P1\_082800C} := \text{submatrix}\left(\text{Data}_{P1\_082800C}, 91, 181, 0, 2\right)$

$\text{Output}_{P1\_082800D} := \text{submatrix}\left(\text{Data}_{P1\_082800D}, 91, 181, 0, 2\right)$

$\text{Output}_{P1\_082800E} := \text{submatrix}\left(\text{Data}_{P1\_082800E}, 91, 181, 0, 2\right)$

$\text{Output}_{P1\_082800F} := \text{submatrix}\left(\text{Data}_{P1\_082800F}, 91, 181, 0, 2\right)$

$$\text{VoltageExtract} := \begin{pmatrix} 0 \\ \text{volt} \\ 0 \end{pmatrix}$$

$$\text{CurrentExtract} := \begin{pmatrix} 0 \\ 0 \\ \text{amp} \end{pmatrix}$$

$\Delta t := 10 \cdot \text{sec}$

$\mathrm{Input}_{S1\_032901A} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901A}, 0, 90, 0, 2)$

$\mathrm{Input}_{S1\_032901B} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901B}, 0, 90, 0, 2)$

$\mathrm{Input}_{S1\_032901C} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901C}, 0, 90, 0, 2)$

$\mathrm{Input}_{S1\_032901D} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901D}, 0, 90, 0, 2)$

$\mathrm{Input}_{S1\_032901E} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901E}, 0, 90, 0, 2)$

$\mathrm{Input}_{S1\_032901F} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901F}, 0, 90, 0, 2)$

$\mathrm{Output}_{S1\_032901A} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901A}, 91, 181, 0, 2)$

$\mathrm{Output}_{S1\_032901B} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901B}, 91, 181, 0, 2)$

$\mathrm{Output}_{S1\_032901C} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901C}, 91, 181, 0, 2)$

$\mathrm{Output}_{S1\_032901D} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901D}, 91, 181, 0, 2)$

$\mathrm{Output}_{S1\_032901E} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901E}, 91, 181, 0, 2)$

$\mathrm{Output}_{S1\_032901F} := \mathrm{submatrix}(\mathrm{Data}_{S1\_032901F}, 91, 181, 0, 2)$

$\mathrm{Input}_{Mk8ASn6A} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6A}, 0, 90, 0, 2)$

$\mathrm{Input}_{Mk8ASn6B} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6B}, 0, 90, 0, 2)$

$\mathrm{Input}_{Mk8ASn6C} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6C}, 0, 90, 0, 2)$

$\mathrm{Input}_{Mk8ASn6D} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6D}, 0, 90, 0, 2)$

$\mathrm{Input}_{Mk8ASn6E} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6E}, 0, 90, 0, 2)$

$\mathrm{Input}_{Mk8ASn6F} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6F}, 0, 90, 0, 2)$

$\mathrm{Output}_{Mk8ASn6A} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6A}, 91, 181, 0, 2)$

$\mathrm{Output}_{Mk8ASn6B} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6B}, 91, 181, 0, 2)$

$\mathrm{Output}_{Mk8ASn6C} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6C}, 91, 181, 0, 2)$

$\mathrm{Output}_{Mk8ASn6D} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6D}, 91, 181, 0, 2)$

$\mathrm{Output}_{Mk8ASn6E} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6E}, 91, 181, 0, 2)$

$\mathrm{Output}_{Mk8ASn6F} := \mathrm{submatrix}(\mathrm{Data}_{Mk8ASn6F}, 91, 181, 0, 2)$

Energy Calibration Sample

$$\text{EnergyIn}_{071900\text{EdgeCal}_0} := \left(\text{Input}_{071900\text{EdgeCalA}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{071900\text{EdgeCalA}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{071900\text{EdgeCal}_1} := \left(\text{Input}_{071900\text{EdgeCalB}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{071900\text{EdgeCalB}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{071900\text{EdgeCal}_2} := \left(\text{Input}_{071900\text{EdgeCalC}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{071900\text{EdgeCalC}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{071900\text{EdgeCal}_3} := \left(\text{Input}_{071900\text{EdgeCalD}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{071900\text{EdgeCalD}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{AvEnergyIn}_{071900\text{EdgeCal}} := \text{mean}\left(\text{EnergyIn}_{071900\text{EdgeCal}}\right)$$

$$\text{AvEnergyIn}_{071900\text{EdgeCal}} = 48.938\,\text{J}$$

$$\text{EnergyOut}_{071900\text{EdgeCal}_0} := \left(\text{Output}_{071900\text{EdgeCalA}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{071900\text{EdgeCalA}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyOut}_{071900\text{EdgeCal}_1} := \left(\text{Output}_{071900\text{EdgeCalB}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{071900\text{EdgeCalB}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyOut}_{071900\text{EdgeCal}_2} := \left(\text{Output}_{071900\text{EdgeCalC}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{071900\text{EdgeCalC}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyOut}_{071900\text{EdgeCal}_3} := \left(\text{Output}_{071900\text{EdgeCalD}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{071900\text{EdgeCalD}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{AvEnergyOut}_{071900\text{EdgeCal}} := \text{mean}\left(\text{EnergyOut}_{071900\text{EdgeCal}}\right)$$

$$\text{AvEnergyOut}_{071900\text{EdgeCal}} = -11.767\,\text{J}$$

Energy - Material P1 on Carbon Veil

$$\text{EnergyIn}_{\text{P1\_082800}_0} := \left(\text{Input}_{\text{P1\_082800B}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{\text{P1\_082800B}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{\text{P1\_082800}_1} := \left(\text{Input}_{\text{P1\_082800C}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{\text{P1\_082800C}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{\text{P1\_082800}_2} := \left(\text{Input}_{\text{P1\_082800D}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{\text{P1\_082800D}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{\text{P1\_082800}_3} := \left(\text{Input}_{\text{P1\_082800E}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{\text{P1\_082800E}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyIn}_{\text{P1\_082800}_4} := \left(\text{Input}_{\text{P1\_082800F}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Input}_{\text{P1\_082800F}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{AvEnergyIn}_{\text{P1\_082800}} := \text{mean}\left(\text{EnergyIn}_{\text{P1\_082800}}\right)$$

$$\text{AvEnergyIn}_{\text{P1\_082800}} = 70.3\,\text{J}$$

$$\text{EnergyOut}_{\text{P1\_082800}_0} := \left(\text{Output}_{\text{P1\_082800B}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{\text{P1\_082800B}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyOut}_{\text{P1\_082800}_1} := \left(\text{Output}_{\text{P1\_082800C}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{\text{P1\_082800C}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$\text{EnergyOut}_{\text{P1\_082800}_2} := \left(\text{Output}_{\text{P1\_082800D}}\cdot\text{VoltageExtract}\right)\cdot\left(\text{Output}_{\text{P1\_082800D}}\cdot\text{CurrentExtract}\right)\cdot\Delta t$$

$$EnergyOut_{P1\_082800_3} := (Output_{P1\_082800E} \cdot VoltageExtract) \cdot (Output_{P1\_082800E} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyOut_{P1\_082800_4} := (Output_{P1\_082800F} \cdot VoltageExtract) \cdot (Output_{P1\_082800F} \cdot CurrentExtract) \cdot \Delta t$$

$$AvEnergyOut_{P1\_082800} := mean(EnergyOut_{P1\_082800})$$

$$AvEnergyOut_{P1\_082800} = -12.396\ J$$

Energy - Material S1 on Carbon Veil

$$EnergyIn_{S1\_032901_0} := (Input_{S1\_032901A} \cdot VoltageExtract) \cdot (Input_{S1\_032901A} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{S1\_032901_1} := (Input_{S1\_032901B} \cdot VoltageExtract) \cdot (Input_{S1\_032901B} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{S1\_032901_2} := (Input_{S1\_032901C} \cdot VoltageExtract) \cdot (Input_{S1\_032901C} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{S1\_032901_3} := (Input_{S1\_032901D} \cdot VoltageExtract) \cdot (Input_{S1\_032901D} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{S1\_032901_4} := (Input_{S1\_032901E} \cdot VoltageExtract) \cdot (Input_{S1\_032901E} \cdot CurrentExtract) \cdot \Delta t$$

$$AvEnergyIn_{S1\_032901} := mean(EnergyIn_{S1\_032901})$$

$$AvEnergyIn_{S1\_032901} = 87.075\ J$$

$$EnergyOut_{S1\_032901_0} := (Output_{S1\_032901A} \cdot VoltageExtract) \cdot (Output_{S1\_032901A} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyOut_{S1\_032901_1} := (Output_{S1\_032901B} \cdot VoltageExtract) \cdot (Output_{S1\_032901B} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyOut_{S1\_032901_2} := (Output_{S1\_032901C} \cdot VoltageExtract) \cdot (Output_{S1\_032901C} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyOut_{S1\_032901_3} := (Output_{S1\_032901D} \cdot VoltageExtract) \cdot (Output_{S1\_032901D} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyOut_{S1\_032901_4} := (Output_{S1\_032901E} \cdot VoltageExtract) \cdot (Output_{S1\_032901E} \cdot CurrentExtract) \cdot \Delta t$$

$$AvEnergyOut_{S1\_032901} := mean(EnergyOut_{S1\_032901})$$

$$AvEnergyOut_{S1\_032901} = -21.73\ J$$

Energy - Mk 8A Graphite Bus Brick Material

$$EnergyIn_{Mk8ASn6_0} := (Input_{Mk8ASn6A} \cdot VoltageExtract) \cdot (Input_{Mk8ASn6A} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{Mk8ASn6_1} := (Input_{Mk8ASn6B} \cdot VoltageExtract) \cdot (Input_{Mk8ASn6B} \cdot CurrentExtract) \cdot \Delta t$$

$$EnergyIn_{Mk8ASn6_2} := (Input_{Mk8ASn6C} \cdot VoltageExtract) \cdot (Input_{Mk8ASn6C} \cdot CurrentExtract) \cdot \Delta t$$

$$\mathrm{EnergyIn}_{\mathrm{Mk8ASn6}_3} := \left(\mathrm{Input}_{\mathrm{Mk8ASn6D}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Input}_{\mathrm{Mk8ASn6D}}\cdot\mathrm{CurrentExtract}\right)\cdot\Delta t$$

$$\mathrm{EnergyIn}_{\mathrm{Mk8ASn6}_4} := \left(\mathrm{Input}_{\mathrm{Mk8ASn6E}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Input}_{\mathrm{Mk8ASn6E}}\cdot\mathrm{CurrentExtract}\right)\cdot\Delta t$$

$$\mathrm{EnergyIn}_{\mathrm{Mk8ASn6}_5} := \left(\mathrm{Input}_{\mathrm{Mk8ASn6F}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Input}_{\mathrm{Mk8ASn6F}}\cdot\mathrm{CurrentExtract}\right)\cdot\Delta t$$

$$\mathrm{AvEnergyIn}_{\mathrm{Mk8ASn6}} := \mathrm{mean}\left(\mathrm{EnergyIn}_{\mathrm{Mk8ASn6}}\right)$$

$$\mathrm{AvEnergyIn}_{\mathrm{Mk8ASn6}} = 53.394\ \mathrm{J}$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_0} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6A}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6A}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_1} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6B}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6B}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_2} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6C}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6C}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_3} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6D}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6D}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_4} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6E}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6E}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}_5} := \left(\mathrm{Output}_{\mathrm{Mk8ASn6F}}\cdot\mathrm{VoltageExtract}\right)\cdot\left(\mathrm{Output}_{\mathrm{Mk8ASn6F}}\cdot\mathrm{CurrentExtract}\right)$$

$$\mathrm{AvEnergyOut}_{\mathrm{Mk8ASn6}} := \mathrm{mean}\left(\mathrm{EnergyOut}_{\mathrm{Mk8ASn6}}\right)\cdot\Delta t$$

$$\mathrm{AvEnergyOut}_{\mathrm{Mk8ASn6}} = -14.202\ \mathrm{J}$$

CONCLUSIONS

- The electrical connections implemented on the test setup provide improved conductivity and therefore lower losses as seen by the ratios of output to input energies on identical samples.

$$\mathrm{EnergyRatio}_{\mathrm{071900Edge}} := \frac{\mathrm{AvEnergyOut}_{\mathrm{071900Edge}}}{\mathrm{AvEnergyIn}_{\mathrm{071900Edge}}} \qquad \mathrm{EnergyRatio}_{\mathrm{071900EdgeCal}} := \frac{\mathrm{AvEnergyOut}_{\mathrm{071900EdgeCal}}}{\mathrm{AvEnergyIn}_{\mathrm{071900EdgeCal}}}$$

$\mathrm{EnergyRatio}_{\mathrm{071900Edge}} = 17.961\,\%$ Old Setup $\qquad \mathrm{EnergyRatio}_{\mathrm{071900EdgeCal}} = -24.044\,\%$ New Setup

- The S1 material on carbon veil appears to have greater storage energy than the production material currently used in the graphite bricks. This makes it a viable candidate for testing in bricks.

  Average energy extracted = 21.73 J compared to 14.2 J for the Mk 8A brick material (previous production runs have produced energies of up to 18 J)

- The S1 material has a lower production cost as will be discussed in later bulletins

- The P1 material has lower performance than existing material and is discarded from future study..

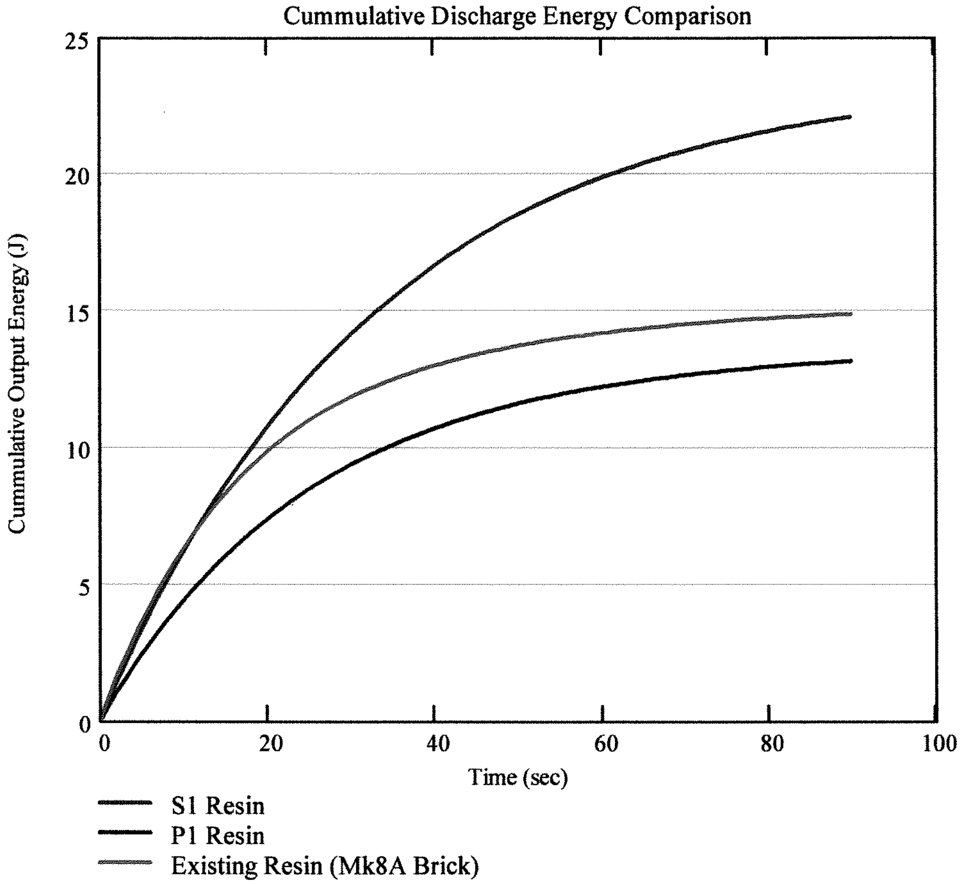
- The Ratio of output to input energy is an indication of resistive losses within the material, the S1 material has a slightly lower ratio and hence higher losses than the Mk 8A brick material. Work should be performed on improving conductivity

$$\text{EnergyRatio}_{\text{S1\_032901}} := \frac{\text{AvEnergyOut}_{\text{S1\_032901}}}{\text{AvEnergyIn}_{\text{S1\_032901}}} \qquad \text{EnergyRatio}_{\text{Mk8ASn6}} := \frac{\text{AvEnergyOut}_{\text{Mk8ASn6}}}{\text{AvEnergyIn}_{\text{Mk8ASn6}}}$$

$$\text{EnergyRatio}_{\text{S1\_032901}} = -24.955\,\% \qquad \text{EnergyRatio}_{\text{Mk8ASn6}} = -26.599\,\%$$

Energy Comparison Graph

The graph below compares the third run of the P1, S1 and Mk8A Sn6 samples in terms of accumulated energy



APPENDIX C

LETTER OF ACREDITATION FROM CDT SYSTEMS, INC

™

CDT SYSTEMS, INC. www.cdtwater.com
13636 Neutron Road, Dallas, Tex~ 75244 * Tel (972) 934-1586 * Fax (972) 934-1592

Prof C.F. Schutte
University of Pretoria
Department of Chemical Engineering Pretoria, 0002
Republic of South Africa

1 September, 2004

Re: Letter of Accreditation to research conducted by T. J. Welgemoed in Capacitive Deionization Technology ™ for partial fulfillment of the requirements for a Master of Engineering Degree.

CDT Systems, Inc. hereby confirms that Mr. Thomas J. Welgemoed was involved in all research mentioned in the attached dissertation, ether directly, or indirectly, in a supervisory/consulting role during the period 1998 to 2004. His practical experience, expertise, dedication and research is, and continue to be, crucial to the development program to commercialize CDT™ from a laboratory scale program to its current industrial scale prototype system.

CDT Systems, Inc hereby also acknowledges that all information published in this dissertation have been reviewed and has been approved for publication as public information by the University of Pretoria.

Yours Sincerely,

Dallas Talley

Dallas Talley, CEO
CDT Systems, Inc