ELECTROLYTES FOR COAL ELECTROLYSIS

By

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OK R. E. White

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SUMMARY

Electrolysis of coal in an aqueous solution to form carbon dioxide at the anode and hydrogen at the cathode has a thermodynamic cell potential of 0.21 volts. It is believed that a coal electrolysis cell can be developed which would lower the cost of hydrogen production over that of a water electrolysis cell. The coal electrolysis is believed to be dependent on the water activity, and thus, the electrolyte used may affect the overpotentials required to drive the reaction.

In this study four electrolytes were investigated, 8.07 N H_2SO_4, 4.23 N HCl, 4.90 N NaOH, and 4.01 N NaCl. The half cell potential versus the current density profile was determined for each electrolyte with about five weight percent carbon black, and without carbon black. Carbon black was used to eliminate the varying amounts of impurities in coal samples.

It was found that significant reduction of cell potential due to the presence of carbon black occurred at low current densities on the order of $10^{-4}\frac{amp.}{cm^2}$. The 8.07 N H_2SO_4 electrolyte provided the lowest cell potential of 0.3 volts at $10^{-4}\frac{amp}{cm^2}$ for the carbon black electrolysis.

INTRODUCTION

In the electrochemical gasification of carbon black, solid particles of the carbon were oxidized within an aqueous electrolyte at the anode of an electrochemical cell. The half cell reaction at the anode was assumed to be:

$$C_{(s)} + 2H_2O_{(l)} \rightarrow CO_{2(g)} + 4H^+ + 4e^-$$

The hydrogen ion was then reduced at the cathode by the half cell reaction:

$$4H^+ + 4e^- \rightarrow 2H_{2(g)}$$

The total cell reaction was the sum of the two half cell reactions:

$$C_{(g)} + 2H_2O_{(l)} \rightarrow CO_{2(g)} + 2H_{2(g)}$$

R. W. Coughlin and M. Faroeque[1] have done most of the previous research of this electrochemical process. Coughlin and Faroeque determined the thermodynamic reversible potential to be 0.21 volts.[1]

The results of experimentation with the electrochemical gasification of carbon black is assumed to be applicable to the electrochemical gasification of coal. Coal contains impurities such as hydrogen, tar, ash, and sulphur. Carbon black was used to assure that the electrolysis in each run was being performed on a sample of carbon with the same properties.

Coughlin and Faroeque have investigated some electrolytes; namely, sulphuric acid, phosphoric acid, and trifluoromethane sulphonic acid. Coughlin and Faroeque reported that sulphuric acid gave the best results with trifluoromethane giving comparable results and phosphoric acid giving much poorer results.

In this investigation the electrolytes sodium hydroxide, sodium chloride, hydrochloric acid, and sulphuric acid were investigated.

APPARATUS

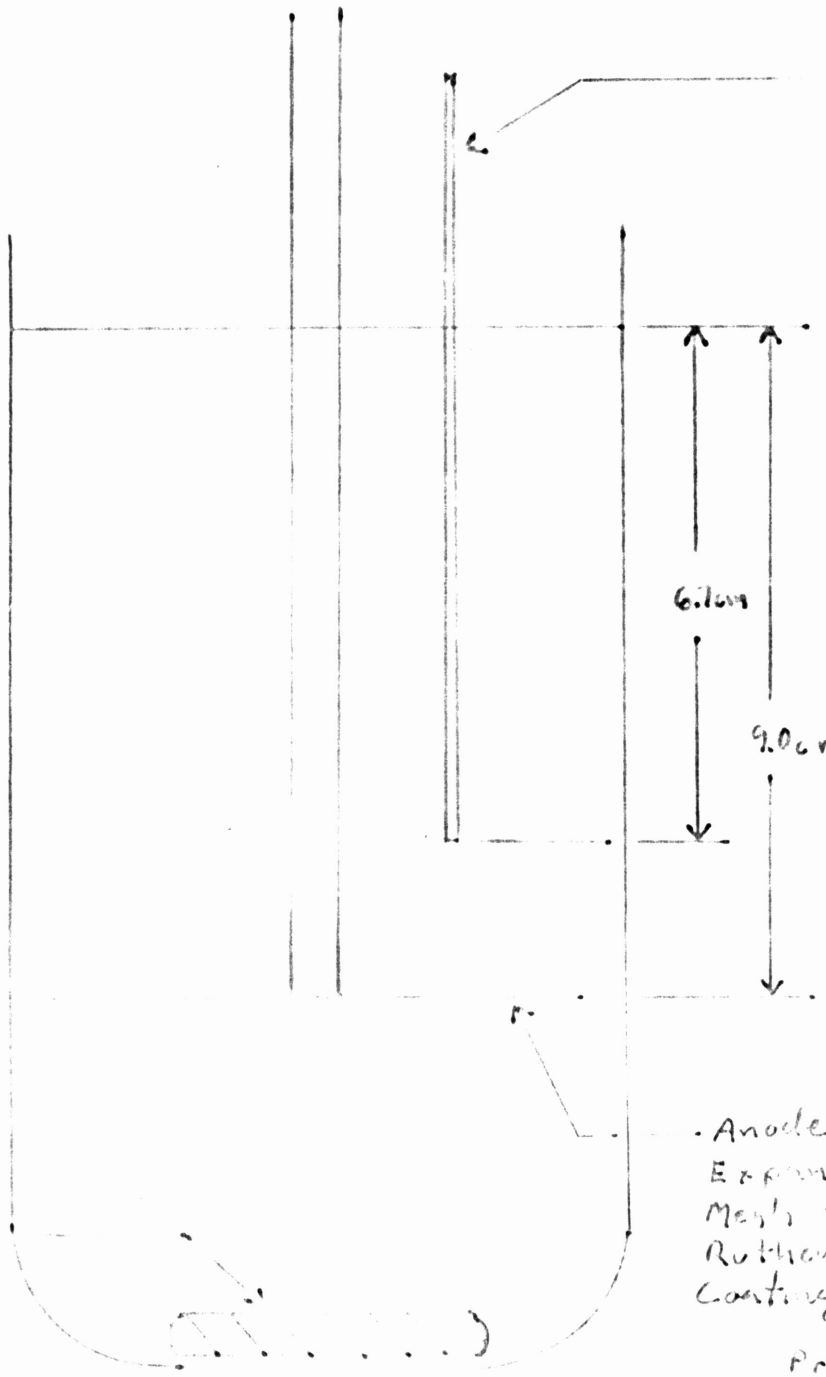
The reaction cell, Figure 1 and Figure 2, was composed of a 93.6cm^2 expanded mesh ruthinium oxide catalysed titanium anode complemented by a 15.8cm^2 titanium strip cathode in a 900 ml. capacity beaker. The ruthinium oxide is an electrochemical catalyst used in the oxidation of chloride ions for clorine production. The cell was operated galvanically with a current supply. The anode and cathode potentials were measured relative to a silver chloride reference electrode. Measurements of the electrode potentials were made through an electrolyte bridge in a pipet which could be placed next to either electrode. Having the reference electrode outside the cell prevented carbon black from clogging the reference. Stirring was accomplished with a magnetic stirrer.

The cell was galvanically operated at ambient temperature and pressure. The anode and cathode were both in direct contact with the carbon black slurry.

For each electrolyte a current-electrode potential profile was taken for solutions with and without carbon. The current was varied between 10^{-3} amps to 3.0 amps. At each selected current the electrode potential was allowed to reach a steady state, usually about a minute, before the potentials and current were recorded.

The carbon was used as obtained from the manufacturer without any pretreatment.

Reaction Kettle
15cm deep
8.5cm Inside Diameter
13cm Solution depth



- cathode
Strip of Titanium
1.0cm wide
0.2cm Thick
produces
Hydrogen
and Methane

- Anode Dia = 7.0cm
Expanded Titanium
Mesh with catalytic
Ruthenium Oxide
Coating
Produces
Oxygen, Carbon Oxides,
and Chlorine

Magnetic
Stirring
Bar

RESULTS

At very low current densities (less than $10^{-4}\frac{Amp}{cm^2}$) 8.07 N H_2SO_4 had a substantially lower cell potential for the carbon black electrolysis than HCl, NaOH, or NaCl electrolytes. At $10^{-4}\frac{amp}{cm^2}$ the overall cell potential in 8.07 N H_2SO_4 was 0.3 volts and the anode potential was 0.01 volts. For electrolysis in 4.23 N HCl, a current density of $10^{-4}\frac{amp}{cm^2}$ produced an anode potential of 0.01 volts and a cathode potential of -0.5 volts. The carbon black electrolysis in 4.90 N NaOH required a cell potential of 0.6 volts at $10^{-4}\frac{amp}{cm^2}$ with anode potential of 0.4 volts and cathode potential of -0.2 volts. The 4.01 N NaCl electrolyte required a cell potential of 0.96 volts with an anode potential of 0.26 volts and cathode potential of -0.70 volts for the electrolysis at $10^{-4}\frac{amp}{cm^2}$.

For both HCl and H_2SO_4 electrolytes at current densities below $5 \times 10^{-4}\frac{amp}{cm^2}$ the cell potential was virtually produced only at the cathode.

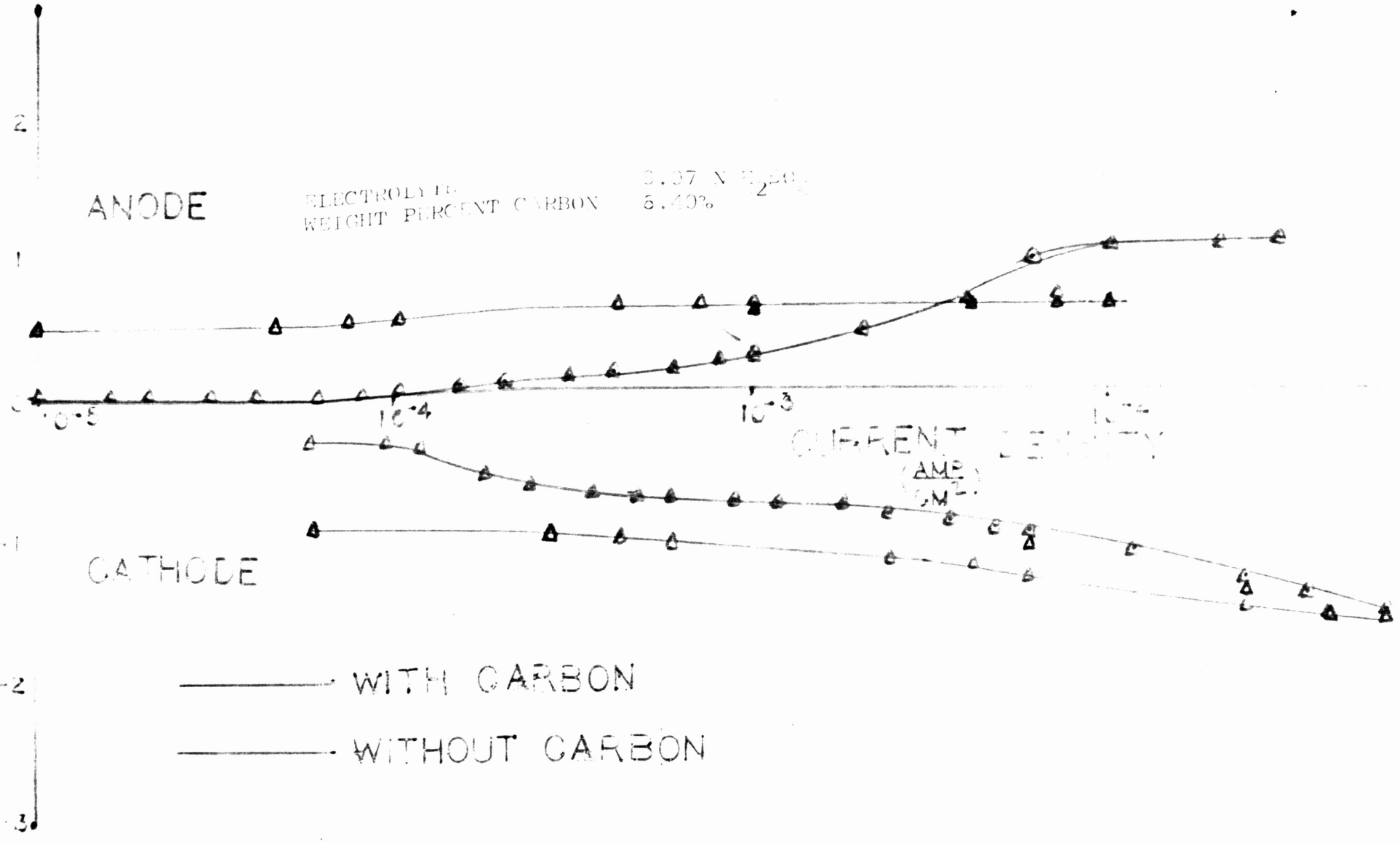
For all the electrolytes the anode potential increased rapidly with current density until reaching a nearly stable anode potential at some point in the potential current density profile. At current densities above the point where the increase in anode potential occurred, the new potential was equal to or greater than the electrolysis of water without carbon black in the base electrolyte. The cathode potential also experienced a jump in

potential, but at a different current density than the anode potential jump.

CONCLUSION

The choice of electrolyte has a dramatic effect on the half cell potentials as shown by Figures three through seven. The 8.07 N H_2SO_4 gives the best overall cell potential. The 4.23 N HCl gives comparable results to the H_2SO_4 electrolyte.

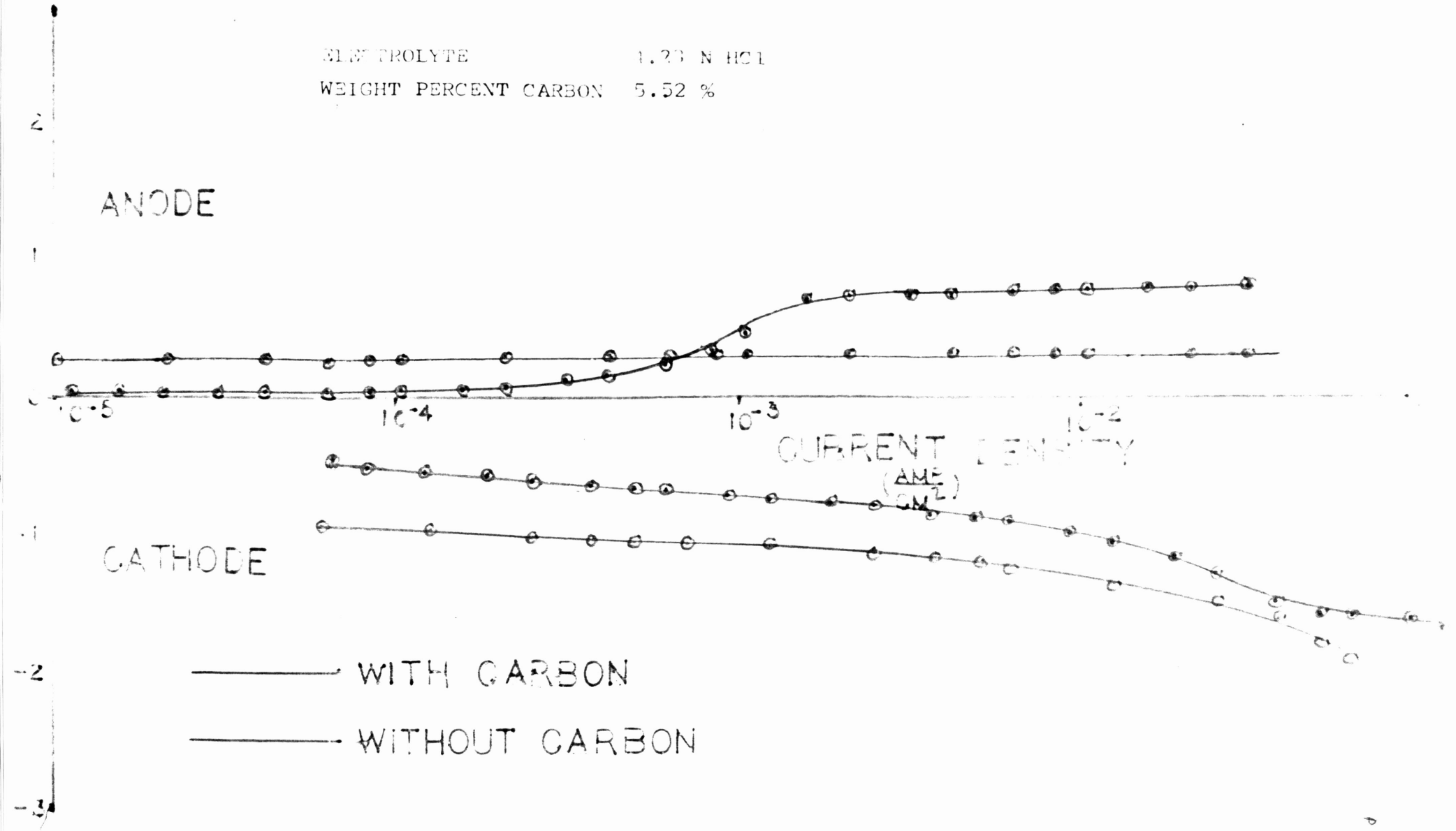
The sudden rise in half cell potentials in the current density-voltage profile (Figures three though six) may be due to a change in the reaction occurring in the cell. Once the rise in half cell potentials occurred, it was no longer of benefit to use carbon black in the electrolysis. Higher current densities might be obtained while still receiving a benefit from the carbon if the cell is operated at higher temperatures[2].

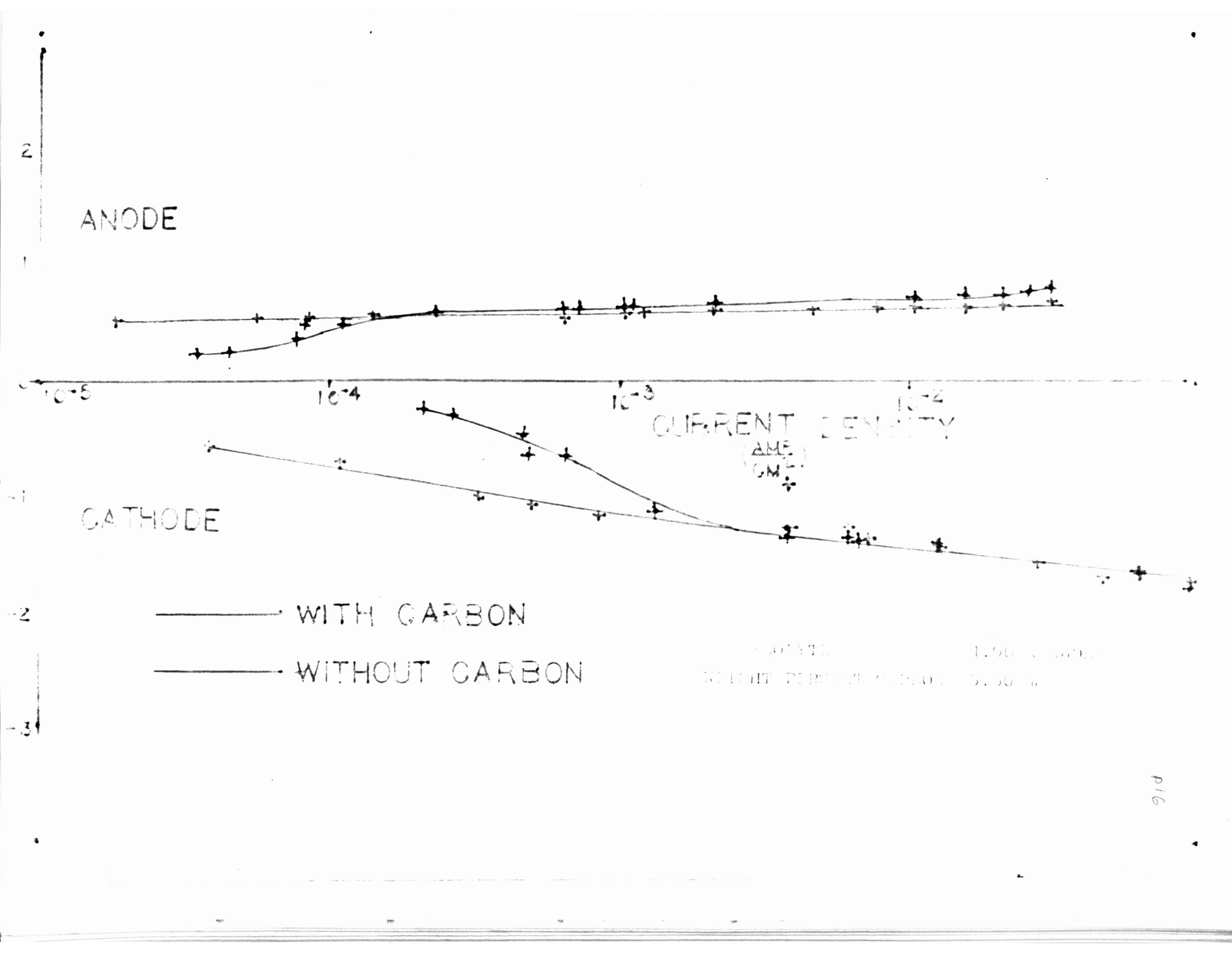

ANODE
ELECTROLYTE 0.37 N H_2SO_4
WEIGHT PERCENT CARBON 6.40%
2
1
0
-1
-2
-3
10^{-5}
10^{-4}
10^{-3}
CURRENT DENSITY
(AMP/CM²)
CATHODE
WITH CARBON
WITHOUT CARBON

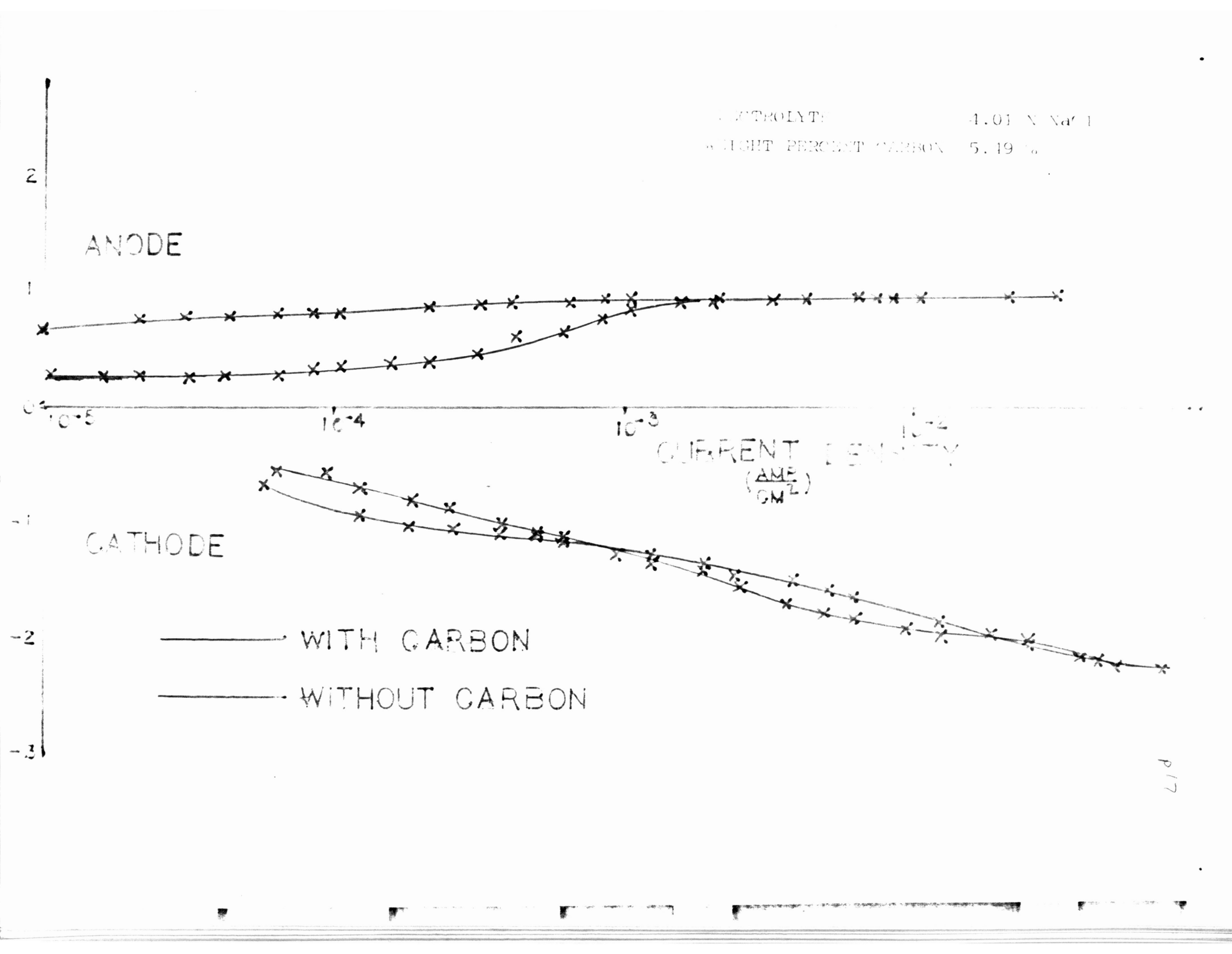
P14

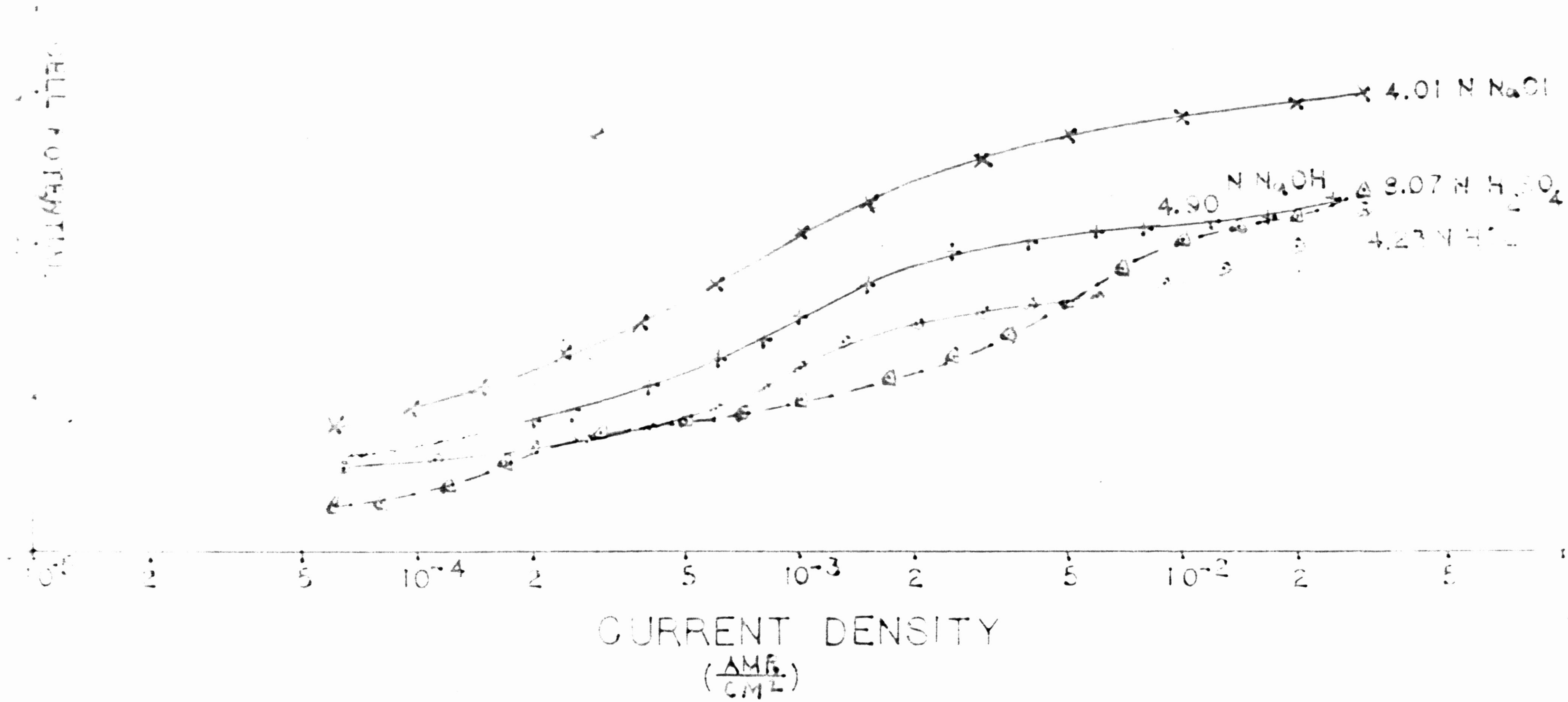
ELECTROLYTE 1.23 N HCl

WEIGHT PERCENT CARBON 5.52 %




2
ANODE
1
10-5
10-4
10-3
10-2
CURRENT DENSITY
(AMP/CM2)
-1
CATHODE
-2
WITH CARBON
WITHOUT CARBON
-3


ELECTROLYTE 4.01 N NaCl
WEIGHT PERCENT CARBON 5.19 %
2
1
0
-1
-2
-3
ANODE
CATHODE
10-5
10-4
10-3
10-2
CURRENT DENSITY
(AMP/CM2)
WITH CARBON
WITHOUT CARBON


4.01 N NaCl
4.90 N NH4OH
3.07 N H
4.23 N H
10^-5
2
5
10^-4
2
5
10^-3
2
5
10^-2
2
5
CURRENT DENSITY
(AMP/CM2)
ELL POTENTI

p18

APPENDIX

p=0

DATA AND CALCULATED VALUES

TABLE I

ELECTROLYTE - 8.07 N H_2SO_4

WEIGHT PERCENT CARBON - 0%

	ANODE			CATHODE		
Current (Amp)	Current Density ($\frac{Amp}{cm^2}$)	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density ($\frac{Amp}{cm^2}$)	Voltage Half to Ref Cell (volts)	Poten. (volts
0	0	0.808	0	0	0.484	0
0.000982	.0000105	1.280	.472	.0000622	-0.250	- .734
0.00459	.0000490	1.308	.500	.000291	-0.311	- .795
0.00725	.0000746	1.319	.511	.000459	-0.394	- .818
0.0101	.000108	1.327	.519	.000639	-0.440	- .828
0.0414	.000442	1.377	.569	.00262	-0.452	- .936
0.0702	.000750	1.388	.580	.00444	-0.500	- .984
0.100	.00107	1.403	.595	.00633	-0.598	-1.082
0.400	.00427	1.444	.636	.0253	-0.790	-1.274
0.699	.00747	1.487	.679	.0442	-0.794	-1.278
0.100	.00107	1.356	.548	.00633	-0.559	-1.043
0.400	.00427	1.403	.595	.0253	-0.87	-1.354
0.700	.00748	1.423	.615	.0443	-1.03	-1.514
1.00	.0107	1.446	.638	.0633	-1.04	-1.524

TABLE II

ELECTROLYTE - 8.07 N H_2SO_4

WEIGHT PERCENT CARBON - 6.40%

	ANODE			CATHODE		
Current (Amp)	Current Density $(\frac{Amp}{cm^2})$	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density $(\frac{Amp}{cm^2})$	Voltage to Ref. (Volts)	Half Cell Potential (Volts)
0	0	0.459	0	0	-0.458	0
0.000976	.0000104	0.467	0.008	.0000618	0.161	-0.297
0.00158	.0000169	0.469	0.010	.000100	0.034	-0.424
0.00200	.0000214	0.470	0.011	.000127	-0.027	-0.485
0.00300	.0000321	0.472	0.013	.000190	-0.137	-0.595
0.00400	.0000427	0.474	0.015	.000253	-0.200	-0.658
0.00600	.0000641	0.480	0.021	.000380	-0.255	-0.713
0.00800	.0000855	0.485	0.026	.000506	-0.269	-0.727
0.0100	.000107	0.489	0.030	.000633	-0.282	-0.740
0.0150	.000160	0.500	0.041	.000949	-0.308	-0.766
0.0200	.000214	0.522	0.063	.00127	-0.324	-0.782
0.0300	.000343	0.552	0.093	.00190	-0.355	-0.797
0.0400	.000427	0.574	0.115	.00253	-0.378	-0.820
0.0600	.000641	0.615	0.156	.00380	-0.428	-0.870
0.0800	.000855	0.668	0.209	.00506	-0.466	-0.924
0.100	.00107	0.717	0.258	.00633	-0.499	-0.957
0.200	.00214	0.883	0.424	.0127	-0.630	-1.088
0.400	.00427	1.185	0.726	.0253	-0.796	-1.254
0.600	.00641	1.427	0.968	.0380	-0.901	-1.359
1.00	.01017	1.481	1.022	.0633	-1.031	-1.489
2.00	.0214	1.519	1.060	.127	-1.099	-1.557
2.97	.0317	1.549	1.090	.188	-1.190	-1.648

TABLE III

ELECTROLYTE - 4.23 N HCl

WEIGHT PERCENT CARBON - 0%

	ANODE			CATHODE		
Current (Amp)	Current Density $\left(\frac{Amp}{cm^2}\right)$	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density $\left(\frac{amp}{cm^2}\right)$	Voltage to Ref. (volts)	Half Cell Potential (volts)
0	0	0.789	0	0	0.689	0
0.00100	0.0000107	1.019	0.230	0.0000633	-0.273	-0.962
0.00205	0.0000219	1.039	0.250	0.000130	-0.304	-0.993
0.00402	0.0000429	1.053	0.264	0.000254	-0.331	-1.020
0.00609	0.0000651	1.061	0.272	0.000385	-0.348	-1.037
0.00813	.0000869	1.066	0.277	0.000515	-0.360	-1.049
0.0101	.000108	1.020	0.251	0.000639	-0.369	-1.056
0.0201	.000215	1.081	0.292	0.00127	-0.394	-1.083
0.0402	0.000429	1.092	0.303	0.00254	-0.444	-1.133
0.0602	0.000643	1.098	0.309	0.00381	-0.477	-1.166
0.809	0.000864	1.103	0.314	0.00512	-0.507	-1.196
0.100	0.00107	1.107	0.318	0.00633	-0.528	-1.217
0.201	0.00215	1.117	0.328	0.0127	-0.635	-1.324
0.402	0.00429	1.128	0.339	0.0254	-0.79	-1.48
0.603	0.00644	1.135	0.346	0.0382	-0.90	-1.59
0.804	0.00859	1.137	0.348	0.0509	-1.09	-1.78
1.00	0.0107	1.141	0.352	0.0633	-1.20	-1.89
2.00	0.0214	1.153	0.364	0.127	-1.49	-2.18
2.97	0.0317	1.160	0.371	0.188	-1.65	-2.34

TABLE IV

ELECTROLYTE - 4.23 N HCl

WEIGHT PERCENT CARBON - 5.52%

ANODE				CATHODE		
Current (amp)	Current Density $\frac{(Amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density $\frac{(amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)
0	0	0.331	0	0	0.325	0
0.00106	0.0000113	0.337	.006	0.0000671	-0.145	-0.473
0.00150	0.0000160	0.340	0.009	0.0000949	-0.189	-0.514
0.00200	0.0000214	0.342	0.011	0.000127	-0.270	-0.545
0.00300	0.0000321	0.346	0.015	0.000190	-0.259	-0.584
0.00400	0.0000427	0.351	0.020	0.000253	-0.285	-0.610
0.00601	0.0000642	0.359	0.028	0.000380	-0.319	-0.644
0.00803	0.0000858	0.368	0.037	0.000508	-0.339	-0.664
0.0100	0.000106	0.376	0.045	0.000633	-0.351	-0.676
0.0150	0.000160	0.394	0.063	0.000949	-0.379	-0.704
0.0201	0.000215	0.415	0.084	0.00127	-0.400	-0.725
0.0298	0.000318	0.452	0.121	0.00189	-0.430	-0.755
0.0398	0.000425	0.493	0.162	0.00252	-0.457	-0.782
0.0588	0.000628	0.576	0.239	0.00372	-0.498	-0.823
0.0796	0.000850	0.679	0.348	0.00504	-0.550	-0.875
0.100	0.00106	0.818	0.487	0.00633	-0.565	-0.890
0.151	0.00161	1.048	0.717	0.00956	-0.65	-0.98
0.201	0.00215	1.078	0.747	0.0127	-0.69	-1.02
0.302	0.00323	1.105	0.774	0.0191	-0.82	-1.15
0.401	0.00428	1.118	0.787	0.0254	-0.95	-1.28
0.603	0.00644	0.131	0.800	0.0382	-1.14	-1.42
0.801	0.00856	1.140	0.809	0.0507	-120	-153
1.00	0.0106	1.145	0.814	0.0633	-1.21	-1.54
1.50	0.0160	1.156	0.825	0.0949	-1.26	-1.59
2.00	0.0214	1.157	0.826	0.127	-1.30	-1.63
2.97	0.0317	1.165	0.834	0.188	-1.37	-1.70

TABLE V

ELECTROLYTE - 4.90 N NaOH

WEIGHT PERCENT CARBON - 0%

ANODE				CATHODE		
Current (amp)	Current Density $\frac{(amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density $\frac{(amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)
0	0	-0.103	0	0	-0.112	0
0.0999	.00107	0.491	0.594	.00632	-1.372	-1.260
0.0615	.000657	0.428	0.531	.00389	-1.003	-0.891
0.00012	1.28×10^{-6}	0.309	0.412	2.59×10^{-6}	-0.45	-0.338
0.00061	6.52×10^{-6}	0.388	0.491	0.0000386	-0.686	-0.574
0.00175	0.0000187	0.407	0.510	0.000111	-0.818	-0.706
0.0053	0.0000566	0.424	0.527	0.000335	-1.115	-1.003
0.0081	0.0000865	0.434	0.537	0.000513	-1.179	-1.067
0.0137	0.000146	0.445	0.548	0.000867	-1.228	-1.116
0.0605	0.000646	0.475	0.578	0.00383	-1.367	-1.255
0.1148	0.00123	0.492	0.595	0.00727	-1.452	-1.340
0.203	0.00217	0.505	0.608	0.0128	-1.528	-1.416
0.445	0.00475	0.525	0.628	0.0282	-1.647	-1.535
0.746	0.00797	0.540	0.643	0.0472	-1.689	-1.577
1.002	0.0107	0.546	0.649	0.0634	-1.752	-1.640
1.517	0.0162	0.558	0.651	0.0960	-1.828	-1.716
1.998	0.0213	0.566	0.669	0.126	-1.845	-1.733
2.97	0.0317	0.582	0.685	0.188	-1.918	-1.806

TABLE VI

ELECTROLYTE - 4.90 N NaOH

WEIGHT PERCENT CARBON - 5.50%

ANODE				CATHODE		
Current (amp)	Current Density (Amp)/(cm^2)	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density (Amp)/(cm^2)	Voltage to Reference (volts)	Half Cell Potential (volts)
0	0	-0.154	0	0	-0.131	0
0.0997	0.00107	0.528	0.682	0.00631	-1.446	-1.315
0.204	0.00218	0.554	0.708	0.0129	-1.522	-1.391
0.0606	0.000647	0.503	0.657	0.00384	-1.378	-1.247
0.100	0.0107	0.594	0.748	0.0633		
1.50	0.0160	0.619	0.773	0.0949		
2.00	0.0214	0.631	0.785	0.127	-1.986	-1.855
2.50	0.0267	0.669	0.823	0.158	-2.08	-1.949
2.97	0.0317	0.680	0.834	0.188	-2.40	-2.269
0.00337	0.0000360	0.082	0.236	0.000213	-0.384	-0.253
0.00436	0.0000466	0.125	0.279	0.000276	-0.431	-0.300
0.00747	0.0000798	0.238	0.392	0.000423	-0.604	-0.473
0.0106	0.000113	0.355	0.509	0.000671	-0.755	-0.624
0.0218	0.000233	0.469	0.623	0.00138	-1.233	-1.199
0.00783	0.0000837	0.358	0.512	0.000496	-0.744	-0.613
0.061	0.000652	0.510	0.664	0.00386	-1.439	-1.308
0.1071	0.00114	0.541	0.695	0.00678	-1.476	-1.345

TABLE VII

ELECTROLYTE - 4.01 N NaCl

WEIGHT PERCENT CARBON - 0%

ANODE				CATHODE		
Current (amp)	Current Density (Amp)/(cm²)	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density (amp)/(cm²)	Voltage to Reference (volts)	Half Cell Potential (volts)
0	0	0.178	0	0	0.121	0
0.000929	9.93×10^{-6}	0.840	0.662	5.88×10^{-5}	0.583	-0.704
0.00200	0.0000214	0.923	0.745	0.000127	-0.838	-0.959
0.00290	0.0000310	0.937	0.759	0.000184	-0.924	-1.045
0.00413	0.0000441	0.948	0.770	0.000261	-0.953	-1.074
0.00603	0.0000644	0.959	0.781	0.000382	-1.006	-1.127
0.00805	0.0000860	0.968	0.790	0.000509	-1.04	-1.16
0.0100	0.000107	0.976	0.798	0.000633	-1.07	- 1.19
0.0200	0.000214	1.016	0.838	0.00127	-1.17	-1.29
0.0305	0.000326	1.050	0.872	0.00193	-1.24	-1.36
0.0390	0.000417	1.061	0.883	0.00247	-1.32	-1.44
0.0619	0.000661	1.075	0.897	0.00392	-1.40	-1.52
0.0819	0.000875	1.080	0.902	0.00518	-1.46	-1.58
0.100	0.00107	1.083	0.905	0.00633	-1.51	-1.63
0.201	0.00215	1.094	0.916	0.0127	-1.72	-1.84
0.402	0.00429	1.104	0.926	0.0254	-1.92	-2.04
0.703	0.00751	1.112	0.934	0.0449	-2.07	-2.19
1.00	0.0107	1.119	0.941	0.0633	-2.13	-2.25
2.00	0.0214	1.126	0.948	0.127	-2.20	-2.32
2.97	0.0317	1.134	0.956	0.188	-2.32	-2.44

TABLE VIII

ELECTROLYTE - 4.01 N NaCl

WEIGHT PERCENT CARBON - 5.49%

	ANODE			CATHODE		
Current (amp)	Current Density $\frac{(amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)	Current Density $\frac{(amp)}{(cm^2)}$	Voltage to Reference (volts)	Half Cell Potential (volts)
0	0	0.190	0	0	0.187	0
0.00102	0.0000108	0.434	0.244	0.0000639	-0.32	0.507
0.00151	0.0000161	0.437	0.247	0.0000956	-0.41	0.597
0.00201	0.0000215	0.441	0.251	0.000127	-0.518	0.705
0.00300	0.0000321	0.445	0.255	0.000190	-0.624	0.811
0.00402	0.0000428	0.455	0.265	0.000254	-0.704	0.891
0.00603	0.0000644	0.467	0.277	0.000382	-0.833	1.020
0.00805	0.0000859	0.490	0.300	0.000509	-0.912	1.099
0.0100	0.000107	0.509	0.319	0.000633	-0.968	1.155
0.0150	0.000160	0.541	0.351	0.000949	-1.088	1.275
0.0202	0.000216	0.569	0.379	0.00128	-1.155	1.342
0.0295	0.000315	0.636	0.446	0.00185	-1.23	1.420
0.0402	0.000428	0.699	0.509	0.00254	-1.37	1.560
0.0586	0.000626	0.802	0.612	0.00371	-1.53	1.720
0.0791	0.000845	0.927	0.737	0.00501	-1.60	1.790
0.100	0.00160	1.008	0.818	0.00633	-1.64	1.82
0.151	0.00161	1.079	0.889	0.00956	-1.73	1.92
0.202	0.00216	1.089	0.899	0.0128.	-1.79	1.980
0.300	0.00321	1.100	0.910	0.0190	-1.74	1.93
0.403	0.00431	1.104	0.914	0.0255	-1.83	2.02
0.605	0.00646	1.114	0.924	0.0383	-1.96	2.15
0.804	0.00859	1.118	0.928	0.0509	-2.04	2.23
1.00	0.0107	1.121	0.931	0.0633	-2.22	2.41
2.00	0.0214	1.134	0.944	0.127	-2.51	2.70
2.97	0.317	1.141	0.951	0.188	-2.97	3.16

SAMPLE CALCULATIONS

(1) CURRENT DENSITIES

The current density was calculated by dividing the cell current by the electrode surface area.

EXAMPLE: Current, I = 0.00106 amp.

Anode surface area = 93.6 cm^2

Cathode surface area = 15.8 cm^2

J ≡ Current Density

$$J_{Anode} = \frac{I}{A_{Anode}} = \frac{0.00106 \text{ amp}}{93.6 \text{ cm}^2} = 1.13 \times 10^{-4}$$

$$J_{Cath} = \frac{I}{A_{Cath}} = \frac{0.00106}{15.8 \text{ cm}^2} = 6.71 \times 10^{-4}$$

(2) HALF CELL POTENTIALS

The half cell potentials were determined as the difference of the electrode potential with current and without current.

EXAMPLE: I = 0.00106 amp.

	Anode Voltage	Cathode Voltage
I = 0 Amp	+ 0.331	+0.325
I =).00106 Amp	+0.337	-0.148

V_{anode} = 0.337 - 0.331 = 0.006 volts

$V_{cathode}$ = -0.148 - 0.325 = -0.473 volts

(3) OVERALL CELL POTENTIALS

The overall cell potentials were determined from the graphs of the half cell potentials versus the current density (Fig. 3 through 6).

NOMENCLATURE

A_{anode}	($93.6\ cm^2$)	Superficial surface Area of Anode
$A_{cathode}$	($15.8\ cm^2$)	Surface area of cathode
I	(amp)	Current through cell
J_{anode}	$(\frac{amp}{cm^2})$	Current density on anode
$J_{cathode}$	$(\frac{amp}{cm^2})$	Current density on cathode
V_{anode}	(volts)	Half cell potential of anode
$V_{cathode}$	(volts)	Half cell potential of cathode

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