EXPERIMENTAL DETAILS FOR LIGHT WATER COLD FUSION RESEARCH AT CAL. POLY.- POMONA

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ABSTRACT

This paper presents a detailed description of the construction and operation of the two types of electrolytic cells employed in the experimental light water cold fusion research of R. Bush and R. Eagleton at California State Polytechnic University - Pomona.

INTRODUCTION

Electrolytic cells of the Fleischmann and Pons[1] type using light water with nickel cathodes and alkali carbonates were first employed at Cal. Poly - Pomona in August of 1991 following the announcement of excess heat production in light water by Mills and Kneizys[2]. Cell design and protocol was partially driven by considerations based upon the theoretical work of R. Bush[3]. Since that time a total of 27 light water cells have been run with alkali carbonate and alkali hydroxide electrolytes using two different cell and calorimeter configurations. These configurations and other details are described in this paper. The experimental results obtained with these cells are not discussed in this paper but are presented elsewhere[4,5,6,7,8].

CELL AND CALORIMETER DESIGN

The two types of cells used in our light water work are actually third and fourth generation cell designs which evolved from earlier work with heavy water. Consequently these cell types are designated as C and D respectively. They are illustrated in figures 1 and 2. Cells of type C were first used with heavy water in July of 1990 and continued to be used until January 1993. During that period 17 light water cells and 36 heavy water cells were run. Type D cells were phased in commencing February of 1993 and used for all cells constructed from that time until the present. To date ten light water cells have been operated using the type D configuration. Table I gives a summary of the light water cells that have been run to date.

The principal features which are common to both cell designs are as follows:

(1) They are all closed cells. This is achieved by use of a platinum black recombiner which is enclosed in the air space above the electrolyte. The recombiner is fabricated by bonding platinum black to a nickel screen mesh and coating one side of the mesh with a non-wetting agent (Teflon). The recombiner for all cells of type D and some of type C were enclosed within a nickel foil baffle that had extensions on either sides which served to return the recombination heat back into the electrolyte. This baffle also served to protect the recombiner from becoming contaminated with electrolyte residue. The recombiner for type C cells that was not placed in the baffle arrangement was instead affixed to the bottom side of the stopper and was unshielded. The cell is vented to the atmosphere via an oil bubbler which serves two purposes: (a) to maintain near ambient pressures, and (b) to isolate the cell from the external environment. A

balloon attached to the open end of the bubbler is used to monitor a cell for recombiner malfunctions. Of the light water cells run to date no recombiner malfunctions have been experienced. (2) Magnetic stirring is used to permit more uniform electrolyte temperatures. Tests have shown that these stirrers have no measurable effect on the electrolyte temperatures. (3) All surfaces except for electrodes and the nickel heat sinks are coated with Teflon. The neoprene stoppers are covered with form fitting Teflon tape and the cells were either pyrex coated with Teflon (type C) or made of Teflon bottles (type D). A special bonding agent is required to prevent the Teflon from becoming unbonded from the pyrex upon repeated thermal cycling. It is anticipated that the nickel heat sinks exposed to the electrolyte should pose no problems since they are shielded electrolytically by the nickel cathodes. (4) The electrodes are as follows: Platinum (AESAR 99.95%) wire anodes were 1 mm diameter and lengths of about 18 cm folded into five equal segments, nickel fibrex cathodes were formed into open ended cylinders having the platinum anode located along their central axis. Figures 3 and 4 are electron micrographs of a typical piece of 80/20 nickel fibrex mesh. Shown in these micrographs are nickel powder (20%) bonded to nickel fibers (80%) where the fibers are about 20 microns in diameter (Fig. 4). Also it should be noted that the nickel fibers are not fabricated from drawn nickel wires but are made from sintered nickel powder. These fibers are formed by extruding a slurry of nickel powder mixed in a plasticizer through a small orifice. After the plasticizer sets, the fibers are sintered in a hydrogen environment so that only porous nickel remains after the heat treatment. (5) Electrolytes were made of chemicals obtained from AESAR/Johnson Matthey and nanopure water (17 Mohm-cm) from a Barnstead filtering system. All electrolytes were 0.57 molar solutions. (6) A port for extracting electrolyte samples consists of a capped 1 mm diameter Teflon tube which passes through the neoprene stopper and into the electrolyte. (7) The electrolyte temperature is monitored by use of two 26 gauge type-K thermocouples. These are threaded into opposite ends of a 1 mm diameter Teflon tube that loops through the neoprene stopper to just below the cathode and above the magnetic stirrer. This tube is filled with mineral oil to permit more efficient thermal contact of thermocouples with the electrolyte. As shown in figures 1 and 2 these thermocouples are placed at different depths in the electrolyte. We find that these thermocouples read very nearly the same temperature provided the magnetic stirrer is operative. However, in the event of a stirrer malfunction the thermocouple readings may differ by as much as two or three degrees Celsius.

Features that differ for the two cells types are as follows:

Cell Type C - As illustrated in Figure 1, this is a double wall pyrex vessel which provides for a water jacket enclosing the electrolytic cell except for the top which is capped with a Teflon covered neoprene stopper. The inlet and outlet coolant temperatures were monitored with type K thermocouples. The pyrex cell was completely enclosed with a one inch thick layer of styrofoam.

Calibration for these cells was performed in one of two ways: (1) Either a nichrome reference heater was used or (2) the cell was calibrated by running anodically. When a nichrome reference heater was used it was placed in a close fitting Teflon tube that looped down into the electrolyte. The nichrome heating element was attached to electrical leads so as to have it completely immersed within the electrolyte. The cell calibration procedure is as follows: (1) The temperature of the coolant flowing through the water jacket was regulated so as to maintain the cell contents at a constant temperature. A typical value for the cell operation temperature was about 39°C. At this temperature the cells could be calibrated from 0 to 20 watts while using the laboratory as the heat sink for the cell bath. Table II gives typical calibration data for this type of cell. Note that the standard deviation in the calibration temperatures is less than 0.1°C. The cell calibration data points are obtained by plotting the steady state thermal power output (P_{out}) from the cell as a function of the average temperature decrease (∂T) across the cell walls. This temperature decrease is found by taking the difference between the average of the two cell thermocouples readings and the average of the inlet and outlet thermocouple readings. (For steady state calibration conditions the electrical power input to the cell is equal to the thermal power output.) This plot of P_{out} versus ∂T was fit by either a linear or a third order polynomial. Figure 5 shows a typical calibration curve that was obtained for cell 62. The excess power (P_{ex}) was determined by subtracting the electrical power delivered to the cell from the steady state thermal power coming out of the cell as calculated from the fit that yielded the smallest value for P_{ex}.

Cell Type D - Cells of this type are illustrated in Figure 2. They are constructed from Teflon bottles and are designed to be immersed directly within the coolant water bath. The bath water was temperature regulated as well as stirred. The calibration procedure for these cells are essentially the same as that for type C cells with the exception that the temperature decrease across the cell walls were obtained by subtracting the bath temperature from the average of the two cell thermocouple readings. Table III gives a typical set of calibration data for this type of cell.

Data Acquisition System

All temperatures, currents, and voltages were monitored and logged using a Macintosh IIx computer equipped with National Instrument's LabView software. For type C cells four type K thermocouples were used: one at the bath inlet port, one at the bath outlet port, and two within the electrolyte. In the case of type D cells there was one type K thermocouple within the bath and two within the electrolyte. The thermocouple sampling rate is 1000/minute with the temperature averaged each minute. The thermocouple voltages were converted to temperature readings (°C) by use of AD595AQ/9217 integrated circuit chips. This system permitted steady state temperature measurements with standard deviations of about 0.05°C. Corrections for thermocouple temperature offsets were made within the software. Cell currents and voltages were logged from Fluke 45 dual display multimeters equipped with IEEE interface. Figure 6 shows a front panel view of the virtual instrument used for cell monitoring and control of data logging. Since our cells are calibrated for only steady state operation at a specified temperature, we make use of this virtual strip chart recorder to determine when the requisite conditions are achieved before logging data. Table IV gives a typical spread sheet of data logged for a cell which produced excess heat. Not shown but recorded with this spread sheet were the following: room temperature, multiplexer reference junction temperature, time mark and date mark. The data acquisition rate for both Table IV and Figure 5 was for one minute intervals. In Table IV it should be noted that the fractional uncertainty in P_{ex} about 2% for the 23 minute time interval shown there. However, all values of P_{ex} which we report are corrected for any differences found after recalibration.

ACKNOWLEDGMENTS

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Cell #	Cathode	Electrolyte	Cell Type
38	Ni Fibrex	0.57M K_2CO_3 in 50cc H_2O	C
41	Ni Fibrex	0.57M K_2CO_3 in 50cc H_2O	C
44	Ni Fibrex	0.57M K_2CO_3 in 50cc H_2O	C
45	Ni Fibrex	0.57M K_2CO_3 in 50cc H_2O	C
47	Ni Fibrex	0.57M K_2CO_3 in 50cc H_2O	C
48	Ni Fibrex	0.57M Na_2CO_3 in 50cc H_2O	C
49	Ni Fibrex	0.57M Rb_2CO_3 in 50cc H_2O	C
50	Ni Fibrex	0.57M Rb_2CO_3 in 50cc H_2O	C
51	Ni Fibrex	0.57M Na_2CO_3 in 50cc H_2O	C
52	Ni Fibrex	0.57M Na_2CO_3 in 50cc H_2O	C
53	Ni Fibrex	0.57M Rb_2CO_3 in 50cc H_2O	C
54	Ni Fibrex	0.57M RbOH in 50cc H_2O	C
55	Ni Fibrex	0.57M Rb_2CO_3 in 50cc H_2O	C
56	Ni Fibrex	0.57M RbOH in 45cc H_2O+2cc D_2O	C
57	Ni Fibrex	0.57M Rb_2CO_3 in 50cc H_2O	C
61	Ni Fibrex	0.57M K_2CO_3 in 200cc H_2O	C
62	Ni Fibrex	0.57M LiOH in 50cc H_2O	C
63	Ni Fibrex	0.57M K_2CO_3 in 62cc H_2O	D
64	Ni Fibrex	0.57M K_2CO_3 in 62cc dedeuterated H_2O	D
65	99.9975 Ni wire	0.57M K_2CO_3 in 60cc H_2O	D
66	99.9975 Ni wire	0.57M K_2CO_3 in 60cc H_2O	D
67	Ni Fibrex	0.57M K_2CO_3 in 70cc H_2O	D
68	Ni Fibrex+10%Cu	0.57M K_2CO_3 in 70cc H_2O	D
69	Ni Fibrex	0.57M Rb_2CO_3 in 65cc H_2O	D
70	Ni Fibrex	0.57M Cs_2CO_3 in 65cc H_2O	D
71	Ni Fibrex+10%Cu	0.57M Rb_2CO_3 in 65cc H_2O	D
72	Ni Fibrex+10%Cu	0.57M Cs_2CO_3 in 65cc H_2O	D

Table I: Details of Cell Type, Cathodes, and Electrolytes for all Light Water Cells Run as of 2/94.

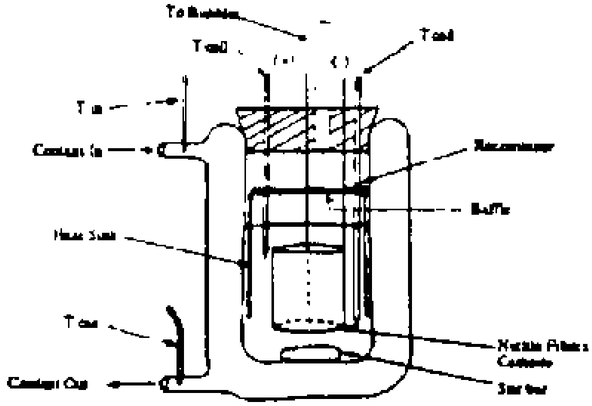


FIGURE 1. Third generation cell design: Cell type "C".

PRINCIPAL FEATURES

- CLOSED CELL OPERATION
- MECHANICALLY STIRRED ELECTROLYTE
- RECOMBINER BAFFLE & HEAT SINK
- TEFLON COATED PYREX CELL
- PLATINUM ANODE
- NICKEL FIBREX CATHODE
- NANOPURE H_2O BASE ELECTROLYTE
- CONSTANT COOLANT FLOW RATE
- CONSTANT CURRENT AND TEMPERATURE OPERATION

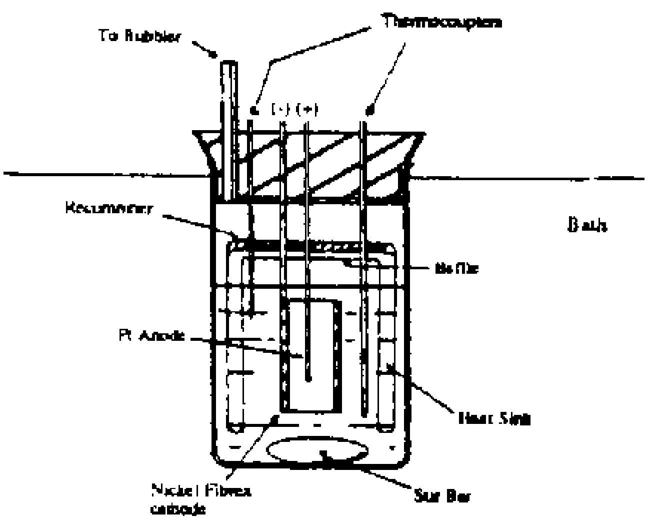


FIGURE 2. Fourth generation cell design: Cell type "D".

PRINCIPAL FEATURES

- CLOSED CELL OPERATION
- MECHANICALLY STIRRED ELECTROLYTE
- RECOMBINER BAFFLE & HEAT SINK
- TEFLON CELL
- PLATINUM ANODE
- NICKEL FIBREX CATHODE
- NANOPURE H_2O BASE ELECTROLYTE
- CELL IMMERSED IN BATH
- CONSTANT CURRENT AND TEMPERATURE OPERATION

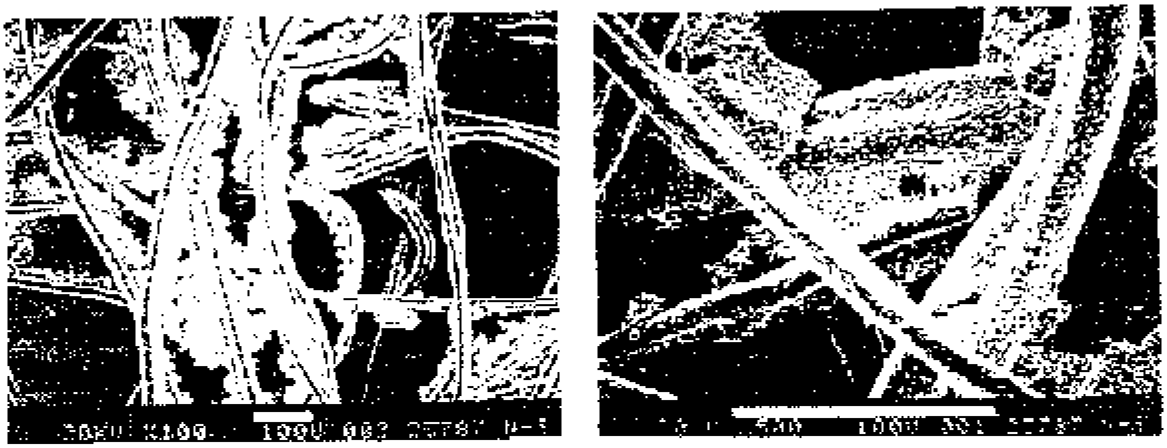


Figure 3. SEM photomicrographs of nickel fibrex cathode material having 80% nickel fiber and 20% nickel powder for magnification of 100x and 500x.

Figure 4. SEM photomicrograph of a single nickel fiber with a magnification of 3000x displaying its granular structure.

Tca	TLD	Tcavg	Tout	Tin	Tinavg	dT	Watts		[illegible]	Time Mark
39.023	39.0[illegible]	39.011	32.443	31.212	31.843	[illegible]	9.740	1.507	14.675	1:48:25 PM
39.023	39.045	39.034	32.409	31.209	31.829	7.225	9.721	1.506	14.643	1:48:24 PM
38.962	38.965	38.963	32.385	31.197	31.791	7.172	9.730	1.507	14.663	1:48:39 PM
39.130	38.967	39.049	32.472	31.144	31.783	7.265	9.725	1.507	14.655	1:48:54 PM
39.112	38.7[illegible]	38.9[illegible]	32.40[illegible]	31.265	31.834	7.155	[illegible]	1.507	[illegible]	1:49:09 PM
38.987	38.955	38.976	32.424	31.175	31.795	7.175	9.761	1.507	14.7[illegible]	1:49:24 PM
39.004	38.997	38.996	32.432	31.122	31.777	7.218	9.736	1.507	14.675	1:49:39 PM
38.985	38.940	38.972	32.442	31.179	31.810	7.189	9.751	1.507	[illegible]	1:49:54 PM
39.052	38.969	39.011	32.371	31.201	31.786	7.225	9.715	1.507	14.647	1:50:10 PM
39.117	38.949	39.042	32.417	31.172	31.794	7.248	9.675	1.506	14.571	1:51:40 PM
39.078	38.905	38.991	32.405	31.230	31.818	7.175	9.700	1.506	14.609	1:51:56 PM
39.121	38.939	39.030	32.424	31.185	31.834	7.225	9.715	1.508	14.631	1:52:11 PM
39.158	38.975	39.068	32.393	31.183	31.788	7.283	9.572	1.507	14.575	1:52:26 PM
39.122	38.926	39.024	32.439	31.180	31.812	7.212	9.746	1.508	14.683	1:52:41 PM
39.141	38.958	39.050	32.388	31.178	31.787	7.263	9.647	1.507	14.533	1:52:57 PM
39.097	38.993	39.045	32.433	31.188	31.839	7.234	9.574	1.508	14.585	1:53:12 PM
38.973	38.930	38.952	32.443	31.187	31.816	7.147	9.716	1.506	14.625	1:53:27 PM
39.123	39.029	39.076	32.429	31.150	31.789	7.287	9.599	1.508	14.407	1:53:42 PM
38.122	[illegible]	38.922	32.474	31.191	31.833	7.183	9.703	1.507	14.622	1:53:57 PM
39.121	39.01[illegible]	39.059	32.444	31.213	31.828	7.241	9.713	1.508	14.673	1:54:12 PM
39.087	39.064	39.075	32.430	31.208	31.817	7.256	9.722	1.508	14.641	1:54:27 PM
39.051	39.004	39.028	32.414	31.214	31.814	[illegible]	9.710	1.507	14.633	1:54:42 PM
39.027	38.941	38.979	32.417	31.183	31.800	7.199	9.715	1.507	14.635	Averages
0.064	0.065	0.049	0.024	0.026	0.018	0.047	0.032	0.000	0.049	Std Dev

Table II: Calibration data for P_{in} = 14.6 watts for cell 62 at T_{cell} = 39C.

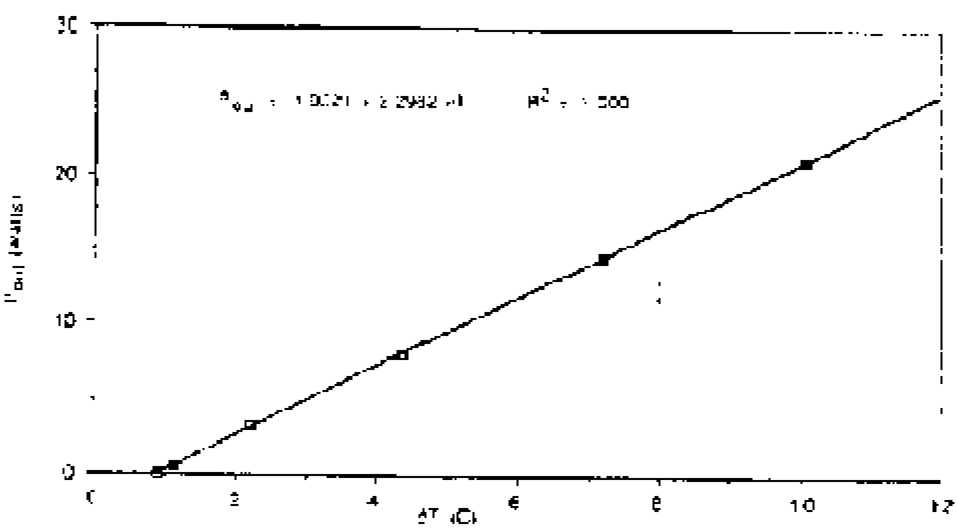


Figure 5. Calibration curve for cell 62 at a cell temperature of 39C

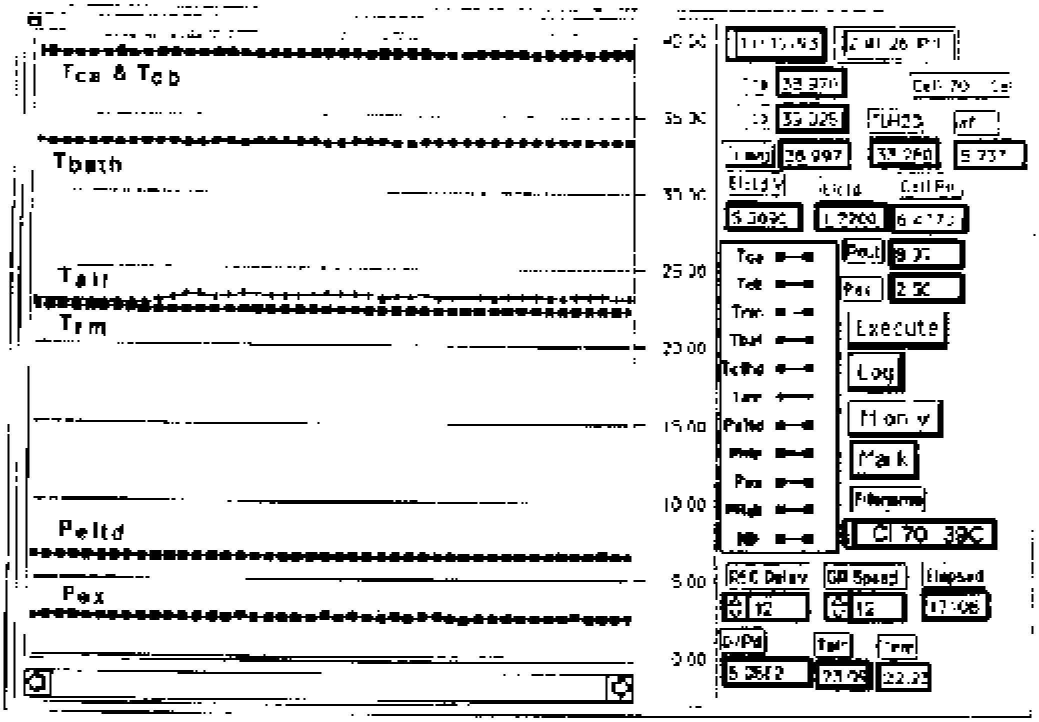


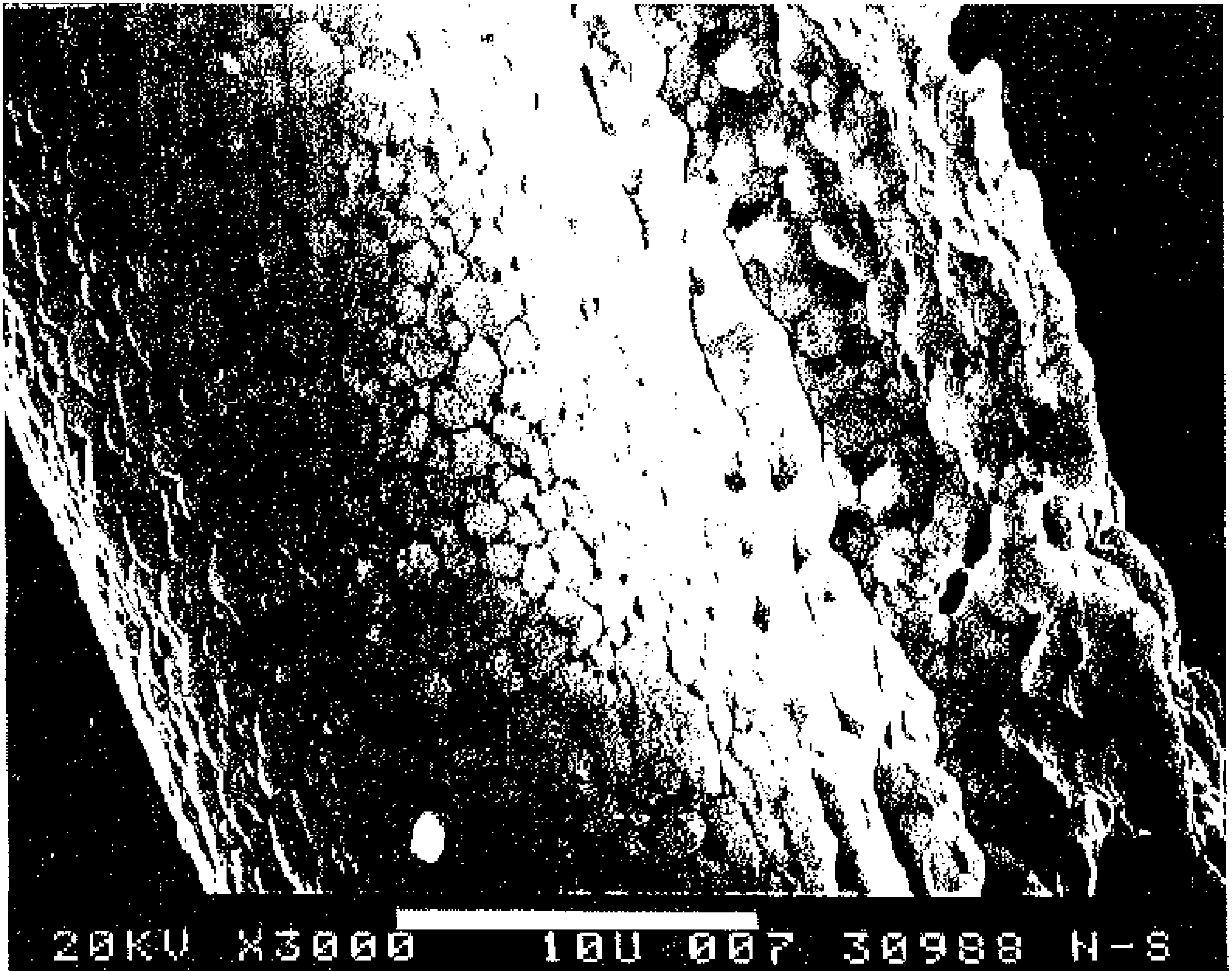
Figure 6. Front panel of virtual strip chart recorder for cell 70.

Tca	Tcb	Tavg	TH2O	ΔT	I(t)	V(t)	PinE(t)	
38.652	38.770	38.711	32.825	5.886	-2.100	-4.559	9.574	
38.689	38.761	38.725	32.852	5.873	-2.100	-4.585	9.628	
38.658	38.755	38.707	32.842	5.864	-2.100	-4.594	9.647	
38.648	38.761	38.705	32.850	5.874	-2.100	-4.556	9.568	
38.751	38.792	38.777	32.813	5.964	-2.100	-4.571	9.599	
38.761	38.792	38.777	32.813	5.964	-2.100	-4.571	9.599	
38.735	38.752	38.744	32.810	5.933	-2.100	-4.571	9.599	
38.658	38.749	38.709	32.805	5.903	-2.100	-4.580	9.618	
38.810	38.824	38.817	32.827	5.990	-2.100	-4.557	9.570	
38.729	38.772	38.751	32.853	5.896	-2.100	-4.564	9.584	
38.709	38.787	38.748	32.841	5.907	-2.100	-4.573	9.603	
38.750	38.806	38.793	32.830	5.963	-2.100	-4.564	9.584	
38.747	38.785	38.766	32.822	5.944	-2.100	-4.574	9.605	
38.747	38.785	38.766	32.822	5.944	-2.100	-4.571	9.599	
38.745	38.776	38.761	32.819	5.941	-2.100	-4.564	9.584	
38.841	38.826	38.834	32.803	6.030	-2.100	-4.560	9.576	
38.751	38.795	38.773	32.817	5.956	-2.100	-4.567	9.591	
38.731	38.782	38.756	32.825	5.931	-2.100	-4.569	9.596	Averages
0.055	0.023	0.036	0.015	0.046	0.000	0.010	0.021	Std Dev

Table III: Calibration data for P_{in} = 9.59 watts for cell 70 at 39C.

Tca	Tcb	Tavg	TH2O	ΔT	I(t)	V(t)	PinE(t)	Pout	Pex	
38.962	39.053	39.008	33.229	5.779	1.220	5.312	6.481	9.040	2.559	
38.940	39.053	38.997	33.233	5.763	1.220	5.352	6.529	9.015	2.486	
38.981	39.087	39.034	33.239	5.795	1.220	5.324	6.495	9.066	2.571	
38.979	39.009	38.994	33.257	5.737	1.220	5.318	6.488	8.974	2.486	
38.965	39.089	39.027	33.247	5.780	1.220	5.319	6.489	9.043	2.554	
38.950	39.079	39.015	33.228	5.786	1.220	5.271	6.431	9.052	2.622	
38.950	39.079	39.015	33.228	5.786	1.220	5.329	6.501	9.052	2.551	
38.947	39.130	39.039	33.241	5.798	1.220	5.304	6.471	9.070	2.599	
38.982	39.022	39.002	33.242	5.760	1.220	5.265	6.423	9.011	2.587	
39.008	39.026	39.017	33.269	5.747	1.220	5.305	6.472	8.990	2.518	
38.940	38.991	38.966	33.268	5.697	1.220	5.313	6.482	8.910	2.428	
38.956	39.074	39.015	33.254	5.761	1.220	5.312	6.481	9.012	2.532	
38.943	39.072	39.008	33.241	5.767	1.220	5.307	6.475	9.021	2.547	
38.941	39.053	38.997	33.242	5.755	1.220	5.308	6.476	9.002	2.527	
38.941	39.053	38.997	33.242	5.755	1.220	5.332	6.505	9.002	2.497	
38.945	39.028	38.987	33.270	5.716	1.220	5.303	6.470	8.940	2.470	
38.957	39.047	39.002	33.253	5.749	1.220	5.335	6.509	8.992	2.483	
38.975	39.039	39.007	33.245	5.762	1.220	5.296	6.461	9.013	2.552	
38.973	39.085	39.029	33.241	5.788	1.220	5.315	6.484	9.055	2.571	
39.002	39.029	39.016	33.250	5.765	1.220	5.334	6.507	9.018	2.511	
38.953	39.067	39.010	33.257	5.754	1.220	5.358	6.527	9.000	2.463	
38.978	39.055	39.017	33.249	5.768	1.220	5.307	6.475	9.022	2.548	
38.978	39.055	39.017	33.249	5.768	1.220	5.303	6.470	9.022	2.553	
38.963	39.055	39.009	33.247	5.762	1.220	5.314	6.483	9.014	2.531	Averages
0.020	0.031	0.016	0.012	0.024	0.000	0.021	0.026	0.058	0.047	Std Dev

Table IV: Excess power data for cell 70 at 39C.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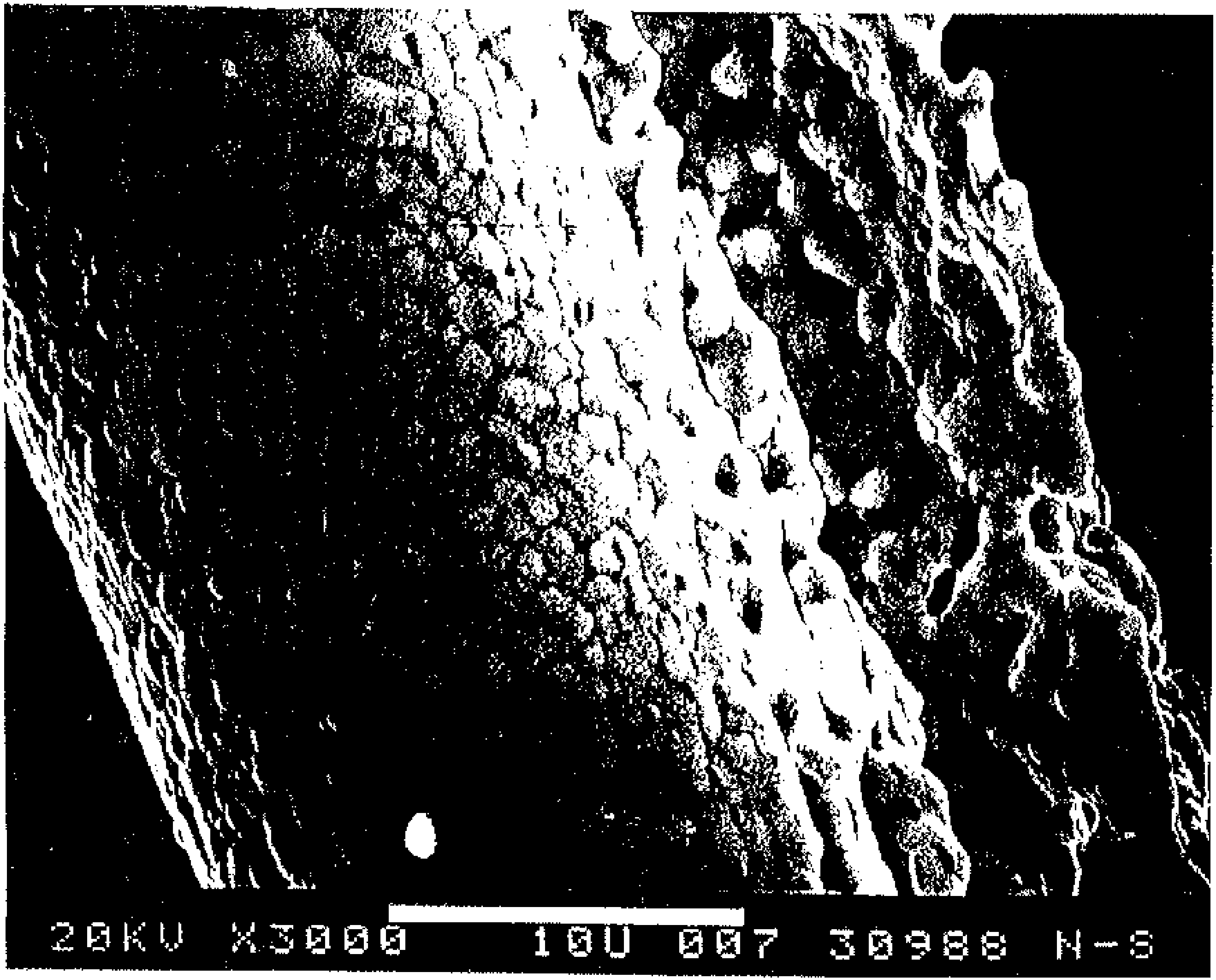
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