PROGRESS REPORT #2
CALIBRATION OF THE SEEBECK CALORIMETER

Subject: Part 2. Calibration of the calorimeter used to study sources of LENR energy
Date: 8/9/15
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INTRODUCTION

This report describes how a Seebeck calorimeter is calibrated in order to measure the amount of excess power produced by a cathode in an electrolytic cell contained in the calorimeter and the expected uncertainty in this value.

A Seebeck calorimeter uses thermoelectric converters (TEC) to create a voltage proportional to the rate at which heat energy leaves the calorimeter. The present design consists of a water-cooled aluminum box with TEC covering the inside of each surface. Consequently, the amount of heat energy leaving the box is measured regardless of where this loss takes place. A calibration using a known source of heat energy is required to calibrate the device.

Two different methods are used to apply known heat energy, with several variations involving the electrolytic cell or resistors external to the cell. Electric power can be supplied to the electrolytic cell containing a platinum cathode, which is presumed to produce no excess energy. Or electric power can be applied to a glass covered internal resistor located in the electrolyte, as can be seen in Fig. 1.

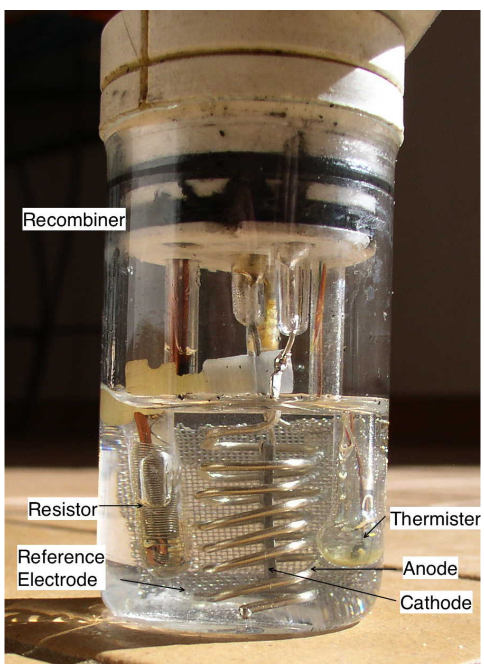

FIGURE 1. Pyrex electrolytic cell. The electrolytic cell consists of a cathode and anode and the internal resistor consists of a coil of nichrom wire immersed in oil contained in a thin wall Pyrex tube.

The electrolytic cell can be removed and two quartz light bulbs (12 V, 50 watt) can be substituted for the resistive load provided by the electrolytic cell and the internal resistor, as shown in Fig. 2. These sources of heat are totally independent of the electrolytic cell and any chemical reaction that might take place therein. In addition, their use allows the calibration to be extended to higher power than the electrolytic cell permits because boiling of the electrolyte limits the maximum power.

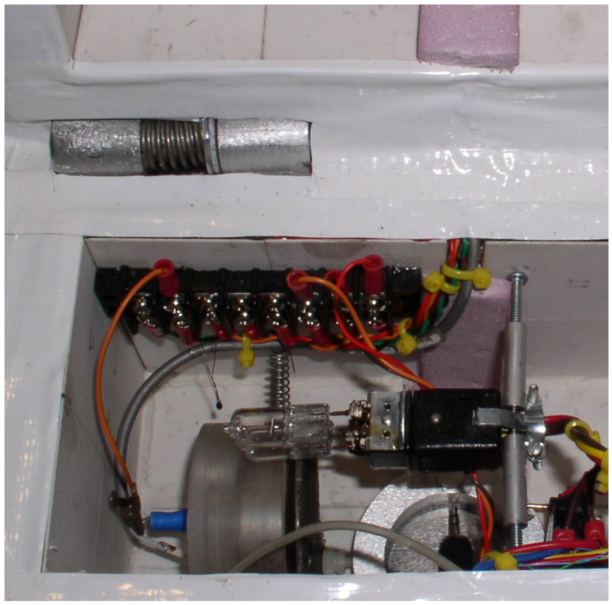

FIGURE 2. Picture of the two small quartz light bulbs used for calibration. One is connected to the circuit providing power to the anode and cathode and the other is connected to the circuit supplying power to the resistor contained in the Pyrex cell, which is removed for this test.

The apparatus is designed to apply power to the internal resistor during electrolysis for the purpose of changing the cathode temperature without changing the current applied to the cathode. This applied power must have the same effect on the Seebeck voltage as do the other sources of applied power, hence requires calibration. The circuit used to switch power to the internal resistor from a separate power supply can be seen in Fig. 3.

The voltage applied to the internal resistor measured at the calorimeter boundary is measured by the same circuit regardless of the source of power. Only the current is measured separately using the voltage drop across two different calibrated resistors depending on whether all the power is applied to the internal resistor or some power is also applied to the electrolytic cell using a separate power supply. The diagram for switching and current measuring circuits is shown in Fig. 3 and a picture of the switches can be seen in Fig. 4.

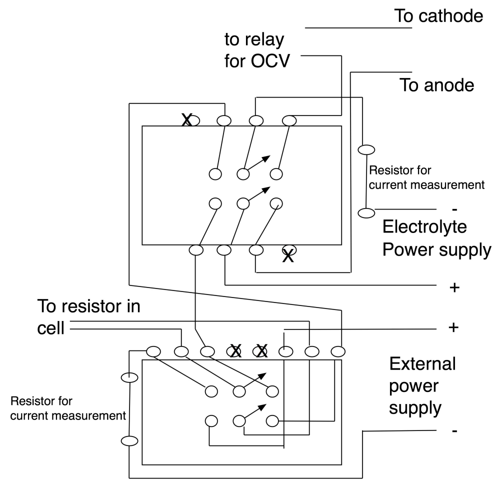

FIGURE 3. Diagram of switches used to change power from internal resistor to electrolytic cell and to apply power to the resistor using an external power supply.

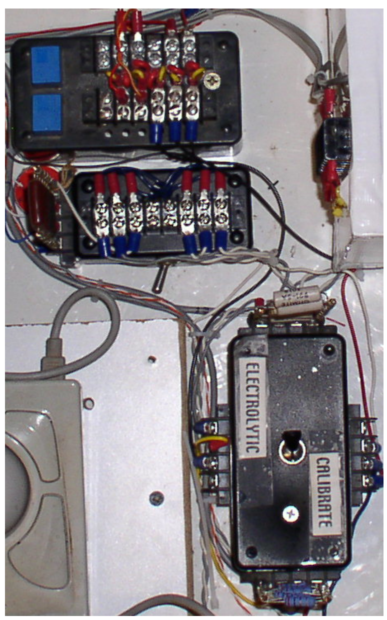

FIGURE 4. Picture of switching system. The top box contains relays for measuring OCV. The relays disconnect the cathode from the power supply and connect it along with the reference electrode to the DA circuit for a total time of 350 msec.

The source of power in all cases is provided by two Kepco BOP-20-5M power supplies operating with constant current.

METHOD

The LabView program provides for automatic calibration during which current is applied in steps going up and then down in applied power. After a delay for the calorimeter to reach equilibrium, values are recorded for the various voltages and currents. Table 1 provides a list values obtained using this method on which the final calibration is based.

TABLE 1

Data on which calibration is based

TIME, min	FAN VOLT	FAN CURRENT	APPLIED VOLT	APPLIED CURRENT	SEEBECK VOLT	TOTAL WATT
#1 Current applied to light bulb using resistor circuit						
41	11.951	0.066	0.298	0.505	0.04452	0.939
81	11.949	0.067	0.765	1.010	0.07845	1.568
121	11.949	0.065	1.819	1.514	0.18197	3.534
161	11.951	0.065	3.204	2.020	0.36199	7.250
201	11.951	0.065	4.863	2.527	0.65932	13.073
241	11.951	0.063	6.855	3.035	1.09553	21.562
281	11.952	0.063	9.185	3.545	1.67089	33.307
322	11.953	0.065	5.226	2.528	0.70134	13.984
362	11.955	0.067	2.198	1.514	0.20531	4.129
442	11.958	0.070	0.966	1.011	0.08568	1.818
482	11.960	0.067	2.104	1.515	0.20648	3.987
522	11.961	0.067	3.308	2.021	0.37715	7.493
562	11.962	0.066	5.107	2.529	0.69073	13.707
602	11.962	0.065	6.979	3.036	1.1068	21.972
643	11.962	0.064	9.049	3.546	1.6667	32.855
683	11.963	0.067	5.027	2.529	0.67884	13.516
723	11.964	0.069	2.151	1.516	0.207	4.082
763	11.964	0.068	0.343	0.507	0.05094	0.990
803	11.965	0.073	0.925	1.012	0.08862	1.813
843	11.965	0.069	2.375	1.516	0.21975	4.421
883	11.965	0.069	3.462	2.022	0.40323	7.827
#2 Current applied to light bulb using electrolytic circuit						
41	11.965	0.069	0.1446	0.507	0.04572	0.895
81	11.965	0.069	0.5218	1.012	0.06779	1.349
121	11.964	0.069	1.5535	1.516	0.15788	3.178
161	11.963	0.067	2.8323	2.021	0.32978	6.528
201	11.962	0.066	4.3610	2.528	0.60099	11.811
241	11.959	0.065	6.1530	3.036	0.98479	19.463
281	11.962	0.065	8.2304	3.545	1.51431	29.953
321	11.959	0.067	4.3568	2.528	0.5984	11.815
361	11.955	0.067	1.5485	1.515	0.15648	3.146
361	11.956	0.068	1.5487	1.515	0.15764	3.154
401	11.954	0.067	0.1418	0.505	0.04598	0.875
442	11.956	0.067	0.5157	1.011	0.07074	1.322
482	11.953	0.067	1.5476	1.514	0.16196	3.147
522	11.951	0.067	2.8268	2.021	0.3345	6.509
562	11.952	0.065	4.3563	2.528	0.59378	11.790
602	11.953	0.066	6.1515	3.036	0.98374	19.458
642	11.952	0.063	8.2210	3.545	1.51167	29.900
682	11.950	0.064	4.3582	2.528	0.60134	11.785
722	11.951	0.066	1.5492	1.514	0.16138	3.138
722	11.950	0.067	1.5485	1.514	0.16233	3.142

Table 1 continued

TIME, min	FAN VOLT	FAN CURRENT	APPLIED VOLT	APPLIED CURRENT	SEEBECK VOLT	TOTAL WATT
#3 Current applied to light bulb using resistor circuit and external power supply						
41	11.953	0.067	0.367	0.513	0.04805	0.994
81	11.956	0.067	0.931	1.028	0.08961	1.755
121	11.956	0.068	2.310	1.539	0.22098	4.372
161	11.958	0.067	3.602	2.053	0.41125	8.201
201	11.958	0.065	5.190	2.567	0.71434	14.104
241	11.959	0.066	7.287	3.081	1.17303	23.240
281	11.960	0.065	9.423	3.595	1.74291	34.649
321	11.962	0.067	5.391	2.568	0.73679	14.645
361	11.961	0.069	2.078	1.540	0.20347	4.026
362	11.961	0.069	1.540	2.078	0.20216	4.027
402	11.962	0.069	0.319	0.515	0.04965	0.995
442	11.969	0.070	0.846	1.029	0.08777	1.705
482	11.964	0.069	2.088	1.541	0.20216	4.043
522	11.965	0.068	3.645	2.054	0.42213	8.303
562	11.965	0.069	5.409	2.569	0.73969	14.718
602	11.965	0.068	7.243	3.083	1.161	23.135
642	11.967	0.067	9.426	3.597	1.74398	34.705
682	11.967	0.069	5.388	2.569	0.73648	14.663
#4 Current applied to resistor in electrolytic cell						
65	11.950	0.067	0.786	0.092	0.04335	bulb
130	11.949	0.068	2.164	0.252	0.07155	1.356
196	11.949	0.067	8.936	1.012	0.49476	9.847
261	11.951	0.067	11.511	1.345	0.83127	16.289
326	11.951	0.067	7.407	0.884	0.38146	7.351
391	11.949	0.069	5.276	0.632	0.21147	4.154
456	11.949	0.068	4.220	0.506	0.15237	2.950
521	11.944	0.069	3.169	0.381	0.09696	2.028
586	11.951	0.068	1.050	0.127	0.04637	0.943
651	11.950	0.068	0.764	0.092	0.04454	0.886
716	11.951	0.068	2.102	0.252	0.06981	1.348
782	11.949	0.068	8.530	1.012	0.48281	9.444
847	11.949	0.067	12.730	1.515	1.03670	20.089
917	11.951	0.068	7.246	0.883	0.37164	7.208
#5 Current applied to platinum cathode in electrolytic cell						
125	11.954	0.068	3.176	0.102	0.05915	1.127
210	11.950	0.068	3.619	0.506	0.13457	2.642
310	11.952	0.068	3.905	1.012	0.24313	4.761
405	11.951	0.067	4.095	1.515	0.35746	7.008
535	11.954	0.068	4.220	2.021	0.47645	9.342
610	11.952	0.067	3.294	0.506	0.12777	2.477

Each of the data sets above can be fit by a quadratic equation, the parameters for which are listed in Table 2. Each of these data sets can be accepted as a suitable calibration, yet they each give a slightly different result. Because the most accurate equation is not known, all the data sets are combined into a single data set and fit by a common equation. This combined data set produces the result shown in Fig. 5

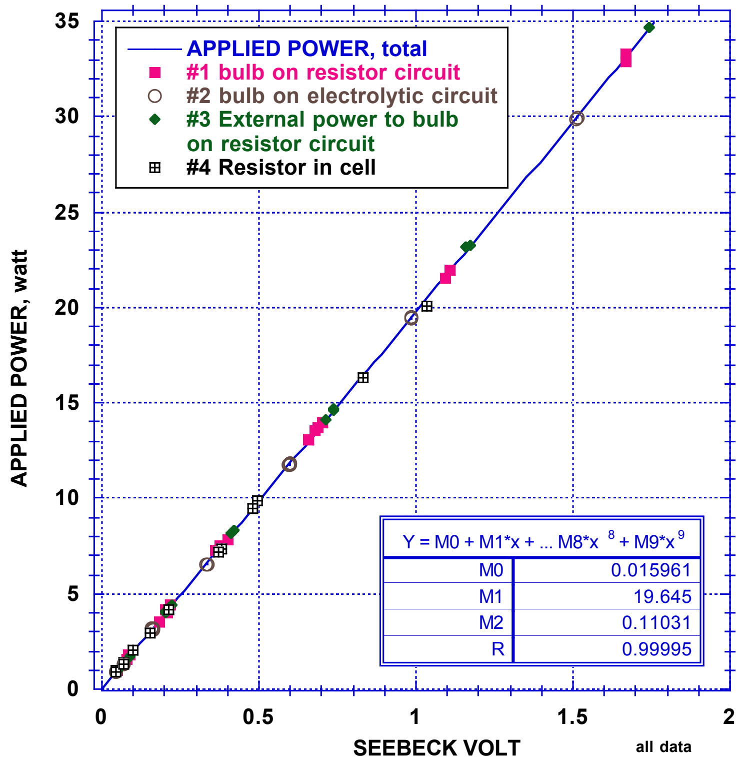

FIGURE 5. Combined values from sources numbered 1 to 4 in Table 2.

TABLE 2

Parameters in W = A + B*V + C*V^2

CONDITION	A	B	C	R
1. Light bulb and resistor circuit	0.0268	19.749	0.0323	0.99995
2. Light bulb and electrolytic circuit	-0.0131	19.717	0.0490	0.99999
3. Light bulb using extra power supply	0.0019	19.820	0.0397	0.99999
4. Resistor in electrolytic cell	-0.00086	19.727	-0.2811	0.99992
5. Pt cathode in electrolytic cell	-0.042	19.844	-0.3185	0.99999

When the electrolytic cell is used, another method to measure excess energy becomes available. The difference in temperature between the electrolyte and the surrounding air in the Seebeck box can be used as an isoperibolic calorimeter to obtain a rough measure of power being generated in the cell. Figure 6 shows the relationship between this temperature difference and power applied to the electrolytic cell when using a platinum cathode. Because temperature gradients exist in the electrolyte, this method is suitable only to verify excess energy is being generated as indicated more accurately by the Seebeck method.

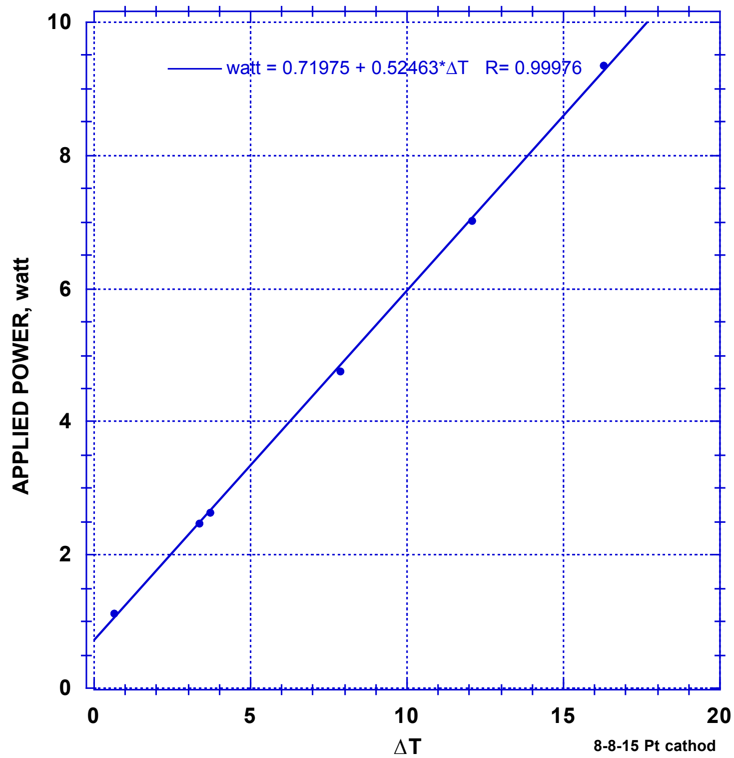

FIGURE 6. Relationship between delta T and applied power.

Two different types of uncertainty affect the values of excess power. Accuracy of the absolute value of excess power depends on the care used in measuring the power applied to the calorimeter as current and voltage and the care used in achieving a calibration equation largely independent of random variations in the Seebeck voltage. The second more common uncertainty is created by changes in the reference temperature that cause random fluctuations in the Seebeck voltage. The set value of the reference temperature[1] is not important; only its variation with time has a noticeable effect. These variations create an error band that is most noticeable at low excess power. Both of these potential errors can be evaluated by applying the chosen calibration equation to an electrolytic cell known not to produce any excess. The apparent excess power is shown in Fig. 7 as a function of time after various values of current are applied to the electrolytic cell. The cell takes about 40 minutes to reach equilibrium and maintains a value within about 50 mW of zero excess energy, which is the magnitude of the random uncertainty. Based on this behavior, a claim for excess energy requires an apparent excess energy greater than 50 mW and all individual values for excess energy can be considered uncertain by ±50 mW. A large part of this uncertainty results from random temperature

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[1] The set value is 20.00±0.01° C, which is chosen to be near room temperature. Other values will be used in the future when the effect of temperature is studied.

changes in the flowing water used to produce the reference temperature and changes in room temperature.

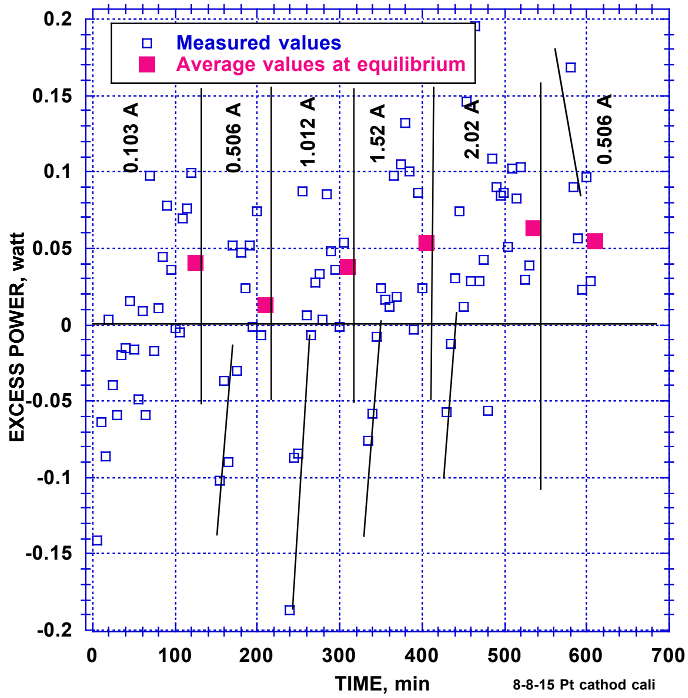

FIGURE 7. Apparent excess energy using a platinum cathode in D_2O+LiOD based on the calibration equation shown in Fig. 5.

This initial calibration provides understanding of the behavior and the errors expected produced by this calorimeter design. As the study of excess energy continues, the calorimeter will be repeatedly recalibrated to insure that normal drift does not introduce a bias in the apparent excess energy and efforts will be made to reduce the scatter in the values.

The following Reports will describe the behavior of the Pd-Ag-D system.