

FLOWING ELECTROLYTE CALORIMETRY

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ABSTRACT

When the specific heat and flow rate of the electrolyte are known, the thermal output of cells using circulating electrolytes can be determined. An independent evaluation of the "Patterson Power Cell™" was conducted using the circulating electrolyte as a heat transfer medium. This allows for real time measurements and alteration of the electrolyte. The cell was found to give measurements consistent with claims of excess power. Suggestions for the improvement of the calorimetry are given. A simplified version of the system was demonstrated during the first 3 days of the International Conference on Cold Fusion - 5 (ICCF-5) and made available to those requesting its examination.

INTRODUCTION

The "Patterson Power Cell™" [1,2] has been claimed as both a light and heavy water system producing "excess heat". Before conclusions can be drawn, however, its unique calorimetry must be investigated. The system uses its electrolyte in a flow calorimetry approach. This allows greater and more rapid adjustment of internal cell conditions, while also permitting real time measurements of reaction products. It is one of few cold fusion systems which has been granted a U.S. Patent. This author was requested to evaluate the system.

The evaluation consisted of three parts- 1) observation of the cell being operated at its original site by its inventor, 2) personally operating the device at its original site [3], and 3) independently reproducing the device at a local site and testing it. All of these gave compatible results. This indicates that the device does give the observable measurements as claimed. However, ruling out systematic or equipment errors required redesign of certain components.

The initial cell design presented to the author used a thick plaster of paris insulation around the cell. The calibration resistor was embedded in the plaster and external to the cell. The overall efficiency, as measured by heat gained by the electrolyte from the resistor, varied from 20 to 70%. Such variability complicated any detailed analysis. The calibration resistor was replaced inside the cell. The cell was wrapped with glass wool, housed inside side two dewar flasks set mouth to mouth, and sealed from humidity changes with parafilm. This raised the thermal efficiency of the calorimeter to 86 to 93% depending on the cell packing and sealing. This lowered the thermal mass and shortened the response time of the cell. Additional sensors were added so that all measurements could be checked by secondary instruments. A quantitative investigation of the cell took place by this author after these modifications were made.

DESIGN

The modified cell is shown in figure 1. The use of plated beads as the cathode is the most unique feature of this design. These beads were supplied by Clean Energy Technologies, Inc. [4] and are produced and used in accordance to existing Patents [5]. The microspheres were originally designed for work as density gradient markers for protein analysis. They were then used in amino acid analysis and ion exchange systems. The spherical construction of the beads allows for uniform expansion and contraction without the development of large stresses and cracks. Current work [6-8] has indicated that, for at least nickel, normal water systems, the cold fusion effects are a surface or near surface effect. Thus, the use of many small spheres provides a large surface area that maintains structural integrity.

The base of the bead is a stable cross-linked copolymer made of styrene divinyl benzene. The beads are first sulfated with chlorosulfonic acid to provide a conductive surface. A copper chloride solution is then fixed to the surface. This allows the beads to withstand higher temperatures while avoiding hot spots that would otherwise blow the metal coatings off. Uniform metal plates are then layered accordingly. First with nickel, then with palladium, and then an outer coating of nickel. These multiple layers of nickel/palladium/nickel on beads thus far have out performed single coatings. Others [9] have investigated such multilayer thin films on plates which eventually detached from the surface. The plated beads have performed continually in cells for over one hundred hours without observable changes. It is estimated that 40 mg of metal (a total of about 2 micron thickness of all layers) and about 1200 beads are used within the cell. It is important to note that the small amount of metal used should be beneficial for searches of isotopic shifts.

The electrolyte outlet temperature, T2, is measured at the top of the cell as it reaches the height of the lower dewer containment lid. The inlet temperature, T1, is measured 5 cm from the lid as the electrolyte flows into the cell. The initial designs used thermocouples (K-type) coated with epoxy. After extended runs, it was determined that the lithium ions from the electrolyte were causing "decalibration errors" in the thermocouples. Furthermore, the thermocouples were not completely electrically isolated from the electrolyte. Thus, the electrolyte current could interfere with the temperature measurements.

The thermocouples were moved to stainless steel wells and insulated with teflon tape and heat sink compound. The two stainless steel wells were connected to a common ground. This increased the thermal response time but prevented additional electrical interference. The upper portion of the thermocouple wells were lightly insulated by tygon tubing. It has been pointed out that the length of the thermocouple well outside the electrolyte may cause the inlet thermocouple to see a weighted average of the temperature between the electrolyte and the environment. Such "wicking effects" have been known to produce errors of 10 to 20%. It is recommended that future designs avoid wells which extend beyond the tubing and employ thick insulation at the site of the measurements. In most experimental runs, the inlet sensor region was also located within the upper dewer and within the glass wool insulation. The physical location of the well was in a region of large flow gradients (i.e. cross sectional areas changed from 1mm² to 10mm² back to 1mm²). This provides some mixing. It is recommended that any redesigns use a commercial in-line mixer just up-stream from the temperature sensor.

The overall system is shown in figure 2. The electrolyte flows in a closed loop 1) from the reservoir 2) to the pump 3) through the flow sensor 4) through the cell 5) to a gas splitter and 6) returns to the reservoir. The input power is calculated from total voltage and current supplied to the cell. The voltage was not corrected for the gas production. The output power was obtained by the heat absorbed by electrolyte flow. The electrolyte is prepared from a one molar lithium sulfate solution of normal water. The electrolyte also serves as the heat transfer fluid. It has an apparent specific heat of approximately 0.95 within the overall system. The output heat can be arrived at via calibration curves of the cells or from first principles using the specific heat of the electrolyte. In practice, both were used and found to agree within 15%.

CALIBRATION

The system was first calibrated using distilled water for the working solution and the internal calibration resistor for its heat source. This produced overall efficiencies for the calorimeter within the range of 86 to 92%. The exact value is dependent on the sealing method (parafilm or silicon rubber) and the packing of the glass wool. The data sets given later (figure 4) are based on the 88% configuration using parafilm to seal the gaps against air flow. A series of calibration runs were conducted by varying both the flow rate and input power independently. Figure 3 shows the relationship between input power and temperature differential for a fixed flow rate and current setting. The efficiency was found to be stable (88% +/- 2%) over all practical flow rates or resistor inputs.

Next, the 1 M lithium sulfate electrolyte was used as the working solution. Its apparent specific heat within the unit was approximately 0.95 based on the above water calibration. It should be noticed lower specific heats of the working fluid could lead to overestimates of the heat generation. However, saturated lithium sulfate solutions are about 3 molar. A 100 ml volume of a saturated solution at the working temperature contains only 88 g of water. Thus, the specific heat of the electrolyte should never be lower than about 0.88. A second calibration series was conducted using the lithium sulfate solution and the calibration resistor.

At the beginning and end of each experimental run, a calibration pulse of 15 minutes was used to check the system's performance. During some runs, a calibration pulse was delivered as the system was generating anomalous heat. In those cases, it was noticed that power delivered to the calibration resistor gave additional heat output greater than can be expected by simple additive processes. This is seen as either a) the heat producing mechanism has a positive temperature coefficient or b) the instrumentation and sensors over estimates the heat generation. All physical mechanisms proposed (gas bubbles at sensors, heat gain and loss via sensor sheaths, etc.) in support of the second alternative appear to be an order of magnitude smaller than the observed effects. To test the first premise, an auxiliary heater was added to the electrolyte's reservoir. Pre-heating of the electrolyte to 40 to 60 degrees C before entry into the cell apparently enhances the power generation. Due to limited time, only a few runs at elevated temperatures were conducted. Further investigation has clearly indicated and should throw light on the heat mechanism and response of the instruments. Such effects are the subject of current experimentation.

There is an initial loading period required of the beads. This is about 12 hours for fresh beads and only 1 hour for pre-loaded beads. This is conducted by using a constant current power supply set at 0.2 to 0.5 amps. The

cell's resistance gradually changes from 135 to 150 ohms. This is thought to be due to hydride production on the surface of the beads. The temperature between the inlet and outlet gradually increases toward the end of the loading period.

TYPICAL DATA POINT

There are 6 primary measurements for each data set: the electrolyte flow, F ; the voltage, V ; the current, I ; the temperatures of the inlet, T_1 ; and the outlet, T_2 ; and the gas production flow, f . The gas flow is monitored only to verify that no appreciable recombination occurs. This was found to be true to the limits of measurements, ± 0.5 ml/min. All measurements were taken by two separate sensor systems and found to be internally consistent. All meters, except the temperature, were calibrated and traceable to national standards. A simplified demonstration system was present at ICCF-5. The following data set is one that was taken immediately prior to this authors presentation: $V=3.80$ V, $I=0.12$ A, $F=10.30$ ml/min., $T_1=24.3$ C, $T_2=26.9$ C, $f=1.2$ ml/min. (average). This and similar data sets were witnessed by some ICCF-5 participants. This specific data point represents an input power of: $P=VI = 0.46$ W. It represents a thermal output of: $d[mc(T_2-T_1)]/dt = 1.77$ W. The gas production represents an additional power production of 0.18 W. The heat loss from the cell is estimated at an additional 14 % of the heat production or 0.25 W. Such a point would appear as power ratio of $1.77/0.46 = 384\%$. Notice that the thermal power production exceeds the electrical input power even without addition of the gas production or heat loss terms.

A series of data sets were taken and the results represented in figure 4. The points in this figure were taken with the complete laboratory device and under environmentally controlled conditions. The power ratio of: power out / power in, is in the range of 1 to 5 when neither gas production or heat loss are added to the output figures. The ratios are slightly higher when those terms are added. It is interesting that the cell gave values of between 1 and 2 for those ratios at high currents (>1 amps.). This is consistent with other studies [10] of nickel based systems showing a higher power ratios at low currents. At low current (<0.2 amps) there is more scatter in the data. This is because any errors or uncertainties of measurements are exaggerated by the ratio at low power levels. However, the ratios are consistently above 2 to 1 even with the most pessimistic data sets. The high current regions of the chart are on firmer experimental grounds. However, it is the low current regions that are the most intriguing for future engineering projects.

During the conference, a simplified version was demonstrated. This used hand meters instead of bench meters, minimum insulation for visibility and other low weight alterations. The demonstration device was displayed and run for 3 days (minus about 3 hours due to transport to nightly storage). Power ratios of between 2 to 6 to 1 were demonstrated for most of that time as represented by the typical data set given above. Conference participants were invited to take data, their data is summarized in table A. The demonstration was run in the low current ranges (<0.5 amps). The device was for demonstration purposes only and was designed to illustrate the reproducibility and reliability of the basic design. The goal was to introduce the unique features of this relatively unknown system to conference participants.

CONCLUSION

The system does appear to be worth further study. Nothing discovered during the evaluation of the cell is inconsistent with the production of excess heat within the cell assembly provided that there is a positive temperature rate coefficient. This evaluation has concentrated on increasing the thermal efficiency of the calorimeter, consistency between measurements, better placement of the calibration resistor, measurement of the gas production in real time, use of calibrated and traceable electrical meters and alternative measurements of key values. It is advised that further study is required to limit uncertainties due to temperature measurement of liquid flow. Additional independent experimentation with "inert beads" as controls and the use of in-line mixers should be considered. The high power ratios at the low current levels need to be revisited using measurements with tighter error bounds. However, regardless of the cause, the system does give repeatable results at substantial levels. If, as expected, the power levels persist with tighter experimental bounds in the low current levels, then the system should have important practical and commercial applications.

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Figure 1
Patterson Power Cell
Design

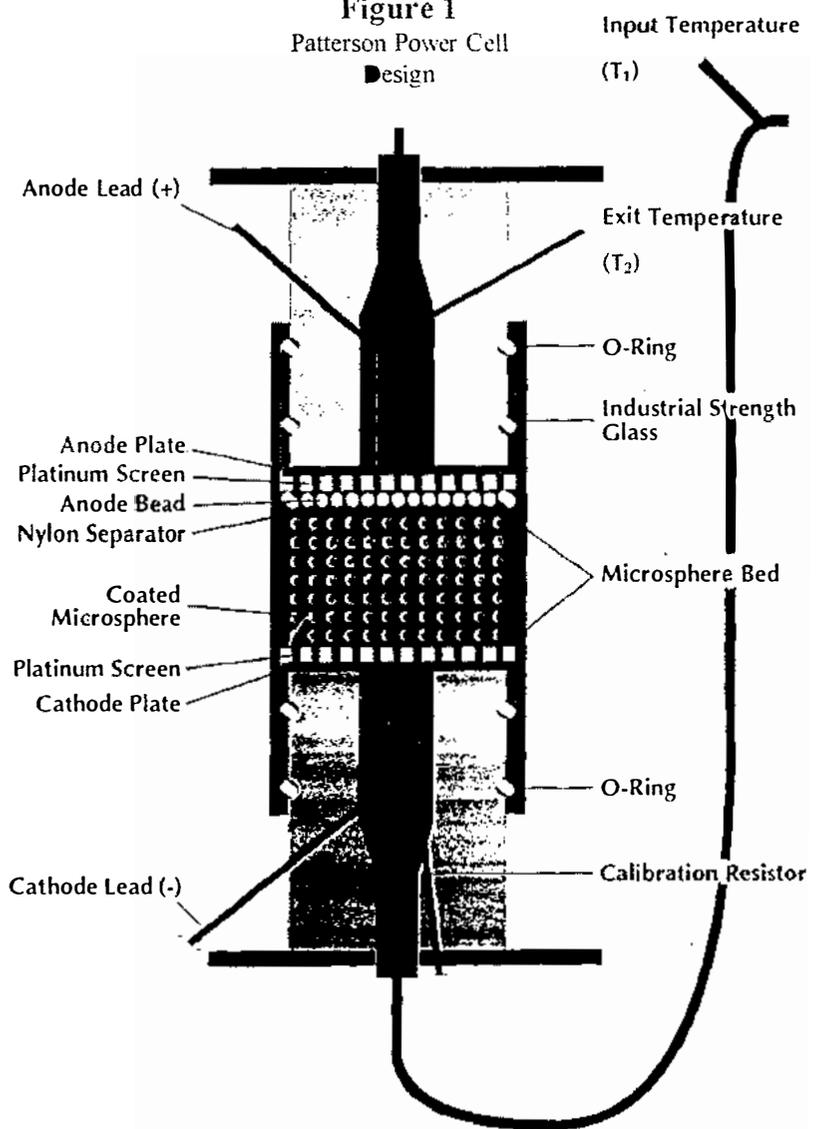
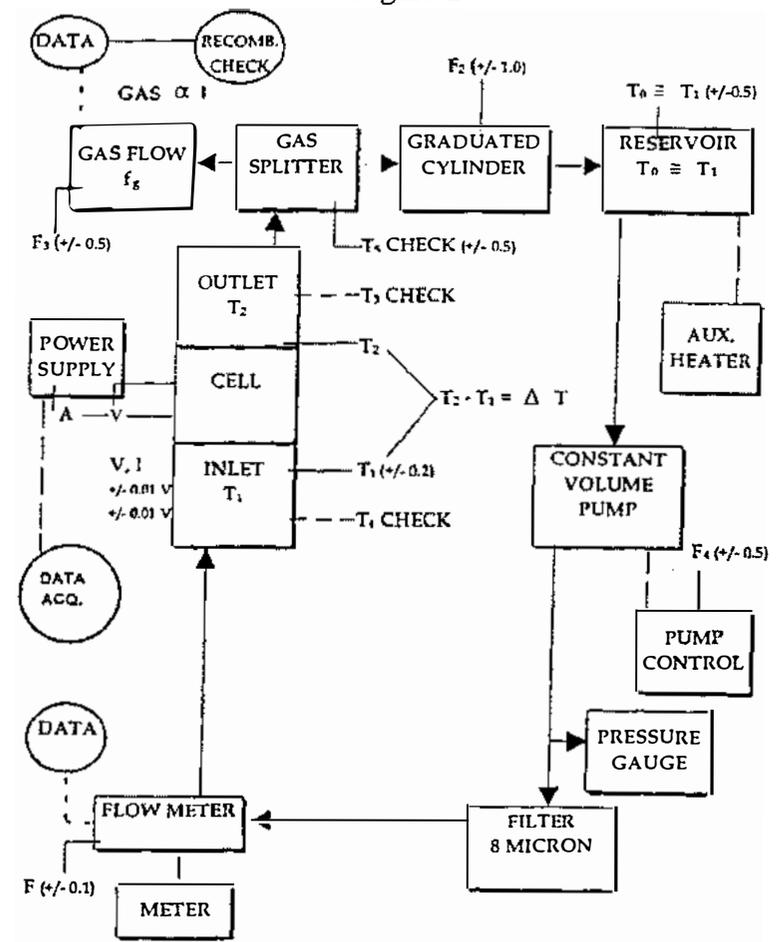


Figure 2



System Diagram

Figure 3

Calibration

delta T vs. input power(resistor)

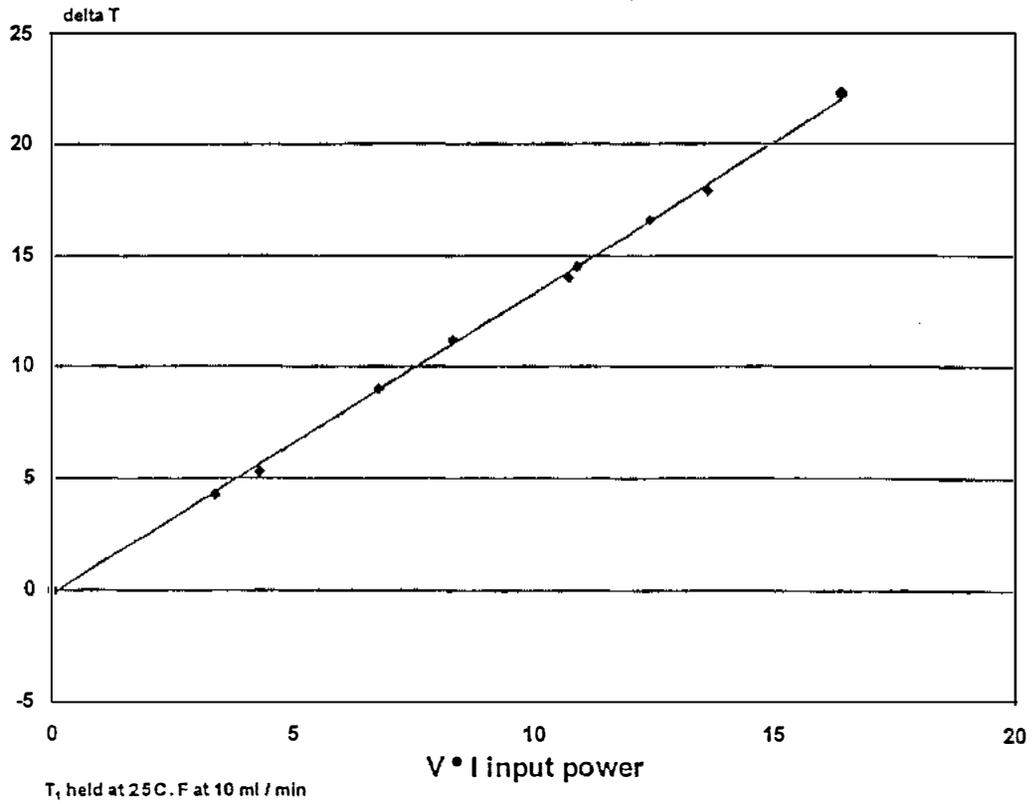


Figure 4

Power Run

excess power vs. current

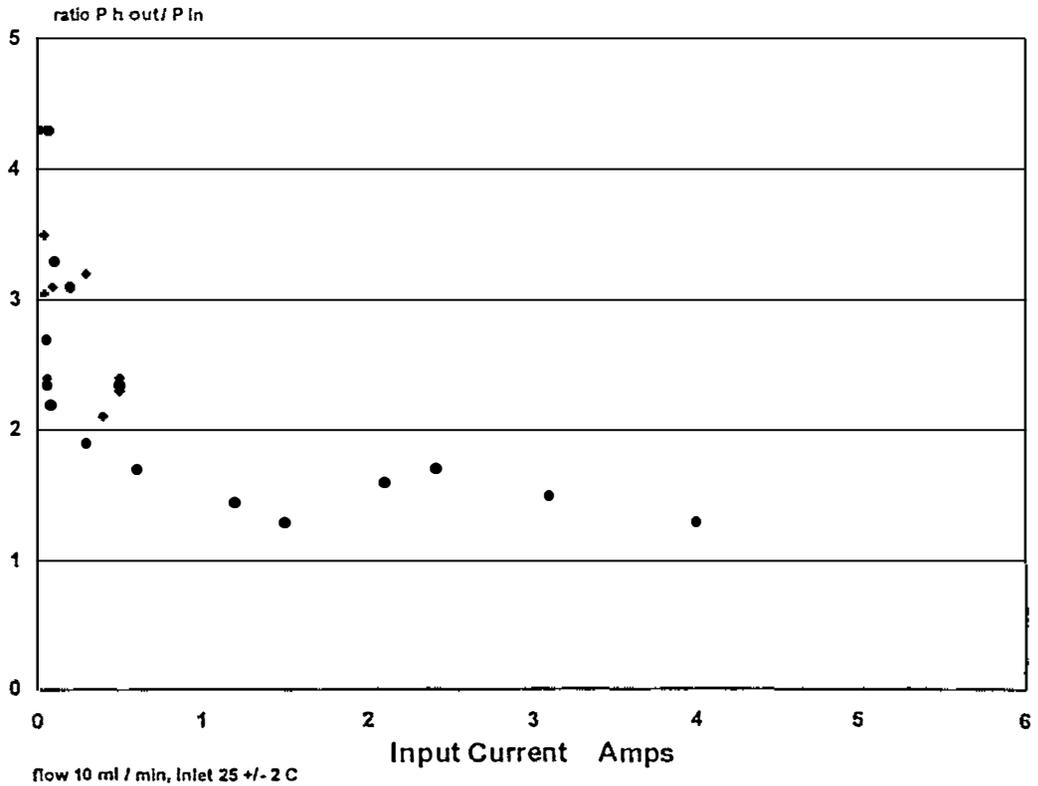


Table A

Patterson Power Cell Demonstration
Data taken by conference attendees at ICCF-5

<u>Date</u>	<u>Time</u>	<u>Voltage (V)</u>	<u>Amp (I)</u>	<u>Flow Rate L/min</u>	<u>ΔT (°C)</u>	<u>Raw Heat Yield (a) (%)</u>	<u>Heat Yield - Correction (b) (%)</u>	<u>Heat Yield w/ Correction (c) (%)</u>
4/9/95	21:10	3.29	.07	10.28	1.1	326	379	688
4/10/95	9:45	3.80	.12	10.08	2.6	381	443	726
4/10/95	14:38	3.80	.12	10.04	3.5	511	594	973
4/10/95	14:45	3.80	.12	10.11	3.6	529	615	1008
4/10/95	15:15	3.80	.13	10.01	3.3	443	516	844
4/11/95	12:28	3.74	.15	10.00	2.4	284	330	546
4/11/95	14:05	3.74	.13	10.00	2.5	341	396	656
4/11/95	18:30	3.43	.10	9.38	2.5	453	527	927
4/11/95	18:50	3.43	.09	10.00	2.4	516	599	1054
4/12/95	12:00	4.15	.21	10.00	3.0	228	265	413
4/12/95	14:10	4.15	.21	10.00	3.2	243	283	440
4/12/95	16:20	4.15	.21	10.00	3.4	259	301	468

Note: Yield calculations assume specific heat of electrolyte of .95.

(a) Raw heat yields without gas or thermal heat loss corrections.

(b) Heat yields with thermal heat loss correction (cell is 86% thermally efficient).

(c) Heat yields with thermal heat loss correction and gas correction (1.48); assuming no recombination.