

Constant Heat Flow Calorimeter

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Abstract

A constant heat flow calorimeter is described and its application to a Fleischmann-Pons experiment is detailed. In this calorimeter the electrolytic cell is contained in an isothermal chamber into which electrical power is fed from two separate sources. One source feeds biasing power P_{aux} to an auxiliary resistive element located in the chamber while the other source provides, P_e , the electrochemical power requirements for the cell. The cell temperature T_1 is maintained at its set point by varying P_{aux} as needed. Clearly power needs to be removed from the cell if a steady state is to be maintained and this is accomplished by inducing heat flow through a thermal link to a reference body whose temperature T_2 is less than T_1 . The heat flow is a function of the thermal gradient, which needs to be closely controlled, which in turn requires active control of T_2 . This is accomplished by coupling the reference body to an external heat reservoir through a Peltier element. Power to the Peltier element is varied to maintain the temperature of the reference body at T_2 . Heat stored in the cell requires an increase in P_{aux} to the cell while heat generated in the cell results in a decrease in P_{aux} , to the cell. The details of the operation of the system over a period of 53 days is presented along with evidence for heat production.

1. Introduction

The Constant Flow Calorimeter discussed is an outgrowth of an experiment requiring precise temperature control. It entails essentially a classic double oven approach where because of the layered temperature control around the experimental volume several potential error sources such as radiation leaks, conductive heat losses, etc to first order are constant as long as the two thermal shells are held constant at their individually controlled temperatures. This allows relatively precise measurement of the heat generated within the experimental volume by knowing that the sum of the energy within the volume from both a resistive heater and the experiment is a constant as determined by the calibration. The use of this calorimeter is illustrated using data from one of our early experiments into Pons - Fleishman cold fusion. Incidentally, this experiment was one of the few that did show excess heat and also a supporting creation of tritium. Ironically, we were not able to reproduce this phenomenon and we have no firm ideas as to what change in chemicals, palladium, or preparation (cleaning, etc) was fatal to the process. However, the calorimeter also showed quite clearly that we did not produce any excess heat in further experiments.

2. Calorimeter Design

The design premise is to create measuring and feedback systems that will establish and maintain a temperature gradient which sustains a constant heat flux from a calorimetric cell chamber. [Figures 1 & 2]

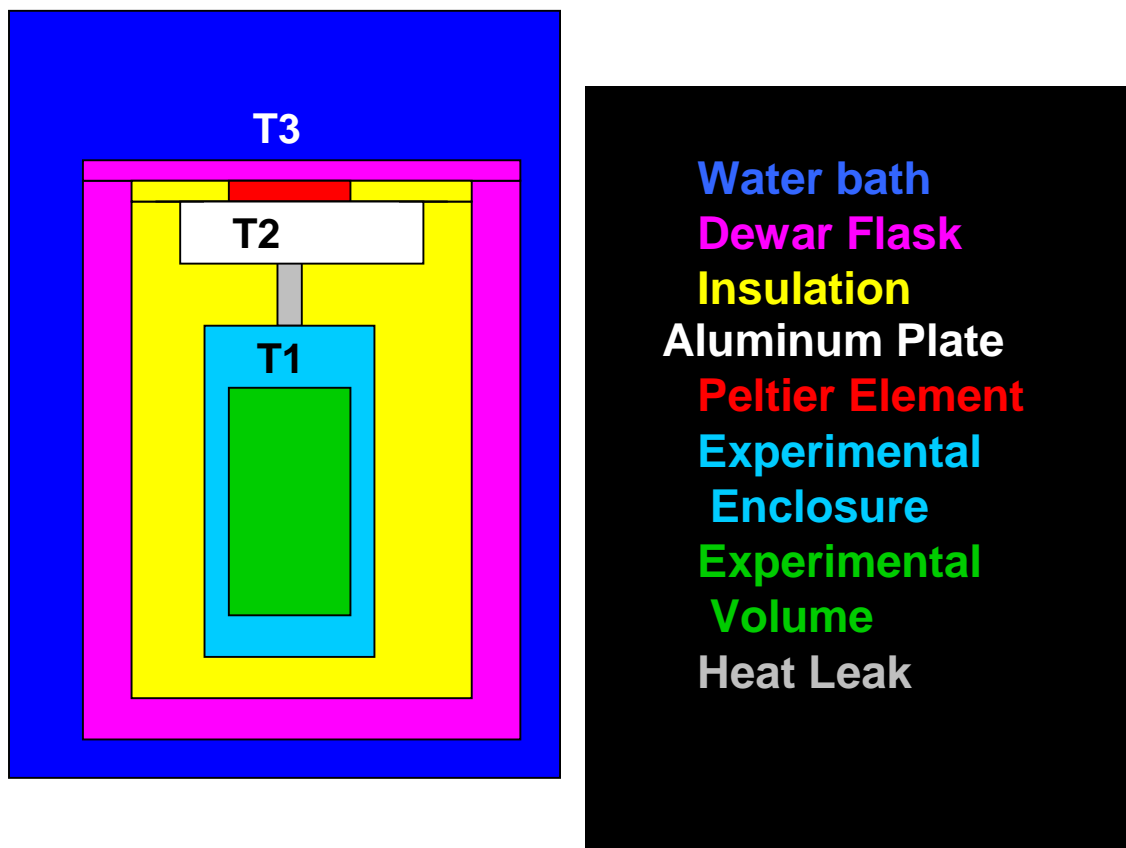


Figure 1. Schematic of Constant Heat Flow Calorimeter. Power to T1 and T2 are measured by HP-2804A Quartz thermometers (Accuracy Limit: +/- 0.0001°C). T3 is controlled by the circulating water bath system (Accuracy Limit: +/- 0.01°C).

The calorimeter cell temperature T1 is maintained constant at a preset value by varying the power delivered to an auxiliary electrical heater located in the experimental chamber. A thin-walled stainless steel channel serves as a heat leak connected to a heat sink formed by the aluminum plate at temperature T2. To insure the constancy of the heat flux, temperature T2 of the aluminum plate is precisely controlled at a constant preset value by a Peltier cell which in turn discharges heat to a thermal reservoir at temperature T3. The entire apparatus is enclosed by the circulating water bath which is maintained at temperature T3 through its own control system.

Calibration

The system was assembled with the electrochemical cell in the calorimeter and the heat leak was calibrated. Setting operating temperatures of 30°C for T1, 20°C for T2 and 28°C for T3 and

with the electrolysis current set to zero, the auxiliary power required to maintain the system at the fixed points was found to be 2.486 W.

The stability of the heat leak calibration over a period of 24 hours is shown in Fig. 3.

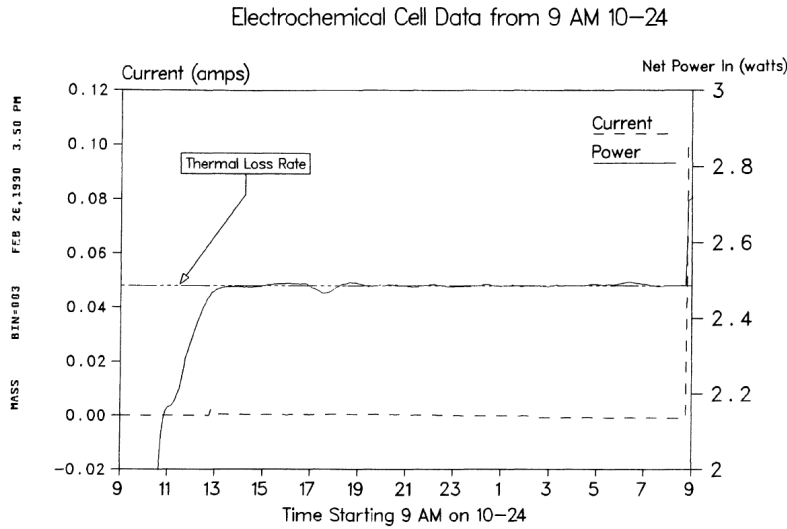


Figure 3. Initial Calibration Data

3. RESULTS

The system was operated for a period of 56 days with varying electrolytic cell currents. Over this period of time a constant flow of 2.486 W exited the cell through the heat leak while electrical power provided by the auxiliary source and the electrolytic cell flowed into the cell. Integrating the total input power over time gives the energy delivered to the cell over this period of time. Similarly the integrated power outflow, through the heat leak, is the energy leaving the cell over the same period of time. If more energy enters the cell than leaves it, the cell is storing energy essentially getting charged like a battery; however if the reverse is true, the cell is generating energy by some internal process.

Figure 4 is a plot of the time history of energy over the 56 days' operation of the cell along with the operating cell current. Positive energy indicates cell storage of energy while negative energies indicate a release of energy from the cell. As seen in Fig. 4, the cell stored 20 kJ during the first 29 days of operation. At Day 29 the cell current was reduced to 40 mA from 400 mA and a period of energy release followed. Initially, a rapid release of 5 kJ was followed by a more moderate release rate over the next eight days. An increased rate is seen for almost all the remainder of the experiment even after the cell current was reduced to zero. The experiment was terminated after the energy release ended. Although the system initially stored 20 kJ, it generated 50 kJ of new energy.

Electrochemical Cell Data

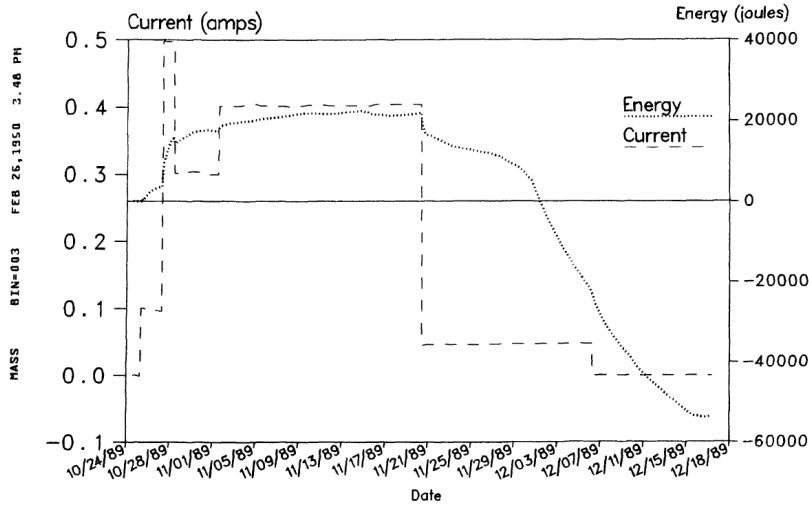


Figure 4. Energy Production and Cell Current for Entire Experiment 10/24/89 to 12/18/89 (56 days)

Figure 5 displays a time history in which energy and power input plotted as a function of time. Although the energy plot is relatively smooth, the power plot shows both transients associated with changes in cell current as well as fluctuations associated with processes inherent in the electrolysis process.

Electrochemical Cell Data

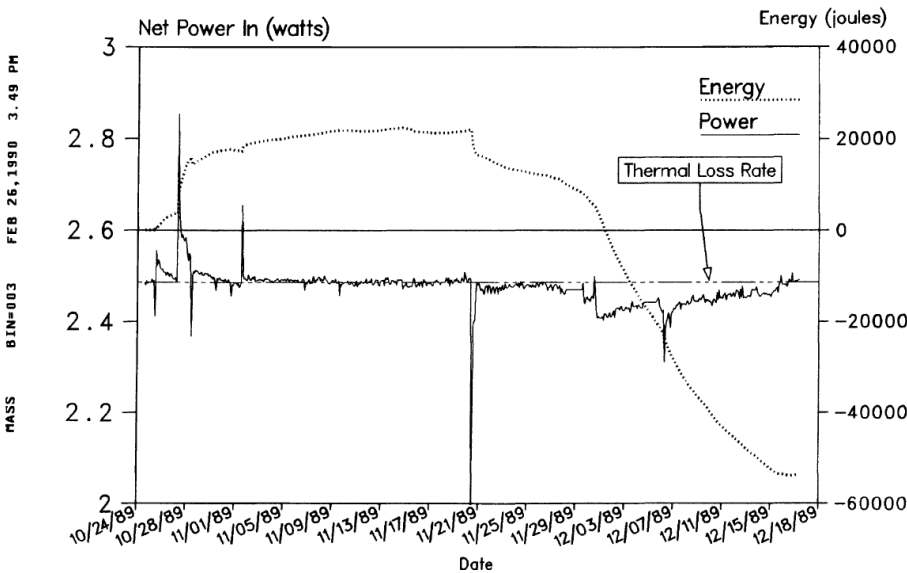


Figure 5. Energy and Power for Entire Experiment 10/24/89 to 12/18/89

4. Discussion

The plot of the system energy E shown in Figure 5 reveals the existence of three phases in the experiment. Initially, there is a storage phase in which deuterons are being absorbed into the palladium lattice. The rate of storage depends initially on the magnitude of the electrolysis current, however, after about 20 kJ have been stored, the system enters the second phase in which the electric power fed into the system is essentially balanced by the power flowing through the heat leak with no further increase seen in the stored energy. The third phase is initiated by the reduction of electrolysis current from 400 mA to 40 mA on 11-21. This stimulates the release of energy from the cell. Data for the cell behavior on 11-21 is given in Fig. 6, showing the current and power for 11-21 time period. The oscillations at a period of the order of one hour are associated with the functioning of the control circuit maintaining the temperature T_1 . There is about an eight hour period in which about 3 MJ of energy are released.

Following this steep reduction energy, there follows a period of a more moderate release – about 7 kJ over a two-week period. A further increase in the rate of energy release occurs spontaneously around 12-04, although as seen in Fig. 7, there is a modest decrease in energy release following the transient which appears in the cell power plot.

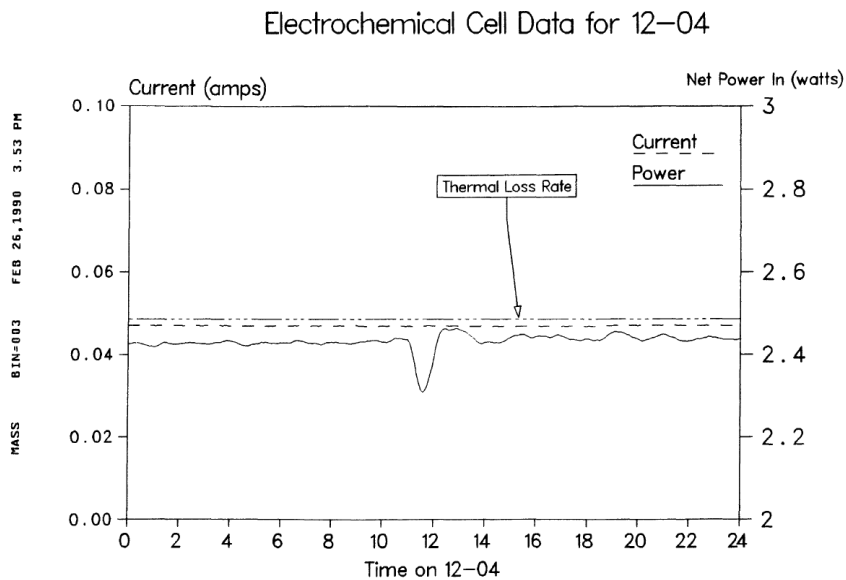


Figure 7. Electrochemical Cell Data for 12-04

The cell continued to release energy even after the cell current was set to zero on 12-07. Although the rate decreased slowly, it finally leveled off on 12-15, after releasing a total of 50 kJ. Figure 8 shows the system data for 12-17. The power supplied to the auxiliary heater is balanced by the power exiting the system through the heat leak.

We note that the fluctuations of the power in Fig. 5 appear to increase after the electrolysis current has been cut off, indicative of the existence of continuing sporadic events in the cathode. The process which started around 12-01 produced an initial sharp burst of power followed by a linear rate of decay for the next two weeks. The transient related to the current shut off seems to

have only a small effect on the decay rate. This observed behavior seems to be consistent with a model in which the energy production process is being controlled by a diminishing fuel supply.

Electrochemical Cell Data from 10 AM 12-17

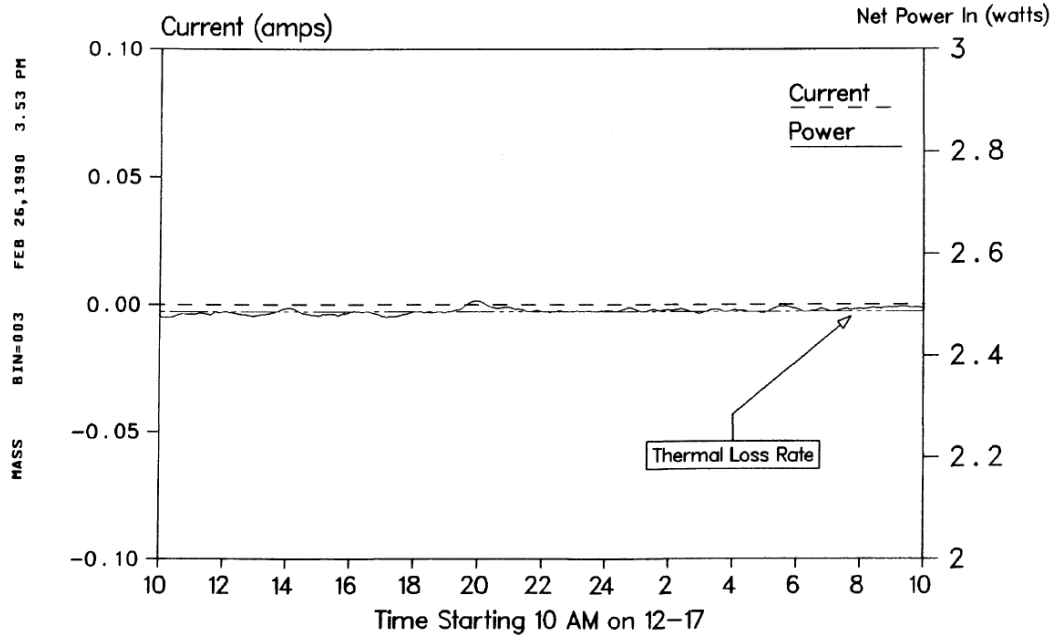


Figure 8. Final Calibration Curve

5. Conclusions

The system performed well within the design parameters. Although the system was operated at input powers of a few watts it would be relatively simple to modify the system to operate with a tenfold increase in power.

The operating temperatures used here can be changed, permitting the cell operating temperature to be varied while maintaining the same temperature gradient. Although the input power to the cell over the life of the experiment results in a large transfer of energy to the cell compared with the 50kJ of heat, the accuracy with which this power was measured is the basis for concluding that the heat effect is real.

Over the 56 day lifetime of the experiment (about 4 million seconds), the heat leak carried away a total of 10 MJ +/- 100 J. It is apparent the 50 kJ measured release is well within the limits of the performance of the system. The key point in support of this analysis rests on the accuracy and stability of the heat leak.

Finally, the tritium level in the electrolyte, initially at 2.5 +/- 1.0 picocuries/ml, increased after the experiment to 7.4 +/- 1.1 picocuries/ml. Although this level of tritium is insufficient to account for the 50 kJ of energy production observed, the apparent production of tritium increases the perception that the heat may be of nuclear origin.