

## Ways to Initiate a Nuclear Reaction in Solid Environments

Edmund Storms  
Energy K Systems, Inc.  
Santa Fe, NM

<http://home.netcom.com/~storms2/index.html>

### ABSTRACT

A large data base now exists to support the claim for nuclear reactions, including fusion, being initiated in solid environments at modest temperatures. This phenomenon is called Chemically Assisted Nuclear Reactions (CANR) or Low Energy Nuclear Reactions (LENR) or “cold fusion”. Detailed information supporting the claims can be obtained from the website (<http://home.netcom.com/~storms2/index.html>) as well as from any scientific data base. These claims provide the incentive for this study. In this work, methods to produce anomalous energy are studied using electrolytic loading in  $D_2O$  of various materials (the Pons-Fleischmann method). Past work has concentrated on using palladium as the active material. This paper will demonstrate that energy-producing reactions can be made to occur in materials other than palladium. A unique method is proposed to explore many of the variables associated with the phenomenon.

### INTRODUCTION

The so-called “Cold Fusion” nuclear reaction has now been studied for 12 years in eight countries resulting in over 3000 papers, many peer reviewed. An increasing number of techniques have been used to initiate the effect as shown in the Table 1. Gradually, more and more of these methods have produced anomalous results during independent duplication, as indicated in *red*. Of these, the first one has been duplicated hundreds of times in dozens of independent laboratories, including in this study. Nevertheless, duplication is difficult and frequently fails. Why is this the case? The most obvious answer, besides error, is that the unique condition required to initiate the effect is not always produced. The problem then is to identify this unique condition and to find ways to create it on demand. That is the goal of this study.

We now know for CANR to occur, very special conditions must be created within a solid. These conditions are required to bring the hydrogen or deuterium atom next to the target nucleus and then lower the coulomb barrier to allow nuclear interaction. This process must also carry away the energy produced. A number of theories have been proposed to explain how this barrier lowering is accomplished. Unfortunately, few of these models address how to produce the required environment. Two models have suggested characteristics that can be tested. These are the Chubb model[1] which focuses on a unique size for the active domain, and the Hora-Miley model[2] which focuses on the interface between two materials having different Fermi energies. Testing these models has been difficult because the required conditions are hard to achieve. I would like to describe a method that I have developed to make this test and show some of the results.

Past work has shown excess power production by electrodes other than palladium[3]. In addition, examination of such electrodes after energy production reveals areas in which molten metal was produced. In addition, a published examination by an imaging IR detector[4] while energy was generated showed many small regions of higher than ambient temperature. These observations suggest that the active regions are not in bulk metal, but are special regions that have grown or have been deposited on the surface of the cathode. This possibility is explored here.

---

**TABLE 1**  
**METHODS CLAIMED TO PRODUCE**  
**CANR or LENR**  
(Methods independently duplicated are shown in *red* )

- 1. Electrolysis of D<sub>2</sub>O-based electrolyte using a Pd or Pt cathode*
  - 2. Electrolysis of H<sub>2</sub>O-based electrolyte using a Ni cathode*
  3. Electrolysis of KCl-LiCl, D electrolyte using a Pd anode
  - 4. Electrolysis of various solid compounds in D<sub>2</sub> (Proton conduction)*
  5. Gas discharge (low energy ions) using Pd electrodes in hydrogen.
  6. Gas discharge (low energy ions) using Pd electrodes in deuterium.
  - 7 Ion bombardment (high energy ions) of various metals by D<sup>+</sup>.*
  8. Gas reaction (H<sub>2</sub>) with Ni under special conditions
  9. Cavitation reaction involving D<sub>2</sub>O and various metals using an acoustic field
  10. Cavitation reaction in H<sub>2</sub>O using microbubble formation
  - 11. Reaction of finely divided palladium with pressurized deuterium gas*
  - 12. Plasma discharge under D<sub>2</sub>O or H<sub>2</sub>O*
  - 13. Biological Systems*
- 

## METHOD

Of the several techniques used successfully, the electrolytic method of Pons and Fleischmann[5] has achieved the greatest understanding. This method is used here with excess energy production being the criteria of success. Two types of calorimeters have been employed; a flow-type and a Seebeck type[6]. An electrolyte consisting of 0.25 g Li<sub>2</sub>O + 50 ml D<sub>2</sub>O is used. The electrolyte was in contact with only Pyrex, Teflon, and Pt, besides the cathode material.

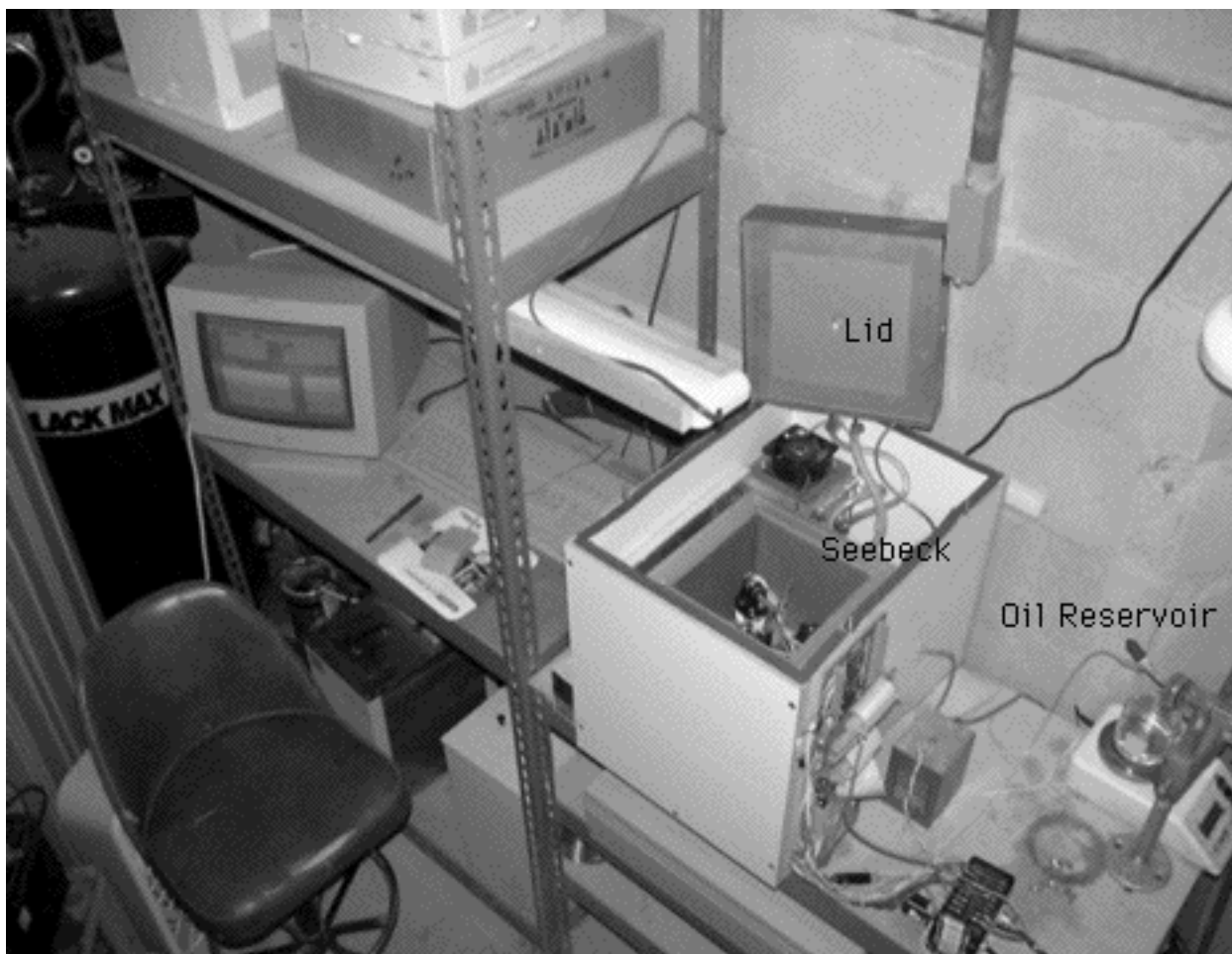
**Calorimetry:** A picture of the flow-type calorimeter is shown in the Fig. 1. The jacketed cell is contained in a Dewar flask and this assembly is contained in a box held at 20±0.02° C, a temperature equal to the input water temperature at the jacket. The cell is stirred at constant rate using a magnetic stirrer. When fully assembled, the Dewar is raised and the stirrer is slipped underneath. An insulated lid covers the Dewar. In this way, any energy that leaves the cell through its Teflon lid is contained in the Dewar where it can be captured by water flowing through the cell jacket. The characteristics of this apparatus are listed in Table 2. Error values noted in the table are based on the calibration equations listed in Table 3. These calibrations were made periodically during the study.

A picture of the Seebeck is shown in Fig. 2. Seen in the picture are the computer and the oil reservoir that seals the cell from the atmosphere. Oil leaves or enters the reservoir in response to changes in pressure within the cell. A change in weight of oil provides a means to monitor the amount of gas within the cell and the effectiveness of the recombiner. A picture of this device as used on the flow-type calorimeter can be seen on the web site noted above. The Seebeck envelope is water cooled at 20±0.02° C and contained in a box held at 20±0.02°C. A picture of the cell is shown in Fig. 3. The upper metallic region is designed to prevent electrolytic spray from attacking the Pt-carbon-based recombiner contained therein. This picture shows a cell to which cooling tubes are attached. Most of the work, to which the listed errors and equations apply, was based on a similar cell without these tubes.



**FIGURE 1.** Picture of open flow-type calorimeter

Both calorimeters were calibrated by using a clean Pt cathode or by using an internal Joule heater. Typical calibrations are shown in Fig. 4. The main difference between the two calorimeters is the temperature that the cell achieves as applied current is increased, with the Seebeck cell being forced to a much higher temperature. In all cases, excess power is the difference between

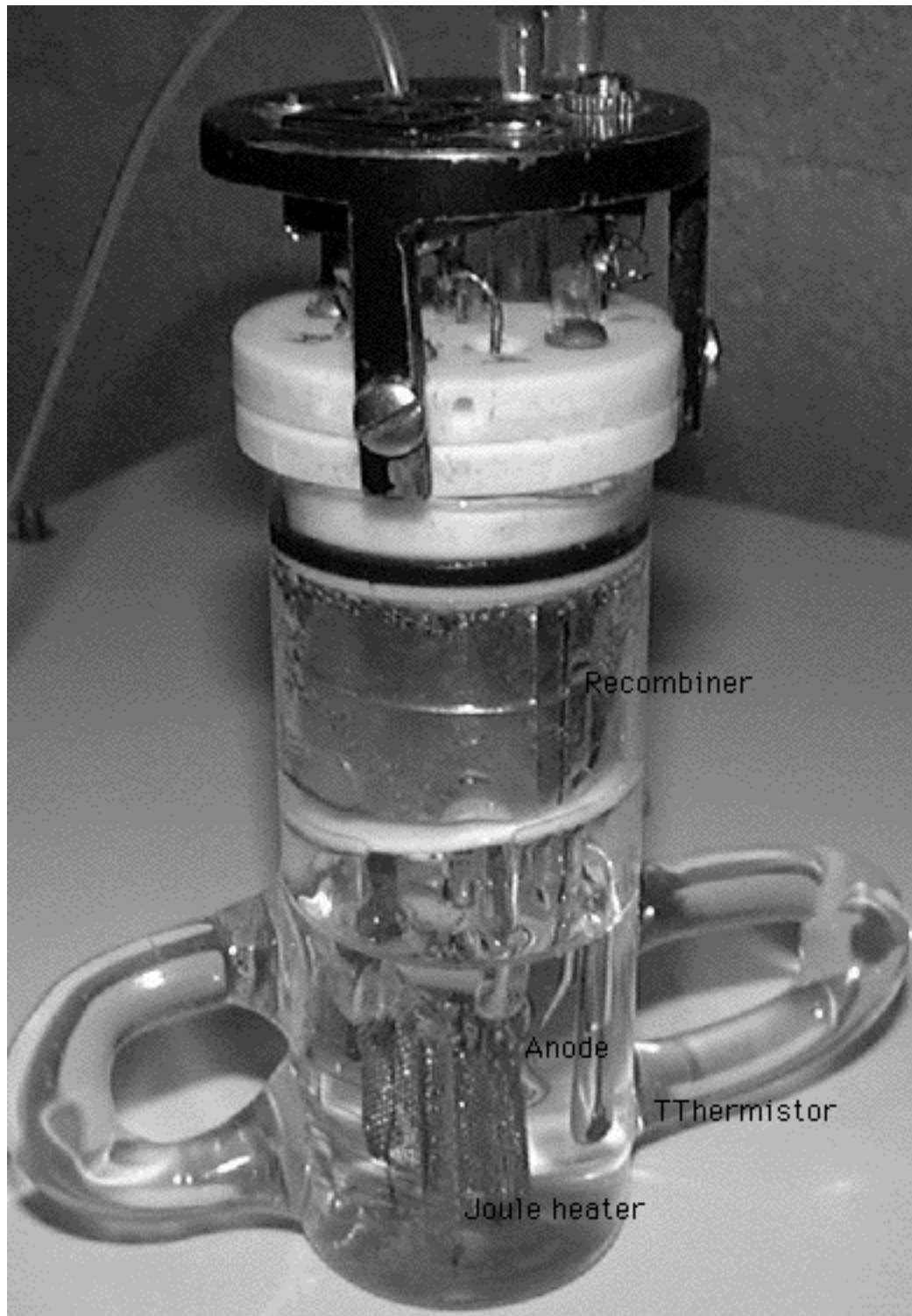


**FIGURE 2.** Picture of Seebeck calorimeter. A MacII fx computer is used while running Lab-view.

applied electrical power ( $V \times A$ ) and the resulting calculated heat based on the calibration equation.

**Sample Preparation:** When a material is electroplated, any particle of foreign material floating next to the cathode can be captured by the growing layer. Consequently, any type of insoluble, inert powder can be incorporated into the deposited metal. This material can then be subjected to high hydrogen or deuterium activity when the cathode is subsequently used in a Pons-Fleischmann electrolytic cell. Aside from providing a way to study materials that can not be fabricated into a coherent structure, suitable for a cathode, the process might also operate by chance in “normal” Pons-Fleischmann cells and be the source of active sites on the otherwise inert palladium cathode. In this case, slow deposition of Pt and Li would capture particles of PtO flaked from the anode or particles derived from the Pyrex, for example.

Samples were prepared by co-plating various powders along with palladium onto clean platinum or silver coupons (1 cm x 2 cm). The plating solution is one that is used in the jewelry trade and is based on an organic palladium compound (pH=5.6).



**FIGURE 3.** Picture of Seebeck cell with cooling tubes

---

**TABLE 2**  
CHARACTERISTICS OF CALORIMETERS

FLOW-TYPE  
[Original design]

Pt-carbon-based recombiner  
 Sealed with oil reservoir  
 Pt mesh anode  
 Average scatter within each data set =  $\pm 0.054$  W  
 Average uncertainty at 3 A between calibrations =  
 $\pm 0.08$  W (0.4% at 20 watts)  
 Average uncertainty in flow measurement =  
 $\pm 0.05$  g/min  
 Fraction of heat capture = 0.986

SEEBECK-TYPE  
[Thermonetics Corp.]

Pt-carbon-based recombiner  
 Sealed with oil reservoir  
 Pt mesh anode  
 Average scatter within each data set =  $\pm 0.030$  W  
 Average uncertainty at 3 A between calibrations =  
 $\pm 0.10$  W ( $\pm 0.5\%$  at 20 watts)  
 Average uncertainty using heater calibration =  
 $\pm 0.04$  W ( $\pm 0.2\%$  at 20 watts)

---

## RESULTS

A variety of materials were studied with some producing excess energy, but with most being dead. Even this method is not completely reproducible, although better than many.

TiO<sub>2</sub> + Pd TiO<sub>2</sub> power (20  $\mu$ m) was mixed with the Pd solution and plating was done at 14.5 mA for 2 hr onto a standard Pt coupon, with stirring. This process caused a weight increase of 0.032 g. After being placed in the Seebeck calorimeter, current was first increased (then decreased) in steps. Data shown in Fig. 5 were taken 90 min after each current change to insure thermal equilibrium. Calibration was done just before and just after the run using the electrolytic method and then the internal heater method. The plotted data are based on the internal heater calibration. Note that the electrolytic current is plotted for the sample, but the heater current is used for the calibration. Both produced about the same applied power at 3 A. The data suggest an increase in excess power as current is increased, as indicated by the sloping line. After the run, the sample was placed on Type 57 high-speed Polaroid film for 8 days. No exposure was seen.

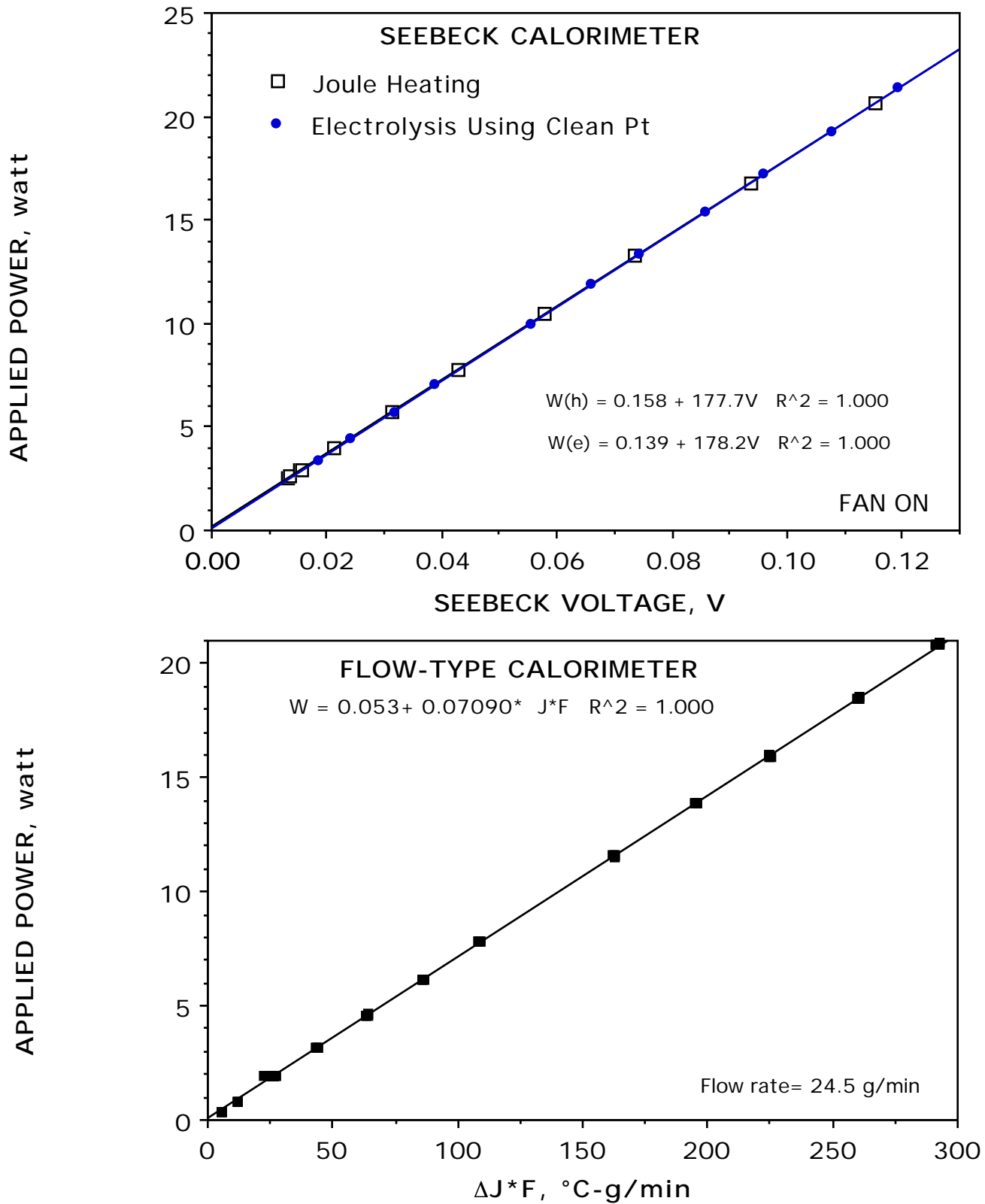
Carbon + Pd Carbon (0.4  $\mu$ m dia. threads) was mixed with Pd plating solution and two samples were made. The first was a Pt coupon plated at 0.1 A for 10 min with stirring, but not heated. This treatment produced a weight gain of 0.00536 g. The second Pt coupon was plated at 0.1 A for 18 min while being stirred and heated to over 50°C. A weight gain of 0.0262 g was

measured. The first sample was placed in the flow-type calorimeter and studied by the usual step method with a delay of 60 min after the current change before data were taken. This sample was removed and replaced by the second sample, which was studied in the same manner. After this run, the sample was removed and replaced by a clean Pt cathode, and calibration was done in the same manner. Next, the second sample was returned to the flow-type calorimeter and rerun. All of the measurements are plotted in Fig. 6. Apparently, similar excess power was produced by the two samples and it increased with applied current.

**TABLE 3**  
Coefficients in Calibration Equations

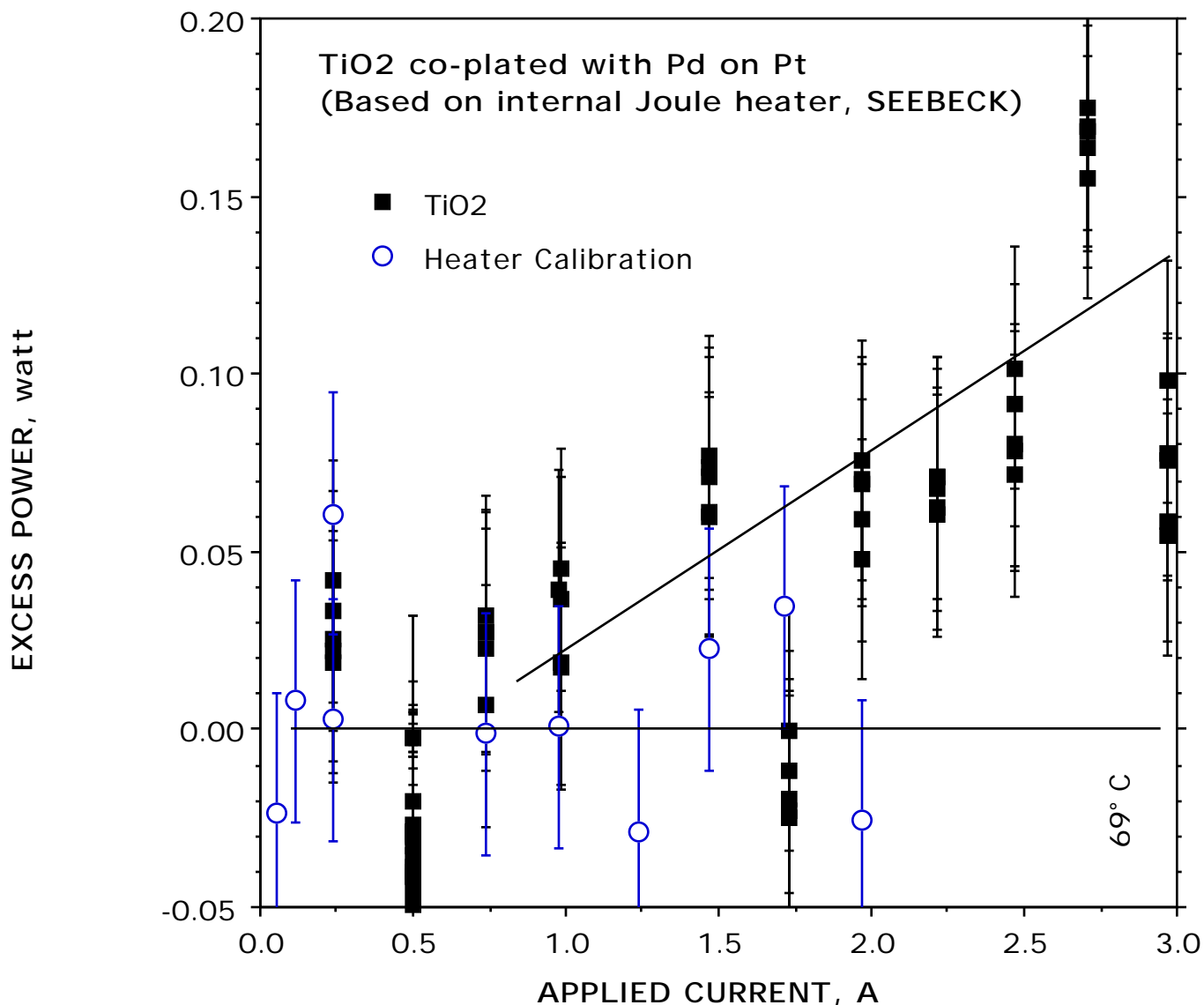
FLOW-TYPE CALORIMETER			
Coefficients in the Equation			
Watt = A + B*( J*F)			
A	B	Flow Rate (F)	
		(g/min)	
-0.0032	0.07090	29.22	
0.0033	0.07090	29.30	
-0.0150	0.07051	29.30	
-0.0140	0.07042	29.30	
0.0590	0.07079	24.30	
0.0746	0.07040	24.50	
0.0530	0.07090	24.50	
AVERAGE=	<b>0.0225</b>	<b>0.07069</b>	
STANDARD DEVIATION=	<b>±0.0382</b>	<b>±0.00020</b>	
( J = temperature of water between inlet and outlet of jacket)			
SEEBECK CALORIMETER			
Coefficients in the Equation			
Watt = A + B*(Seebeck Volt)			
A	B	Method	
0.139	178.16	E	
0.178	177.42	H	
0.134	179.81	E	
0.132	178.97	E	
0.108	179.30	H	
0.133	178.74	E	
0.138	178.78	H	
AVERAGE=	<b>0.137</b>	<b>178.74</b>	
STANDARD DEVIATION=	<b>±0.021</b>	<b>±0.77</b>	
(H = internal Joule heater; E = electrolysis using clean Pt cathode)			

Sterling Silver + CO<sub>2</sub> A coupon of Sterling silver was electrolyzed at 7-20 mA for 24 hr as the cathode in a cell containing a saturated solution of CO<sub>2</sub> in distilled water. A weight gain of 0.00049 g was measured and the sample was observed to have acquired a yellow-gray coating. This sample was placed in the flow-type calorimeter and run in the usual manner, followed by calibration. The result is shown in Fig. 6. Higher apparent excess power was seen as the current was decreased compared to when it was increased during the initial steps. In addition, holding the current at 2 A caused a steady decrease in excess power, as shown in Fig. 7. Allowing the sample to remain in the electrolyte without applied current caused a loss of silver from the surface and a complete loss of excess power. Following this run, the previously clean Pt calibration



**FIGURE 4.** Graphs of typical calibrations for the flow-type and Seebeck calorimeters.



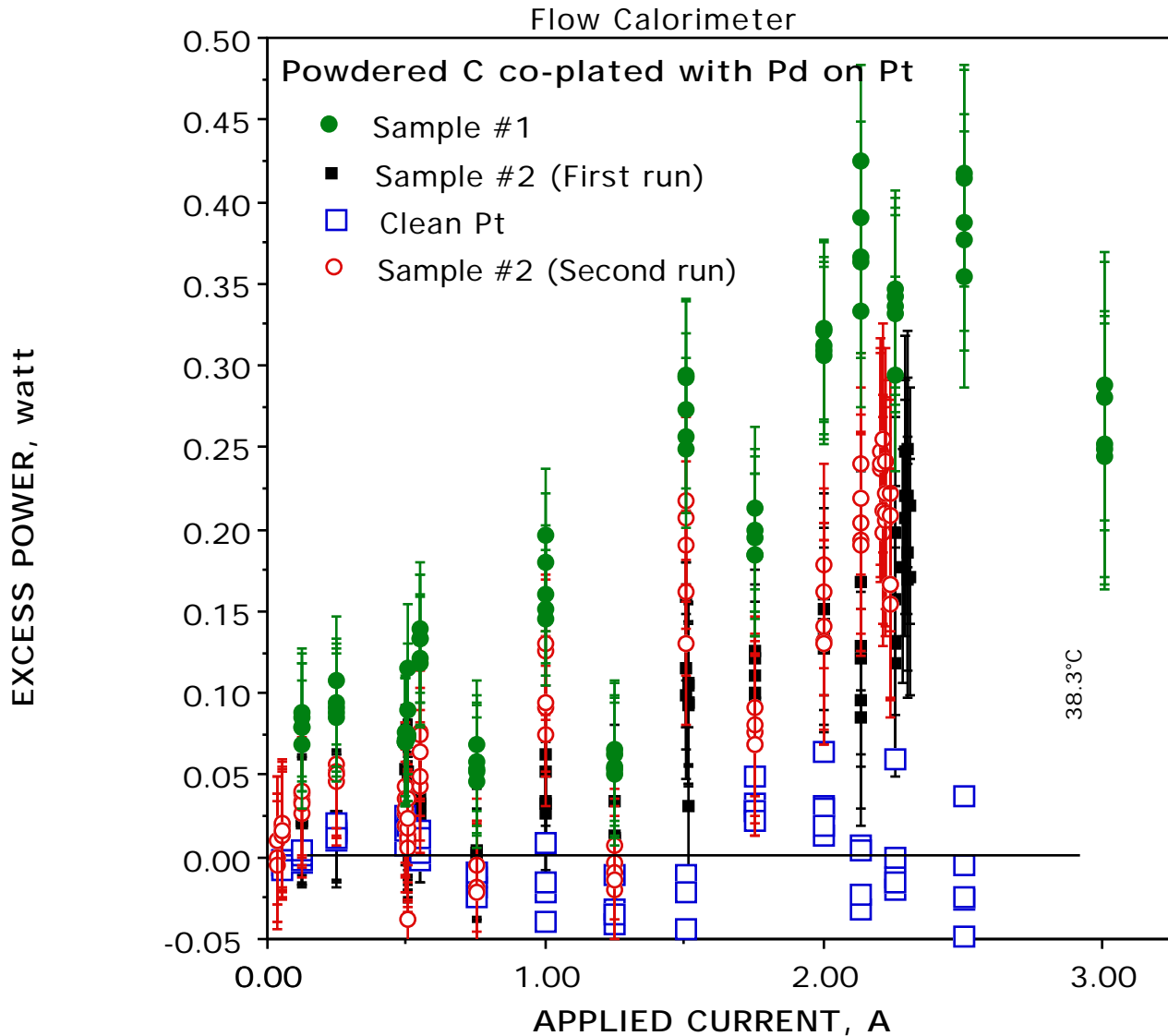


**FIGURE 5.** Effect of applied current on excess power production using a cathode made from TiO<sub>2</sub> co-deposited with Pd.

cathode was found to have acquired a surface coating of Ag and to have produced apparent excess power, although not as much as the Ag sample.

CeO<sub>2</sub> + Pd Powdered CeO<sub>2</sub> (0.8 μm) was mixed with the plating solution and two samples were made. The first (C#6) was made by plating on a Pt coupon at 50 mA for 6 min, with stirring and heating. A weight gain of 0.00625 g was produced. The second sample (F#1) was plated at 20 mA for 109 min, with stirring and heating, and showed a weight gain of 0.04208 g. Both samples were studied in the Seebeck calorimeter with the result plotted in Fig. 8. Next, sample F#1 was transferred to the flow-type calorimeter and studied in the usual manner. As can be seen in Fig. 8, sample F#1 produced similar, although small amounts of excess energy in both

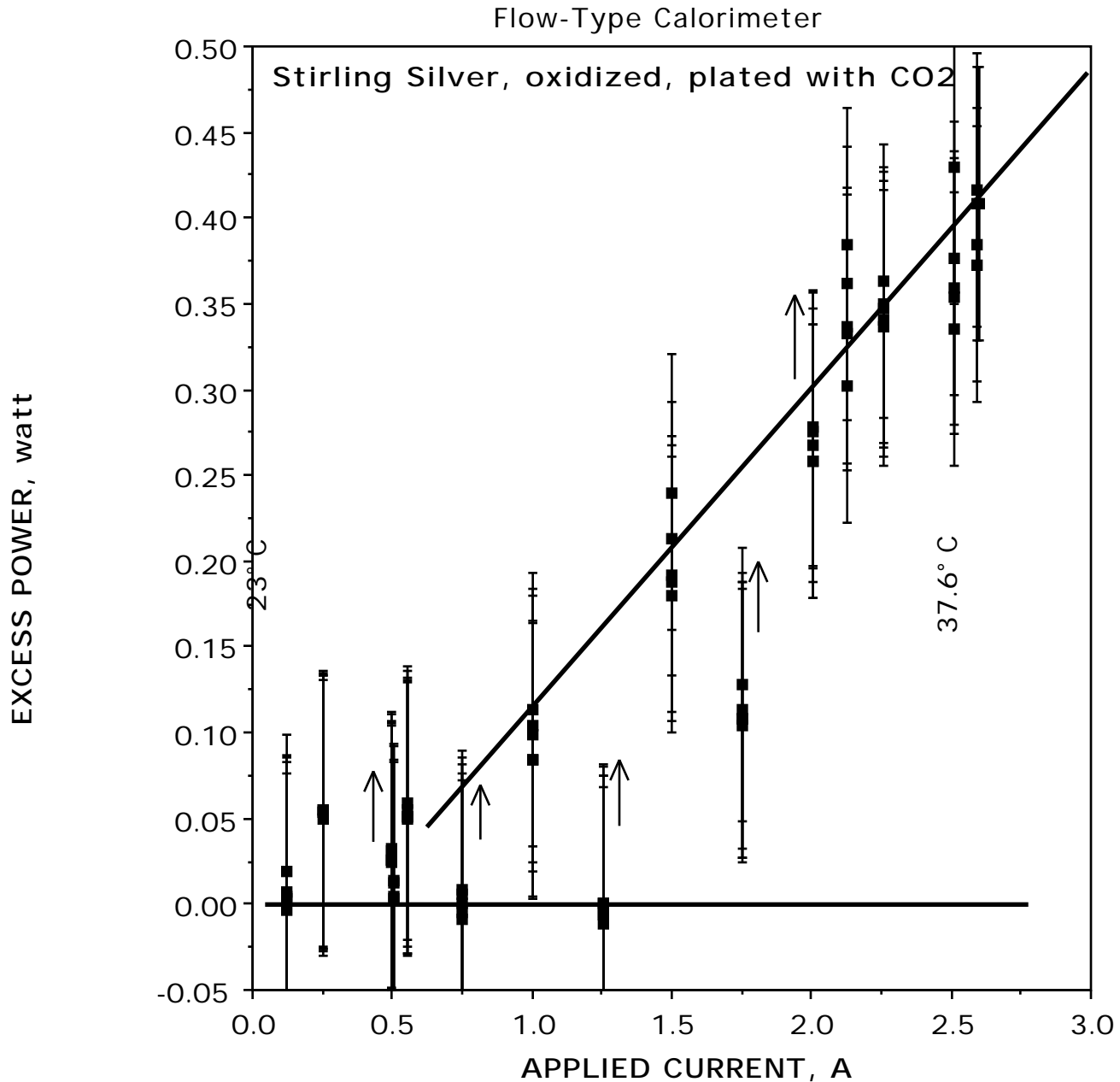
calorimeters. In addition, the effect of applied current was similar, even to the extent that the same currents produced the same behavior. Note the abrupt rise above 2.0 A and the drop at 3.0 A in both cases, in spite of different temperatures being applied and use of entirely different data acquisition systems. Sample C#6 was essentially dead in the Seebeck calorimeter.



**FIGURE 6.** Effect of applied current on excess power production using a cathode made by co-plating carbon with palladium.

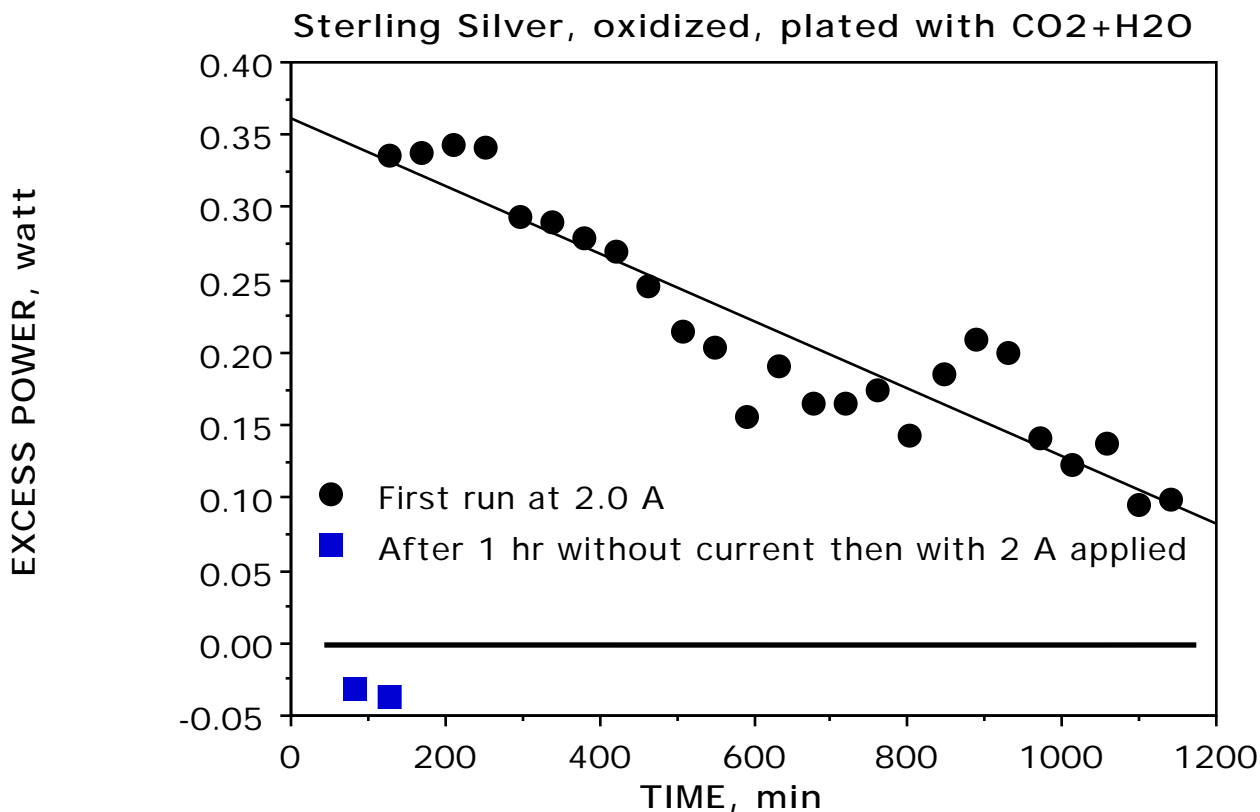
## DISCUSSION

Skeptics have previously concluded that any claim for excess power under these conditions must be caused by ignored errors in calorimetry. This study has used two different types of calorimeter and found excess power that lies outside of a careful evaluation of random errors in both instruments. In addition, samples made using the same technique were found, on occasion, to give similar values for excess energy. While the results might be caused by random error, the pattern of behavior is consistent with previous reported studies and with the assumption that the nature of the material is the main variable



**FIGURE 7.** Effect of applied current on excess power production using a cathode made by depositing carbon from CO<sub>2</sub>+H<sub>2</sub>O solution onto sterling silver.

affecting apparent excess energy production. Once error is no longer a viable explanation, a problem remains to understand what about the sample causes the effect. This study can not fully answer the question at this time. It can only show that by co-plating finely divided materials of various kinds, excess energy can be produced more frequently than was previously possible. An interpretation of the behavior must await use of proper diagnostic tools to see just how the small grains of material are situated within the palladium layer. For example, one might speculate that the grains of oxide, being completely surrounded by palladium, are prevented from losing oxygen as they would on the surface. Consequently, they can be exposed to a higher deuterium activity without being changed, thereby producing unexpected behavior. Grains of carbon, on



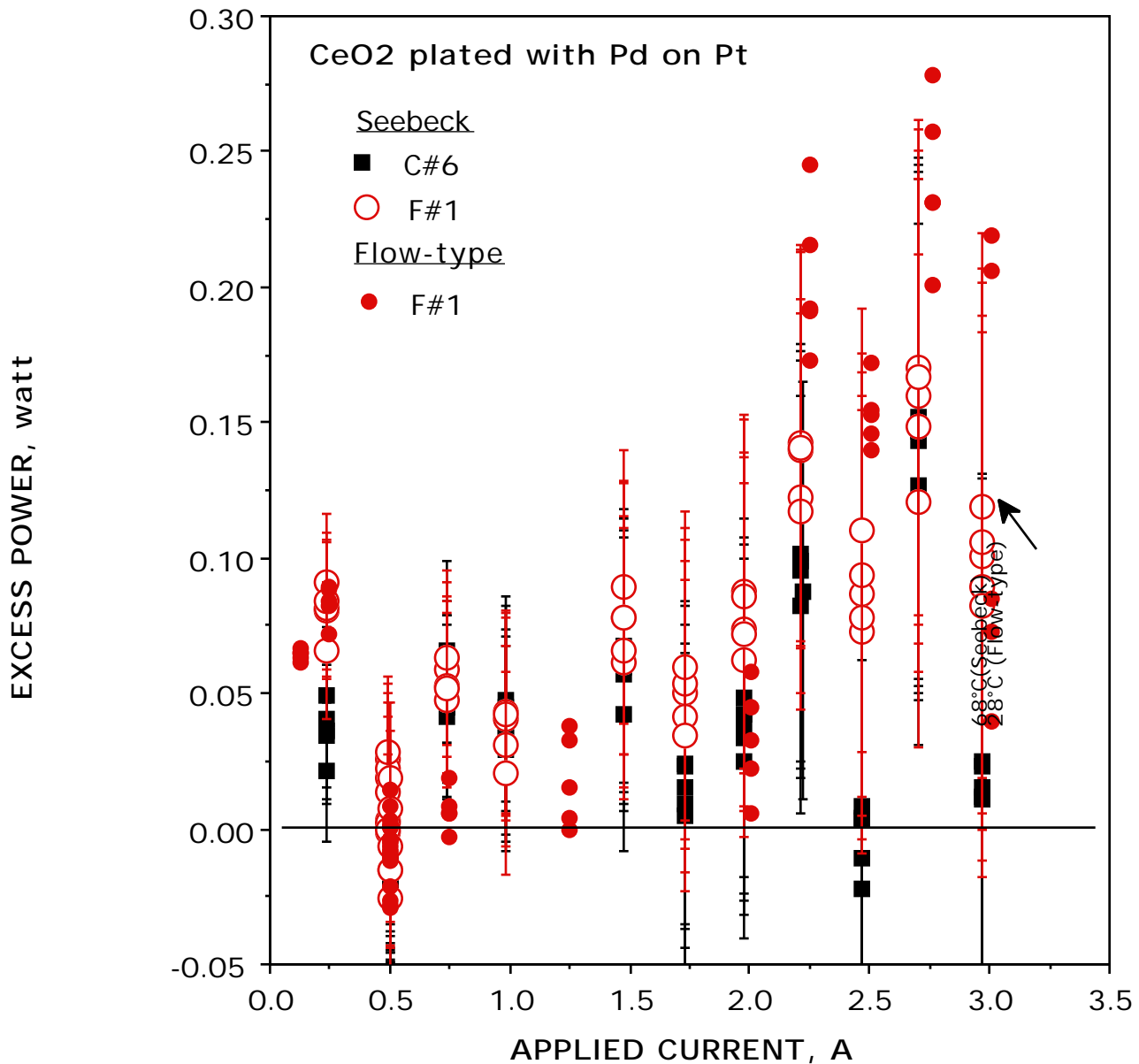
**FIGURE 8.** Effect of time at 2 A on excess power production using the Ag+C cathode.

the other hand, can have a physical form that is not possible under equilibrium conditions within bulk palladium metal. In addition, such grains can not be made into a coherent structure suitable for use as a cathode, hence this method is the only one available for their study. After being incorporated within Pd, the carbon grains could then absorb deuterium at very high activity from the surrounding Pd and obtain a deuterium content not possible under any other condition. Introduction of various powdered metals would allow the model of Hora-Miley to be tested without layer separation normally experienced in past attempts. The Chubb model could be easily tested by incorporating particles of different sizes, something that is not possible to do in normal bulk palladium. While this study focused on palladium, the method can also use any metal that can be plated from solution. The number of available possibilities is much greater than the resources presently available to the author for their exploration. An additional advantage of the method is production of excess energy without delay, in contrast to the usual experience when the Pons-Fleischmann method is used.

Production of excess power from Pd in contact with various oxides is unexpected. Such materials are good insulators without an occupied Fermi band and do not take up much hydrogen within their structure. It would seem that they qualify as suitable materials for neither the Chubb nor the Hora-Miley models.

This study is unique in using two different types of calorimeter to test the same sample. Although the amount of excess energy is small, it is outside of expected random error. More interesting is the observation that excess power, in both cases, shows the same complex relationship to applied current, even at two different temperatures. Eagleton and Bush[7] found a similar fine-structure when studying cells containing H<sub>2</sub>O with a Ni cathode. Swartz[8] also reported a

similar fine-structure he attributes to an optimum operating point (OOP), although in this case the fine structure was seen in the applied power vs excess power fraction relationship.



**FIGURE 9.** Effect of applied current on excess power production using a cathode made by co-plating CeO<sub>2</sub> and Pd on Pt. Also shown is a comparison between excess power production using the same sample in the flow-type and the Seebeck calorimeters.

## CONCLUSION

1. Co-plating with various finely divided suspensions makes possible a unique exploration of many variables associated with the Pons-Fleischmann effect and shows a reproducibility greater than has been obtained in the past.
2. This study has produce anomalous power on several occasions using different calorimeters and materials. The amount of material being used is too small to offer a conventional chemical

explanation.

## References

- (1) Chubb, T. A. and S. R. Chubb, "Cold Fusion as an Interaction Between Band States", *Fusion Technol.* **20** (1991) 93.
- (2) Hora, H., Kelly, J. C., Patel, J. U., Prelas, M. A., Miley, G. H., and Tompkins, J. W., "Screening in Cold Fusion Derived from D-D Reactions", *Phys. Lett. A* **175** (1993) 138.
- (3) Lonchamp, G., Biberian, J.-P., Bonnetain, L., and Delepine, J. 1998. "Excess Heat Measurement with Pons and Fleischmann Type Cells" *Proc. of the Seventh International Conference on Cold Fusion*, April 19-24, Vancouver, Page 202.
- Dash, J. "Chemical Changes and Excess Heat Caused by Electrolysis with H<sub>2</sub>SO<sub>4</sub>-D<sub>2</sub>O Electrolyte", *Proc. Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*, Oct. 13-18, 1996 (M. Okamoto, ed.) New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan (1997), Vol. 2, page 477.
- Ohmori, T., Mizuno, T., and Enyo, M. 1996. "Isotopic Distributions of Heavy Metal Elements Produced During the Light Water Electrolysis on Gold Electrodes", *J. New Energy* **1**, #3, 90. See also: Notoya, R. and Enyo, M. 1992. "Excess Heat Production during Electrolysis of H<sub>2</sub>O on Ni, Au, Ag and Sn Electrodes in Alkaline Media," *Proc. Third International Conference on Cold Fusion*, October 21-25, Nagoya Japan, *Frontiers of Cold Fusion*, (H. Ikegami, ed), published by Universal Academy Press, Inc., Tokyo, Japan, p. 421; Ohmori, T. and Enyo, M. 1993. "Excess Heat Evolution During Electrolysis of H<sub>2</sub>O with Nickel, Gold, Silver, and Tin Cathodes," *Fusion Technol.* **24** (1994) 293.
- Storms, E., "Excess Power Production from Platinum Cathodes Using the Pons-Fleischmann Effect", *Proc. 8th International Conference on Cold Fusion*, Lerici, Italy, May 21-26, 2000.
- (4) Mosier-Boss, P. A. and S. Szpak, "The Pd/<sup>1</sup>H System: Transport Processes and Development of Thermal Instabilities", II. *Nuovo Cimento* **112A**, #6 (1999) 577.
- (5) Pons, S., and M. Fleischmann, "Calorimetric Measurements of the Palladium/Deuterium System: Fact and Fiction", *Fusion Technol.* **17** (1990) 669.
- (6) Manufactured by Thermonetics Corp. (Heinz Poppendiek) 7834 Esterel Drive, La Jolla, CA 92037 (858 453 5483)
- (7) Eagleton, R. D., and R. T. Bush, "Calorimetric Experiments Supporting the Transmission Resonance Model for Cold Fusion", *Fusion Technol.* **20** (1991) 239.
- (8) Swartz, M., "Optimal Operating Point Characteristics of Nickel Light Water Experiments", *Proceedings of The Seventh International Conference on Cold Fusion*, Vancouver, Canada, April 19-24, 1998, ENECO, Inc., Salt Lake City, UT. (1998), page 371