# SOME CHARACTERISTICS OF HEAT PRODUCTION USING THE "COLD FUSION" EFFECT

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## Abstract

Additional evidence is presented to show that heat production resulting from the Pons-Fleischmann Effect has a positive temperature coefficient, has a critical onset current density, and originates at the palladium cathode.

## Introduction

The Pons-Fleischmann effect is proposed to produce energy by initiating a fusion reaction between two deuterium atoms within an electrolytic cell. While an understanding of this phenomenon is still lacking, the reality of anomalous heat production has been established by many studies.

Work done during this program demonstrates that the effect can be reproduced when the proper palladium and protocols are used. During the first part of the study[1], the methods of Takahashi[2] were used with success. The present study reproduced the effect using the addition of aluminum to the electrolyte as first suggested by McKubre et al.[3]. These studies also revealed several of the reasons why negative results were obtained in the past.

This work further defines conditions that influence excess heat production. The effects of current density and cell temperature are explored. The location within the cell from which excess heat production originates is also determined.

## Experimental

The study uses a closed, stirred, pyrex-glass, isoperibolic-type calorimeter as described previously[1]. Calibrations were done using the electrolytic method before excess energy was observed and an internal heater after excess heat production started. Generally, calibration was done before and after excess heat production. No significant changes were observed in the calibration constant during the study. The total uncertainty in the measured heat value was about ±4%. Because random variations of ±0.2 watt were observed, excess heat was not claimed unless the excess exceeded 0.5 watt. Details of the calorimeter design and the calibration methods are described in reference 1.

A palladium cathode obtained from Tanaka Metals Company, Japan, (Batch #4) was used after being washed with acetone. This was charged with deuterium in 0.4M LiOD at 20 $mA/cm^2$ until the D/Pd ratio became constant at 0.84 after 9 hours. The charging behavior was similar to that produced by Batch #1 which produced significant excess heat.[1] Electrolysis was continued with variations in cell current, cell temperature, and periodic calibrations without the production of excess energy. After 575 hrs, excess heat was observed following the addition of 28 ppm of aluminum to a new electrolytic solution. Once excess power was observed, the magnitude of the excess increased each time the cell current was raised to 2.5 A as shown in Fig 1. Eventually, excess power became stable and the study was commenced.
The excess volume in this sample is 2% when the D/Pd ratio is 0.7.

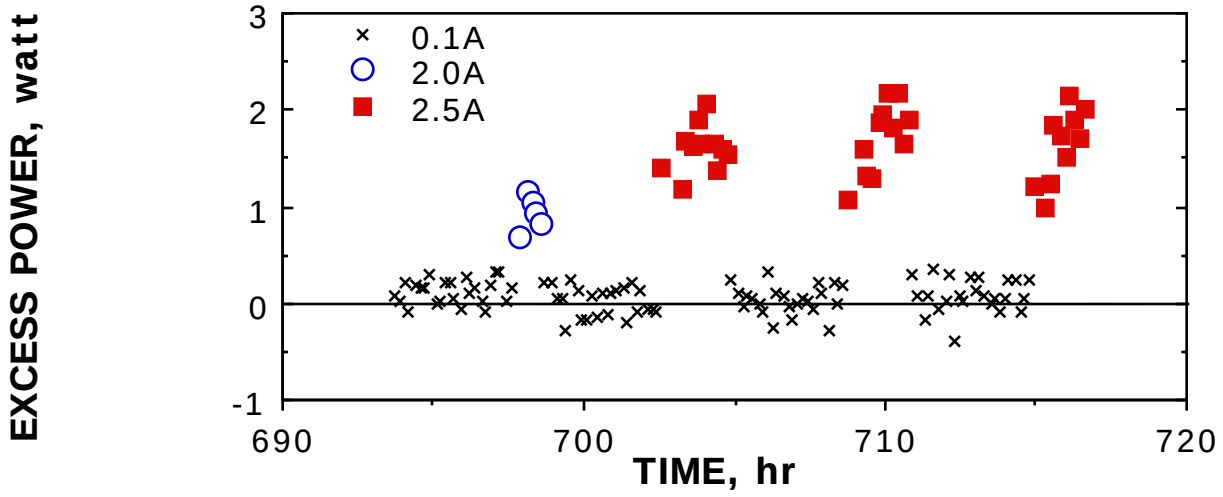


**FIGURE 1.** Variation of excess power at 0.1 A, 2.0 A and 2.5 A as a function of time.

The anode-cathode assembly was modified to allow temperature measurement near the cathode. Figure 2 shows the configuration of the anode-cathode assembly and the location of the glass encased thermocouple probes. Because the anode is made from platinum wire mesh, fluid flow is restricted and the inner probe tends to have a higher temperature than the outer probe when heat originates at the palladium cathode. Consequently, the location of excess heat is revealed by this design.

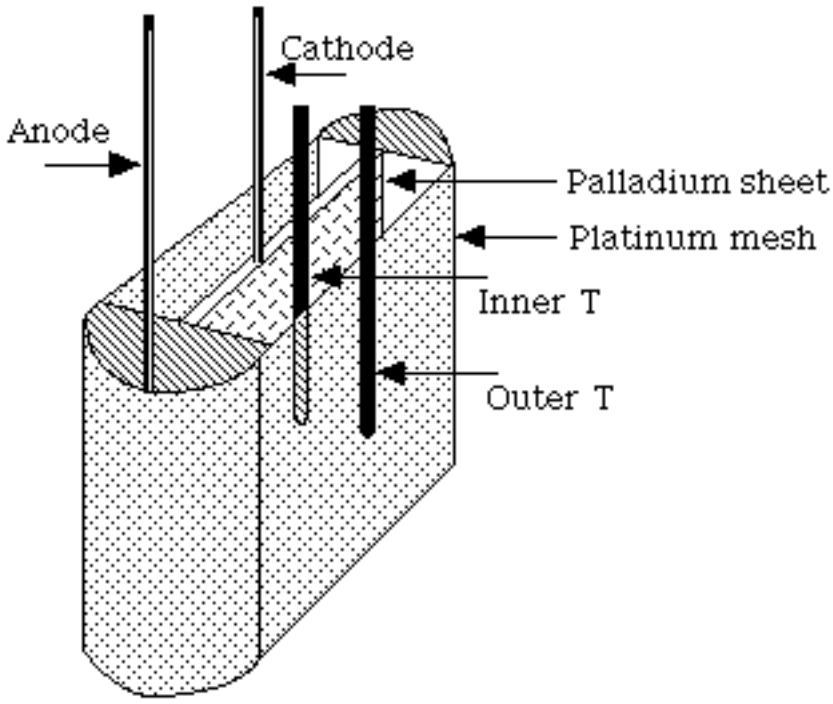


**FIGURE 2.** View of the anode-cathode assembly showing the location of thermocouple probes.

## Results

### *Relationship Between Cell Current and Excess Power*

The effect of cell current is determined by changing the cell current from 0.1 A to 3 A in steps and back down to 0.1 A. This cycle is repeated twice during each data set. Steady-state is reached after 15 min and the current is maintained constant for an additional 15 min. Data are taken each minute during this second interval and averaged to give the plotted value.

Figure 3 compares several examples of how the current density affects excess power density. Most of the plotted points showing the behavior observed during other studies are averaged values extracted from published graphs containing many points. Several studies show a clear onset to the production of excess energy near 0.1 A/cm$^2$. Pons and Fleischmann were the first to mention the effect and Kainthla et al.[4] were the first to show data. While these studies all give current onset values between 0.05 and 0.1 A, a variety of values have been observed in this study. In earlier work[1], the onset was above 0.35 A/cm$^2$. This variation in onset value may partly account for the early lack of reproducibility if the onset happened to be larger than the applied current.

There is a wide variation in the slope of the lines. These differences in slope are believed caused by variations in the area producing the excess energy. The slope reported by McKubre et al.[3] is affected by a very nonuniform current density typical of their apparatus. The slope through the data reported by Kunimatsu et al.[5] is uncertain because the data are reported as W/cm$^3$ and insufficient information is provided to allow an accurate conversion to W/cm$^2$. Although not shown in the figure, a variation in slope over an extended time can be seen in the low-high values reported by Takahashi et al.[6]. McKubre et al.[3], Kunimatsu et al.[5], Hasegawa et al.[7], and Mizuno et al.[8] show that this relationship is caused by an increased D/Pd ratio that results when the current density is increased. Apparently, the D/Pd ratio for a fixed current and/or the affected area are not constant during extended electrolysis nor between studies.

There is no indication in any of the studies for the fine structure reported by Bush[9] and required by his theory.

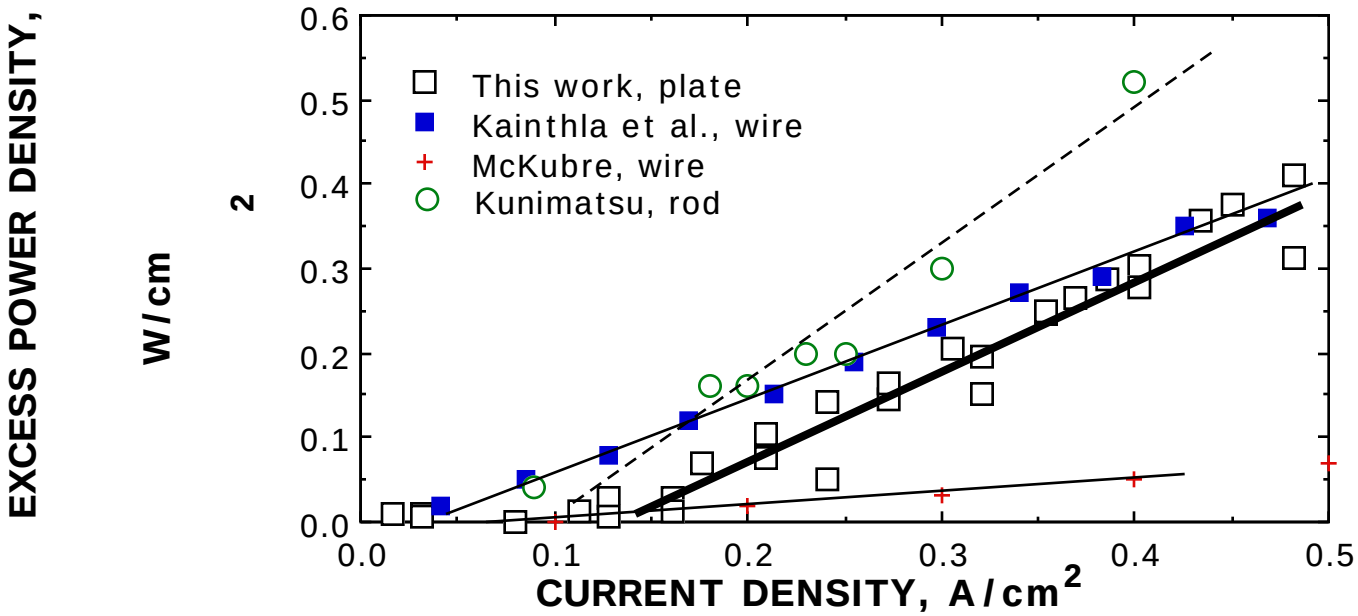

**FIGURE 3**. Relationship between excess power density and current density.

### *Source of Excess Energy*

Three potential sources of energy can be suggested to exist in the cell. These are (1) the energy being applied to the cell as current, (2) the energy that results from any chemical reactions within the cell, and (3) the energy that is called excess. Some people believe that sources (2) and (3) are identical. Nevertheless, it is instructive to find the physical source of excess energy within the cell.

Figure 4 shows the temperature difference between thermocouples located outside and inside the anode structure. The solid line results when the applied power is increased in the absence of excess power. Up to 40 watts of applied power is used to determine this line. Clearly, normal electrolytic power has very little effect on this temperature difference. On the other hand, production of excess power causes a marked increase in the temperature near the cathode compared to that outside the anode. A+0.25° offset error is present in the calibration of the two thermocouples and should be ignored. This result indicates that the excess power originates at or near the cathode. Changes in this relationship over a period of time indicates that the location of power production on the cathode gradually changes.

Two thermocouples located outside the anode-cathode structure in a region that is actively stirred are used to determine the calibration constant. Therefore, the warming trend within the anode-cathode structure does not affect the calibration of the calorimeter.

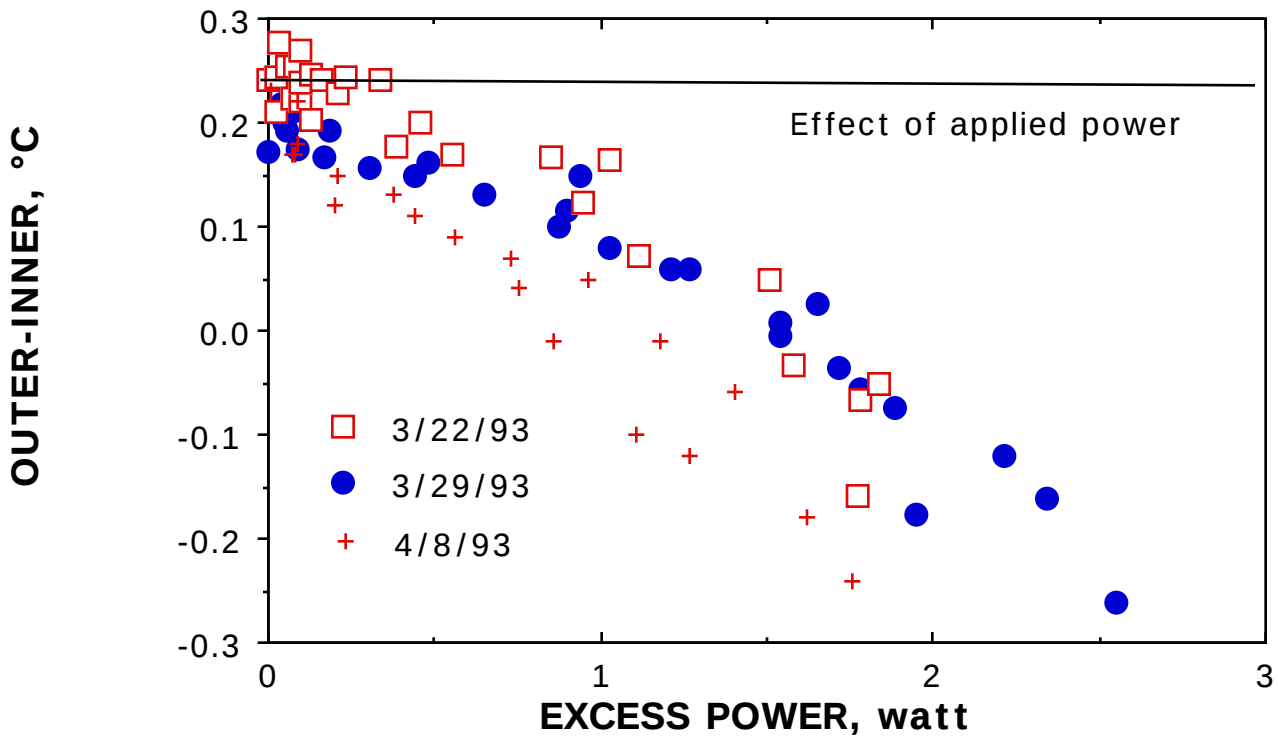


**FIGURE 4.** Temperature difference between thermocouples located near the anode and near the cathode as a function of power. The line results from applied power in the absence of excess power and the points result from only excess power.

### *Effect of temperature on excess power production*

The effect of temperature on excess power production is determined as follows. The cell temperature is increased at fixed electrolysis current (1.8A) by applying power to the internal heater. This additional power is subtracted from the total power when calculating excess power. While this method avoids changes in the calibration constant, it has a very limited temperature range. Consequently, the calculated temperature coefficient must be viewed as an approximation. Clearly, this measurement needs to be made over a wider temperature range and for various current densities.

Figure 5 shows the relationship between cell temperature and excess power. Excess power is chosen over percent excess power for the following reasons. When temperature is increased, the cell resistance is reduced, thereby reducing the applied power. Consequently percent excess power increases more rapidly than does excess power alone. Because the cell resistance depends on the geometry of the cell and variable characteristics of the electrolyte, this ratio is not a fundamental property of the phenomenon.

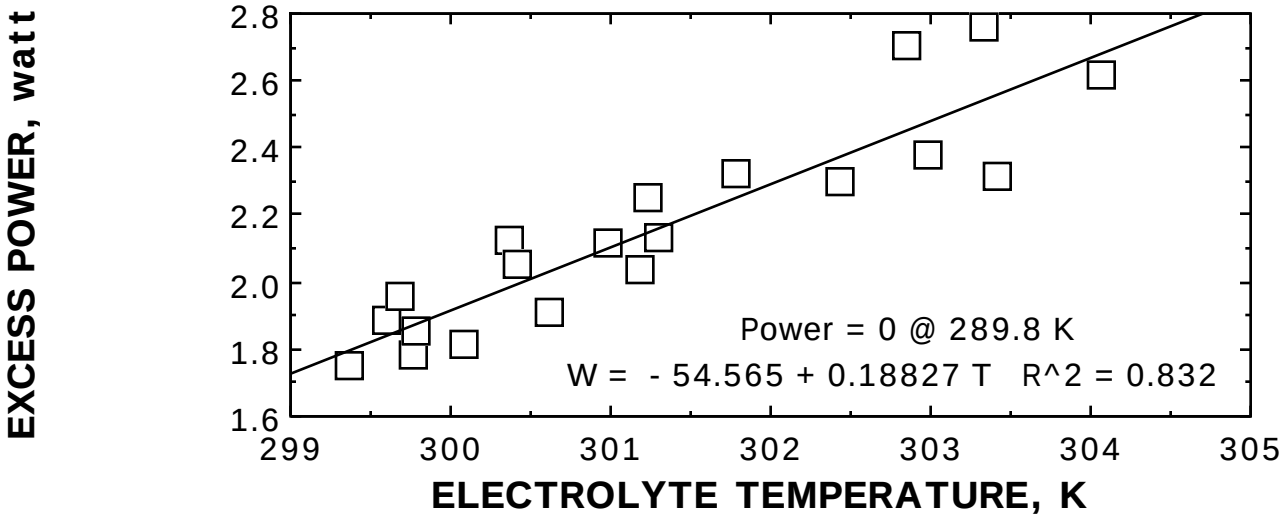


**FIGURE 5.** Relationship between excess power and cell temperature.

When plotted as log excess vs 1/T (Figure 6), the energy of the chemical reaction affecting excess heat production is determined to be about 15 kcal/mol.

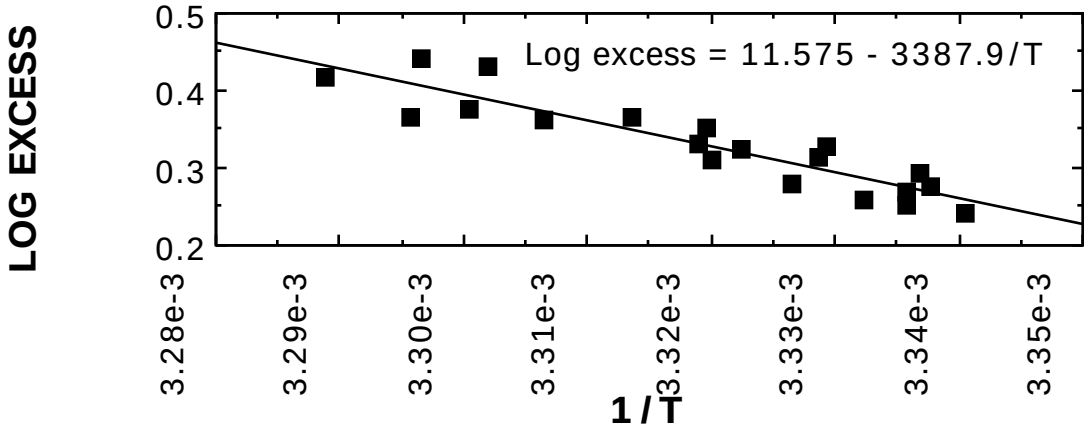

**FIGURE 6.** Relationship between log excess heat and 1/T.

## Conclusions

Reproductivity of the Pons-Fleischmann Effect is no longer an issue. If proper palladium and protocols are used, a high probability of successful excess energy production can now be expected using the electrolytic technique.

The amount of excess power production depends on the D/Pd ratio above a critical value and the area of the palladium having the necessary ratio. The region having the necessary deuterium concentration changes with time during electrolysis. Those factors that affect the deuterium concentration are different between different studies and change with time during a study. This variability adds to the difficulty in achieving stable heat production.

The D/Pd ratio is sensitive to chemical conditions that exist on the surface of the palladium. These chemical conditions produce a temperature coefficient for the heat producing reaction that imply a barrier energy of ≈15 kcal/mole. The large magnitude of this value suggests that deuterium diffusion in palladium is not the rate limiting step. Because this reaction plays a major role in achieving the necessary deuterium concentration, a more detailed study is essential.

## Acknowledgement

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