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# Anomalous Heat Generated by Electrolysis Using a Palladium Cathode and Heavy Water

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## ABSTRACT

Samples of palladium sheet supplied by IMRA Japan were tested for anomalous energy production using electrolysis in heavy water and a sensitive calorimeter. Several samples were found to produce significant power above that being applied to produce electrolysis. This behavior was found to correlate with certain properties of the palladium metal. In addition, the anomalous heat was shown to originate at the cathode

## INTRODUCTION

Ten years ago, Profs. Pons and Fleischmann claimed to produce excess energy when palladium was electrolyzed in $D_2O$. Unfortunately, this claim was very difficult to duplicate. The present study was undertaken to understand the nature of palladium which might affect those conditions needed to initiate the claimed anomalous reaction.

It is generally agreed by people in the field that a very high D/Pd ratio is required and this high composition exists in the near surface region. Very few samples of palladium are able to achieve this high composition, much less produce excess energy. If conditions affecting the ability to reach high compositions could be understood, potentially useful palladium could be identified and the claims could be explored with greater success. At least then, the reality of the claims could be better evaluated.

## EXPERIMENTAL

The basic reason most palladium is not able to achieve high compositions is because the metal expands and forms submicroscopic cracks upon reacting with hydrogen. These cracks provide a pathway for hydrogen loss. Figure 1 shows how palladium expands as hydrogen is added. When the measured volume follows the line, based on the lattice parameter, no cracks are present. However, when the measured volume rises above the line, the presence of internal cracks is indicated. Fig. 2 shows a histogram of the amount of excess volume in a collection of palladium samples. As you can see, only a few samples have a small amount of crack

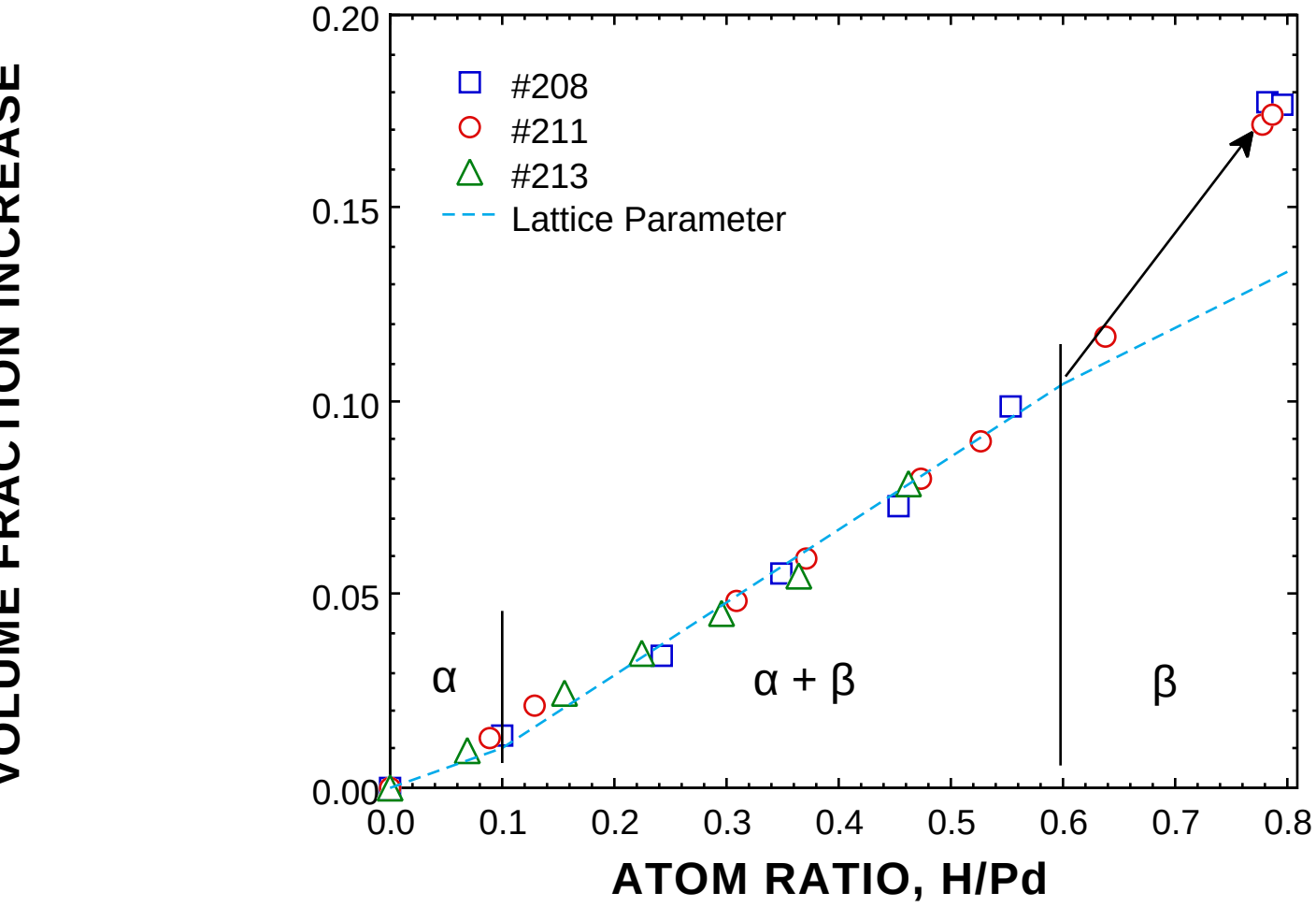


**FIGURE 1.** Volume increase caused by hydrogen addition with palladium. Excess volume is seen to increase as hydrogen is added within the beta phase.

formation, a requirement for achieving high surface compositions. Indeed, samples having excess volume above about 3% are essentially useless. It is easy to measure the average composition of a sample. However, because the required composition exists in a thin region near the surface, determining a value for the active region is another matter. Fortunately, the average activity of hydrogen at the surface can be determined by measuring the average open-circuit-voltage (OCV). This quantity is obtained by measuring the voltage between the sample and a stable reference electrode, in this case platinum, while the applied current is interrupted for about 1 sec. Figure 3. shows how the OCV changes with time as a sample reacts with deuterium. Typically, the value rises while deuterium is added to the alpha phase, remains constant while α-phase converts to β-phase, then rises again as deuterium is added to the beta phase. A reverse behavior is seen when current is turned off for an extended time and the contained deuterium is allowed to leave the sample, as shown in Fig 4. Given enough time, all deuterium will leave the metal

as $D_2$ gas.

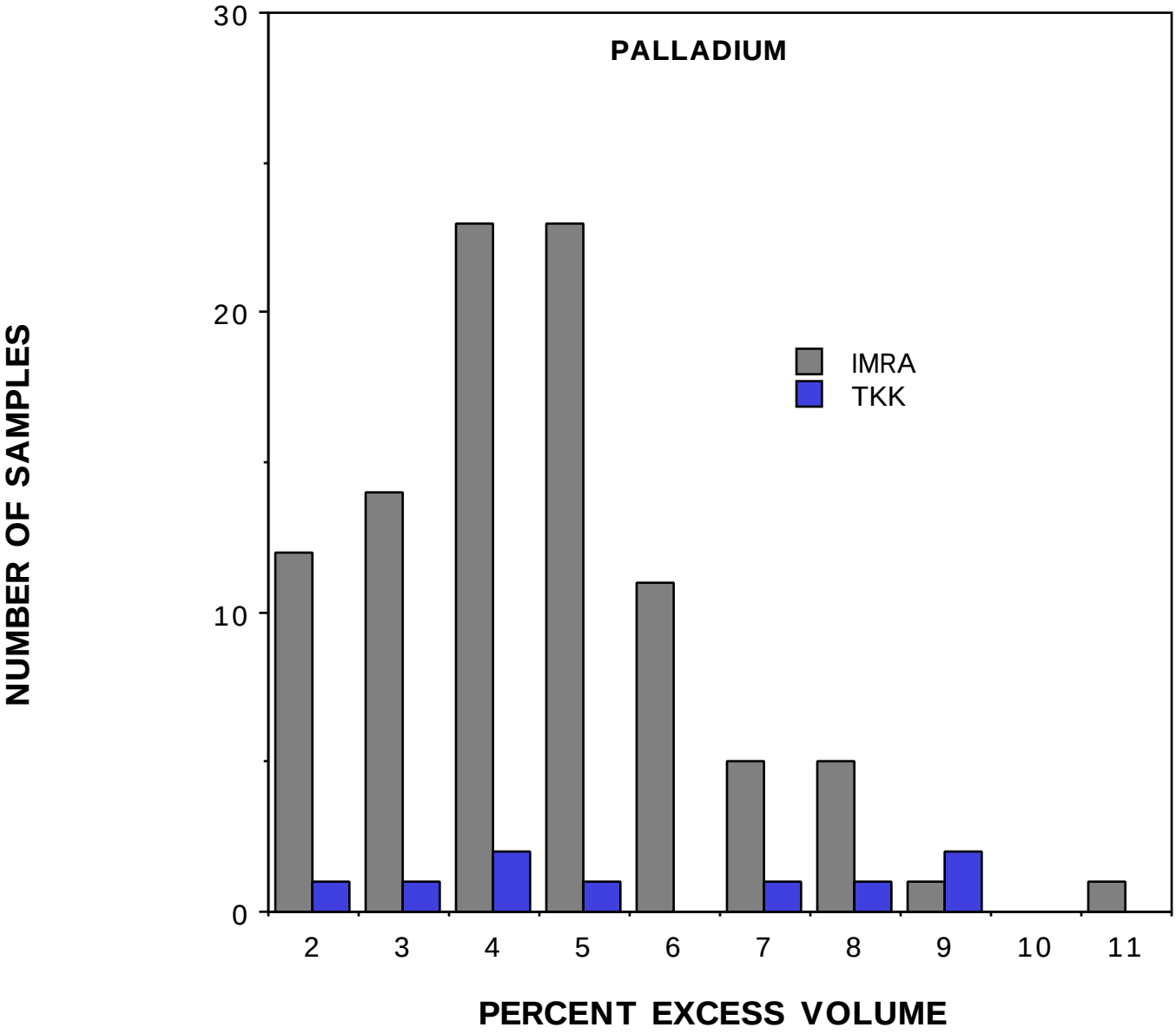


**FIGURE 2**. Volume excess over that expected from lattice parameter increase upon reaction with deuterium.

Only those samples able to achieve an average OCV in excess of 1.2 V will produce significant excess energy. Figure 5. shows how the average OCV of a sample which was making excess energy at the time changed when the applied current was stopped. A phase transition is clearly evident starting a 1.1 V where a new phase converts into β-phase. If this deuterium loss were allowed to continue, another

transition would be seen between 0.93 V and 0.97 V where β-PdD begins to convert to α-PdD. This behavior indicates that for excess energy to be produced,

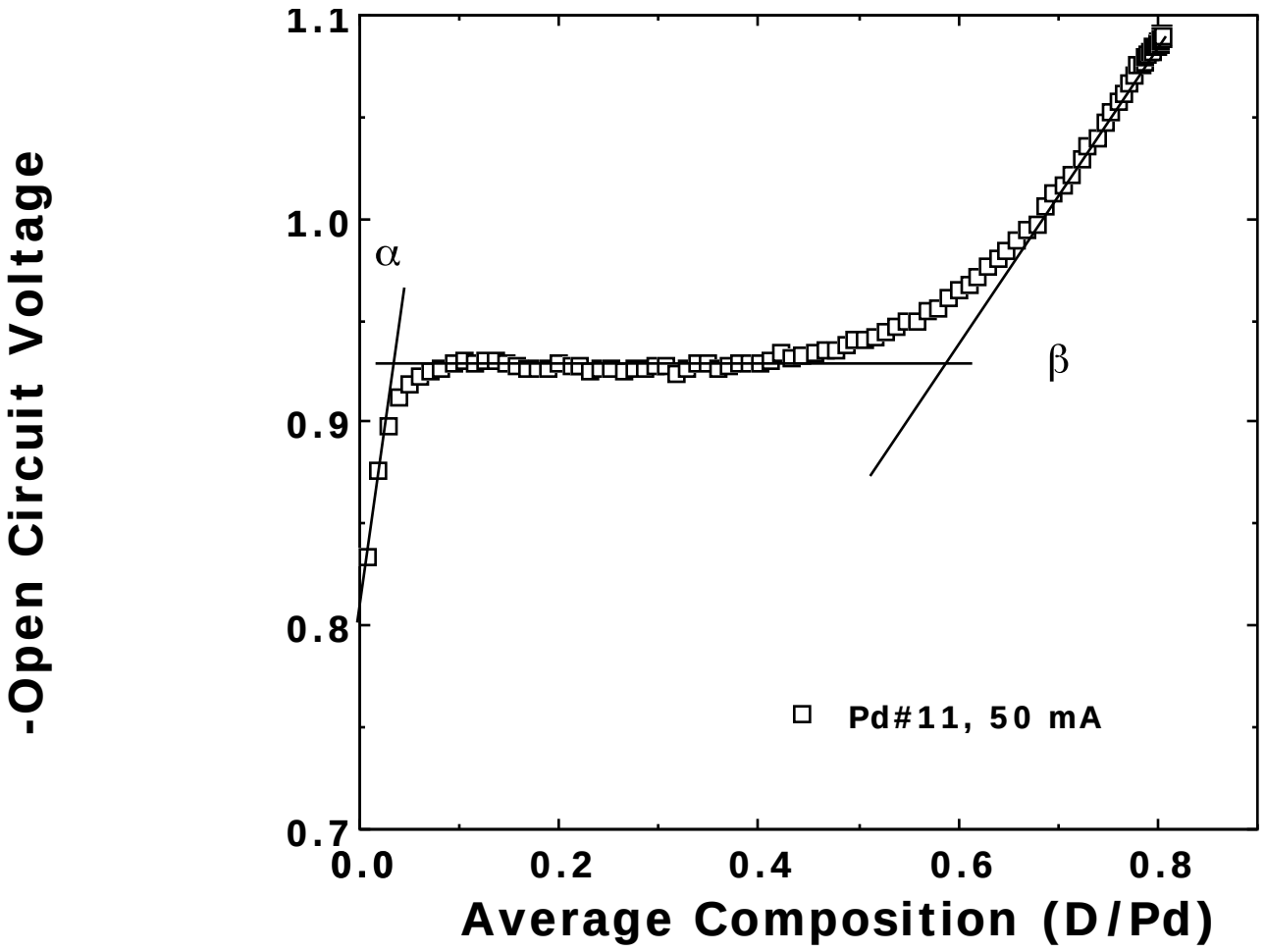


**FIGURE 3.** Open circuit voltage relative to platinum during reaction with deuterium during electrolysis.

β-phase must first convert to another phase having a much higher deuterium activity and composition. Direct measurements of thin films place the composition of this phase above D/Pd=1.5. I propose this phase to be $PdD_2$.

The calorimeter used to determine excess energy is a isoperibolic-type shown as cross-section in Fig. 6. The cell contains a catalyst to return $D_2$ and $O_2$ back to $D_2O$, the electrolyte is stirred at a constant rate, and temperature is measured at two levels in the solution and at the cathode using precision thermistors. The amount of heating power is determined by measuring the average temperature across the cell wall and multiplying this value by a previously determined calibra-

tion constant. This constant is obtained by applying electrolytic power to the sample after it has been loaded with deuterium but before excess energy is generated.

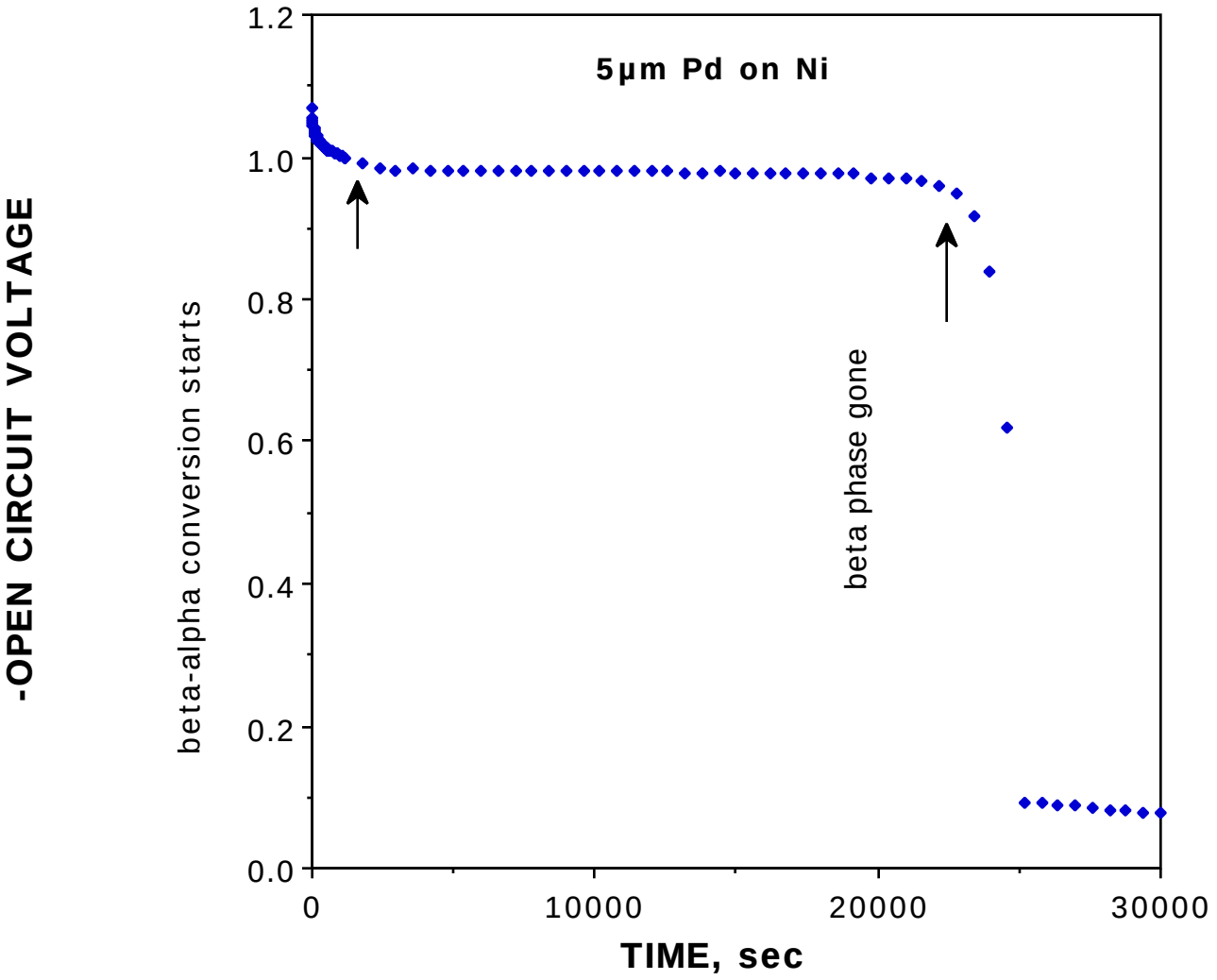


**FIGURE 4.** Open circuit voltage measured during deuterium loss from a thin layer of Pd on Ni.

Thus, any claim for excess energy is relative to power produced by the inert sample. Absolute calorimetry is not used. This is important because relative calorimetry removes many errors which skeptics use to reject the measurements.

A plate of palladium (10 mm*20 mm*1 mm) supplied by IMRA (Japan) is loaded at 0.4 A and 9° C. The average composition is D/Pd=0.89 with 1% excess volume. After calibration, the current is periodically stepped from 0.1A to 3 A. Figure 7 shows the excess power as a function of applied current at various times. After 19 hr of electrolysis, no sign of excess energy is visible. A small amount of excess power is apparent after 63 hr and this excess increases until 4.5 W is seen at 3 A

after 196 hr. A clear onset for the effect is seen at 1 A. A similar onset has been seen in all previous studies by other workers when such measurements were made.

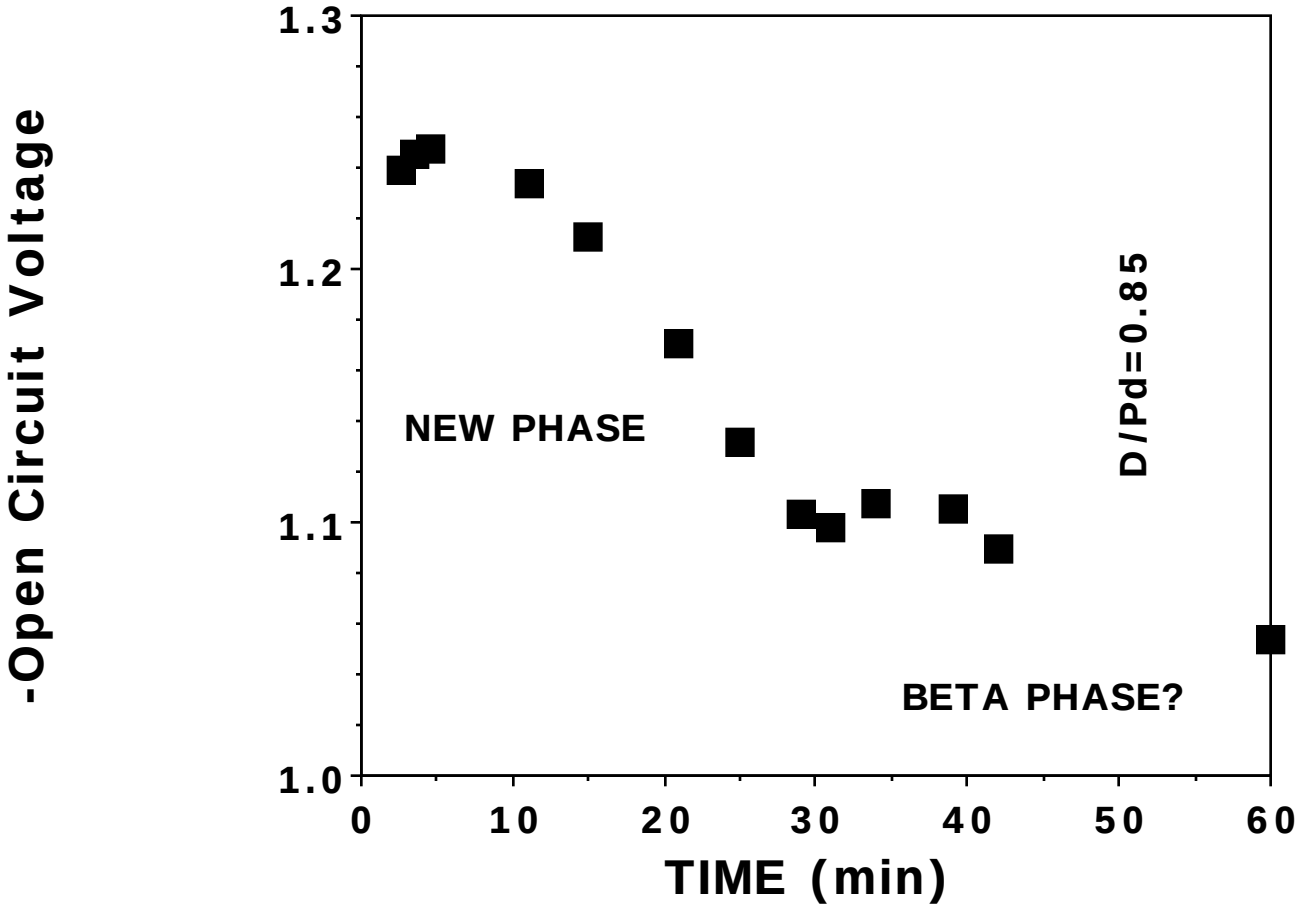


**FIGURE 5.** Open circuit voltage during deuterium loss from a sample of palladium which was making excess energy

The deloading behavior of the OCV, shown previously as Fig. 4, was obtained between data sets #6 and#7. This same general behavior was also seen several times after the sample had been repeatedly deloaded and then reloaded within the calorimeter. In other words, the sample showed reproducible behavior.

Ninety samples were studied during this work. Of these, only 5 samples were found to have the ability to achieve a high average OCV and exhibit excess power. Clearly, the lack of reproducibility using the Pons-Fleischmann method is caused by a materials problem, not because of error or sloppy work.

## CONCLUSION

The initial claims for excess energy production made by Pons and Fleischmann were prematurely rejected. Continued world-wide work shows evidence for excess energy production using 9 different methods, several different materials, and five different styles of calorimetry. The work presented here shows that the difficulty in reproducing the Pons-Fleischmann method is caused in part by the nature of palladium. Suitable palladium produces the effect without difficulty. This experience

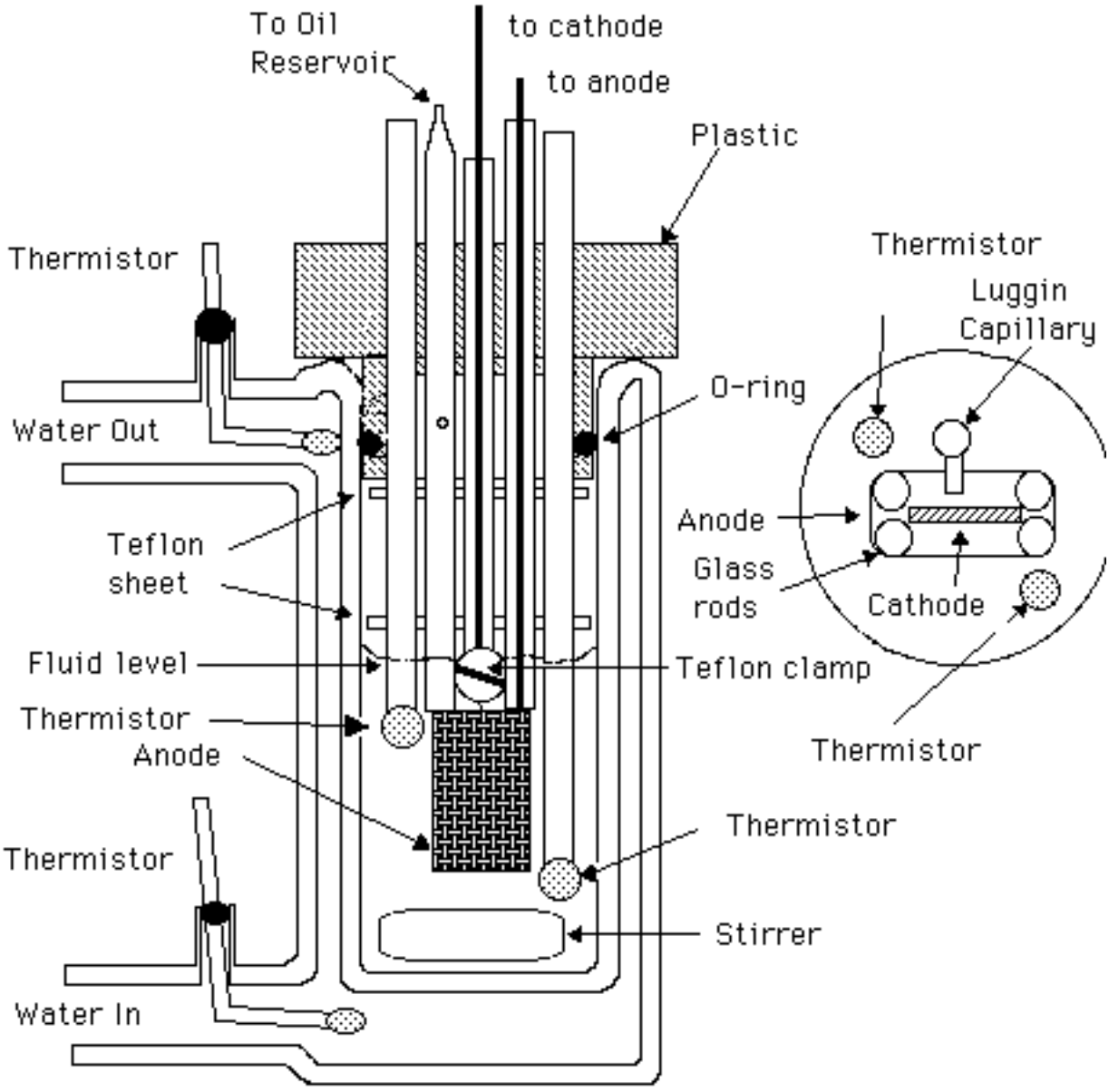


**FIGURE 6.** Cross-section of the calorimeter

has been shared by those workers who have studied a large number of samples, including Dr. Mike McKubre (SRI), Dr. Mel Miles (Naval Weapons Laboratory), and Profs. Pons and Fleischmann (IMRA Europe).

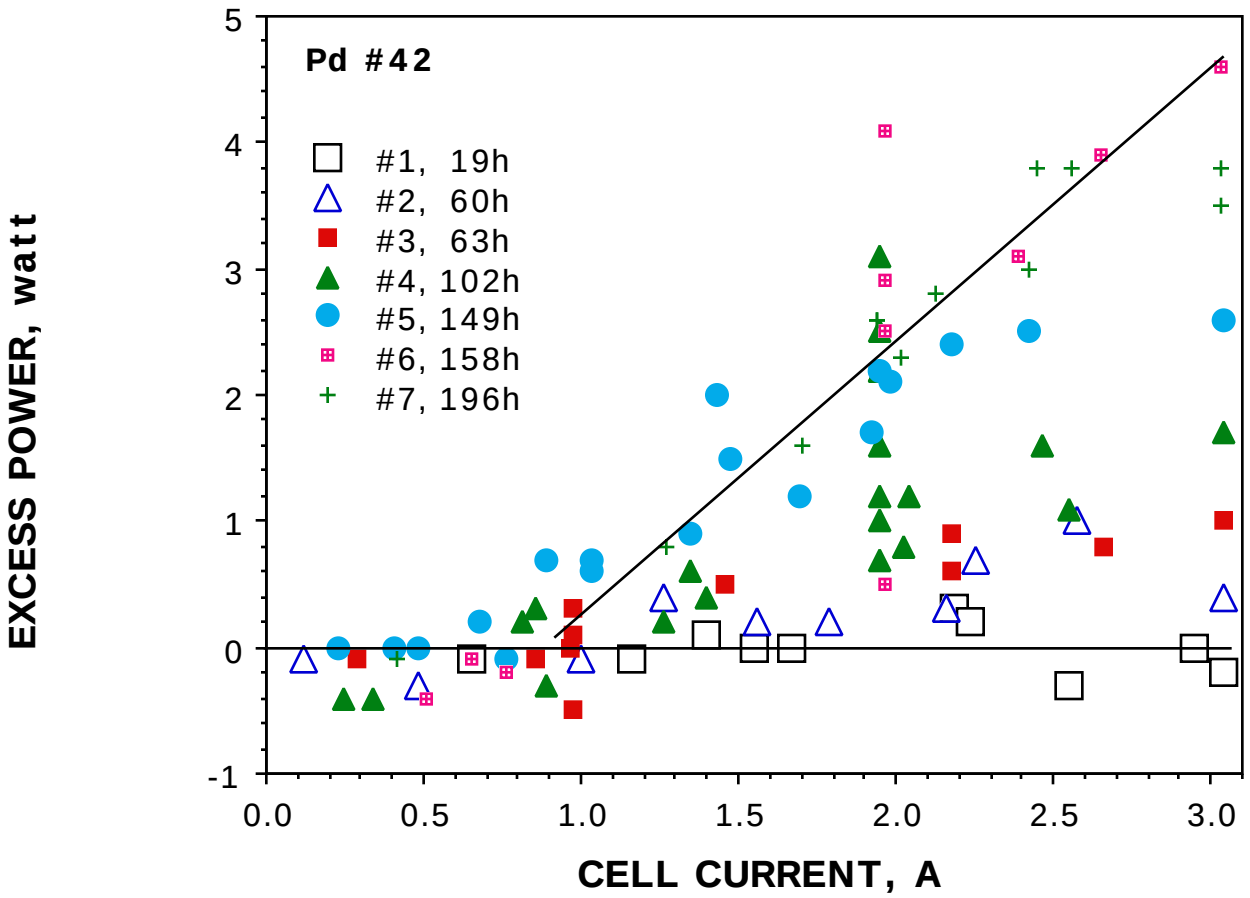


**FIGURE 7**. Excess power as a function of applied current after the indicated times of electrolysis at 0.1 A.