

## PROGRESS REPORT #4

### EFFECT OF IMPORTANT VARIABLES

Subject: Part 4. Initial studies showing the effect of important variables

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#### INTRODUCTION

The previous Progress Reports can be read at [www.LENRExplained.com](http://www.LENRExplained.com). The various novel features of the calorimeter are explored in this Progress Report. These features included measurement of OCV, loading behavior, the effect of temperature on the various behaviors, and the behavior of volume expansion resulting from repeated loading and deloading.

A number of Pd-Ag compositions have been made and subjected to treatments and measurements considered important to this study. These treatments include measurement of the sample volume during various stages in its treatment and subjecting the sample to various methods to improve its reaction with hydrogen. The relationship between each of these variables and production of excess energy will be established in order to improve the reproducibility of producing this extra energy.

The initial results from the study of each of these variables are described and discussed below.

#### RESULTS

##### 1. Expansion behavior

As described previously(1, 2), the guide used to design this research identifies expansion of the material as result of reaction with hydrogen as being an important variable for excess power production. Because the excess power requires deuterium to be present, the sample must first react with deuterium. This reaction causes the material to expand and change shape by more than would be expected based on the known increase in lattice parameter of the beta phase. This additional volume is retained when the hydrogen isotope is removed. This shape change is proposed to produce uneven stress and formation of cracks, which allow a nuclear process to take place in the gaps when the gap is exactly right. Consequently, the amount of hydrogen able to react and the resulting uneven expansion is important to know and control.

The expansion is measured using micrometers after various treatments have been applied. An example of this behavior using pure palladium is summarized in Table 1. The sample is reacted with hydrogen in an electrolytic cell followed by heating in air at about 150° C to remove the hydrogen. A typical palladium sheet is reduced in length and width by this process but increases in thickness. These changes cause the volume to increase with each cycle, but by a smaller amount each time, as shown in column 7 in Table 1. Nevertheless, many cycles are reported to convert a flat sheet to a cube shape.

Previous studies(3-5) have shown the amount of excess volume to be very sensitive to the impurities present in the Pd and its previous treatment. Furthermore, a large amount of excess volume typically forms cracks too large to be nuclear active.(6) The goal of this study is to create alloys having just the right amount of excess volume and the right number of weak regions in the surface so that gaps of the right size will

form and grow no larger. Because the amount of silver required to achieve this result is expected to be high, the formation of suitable gaps hopefully would be less sensitive to the amount of this added impurity than is the case when the impurity content of nominally pure palladium changes without knowledge or easy control. Thus, production of excess energy can be made more reproducible using premade alloys.

**TABLE 1**

Effect of loading and deloading with H<sub>2</sub> on the dimensions of pure Pd

Weight g	Volume mm <sup>3</sup>	H/Pd	Length mm	Width mm	Thickness mm	% Excess Volume
2.59523	229.2	0	18.88	9.76	1.244	
	277.1	0.863	19.46	10.12	1.407	
2.59535	237.0	0	18.55	9.67	1.321	3.37%
	269.5	0.865	19.16	9.96	1.412	
2.59537	241.6	0	18.08	9.49	1.408	1.95%
	289.4	0.86	18.5	9.85	1.588	
2.59526	245.8	0	17.77	9.41	1.47	1.75%
	300.3	0.867	18.2	9.78	1.687	
2.59520	249.4	0	17.36	9.31	1.543	1.45%

As silver is added to the Pd-Ag alloy, the amount of hydrogen able to enter the lattice and the amount of excess volume is reduced. This behavior is well known and is exploited to reduce crack formation in palladium diffusion barriers used in hydrogen purifiers.

Table 2 summarizes the behavior of a sample containing 27.7 atom % Ag. The excess volume is much less than pure Pd and perhaps too small to produce any cracks at all, especially because the sample tends to shrink in all dimensions rather than experiencing uneven expansion. Non-uniform expansion is required to produce stress cracking. Non-uniform loading and deloading can also generate this stress, but the result is difficult to control. Consequently, the samples studied here are made to load as evenly as possible.

This sample did not produce excess energy or radiation.

**TABLE 2**

Volume change produced by an alloy of 27.7 atom % Ag in Pd

Treatment	Width mm	Length mm	Thickness mm	Volume mm <sup>3</sup>	% Change in volume
initial size	10.51	17.86	1.074	201.60	
D/Pd = 0.51	10.7	18.15	1.098	213.24	5.77%
D removed	10.31	17.69	1.096	199.89	-0.85%
<b>polished</b>					
initial size	10.42	17.65	0.986	181.34	
D/Pd = 0.45	10.62	18	1.031	197.09	8.68%
D removed	10.32	17.56	1.005	182.13	0.43%
D/Pd = 0.45	10.62	18.05	1.029	197.25	8.30%
D removed	10.36	17.58	0.989	180.13	-1.10%

## 2. Loading behavior

Loading, or in other words, reaction with hydrogen is achieved using electrolytic action with  $\text{LiOD}+\text{D}_2\text{O}$  as the electrolyte. Reaction with hydrogen is greatly improved by slowing cooling the sample in air from  $900^\circ$  before it is placed in the electrolytic cell. Fig. 1 compares the loading behavior for Pd-Ag #5 after being cooled from  $900^\circ\text{C}$  in air and after having only been heated to  $200^\circ\text{C}$  in air to remove the previously reacted deuterium. After being cooled from  $900^\circ$ , the sample initially reacts with every D presented to its surface by the current. Without this treatment, about 60% of the available D are rejected during the initial loading phase. Without this treatment, the rate of the reaction and maximum composition are reduced because the surface in this case is covered by a thin layer of Cu and Pt as result of the previous electrolytic process. Treatment at  $900^\circ$  results in faster loading because any impurities on the surface are removed by either being absorbed into the bulk or vaporized into the air. In addition, a blue colored oxide layer forms while the sample slowly cools from  $900^\circ$ , which is very reactive to hydrogen isotopes.

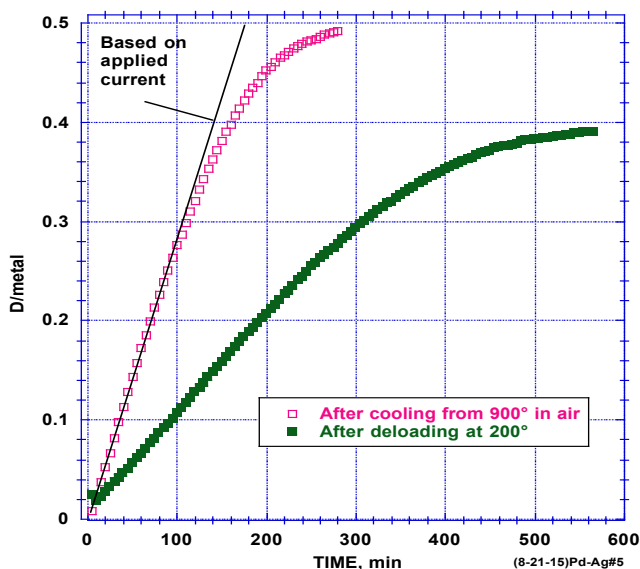


FIGURE 1. Comparison between loading behavior at 0.1 A applied current after cooling from  $900^\circ$  and after deloading at  $200^\circ$ . The line shows the D/metal ratio based on applied current. The D/metal ratio is based on the total number of moles of Pd+Ag in the sample combined with the measured moles of D

The maximum composition has an apparent upper limit near  $\text{D/metal} = 0.5$ , which, as expected, is much less than the limit achieved using pure Pd. This behavior is expected because pure Ag has a negligible reaction with deuterium. Apparently, the energy state to which the D electrons go to form a bond is filled in the Ag lattice. This energy state becomes partly filled with electrons in the alloy structure as the Ag/Pd ratio is increased, thereby reducing the amount of hydrogen able to enter the face-centered-cubic structure. Additional details will become available as other compositions are

examined. At the very least, the rate of reaction and the maximum loading will affect the amount of stress in the material and creation of stress cracks. Consequently, these variables have importance in the proposed mechanism for creation of nuclear active sites.

This sample showed no indication of crack formation.

### 3. Behavior of open circuit voltage (OCV)

The OCV is generated by the activity of hydrogen in the surface of the cathode and is measured relative to an inert Pt anode when no voltage is applied to the cell and no current flows. A relay briefly disconnects the power supply from the cell and connects the cathode and reference electrode to the data acquisition system. The amount of voltage measured is sensitive to the time applied current is interrupted, as shown in Fig. 2 for a platinum cathode. Because the absolute value cannot be accurately measured this way and because the reference electrode has an unknown potential of its own, the interpretation of the behavior is based on relative values, i.e. by how much the OCV is changed by changing the conditions. All values of OCV during this study are obtained by interrupting the applied current for 4 msec and taking 5 points over a period of 5 msec, which are then averaged.

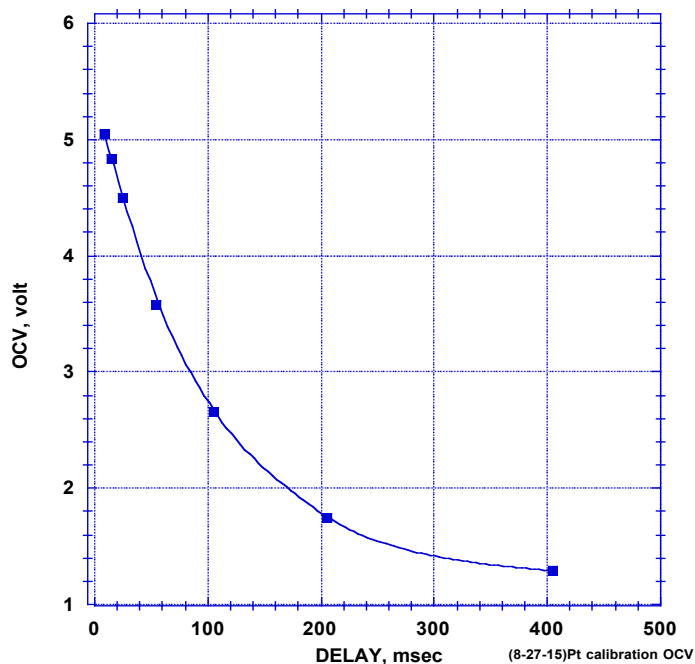


FIGURE 2. OCV resulting after applied current is interrupted for various times when using a platinum cathode and platinum reference electrode.

The value of OCV is also sensitive to the temperature of the cathode surface, as shown in Fig. 3. This behavior is studied by holding the applied current constant while increasing temperature within the cell by applying power to the resistor located in the cell. The effect is different for Pt and a sample of Pd+Ag because the Pd-Ag is able to react with D to form a compound, which has different thermodynamic properties compared to the nonreactive Pt surface. The temperature effect is a useful tool for identifying these properties.

Because the OCV is determined by the activity (composition) of hydrogen at the surface, with increased voltage being produced by increased composition, this means the activity (composition) of hydrogen at the surface is also very sensitive to temperature. This fact has been largely overlooked when the effect of increased applied current is found to cause increased power production. Overlooked is the effect of the applied power on causing increased temperature. This increased temperature reduces the D concentration, as revealed by reduction of the OCV, even though more D ions are being applied to the surface. Nevertheless, the excess power produced by LENR is found to increase. How can these contradictory behaviors be reconciled?

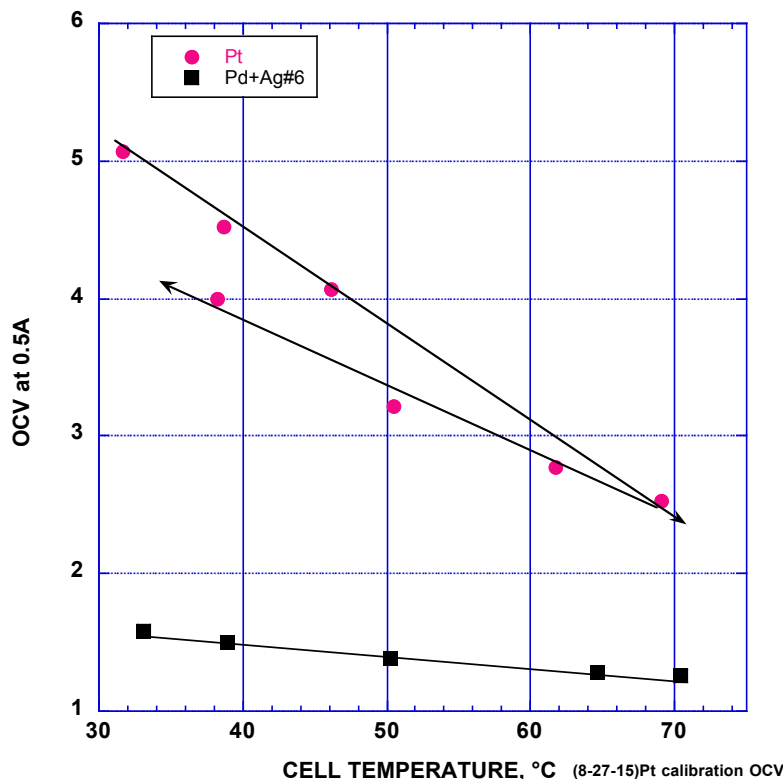


FIGURE 3. Effect of temperature on the OCV produced by Pt and Pd+Ag when subjected to 0.5 A of applied current. The initial values are taken as the temperature is increased. Reduction in temperature produced a different slope for the Pt cathode because the composition of D on the surface is not stable. In contrast, the OCV on the Pd-Ag sample is stable.

When current is turned off, the Pt loses its D very rapidly and the OCV quickly drops to near zero. In contrast, the OCV of Pd-Ag drops rapidly only while D is lost from the beta phase. The value remains constant once the beta+alpha two-phase mixture forms in surface because the chemical activity is then fixed at a constant value. By knowing the activity and composition in the two-phase mixture of pure Pd-D, the OCV can be calibrated and used to determine the deuterium activity within the single-phase region of the Pd-Ag system. This provides a powerful tool to help understand conditions existing in the surface region where LENR is known to occur.

Figure 4 shows examples of how applied power affects the production of excess energy. Of the plotted values, only the ones provided by McKubre were taken when the temperature of the electrolyte is held constant. Even in his study, the temperature of the cathode surface could not be held constant. The small effect of applied current could be caused solely by this small temperature increase as applied current is increased. In other words, the apparent effect of applied current on production of excess energy might be owing only to changes in the temperature of the cathode surface once nuclear active sites have been created. The behavior shown in Fig. 3 and the observed reduction in composition at the cathode surface produced by increased temperature suggests an explanation for this behavior worth exploring in subsequent Progress Reports.

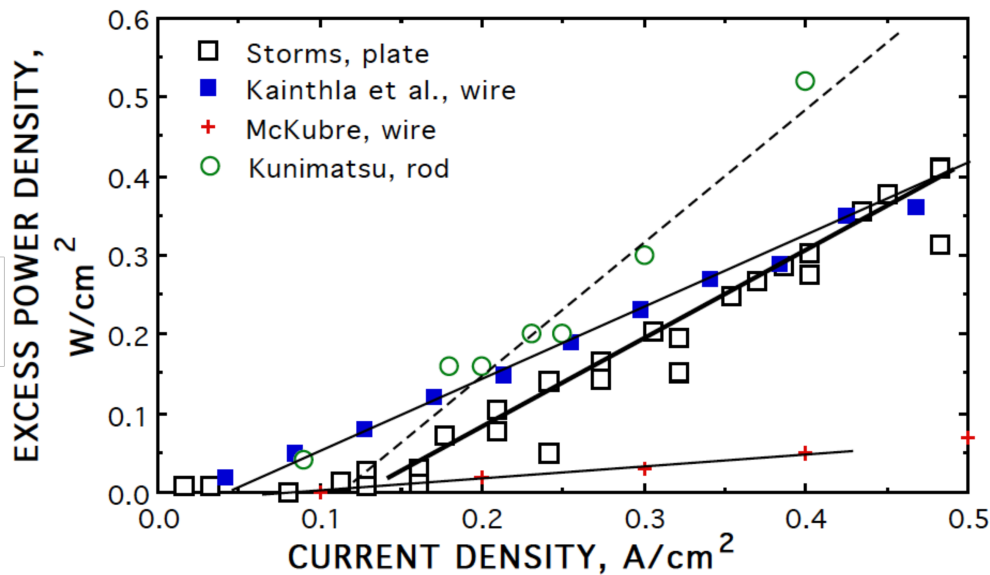


FIGURE 4. Examples showing the measured effect of applied current on the production of excess power.(From Storms(7))

## DISCUSSION

The important variables are identified and their response to various treatments is being explored. However, lack of the equipment required to fully control the variables adds uncertainty to the hoped for success. Nevertheless, the study will reveal behavior not considered in past studies or in present explanations. Hopefully, the variables can be adjusted to produce the required conditions to initiate LENR and these conditions can be easily duplicated, which has been difficult to do in the past.

## References

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