

## **Excess Energy and Nuclear Products**

### **Reply to S. E. Jones and L. D. Hansen Concerning Claims of Miles, et al. in Pons-Fleischmann-Type Cold Fusion Experiments**

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#### **Abstract**

The simultaneous measurements of power and the rate of evolution of the electrolysis gases in our experiments prove that faradaic efficiencies less than 100% cannot account for our reports of excess heat. Furthermore, our calorimetric results are strikingly similar to reports from other laboratories including measurements in closed calorimetric systems where faradaic efficiencies are not a factor. Excess enthalpy for the Pd/D<sub>2</sub>O system generally involves high current densities that exceed 100 mA/cm<sup>2</sup>; therefore, the report by S. E. Jones et al. of low faradaic efficiencies using current densities of only 1 to 2 mA/cm<sup>2</sup> is not applicable to cold fusion experiments. Based on experiments at our laboratory, there is compelling evidence that the anomalous excess heat is correlated with helium-4 production. For example, 30 out of 33 heat and helium studies yielded either excess helium when excess power was measured or no excess helium when no excess power was present. The probability of obtaining this result by random errors in our heat and helium measurements is very small. Permanent laboratory records always defined the presence or absence of excess power prior to any helium measurement. The measurement of helium in the electrolysis gas samples at three different laboratories places our rate of helium-4 production at 10<sup>11</sup> to 10<sup>12</sup> atoms/s per watt of excess power. This is the correct magnitude for typical deuteron fusion reactions that produce helium-4 as a product.

#### **1. Introduction**

This paper is a response to S. E. Jones and L. D. Hansen<sup>1</sup> who critically examined our claims of excess heat and helium-4 production during electrolysis of the Pd/D<sub>2</sub>O + LiOD system.<sup>2</sup> Excess enthalpy for the Pd/D<sub>2</sub>O system generally involves high current densities that exceed 100 mA/cm<sup>2</sup>. Therefore, the report by S. E. Jones et al.<sup>3</sup> of low faradaic deficiencies using current densities of only 1 to 2 mA/cm<sup>2</sup> is not applicable to cold fusion experiments.

#### **2. Excess Heat Production**

Many scientists attribute reports of excess power production in cold fusion experiments to calorimetric errors. This is reflected in the publications by S. E. Jones et al.<sup>1,3</sup> However, it is nearly impossible to explain how calorimetric errors could lead to practically identical results between independent laboratories. For example, the major conclusions from the China Lake calorimetric experiments are almost identical to those reported by M. McKubre et al. at SRI.<sup>4,5</sup> The excess power measurements in the China Lake experiments can be summarized by the following conclusions:

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1. The excess power effect is typically 5 to 10% larger than the input power. The largest excess power effect was 30%.
2. The excess power in terms of the palladium volume typically yields 1 to 5 W/cm<sup>3</sup>.
3. Long electrolysis times are required before the onset of the excess power effect. This time period usually ranges from 6 to 14 days of electrolysis for 1 to 6 mm diameter palladium rods.
4. Excess power production requires a threshold current density of 100 mA/cm<sup>2</sup> or larger.
5. Most experiments produced no evidence of any excess power. Overall, only 30% of our experiments yielded evidence for excess power.
6. Our success ratio in obtaining excess power varied greatly with the source and batch of palladium used.

The SRI results typically yielded 5 to 10% excess power with a maximum of 28% excess power, the excess power in terms of the palladium volume was 1 to 5 W/cm<sup>3</sup> on the average, the initiation time was on the order of 300 hours for 1 to 4 mm diameter Pd wires, the threshold current density ranged from 100 to 400 mA/cm<sup>2</sup>, and the success rate varied greatly with the source of the palladium.<sup>4,5</sup> This striking agreement between the China Lake and SRI results simply cannot be explained by calorimetric errors. Furthermore, the calorimeters used at China Lake and SRI are totally different. China Lake used an open, isoperibolic calorimetric system<sup>2</sup> while SRI employed a closed, isothermal flow calorimetric design.<sup>5</sup>

The China Lake calorimetric results are also very similar to those reported by M. Fleischmann et al.<sup>6</sup> when the excess power density (W/cm<sup>3</sup>) in terms of the palladium volume is compared with the experimental current density. Both China Lake and M. Fleischmann et al.<sup>6</sup> report approximately 1 W/cm<sup>3</sup> of palladium at current densities of 100 to 200 mA/cm<sup>2</sup>. In a review by E. Storms,<sup>7</sup> the China Lake calorimetric excess heat effects are shown to be very similar to those reported by many other laboratories. This leaves the unanswered question of how calorimetric errors could yield this correlation of our excess heat results with various other laboratories.

The accuracy of our calorimetry is illustrated in Figure 1 that features one of many experiments that never displayed any evidence for excess power. The measured output power tracks very closely to the electrochemical input power. Approximately 70% of our experiments never displayed any evidence for excess power. These studies, therefore, served as controls for our calorimetry.

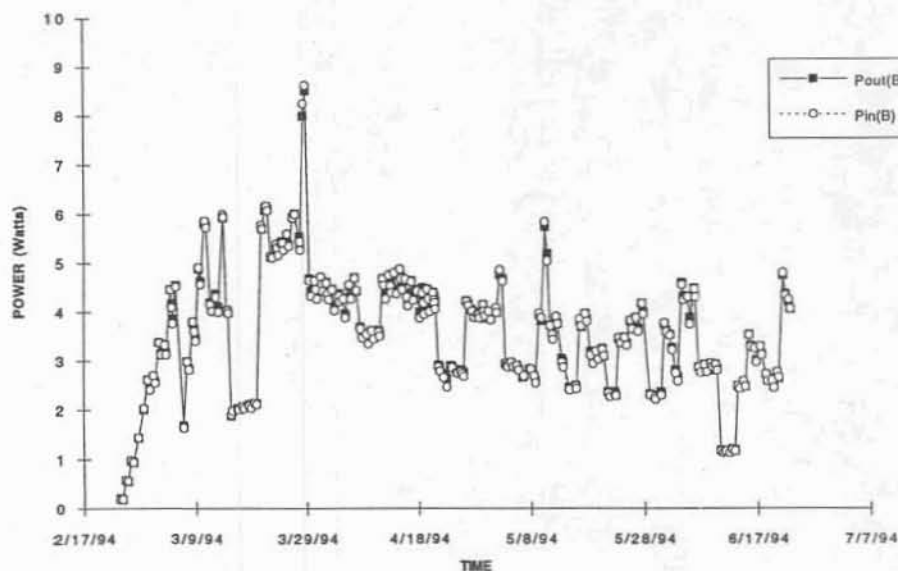


Figure 1. Electrochemical Input Power and Calorimetrically Measured Output Power for a Palladium Cathode That Produced No Excess Power.

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Many experiments have proved that the recombination of  $D_2$  and  $O_2$  electrolysis gases does not occur to any significant level for typical cold fusion studies using high current densities and solid, fully-submerged palladium cathodes.<sup>2,7</sup> Some scientists, however, ignore this evidence and continue to claim that the excess heat effect can be explained by faradaic efficiencies less than 100% ( $\gamma < 1$ ).<sup>3</sup> The recombination effects for Ni and Pd cathodes reported by Jones et al.<sup>3</sup> used current densities of only 1 to 2 mA/cm<sup>2</sup>. Such studies are irrelevant since excess heat effects for the Pd/D<sub>2</sub>O system require a threshold current density of about 100 mA/cm<sup>2</sup> or higher. This requirement of high current densities was reported by M. Fleischmann et al.<sup>6</sup> in 1990. Lowering the current density in water electrolysis experiments will always decrease the current efficiency due to the slower gas evolution that allows the product at one electrode to more readily invade the vicinity and react at the opposing electrode. Furthermore, the current fraction consumed by the electrode reaction of impurities becomes larger at smaller current densities. Contrary to the comments by Jones and Hansen,<sup>1</sup> we always measured the current efficiency at the time of collection of an electrolysis gas sample for helium analysis. This was done volumetrically by measuring the rate of the displacement of water by the electrolysis gases.<sup>2</sup>

Several other measurements and observations provided secondary checks for any recombination of  $D_2$  and  $O_2$  in our experiments. The volume of  $D_2O$  added to replenish the cell was always recorded to provide another test for any significant recombination effects. Furthermore, the rate of the electrolysis gases passing through the oil bubbler could always be directly observed. If recombination of  $D_2$  and  $O_2$  within the electrolysis cell occurs, this would slow or even stop the evolution of gases through the bubbler.<sup>8</sup>

### 3. Helium-4 Production in Electrolysis Cells

A major point raised by S. E. Jones and L. D. Hansen<sup>1</sup> was that our helium-4 detection limit was first reported as  $10^{12}$  atoms/500 mL of effluent gases and then later increased to  $10^{13}$   $^4He$  atoms/500 mL. Our earlier limit was based on measurements at the University of Texas laboratory where 10 mTorr air in 500 mL of nitrogen gas yielded the observation of helium-4 at the detection limit of the mass spectrometer.<sup>9</sup> We originally used a conservative value because we did not want to overstate the amount of helium-4 produced in our experiments.

Solid evidence that we should have originally reported considerably higher helium-4 production rates was obtained in later studies where the electrolysis gas samples were collected in metal flasks rather than in Pyrex glass flasks and then analyzed by a commercial laboratory.<sup>10</sup> For six control experiments yielding no excess power, the mean background helium concentration in our system was  $4.5 \pm 0.5$  ppb or  $5.1 \pm 0.6 \times 10^{13}$   $^4He$  atoms/500 mL.<sup>10,11</sup> These values, therefore, accurately define a minimum helium-4 detection limit for our original studies. In order to clearly resolve this helium-4 detection limit issue, exactly the same procedures and apparatus were used in these experiments except for the replacement of the glass flasks with the metal flasks. This eliminated the diffusion of atmospheric helium into the sample flasks. These quantitative commercial measurements of background helium-4 concentrations in our calorimetric system dictated an upward revision of our original helium reports.

In retrospect, the higher helium-4 detection limit resolves the issue of atmospheric helium diffusion into our glass flasks and is consistent with the detection limits reported by a commercial laboratory.<sup>10,11</sup> Furthermore, this higher helium-4 detection limit yields helium production rates of  $10^{11}$  to  $10^{12}$   $^4He/s \cdot W$ , which is the correct magnitude for typical fusion reactions that yield helium as a product.<sup>10</sup> The consistent merging of these various results would have been highly improbable if our initial measurements were due to errors or atmospheric contamination. Nevertheless, the revision in our helium-4 detection limit was a major issue raised by S. E. Jones and L. D. Hansen<sup>1</sup> in their criticism of our work. Our explicit explanations for this change<sup>10</sup> were completely ignored.



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S. E. Jones and L. D. Hansen<sup>1</sup> report that our designation of an experiment as a "control" is done after the experiment is run, not before. Neither Jones nor Hansen has been in our laboratory, hence they have no basis for such a statement. Permanent laboratory records always defined the amount of excess power prior to any helium measurements. In general, excess power was consistently produced in experiments that yielded excess helium-4 production, while no excess power was detected in experiments that served as controls.

Based on experiments at our laboratory, there is compelling evidence that the anomalous excess heat is correlated with helium-4 production. For example, 30 out of 33 heat and helium studies yielded either excess helium when excess power was measured or no excess helium when no excess power was present.<sup>8,11</sup> A statistical treatment shows that the odds are approximately one in 750,000 that our complete set of heat and helium results could be this well correlated due to random experimental errors in our calorimetry and helium measurements.<sup>8,11</sup> It is even more unlikely that random errors would consistently yield helium-4 production rates in the appropriate range of  $10^{11}$  to  $10^{12}$  atoms/s per watt of excess power.

### **4. Conclusions**

Although S. E. Jones and L. D. Hansen<sup>1</sup> presented many harsh comments about our experiments, we were never officially informed about their paper by the authors, reviewers, or editors involved. Even after we requested a delay of this publication to allow a response to be published back-to-back, the authors and editors refused our request. Our detailed response to this attack by Jones and Hansen has been submitted but has not yet been accepted for publication.<sup>12</sup>

S. E. Jones and L. D. Hansen<sup>1</sup> ignored our previous explanation on many issues that are contained in our publications. Their mixture of facts, distortions, and misunderstandings regarding our work certainly does not facilitate any scientific resolution of the cold fusion controversy.

Jones et al.<sup>3</sup> used current densities of only 1 to 2 mA/cm<sup>2</sup> in their studies of faradaic efficiencies during water electrolysis. Excess enthalpy for the Pd/D<sub>2</sub>O system involves much larger current densities that exceed 100 mA/cm<sup>2</sup>. It is essential that Jones et al.<sup>3</sup> use current densities in the right ballpark if they wish to investigate faradaic efficiencies in cold fusion experiments. The arguments of Jones et al.<sup>3</sup> are not relevant for the large current densities used in cold fusion experiments.

### **5. Acknowledgment**

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