



# Investigation of Anomalous Heat Observed in Bulk Palladium

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# BACKGROUND: “Cold Fusion”?



## Headlines 1989

Two electrochemists...

**Martin Fleischmann**

**Stanley Pons**

claimed to have tapped nuclear power  
in a simple electrochemical cell.

*"It could be the end of the fossil fuel  
age: the end of oil and coal. And the  
end, incidentally, of many of our  
worries about global warming."*

-- Sir Arthur C. Clarke



# BACKGROUND: The Advantage of Fusion

## Burning Coal:

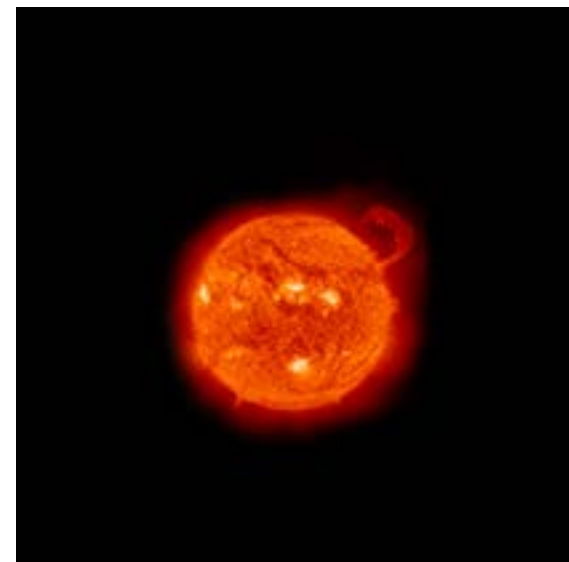
- $C + O_2 \rightarrow CO_2$  (4 eV)

## Fission Power Reaction:

- $^{235}\text{U} + n \rightarrow ^{236}\text{U}$   
 $\rightarrow ^{141}\text{Ba} + ^{92}\text{Kr} + 3 \cdot n$  (170 MeV)

## Fusion Processes:

- $D + D \rightarrow T$  (1.01 MeV) +  $p$  (3.02 MeV)
- $D + D \rightarrow ^3\text{He}$  (0.82 MeV) +  $n$  (2.45 MeV)
- $D + D \rightarrow ^4\text{He}$  (73.7 keV) +  $\gamma$  (23.8 MeV)
- $D + T \rightarrow ^4\text{He}$  (3.5 MeV) +  $n$  (14.1 MeV)
- $D + ^3\text{He} \rightarrow ^4\text{He}$  (3.6 MeV) +  $p$  (14.7 MeV)  
 –  $D = ^2\text{H}$ ,  $T = ^3\text{H}$
- Fusion is at least 13% more productive per mass of fuel (without the nasty waste products)





# BACKGROUND: 1989 Cold Fusion Experiment

- Tested non-electrochemical variant of “Cold Fusion” – where Deuterium ( $D_2$ ) gas used with palladium (Pd) filter
- Used Pd filter from hydrogen purifier
- Gas is “loaded” and then “unloaded” from palladium, while monitoring purifier temperature and neutrons.
- Compared to Hydrogen gas as the experimental control.



## Results

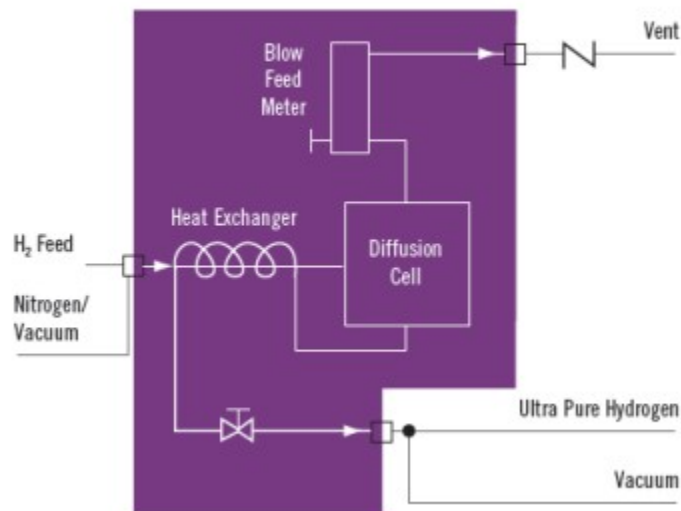
- Published: *Fralick, Decker, & Blue (1989) NASA TM-102430*
- $15^{\circ}C$  increase in purifier temperature consistently seen with  $D_2$  that was not seen with the  $H_2$  control when gasses were unloaded from the purifier.
- Neutron detector counts did not differ significantly ( $\leq 2\sigma$ ) from background in any run (Monitored with  $BF_3$  w/ Polyethylene [“Snoopy”] detectors).

# BACKGROUND: Purifier Schematic

- Johnson Matthey HP Series palladium membrane hydrogen purifier
- Used in the semiconductor industry and applications where ultra-high purity hydrogen is required (to 99.9999999%)
- An at-hand substitute for a palladium electrolytic cell



Flow Diagram HP Series





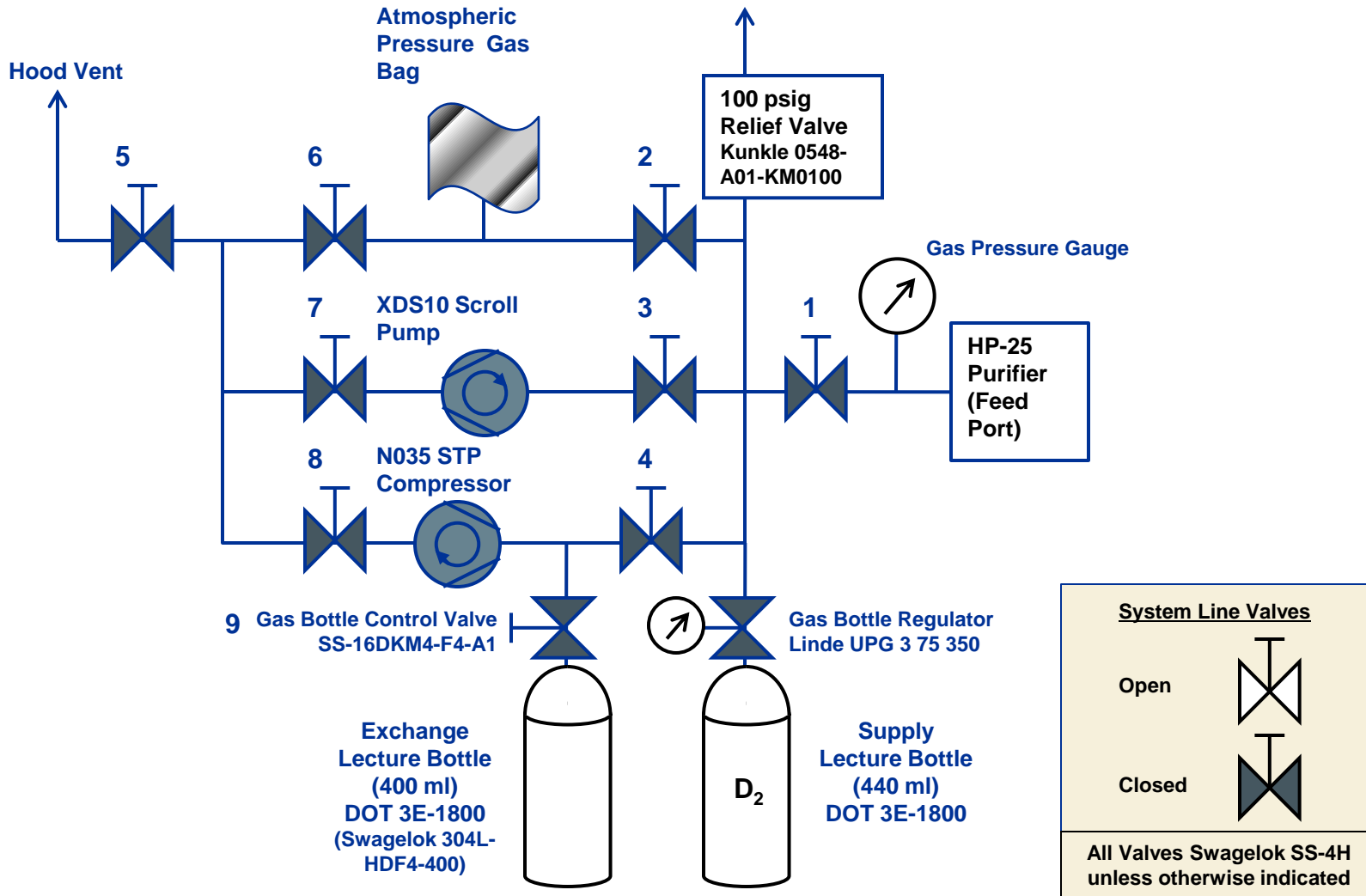
# BACKGROUND: Changes from 1989 to 2009

- Previous NASA experiment (Fralick, et al.; 1989) looked for neutrons (saw none) – but saw anomalous heating
- After 1989, Cold Fusion research evolved into research in “Low Energy Nuclear Reactions” (LENR), primarily at U.S. Navy, DARPA & various Universities
- Some recent LENR theories suggest He-3,-4 generation or transmutations occurring in PdH/D is the cause of anomalous heating
- **2009: NASA IPP-sponsored effort to:**
  - Repeat the initial tests to investigate this anomalous heat
  - Apply GRC’s instrumentation expertise to improve the diagnostics for this experiment
  - Establish credible framework for future work in LENR

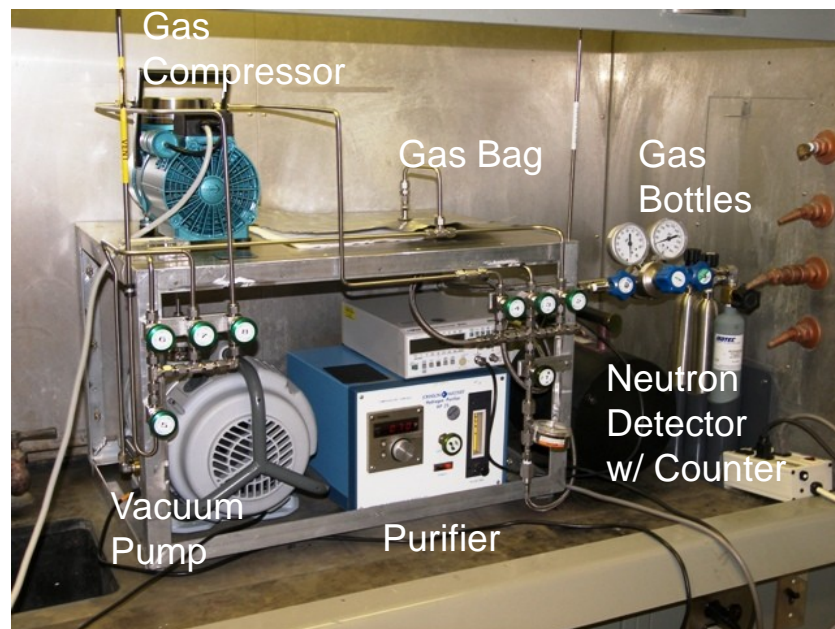
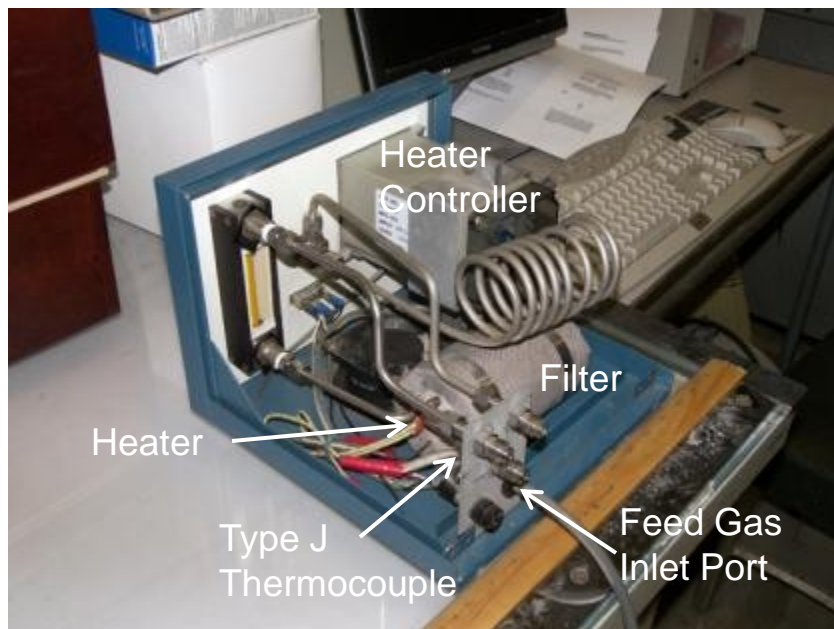




# APPROACH: Flow System Schematic



# APPROACH: 2009 Test Apparatus



- Johnson Matthey HP-25 hydrogen purifier
  - Purifier Filter contains a ~50g heated Pd-25%Ag membrane
- Load Filter by flowing hydrogen gas into the purifier
- Unload Filter by pumping the gas out of the purifier into a sample bottle
- Turn off filter heater for a time when Loading & Unloading
- Monitor changes in temperature, neutron/gamma background
- Repeat with deuterium gas; Compare results





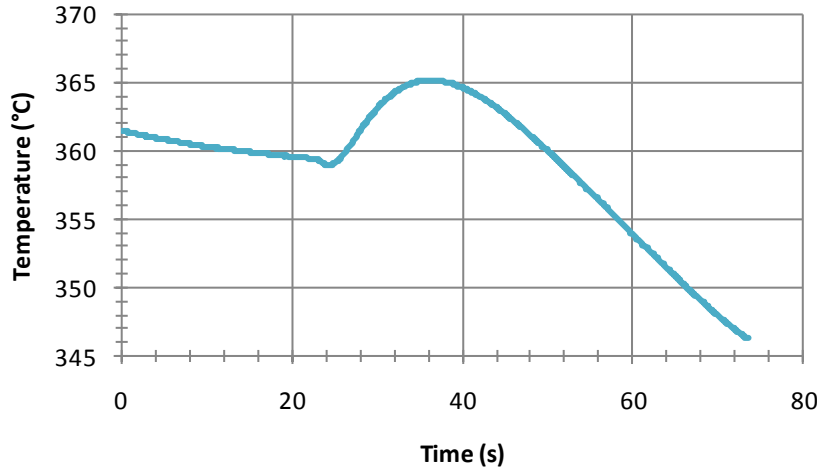
# RESULTS (Preliminary): Temperatures vs. Time

## Loading

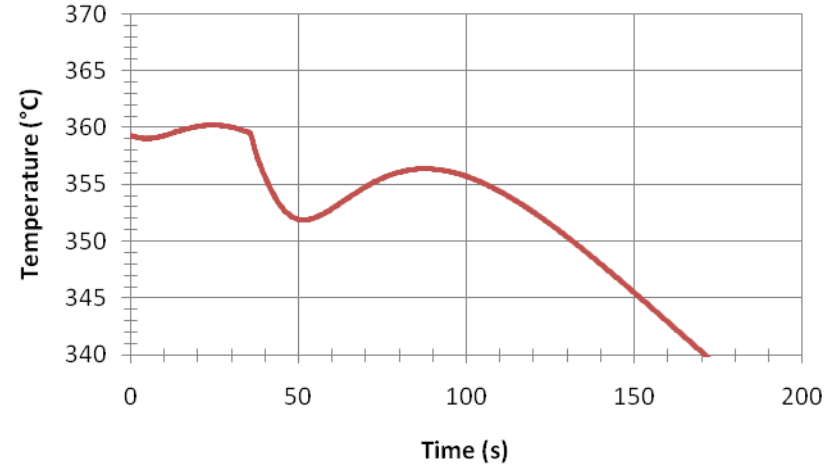
## Unloading

Hydrogen

Observed Temperature for H2 Load

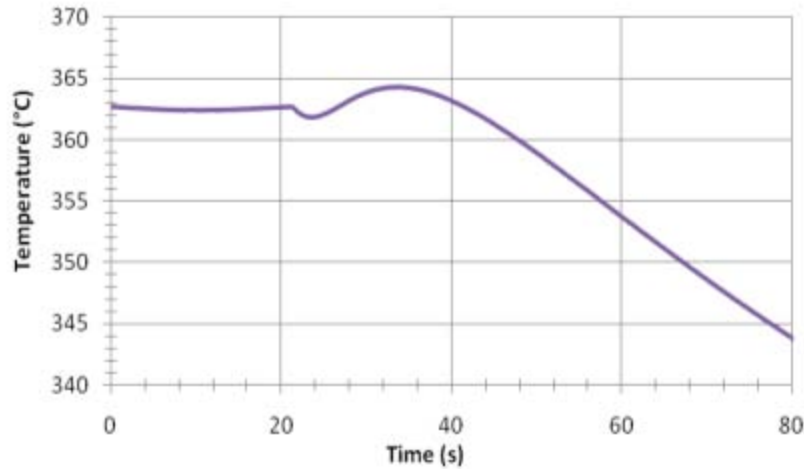


Observed Temperature for H2 Unload

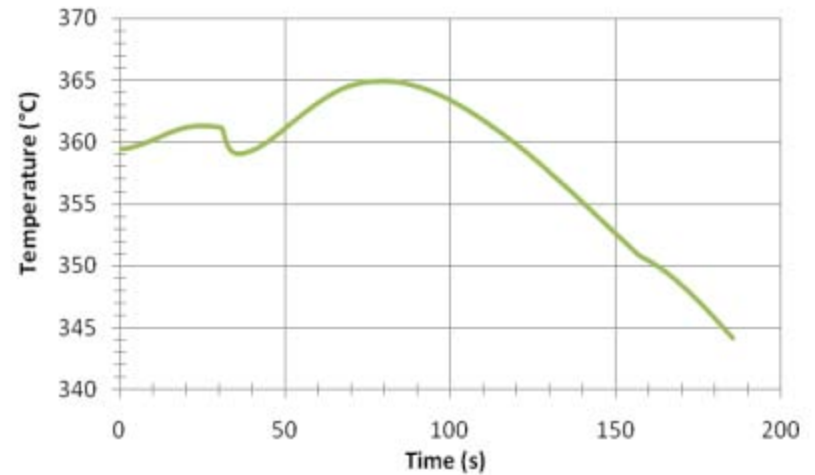


Deuterium

Observed Temperature for D2 Load



Observed Temperature for D2 Unload





# The Path Forward

- More loading/unloading data on the temperature evolution of the loading/unloading process should be collected
- Analysis of the gas samples collected should be performed to look for evidence of tritium or helium
  - Mass spectrum analysis and optical emission spectrum analysis should be able to identify gas species in the samples
  - Existence of either in the sample would indicate a nuclear origin for the anomalous heating
- Further examination of the thermodynamics of hydrogen absorption in palladium should be pursued to fully quantify the extent of the observed heating effects
- Improve experiment controls:
  - Upgrade Purifier heater control
  - Improve loading/unloading process timing
  - Fabricate in-house palladium samples
  - Improve neutron and gamma radiation detection



# References

- Fralick, Gustave C.; Decker, Arthur J. and Blue, James W.: “Results of an Attempt to Measure Increased Rates of the Reaction  ${}^2\text{D} + {}^2\text{D} \rightarrow {}^3\text{He} + \text{n}$  in a Nonelectrochemical Cold Fusion Experiment,” NASA TM-102430 (1989).
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- Li, Xing Z.; Liu, Bin; Tian, Jian; Wei, Qing M.; Zhou, Rui and Yu, Zhi W.: “Correlation between abnormal deuterium flux and heat flow in a D/PD system,” *J. Phys. D: Appl. Phys.* **36** 3095-3097 (2003).
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- Biberian, J.P. and Armanet, N.: “Excess Heat Production During Diffusion of Deuterium Through Palladium Tubes” *8<sup>th</sup> International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*, Sicily, Italy, 2007.