# LENR at GRC

Gustave C. Fralick
John D. Wrbanek, Susan Y. Wrbanek,
Janis Niedra (ASRC)

NASA Glenn Research Center
Cleveland, Ohio

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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)

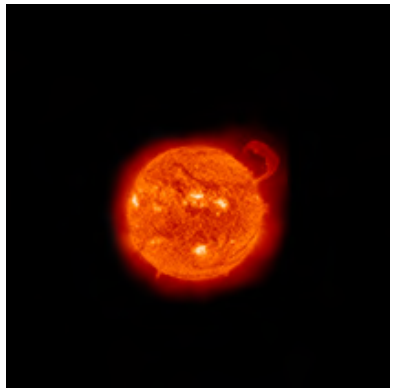
Fission Power Reaction:

- $^{235}U + n \rightarrow {}^{236}U$

  $\rightarrow {}^{141}Ba + {}^{92}Kr + 3 \cdot n$ (170 MeV)

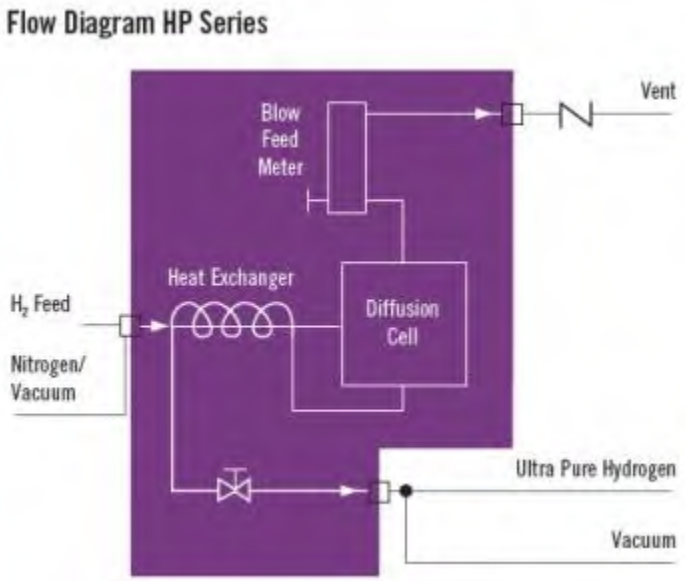
Fusion Processes:

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



# **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


# **BACKGROUND:**1989 Cold Fusion Experiment

## EQUIPMENT

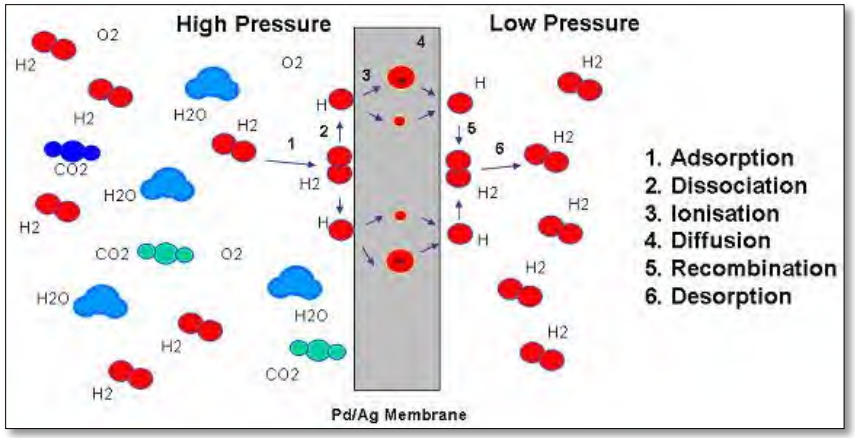
Hydrogen purifiers are made using Palladium membranes

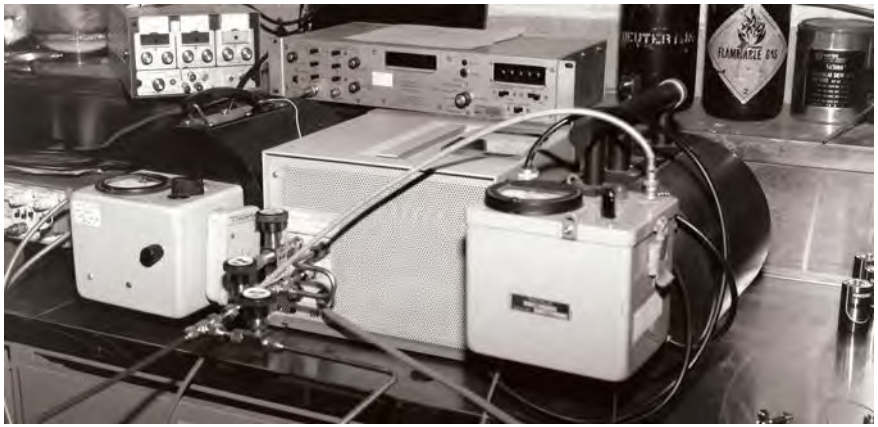
## EXPERIMENT

After evacuating purifier, it was loaded with deuterium gas at pressures up to 250 psig.

Purifier temperature and neutron count monitored for several months–non electrochemical variant of Pons-Fleischmann experiment

- "Snoopy" Detector



# **BACKGROUND:** 1989 Cold Fusion Experiment

## Results:

- Temperature increase noted while gas was loaded into palladium cell, for both D & H
- Neutron detector counts did not differ significantly ($\leq 2\sigma$) from background in any run (Monitored with $BF_3$ w/ Polyethylene [“Snoopy”] detectors).
- Temperature increase noted when D unloaded at end of experiment
- Compared to hydrogen gas as the experimental control: 15°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.

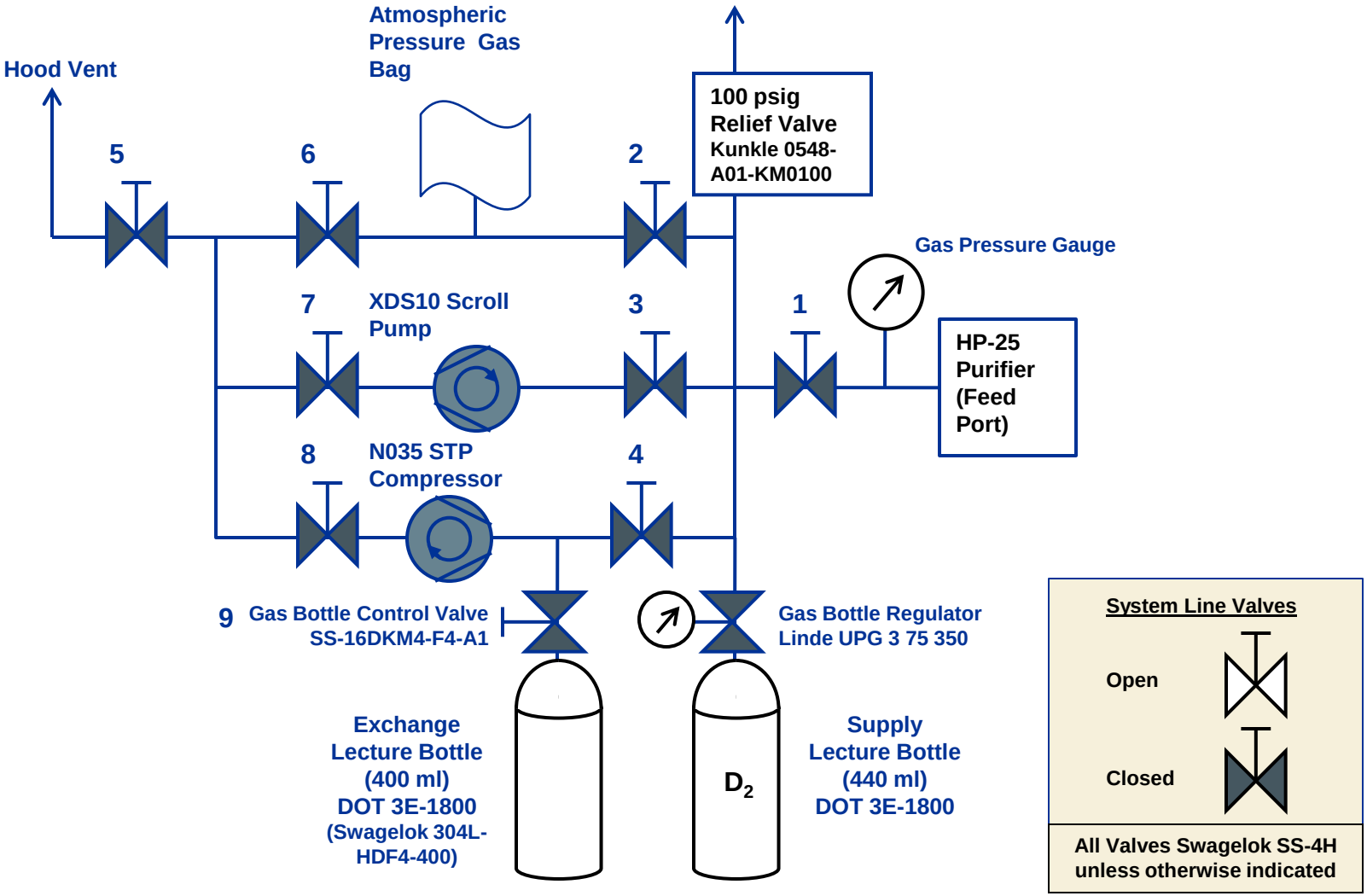
## Published:

- *Fralick, Decker, & Blue (1989)* NASA TM-102430

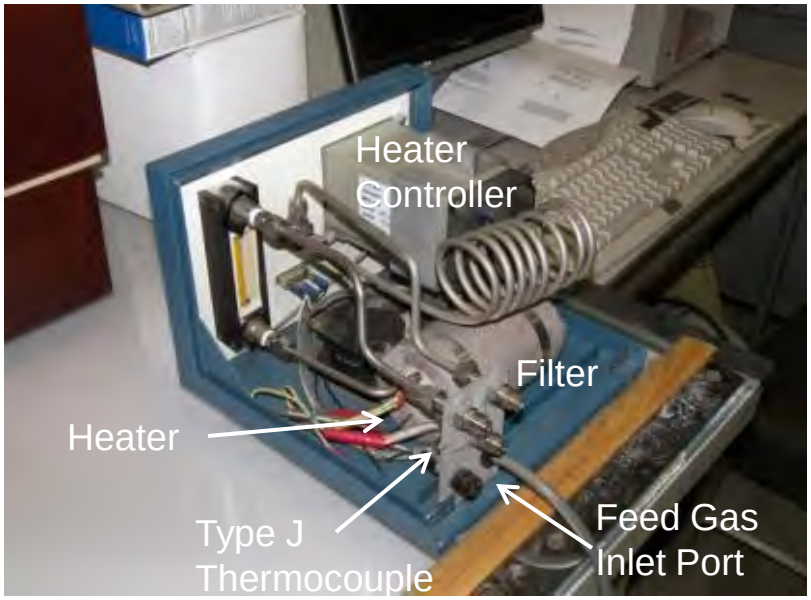
# **BACKGROUND:** Changes from 1989 to 2009

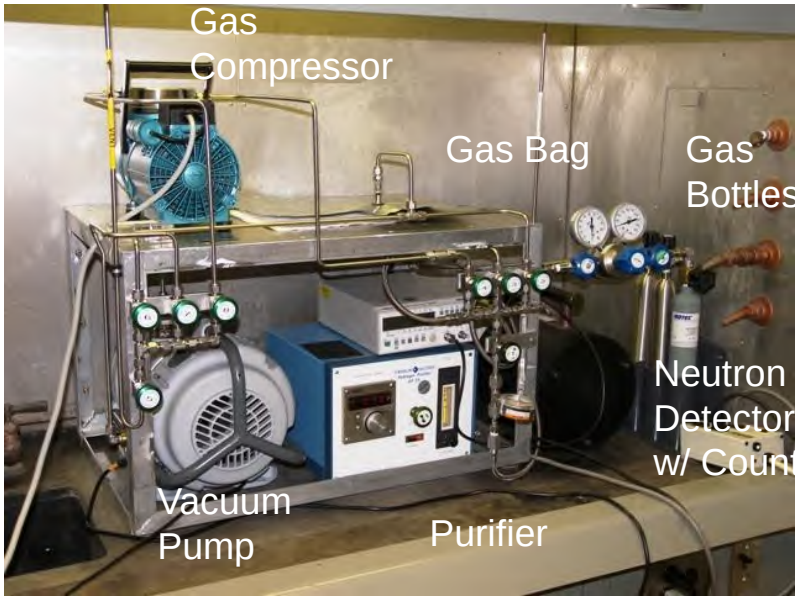
- Previous NASA D-Pd experiment (Fralick, et al.; 1989) looked for neutrons (saw none) – but saw anomalous heating
- NASA $H_2O$-Ni-$K_2CO_3$ Electrolytic Cell experiment (Niedra et al,1996) Apparent current-dependent excess heat consistent as heat from hydrogen-oxygen recombination
- NASA Sonoluminescence Experiment (Wrbanek, et al) - Cratering seen with heavy water, not seen with light water
- After 1989, Cold Fusion research evolved into research in “Low Energy Nuclear Reactions” (LENR), primarily at U.S. Navy, DARPA & various Universities
- **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 for 2009 Tests



# **APPROACH:** 2009 Test Apparatus



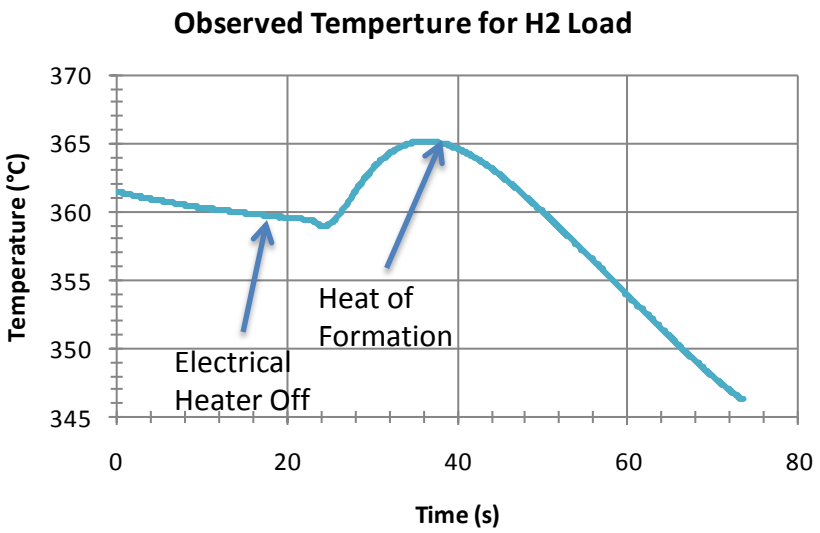

- Johnson Matthey HP-25 hydrogen purifier
  - Purifier Filter contains a ~50g heated Pd-25%Ag membrane
- Load Filter by flowing hydrogen gas into the purifier
- Unload Filter by pumping the gas out of the purifier into a sample bottle
- Turn off filter heater for a time when Loading & Unloading
- Monitor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

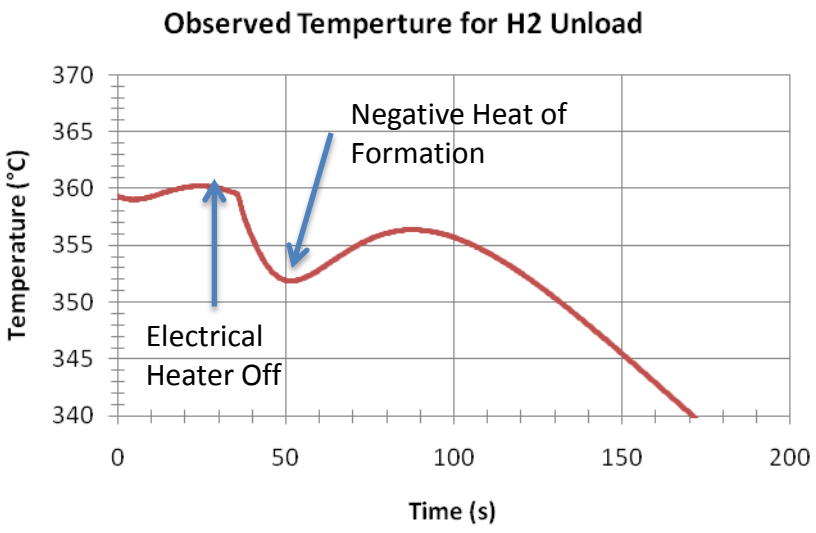
# **RESULTS** (Preliminary): Temperatures vs. Time

## Loading

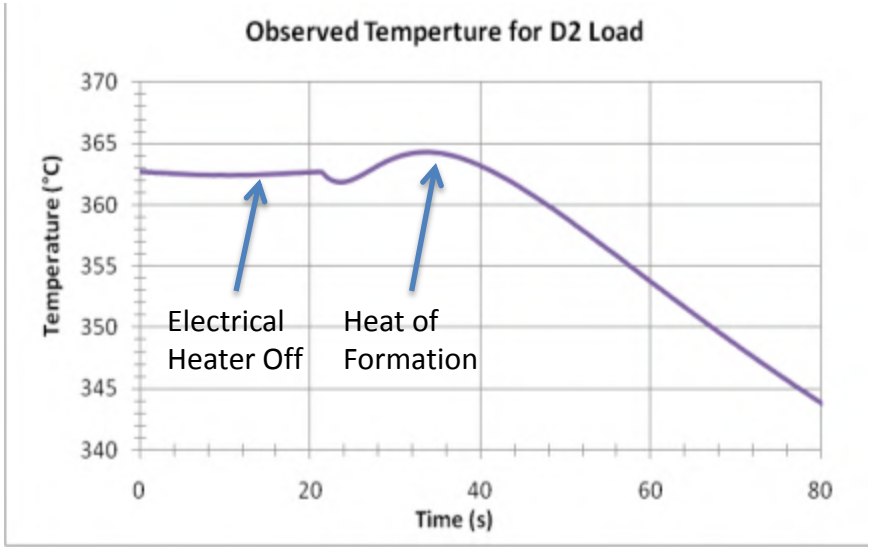
## Unloading

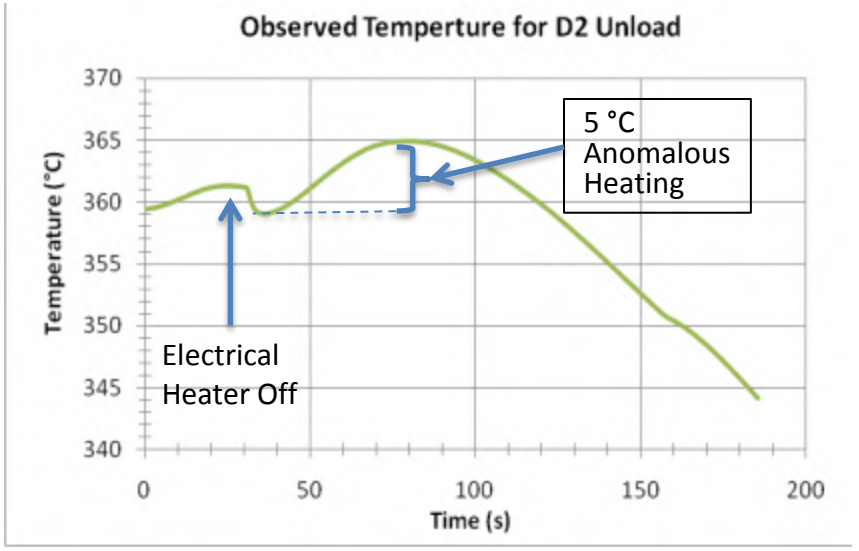
**Hydrogen**



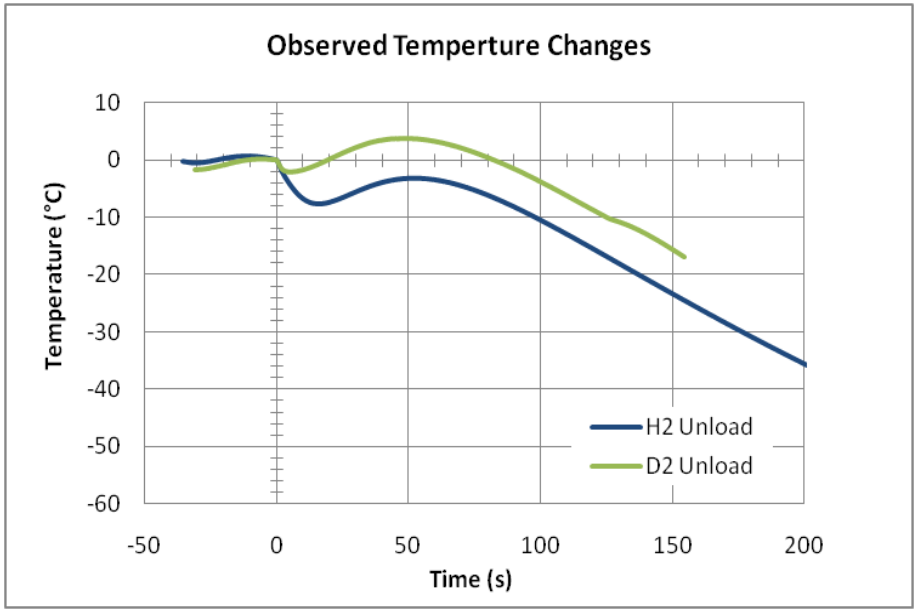



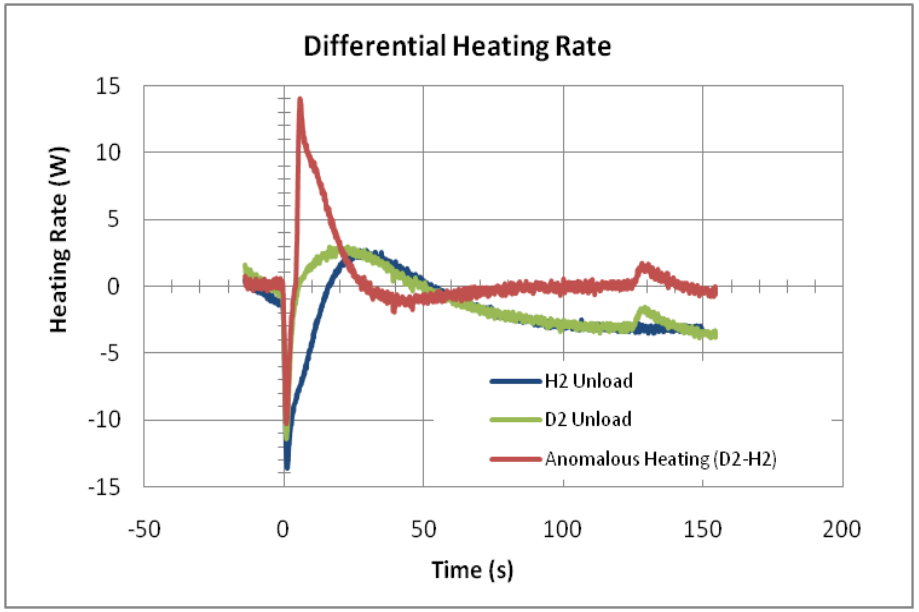

**Deuterium**



# RESULTS (continued): Temperature vs. Time




Results of GRC IPP investigation:

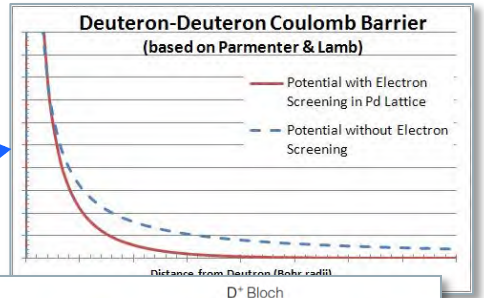
a) the temperature data is shown for H2 and D2 unloading (left);

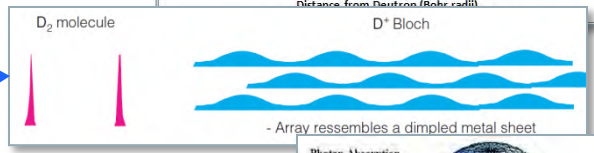
b) the calculated thermal power in/out is given with the net anomalous heating (right).

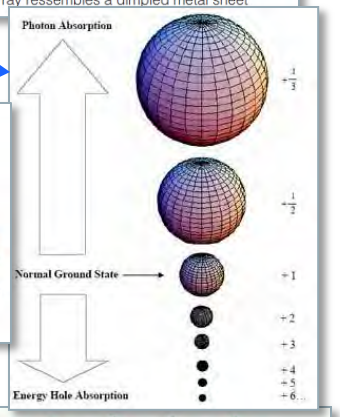
# Hypotheses

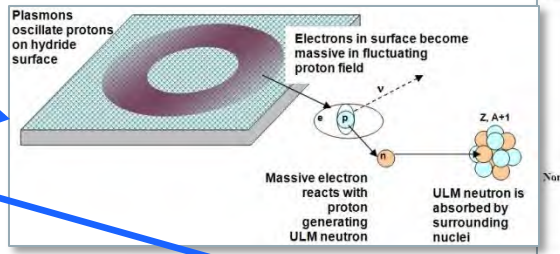
Theories (i.e., Hypotheses where proponents already published in peer-reviewed journals):

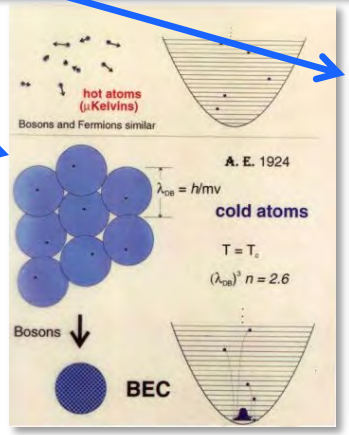
- Electron Screening (Parmenter & Lamb)
- Band States (Chubb & Chubb)
- Shrunken Hydrogen (Maly, Vavra & Mills)
- Ultra Low Momentum Neutrons (Widom & Larsen)
- Dislocation Loops (Hora & Miley)
- Bose-Einstein Condensates (Kim)

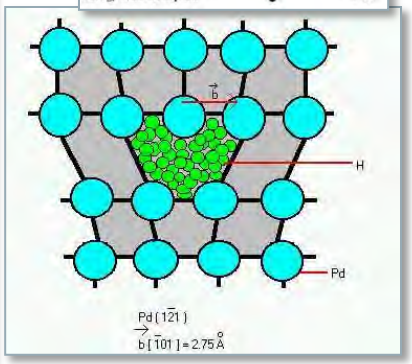



Do any of these encompass <u>all</u> reported observations?

- *More than one effect may be occurring*

# Ongoing Work

- Based on this anomalous heating, GRC team is examining following:
  - Modeling to assess what Pd/Ag coil temperature was to achieve measured temperature rise in thermowell
  - Improved cartridge design to allow direct measurement of coil temperature rise
  - Other advanced material concepts and approaches

# Benefits for NASA

- Replace $^{238}Pu$ as power source in deep space missions
  - Currently in short supply
  - Now depend upon foreign sources
  - Perhaps 5 years to supply our own
  - No money in new budget to restart domestic production
- Replace fission reactors as power source for human habitation missions
  - No radioactive waste
  - No radioactive material accident hazard on launch

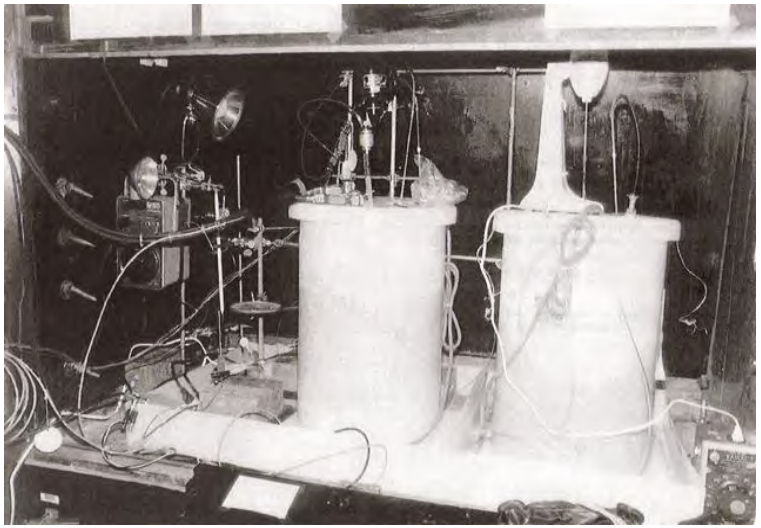
# Other Experiments

# Hydro Catalysis Corporation
# (Currently known as Blacklight Power)

# $H_2O$-Ni-$K_2CO_3$ Electrolytic Cell

**Experiment:**

- Investigated reports of significant long-term excess heat in light water-Ni-$K_2CO_3$ electrolytic cells
- Two 28-liter electrolytic cells for tests, one active cell for electrolytic tests, second inactive cell for reference thermal measurements
- Tested at several dc currents and a pulse mode current



**Results:**

- Apparent current-dependent excess heat exhibited when tested in all modes
- Excess heat consistent as heat from hydrogen-oxygen recombination catalyzed by the Pt and Ni electrodes within the cell
- Did not reproduce the large excess heat reported in literature
  - Gain Factors of <1.7 @ GRC vs. >10 in literature

- NASA TM-107167 (J. Niedra, I. Myers, G. Fralick, R. Baldwin; 1996)

# Sonoluminescence

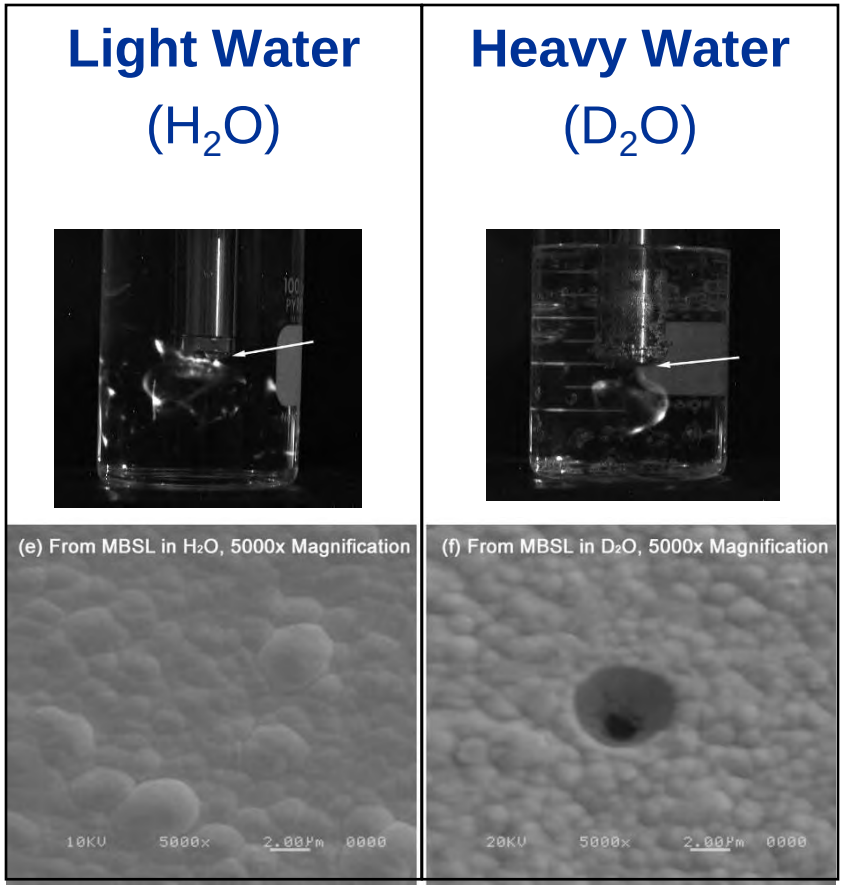
# Sonoluminescence

## Experiment

- Sonoluminescence with Palladium-Chromium (PdCr) Thin Films Over Platinum (Pt) RTD (Resistance Temperature Device)Traces on Alumina

## Result

- No Crater seen in $H_2O$, Crater Formation seen in $D_2O$
- Large Grain Failures usually seen in thin films due to mismatches in coefficients of thermal expansion at high temperature (~1000°C)





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