NASA Glenn Research Center experience with “LENR Phenomenon”

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Outline

- LENR Brief History
- Advantages of Fusion
- Selected Hypothesis
- NASA Glenn Research Center small related experiments
LENR – Brief History

• 1989 Electrochemists Stanley Pons and Martin Fleischmann observed higher than expected heating in electrolysis experiments involving Deuterium and Palladium.
  – Observed that the temperature rise was higher than could be accounted for by known chemical processes.
  – Speculated that nuclear reactions might explain excess energy.
• Actual cause of reactions still debated at this time.
• A variety of experiments and theories since 1989
Fusion Processes

Known Fusion Processes:
• \( D + D \rightarrow T (1.01 \text{ MeV}) + p (3.02 \text{ MeV}) \)
• \( D + D \rightarrow ^3\text{He} (0.82 \text{ MeV}) + n (2.45 \text{ MeV}) \)
• \( D + D \rightarrow ^4\text{He} (73.7 \text{ keV}) + \gamma (23.8 \text{ MeV}) \)
• \( D + T \rightarrow ^4\text{He} (3.5 \text{ MeV}) + n (14.1 \text{ MeV}) \)
• \( D + ^3\text{He} \rightarrow ^4\text{He} (3.6 \text{ MeV}) + p (14.7 \text{ MeV}) \)
  - \( D = ^2\text{H}, T = ^3\text{H} \)
  - Some have suggested that yet unknown “fusion processes” may be involved.
  - Many “LENR phenomenon” occur without energetic particle or wave radiation measured.
  - A few research efforts have claimed radiation from LENR phenomena, but too little to attribute to known processes.
Some Hypotheses

“Pet Theories” (i.e., Hypotheses where proponents already convinced 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 all reported observations?

- More than one effect may be occurring
Related Experiments at NASA Glenn Research Center (GRC)

- **Instances of short-term experiments**
  - 1989: Gaseous D₂, H₂ in Hydrogen Purifier
    - Fralick, Decker, Blue
  - 1996: H₂O-Ni-K₂CO₃ Electrolytic Cell
    - Niedra, Meyers, Fralick, Baldwin
    - Fralick, Wrbaneck J., Wrbaneck S.
  - 2009: “Anomalous Heating in Bulk Palladium” Innovative Partnership Program (IPP)
    - Fralick, Wrbaneck J., Wrbaneck S., Millis, Niedra
1989 Gaseous $\text{H}_2$ and $\text{D}_2$

- 1989 – Following Pons and Fleischmann announcement GRC team of Fralick, Decker, and Blue performed gaseous $\text{H}_2$ and $\text{D}_2$ experiments using a hydrogen purifier containing Pd/Ag alloy.
  - Goal: avoid wet electrochemical cell since they were not electrochemists.
  - Look for neutrons.
  - Use resources readily available.
  - Keep experiment as simple as possible.
1989 Gaseous H$_2$ and D$_2$

- 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
1989 Gaseous H$_2$ and D$_2$

**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
1989 Gaseous H$_2$ and D$_2$

Results:

- Temperature increase noted while gas was loaded into palladium cell, for both D & H
- Neutron detector counts did not differ significantly ($\leq$2σ) from background in any run (Monitored with BF$_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

Purifier plumbing, showing vacuum pump used to evacuate cell, and gas bottle used to load cell
1996 H₂O-Ni-K₂CO₃ Electrolytic Cell

Experiment:

• Investigated reports of significant long-term excess heat in light water-Ni-K₂CO₃ 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)
Multi-Bubble Sonoluminescence

Experiment:
• Investigated energy of ultrasonic-generated multi-bubble sonoluminescence (MBSL)
• Sonoluminescence with Palladium-Chromium (PdCr) Thin Films Over Platinum (Pt) Traces on Alumina

Results:
• No Crater seen on films in H₂O, but Crater Formation seen in D₂O
• Large Grain Failures usually seen in thin films due to mismatches in coefficients of thermal expansion at high temperature (~1000°C)
  – Indicates point heating in films?
Summary Observations from 1989 to 2009

- Previous NASA D-Pd experiment (Fralick, et al., 1989) looked for neutrons (saw none) – but saw anomalous heating
- NASA H₂O-Ni-K₂CO₃ 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., 2007) – Crater formation in PdCr films 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 1989 tests to investigate the anomalous heat
  - Apply GRC’s instrumentation expertise to improve the diagnostics for this experiment
  - Establish credible framework for future work in LENR
2009 IPP APPROACH: Flow System Schematic

- Hood Vent
- Atmospheric Pressure Gas Bag
- Relief Valve: Kunkle 0548-A01-KM0100
- Gas Pressure Gauge
- HP-25 Purifier (Feed Port)
- System Line Valves:
  - Open
  - Closed

Valves:
- All Valves Swagelok SS-4H unless otherwise indicated

Gas Bottles:
- Exchange Lecture Bottle (400 ml) DOT 3E-1800 (Swagelok 304L-HDF4-400)
- Supply Lecture Bottle (440 ml) DOT 3E-1800
- D₂
**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: Temperatures vs. Time

**Loading**

- **Observed Temperature for H2 Load**

**Unloading**

- **Observed Temperature for H2 Unload**

**Hydrogen**

**Deuterium**

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RESULTS (continued): Temperature Changes 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).

- No changes seen in neutron background counts
Summary & Conclusions

- NASA GRC has conducted a variety of small-scale short-term investigations into LENR-related claims
- Isotope-dependent heating was seen in a hydrogen purifier during gas evacuation in 1989
- Point craters in films exposed to sonoluminescence in water in 2007 also had isotope dependence
- Follow on study of hydrogen purifier heating done in 2008 documented the 1989 anomalous heating effect
  - More data needed to draw conclusion of its nature
- Small-scale work continues:
  - 2011 Center Innovation Fund “Fast-Track” 2-week project to determine dependency of rate of withdraw on the heating effect
  - Short project time limited effort to experiment setup and rough preliminary data run; more data still needed to clarify uncertainties
- If proven useful, the transient nature of this heating effect needs to be better characterized for applications to cyclic power systems
References

• Fralick, G., Decker, A., Blue, J., “Results of an Attempt to Measure Increased Rates of the Reaction $^2$D + $^2$D $\rightarrow$ $^3$He + n in a Non-electrochemical Cold Fusion Experiment,” NASA TM-102430 (1989).


