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.
“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 D$_2$, H$_2$ in Hydrogen Purifier
    • Fralick, Decker, Blue
  – 1996: H$_2$O-Ni-K$_2$CO$_3$ Electrolytic Cell
    • Niedra, Meyers, Fralick, Baldwin
    • Fralick, Wrbanek J., Wrbanek S.
    • Fralick, Wrbanek J., Wrbanek S., Millis, Niedra
1989 Gaseous H\(_2\) and D\(_2\)

- 1989 – Following Pons and Fleischmann announcement GRC team of Fralick, Decker, and Blue performed gaseous H\(_2\) and 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 H₂ and D₂

- 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

Hydrogen purifier (center) with neutron detectors on either side
1989 Gaseous H₂ and D₂

Results:

- Temperature increase noted while gas was loaded into palladium cell, for both D & H
- Neutron detector counts did not differ significantly (<2σ) from background in any run (Monitored with BF₃ 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 D₂ that was not seen with the H₂ 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
Experiment:

- Investigated reports of significant long-term excess heat in light water-Ni-K$_2$CO$_3$ 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
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 H$_2$O, but Crater Formation seen in D$_2$O
- 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?


**Light Water**
- (H$_2$O)

**Heavy Water**
- (D$_2$O)

Surface morphology of films exposed to sonoluminescence in light water (left) and heavy water (right)
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 H$_2$O-Ni-K$_2$CO$_3$ 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., 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

- System Line Valves
  - Open
  - Closed
  - All Valves Swagelok SS-4H unless otherwise indicated

- Hood Vent
- Atmospheric Pressure Gas Bag
- HP-25 Purifier (Feed Port)
- Gas Pressure Gauge
- XDS10 Scroll Pump
- N035 STP Compressor
- Gas Bottle Control Valve SS-16DKM4-F4-A1
- Exchange Lecture Bottle (400 ml) DOT 3E-1800 (Swagelok 304L-HDF4-400)
- Gas Bottle Regulator Linde UPG 3 75 350
- 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

**Hydrogen**

*Loading*

*Observed Temperature for H2 Load*

*Unloading*

*Observed Temperature for H2 Unload*

**Deuterium**

*Loading*

*Observed Temperature for D2 Load*

*Unloading*

*Observed Temperature for D2 Unload*
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 $^2D + ^2D \rightarrow ^3He + n$ in a Non-electrochemical Cold Fusion Experiment,” NASA TM-102430 (1989).


