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.
  - Dubbed “cold fusion” in the press, often known as “Low Energy Nuclear Reactions (LENR),” sometimes “Chemically Assisted/(activated) Nuclear Reactions (CANR)
- Actual cause of reactions still debated at this time.
- A variety of experiments and theories since 1989

Fusion Processes

Known Fusion Processes:

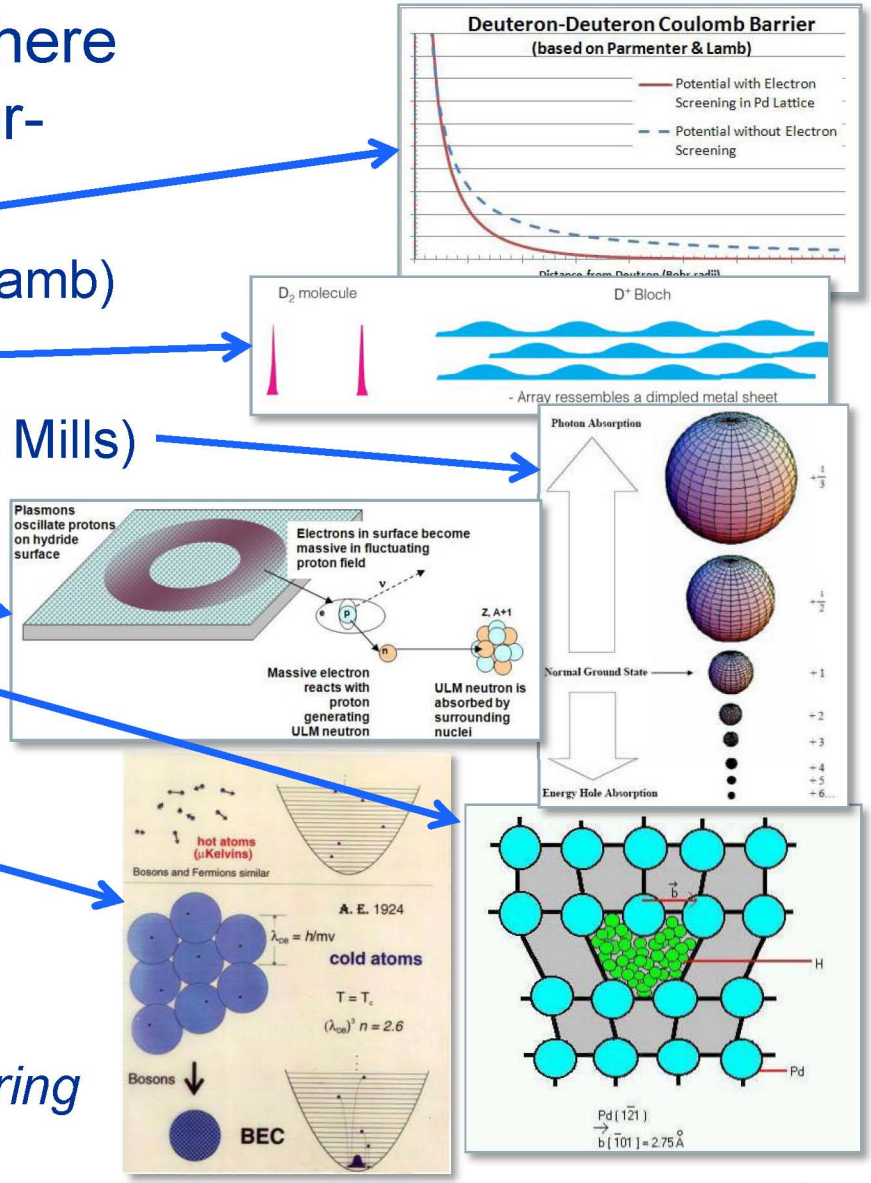
- $D + D \rightarrow T\ (1.01\ MeV) + p\ (3.02\ MeV)$
- $D + D \rightarrow {}^{3}He\ (0.82\ MeV) + n\ (2.45\ MeV)$
- $D + D \rightarrow {}^{4}He\ (73.7\ keV) + \gamma\ (23.8\ MeV)$
- $D + T \rightarrow {}^{4}He\ (3.5\ MeV) + n\ (14.1\ MeV)$
- $D + {}^{3}He \rightarrow {}^{4}He\ (3.6\ MeV) + p\ (14.7\ MeV)$
  - $D = {}^{2}H$, $T = {}^{3}H$

  - 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 <u>all</u> reported observations?

- *More than one effect may be occurring*

Related Experiments at NASA Glenn Research Center (GRC)

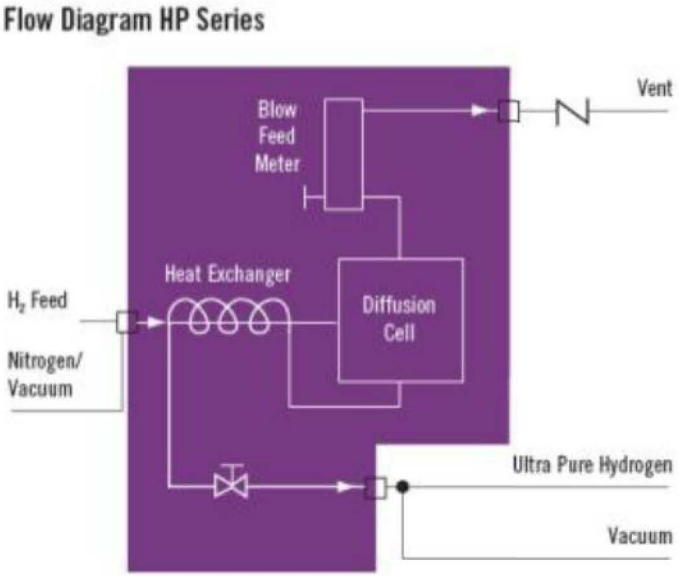
- Instances of short-term experiments
  - 1989: Gaseous D_2, H_2 in Hydrogen Purifier
    - Fralick, Decker, Blue
  - 1996: H_2O-Ni-K_2CO_3 Electrolytic Cell
    - Niedra, Meyers, Fralick, Baldwin
  - 2007: Multi-Bubble Sonoluminescence investigation sponsored by Low Emissions Alternative Power (LEAP) Project & Breakthrough Propulsion Physics (BPP) Project
    - Fralick, Wrbanek J., Wrbanek S.
  - 2009: "Anomalous Heating in Bulk Palladium" Innovative Partnership Program (IPP)
    - 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 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



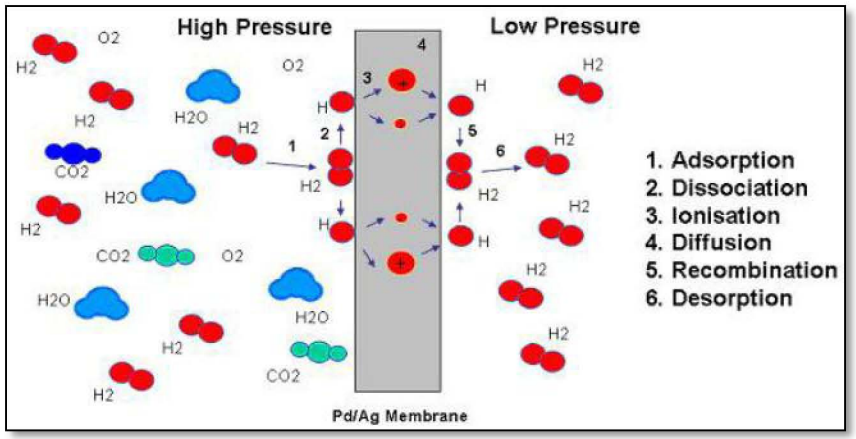
1989 Gaseous H_2 and D_2

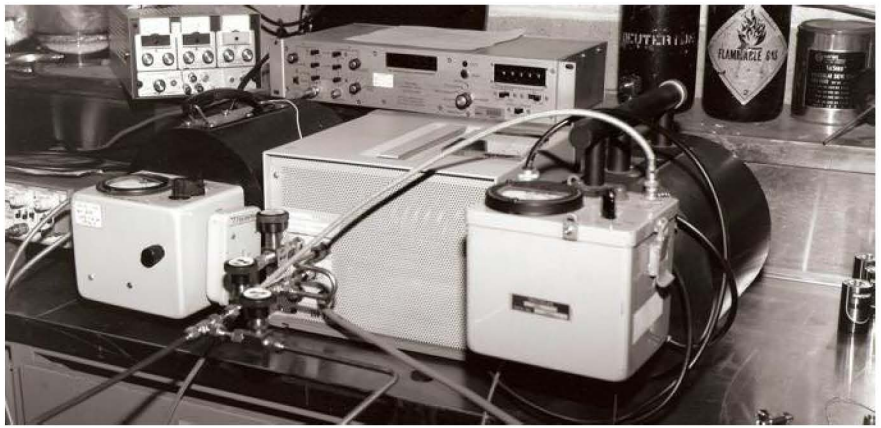
EQUIPMENT

- 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





Hydrogen purifier (center) with neutron detectors on either side

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 ($\leq 2\sigma$) 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.

Purifier plumbing, showing vacuum pump used to evacuate cell, and gas bottle used to load cell

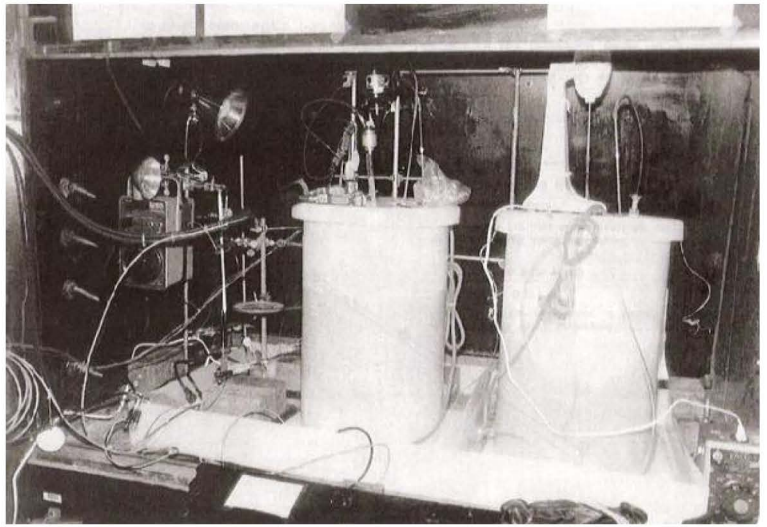
Published:

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

1996 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



Two 28 liter electrolytic cells

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)

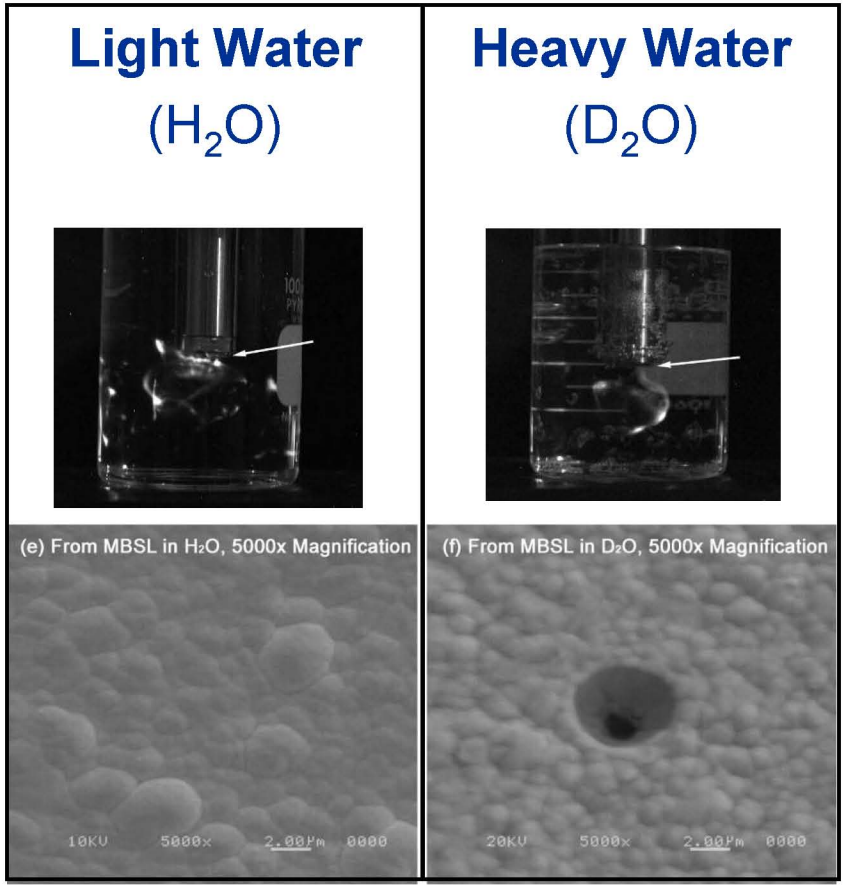
Multi-Bubble Sonoluminescence

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 H_2O, but 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)
  - Indicates point heating in films?



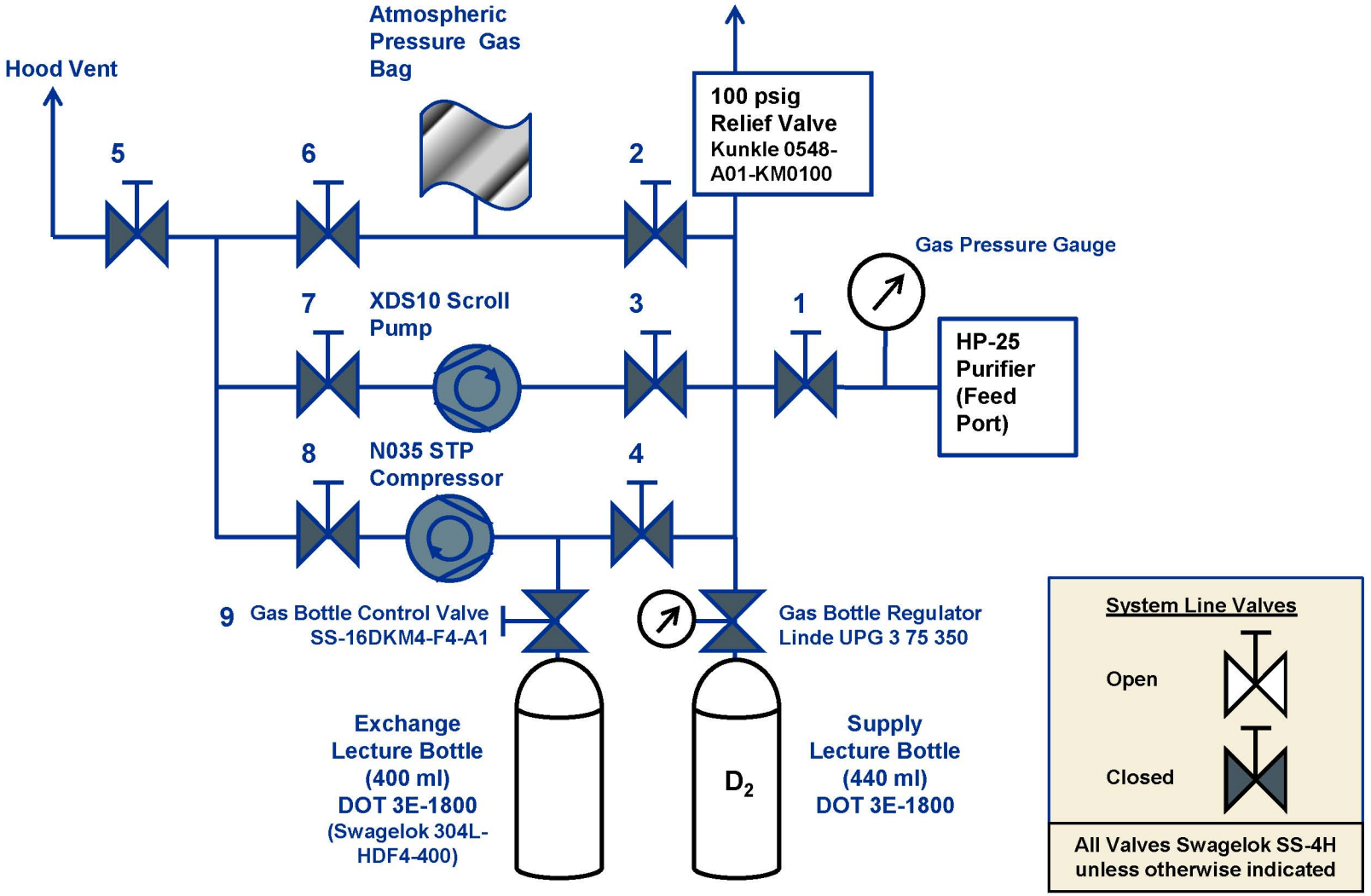
Surface morphology of films exposed to sonoluminescence in light water (left) and heavy water (right)

- J. Wrbanek, G. Fralick, S. Wrbanek, & N. Hall, "Investigating Sonoluminescence as a Means of Energy Harvesting," Chapter 19, *Frontiers of Propulsion Science*, Millis & Davis (eds), AIAA (2009), pp. 605-637.

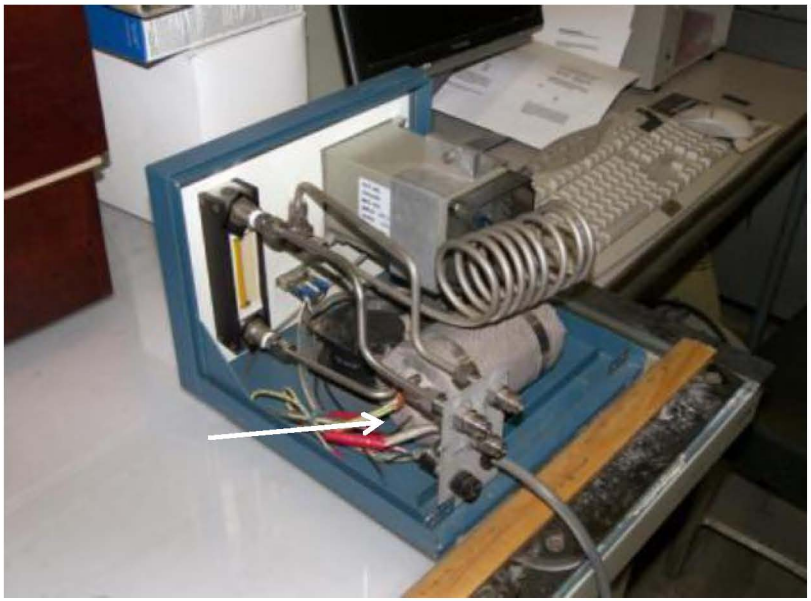
Summary Observations from 1989 to 2009

- Previous NASA D-Pd experiment (Fralick, et al., 1989) looked for neutrons (saw none) – but saw anomalous heating
- NASA H_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., 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



APPROACH: 2009 Test Apparatus



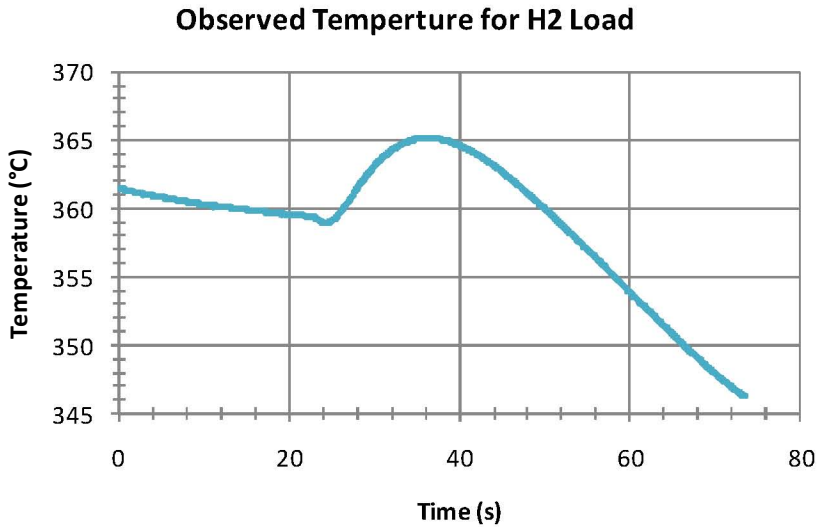
- Johnson Matthey HP-25 hydrogen purifier
  - Purifier Filter contains a ~50g heated Pd-25%Ag membrane
- Load Filter by flowing hydrogen gas into the purifier
- Unload Filter by pumping the gas out of the purifier into a sample bottle
- Turn off filter heater for a time when Loading & Unloading
- Monitor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

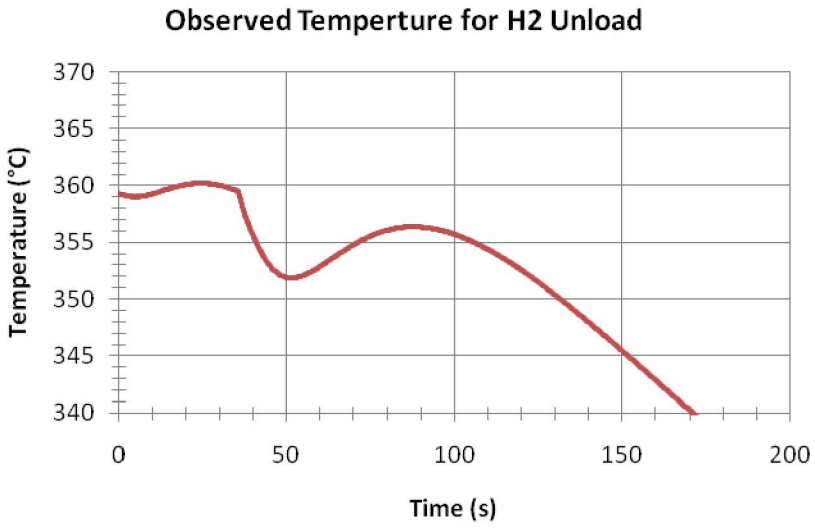
RESULTS: Temperatures vs. Time

Loading

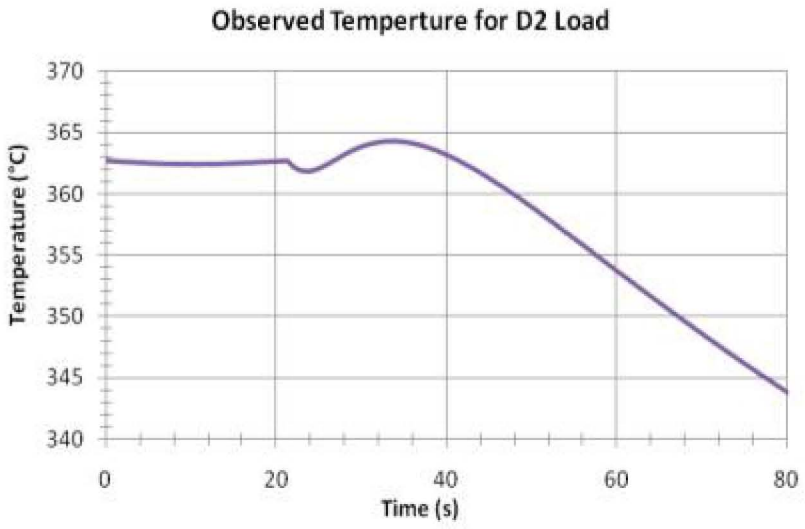
Unloading

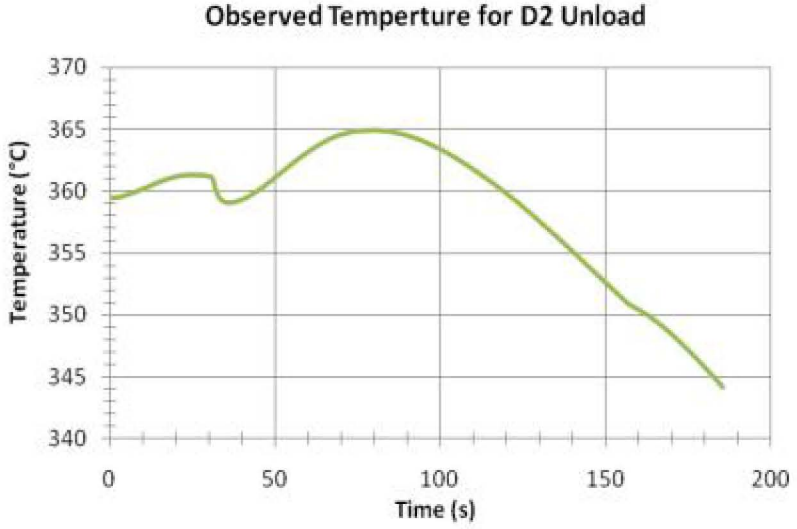
Hydrogen



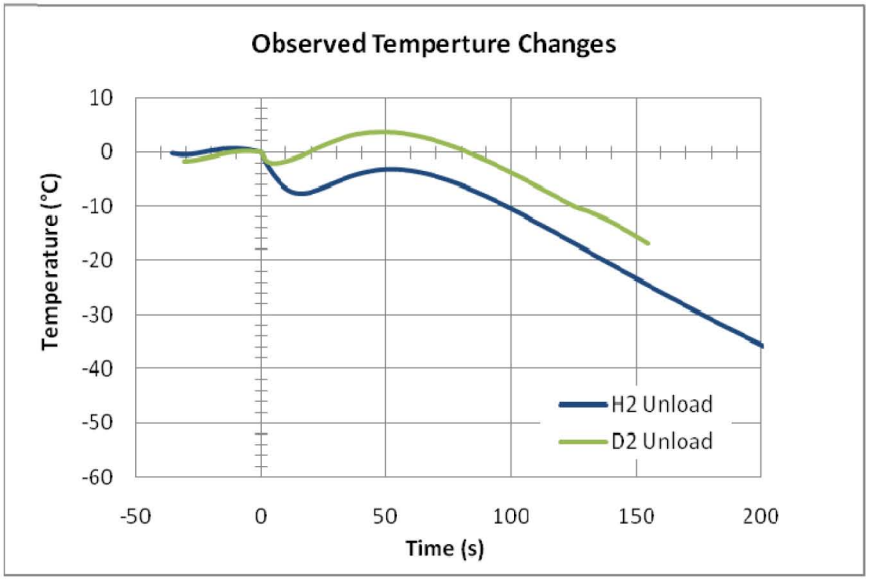


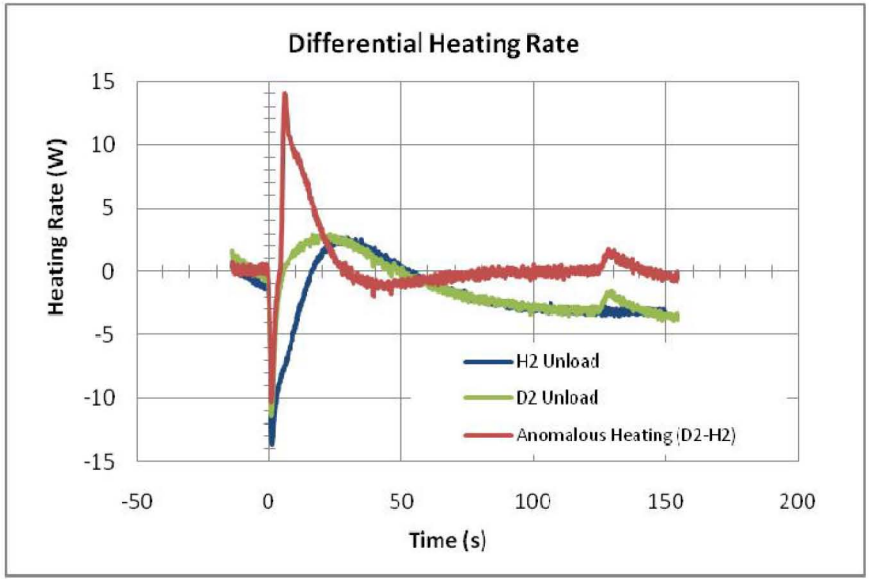
Deuterium





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).
- Niedra, J., Myers, I., Fralick, G., Baldwin, R. "Replication of the Apparent Excess Heat Effect in a Light Water-Potassium Carbonate-Nickel Electrolytic Cell", NASA TM-107167 (1996)
- Wrbanek, J., Fralick, G., Wrbanek, S., "Development of Techniques to Investigate Sonoluminescence as a Source of Energy Harvesting", NASA TM-2007-214982 (2007)
- Wrbanek, J., Fralick, G., Wrbanek, S., Hall, N. "Investigating Sonoluminescence as a Means of Energy Harvesting," Chapter 19, *Frontiers of Propulsion Science*, Millis & Davis (eds.), AIAA (2009) pp. 605-637.
- Fralick, G., Wrbanek, J., Wrbanek, S., Niedra, J., Millis, M., "LENR at GRC", Presentation at LENR Workshop, NASA GRC, September 22, 2011.