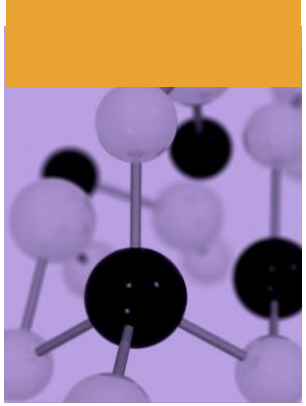
SRI International



CMNS Research at SRI

Francis L. Tanzella
Jianer Bao
Michael C. H. McKubre

SRI International, Menlo Park, CA USA

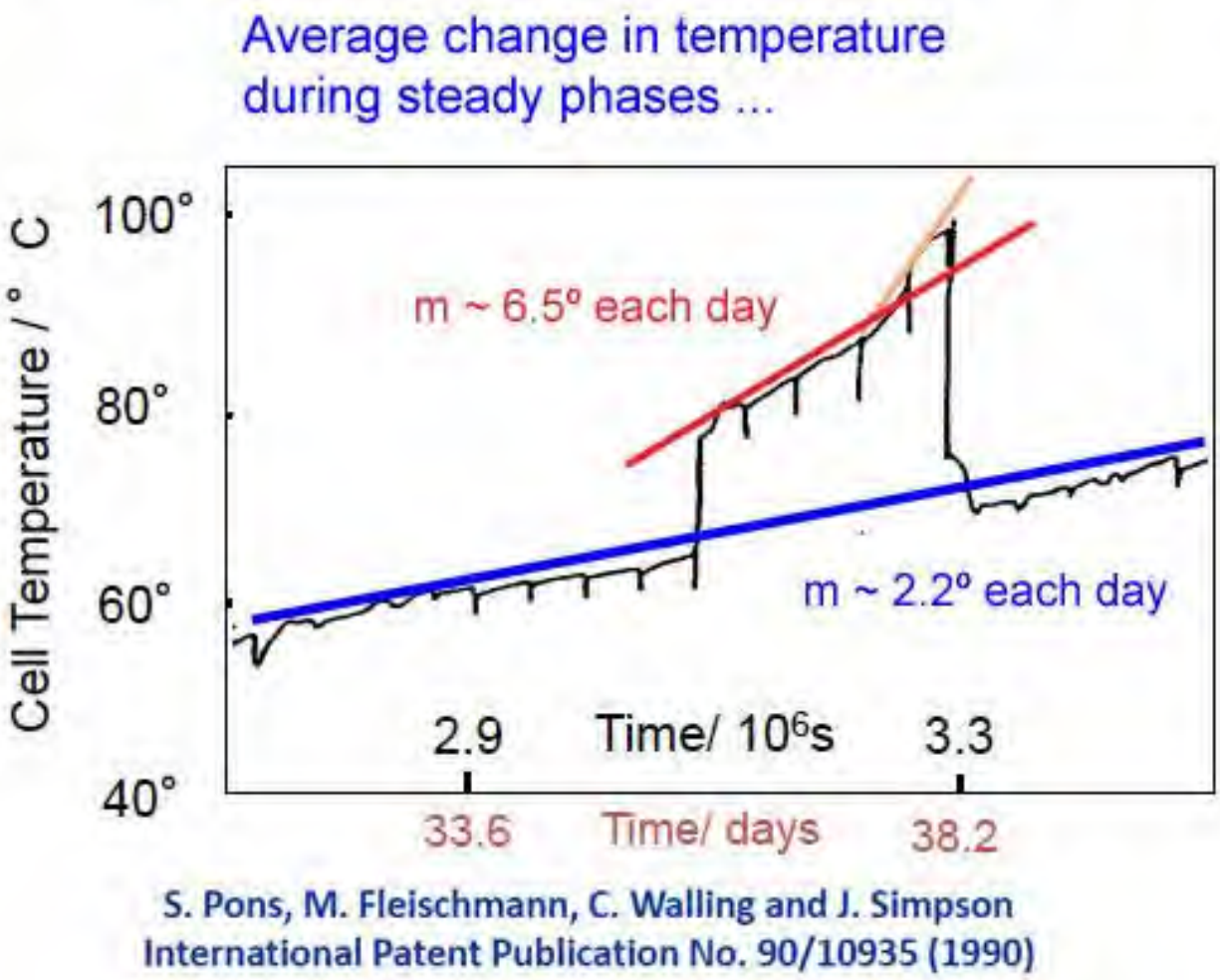
Presented at the International Low Energy Nuclear Reactions Symposium, ILENRS-12
Williamsburg, Virginia
July 2, 2012

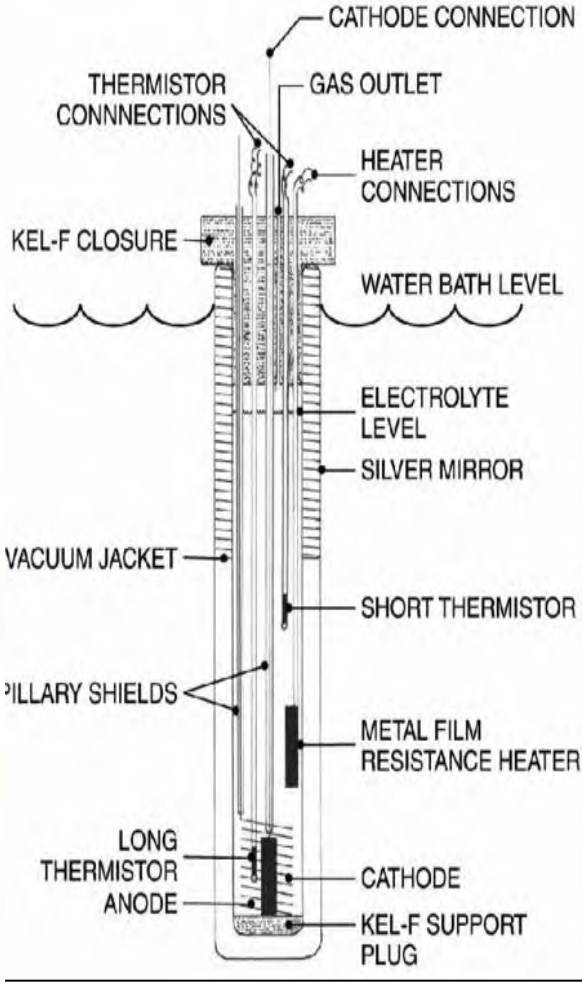
FPE Experiments, Electrochemistry and Calorimetry

In the beginning….

Fleischmann and Pons early results

Early Data on Cell Temperature





Cold Fusion Now 2/4/12 http://coldfusionnow.org/?p=12291

"This result, by itself, with no more explanation really, is sufficient – if you believe Martin Fleischmann – to convince you that there is a real thermal (anomalous heat) effect in the deuterium-palladium system." - Michael McKubre, SRI, 10/11/11

The Claim….

Deuterium,
Electrochemically inserted into Palladium
to a sufficient degree
Revealed a source of heat (thermal energy) 100 eV – 20 keV
inconsistent with known Chemical Energy sources 0.1 – 3 eV
or lattice energy storage effects. < 0.3 eV

If true….
there must be another energy source.
Fusion?
Other Nuclear?
Zero Point??
Something more exotic???

Three Major Parts of the Field Now

- Electrochemical loading of Deuterons into Palladium
  - The initial Fleischmann-Pons approach [FPE]
  - Most work in the field has been in this class
  - 90% of the effort at SRI has been directed to this
- Gas loading of Deuterons into Palladium
  - Les Case “nano”-Pd on C
  - Arata-Zhang combined electrochemistry and gas loading
- Gas loading of Protons (and D) into Nickel (and other metals)
  - Work began by Piantelli in early 1990s
  - Recent results at SRI

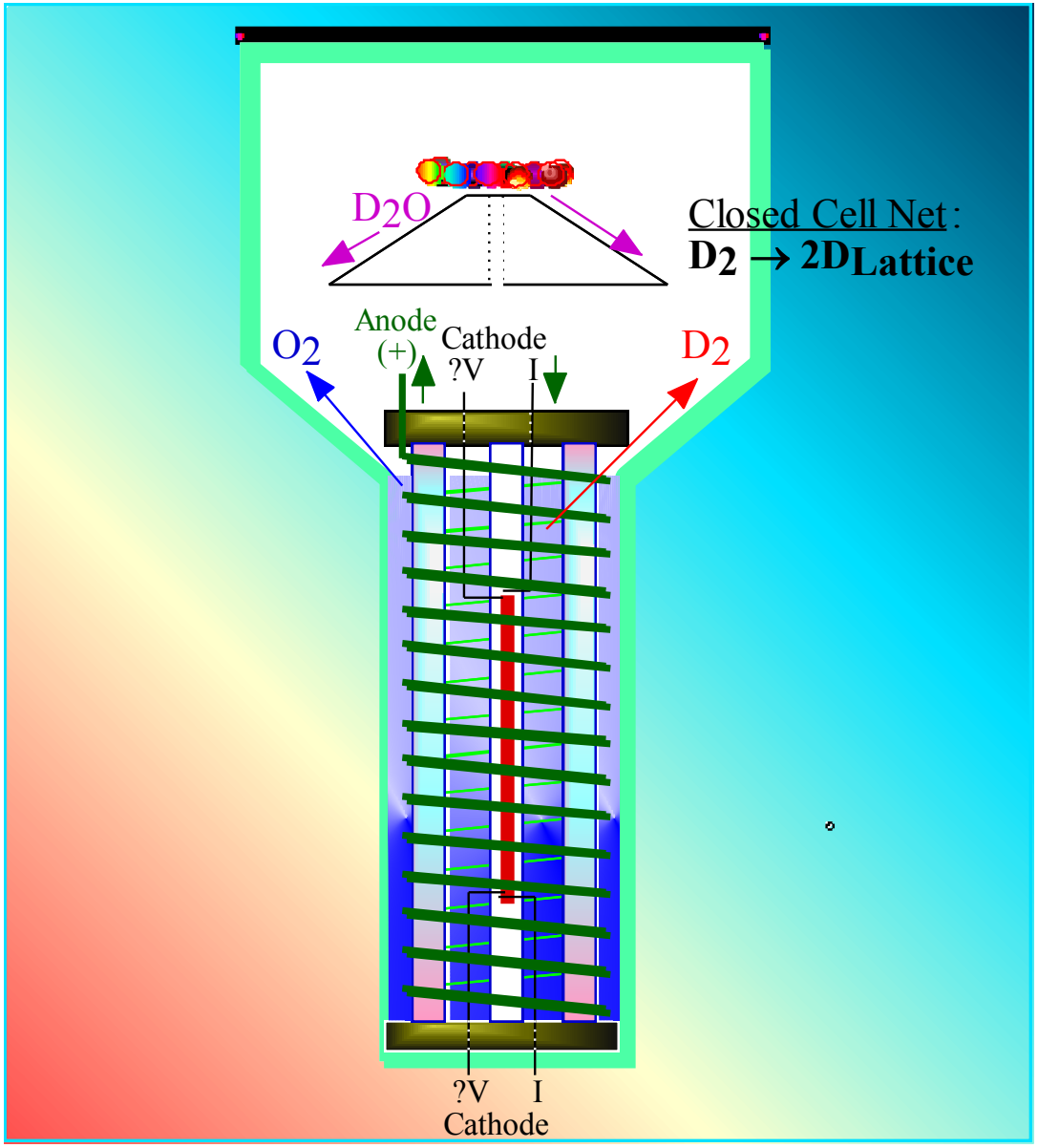
Loading Cell and Reactions

Wires:

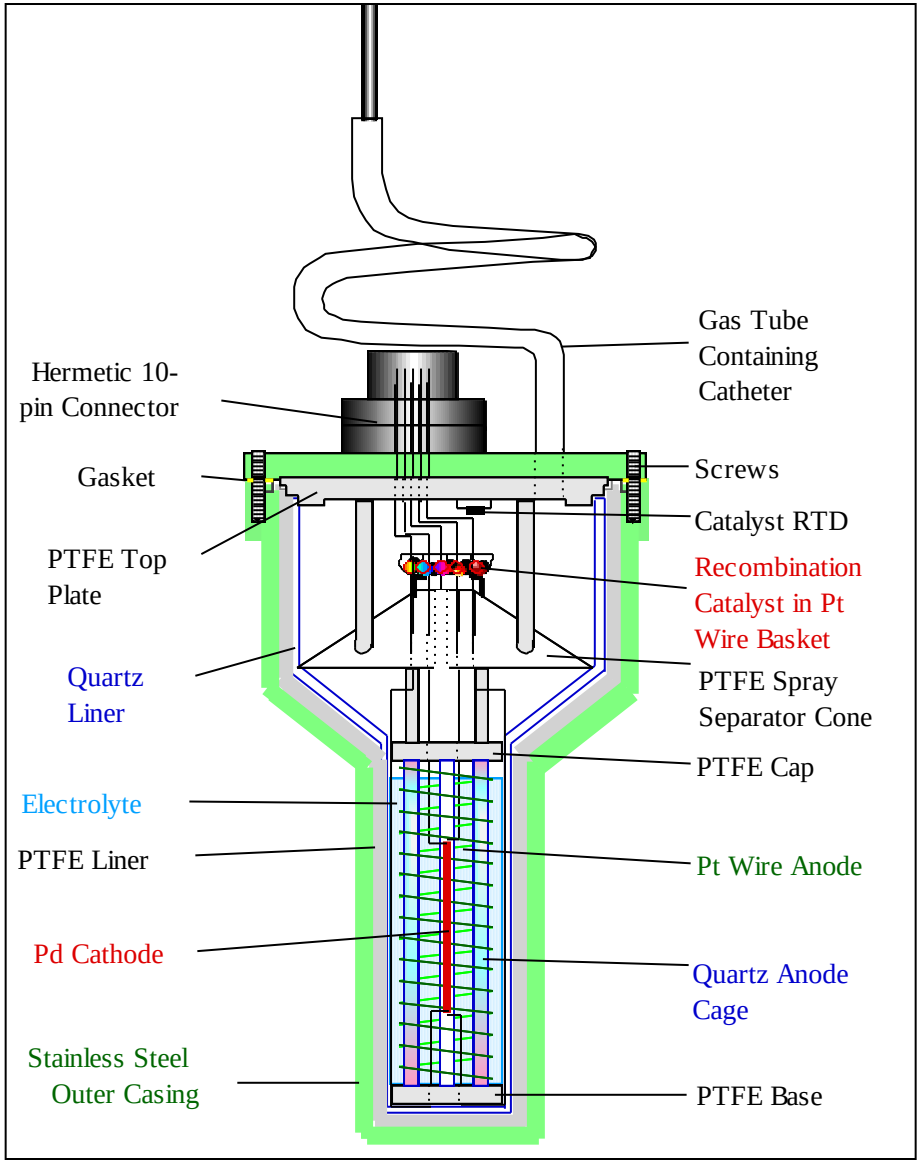
1 – 3 mm in diameter

3 – 5 cm in length

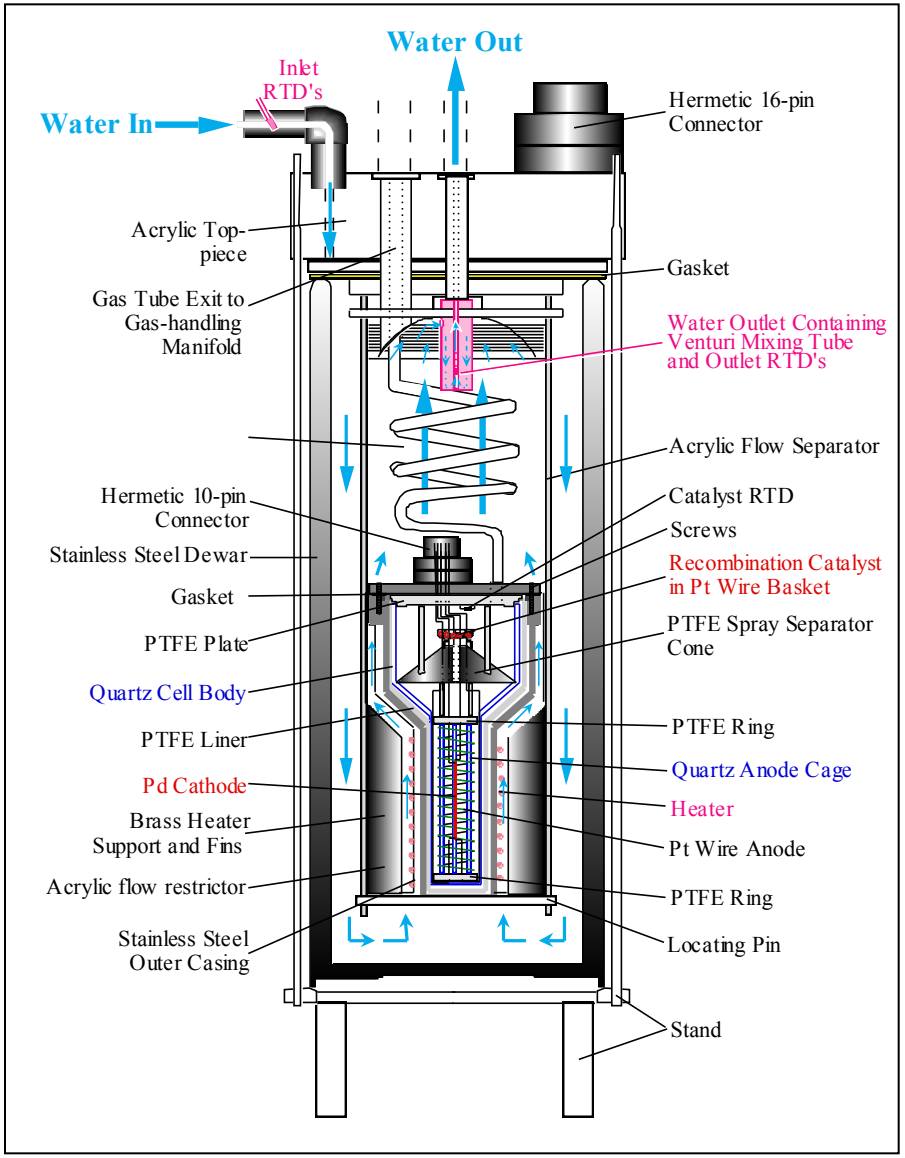
1M LiOD Electrolyte



SRI Quartz Calorimeter and Degree of Loading (DoL) Cell



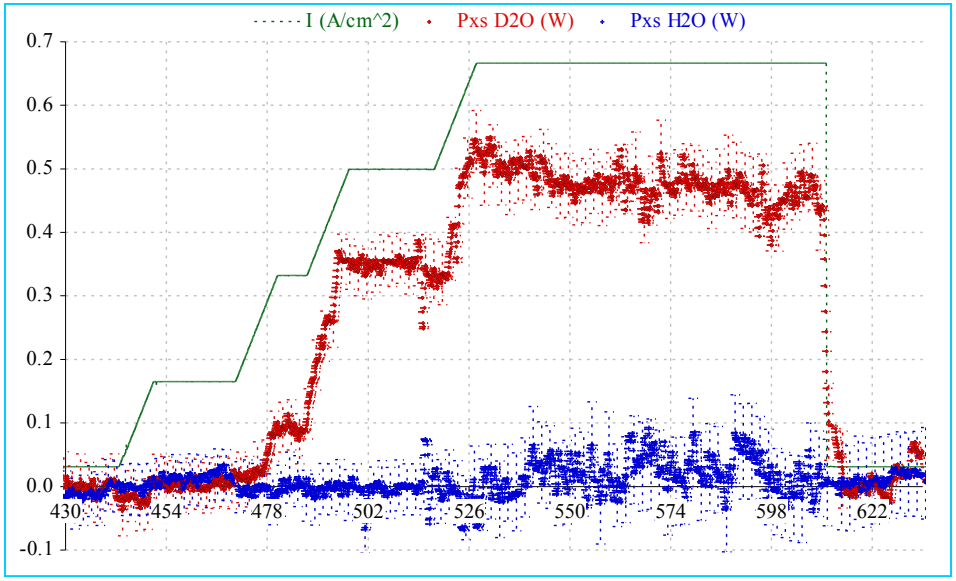
SRI Labyrinth (L and M) Calorimeter and Cell

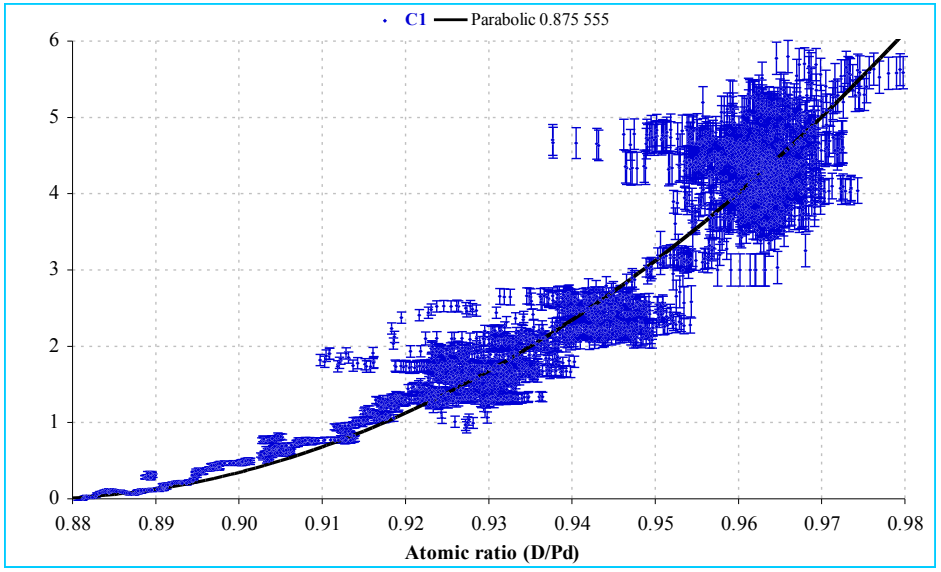


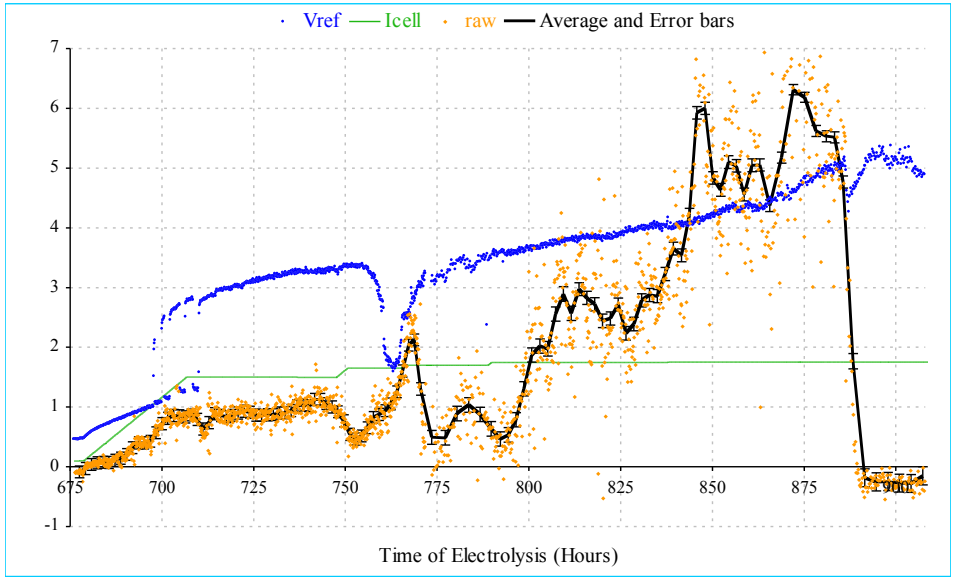
Accuracy: ±0.35%
Operation:
100 mW – 30W
Stability:
> 1000 hours

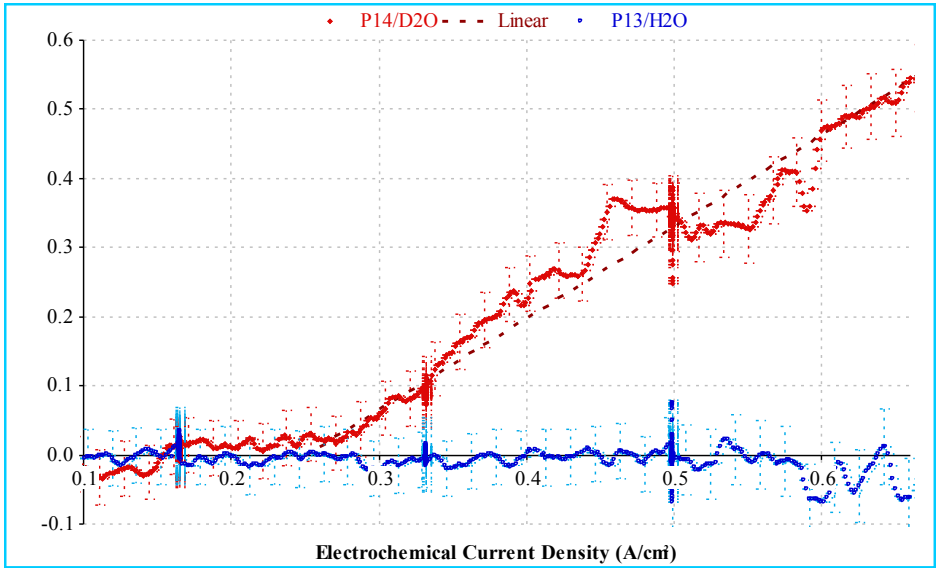
SRI >100,000 Hours of Precision Calorimetry using this and other Calorimeters

DoE Review 2004





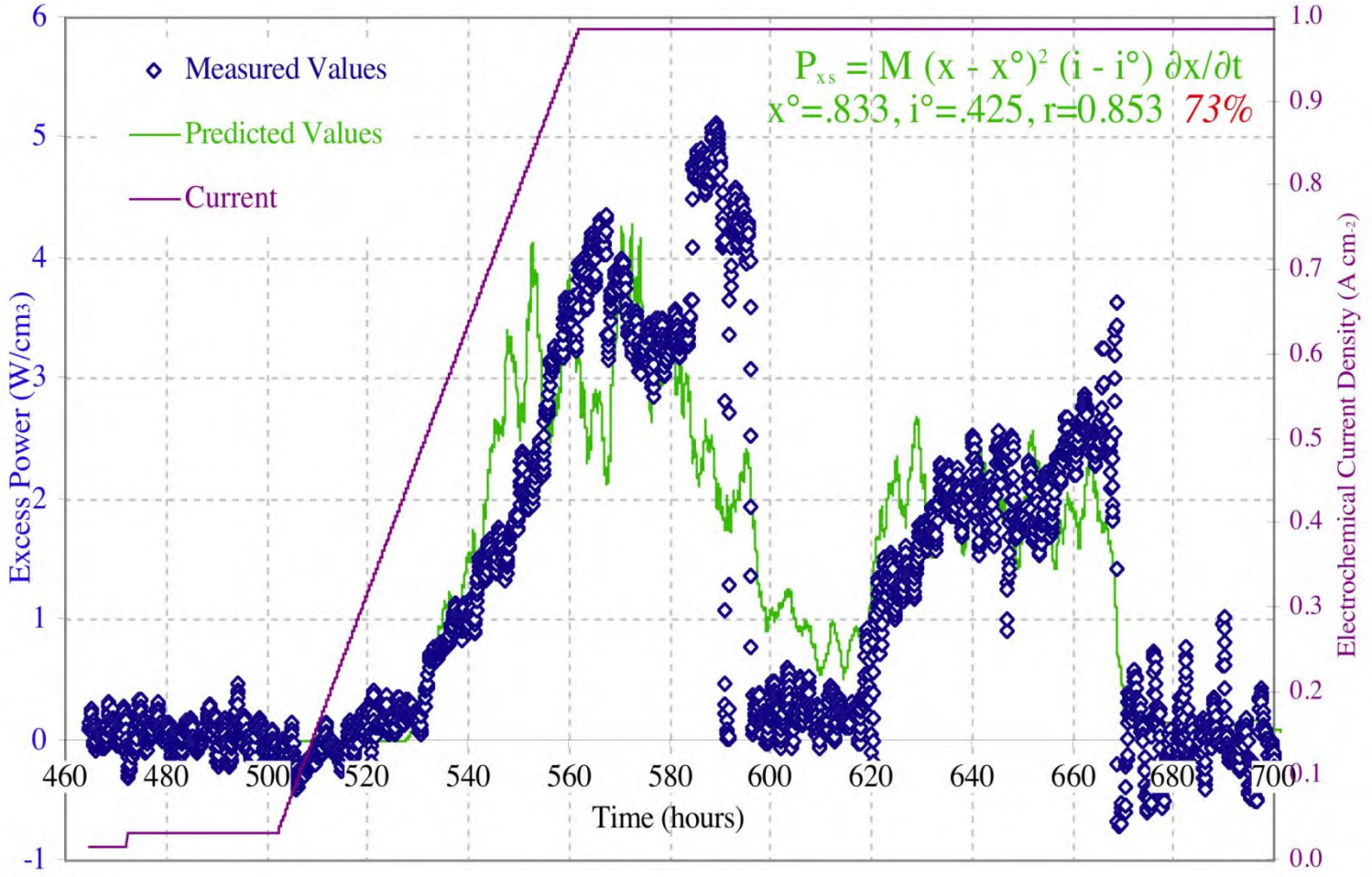




A Predictive Equation

$$P_{XS} = M\,(x-x^{\circ})^2\,(i-i^{\circ})\,|i_D|$$

$x = D/Pd$, x° ~0.875, i° =50-400mA cm^{-2}, i_D=2-20 mA cm^{-2}, t° >20 $\lambda_{D/D}$



Necessary but Not Sufficient….

- Necessary conditions:

  Maintain High Average D/Pd Ratio (*Loading*)

  For times >> 20-50 x $\tau_{D/D}$ (*Initiation*)

  At electrolytic i >250-500mA cm^{-2} (*Activation*)

  With an imposed D Flux (*Disequilibrium*)

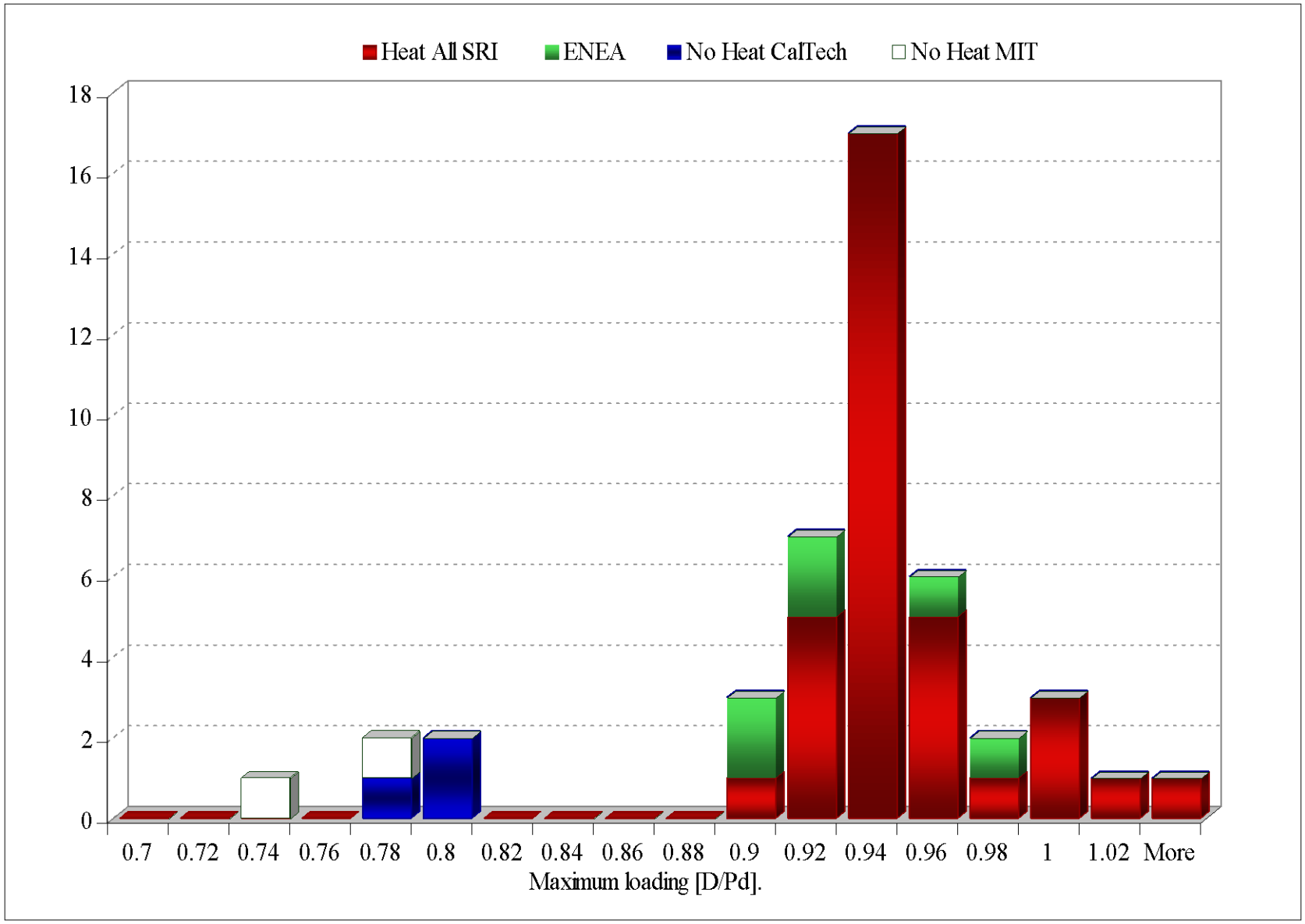
- Heat correlated with:
  - Electrochemical current or current density
  - D/Pd loading (bulk average measurement)
  - $V_{ref.}$ surface potential
  - Pd metallurgy (ENEA Frascati)
  - Laser stimulus (single and double)

- For 1mm diameter Pd wire cathodes:

  $P_{xs} = M (x-x^{\circ})^2 (i-i^{\circ}) \partial x/\partial t$

  x° =0.84-0.88, i° =250-425mA cm^{-2}, t° >200 $\tau_{D/D}$

“Achieve High Maximum D/Pd Ratio (Loading)”



Some open questions for the FPE

- Energy Densities measured >20,000 times Chemistry

  What (if anything) limits the Power?

- The Effect requires: Loading, Flux, Stimulation

  [How] Can we simultaneously achieve Loading and Flux?

  [How] Can we decouple Loading and Stimulation?

- FPE experiments take weeks or months to complete

  How can we learn faster?

  Looking for a “Lab Rat” experiment that is:

  - Repeatable
  - Rapid
  - Unambiguous

Axial current stimulus

❖**DeNinno, Scaramuzzi, *et al.*:**

- Axial current through PdD_x yields high loading and generates excess power
- ICCF8 Conference Proceedings, 70, 47 (2000)

❖**Mengoli *et al.*:**

- Axial current through PdD_x increases loading and gives nuclear effects (*i. e.* n^0)
- Nuovo Cimento A, 108A, 1187 (1995)

❖**Celani *et al.*:**

- Microsecond pulse electrolysis yields excess power
- Electromigration leads to high loading and yields excess power
- Fusion Technology, 29, 398 (1996)

❖ **Tripodi *et al.*:**

- Low concentration electrolyte (high electrolytic and axial voltage) leads to high loading
- *In situ* electrodeposition of base metal holds high loading *ex situ*
- Further electrolysis (including axial current) yields excess power and HT Superconductors
- Physics Letters A, 276, 122 (2000)

Background: Exploding Wire Effects

- ***Nairne***
  - "Electrical Experiments by Mr. Edward Nairne, of London, Mathematical Instrument-Maker, Made with a Machine of His Own Workmanship, a Description of Which is Prefixed", Phil. Trans. 64, 79-89 (1774)
- ***Faraday***
  - High current through thin wires can cause the wires to "explode"
  - Exploding wires can yield very fine, pure metal powders
  - Philos. Trans. Royal Society London, 147, 145 (1857)
- ***Chace and Moore***
  - Proceedings of the Conferences on the Exploding Wire Phenomenon, 1959 and 1961
- ***Hypothesis***
  - Fast, high current "exploding" of thin, highly loaded PdD_x wires can stimulate excess heat effects

Procedure:

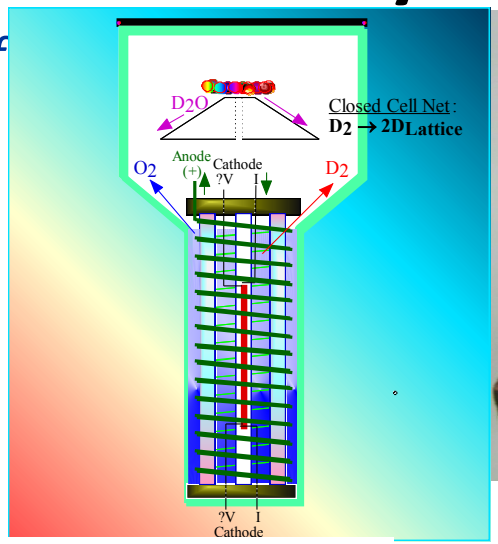
- Electrochemically load D or H to high levels in fine wires
  - Pd, Ni, Ag
- [Co-deposit additional loaded metal]
- Seal loading with Hg
- Make electrical connections for axial current flow
- Transfer to Liquid N_2
- Allow gas evolution to stabilize
- Attempt to fuse
- Measure excess evolved gas
- [Search for evidence of potential products of nuclear reaction]

Phase Change Calorimetry:

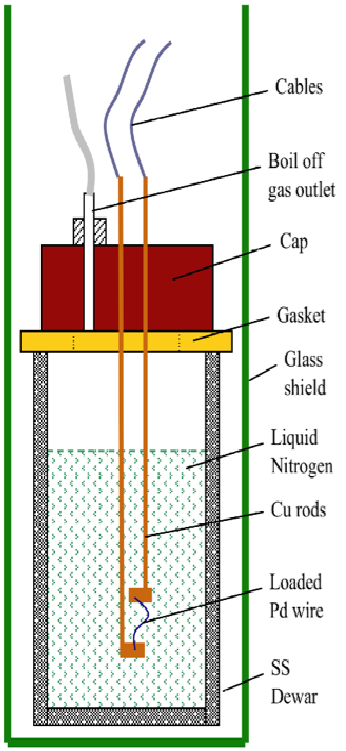
Liquid Nitrogen Boil-Off

Measurements:

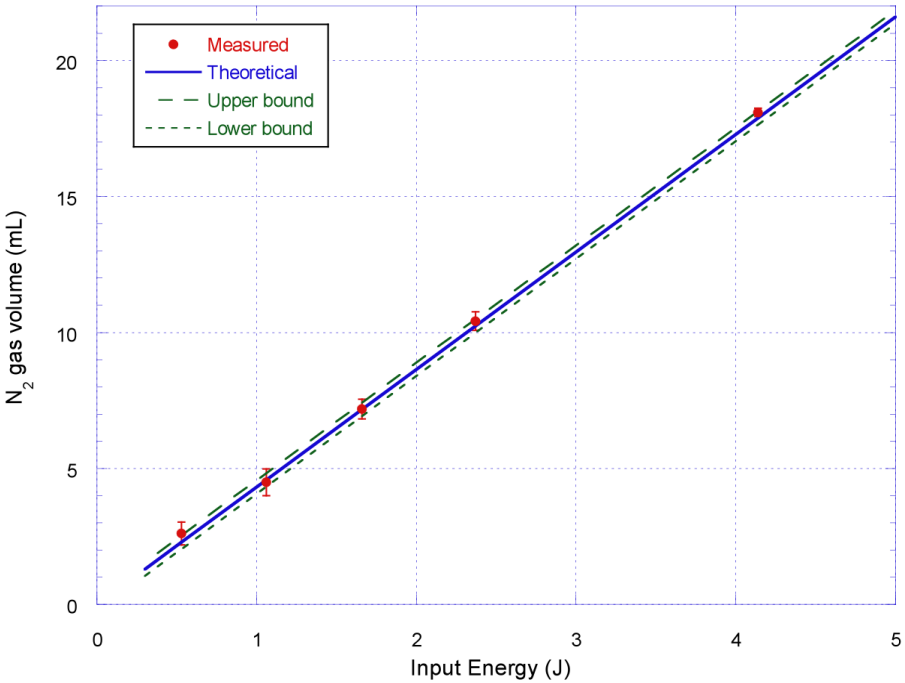
$Q_o = (\delta m/\delta t)\ [C_{vap.}]$



Apparatus



mL N_2 gas



Calorimeter accurate and precise.

Precision reduced by baseline drift (heat leaks).

Excess Heat from **12/12** PdD_x on PdD_x (codeposit)

Largest amount 3.9 J for thicker (250µm) wire.

Excess Heat from **2/3** Ni/NiH_x

Largest amount 0.79 J or 87 ± 8 % .

"Nickel/deuteride or mixed nickel deuteride/hydride system may … produce excess energy"*.

*Tanzella *et al* Proc. ICCF16 (2011)

Conclusions

1. *"An unexpected source of heat can be observed in the D/Pd System when Deuterium is loaded electrochemically into the Palladium Lattice, to a sufficient degree."*
2. *Low Z products of nuclear reactions can be measured:*
   - *time and quantity correlated with excess heat production [^{4}He]*
   - *and (apparently) uncorrelated with the heat [^{3}H and ^{3}He].*
3. **It is possible to initiate nuclear reactions with chemical energies…**
4. **The reactions yield significant power and energy.**
5. **Meaningful Energy from Ni/Natural H_2 ?**

Current Major Scientific Problems:

- Reproducibility and controllability
- Lack of quantitative understanding

Thank you!

Funding Support:
EPRI, MITI, DARPA, DTRA

The speaker is also very much indebted to a group of scientists and engineers which had as its core:
Esperanza Alvarez, Yoshiaki Arata, Jianer Bao, Les Case, Jason Chao, Bindi Chexal, Brian Clarke, Dennis Cravens, Steve Crouch-Baker, Jon McCarty, Irving Dardik, Arik El Boher, Ehud Greenspan, Peter Hagelstein, Alan Hauser, Graham Hubler, Nada Jevtic, Dennis Letts, Shaul Lesin, Robert Nowak, Tom Passell, Andrew Riley, Romeu Rocha-Filho, Joe Santucci, Maria Schreiber, Stuart Smedley, Francis Tanzella, Paolo Tripodi, Robert Weaver, Vittorio Violante, Kevin Wolf, Sharon Wing and Tanya Zilov.

SRI International

Headquarters: Silicon Valley

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025-3493
650.859.2000

Washington, D.C.

SRI International
1100 Wilson Blvd., Suite 2800
Arlington, VA 22209-3915
703.524.2053

Princeton, New Jersey

SRI International Sarnoff
201 Washington Road
Princeton, NJ 08540-6449
609.734.2553

Additional U.S. and international locations

www.sri.com

The ICCF Series of Conferences

AMERICA	EUROPE	ASIA
1. Salt Lake City, Utah	2. Como, Italy	3. Nagoya, Japan
4. Maui, Hawaii	5. Monaco	6. Sapporo, Japan
7. Vancouver, B.C.	8. Lerici, Italy	9. Beijing, China
10. Cambridge, Mass.	11. Marseilles, France	12. Yokohama, Japan
14. Washington, D.C.	13. Sochi, Russia	16. Chennai, India
18. *Columbia, MO* 2012	15. Rome, Italy	17. Korea Aug
Proposed		Upcoming

Other Conferences

13 in Russia, 7 in Japan, 6 in Italy and
many sessions at various society conferences [APS, ACS, ECS, *etc*.]