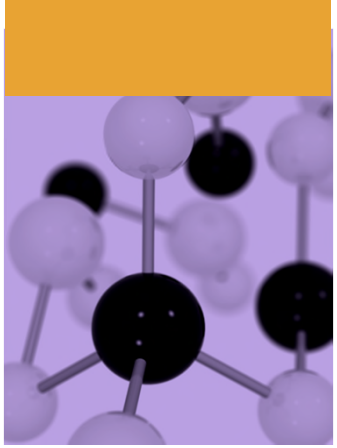
McKubre, M.C.H., *Cold Fusion; 25 years of research at SRI*, in *NTVA - Tekna, Can LENR provide cheap and clean energy?* 2014: Oslo, Norway.

These slides were presented by Michael C. H. McKubre at a seminar at the Norwegian Academy of Technological Sciences (NTVA) and The Norwegian Society of Graduate Technical and Scientific Professionals (Tekna) on November 5, 2014.

McKubre described the seminar here:

http://www.infinite-energy.com/iemagazine/issue119/norway.html

SRI International



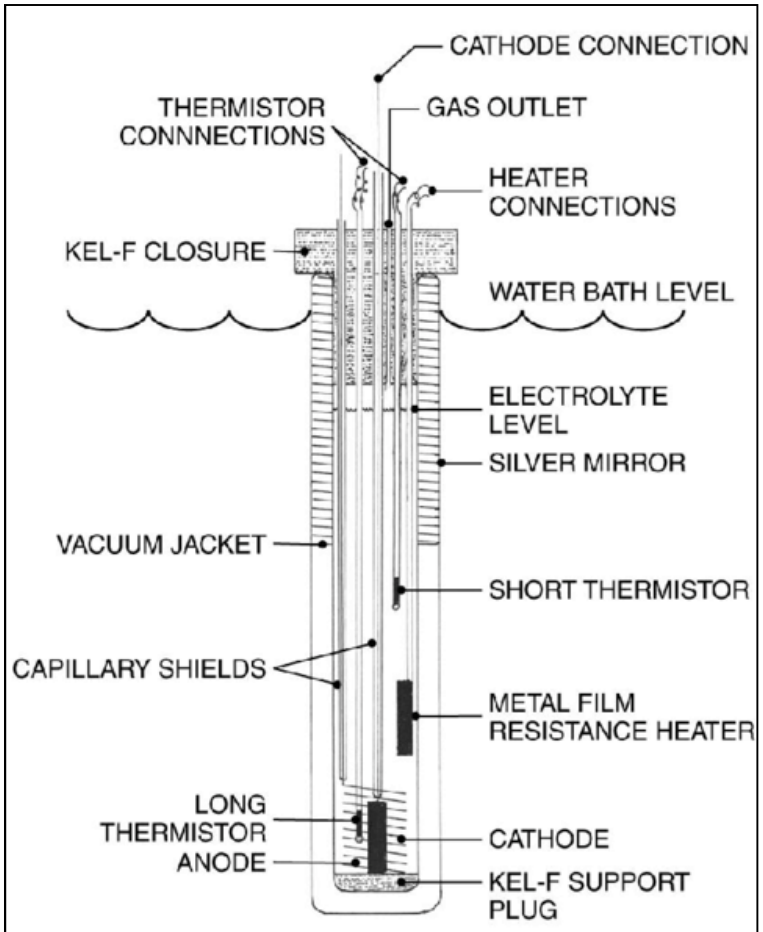
Cold Fusion; 25 years of research at SRI.

Michael McKubre, Esperanza Alvarez, Jianer Bao, Steven Crouch-Baker, Jon McCarty, David Golden, Alan Hauser, Palitha Jayaweera, Nada Jevtic, Andrew Riley, Romeu Rocha-Filho, Angel Sanjurjo, Maria Schreiber, Stuart Smedley, Francis Tanzella, Paolo Tripodi, Bob Weaver, Mark Williams, Sharon Wing.

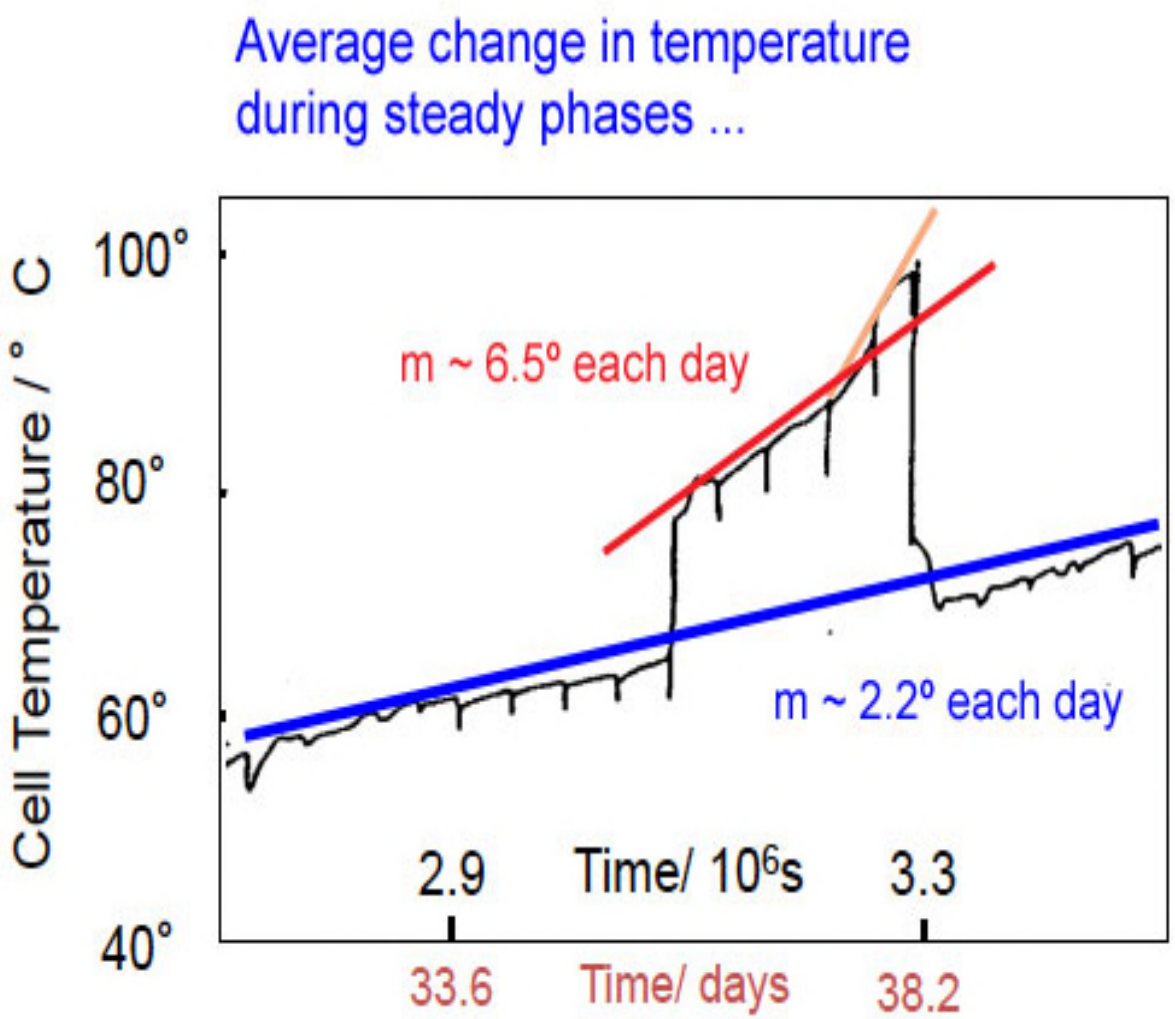
NTVA - Tekna
Can LENR provide cheap and clean energy?
Seminar in Oslo, November 5, 2014.

In the beginning….

March 23rd 1989
Martin Fleischmann
and Stanley Pons
announced their observation of a
non-Chemical heat source in the
D_2O/Pd system. Fusion?



Early Data on Cell Temperature



S. Pons, M. Fleischmann, C. Walling and J. Simpson
International Patent Publication No. 90/10935 (1990)

Cold Fusion Now February 4, 2012

The Fleischmann Pons Calorimeter (why the initial data were not well accepted)

- ❑ Not (completely) Integral Boundary
- ❑ Not Absolute Measuring
- ❑ Thermodynamically Open
- ❑ Mathematically Complex
- ❑ Not well or properly understood
- ❑ Well understood by only one other (Miles)
- ❑ Reproduced in exact form only once! (Lonchampt/Biberian in France)
- ❑ Failure to replicate at prestigious institutions

- ✓ When understood, the F&P calorimeter was seen to have high precision and accuracy (±0.1%)
- ✓ The instrument was superbly designed and able to take advantage of positive thermal feedback
- ✓ Many successful replications of the FPHE [Fleischmann Pons Heat Effect]
  - ✧ ~100 at SRI in 5 different calorimetric modes, >90 Sigma. >100 MJ E_{XS}
  - ✧ thousands elsewhere around the world
  - ✧ many hundreds or thousands of peer reviewed publications

Loading Cell and Reactions

Pd Wires Cathodes:

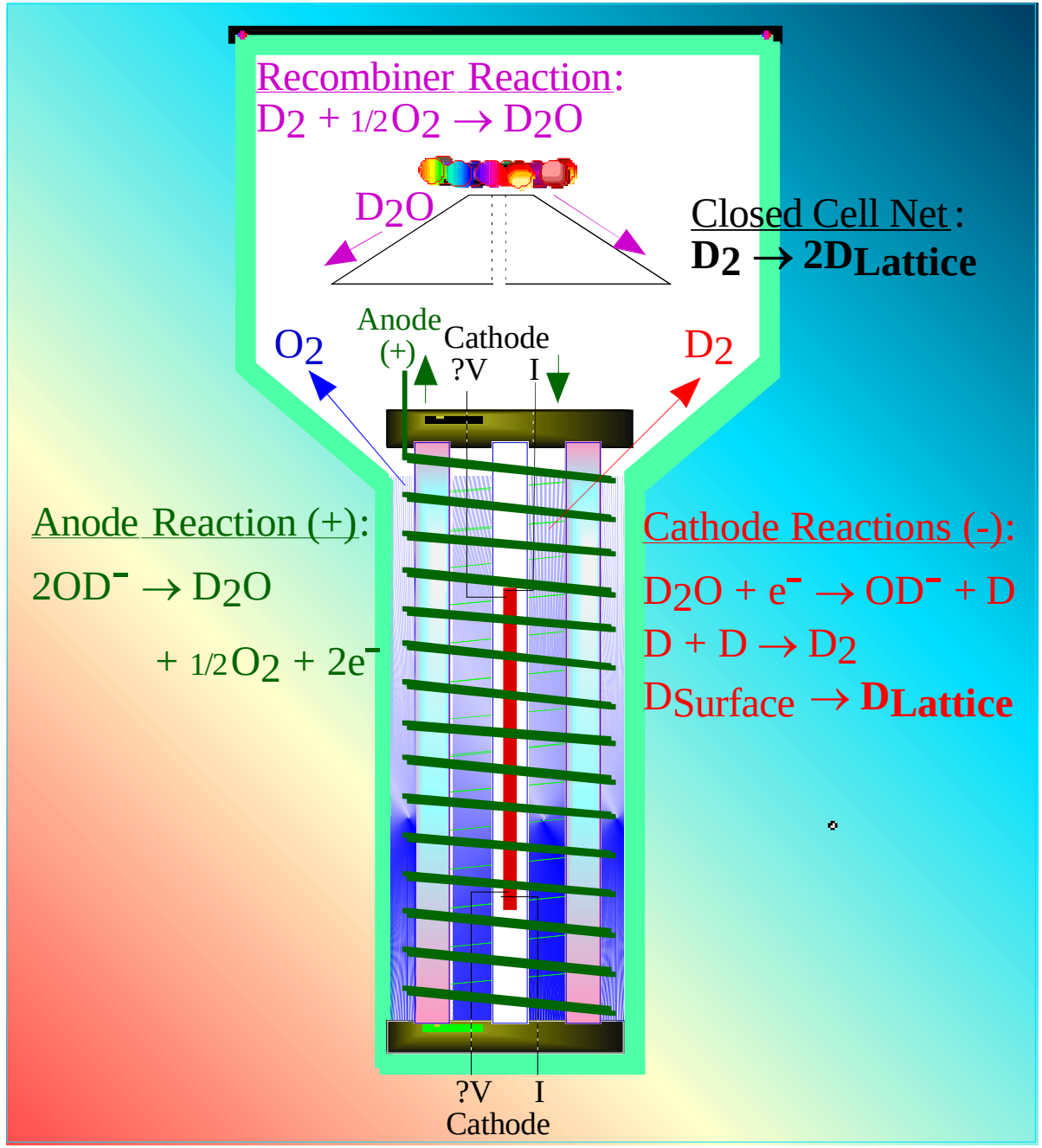
1 – 3 mm in diameter

3 – 5 cm in length

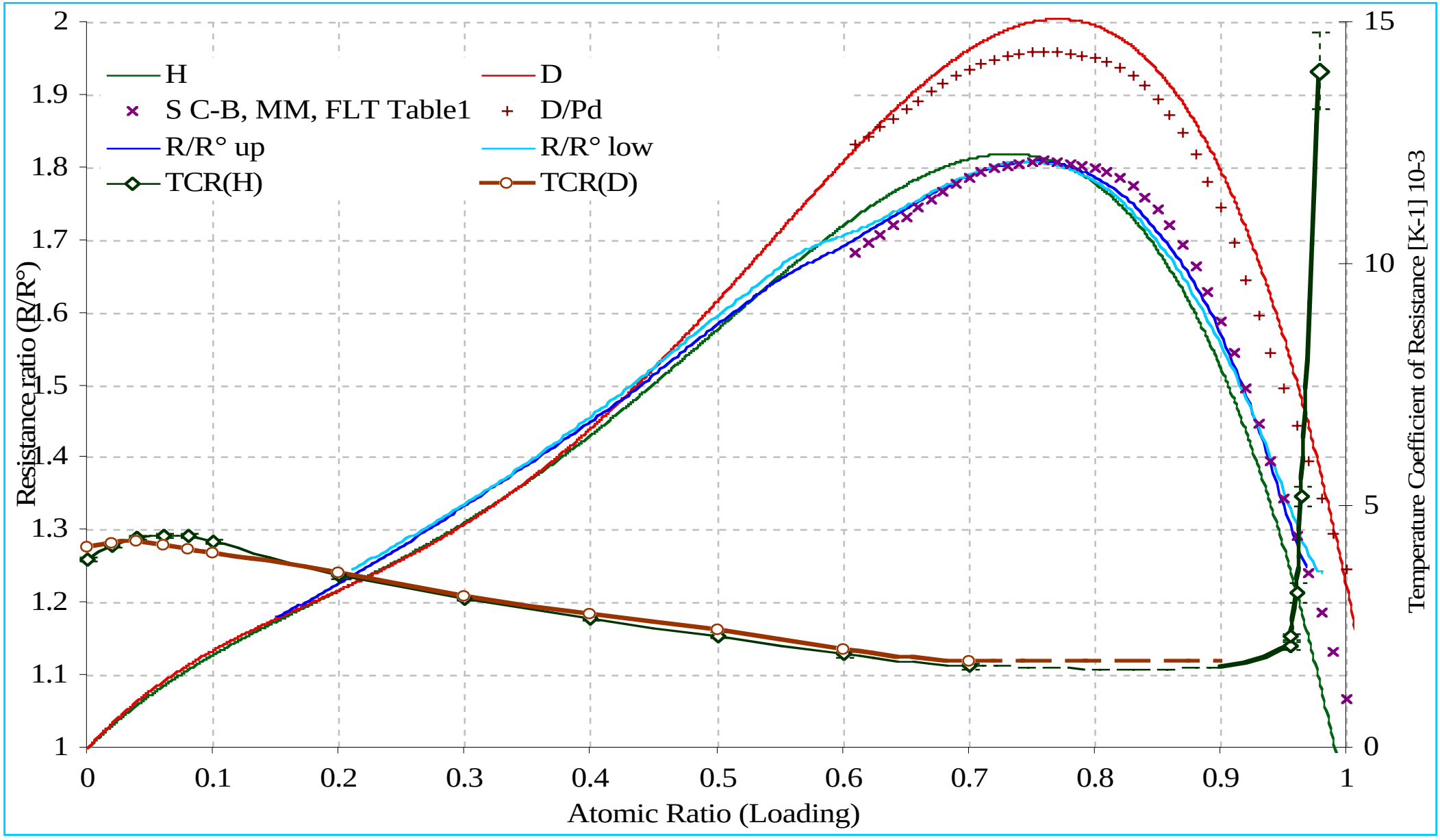
1M LiOD Electrolyte

Hypothesis:

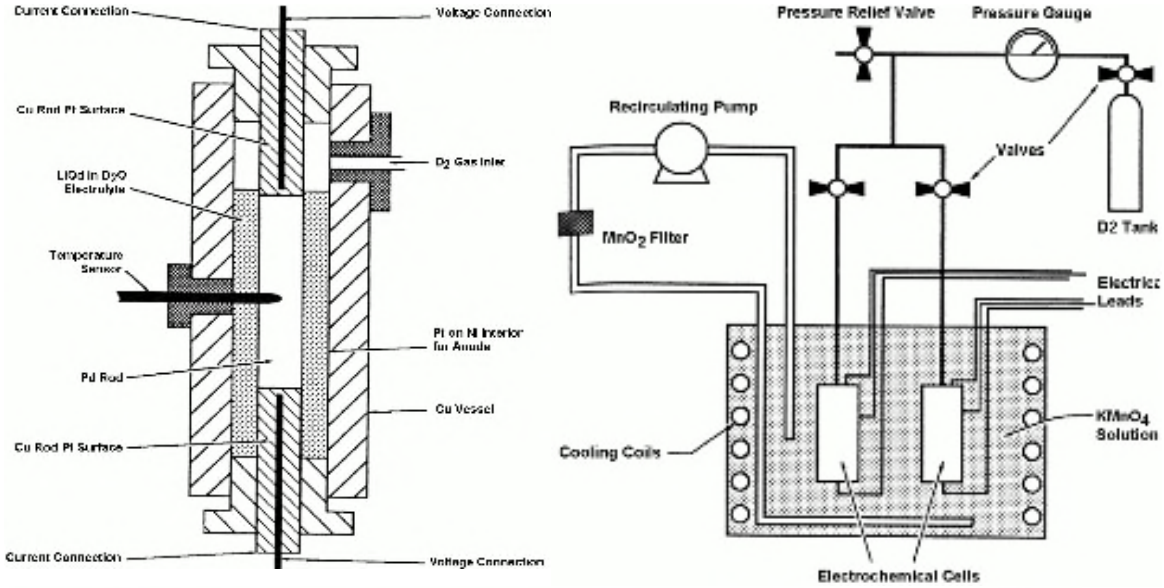
"There is an unexpected and unexplained source of heat in the D/Pd System that may be observed when Deuterium is loaded electrochemically into the Palladium Lattice, to a sufficient degree."



Resistance Ratio *vs.* Loading Function



SRI Heat Flow Calorimeter (1989) – Closed



Experiments operated at 5° C and 50 Atm.

D_2

P1a bulk Pd 6cm x 0.6 cm dia.

P1b palladized Cu "reference"

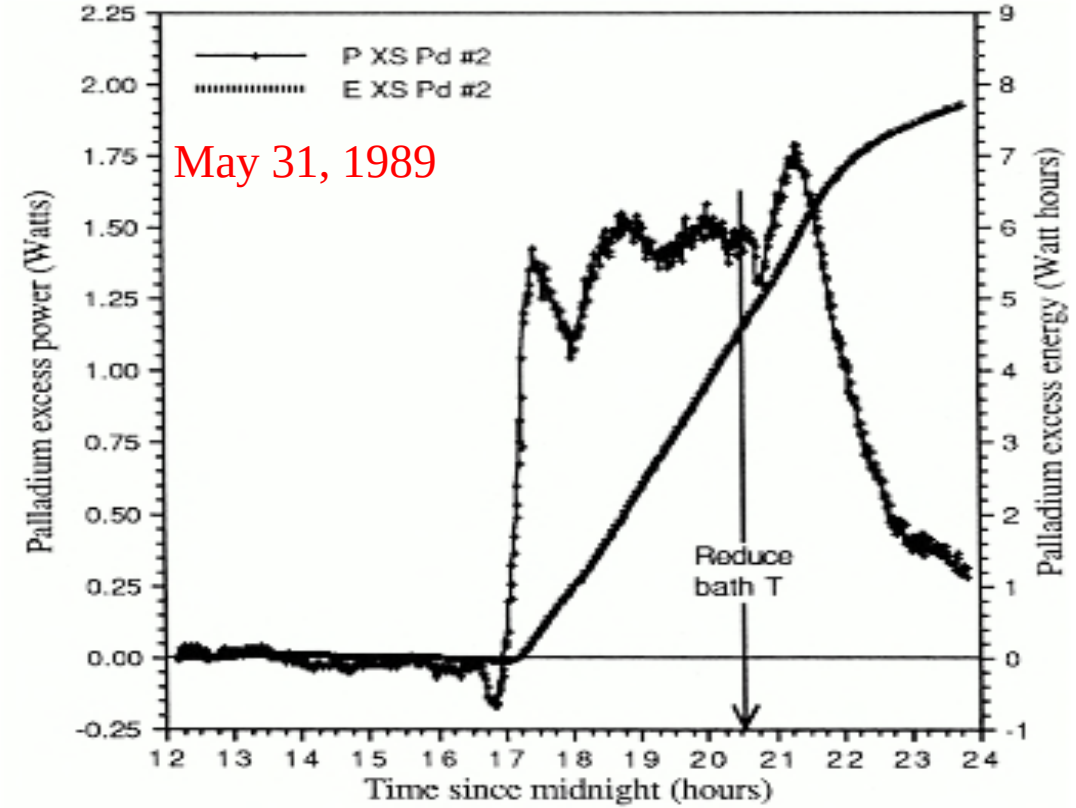
P1a loading D/Pd ~ 1.0

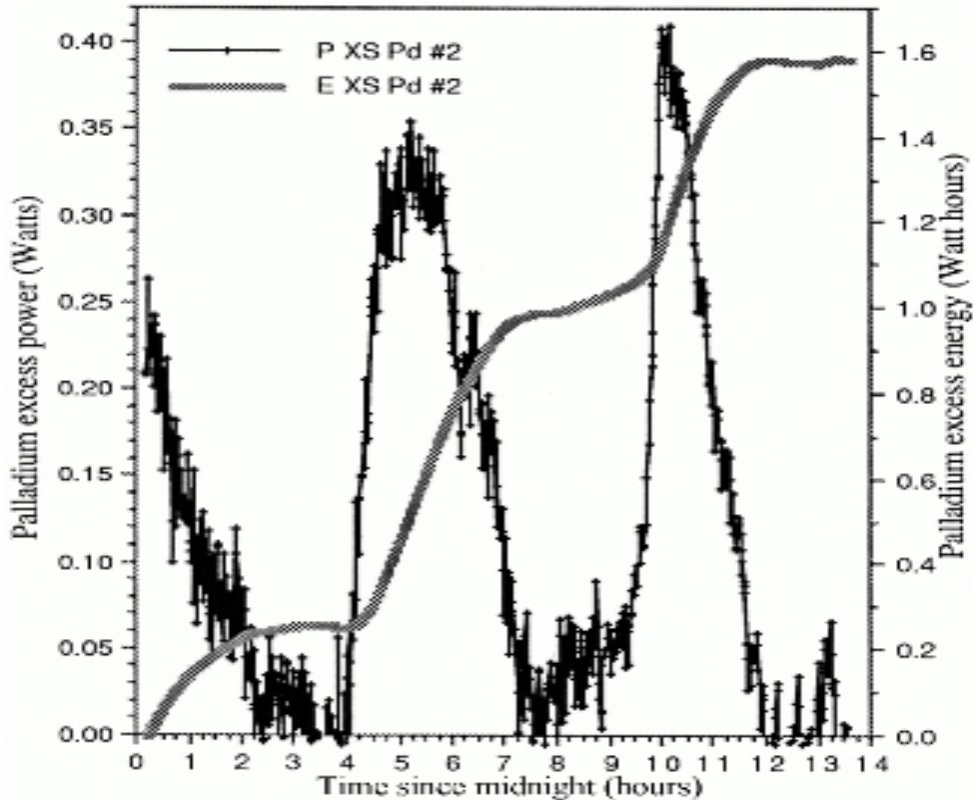
Four "bursts" of P_{XS} lasting several hours

Initiated after several weeks of electrolysis…

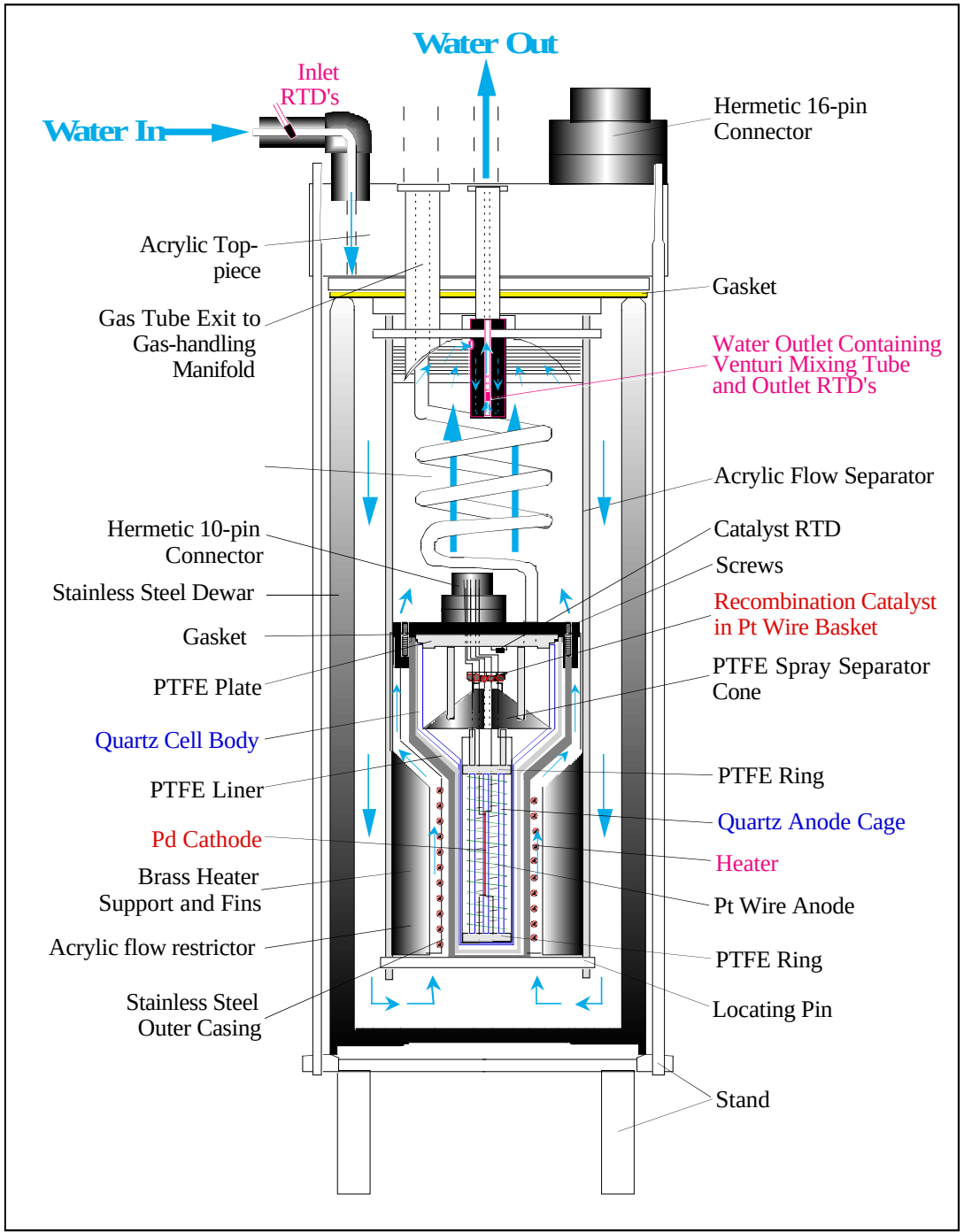
E_{XS} > 70 kJ

June 1, 1989





The SRI Absolute Mass Flow Calorimeter



"An absolute calorimeter gives the [heat] result by calculation without needing to introduce a constant obtained by calibration".

$$Q_o = \delta m/\delta t \; C_{ps} (T_o - T_i) \qquad [1]$$

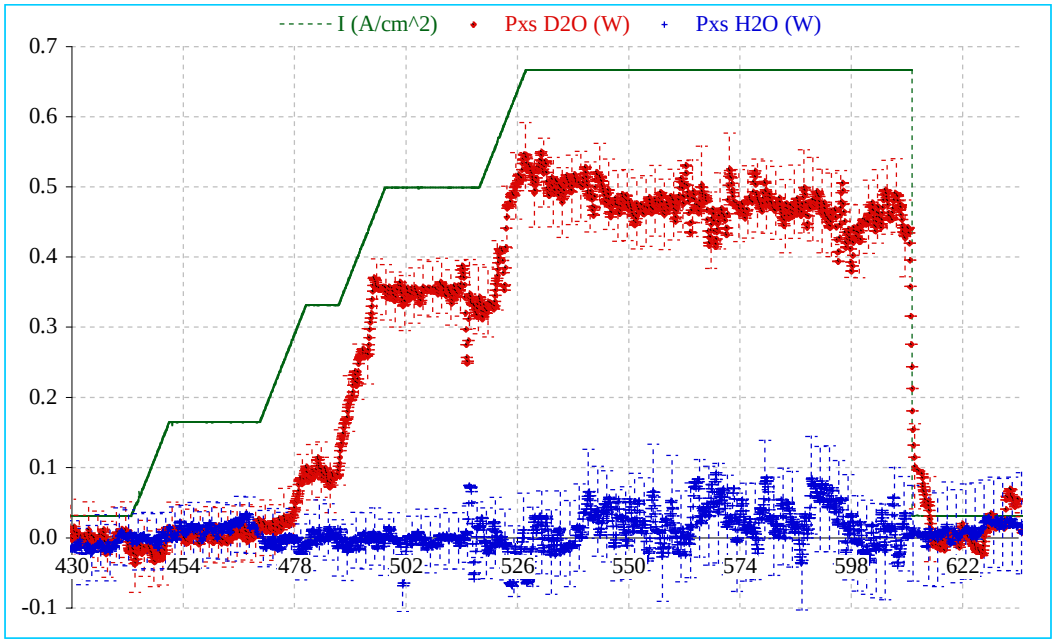
Q_o = Heat output power (W)
$\delta m/\delta t$ = mass flow of heat transfer fluid (kg/s)
C_{ps} = specific heat of heat transfer fluid (J/(kg K)
T_i = inlet temperature (K)
T_o = outlet temperature (K)

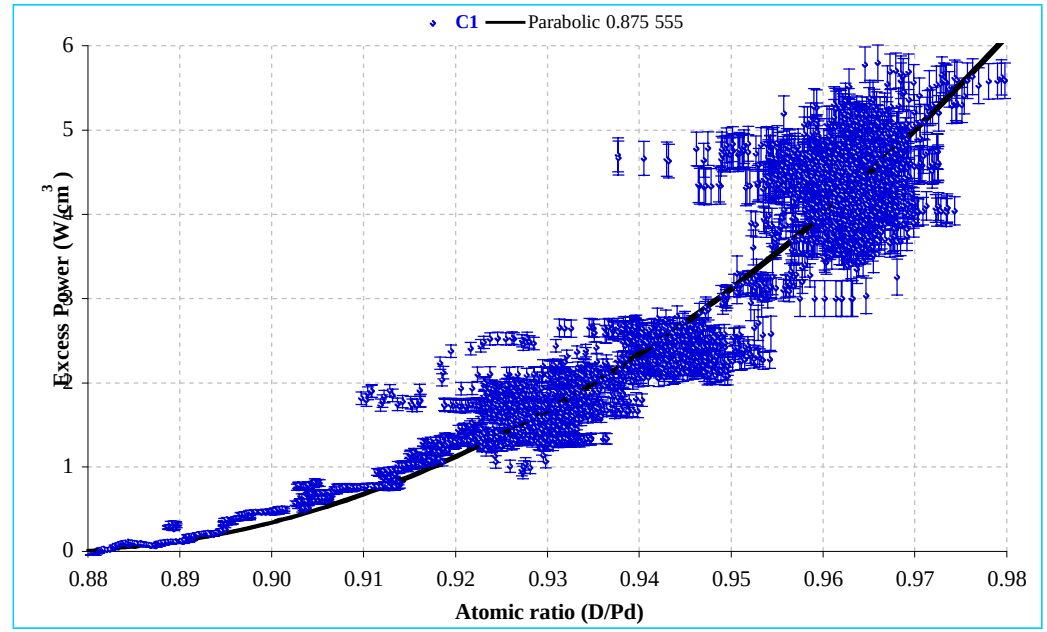
$$Q_i = I_h * V_h + I_e * V_e = \text{Constant} \qquad [2]$$

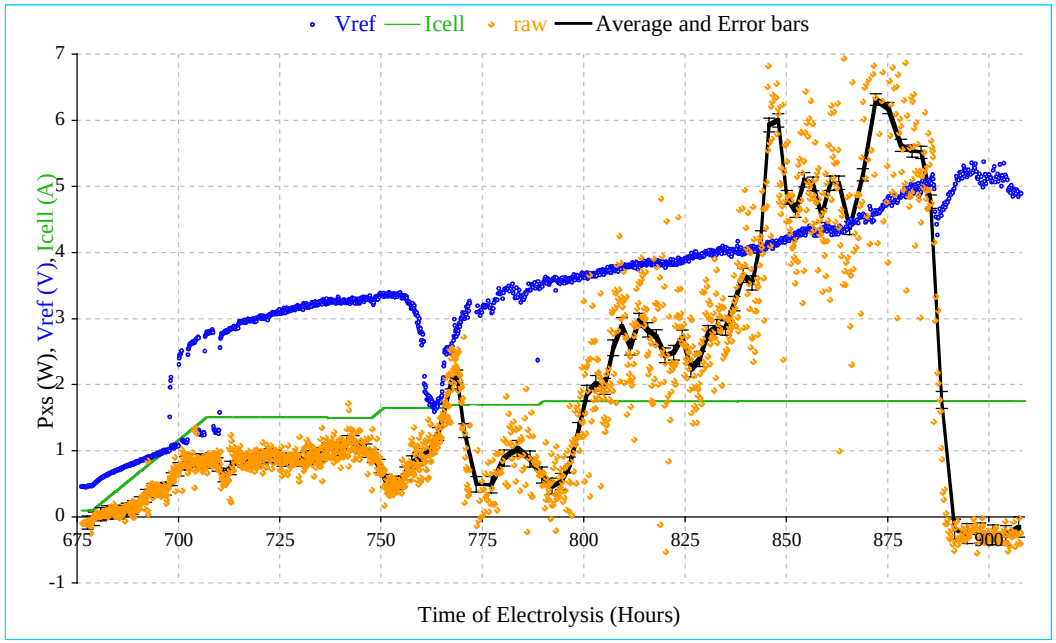
$$Q_{XS} = Q_o - Q_i \qquad [3]$$

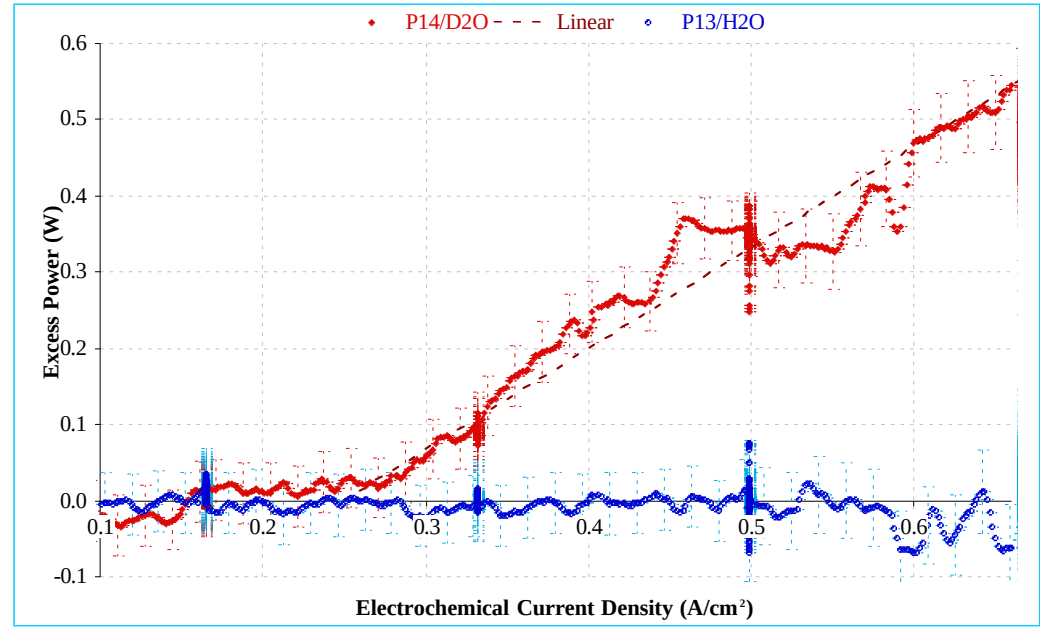
Thermal Efficiency 99.3%
Absolute Accuracy ±0.35%

DoE Review 2004





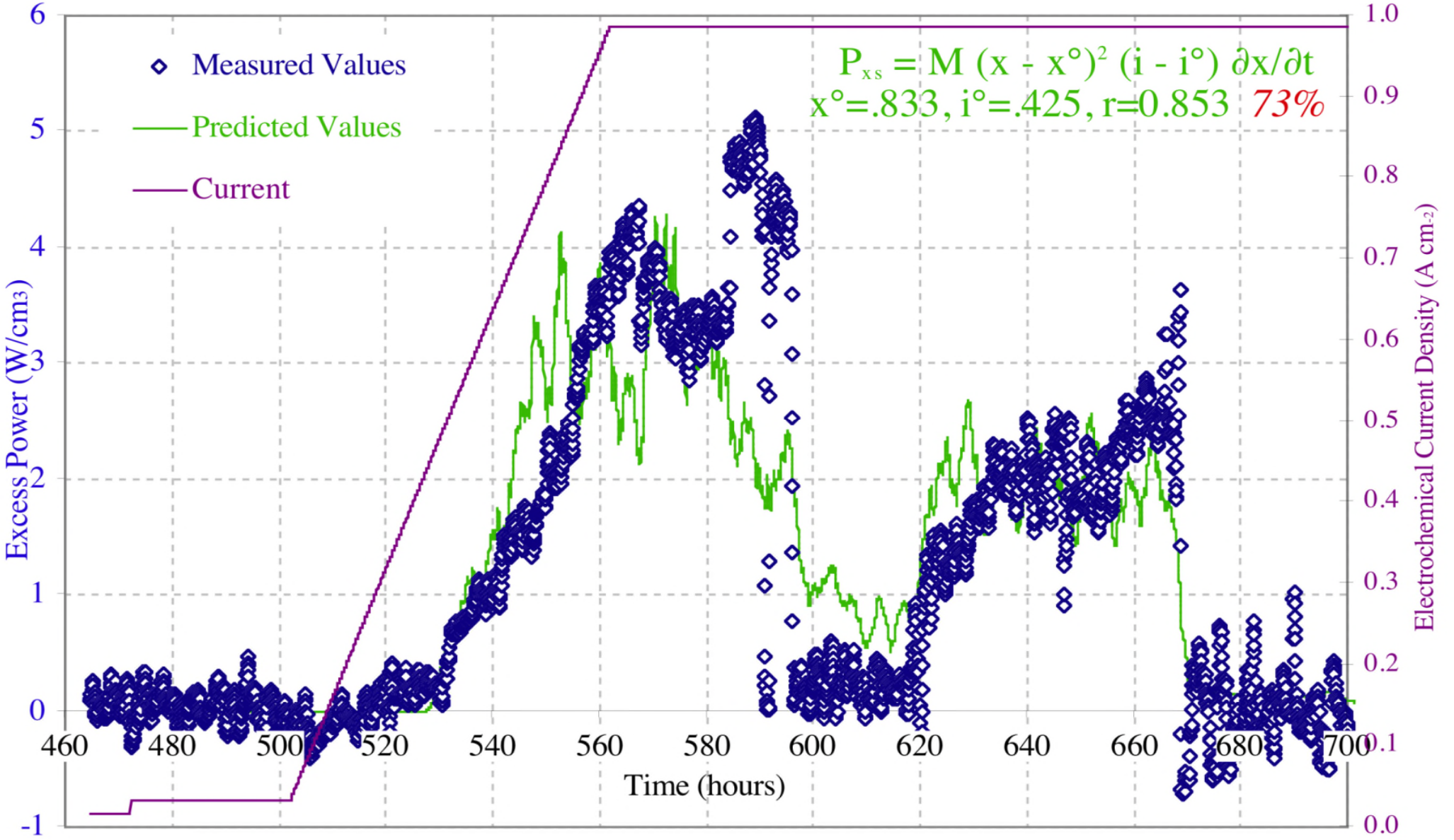




A Predictive Equation

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

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



Summaryof the FPHE:

Nuclear level thermal energy density produced from the electrochemical loading of deuterium into palladium.

What do we need to do to produce it?

Known critical conditions:

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

2) For times >> 20-50 x $\tau_{D/D}$ (>300 h / 3mm) (*Initiation*)

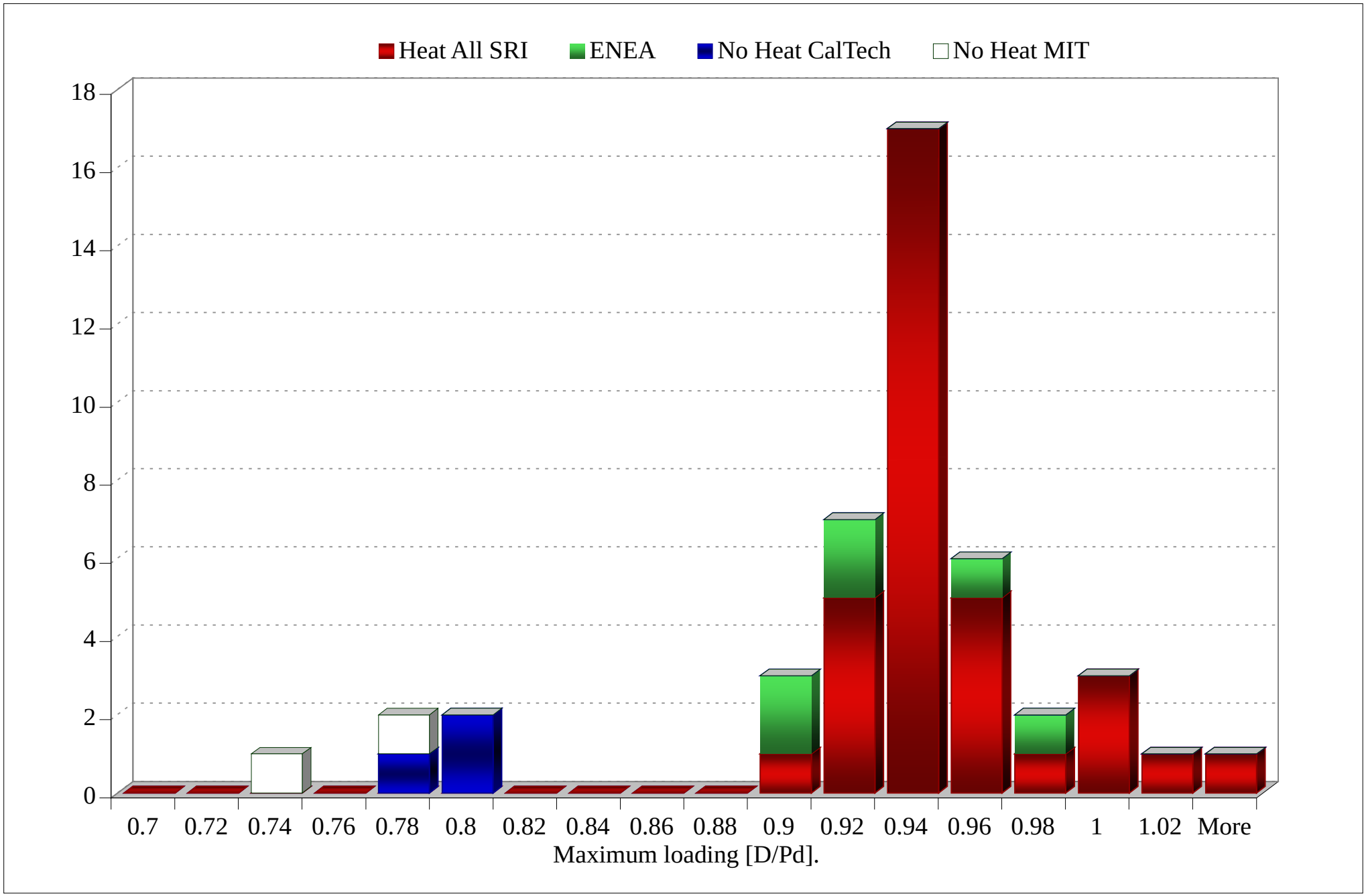
3) At electrolytic i >250-500mA cm^{-2} (*Activation*)

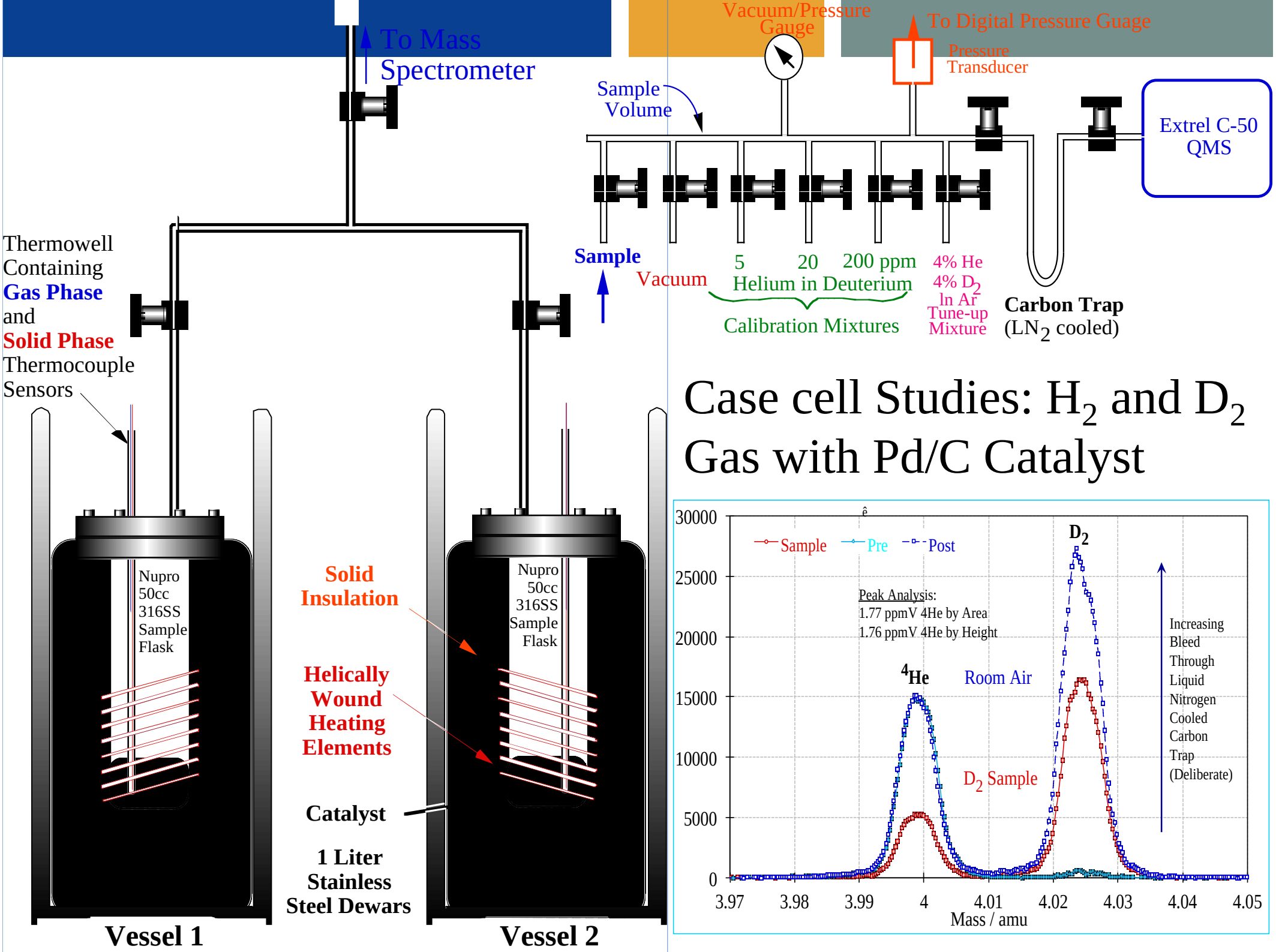
4) With an imposed or adventitious D Flux (*Disequilibrium*)

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

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

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

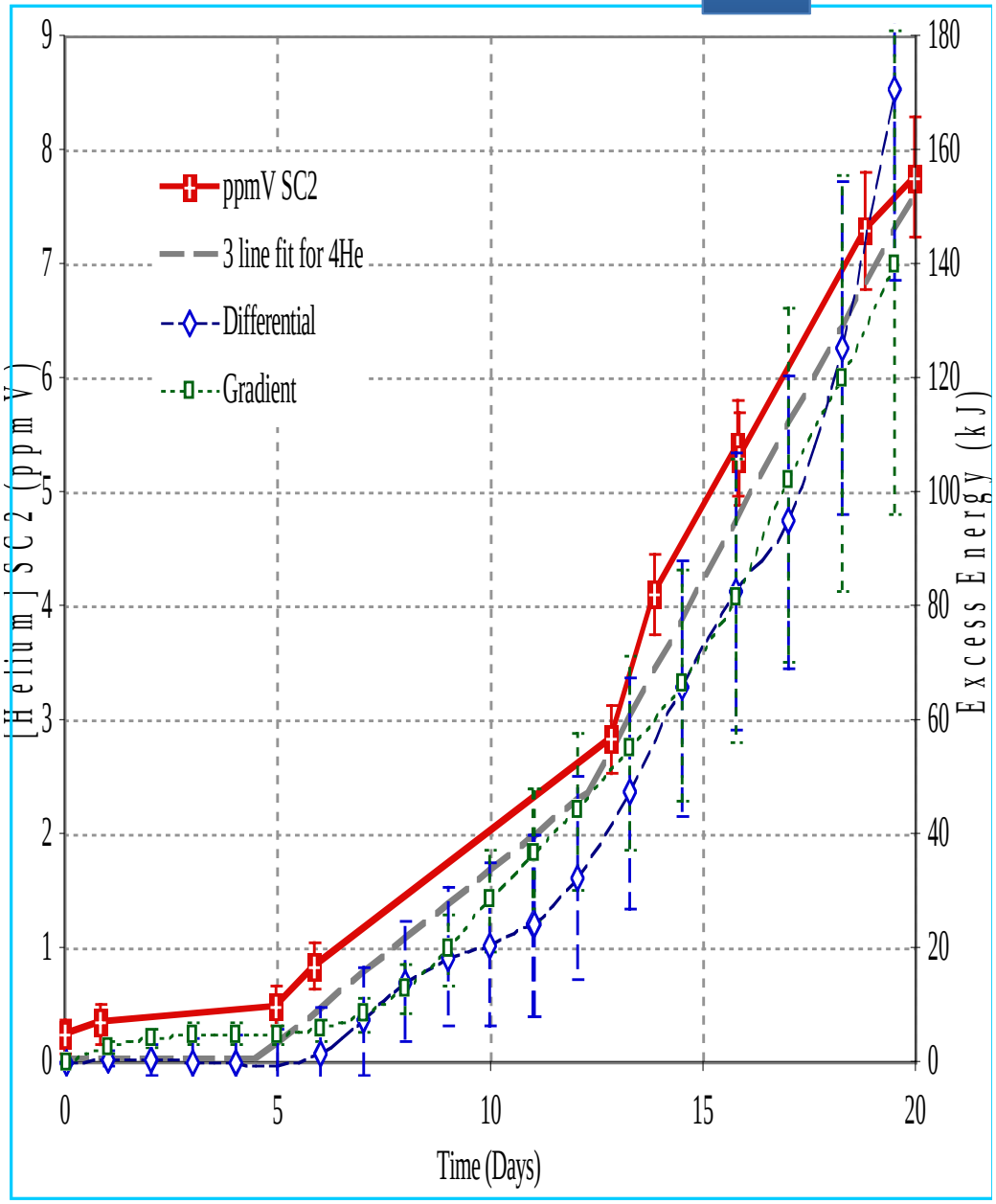


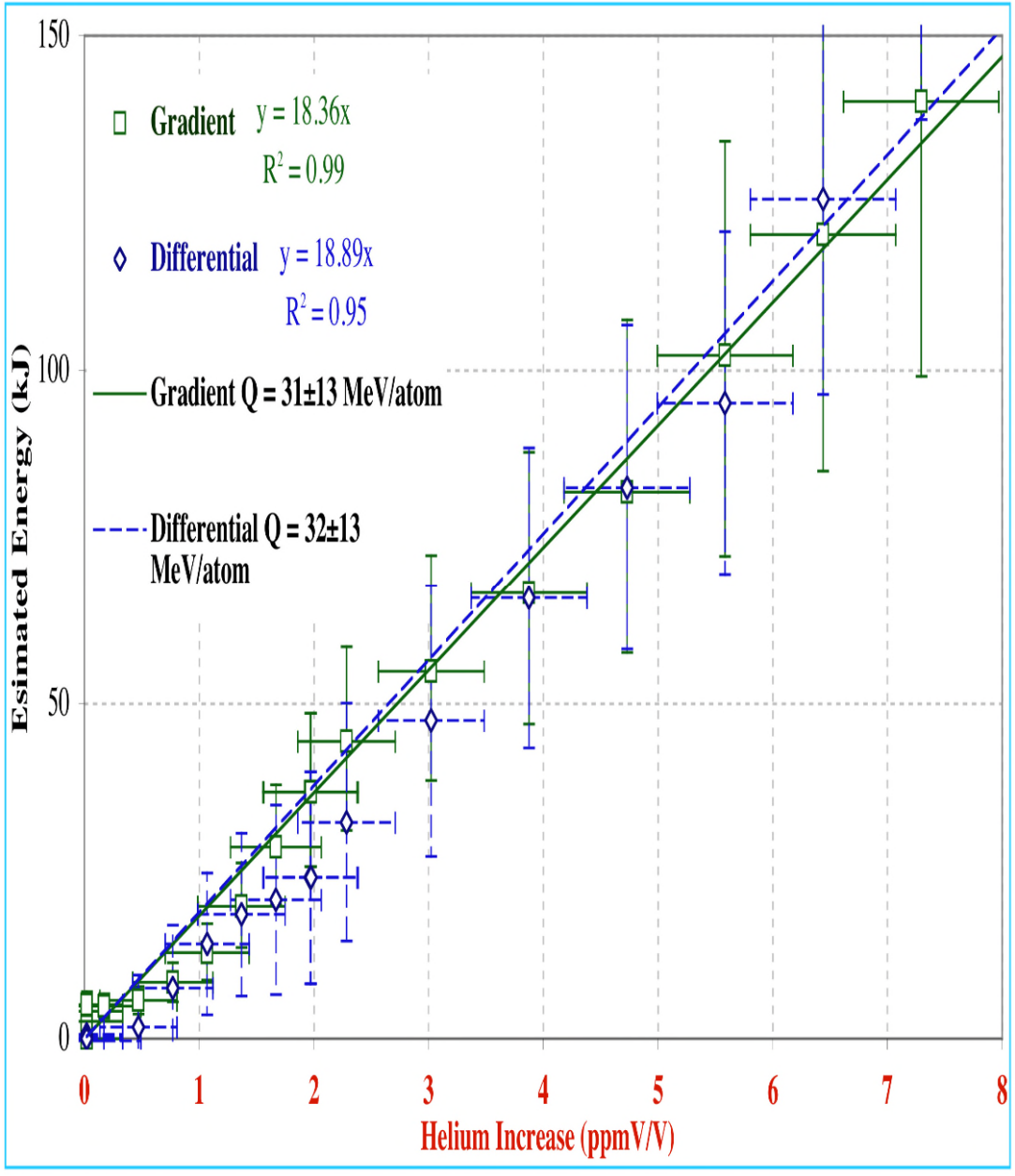


Case cell Studies: H_2 and D_2 Gas with Pd/C Catalyst

Case: ^{4}He *vs.* time and Measured "Q" Value

D + D → ? → ^{4}He + 23.8 MeV



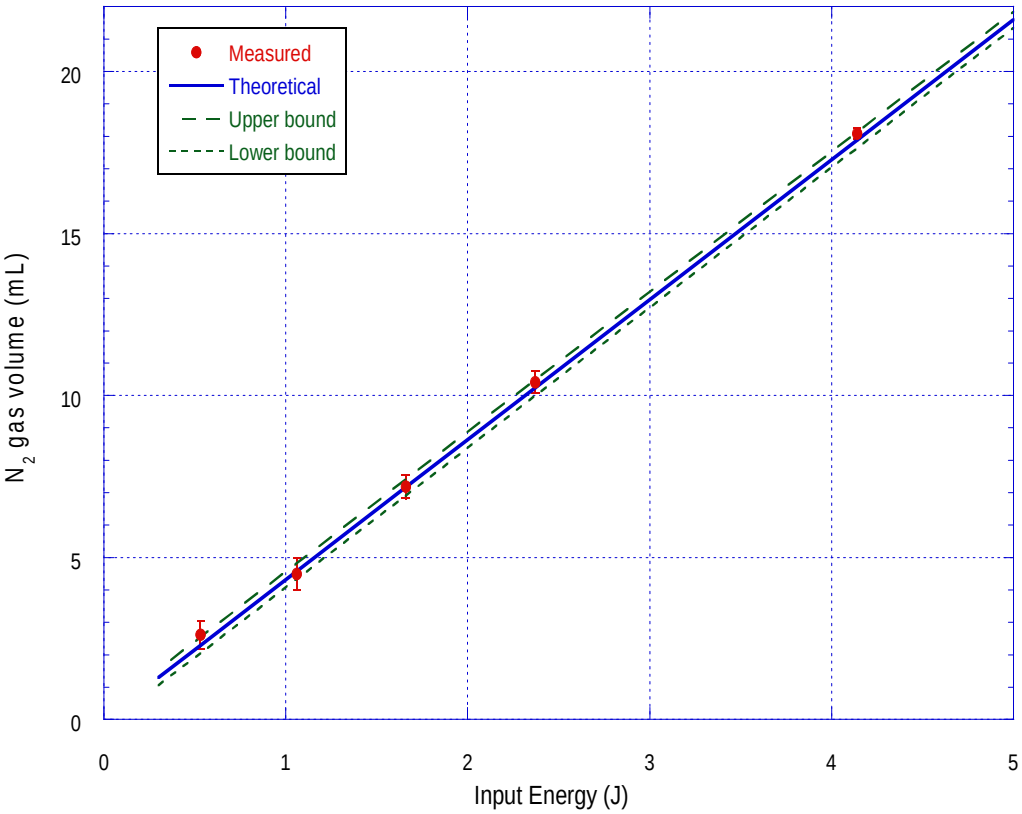


A phase change (Latent Heat) calorimeter:

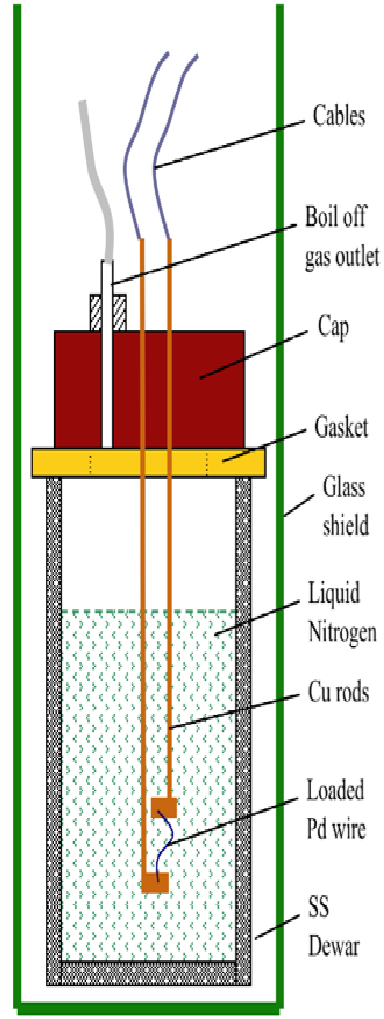
Liquid Nitrogen Boil-Off

Measurements:

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



Apparatus

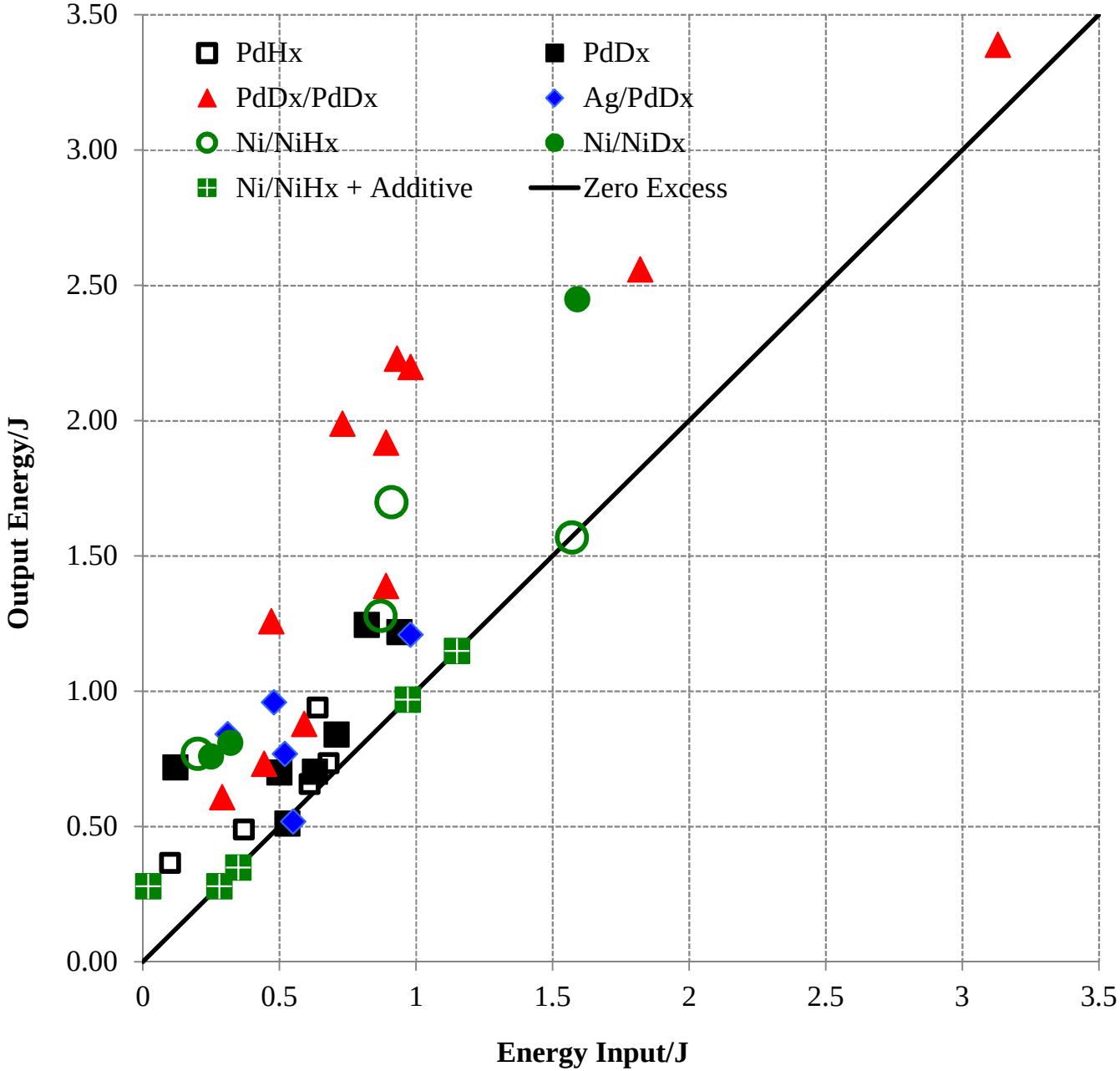


Calibration with Joule Heater and Unloaded Pd Wires

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

Phase Change Calorimetry:

Results and Conclusions



Calorimeter accurate and precise.

Precision reduced by baseline drift (heat leaks).

12/12 PdD_x on PdD_x (codeposit) produced P_{XS}

2/3 Ni/NiH_x produced P_{XS}

*"The nickel/deuteride or mixed nickel deuteride/hydride system may be an appropriate material to produce excess energy"**.

*Tanzella *et al* Proc. ICCF16

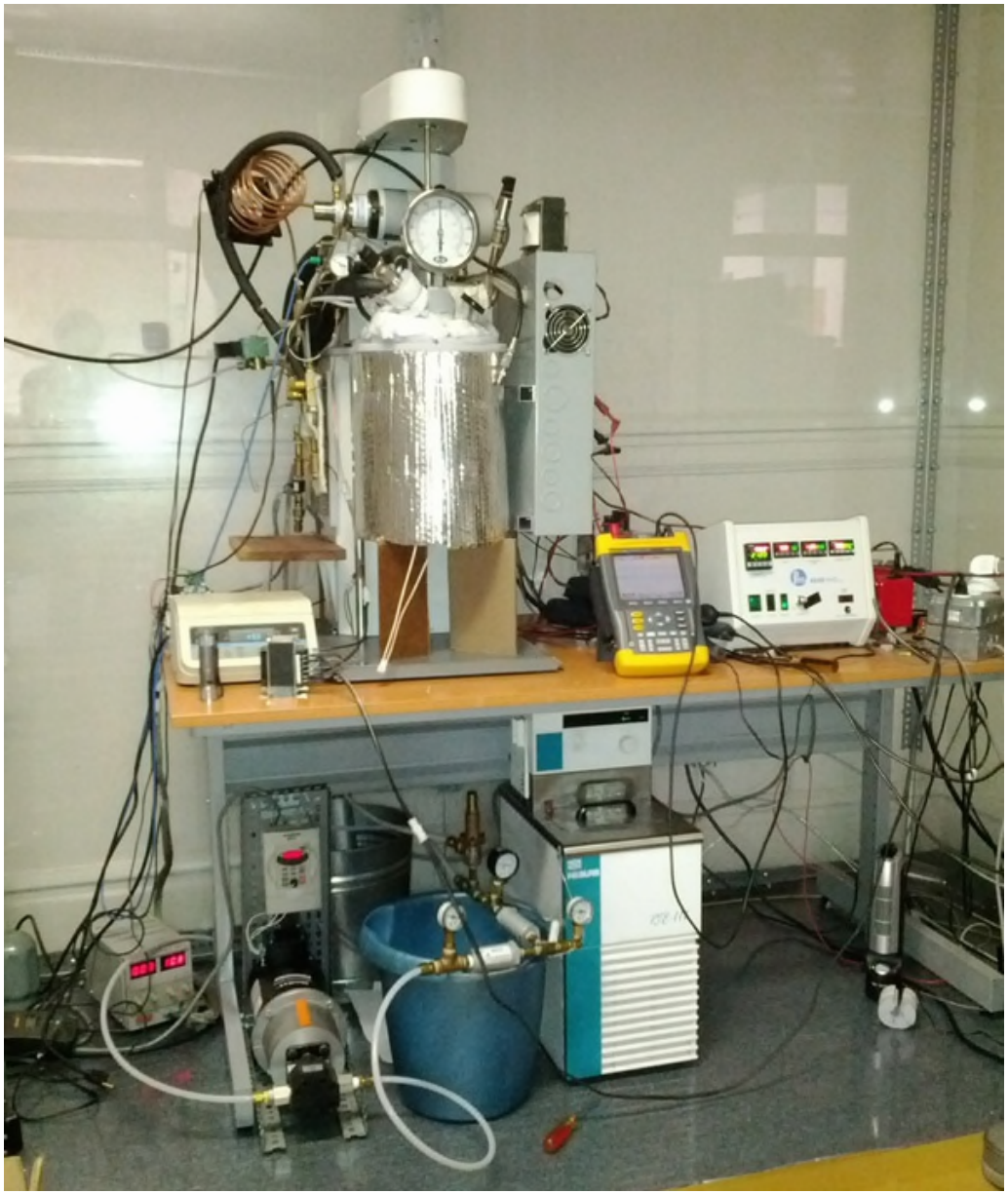
McKubre *et al* Proc. ICCF17

SRI Replications:

1. 1989-1991 Fleischmann Pons Heat Effect.
2. 1992 Kevin Wolf Gamma activation.
3. 1993 Ni – Natural Water Heat Effect.
4. 1993-1996 Mel Miles Heat-^{4}He correlation.
5. 1995 Patterson “Light” Water Excess Heat.
6. 1996-1998 Les Case Heat and ^{4}He.
7. 1997-1998 Arata-Zhang “DS” Cathodes Heat and ^{3}He.
8. 2003-2011 Energetics “SuperWave” Excess Heat and ^{3}H.
9. 2012-2014 Brillouin Excess Heat.

Brillouin Energy Corporation, BEC, Berkeley.

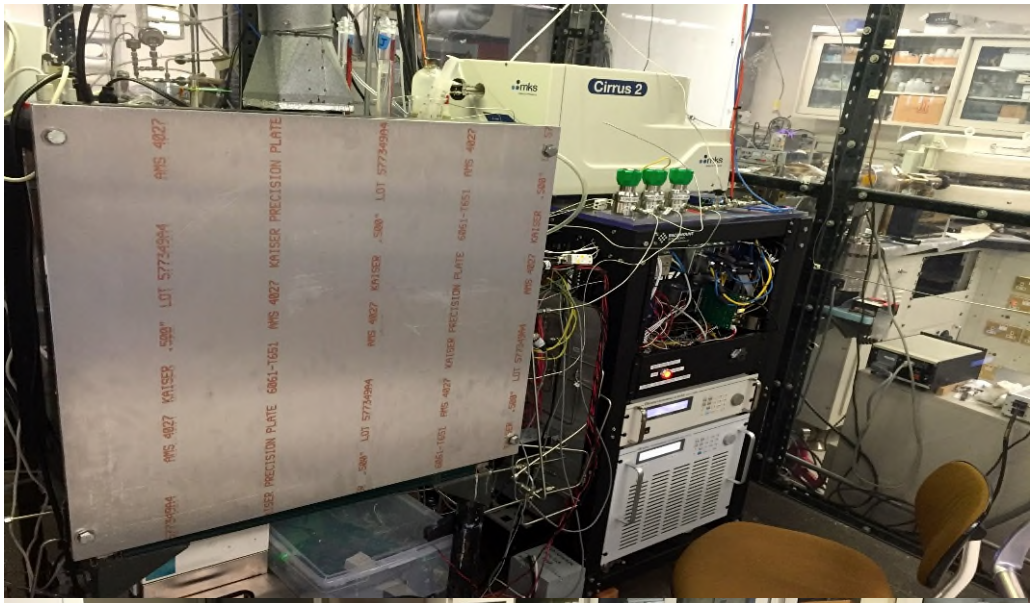
- First involved in 2011-2012



- **130 bar pressure vessel with heater.**
- **28AWG (.31mm) Ni 270 cathode.**
- **Ni 270 wire mesh anode.**
- **0.5 liter of 0.15 to .5M NaOH electrolyte.**
- **MobilTherm 603 Heat transfer fluid in immersed heat exchanger coolant loop.**
- **98% of resistive heater input recovered.**
- **RTD's measuring input and output coolant temperatures.**
- **Mass Flow meter in the coolant line.**
- **A catalytic recombiner.**
- **Resistance heater for calibration.**
- **Excess power >100% in Ni/H_2O system.**
- **Pulse shape crucial … Control?**

Brillouin Energy Corporation, BEC, SRI.

- All gas system 2013-present



- H_2/D_2 gas flow through "packed bed"
- Pressure up to a few bar.
- Ni, Pd and Pd on Ni structures
- Temperature up to ~650° C
- Gas Flow and Water Flow calorimetry
- Progress slow but accelerating:
  - Gas leaks
  - Heat leaks
  - Input coupling of fast pulses
  - Calorimetry
  - Mass Spec. "issues"
- Fluidized bed…

What is the future?

- **The evidence of a nuclear-level heat source with associated nuclear products is overwhelming to all who have studied it. The FPHE is real.**

- ***"…no test, no result, no analysis, no data and no theory can effectively change the reactionary mindset…the proof of this pudding will be in working and useful technology that will provide all necessary impetus to backtrack the science. "***

- **Those embarked on practical demonstration include:**

  - **Black Light Power (US) – raised ~80M, know little about them. Not CF?**
  - **Piantelli (Italy) – visited 2012, confirmed results, still working on science.**
  - **Rossi (Italy and US) – sold, bought & verified? Report reviewed in October.**
  - **Defkalion (Greece, Italy and Canada) – Rossi spin-off, real product?**
  - **Brillouin (US) – working with SRI.**

- **All of these are working with small dimension-Ni and natural-H systems.**

Thank you!

Major Funding Support:
EPRI, MITI, DARPA, DTRA, BEC

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, E. Castagna, Jason Chao, Bindi Chexal, Brian Clarke, Dennis Cravens, Steve Crouch-Baker, Irving Dardik, Arik El Boher, Ehud Greenspan, Peter Hagelstein, Alan Hauser, Graham Hubler, Nada Jevtic, Dennis Letts, Shaul Lesin, Jon McCarty, Robert Nowak, Tom Passell, Andrew Riley, Romeu Rocha-Filho, Joe Santucci, F. Sarto, Maria Schreiber, Stuart Smedley, Francis Tanzella, Paolo Tripodi, Vittorio Violante, Robert Weaver, Mark Williams, Kevin Wolf, Sharon Wing and Tanya Zilov*.

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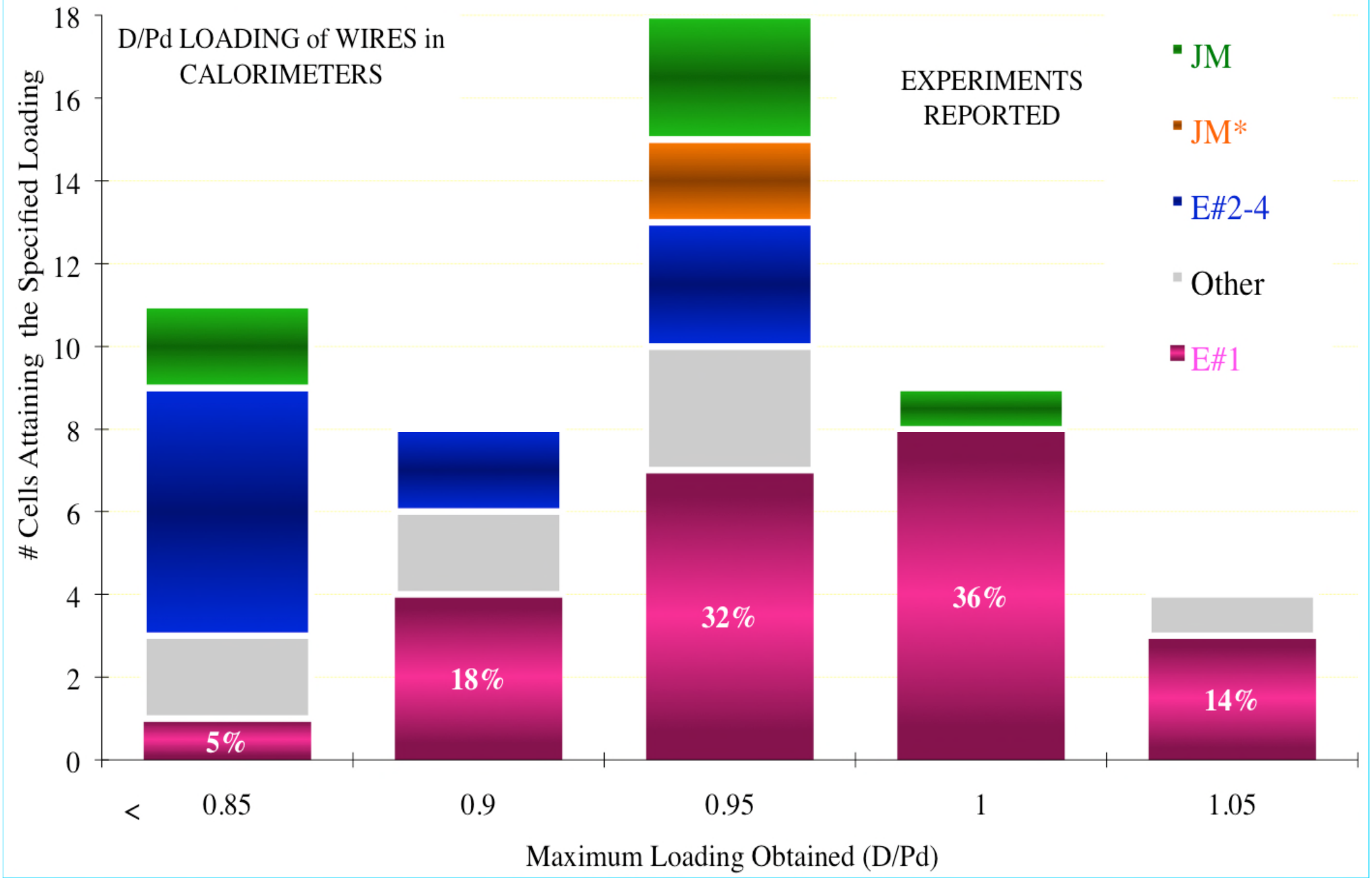
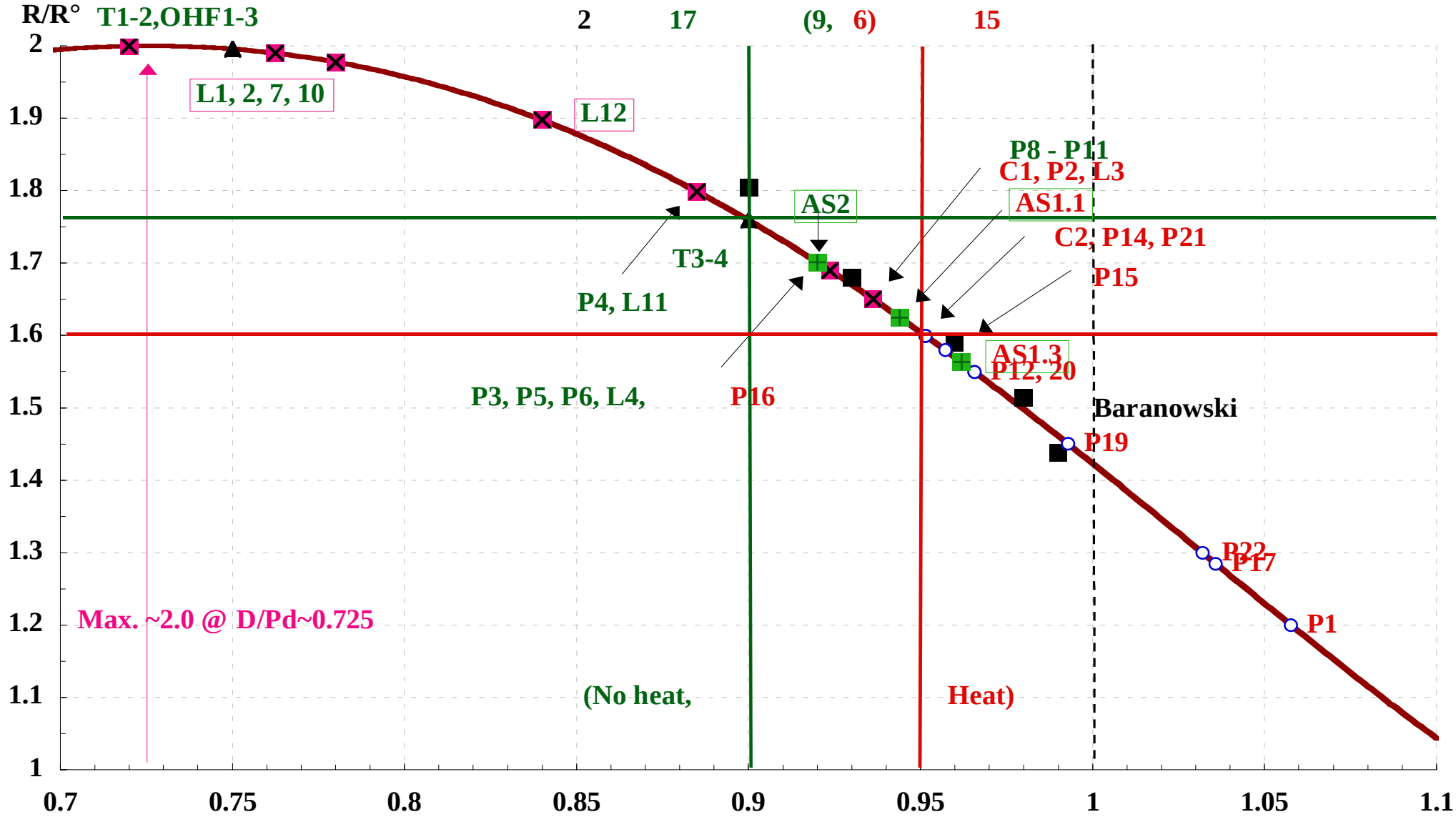
Materials Influence on Loading

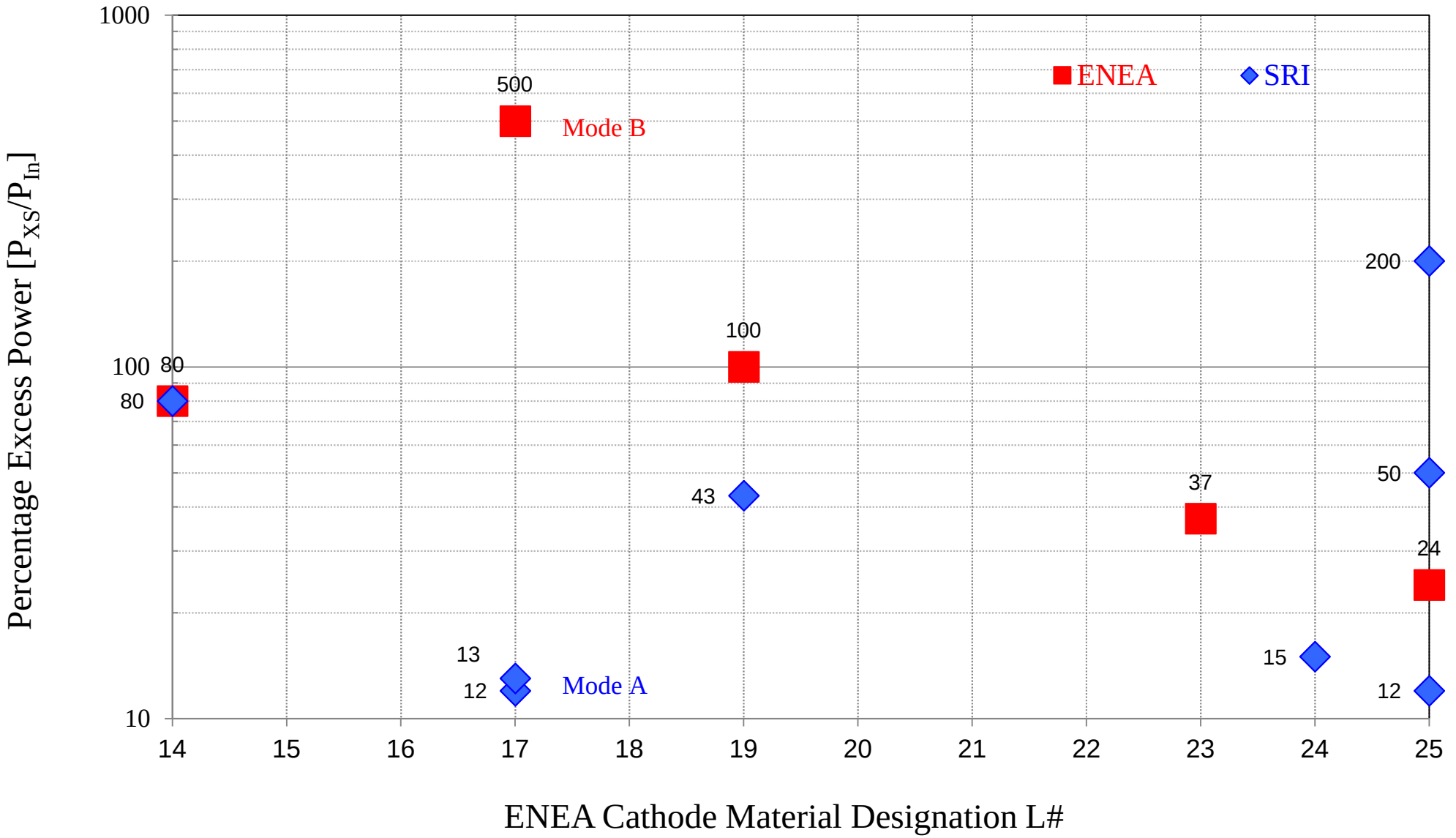


Excess Power *vs.* Maximum Loading

[6] B. Baranowski, S. Filipek, M. Szustakowski, J. Farny and W. Wornya, J. Less Common Met., 158, p. 347, (1990).



The power of Metallurgy at ENEA



Excess power as a percentage of input power in experiments run at SRI and ENEA (Frascati) for different lots of 50 µm foil cathodes manufactured at ENEA.