EARLY EXCESS POWER USING NRL Pd-B Cathodes

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Presentation Outline

I. **Show Experimental Results For Early Excess Power Using NRL Pd-B Cathode.**

A. NHE Laboratory (Japan) Using F-P Dewar Calorimetry (1997).

B. Ridgecrest, California (U.S.A.) Using Copper Heat Conduction Calorimeter (2016).

C. Naval Research Laboratory Results Using a Seebeck Calorimeter (1995).

(Importance Not Realized Until 2018)

II. **Discuss Possible Calorimetric Error Sources.**

A. Thermoneutral Potential (E_H).

B. Cell Heat Capacity (C_pM).

C. Rate of Cell Temperature Change (dT/dt).

III: **Discuss Possible Boron Effects For Cold Fusion.**

A. Direct B+D Reactions Have Been Proposed.

B. Essential Element For Fusion Process.

C. Provides Nuclear Reaction Zones.

(Vacancies, Cracks, Grain Boundaries, Electrical Double Layers).

D. Boron May Act as "Trigger" For Cold Fusion Reactions.

EARLY EXCESS POWER EVENTS FOR Pd-B CATHODES

1. <u>NHE Laboratory (Japan) Using F-P Dewar Calorimeter</u>

   (December 5, 1997)

   ❖ First Noted by Martin Fleischmann
   -- Mean Excess Power of 57 mW at 55 minutes
   -- Mean Excess Power of 38 mW for First 24 hours
   "It is obviously very important to establish whether this early establishment of positive feedback is a property of Pd-B alloys ---".
   (M. Fleischmann, NRL Report (2001), p. 25)

2. <u>Ridgecrest, California Laboratory Using a Heat Conduction Calorimeter</u>

   (July 3, 2016)

   ❖ Measured Excess Power was 118 mW at 8 minutes

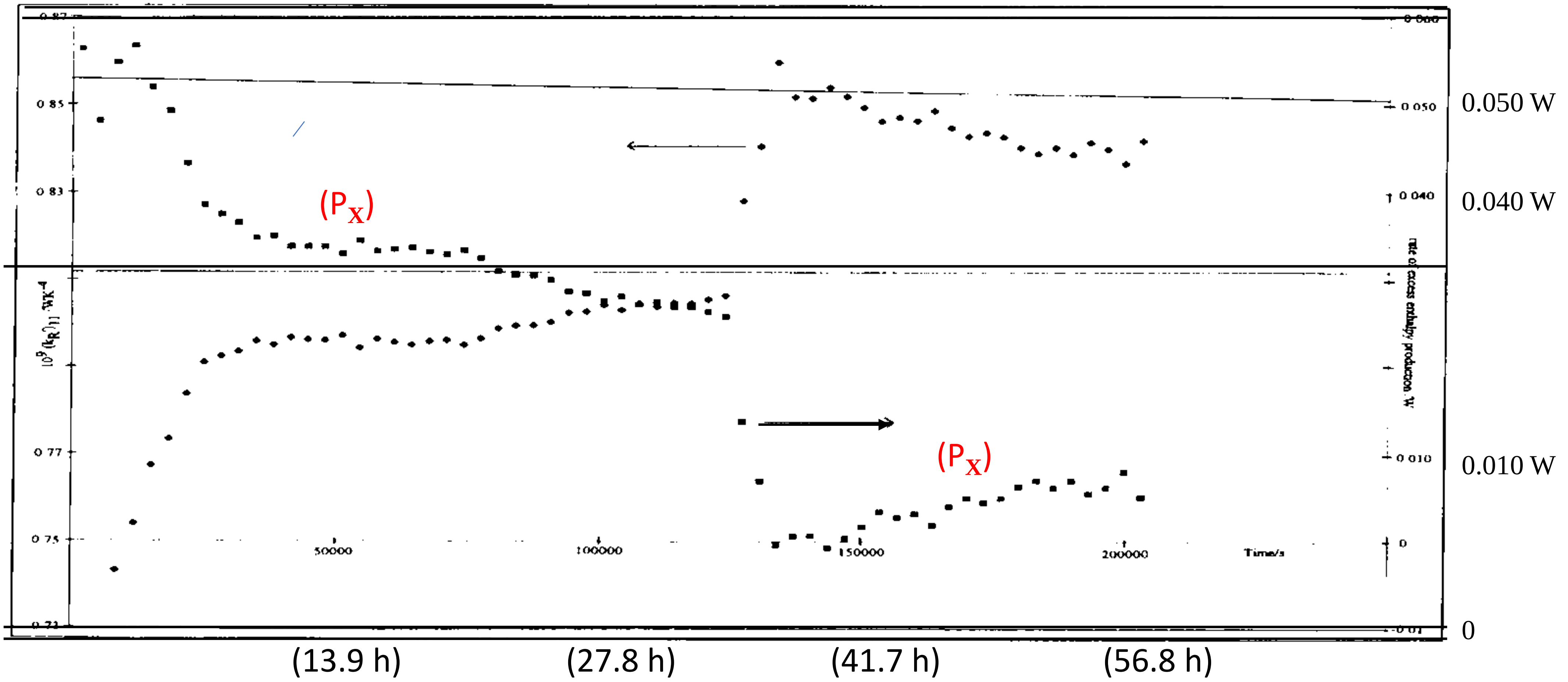
3. <u>Naval Research Laboratory (U.S.A.) Using a Hart Seebeck Calorimeter</u>

   (January, 1995)

   ❖ Continuous Excess Power During and Following Loading (5 to 15 mW)
   (Not Recognized Until 2018)

Pd – 0.5 B At NHE (Japan)
(Fleischmann's Analysis For First Two Days)

Early Excess Power



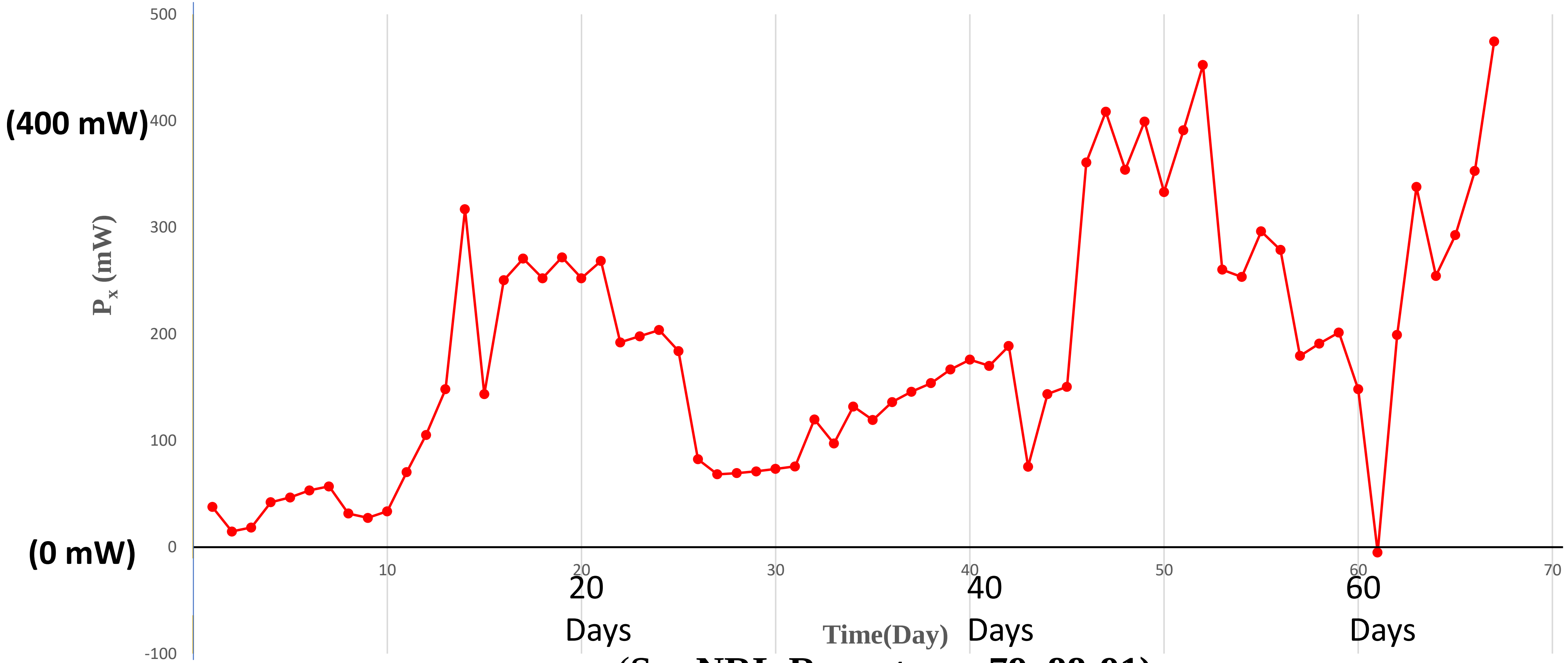
M.H. Miles, M. Fleischmann and M.A. Imam, "Calorimetric Analysis of a Heavy Water Electrolysis Experiment Using a Pd-B Alloy Cathode." NRL/MR/6320-01-8526, March 26, 2001, P. 81. Each point is a 55 minute average.

(Other Experimental Points Show the "Lower Bound" heat transfer coefficient).

Fleischmann Analysis

Mean Excess Power per Day for the NHE (Japan) Pd-0.5 B Experiment

(k_R = 0.85065x10^{-9} W/K^4, C_pM = 450 J/K)

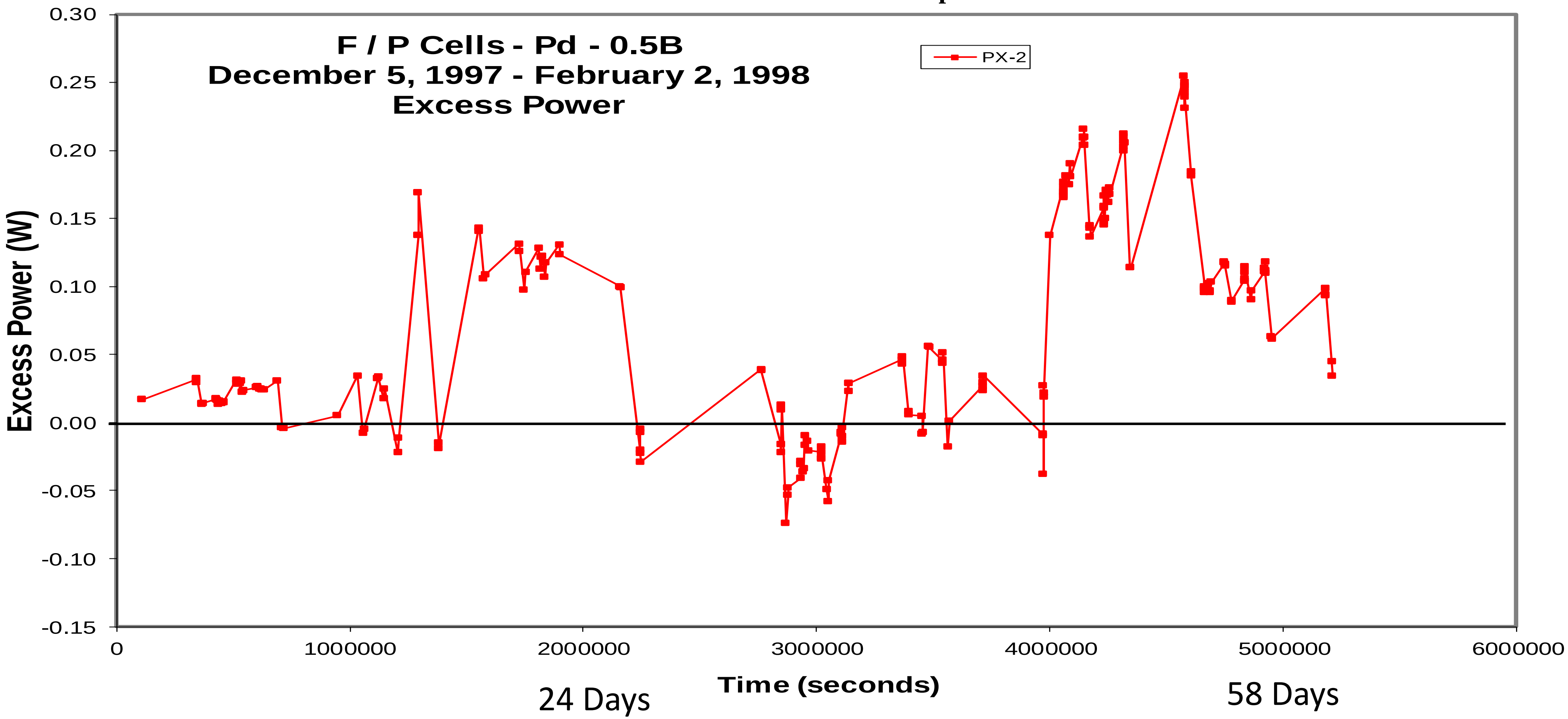


(See NRL Report, pp. 79, 88-91)

Miles Analysis

Study of NRL Pd-B Rod In Japan (NHE)
(0.50 wt. % B, 0.471 x 2.01 cm, V=0.35 cm^3,
December 1997 – February 1998)

(k_R = 0.81120x10^{-9} W/K^4 , C_pM = 490 J/K)



*** The k_R Value Used Was Too Small**

Early Excess Power For Ridgecrest California Experiment
(Pd-0.5 B Cathode Using My Copper Calorimeter)
March 18, 2017

(k_C = 0.1205 W/K , C_pM = 450 J/K)

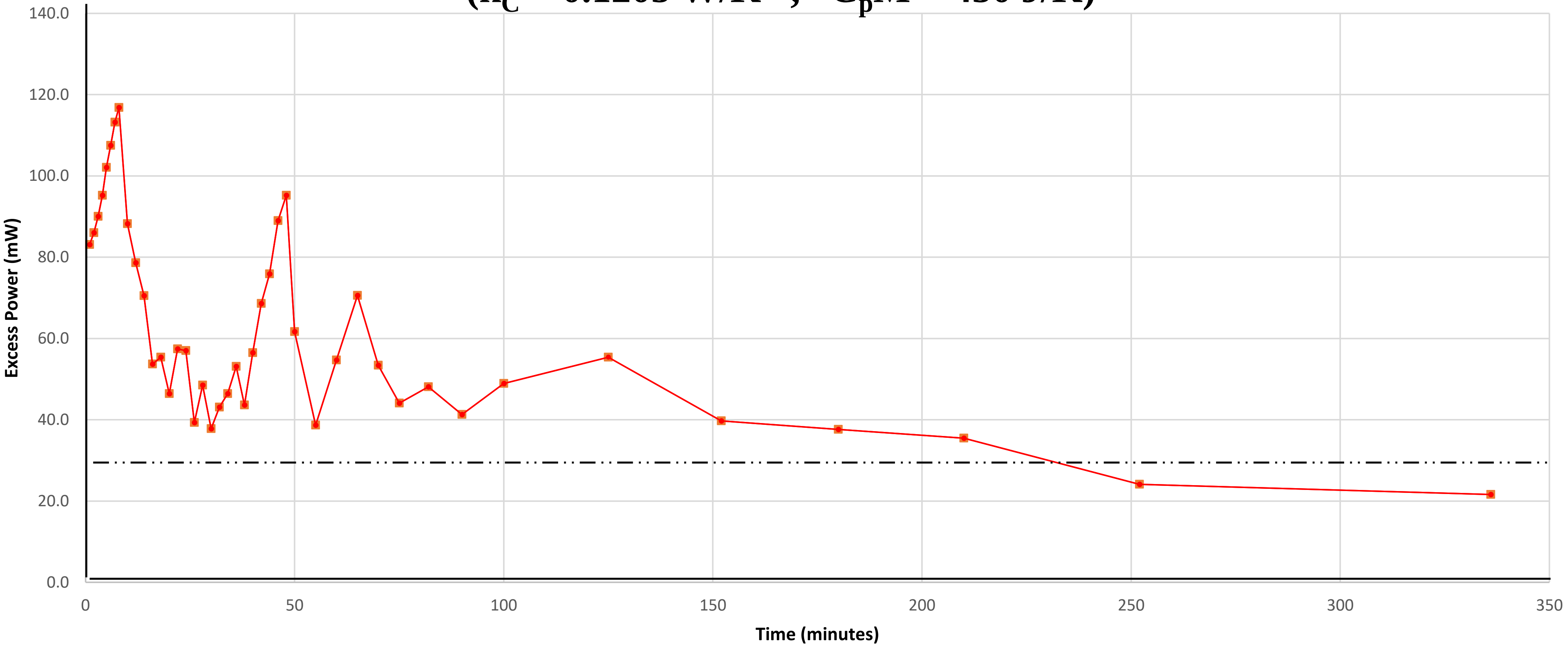


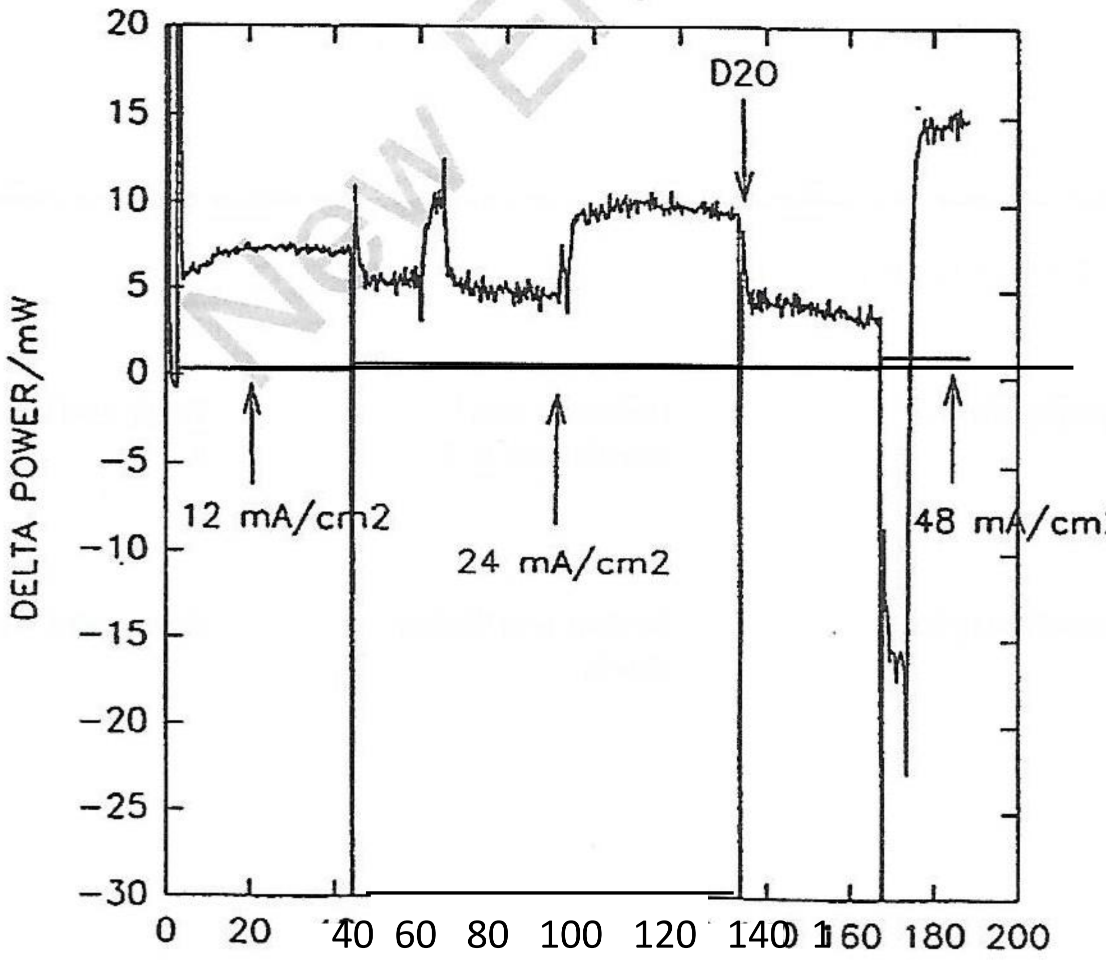
Figure 3. Early excess power for a Pd-0.5 B rod (0.47 x 2.01 cm). The dashed line shows the maximum excess power expected for 100% deuterium loading at the cell current of I = 0.150 A. P_L = (1.5267 – 1.3448)(0.150 A) = 0.0273 W.

Early Excess Power For Pd – 0.75 B At NRL

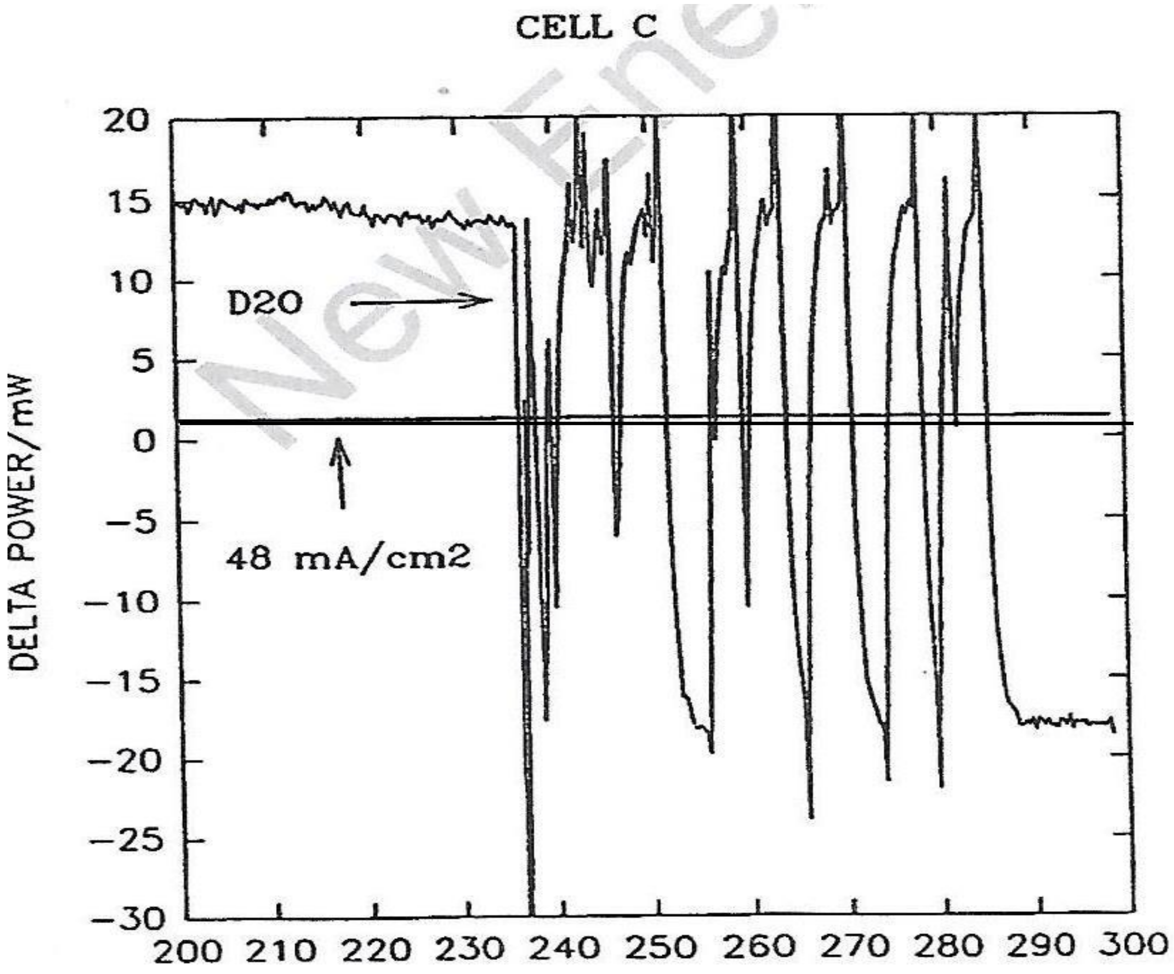
Miles/Dominguez / January 1995

New Seebeck Calorimeter (Hart)

Cell C



Time/Hours



Time/Hours

Possible Calorimetric Error Sources
A. The Thermoneutral Potential (E_H)

- **Assume 100% Deuterium Loading**

$$Pd + 0.3\ D_2O \longrightarrow PdD_{0.6} + 0.15\ O_2$$

$$\Delta H^\circ = 77.85 \text{ kJ/mol Pd}$$

$$E_H^\circ = -\Delta H^\circ / 0.6\ F = \boxed{-1.3448 \text{ V}}$$

- **Only Explains Excess Power Due To Loading**

$$P_X = (1.5267 - 1.3448)\ I = \underline{0.1819\ I}$$

For $I = 0.1500\text{A}$, P_X (Loading) $= \underline{0.0273 \text{ W}}$ (27.3 mW)

(Note: Previous Calculation Error for ΔH° Led To Incorrect Conclusion)

✓ **E_H is NOT An Error Source**

✓ Decreases In E_H Explained By Deuterium Loading.

Possible Calorimetric Error Sources
B. The Cell Heat Capacity (C_pM)

$$P_X' = C_pMdT/dt + k\ f(T) - (E - E_H)\ I$$

- Where $P_X' = P_X + P_G + P_W$ and $f(T) = T - T_b$ (Heat Conduction)

  $f(T) = T^4 - T_b^4$ (Heat Radiation)

Note: Initially C_pMdT/dt is Large

F-P Dewar Cell	CHECK C_pM	= 450 J/K
90 mL D_2O		= 419 J/K
20 cm^3 Pyrex Glass		= 30 J/K
Pd + Pt Metals		= 2 J/K
EXPERIMENTAL CHECK	**TOTAL**	**= 451 J/K**

C_pM Is NOT An Error Source

No Discontinuities Across Cell Heating Pulses (Large C_pMdT/dt)

(See NRL Report, pp. 72,73)

Possible Calorimetric Error Sources

C. Rate of Cell Temperature Change (dT/dt)

Accurate Methods Exist For Determining dT/dt

- ➢Graphical (T vs. time Graph)
- ➢Polynomial Fitting ($T = a + bt + ct^2 + dt^3 + ----$)

$$dT/dt = b + 2ct + 3dt^2 + ---$$

- ➢Numerical Integration (Avoids dT/dt use)

(Simpson or Trapezoidal Rule)

$$\underline{C_p M dT/dt \approx> C_p M (T_2 - T_1)}$$

(W) (J)

Any Error Due to dT/dt Can Be Minimized or Avoided

Lower Bound Cell Constant (k')

(Sensitive To Early Excess Power)

- Calculation of k' Assumes Zero Excess Power

$$P_X = (k - k')\,\Delta T$$

Rearranged ≈>

$$k' = k - P_X/\Delta T$$

- k' Often **Negative** For Real P_X and Small ΔT

(Early in Experiment)

Pd-0.5 B Data Point At t = 8.0 Minutes

$\Delta T = 0.55$ K, E = 4.440 V, I = 0.150 A, dT/dt = $1.083\text{x}10^{-3}$ K/s (0.065 K/m)

$$k = 0.1205 \text{ W/K}$$

$$k' = -0.09155 \text{ W/K}$$

P_X = (0.1205 + 0.09155)(0.55K) = 0.1166 W

(Omitting P_G and P_W) (117 mW)

(See M. Fleischmann and S. Pons, Physics Letters A, 176, 118-129, 1993)

Possible Boron Effects For LENR

1. **Boron As An Essential Element For LENR.**
   - ✓ Boron In Pyrex May Explain Weeks/Months of Electrolysis Before LENR Appears.
   - ✓ Explains Why Repeated Experiments With The Same Cathode Often Produce Larger Effects.
2. **Boron May Participate in Fusion Reactions.**
   - ✓ D + B-10 → 3 He-4 + 17.6 MeV
   - ✓ Active Electrodes Show B-10 Depletion
     (See T.O. Passell, ICCF-6 and ICCF-11 Proceedings)
3. **Boron May Aid Creation of Nuclear Reaction Zones.**
   - ✓ Vacancies, Cracks, Grain Boundaries, Double Layers.
4. **Boron May Act as "Trigger" For LENR**
5. **Boron Greatly Slows Deuterium Deloading Rate.**
6. **Boron Is An Unusual Element.**
   - ✓ B Atom Has Three Unpaired Electrons.
     (Unpaired electrons affect NMR Spectra, see DNP).
   - ✓ Calcium Boride Often Used in Palladium Preparation.
     (Oxygen Getter)

Mathematical Modeling Of Early Cell Behavior

(Theoretical Increase of $T - T_b$ With Time For $P_X' = 0$)

- $C_p M d\Delta T/dt = (E - E_H)I - k(T - T_b) + P'_X$ Where $\Delta T = T - T_b$
  - ✓ Assume $P'_X = P_X + P_G + P_W = 0$ $(T_b = T_0)$

$$d\Delta T/dt = \alpha - \gamma\Delta T$$

Where $\alpha = (E - E_H)I / C_p M$ (K/s), $\gamma = k/C_p M$ (s^{-1})

- **Integration Yields**

$$\Delta T = T - T_0 = (\alpha/\gamma)[1 - \exp(-\gamma t)]$$

For Small $-\gamma t$ then $\exp(-\gamma t) \approx 1 - \gamma t$ **Thus** $\Delta T \approx \alpha t$

- ❑ **Cell Temperature Initially Increases Linearly With Time**

Initial Experimental And Calculated ΔT Values

Table 2. Initial Cell Temperatures: Experimental and Calculated.

t (minutes)	$T - T^o$ (K) (Experimental)	$T - T^o$ (K) Calculated)	E (V)	P'_X (mW)
0.0	0	0	--	--
2.0	0.120	0.111	4.345	87
4.0	0.270	0.222	4.389	98
6.0	0.420	0.331	4.419	112
8.0	0.550	0.437	4.440	118
10.0	0.675	0.540	4.451	93
12.0	0.800	0.633	4.425	84
14.0	0.910	0.730	4.440	76
16.0	1.010	0.824	4.446	59
18.0	1.110	0.916	4.458	60
20.0	1.190	1.005	4.465	50

For First 10 Minutes: $\Delta H = C_pM\,[(T - T_0) - (T' - T_0)]$

$= 450\ J/K\ [0.135\ K] = 61\ J$

Mean Excess Power: $<P_X> = 61\ J/(10)(60)s = 0.102\ W$

P_X [87, 98, 112, 118, 93 mW] $<P_X = 102 \pm 13\ mW = 0.102\ W$

≈> Excess Power Measurements Are Correct.

(Early Excess Power Mainly Used To Heat Cell)

SUMMARY For Pd-B CATHODES

1. Very Early Excess Power Measured In Different Experiments.
   - Excess Power Detected Within Minutes Of Electrolysis.
   - Three Different Laboratories Using Three Different Calorimeters.

2. **No Error Source Explains This Early Excess Power.**
   - E_H, C_pM, dT/dt Are **Not** Error Sources.

3. Possible Boron Effects For Cold Fusion (LENR).
   - Direct B + D Reactions.
   - Boron Is An Essential Element For LENR.
   - Boron May Aid In Creating Nuclear Reaction Zones.
   - Boron May Serve as "Trigger" For Start of LENR.

Note: Boron Loads Normally But De-Loads Very Slowly.

(Boron Atoms In Grain Boundaries May Block Deuterium Escape).

Acknowledgements

1. **Masao Sumi**
   - ✓ Helped At NHE In Setting Up F-P Type Experiments.
   - ✓ Sent Me Complete Computer Data For My NHE Experiments.

     (I was denied this data when leaving NHE).
2. **Dr. Martin Fleischmann**
   - ✓ **Provided Detailed Analysis For My NHE Pd-0.5 B Experiment.**
   - ✓ **First To Show Early Excess Power For NRL Pd-0.5 B Cathode.**
3. **Dr. M.A. Imam**
   - ✓ Prepared Pd-B Cathodes At Naval Research Laboratory (NRL).

     (U.S. Patent 6764561B1, July 20, 2004)
4. **Dr. Fred Saalfeld, Head of NRL In 2001**
   - ✓ Allowed Publication of Fleischmann's Analysis As a NRL Report.

     (Despite Considerable Cold Fusion Controversy Within U.S. Navy).

5. **M Fleischmann and S. Pons For Accurate Calorimetric Equations.**

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