Excess Power Measurements For Palladium-Boron Cathodes

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One of the major goals of the U.S. Navy cold fusion program (1992-1995) was to produce our own palladium cathode materials at the Naval Research Laboratory (NRL). However, none of these Navy palladium metals and alloys were successful in producing the Fleischmann-Pons (F-P) excess power effect during the first two years. This all changed with the NRL preparation of palladium-boron (Pd-B) alloy cathodes in 1994. Seven out of eight experiments using these NRL Pd-B cathodes produced significant excess power in calorimetric studies at the Navy laboratory at China Lake, California (C/L). The one failure was related to a folded over metal region which acted as a long crack on the electrode surface. This success with Pd-B alloys made by NRL came too late to prevent the closure of the U.S. Navy cold fusion program in 1995, but these results are documented in a Navy report [1].

The author had the opportunity once again to work on cold fusion in 1997-1998 at the New Hydrogen Energy laboratory (NHE) in Sapporo, Japan. Three F-P Dewar calorimeters were available for this work, and a new Pd-B cathode from NRL was included in these experiments. Significant excess power for Pd-B was again observed [2]. The computer data from this experiment was also later carefully processed by Martin Fleischmann and published in a detailed NRL report [3]. The excess power was verified throughout most of this experiment and increased to nearly 10 watts during the boil-off of the cell contents. A significant new observation for this Pd-B cathode was the very early appearance of the excess power effect within the first two days of this experiment [3].

Last year (2017), this same Pd-B cathode was tested again using a different calorimeter at Ridgecrest, California (R/C). Excess power was observed, although the effect was considerably smaller than found at the NHE laboratory in 1998. Nevertheless, the excess power of 70 mW was clearly above the experimental calorimetric error of ±3 mW.

In summary, 9 out of 10 of my experiments using NRL Pd-B cathodes have produced excess power in six different calorimeters. Selected examples are shown in Table 1. The calorimetric results for all ten Pd-B experiments will be presented, and possible important properties of these Pd-B materials will be discussed. The effects of boron added to the palladium include a much greater hardness of the metal, a much slower rate of deuterium escaping from the cathode, the fact that boron acts as an oxygen getter, and that the Pd-B is a two-phase material. Two important unreported Pd-B experiments at NRL in 1995 will also be discussed.

Table1. Selected Examples of Pd-B Experiments.

Date	Location	Calorimeter	% B	Excess power (mW)
May, 1994	C/L	C/L-B	0.75	150
October, 1994	C/L	C/L-C	0.75	300
March, 1995	C/L	C/L-A	0.50	100
March, 1995	C/L	C/L-D	0.25	80
December, 1998	NHE	F-P	0.50	450
March, 2017	R/C	Copper-B	0.50	70

1. M.H. Miles, B.F. Bush, K.B. Johnson, “Anomalous Effects in Deuterated System”, NAWCPNS TP 8302, September, 1996.
2. M.H. Miles, “Calorimetric Studies of Palladium Alloy Cathodes Using Fleischmann-Pons Dewar Type Cells” in ICCF-8 Conference Proceedings, pp. 97-104, 2000.
3. M.H. Miles, M. Fleischmann, 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.

EXCESS POWER MEASUREMENTS FOR PALLADIUM-BORON CATHODES

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ICCF-21 / Colorado State University
June 3-8, 2018

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1978 - 2002

U.S. NAVY COLD FUSION PROGRAM (1992-1995)

ICCF - 2 Como, Italy

June 29 – July 4, 1991
"The Science of Cold Fusion" (ICCF-2 Proceedings)
(T. Bressani, E. Del Giudice, G. Preparata, Editors)

ICCF - 2

Miles-Bush: He-4 Production Correlated With Excess Heat (NWC)
Szpak-Boss: Reliable Co-Deposition Method (NOSC)
Chubb-Chubb: LINC Theory (Predicts He-4 Production in Gas Phase)

Navy Program: Anomalous Effects In Deuterated Materials

Funding: NWC (China Lake), NOSC (San Diego), NRL (Washington, D.C.)

Key Players: Dave Nagel (NRL), Scott Chubb (NRL)
Robert Nowak (ONR), Fred Saalfeld (ONR)

January 1992 → June 1995

NAVY PROGRAM GOALS

- **Make In-House Navy Palladium Materials (Imam, NRL)**
- **Calorimetric Tests For Navy Materials (Miles/Bush, NWC)**
- **Co-Deposition Studies (Szpak/Boss, NOSC)**
- **Re-Produce Calorimetric Results at NRL (Dominguez)**
- **Analysis of Palladium Materials (Imam, NRL)**

Disappointing Results

No Navy (NRL) Palladium Materials Produced Excess Heat

(1992-1994)

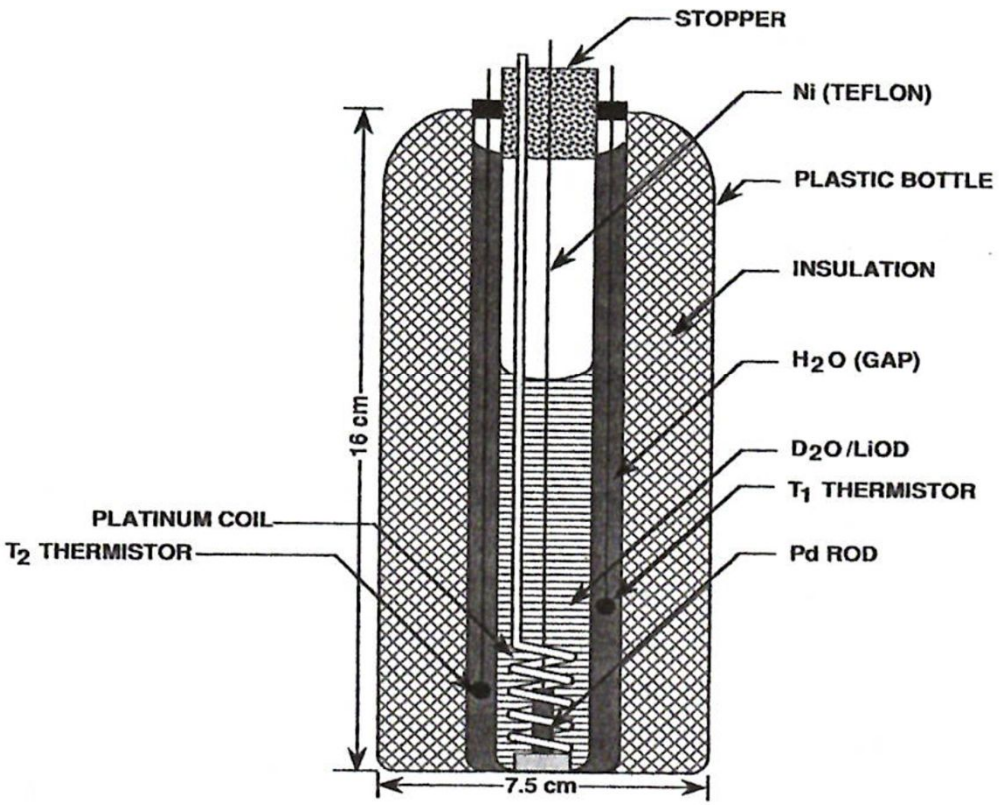
Exciting Results

NRL Pd-B Produced Excess Heat In 7/8 Experiments

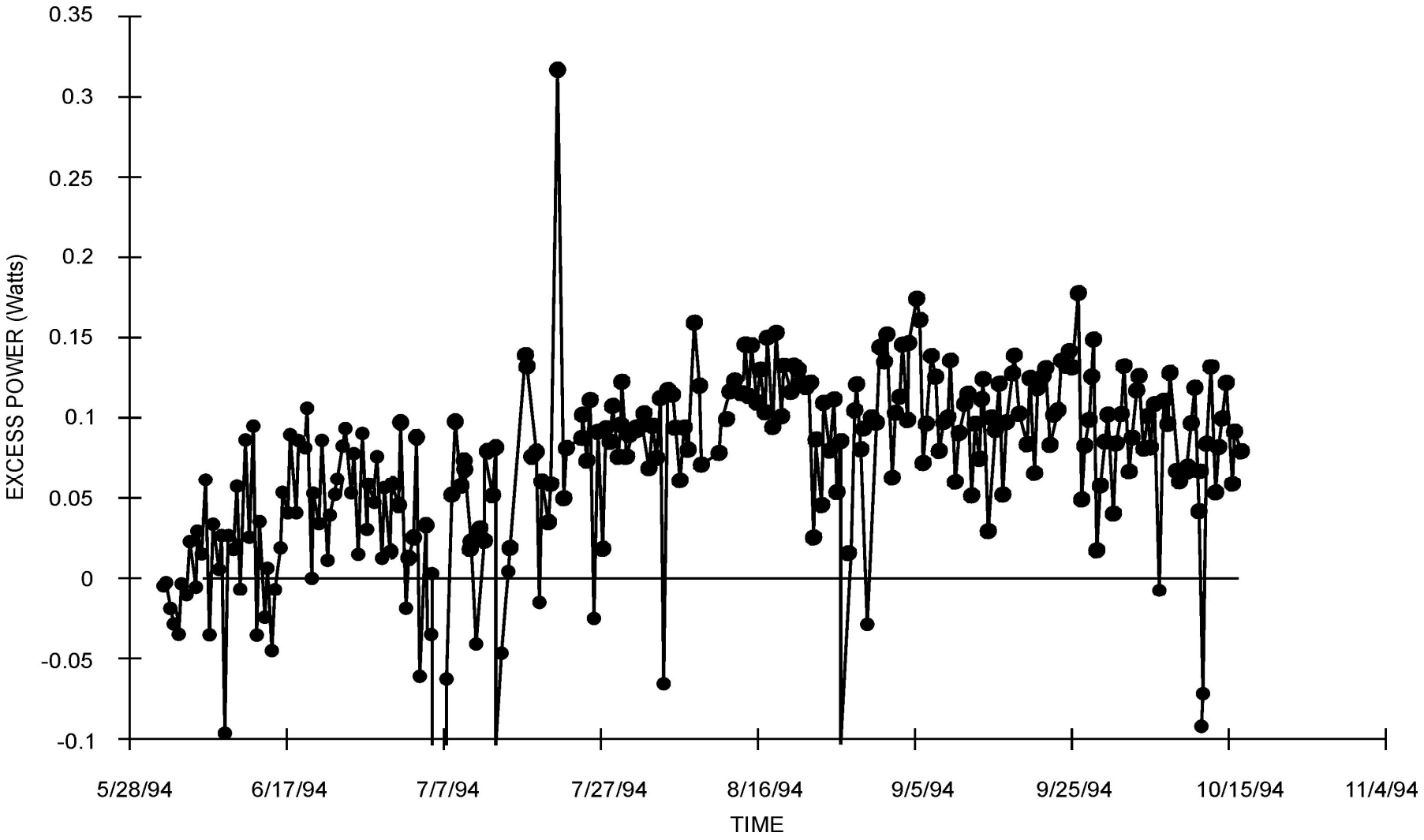
(May 1994 – June 1995)

China Lake Calorimetry
(1989 – 1995)

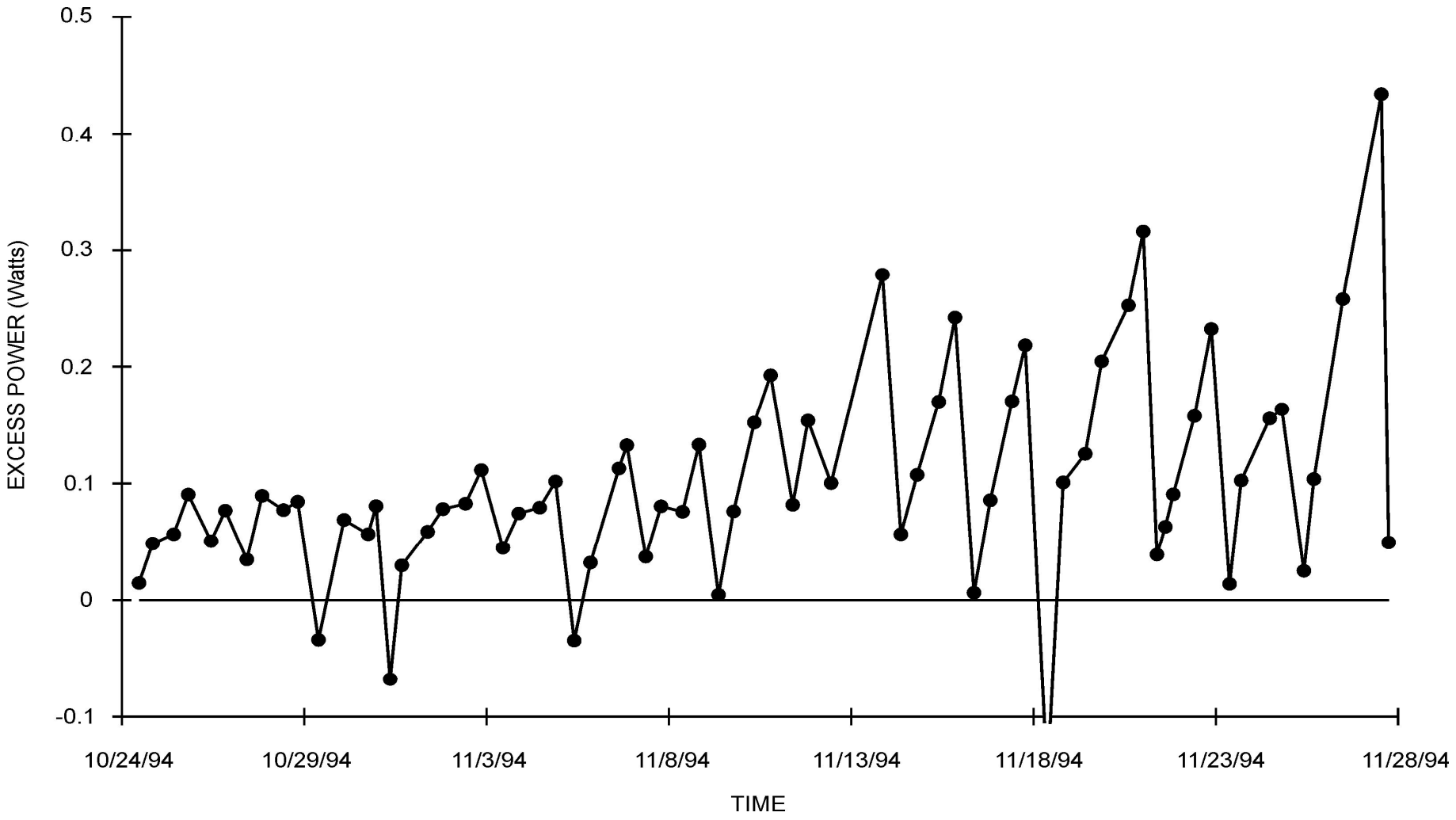
- **Cells A, B, C, D Nearly Identical**
- **Small Glass Test Tubes / 18.0 mL Electrolyte**
- **Heat Integrator / Outer Water Jacket**
- **Insulation ($K_C \approx 0.140\ WK^{-1}$)**



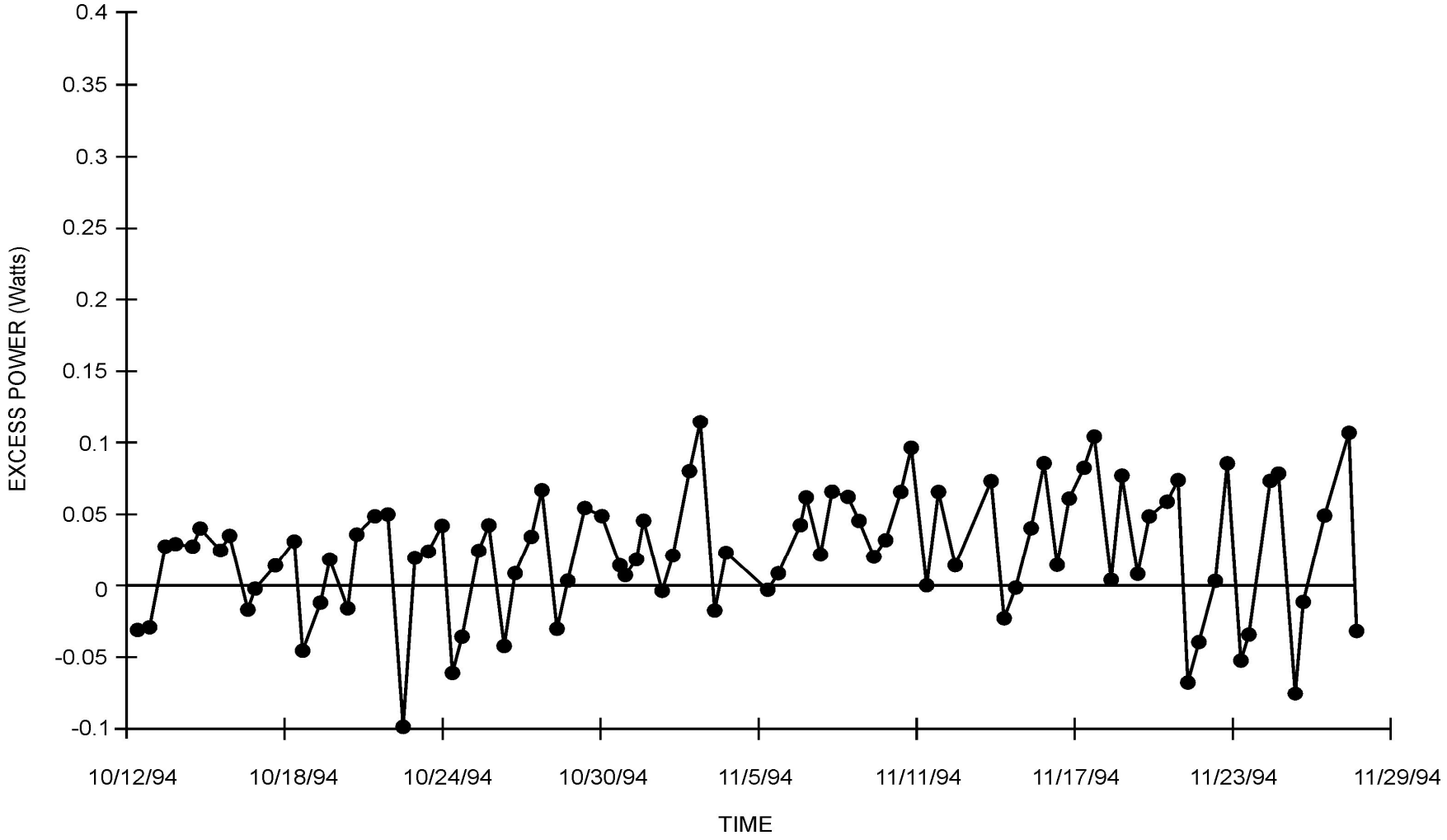
EXCESS POWER FOR NRL Pd-B ROD (Cell B)
(0.75 wt. % B, 0.60 x 2.0 cm, V=0.57 cm^3)
May 1994 –October 1994 P_X (max) = 330 mW



SECOND EXPERIMENT USING SAME NRL Pd-B Rod (Cell B) (October 1994 – November 1994) P_X (max) = 420 mW

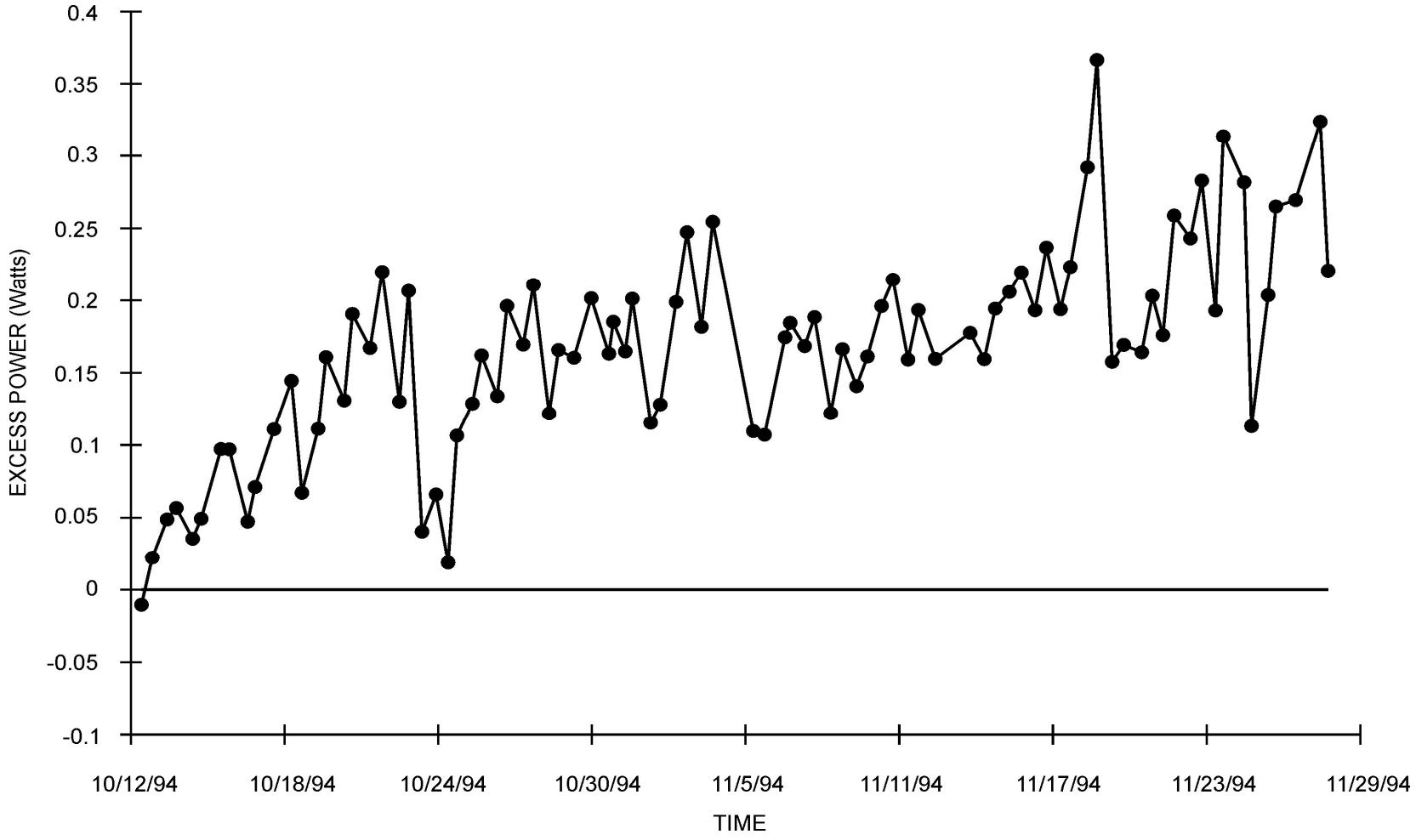


No Significant Excess Power For NRL Pd-B Rod (Cell D)
(0.75 wt. % B, 0.25 x 2.5 cm , V = 0.12 cm ^{3})
FLAW: Folded Over Metal Region Acts As Crack,
October 1994 – November 1999

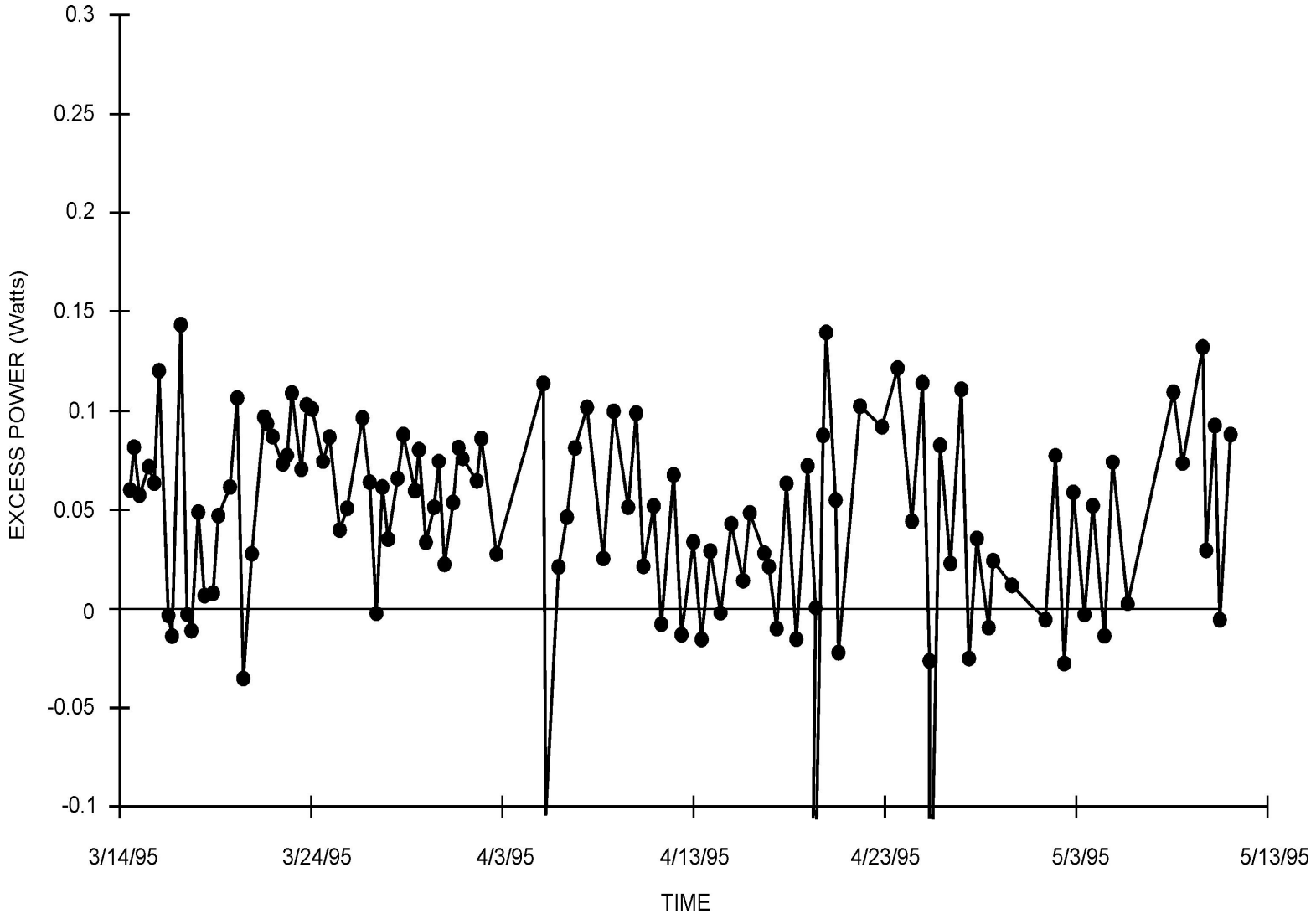


Excess Power For NRL Pd-B Rod (Cell C)
(0.75 wt. % B, 2.5 x 2.5 cm, V=0.12 cm^3) October 1994 – November 1994
P_X (max) = 380 mW

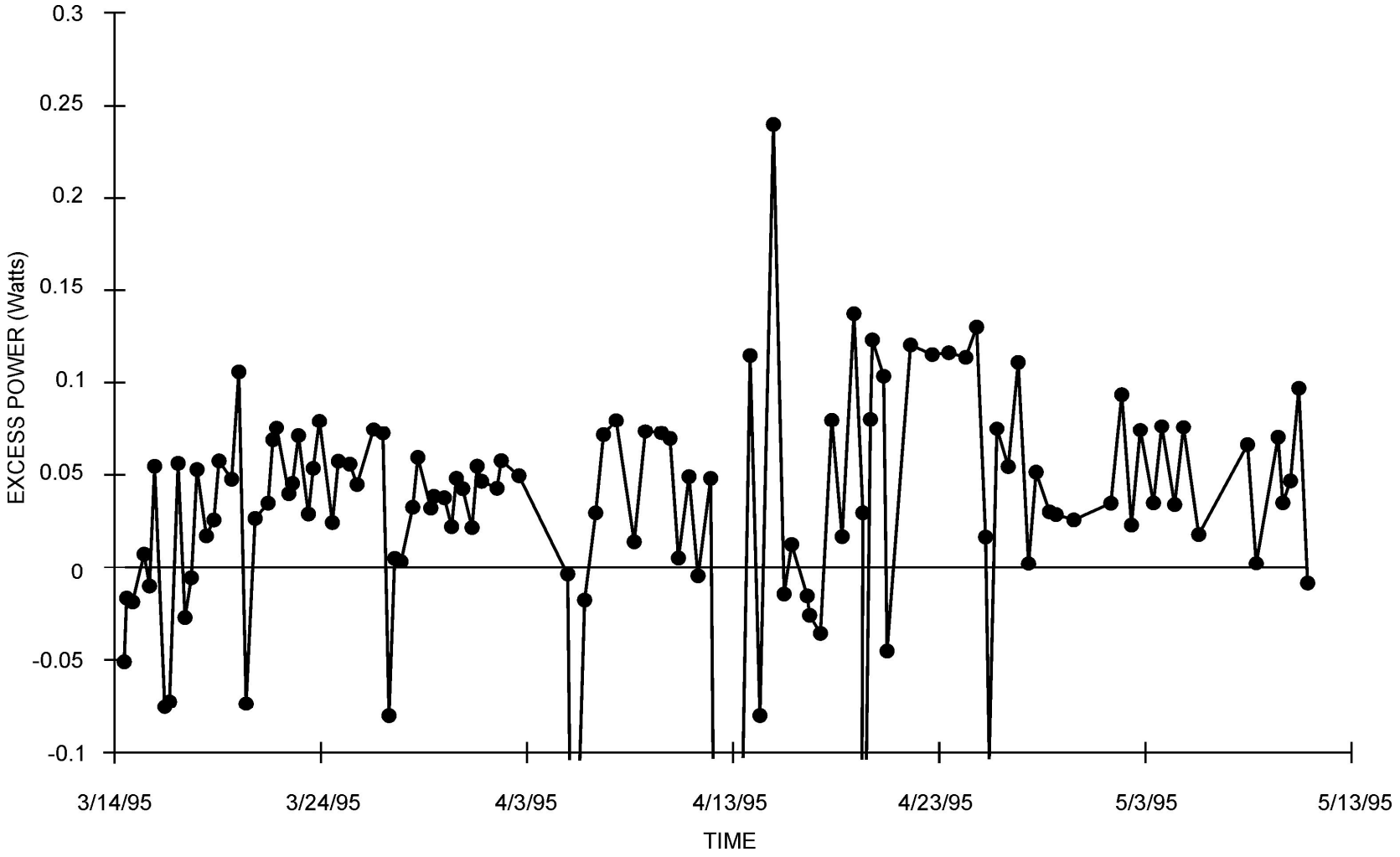
Best Pd-B Result



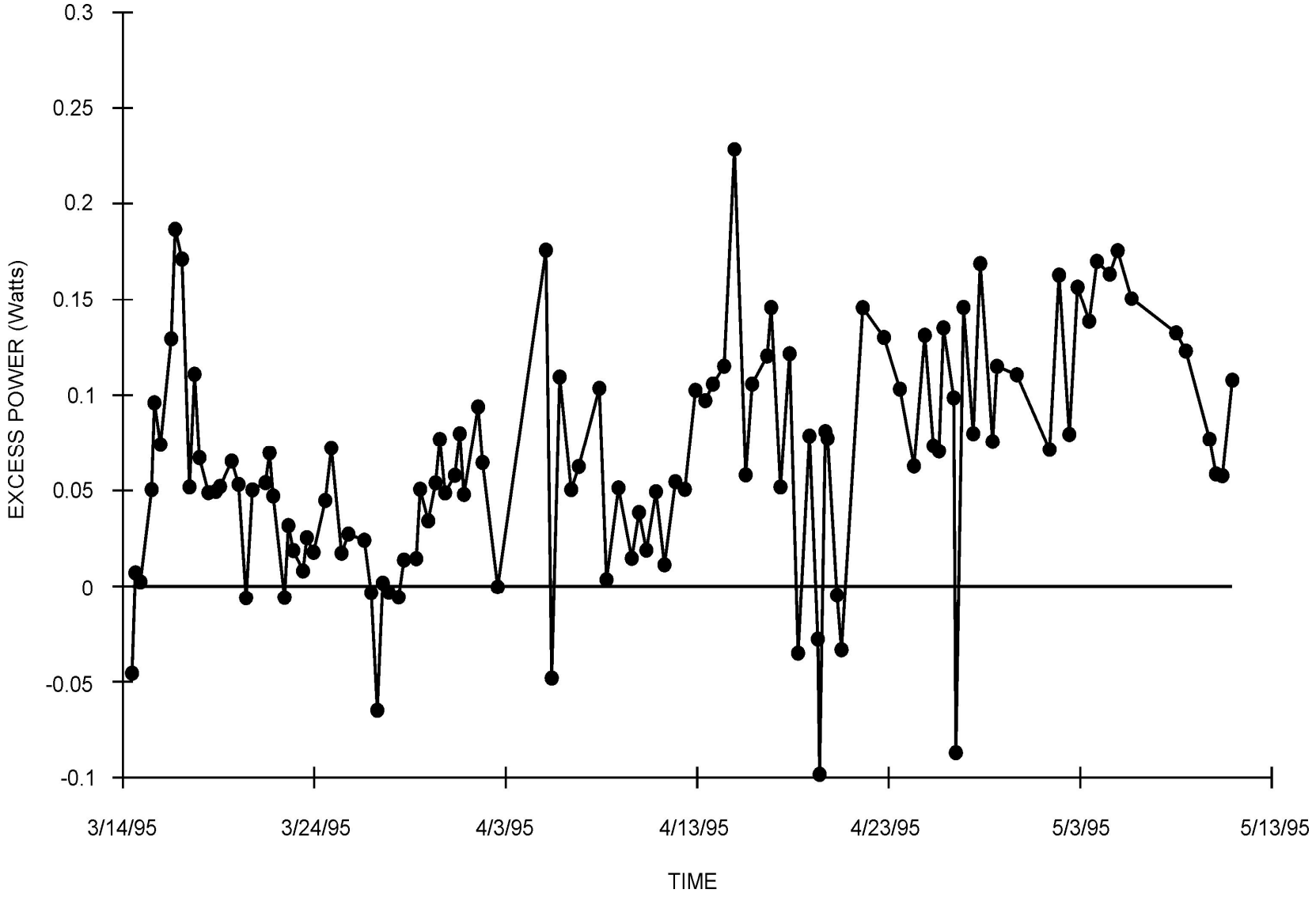
Excess Power For NRL Pd-B Rod (Cell A)
(0.50 wt. % B, 0.40 x 2.0 cm, V=0.25 cm^3, March 1995-May 1995
P_X (max) = 150 mW



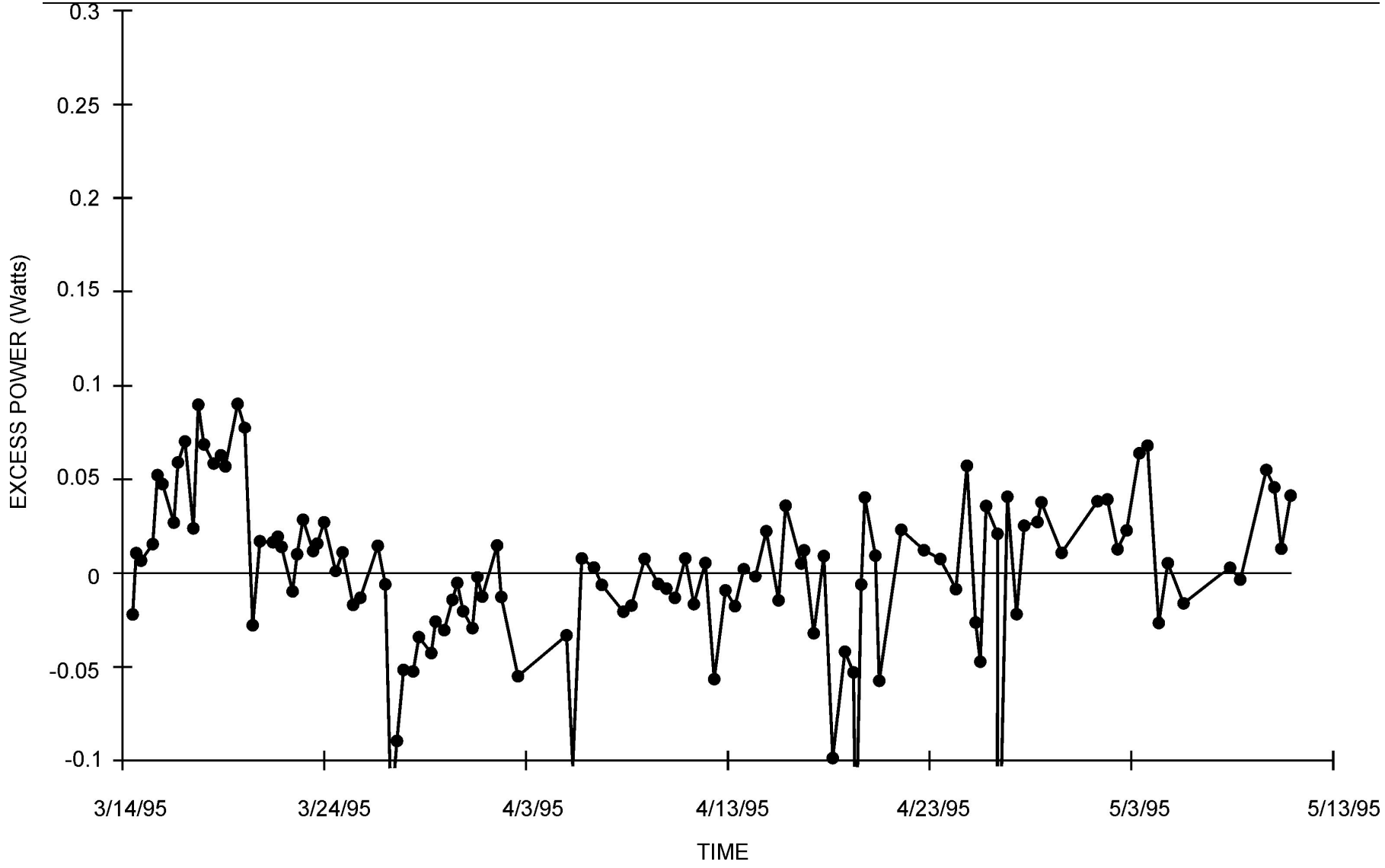
Excess Power For NRL Pd-B Rod (Cell B)
(0.50 wt. % B, 0.40 x 2.0 cm, V=0.25 cm^3, March 1995-May 1995
P_X (max) = 240 mW



Excess Power For NRL Pd-B Rod (Cell C)
(0.25 wt. % B, 0.40 x 2.0 , V=0.25 cm^3, March 1995-May 1995
P_X (max) = 200 mW



Initial Excess Power For NRL Pd-B Rod (Cell D)
(0.25 wt. % B, 0.20 x 2.0) V = 0.25 cm^3, March 1995 – May 1995
P_X (max) = 90 mW

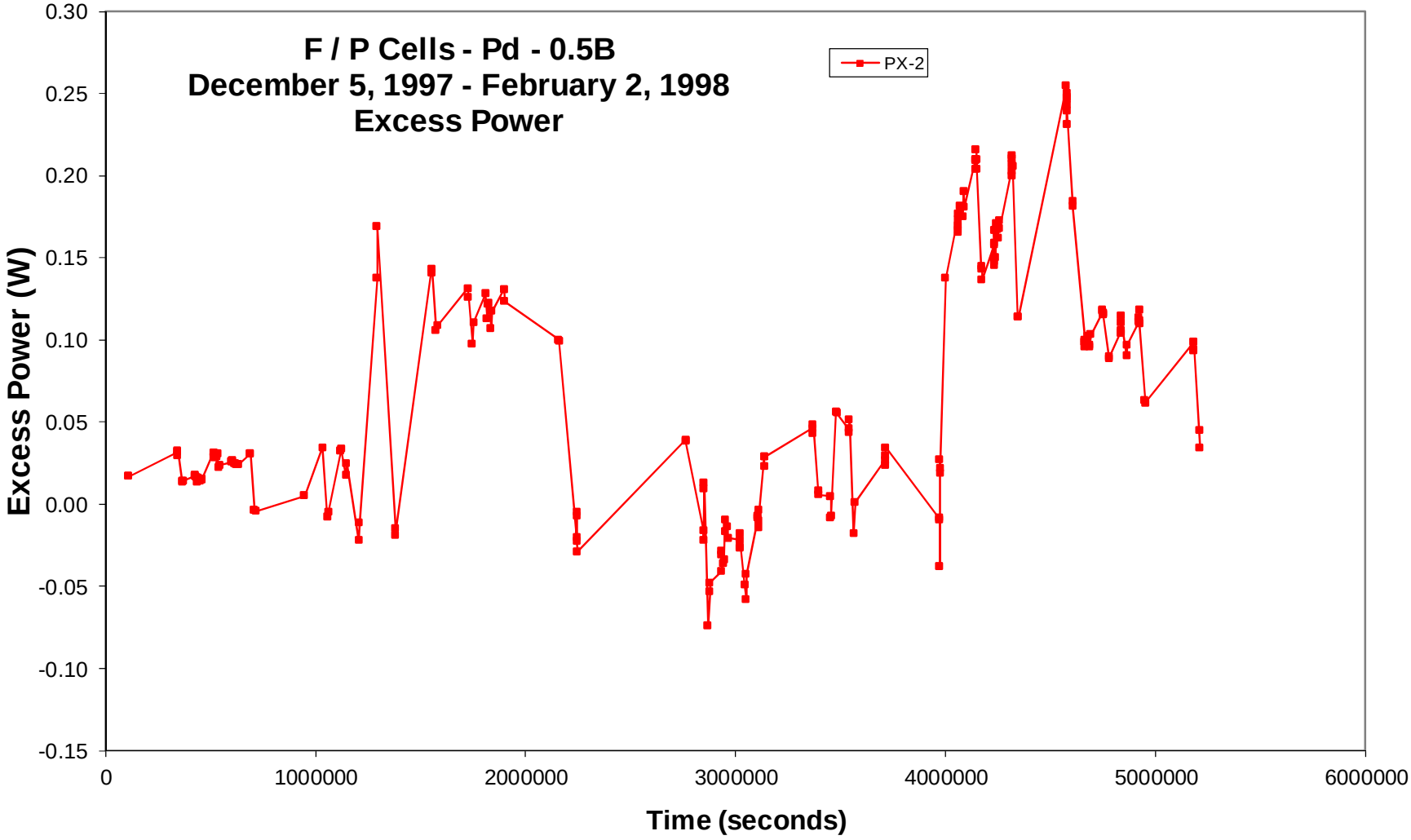


CHINA LAKE SUMMARY
NRL Pd-B Rods

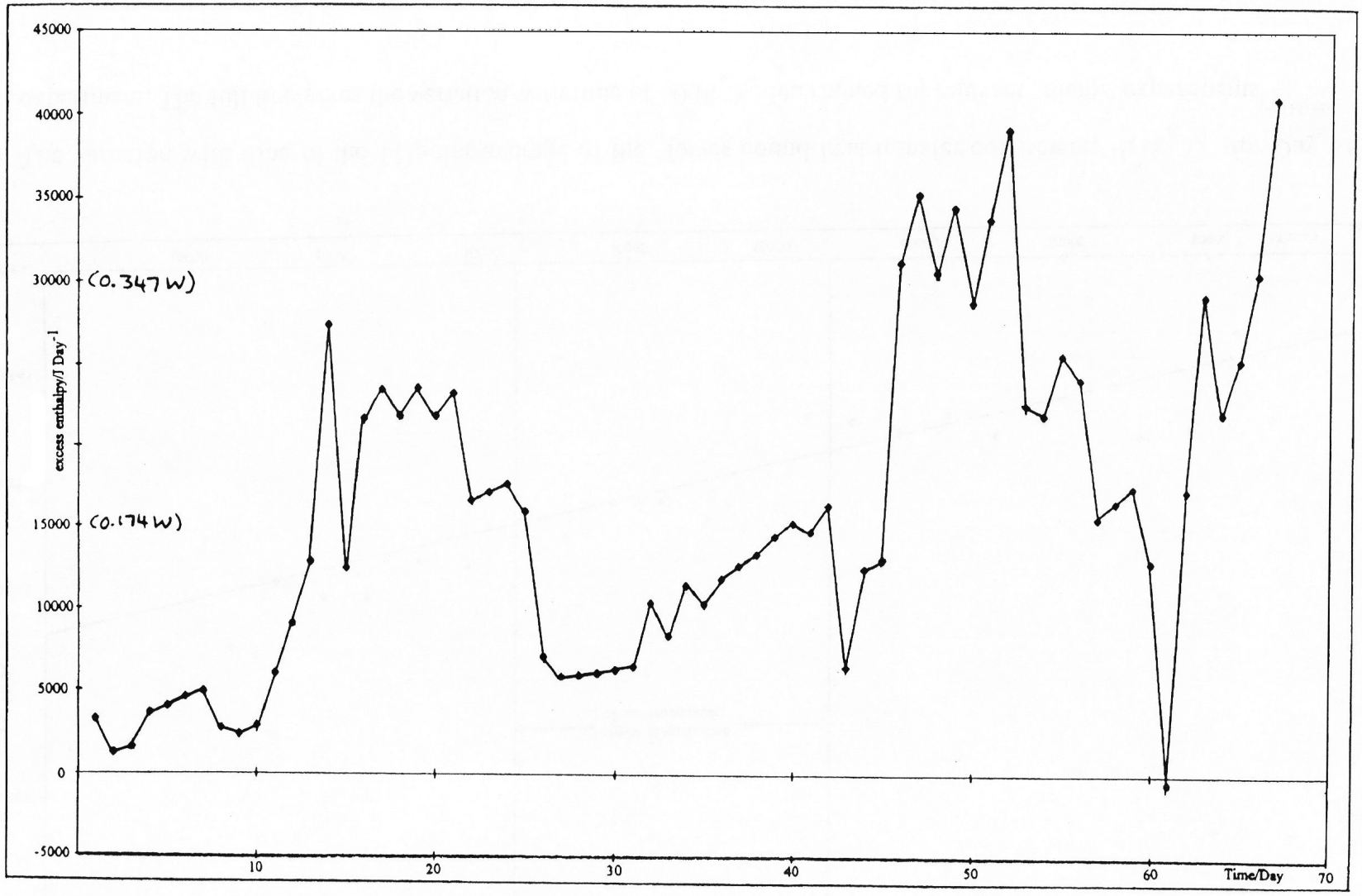
StartDate	Cell	Wt. % B	Dimensions (cm)	Avg P_x (mW)	Max P_x (mW)	W/cm^3
5/28/94	B	0.75	0.60 x 2.0	100	330	0.58
10/24/94	B	0.75	0.60 x 2.0	80/125	420	0.74
10/12/94	C	0.75	0.25 x 2.5	180/250	380	3.10
10/12/94	D	0.75	0.25 x 2.5	25	0	0
3/14/95	A	0.50	0.40 x 2.0	60	150	0.60
3/14/95	B	0.50	0.40 x 2.0	50	240	0.96
3/14/95	C	0.25	0.40 x 2.0	100	200	0.80
3/14/95	D	0.25	0.40 x 2.0	50/0	90	0.36

All using D_2O + 0.1 M LiOD

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



Japan Pd-B Study / Fleischmann Analysis
(Naval Research Laboratory Report, March 26, 2001)



Negative Excess Power Explained by Work Term (Day 61)

$V = nRT/P \quad W = -P\Delta V \quad \rightarrow \quad P_W = -RT(0.75\ I/F)$

Day 3 (P_X = 18.3 mW) I = 0.150 A, T = 301.1 K $\rightarrow P_W$ = -2.9 mW

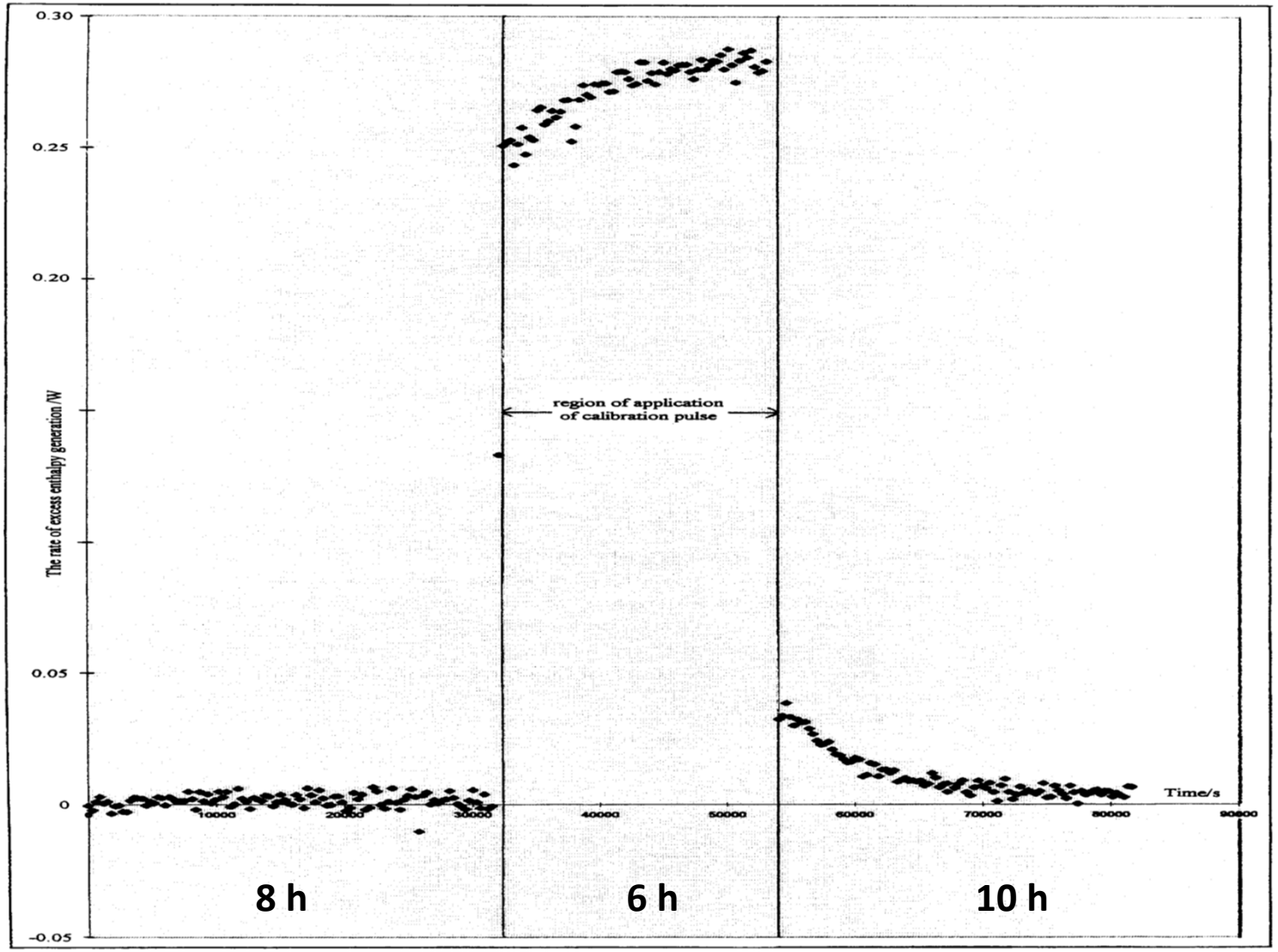
Day 61 (P_X = -5.2 mW) I = 1.001 A, T = 345.4 K $\rightarrow P_W$ = -22.3 mW

Corrected For P_W

Day 3 $P_X = 18.3 + 2.9$ mW $= 21.2$ mW

Day 61 $P_X = -5.2 + 22.3$ mW $= 17.1$ mW

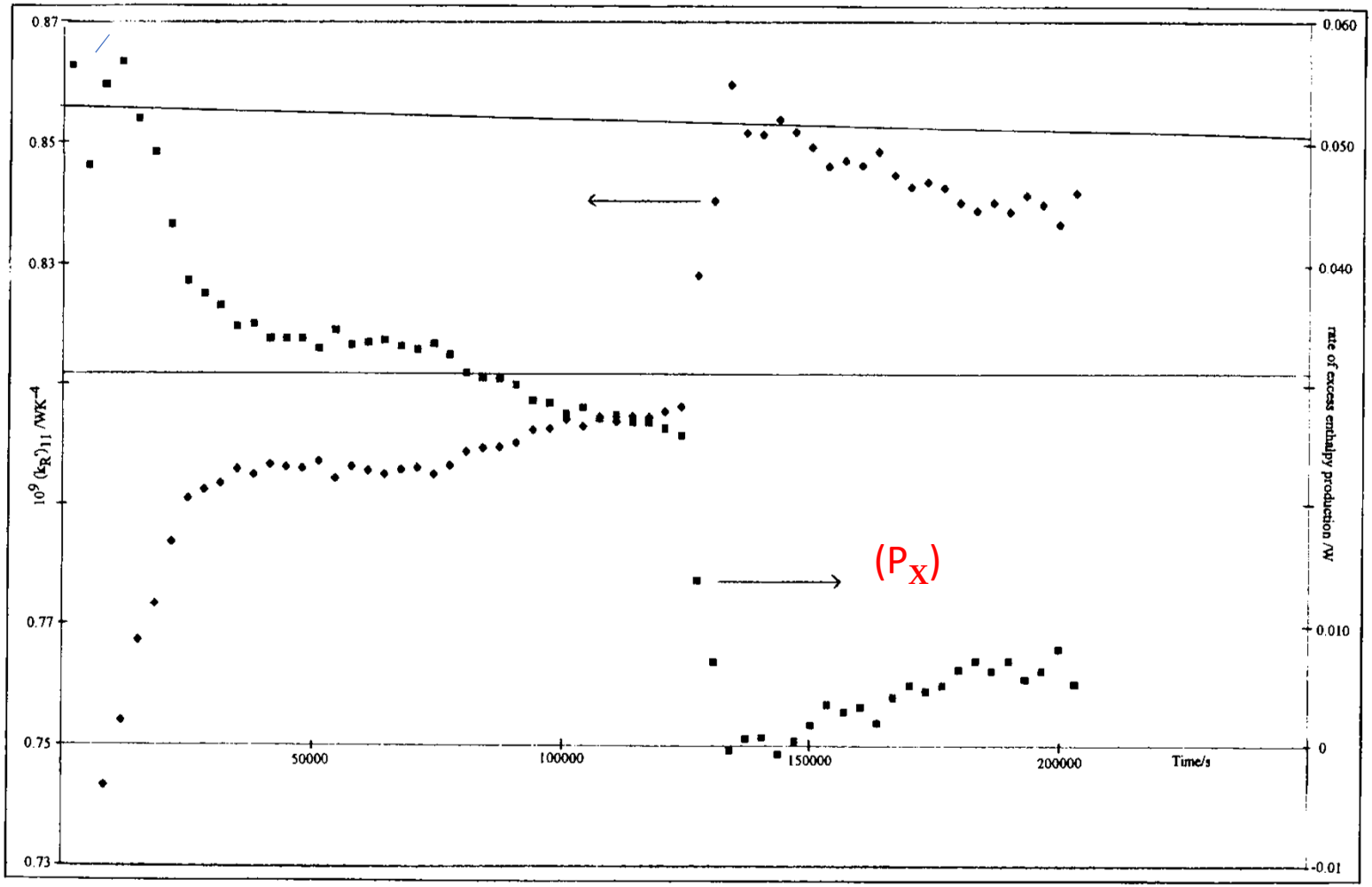
Pd – 0.5 B / NHE Japan
Excess Power On First Heating Pulse (Day 3)



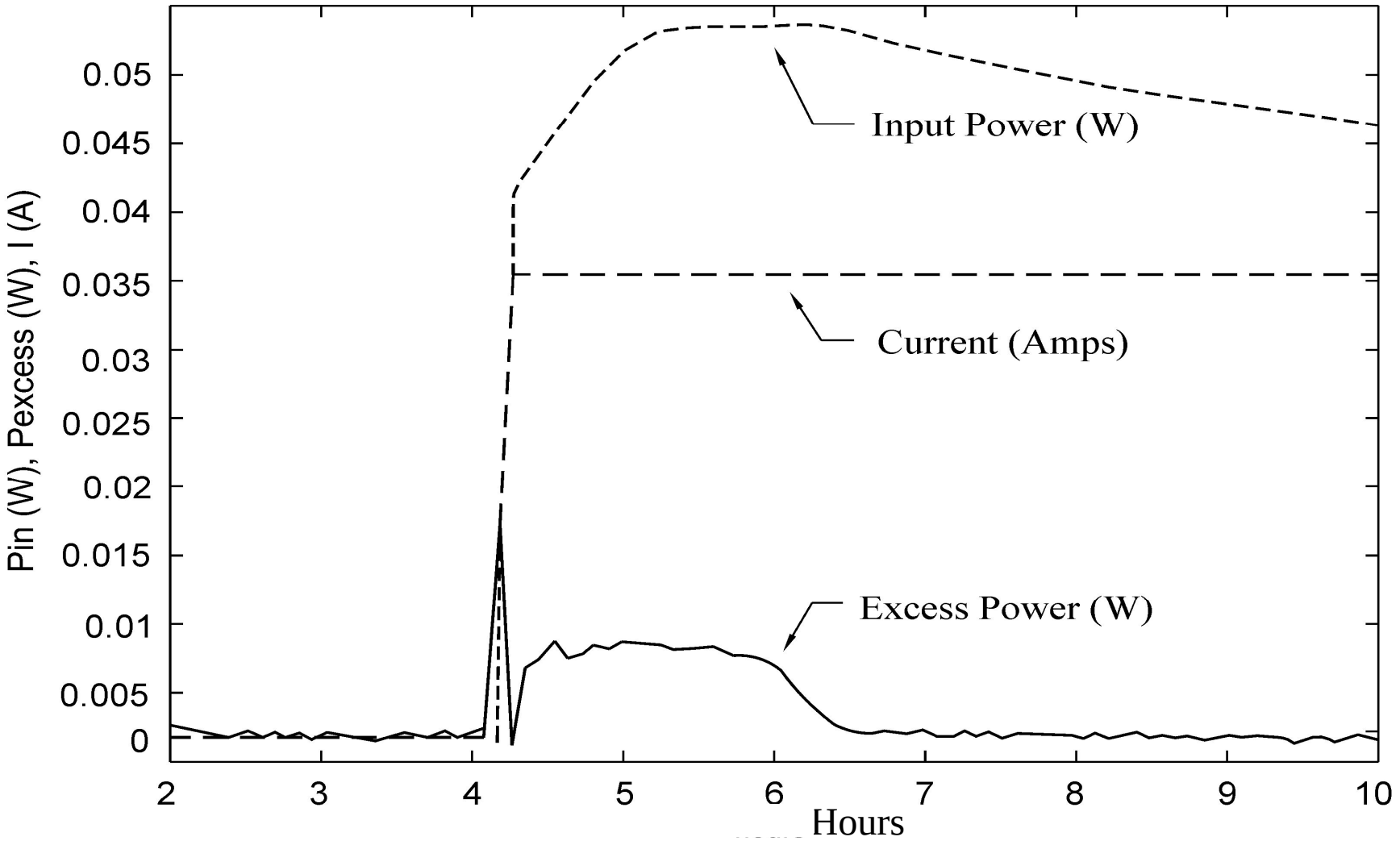
NHE → 1-Day Cycles

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

Early Excess Power



Exothermic Palladium Loading Improved China Lake Isoperibolic Calorimeter (Pd 0.1 x 4.3 cm) (Kendall Johnson 1995)

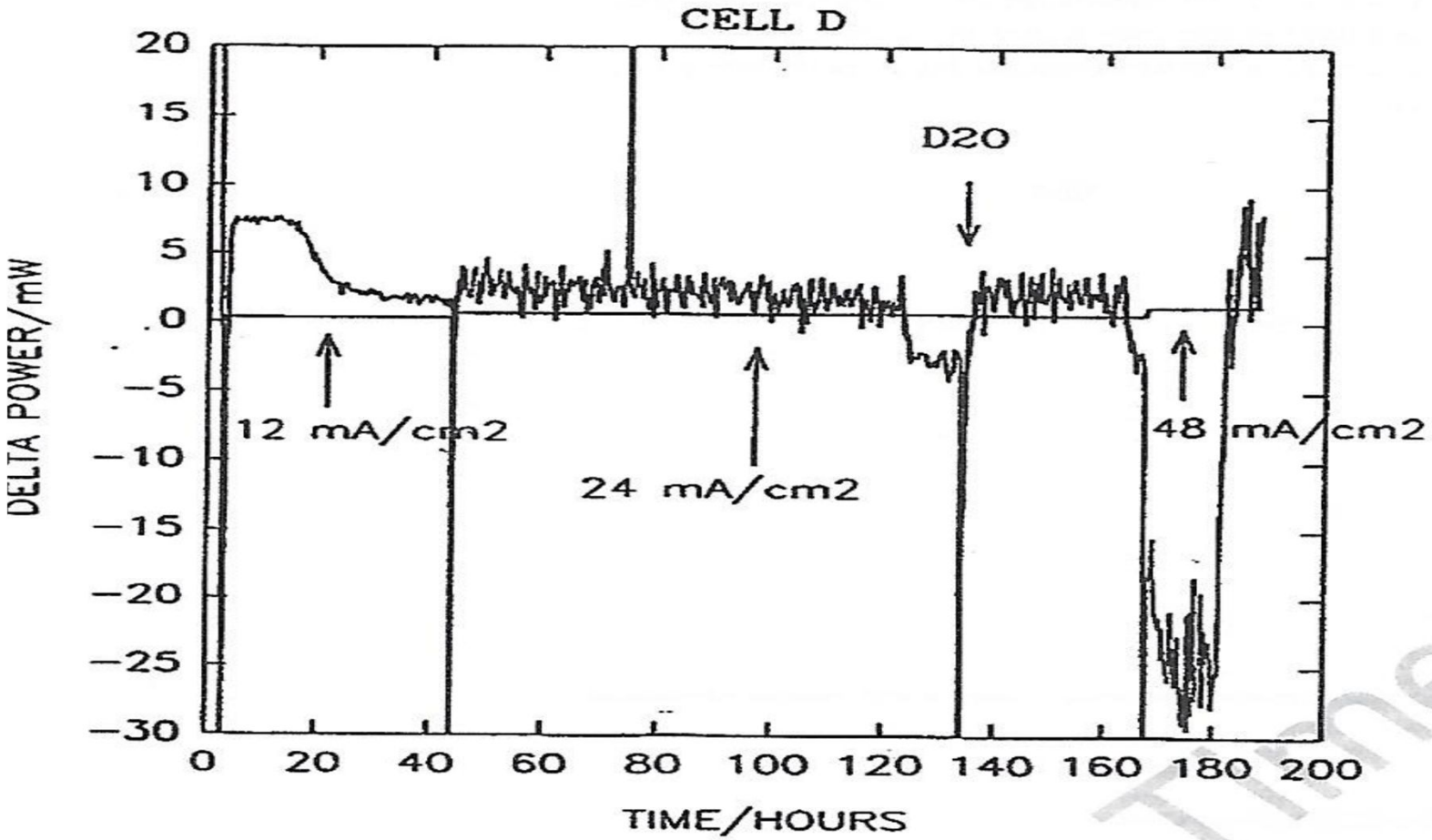


China Lake Experiment = -38 ± 3 kJ/mol D_2 for Palladium ($PdD_{0.6}$)
Exothermic Heat of Loading = -35.1 kJ / mol D_2

NRL Experiment For Pd-0.75 B (0.4 x 3.5 cm)
Miles – Dominguez / January 1995 / Seebeck Calorimeter

Gas Exit Lines Clog → NOISE

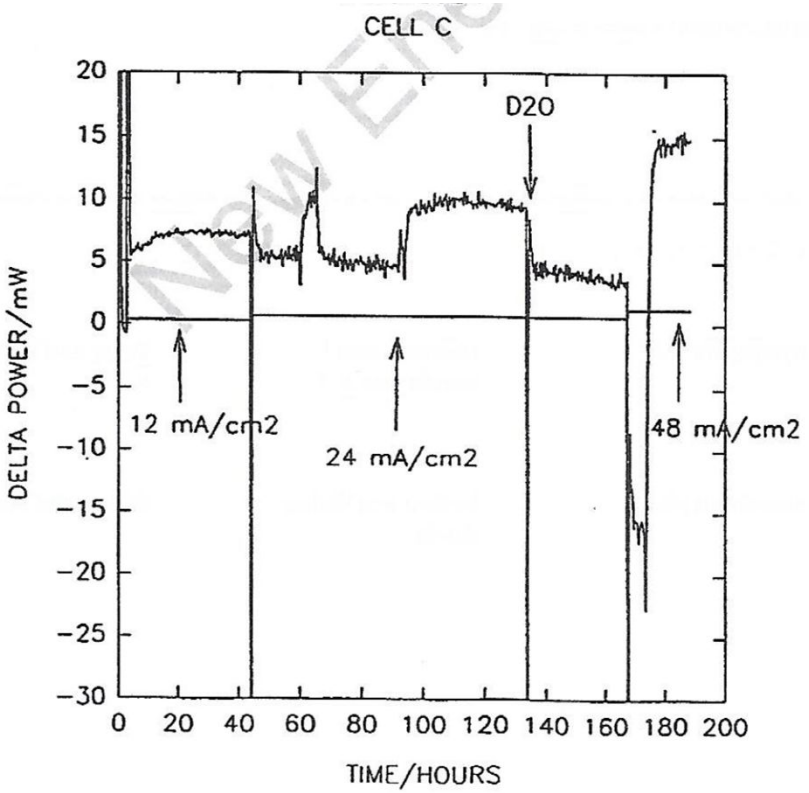
$0.3\ D_2 + Pd \rightarrow Pd\ D_{0.6}$

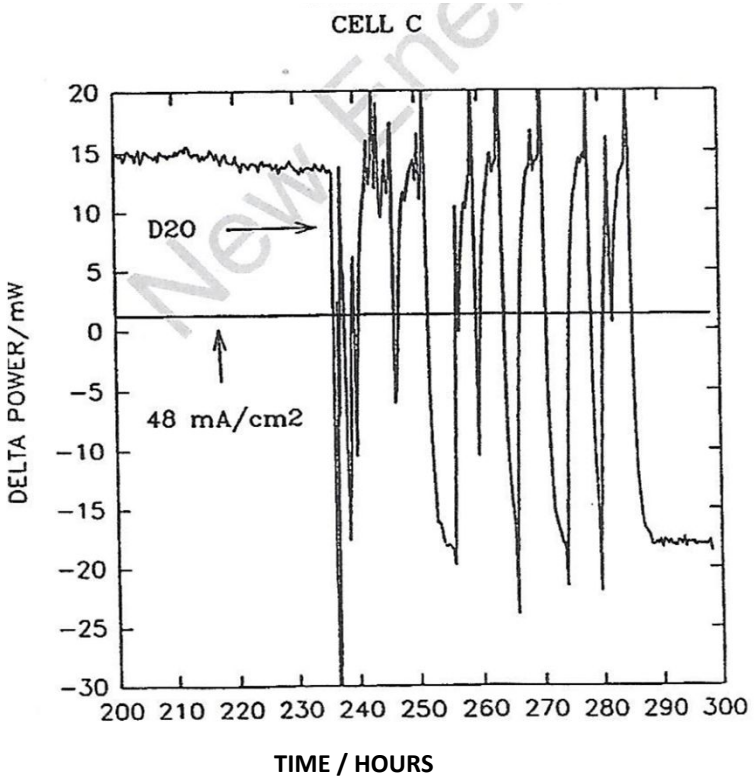


NRL Experiment = -33 ± 3 kJ/mol D_2 (Pd-B)

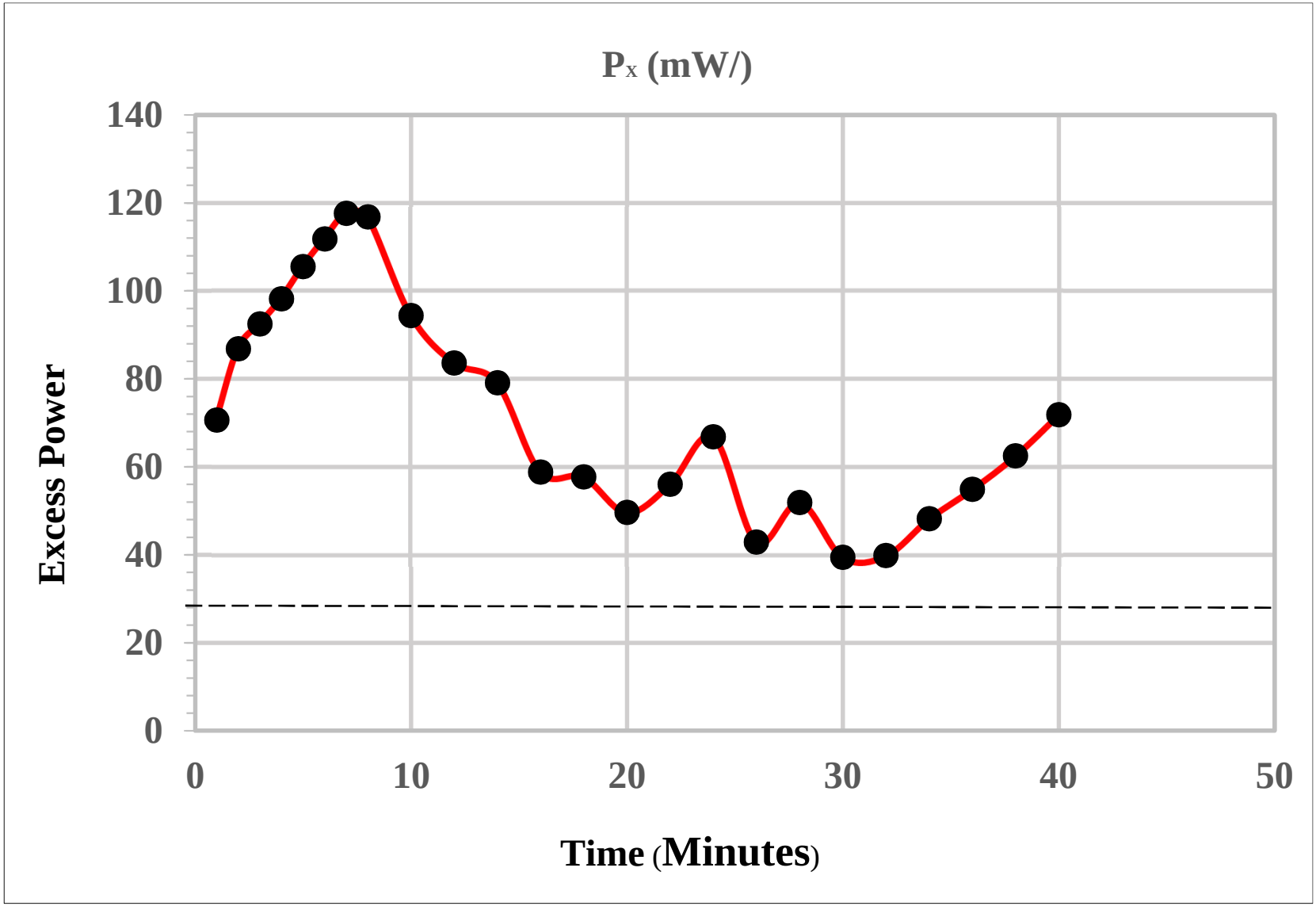
Early Excess Power For Pd – 0.75 B At NRL
Miles – Dominguez / January 1995

New Seebeck Calorimeter (Hart)

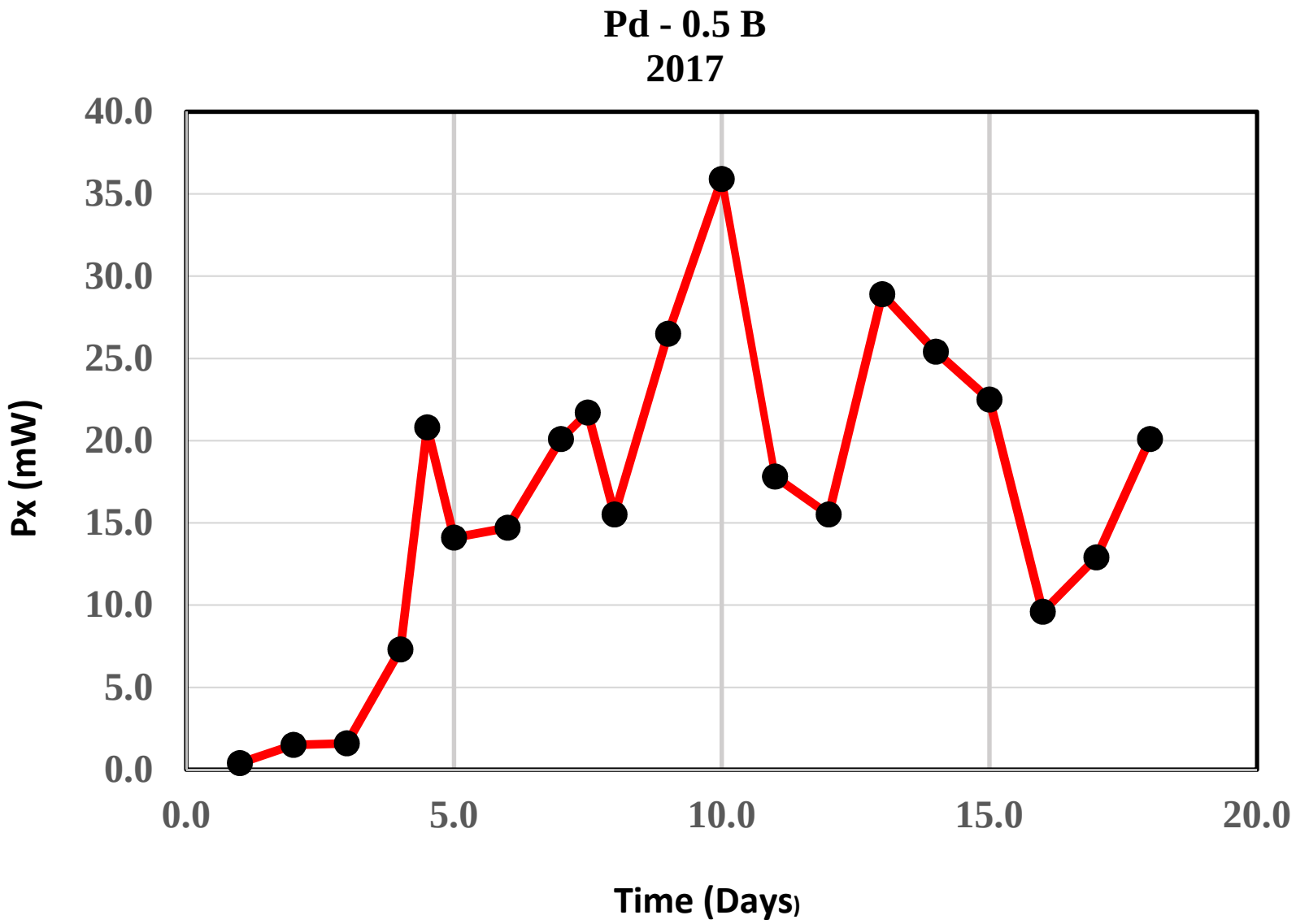




Early Excess Power For Pd-0.5 B
(Ridgecrest, California, March 18, 2017



Repeated Pd – 0.5 B Experiment
Ridgecrest, California (March 18 – April 6, 2017)



Why Does NRL Pd – B Work ?
Possible Factors

- **Greater Hardness Of The Metal / Does Not Deform With Loading**
- **Slower Rate of Deuterium Escaping**
- **Pd – B (At Low Weight Percent Boron) Is A Two-Phase Material**
- **Boron Removes Oxygen As B_2O_3 During Melting**

→ **F-P Type A Pd Made Under a N_2 + H_2 Blanket**

→ **Co-Deposition Pd is Oxygen-Free**

Summary For Pd-B Cathodes

- **NRL (Imam) Pd-B Cathodes Produced Excess Power In 9 out of 10 Experiments**
- **Early Appearance of the Excess Power Effect * ***
- **Normal Loading Rate But Very Slow De-Loading**
- **Oxygen Free Palladium Materials Likely Important**
- **Repeated Experiments With Same Cathode Work**
- **Ten Experiments For NRL Pd-B Involved Six Calorimeters At Three Locations**
- **More Research For Pd-B Cathodes Is Needed**

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- **Adjunct Professor At University of LaVerne (Dr. Iraj Parchamazad)**
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