PRECISION AND ACCURACY OF COLD FUSION CALORIMETRY

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OBJECTIVES

Establish Thermal Balance For A Blank System (Pt/D_2O)

(0.01% Error)

- **Precision of ±0.1 mW for 800 mW Input**
- **Measure Excess Power From Oxygen Reduction (Recombination)**

(1.1 mW)

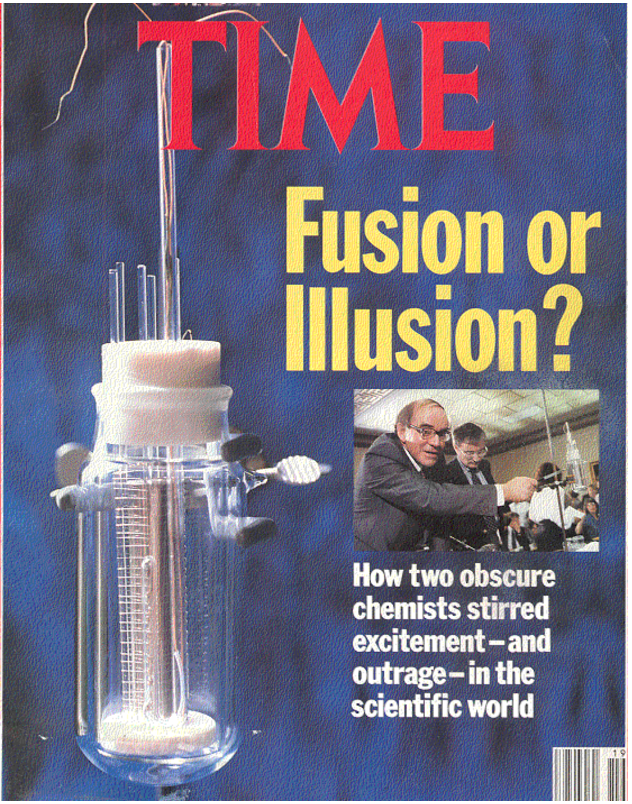
Compare With Pd-B/D_2O System

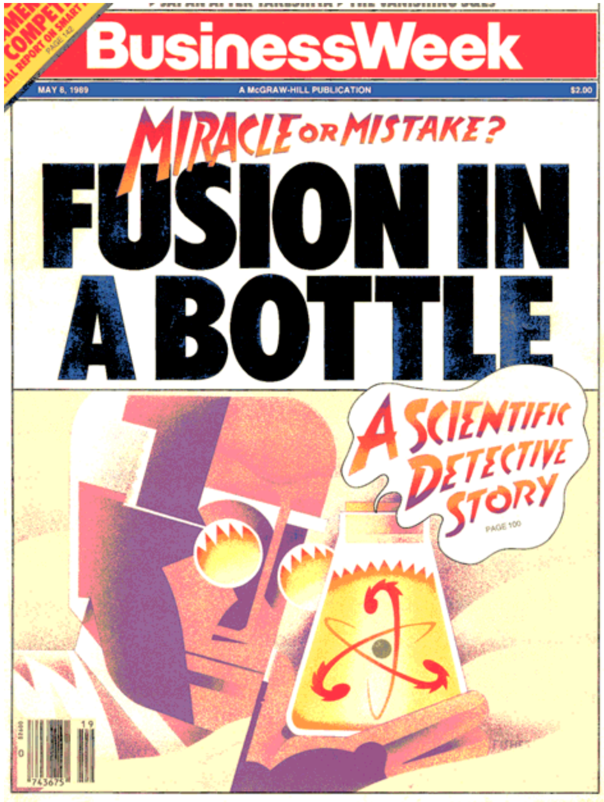
- **Excess Power of 50 to 500 mW**
- **Increase of Excess Power to 10 W During Boil-Off**

Explain The Different Behavior of Pt/D_2O and Pd-B/D_2O

$$ {}^{2}_{1}D + {}^{2}_{1}D \rightarrow {}^{4}_{2}He + 23.8\ \text{MeV} $$

Magazine Cover Stories
8 May 1989

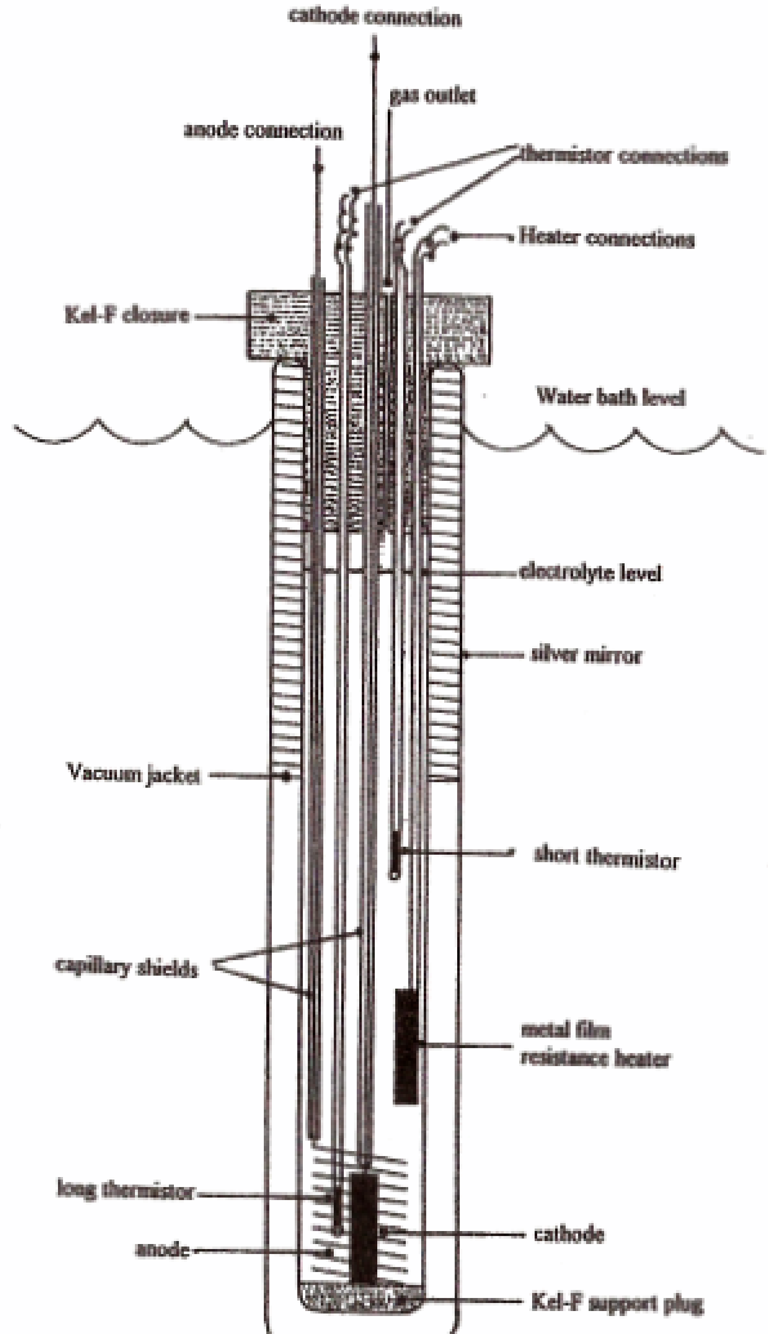




TRULY EXTRAORDINARY INTEREST

Isoperibolic Dewar

Calorimetry Cell



FUSION ENERGY CALCULATION

$$^{2}_{1}D + ^{2}_{1}D \longrightarrow ^{4}_{2}He + 23.8\text{ MeV}$$

$$(1.5\text{x}10^{43}\text{ D atoms})\left(\frac{1 fusion}{2 Datom}\right)\left(23.8\text{x}10^{6}\frac{eV}{fusion}\right)\left(1.602\text{x}10^{-19}\frac{J}{eV}\right) = 2.9 \times 10^{31}\text{ J}$$

Energy per person per year (USA)

$$\left(10.0\ \frac{kW}{person}\right)\left(1000\frac{W}{kW}\right)\left(365\ \frac{days}{year}\right)(24\text{ hr/day})(60\text{ min/hr})(60\text{ s/min}) = 3.15 \times 10^{11}\text{ J}$$

World (7 billion) Energy per year

$$(7 \times 10^{9})\ (3.15 \times 10^{11}\text{ J}) = 2.2 \times 10^{21}\text{ J/year}$$

Years Fueled by D + D Fusion

$$(2.9 \times 10^{31}\text{ J}) / (2.2 \times 10^{21}\text{ J/year}) = 1.3 \times 10^{10}\text{ years}$$

(13 billion years!)

HEAT TRANSFER PATHWAYS
POWER (J/S OR W)

Calorimetric System, P_{calor}

Electrochemical Power, P_{EI}

In-Cell Heater Power, P_H

Anomalous Excess Power, P_X

Gas Evolution Power, P_{gas}

Heat Radiation Power, P_R

Heat Conduction Power, P_C

Rate of Work Done By Gases, P_W

CALORIMETRIC EQUATIONS
(First Law of Thermodynamics)

$$0.5\ D_2O_{(l)} \rightarrow 0.5\ D_{2(g)} + 0.25\ O_{2(g)}$$

$$P_{calor} = P_{EI} + P_H + P_X + P_{gas} + P_R + P_C + P_W$$

where

$$P_{calor} = C_P M\ (d\ T_{cell}/dt)$$

$$P_{EI} = (E(t) - E_H)\ I$$

$$P_{gas} = -(I/F)\{[0.5C_{P,D2} + 0.25C_{P,02} + 0.75(P/(P^* - P))C_{P,D2O(v)}]\Delta T + 0.75(P/(P^* - P))L\}$$

$$P_R = -k_R f(T) \text{ where } f(T) = T^4_{cell} - T_b^4$$

$$P_C = -k_C(T_{cell} - T_b)$$

$$P_W = -RT(dn_g/dt) = -RT(0.75I/F)$$

FLEISCHMANN'S DEWAR CALORIMETRY

$$P_R >> (P_C + P_W)$$

$$P'_R = P_R + P_C + P_W = -k'_R f(T)$$

Thus

$$P_{calor} = P_{El} + P_H + P_X + P_{gas} + P'_R = P_{El} + P_H + P_X + P_{gas} - k'_R f(T)$$

Lower Bound Heat Transfer Coefficient (Assume P_X=0)

$$(k'_R)_1 = (P_{El} + P_H + P_{gas} – P_{calor})/f(T)$$

True Heat Transfer Coefficient (Assume P_X is Constant)

$$(k'_R)_2 = (P_{El} + P_H + P_X + P_{gas} – P_{calor})/f(T)$$

$$P_X = [(k'_R)_2 – (k'_R)_1]f(T)$$

THEORETICAL RADIATIVE HEAT TRANSFER COEFFICIENT

Stefan-Boltzmann Coefficient

$k_B = 5.6703 \times 10^{-12}\ Wcm^{-2}K^{-4}$

Radiant Surface Area of Cell

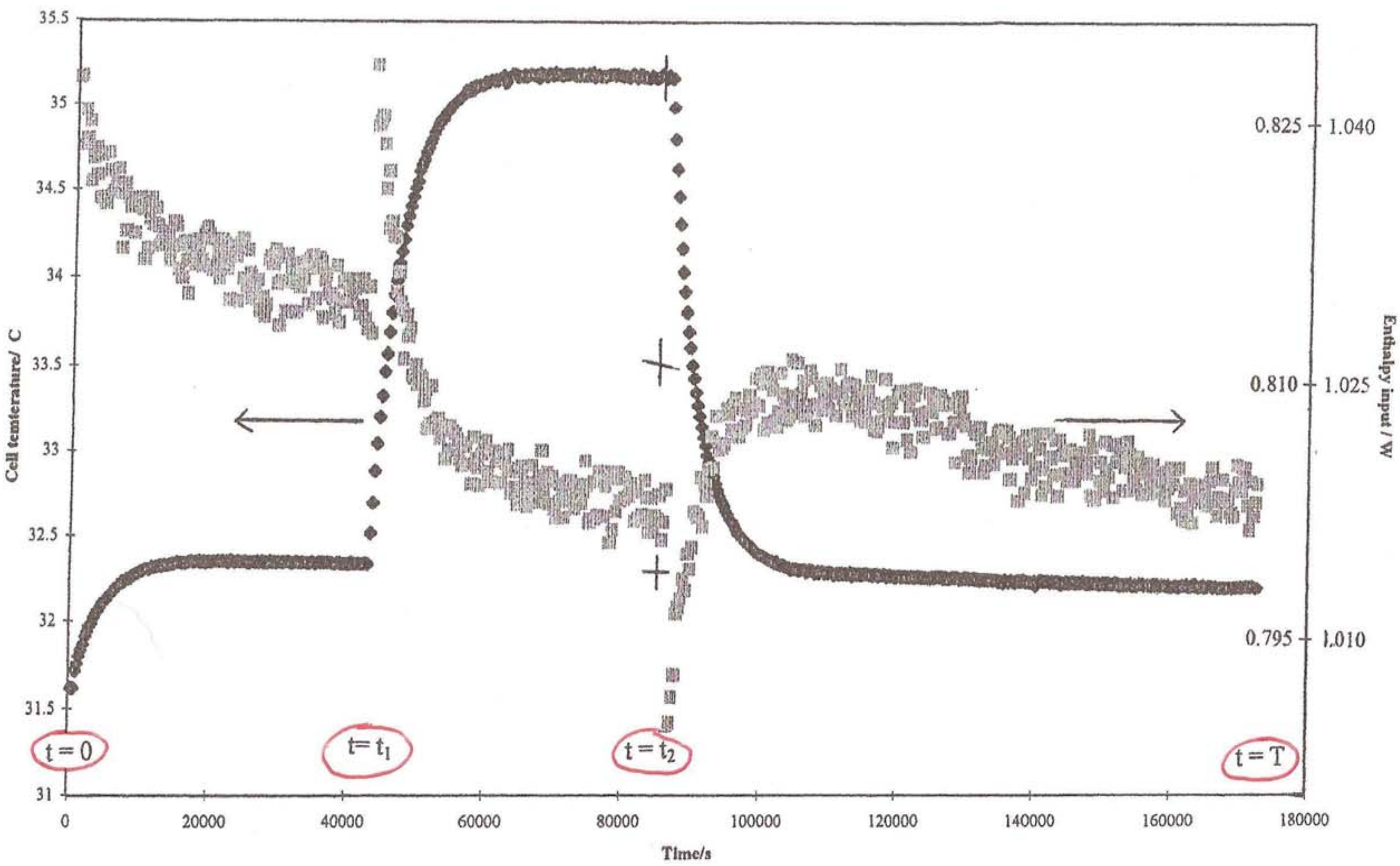
$A = 109.7\ cm^2$

Theoretical Radiative Heat Transfer Coefficient

$k_R = k_B\, A = (5.6703x10^{-12}\ Wcm^{-2}K^{-4})(109.7cm^2)$

$k_R = 0.622 \times 10^{-9}\ WK^{-4}$

RAW DATA FOR DAYS 9 AND 10
(I = 0.200 A)



EVALUATION OF $(k'_R)^2$ AT $t=t_2$

$$(k'_R)_2 \; f(T)(t_2) = (P_{El} + P_H + P_X + P_{gas} - P_{calor})(t_2) \qquad (1)$$

$$(k'_R)_2 \; f(T)(t'_2) = (P_{El} + P_X + P_{gas} - P_{calor})(t'_2) \qquad (2)$$

Assume P_X is constant

(1) – (2) yields

$$(k'_R)_2 \; f_2(T) = [P_{El}(t_2) - P_{El}(t'_2)] + P_H + [P_{gas}(t_2) - P_{gas}(t'_2)] - [P_{calor}(t_2) - P_{calor}(t'_2)]$$

where

$$f_2(T) = (T^4_{cell})t_2 - (T^4_{cell})t'_2$$

STRAIGHT LINE FORM
$(Y = a+bX)$

$$(P_{El}+P_H+P_X+P_{gas})/f(T) = (k'_R)_2+C_PM(dT_{cell}/dt)/f(T)$$

$$\text{Intercept} = (k'_R)_2$$

$$\text{Slope} = C_pM$$

$$f(T) = T_{cell}^{4} - T_{b}^{4}$$

CHEMICAL KINETICS ANALOGY

First Order Rate Law $A \rightarrow P$

Differential Equation

$$-dA/dt = kA$$

Integrated Rate Law

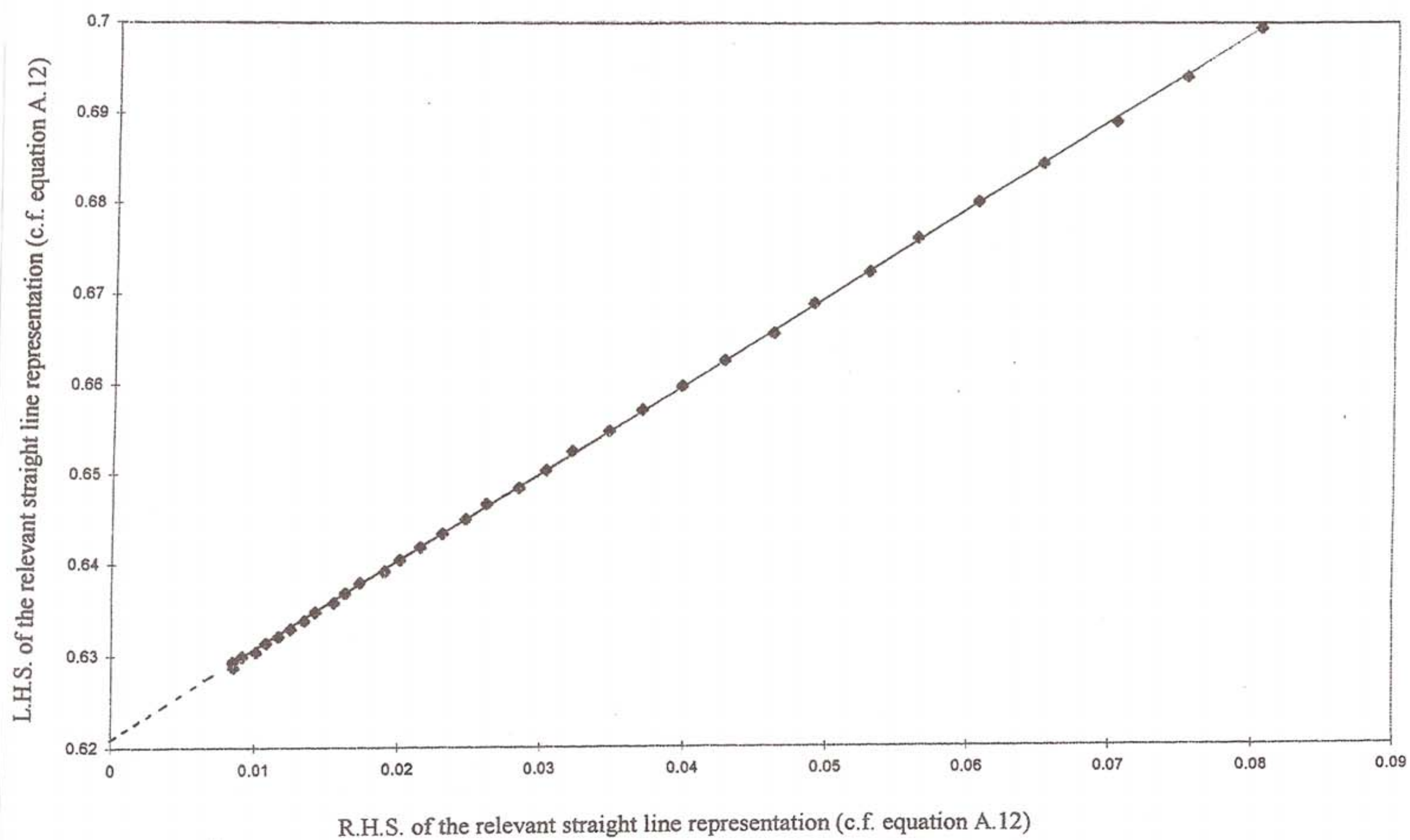
$$\ln A = \ln A_o - kt \qquad (y = a + bx)$$

slope = $-k$

Intercept = $\ln A_o$

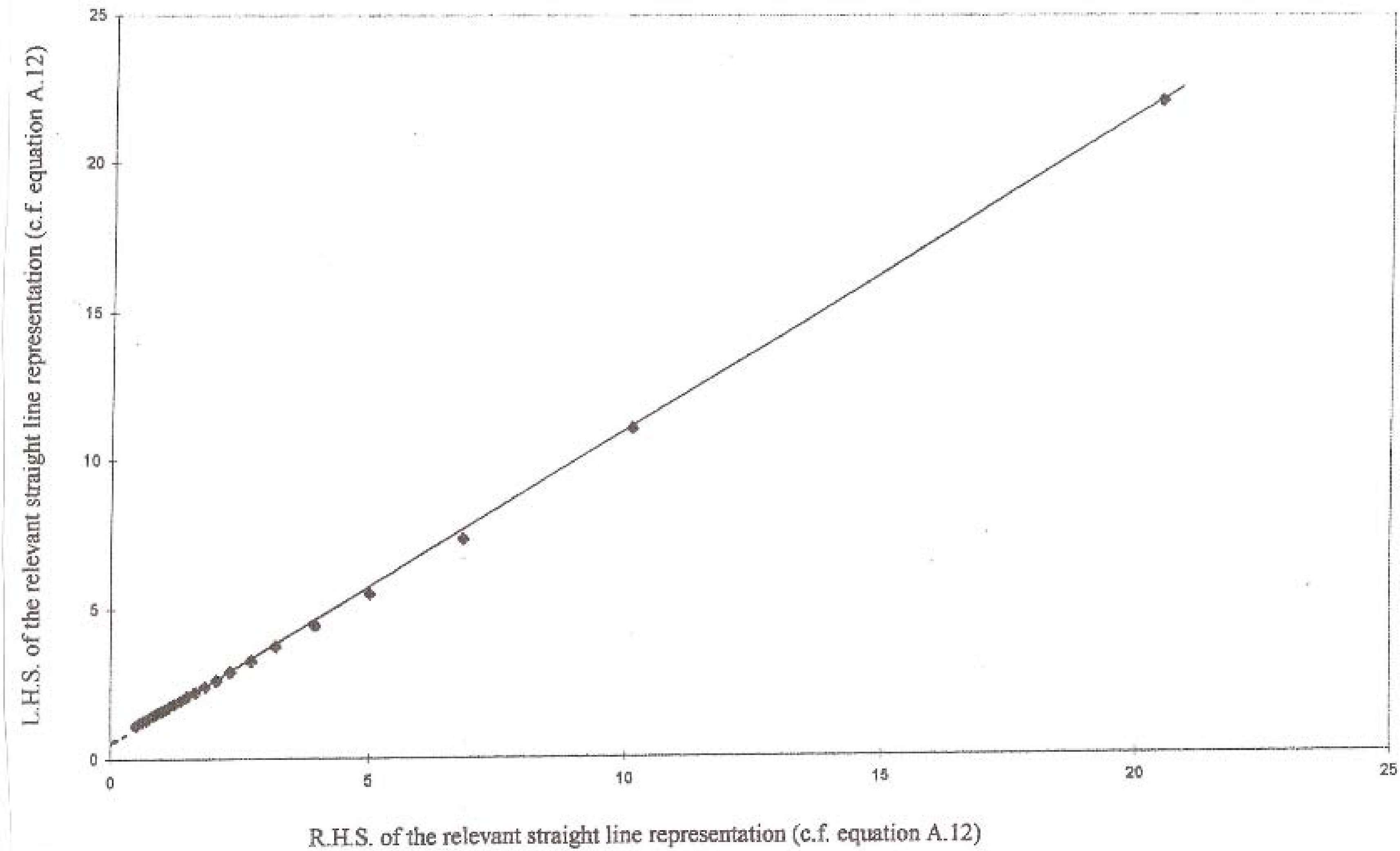
EVALUATION OF $(k_R^{'})_{262}$ AND C_pM

(Backward Integration)



EVALUATION OF $(k_R^{'})_{362}$ AND C_pM

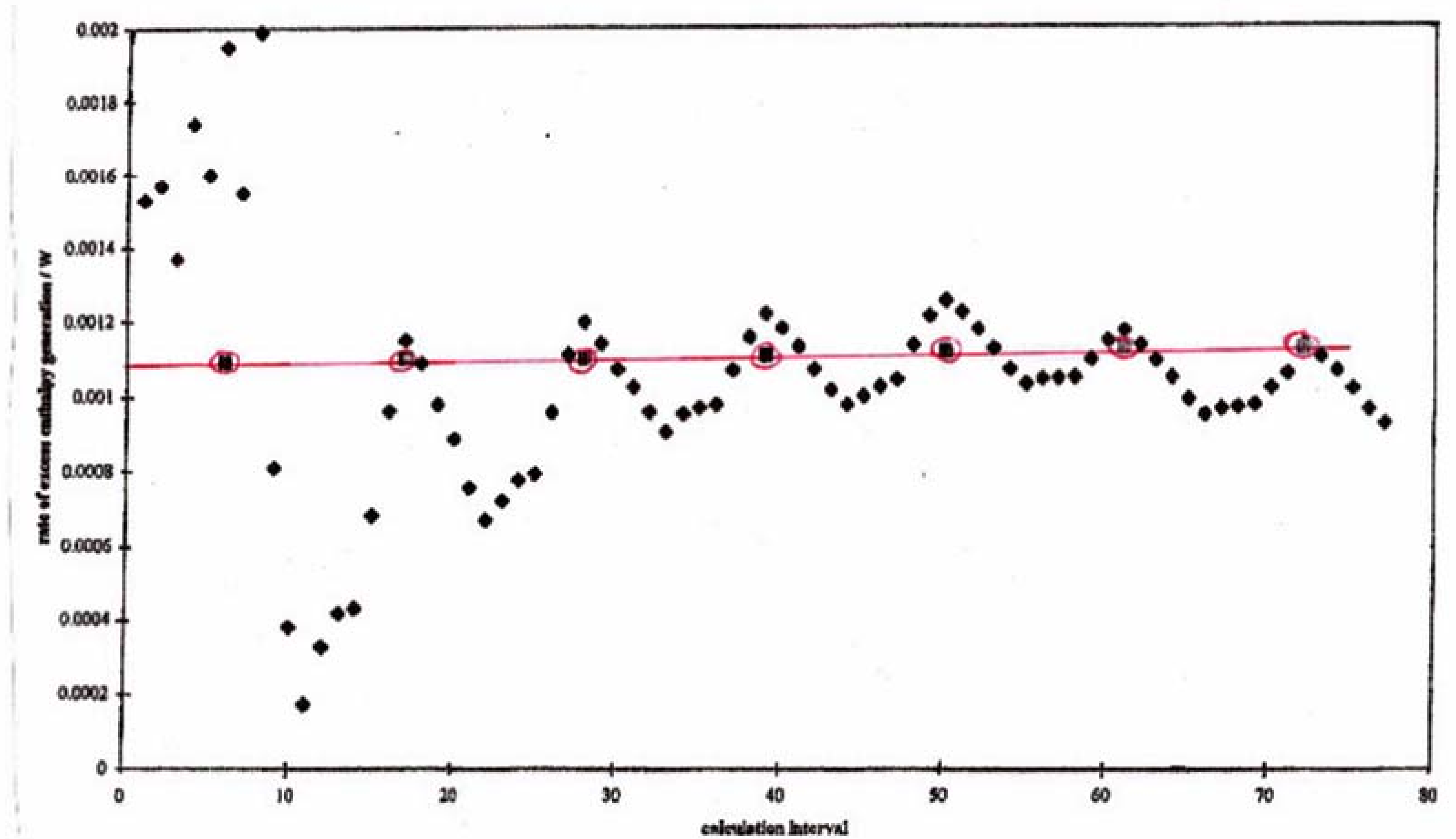
(Forward Integration)



MEAN VALUES FOR K AND C_PM

Description	$10^9(k'_R)$, WK^{-4}	C_PM, JK^{-1}
Theoretical	0.622	340
$(k'_R)_1$ (lower bound)	0.62013 ±0.00058	-----
$(k'_R)_2$ (true)	0.62059 ±0.00240	-----
$(k'_R)^{0}_{262}$ (backward Integration,True)	0.62083 ±0.00059	339.2 ±1.7
$(k'_R)^{0}_{362}$ (forward Integration, True)	0.62031 ±0.00156	339.8 ±18.3

Excess Power Due to Oxygen Reduction (Differential / Integral)



THEORETICAL RATE OF OXYGEN REDUCTION EXCESS POWER

Henry's Law $[O_2] = 1.2 \times 10^{-3}\ M = 1.2 \times 10^{-6}\ mol/cm^3$

Fick's Law of Diffusion

$I_L = DnF[O_2]\ A_E/\delta = 0.001A$

where $D = 6 \times 10^{-6}\ cm^2/s$ $\quad A_E = 0.63\ cm^2$

$n = 4\ eq/mol$ $\quad \delta = 0.002\ cm$

Excess Power Due to Oxygen Reduction

$P_X = E_H\ I_L = (1.527\ V)\ (0.001\ A) = 1.5\ mW$

for $\delta = 0.01\ cm\ I_L = 0.0002\ A,\ P_X = 0.3\ mW$

for $\delta = 0.001\ cm,\ I_L = 0.002\ A,\ P_X = 3.0\ mW$

PALLADIUM-BORON MATERIAL
PREPARED BY DR. M.A. IMAM, NAVAL RESEARCH LABORATORY

Excess heat produced in 7 out of 8 experiments at China Lake

Excess heat produced in NHE (Japan) experiment

Materials contained 0.25 to 0.75 weight % boron

Boron removes oxygen contamination in palladium

Boron hardens palladium material

Boron resides in grain boundaries of palladium

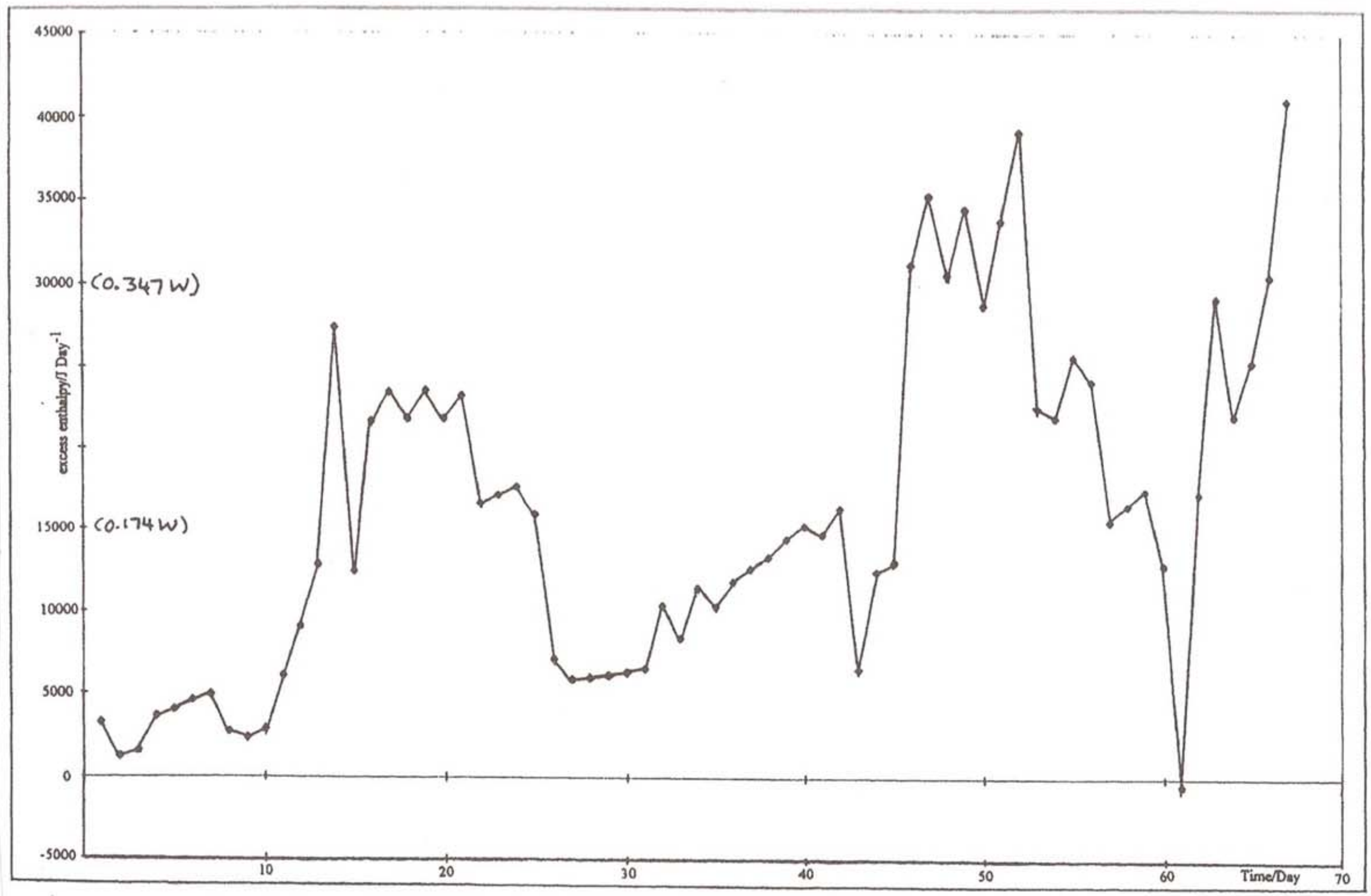
U.S. Patent

"Palladium-Boron Alloys for Excess Enthalpy Production"

M.H. Miles and M. Ashraf Imam

U.S. Patent No. 6,764,561, June 20, 2004

Pd-B RESULTS
NHE/JAPAN



CALORIMETRIC EQUATIONS AND CALCULATIONS
(Further Information)

SEE:

1. **Miles, M.H., Fleischmann, M. and Imam, M.A. (2001). Naval Research Laboratory Report Number NRL/MR/6320-01-8526, March 26, 2001.**

2. **Szpak, S. and Mosier-Boss, P.A. (2002). SPAWAR Systems Center Technical Report Number 1862, Volume 2, San Diego, CA.**

3. **Fleischmann, M. and Miles, M.H. (2006). In "Condensed Matter Nuclear Science", pp. 247-268, P.L. Hagelstein and S.R. Chubb, Editors, World Scientific, New Jersey, ISBN No. 981-256-564-7.**

4. **Fleischmann, M. and Miles M.H. (2006). Manuscript No. JP058292J submitted to *J. Phys. Chem*. Note: Editor George C. Schatz rejected this manuscript and ruled that the two reviewers did not need to respond to the detailed rebuttal by the authors to the reviewers comments.**

SUMMARY

- **Correct Equations Yield High Calorimetric Accuracy**
- **Backward Integration of Data Sets Yields Best Results**
- **Excess Power Measurable to ±0.1 mW**
- **Reduction of Oxygen Measurable at 1.1 mW in Pt/D_2O system**
- **Recombination Effects are Very Small (1.1 mW)**
- **Pd-B Material Yields Large Excess Power Effects (50 to 500 mW)**

FURTHER INFORMATION / QUESTIONS

Further Information

See: "Condensed Matter Nuclear Science",
Proceedings of ICCF-10, P.J. Hagelstein and S.R. Chubb, Editors,
World Scientific, New Jersey ISBN 981-256-564-7, 2006, pp. 247-268.

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