CROSSROADS TECHNOLOGY, INC 5/16/91

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Walter:
Enclosed is the "Nuclear Reactions in Metals" review and suggested program which I discussed with you. I enjoyed very much talking with you in such a frank manner on how any formal program could get started. Since talking with you I have heard exerpts of Watkins' Vancouver, BC speech containing Robert Park type bashing of cold fusion and scientists associated with it. With that backdrop it would seem political hari kari to initiate a program in this area(at least under the name of cold fusion).

It is unfortunate that these public statements, by people who have neither performed experiments or like Feshbach shout(literally) "I don't need to look at any data", carry so much weight. Fortunately, though, there are a growing number of patient, resilient, scientists working in this field of immense promise with virtually no support-natural selection lives!

Also enclosed is an outline of an experimental study of laser initiated nuclear reactions in metals. This type of experiment should yield a great deal of information for the cost. I estimate it would cost ~$250K if it was carried out at LLL, MIT/LL, NRL, LASL or equivalently equipped lab-ie the major equipment didn't need to be purchased. I would like to be the PI on this experiment in collaboration with a group of scientists as discussed in my review.

The highest priority is planning and initiating a formal program in this area-I would very much like to participate in this process. This may be politically more difficult within DOE than an individual experiment

It would be either a bold step or a crazy one to start a national program at this time. You can guess my leaning.

Sincerely,

Don E. Yansen

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AN INVESTIGATION OF LOW ENERGY NUCLEAR REACTIONS IN METALS

by

Don E. Yansen

Introduction

Recent developments have created an unusual opportunity for making a major advance in a new technological area-*energy from metals*. This controversial field popularly called "cold fusion" has experienced wild fluctuations not unlike the early days of fission exploration and more recently high T_c superconductors. The myriad experimental findings coupled with early reproducibility difficulties has slowed progress in developing a coherent model for the phenomena. The dispersed and uncoordinated nature of the serious work to date has slowed the determination of a prescriptions for obtaining repeatable results. Recent developments-one of which is achieving 600watts/cm^3 excess power-have begun to change this situation and it is now clear that certain configurations can be made repeatable over a very limited range of conditions.

Below we give a selected summary of the status of the field and a proposed federal r&d program.

Background

The various phenomena included under the heading of "cold fusion" have been activated by the following mechanisms:

chemical reactions
mechanical fracture/gas loaded
electrolysis
laser/phonon heating/gas loaded
ultrasound
ion bombardment/gas loaded
electrical/gas loaded
cryocycling

The wide variety of solid state systems and activation mechanisms provides many choices in considering optimum configurations for particular applications.

Recent History

Over the past two years a large amount of unexplained experimental data pertaining to phenomena loosely classed as "cold" or "warm" fusion has accumulated. There are now roughly 600 scientists world wide working in this field. In the last few months several significant events have occurred which have changed the picture to give a firmer foundation and to set the stage for a high stakes technology race. They are:

1. A large conference presenting strictly Soviet work reported an immense amount of data- with almost no collaboration with the west.
2. A new round of positive Indian results was published.
3. Dr. M. Mc Kubre-SRI and Dr. S. Szpak-UOSC report privately controlled excess heat-Szpak has additional new findings.
4. A molten salt experiment obtained excess heat/cm^3 **greater** than many fission reactors.

The weight of positive data around the world is now quite impressive. These anomalous bursts of heat, neutrons, gamma rays, x-rays, charged particles are

undeniably real . Below we briefly review what we believe to be the most significant world wide experimental results. Included in the appendices are a number of original papers and over 300 references in the 2 recent reviews by Srinivasan[1] and Storms[2]. To quote Dr. M. Srinivasan " go to the original work, do not accept what others tell you"

Results

I. Autoradiography

Repeatable radiographs have been obtained in both Ti/D gas loaded and Pd electrolysis systems.The first autoradiography pictures were obtained in India at the Bhabha Atomic Research Complex(BARC). Drs. Iyenger and Srinivasan led this effort and Dr. Srinivasan has recently published an extensive review[1] of the more recent work in this field. Figure 1,2 show the experimental setup and an example of the type of autoradiograph they have obtained by placing the electrode on x-ray film after a plasma focus run. Pictures such as this were taken early this year and as much as 3 months apart.

The exposed regions are probably due to a combination of tritium ß's and low energy x-rays. It is suggestive that significant activity is present along metal grain boundaries.

Figure 3 is one of the first autoradiographs taken in '89 showing intense emission from highly localized, microburst regions. Figures 4,5 are different compositions and different shaped electrodes all used at BARC. Figure 6 is a recent radiograph taken by Szpak in an innovative, dual deposition Pd electrolysis experiment. Here he deposits Pd from solution on to a nickel grid. After most of the Pd is extracted from solution the system is run in the water electrolysis mode and nuclear reaction(s) start. A well sealed x-ray film strip is placed in the solution very close to the primary electrode.

Excess Heat

We now step into the storm! Pons and Fleischmann's early reports of strong bursts of heat even to the point of boiling the electrolyte and in one case exploding the dewar were greeted with shock and soon after angry disbelief. Even their follow on paper[3] answering the critics questions failed to sway the disbelieving portion of the US and British scientific community. The early difficulties with excess heat combined with the lack of calorimetry experience of many experimenters, heightened frustration and increased the skepticism. Because of the tremendous implications and extreme early criticism, heat researchers are now being very secretive about their results. Below we present a sampling of excess heat results and discuss some private communications.

Figure 7 is one of many Pons&Fleischmann curves[3] the character of which has been duplicated by Oriani[4], McBrine(private communication), and Kline et al-OSU and others. Figure 8 is an excess heat plot from a completely different type of experiment-molten salt. It is interesting to compare the watts/g of the electrode(source of power) to currently operating fission reactors. The Liebert and Liaw data translates to 50w/g or 600w/cm^3. Many currently operating reactors are operating at 200w/cm^3 or less.

There are two US researchers(outside Pons and Fleischmann): M. McKubre-SRI and T. Bush-Cal Poly who have privately discussed having controlled excess heat in their electrolysis cells, meaning they can turn it on and off. Mc Kubre is funded by a private organization, EPRI. Recently, an independent evaluation of Pons and Fleischmann's latest excess heat data was carried out by W. Hansen-U of Utah. Hansen publicly

(Utah State?

verified that their experiments show excess heat.

Charged Particles

Two US researchers have pioneered charged particle measurements and examples of their results are given. One use Ti as the interaction lattice the other Pd, the target construction and excitation are quite different. Figure 8 is from Chambers et al[6], here a Ti foil was bombarded with low energy ~.35-1kev deuterons and the exit energy corresponds to what would be expected for ~5 Mev tritons. Figure 9 is from Cecil et al[7] where a Pd foil was gas loaded with D and then high DC currents applied. The energy again suggests tritons. Also thermal anomalies were observed.

Tritium

Tritium production has been observed by a number of groups, but by far the largest and most consistent is the BARC contingent. Tables I,II tabulate the results of many experiments over a 3 month span. Their work has continued and recent results are contained in a review paper[1].

Another remarkable experimental arrangement developed and tested by Claytor[8] et al of Los Alamos uses a compressed, multilayer Pd/Si sandwich which when gas loaded at high pressure with D displays strong tritium production.

Neutrons

Again, extensive neutron measurements including the neutron/tritium ratio have been made, particularly, in the Soviet Union[9] and India. We include here one Japanese result, figure 9, from a large-several cm diameter Pd cathode system subject to large thermal excursions. Results from a very different experiment-Menlove et al-are shown in figure 10 where Ti chips were gas loaded at high pressure, cooled to liquid nitrogen temperature and slowly allowed to rise to room temperature. The Ti chips were thermally cycled many times and the measurements repeated.

Summary

What inferences can we draw from this growing body of varied data.

Virtually all the products are low energy-a few ev to 5 Mev

Temporal response and spatial distribution indicates most products originate on or near the electrode surface.

More than one type of nuclear reaction is occurring depending on-a myriad of parameters.

An examination of some common elements in successful experiments reveals several requirements:

attaining strong nonequilibrium
high +deuteron density/mobility
high free electron mobility
free of poisons or molecular barriers to these factors
achieving ß phase in the lattice
achieving dendrite growth[2]

Conclusions

We can also draw some conclusions looking at the sum of present data.

1. Heat, when it occurs, is by far the most energetic output product.

2. It is now possible, in a few cases, to pick a set of parameters that produce repeatable outputs.

3. d-d fusion is an open question if it occurs at all.

4. Excess power up to 1000w/cm^3 appears possible.

What next?

Experiments should be designed to maximize the spatial, temporal, spectral information obtained and include the facility to multiplex the measurement of many systematic parameter changes. Heat should be measured in virtually every experiment.
The following areas should be addressed in a systematic way.

surface chemistry vs internal D loading*(electrolyte)*	
surface state vs internal D loading*(gas)*	
controllability	*initiation mechanisms*
potential power levels	*optimum materials (including*
stability	*trace elements)*

Ideally, this effort would be undertaken by several multi-disciplinary teams of scientists or a closely coordinated series of groups each working on a different host/activation approach. Accomplishing the above in an efficient manner is an extreme challenge similar in ways to the early high energy laser program. It is clear now that the disciplines of Metallurgy or Materials Science,Solid State Physics, Nuclear Physics, Plasma Physics, Electrochemistry, Calorimetry, Atomic Physics &Spectroscopy all would be germain to solving the many puzzles along the path to usable *nuclear metallic power sources.*

The following approach would be a good start.

INITIAL PROGRAM PLAN

I. Select a small, experienced, panel to review the current status of the field and develop an appropriate program plan. ex.1) gas loaded charged particle exp'ts 2)D_2O electrolysis, 3)molten salt electrolysis, etc. Plan regular workshops for program members.

II. Select program managers to formulate the individual projects in sufficient detail to allow budgeting and early stage planning.

III. Fund this initial stage at roughly the $10-20M level .

VI. Immediately start the groups that are already working in this area and begin putting together the newly formed ones.

EXPERIMENTS

General

The following describes some ideas on new experiments in the area of nuclear reactions in metals. The use of the ∂/ß phase change region is suggested from the work of Jorne'[15].

The intent is: **an experimental design that optimizes the rapid gathering of data on different parameter variations-a multiplexing data collection.**

EXPERIMENTAL DESIGN FOR LASER INITIATED NUCLEAR REACTIONS IN METALS

I. Goal: Generate spatially defined, surface impulse initiated reaction zones that can be accessed by high spatial and temporal bandwidth: ir imagers, spectrometers, radioactivity detectors.

II. Materials and Equipment

Pd, Ti, foils with specific preparation differences
Mode lockable Nd:Yag laser
Pressure chamber with laser transmitting window
(temp controlled)
IR microscopy system,10μm spot size, < 16ms/frame
∂,ß,x-ray detection systems
2-D optical scanner
optical, uv,x ray spectrometers
atomic probe microscope-Temp, force, electrical

III. Phase 1

Place the foils-with many regularly positioned regions of varying trace composition and surface states-in the chamber such that after saturation with deuterium they can be irradiated with variable length laser pulses. The spot size should be accurately controlled to provide a known initial reaction zone.

The saturated foil should be brought up slowly in temperature to the ∂–ß phase change region and then laser irradiation should begin. The laser should be precisely scanned to irradiate the regions where different trace elements have been implanted or other parameter variations have been induced.

IV. Phase 2

Start a new set of trials using optimized(hopefully)foil compositions and different gas mixtures suggested by the results of Phase I. Particularly, H/D, D/T ratios.

V. Phase 3

A.

We propose generating a number of different metal electrodes, including Ti and Pd, by high temperature evaporation in a D_2 atmosphere being extremely careful to control gas composition and to maintain a submicron granule characteristic size.

B. Deposit controlled trace amounts-by CVD or ion implantation-of specific isotopes of elements which are potential reacting species. Repeat the reaction trials.

C. Attempt to activate nuclear reactions while metal is being deposited on the electrode. A setup a la Cecil would be a candidate.

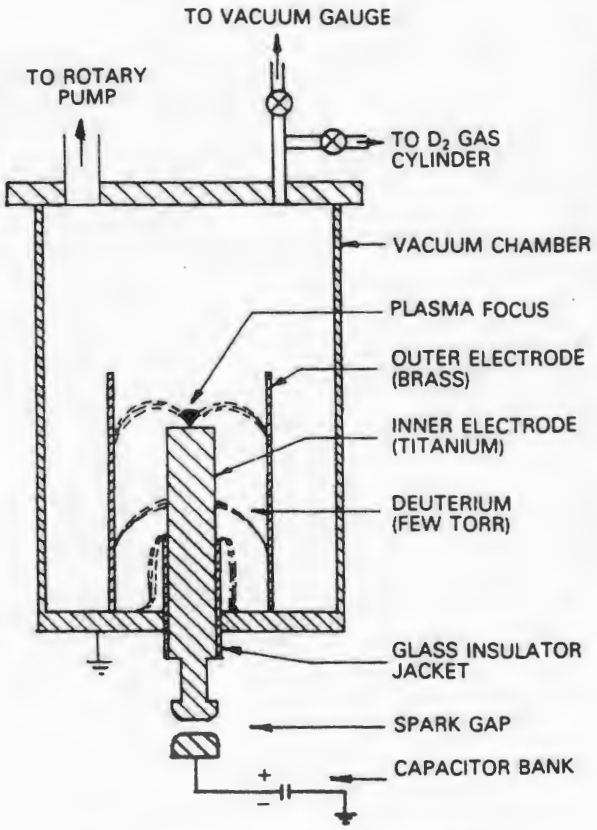

Fig. 1. Schematic of a plasma focus device.

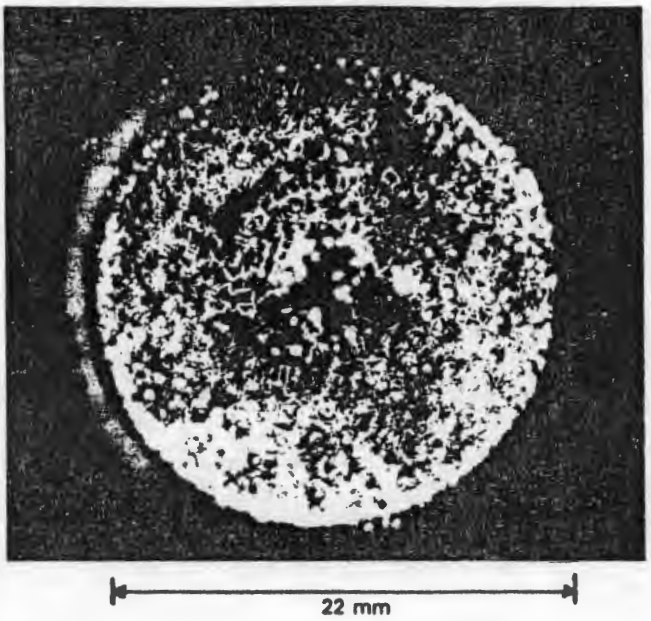

Fig. 2. Autoradiograph of end surface of the central titanium electrode (TA1).

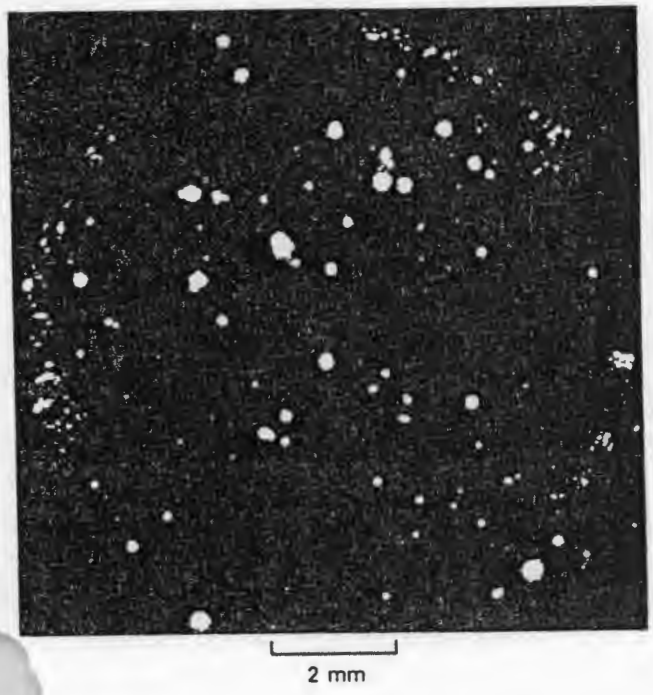

Fig. 3 Radiograph of titanium disk target

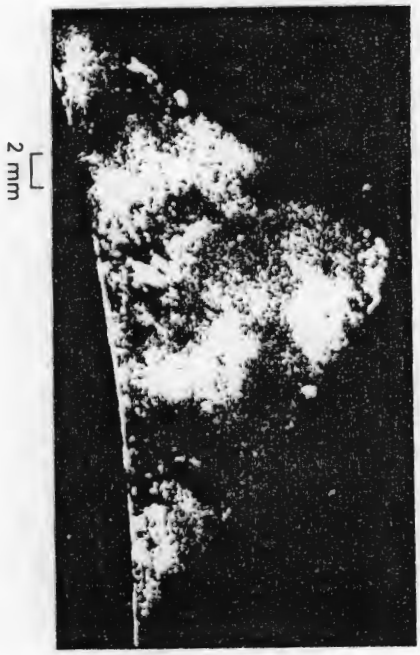

Fig. 4 Radiograph of palladium-silver foil target.

Fig. 5 Radiograph of conical titanium target.

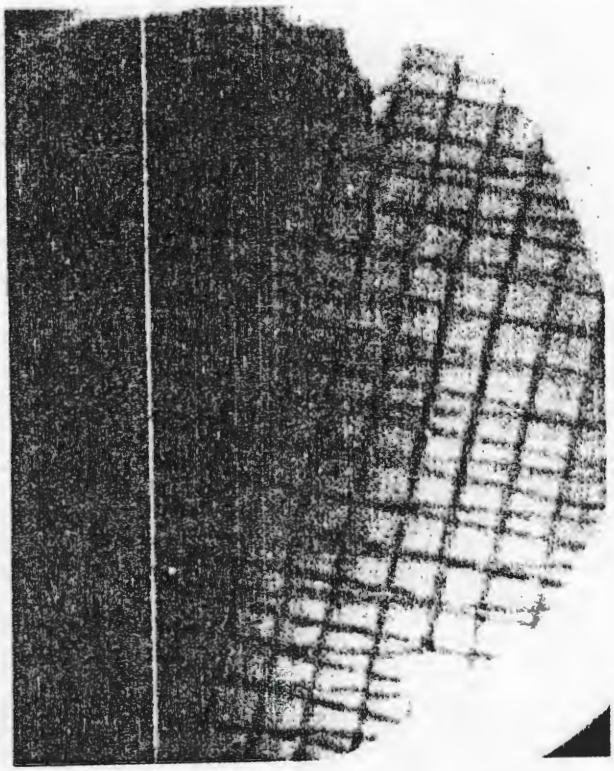

Fig. 6 Radiograph Pd plated Ni grid during codeposition electrolysis. (Szpak et al)

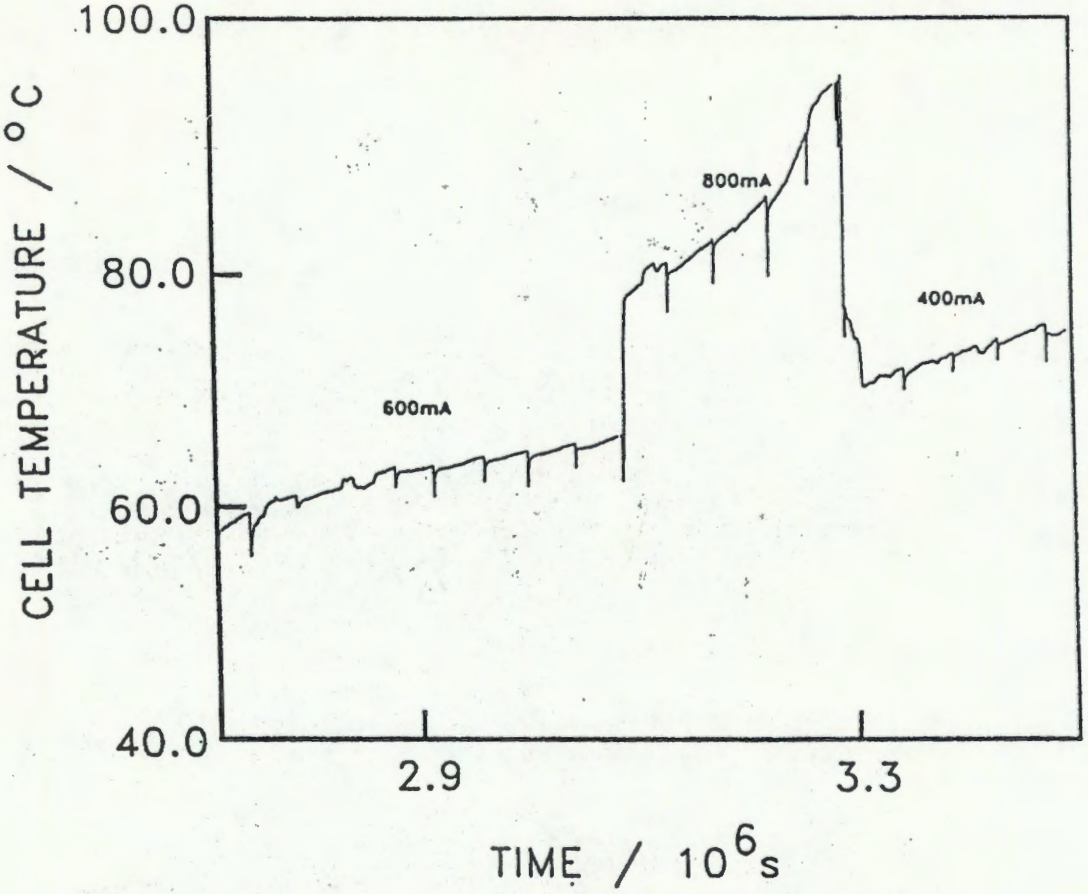

Fig. 7 Heat burst event lasting several days during which electrolyte temperature approached boiling point (From Fleishmann et al /45/)

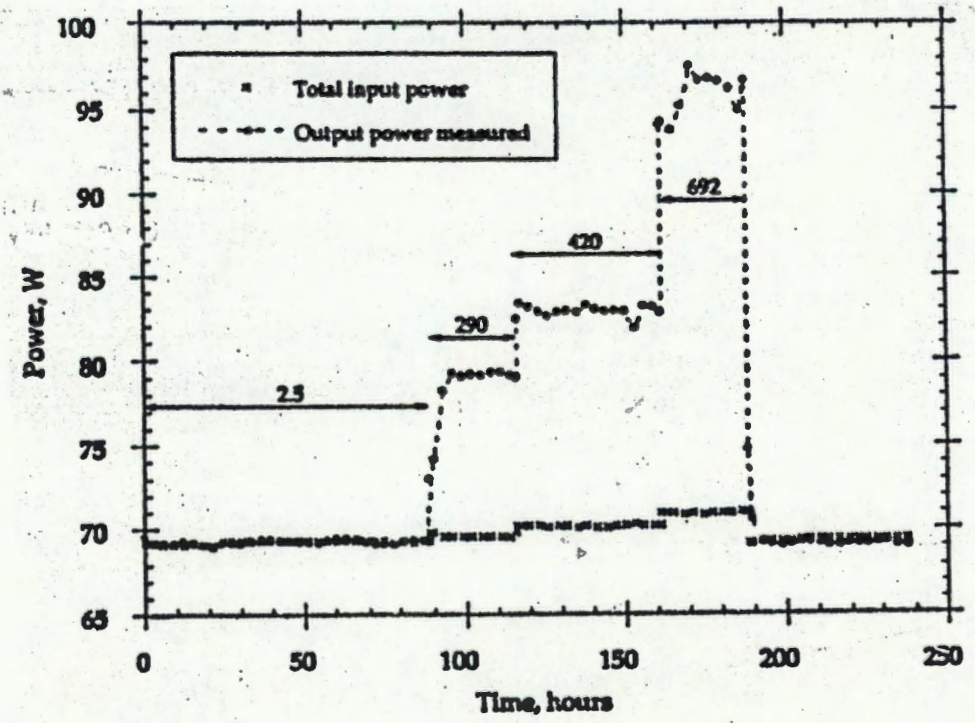

Fig. 8 Excess power generating during Molten Salt Electrolysis experiment with Pd anode (From Liaw et al /59/)

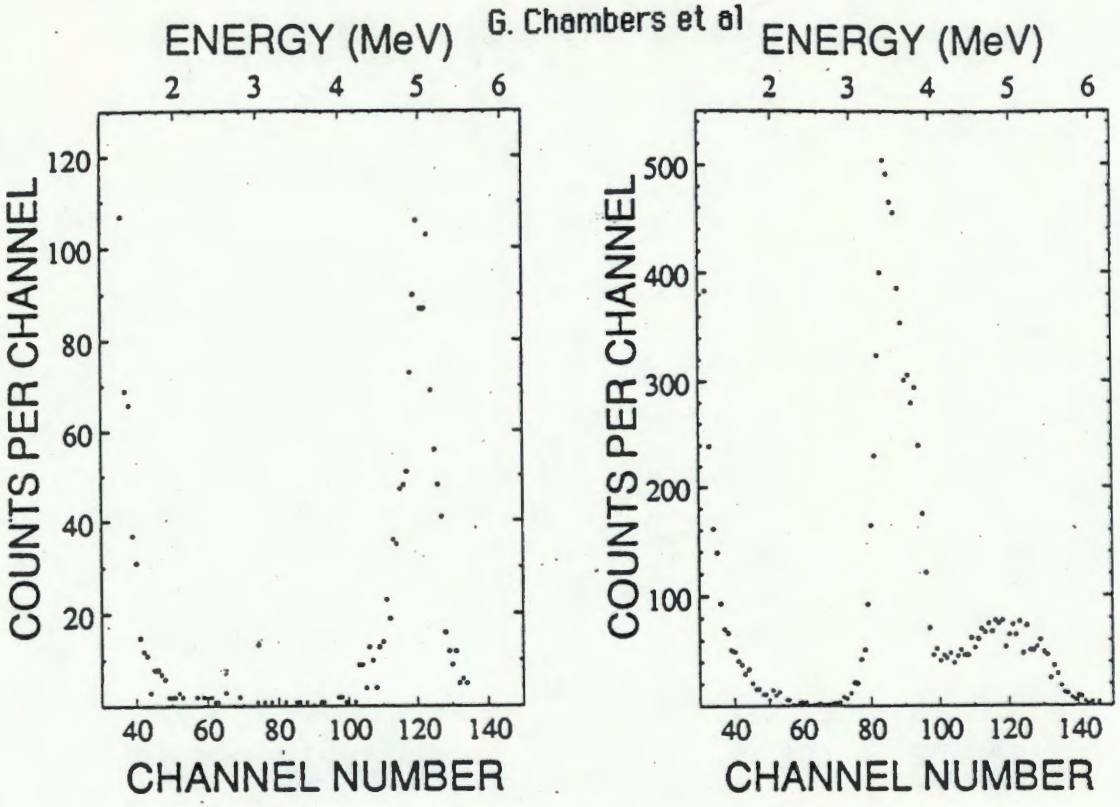

Fig. 9 Spectra acquired after 40 minutes of 350 eV deuterium bombardment of a 1-μm thick titanium film evaporated onto 500 nm gold on a 3.8 μm thick nickel foil. The spectral peak, centered at 5 MeV, occurred during two approximately minute long bursts and consists of over 1100 counts. (b). Spectra acquired after 5 minutes of 350 eV deuterium bombardment of a 1-μm thick titanium film evaporated onto a 3.8 μm thick nickel foil, during a five minute long burst. The double peaks are due to the changing of detector bias voltage form -200 volts to zero and back to -200 volts again during the reaction. The spectrum consists of over 8000 counts.

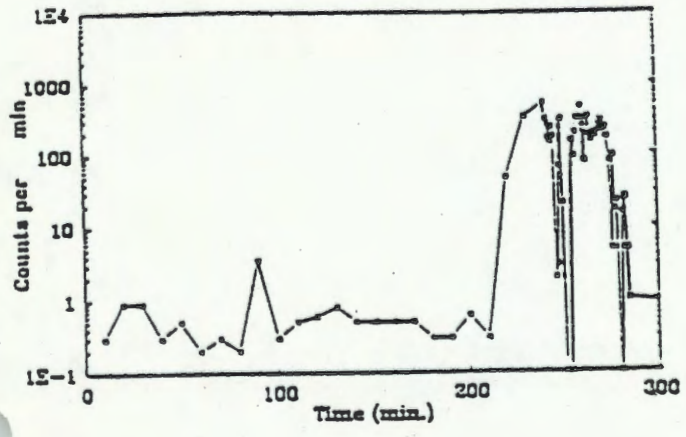

Fig. 10 Time history of count rate for high energy events in bursts. (Cecil et al)

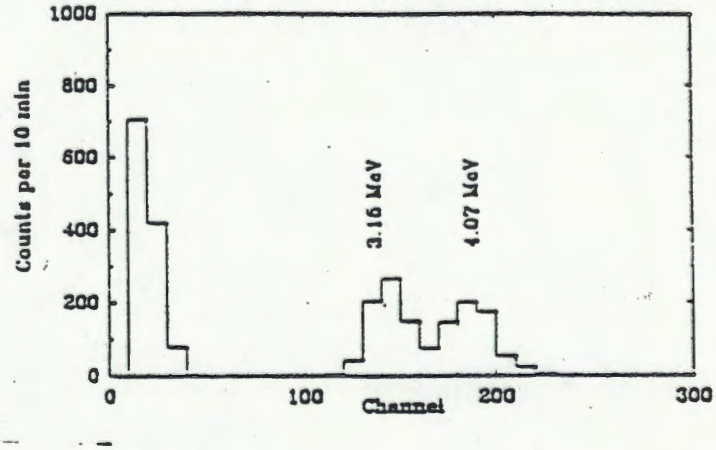

Fig. 11 Energy spectrum of a burst with double foil in front of the detector (Cecil et al)

TABLE I

Summary of the PDC-II Experiment

Electrolysis	Dates	A·h
Constant current mode	July 10–12, 1989	40.33
Pulsing current mode (during day)	July 12–25, 1989	133.99
Constant current mode (during night)	July 12–25, 1989	248.85
Total		423.17

Tritium Levels in D_2O During Electrolysis

Volume of D_2O/0.1 LiOD electrolyte (ml)	60
Tritium activity in blank D_2O/LiOD [μCi/ml (dpm)]	0.076×10^{-3} (170)

Date	Sample	Cumulative A·h	Cumulative D_2O Added (ml)	Tritium Activity (μCi/ml D_2O)	Excess Tritium (times)
July 13, 1989	PDC-II-1	75	40	1.59	1.25×10^4
July 19, 1989	PDC-II-2	235.6	111	0.76	3.5×10^3
July 20, 1989	PDC-II-3	273.3	131	0.62	2.56×10^3
July 24, 1989	PDC-II-4	381.5	176	0.39	1.31×10^3
July 25, 1989	No sample	423.17	196	---	
July 26, 1989	No sample	433.32	196	---	
July 28, 1989	PDC-II-5	433.32	196	0.31	0.95×10^3

Tritium Activity in the Overall Experiment

Source	Volume (ml)	Total Activity (μCi)
Total input of tritium activity	256	0.02
Output		
End electrolysis D_2O cell sample recovered (PDC-II-5)	52	15.96
Vapor and condensate recovered	16	11.87
Deoxo-recombined D_2O recovered after termination of electrolysis	16 + 52	20.82
Vapor and condensate II recovered	0.5	0.14
Deoxo-recombined D_2O II recovered	2.8	0.57
Bubbler (H_2O)	16	1.16
Electrode gas control extracts after the electrolysis	---	0.03
Samples drawn during electrolysis	8	5.72
Total output		56.27

Note: Excess tritium recovered = $56.25/0.02 = 2.812 \times 10^3$ times.

TABLE II

A Summary of Electrolysis for PDC-III

Electrolysis	Dates	A·h
Constant current mode	September 6–9, 1989	71.75
Pulsing current mode	September 9–14, 1989	214.87
Total		286.62

Tritium Levels in D_2O During Electrolysis

Volume of D_2O/0.1 *M* LiOD electrolyte (ml)	80
Tritium activity in blank D_2O (dpm)	166 ± 4
Tritium activity in blank D_2O/LiOD [μCi/ml (dpm)]	0.075×10^{-3} (166 ± 4)

Date	Sample	Cumulative A·h	Cumulative D_2O Added (ml)	Tritium Activity (dpm/ml)
September 7, 1989	PDC-III-4	18.0		195 ± 4
September 8, 1989	PDC-III-5	42.0	15	276 ± 8
September 8, 1989	PDC-III-6	Current stopped	---	263 ± 8
September 9, 1989	PDC-III-7	65.67	30	249 ± 8
September 10, 1989	PDC-III-8	106.12	45	216 ± 4
September 11, 1989	PDC-III-9	137.87	53	248 ± 10
September 12, 1989	PDC-III-10	170.22	65	256 ± 10
September 12, 1989	PDC-III-11	185.87	75	260 ± 5
September 13, 1989	PDC-III-12	218	80	250 ± 5
September 14, 1989[a]	No sample	286.2	105	End of experiment

Tritium Activity in the Overall Experiment

Source	Volume (ml)	Total Activity (dpm)
Total input of tritium activity	185	30 710 (0.0138 μCi)
Output		
Cell wash/broken quartz pieces	2	8 592
Vapor and condensate recovered	2.5 + 5.0	114 025
Palladium catalyst recombined D_2O recovered	70 + 20	68 605
D_2O recovered after copper oxide	1 + 1.1	4 285
Bubbler (H_2O)	---	3 068
Electrode gas content extracted after explosion	---	5 530
Samples drawn during electrolysis	18	4 426
End electrolysis D_2O cell sample[b]	---	---
Total output		208 531 (0.0939 μCi)

Note: Excess tritium recovered = 177 821/30 710 = 0.080 μCi = 5.79 times.

[a]There was an explosion and all the D_2O in the cell was lost; therefore, no sample could be taken.
[b]Calculation of total tritium activity does not take into account 80 ml of D_2O spilled due to the explosion.

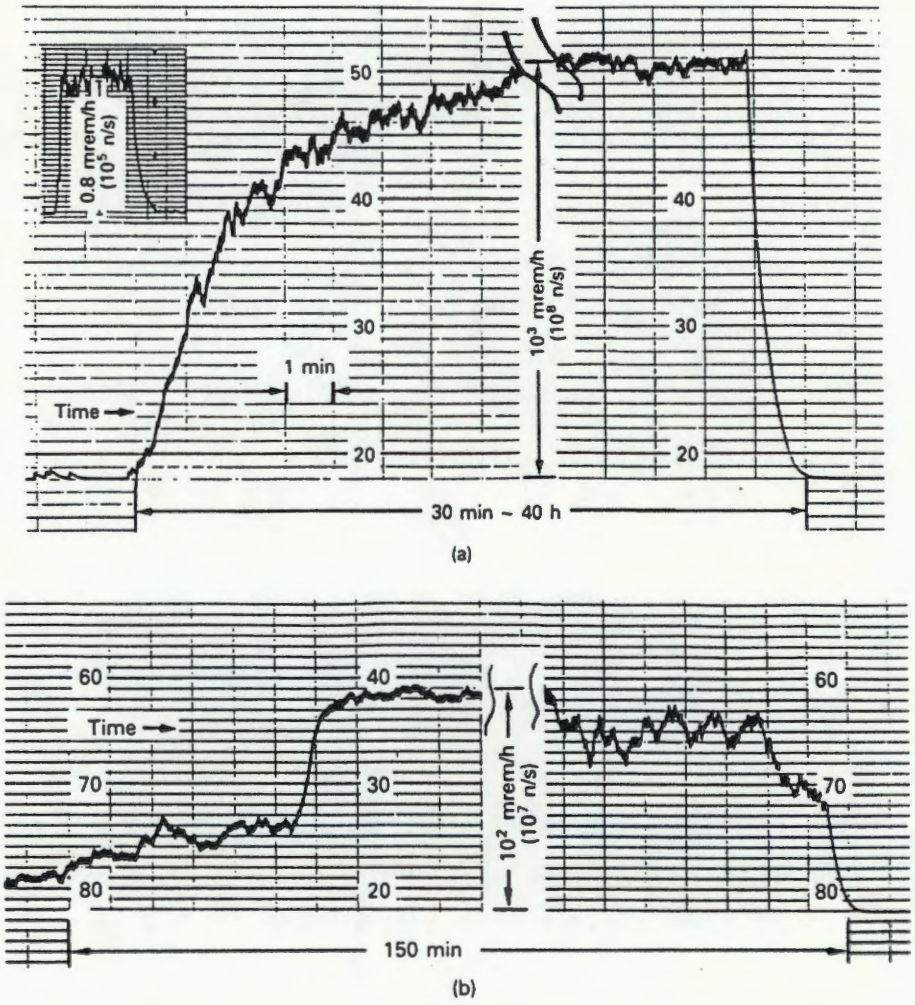

Fig. 12 Waveforms of neutron emission for Pd.(Arata and Zhang)

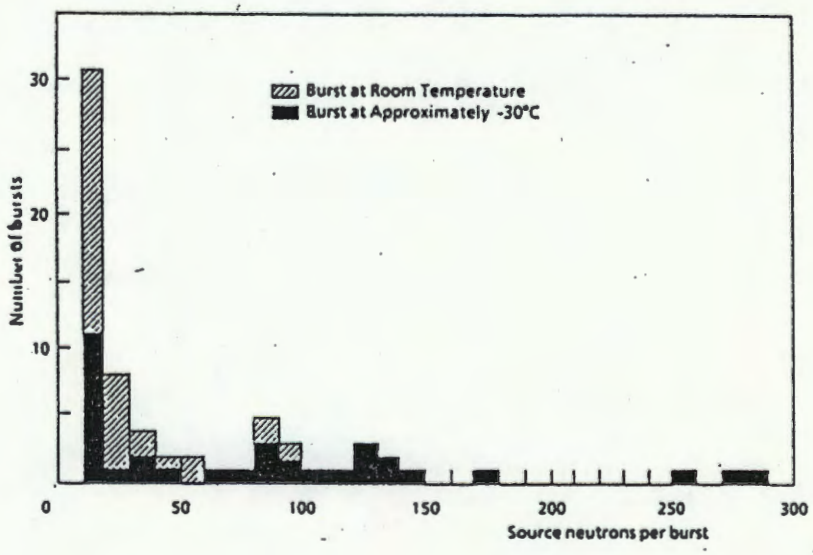

Fig. 13 Characteristics of neutron burst production from TiD_x chips subject to thermal cycling (From Menlove et al /17/)

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Department of Physics

Press Release -- 16 April 1991

Comments on results of independent investigation of Pons-Fleischmann data by WNH for the Utah State Fusion/Energy Council

(If quoted, please include the essence of both I and II)

I. Based on unpublished raw data given to me by Drs. Stanley Pons and Martin Fleischmann, my independent analysis shows that indeed they do have cells which generate significant excess heat. The total excess heat amounts to hundreds of electron volts per palladium atom in some cases. This seems to rule out ordinary chemistry as a source of the excess energy.

Drs. Pons and Fleischmann supplied raw data and answered hundreds of questions during this difficult and tedious investigation. I wish to thank them for their cooperation. They did not counsel me on the analysis, however. The data are theirs. The analysis is mine.

II. This is a preliminary release and tentative in the sense that I will not present my review in detail in public nor put my signature on it until I have discussed it with respected colleagues and answered the challenges they might have to my methods and reasoning.

W N Hansen

Wilford N. Hansen
April 16, 1991

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