# FUSION facts

A Monthly Newsletter Providing Factual Reports On Cold Fusion Developments

ISSN 1051-8738 • University of Utah Research Park •

Volume 1 Number 10 Salt Lake City, Utah April 1990


CONTENTS FOR APRIL 1990



* * * * * * * * * *

## A. SUMMARY OF THE FIRST ANNUAL COLD FUSION CONFERENCE.

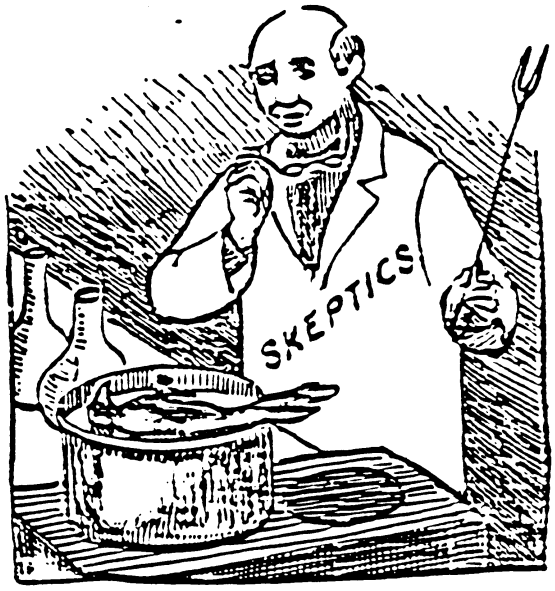
By the staff of Fusion Facts.

In spite of the unrealistic predictions of the President of the American Physical Society who dubbed the conference as the last twitch of a dying corpse, the First Annual Cold Fusion Conference was a success.

The technical coverage from the conference papers was threefold:

1. To demonstrate, in detail, the careful scientfic manner in which large amounts of data were taken to demonstrate evidence of cold fusion.

2. To construct fusion theories consistent with the numerous and varied experimental data on cold fusion.




COLD FUSION COOKED CROW

3. To provide a form for the exchange of ideas, information, and constructive criticism.

Many papers were presented showing the detailed preparations made to perform accurate cold fusion experiments. These presentations left little room for the skeptics and doubters to cite errors of judgement, measurement, or scientific inaccuracies.

One of the more intense discussions at the conference was based on the statement that the lack of reproducibility had destroyed the confidence of the scientific community. Such scientists would find it difficult to work with atmospheric lightning or with many of the biological sciences.

Actually, the numerous reports (over 40 papers) of successful experiments, observations, and theories demonstrated that the original findings of Fleischmann and Pons (regardless of the complete accuracy of their preliminary paper) has now been replicated many times. Of considerable importance were the several theory papers (Preparata from Milano, Hagelstein from MIT, Schwinger - Nobel Laureate, Kim from Purdue, Bush from Cal Poly Pomona, Handel from Missouri, and Andermann from Hawaii).

The following are notions winnowed from the conference that are deemed to have immediate application to experimentalists:

* Make careful analytical measurements of the cathode material both before and after excess heat experiments.

* Try to design experiments in which measurements are continually being made for excess heat, tritium, neutrons, and other radiation.

* Follow the history of solid-state semiconductors in taking great care to avoid contamination and maintain precise knowledge of all chemical and physical parameters in a working cell.

* Follow closely the theoretical work so that a close relationship is maintained between theory and practice.

* Design experiments that will provide non-obstrusive methods of monitoring desired parameters. For example, optical methods may be suitable for measurement of temperature, cathode dimensional changes, cathode surface conditions, cathode mass, and electrolyte constituents.

* As soon as excess heat can be reliably produced, provide for experiments at higher pressures and temperatures.

* Some theory suggests that the fusion intensity is closely related to temperature, others to metal crystal regularity, others to the idea that neutron production is unlikely but that lower energy gamma rays or X-rays may be involved in the nuclear reactions.

* The role of lithium and deuterium should be carefully determined.

* Cells that produce reasonable amounts of excess heat should be constructed so that the evolved gases can be recombined and collected for later examination.
Long-run times are suggested to concentrate helium or other ashes of nuclear reactions.

* The production and possible consumption of tritium should be examined. There has been some evidence that fusion cells have both produced and consumed tritium.

* Deuterium loading experiments should continue with measurements of tritium.

Following are the abstracts and our reporter's comentaries on each of the papers presented.

* * * * * * * * * * *

## B. ABSTRACTS AND COMMENTARIES OF CONFERENCE PAPERS

### CALORIMETRY-PONS

Stanley Pons (U/U, NCFI), "Calorimetry of the Palladium-Deuterium System", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

In this talk, we present our method for accurate determination of heat flow in simple, single compartment Dewar-type calorimeter cells and present data for the electrolysis of light and heavy water at Pd and Pt electrodes in an extensive set of experiments. The precise evaluation of the rate of enthalpy generation relies on the non-linear regression fitting of the "black-box" model of the calorimeter to an extensive set of cell temperature-time and cell potential-time measurements. We show that the method of data analysis always gives a systematic underestimate of the enthalpy output and, in consequence, to a slightly negative excess rate of enthalpy generation for the large number of blank experiments. Further, we observe positive excess rate of enthalpy generation for heavy water electrolysis at a large number of palladium electrodes.

It is also shown that prolonged polarization of some palladium cathodes in heavy water leads to bursts in the rate of enthalpy generation; the thermal output of the cells exceeds the enthalpy input (or the total energy input) to the cells by factors in excess of 40 during these bursts. The total specific energy output during the bursts as well as the total specific energy output of fully charged electrodes subjected to prolonged polarization (5-50 MJ cu cm) is 100 to 1000 times larger than the enthalpy of reaction of chemical processes.

REPORTER'S COMMENTARY

Dr. B. Stanley Pons presented this first paper of the conference which will also be printed in the July 1990 issue of *Fusion Technology.*

During the past few months, a large effort has been made to ensure accurate complete data on excess heat measurements. During the more than 200 experiments, more than 2,000 calibrations were made to ensure accurate results. The results show solid evidence for some excess heat in many of the experiments, however the scatter is large. Some cells have produced bursts of excess heat that defy current theory.

In response to questions, Dr. Pons stated that he thinks that the effect is a volume effect but he is not sure. Dr. Fleischmann noted that the scatter of the data for excess heat covers two orders of magnitude but that the errors of heat measurement is less than 0.1%. Dr. Nate Hoffman stated that they found zirconium on the palladium cathode in analysis of a Pons cathode.

**CALORIMETRY-McKUBRE**

Michael C. H. McKubre, Romeu C. Rocha-Filho, Stuart Smedley, Francis Tanzella Bindi Chexal, Tom Passell and Joseph Santucci, (Stanford Resource Inst.) "Calorimetric and Electrochemical Studies of the Deuterium-Palladium System", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

We have carried out a series of experiments designed to examine the anomalous effects associated with the D/Pd system, and to discover some of the experimental variables that might be important to the effect. Our experiments were concerned with calorimetry of the D/Pd system, but also monitored those experimental variables that might be important in causing the effect: the D/Pd ratio and its rate of change, and interfacial phenomena such as the reduction of $D_20$.

Two types of calorimeters are employed: a differential calorimeter and flow calorimeter. In both of these instruments, the electrochemical cell was pressurized with $D_2$ gas to 900 psi. The calorimeters were designed to facilitate the on-line measurement of the resistance of the Pd cathode, and for high quality measurements of the interfacial impedance. In both calorimeters, the electrochemical system has produced evidence of heat output appearing in bursts, apparently in excess of known input power sources. These bursts last for several hours and produce energies up to several hundred thousand joules.

In electrodes that are heavily loaded with D, the electrical resistance of the Pd cathodes was observed to pass through a maximum with increasing time of cathodic charging, which is consistent with the known behavior of the H/Pd system. The electrochemical interfacial impedance of the cathode gives evidence of one, and at times two relaxation phenomena: it is also sensitive to accumulation of cathodically deposited impurities that may influence the rate and degree of D loading.

REPORTER'S COMMENTARY

Dr. McKubre was unequivocal in stating that the palladium/lithium deuteroxide system shows unexpected properties when the D/Pd ratio exceeds about 0.75. The resistance of the palladium cathode is a good indicator of D loading and was used in their work.

Some experiments showed an anomalous deloading of the deuterium from the cathode that occurred, ceased, and then began loading again. Oxygen was found to be detrimental to the procedure which means that considerable care should be exercised to keep evolved oxygen away from the cathode.

Experiments were made using both platinum and nickel as the anodes. A slide was shown where three major excess heat excursions were observed. A slide showing the autoradiography of a cathode was shown. However, no helium 3, helium 4, nor tritium was measured - only excess heat.

During the question periods, Dr. Wills comments on the cathode fissures and cracks as being a source for rapid out-diffusion of gases (especially deuterium). A warning was then given by one attendee that some photographic film can be exposed by direct contact with base metals. Care in autoradiography should be exercised to ensure that the film is protected against direct contact with base metals as was done by McKubre.

**CALORIMETRY-MURPHY**

O.J. Murphy, A.J. Appleby, and S. Srinivasan, "Palladium/Hydrogen Isotope Systems: Microcalorimetric Measurements and Surface Analyses." *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Palladium/hydrogen isotope systems have been the object of renewed scientific investigations. These stem from the recent observations of anomalous heat generation and the detection of nuclear particles (neutrons) as well as elemental transformations (tritium production) on electrochemically saturating palladium metal lattices with deuterium. The unexpected results have also been obtained with other metals, e.g. titanium and on using alternative methods of introducing deuterium into metal lattice interstitial sites, e.g., deuterium gas pressure loading. The yet to be established nuclear-induced phenomena are attributed to processes taking place within the bulk metal lattice and/or to processes identified with localized surface microscopic features. The former

processes are thought to give rise to D-D fusion as a result of either multiple deuterium ion occupancy of interstitial sites together with a lowering of the Coulomb repulsion barrier by the electron cloud of the metal, or to the generation of high electric fields and highly energetic particles between the opposing walls of developing cracks (fractofusion). In the latter processes, dielectric breakdown phenomena at deuterium gas covered microscopic protrusions ("dendrites") at electrode surfaces and an associated deuterium ion acceleration towards the tip of a protrusion (high local electric field) is supposed to initiate D-D fusion events. To account for the high experimentally measured tritium/neutron ratios, rotation/ orientation restrictions on interstitial deuterons, or surface adsorbed deuterium atoms, are invoked.

In the present investigation, electrolysis of heavy and light water solutions of lithium and sodium deuteroxide were performed using both palladium and platinum metal cathodes. For the former cathodes in light water solutions and the latter in heavy water solutions, no anomalous heat fluxes were measured using a microcalorimeter. With palladium cathodes in heavy water solutions containing lithium deuteroxide of various lithium isotope compositions, anomalous heat fluxes were produced. These heat fluxes were quenched, or considerably reduced, on exchanging sodium deuteroxide solutions for lithium ones, or lithium containing light water solutions for the corresponding heavy water solutions.

After extended electrolysis in lithium-containing light and heavy water solutions, palladium cathodes were subjected to AES and SIMS analysis. Auger spectroscopy revealed the presence of a large number of elemental impurities on the darkened surfaces of palladium electrodes. Most notable, however, was the absence of a signal due to palladium which appeared only after argon ion sputtering to a depth of 200 angstroms. Positive SIMS showed the presence of lithium isotopes in addition to the elemental impurities detected by AES.

In this paper, the experimental techniques used (in particular the microcalorimeter), anomalous heat fluxes measured, error limits of the heat measurements, surface analysis of the palladium cathodes and the sources of elemental impurities will be discussed.

REPORTER'S COMMENTARY

As was typical of many of the papers, the authors were most careful to assure the greatest degree of accuracy in their experimental work. Obviously, this action had been adopted, as a part of "good science", to ensure that some of the criticism that has been received was properly answered.

Murphy points out that the critical current density is in the region of 60 to 200 mA/sq cm of the palladium surface. The cathode sizes used in these experiments were small diameter wires and a 2 mm sphere. Dendritic growth on the cathode surface was evident.

Materials found on the cathode surface included Pt, Ca, Cu, and Pd. Fe from the stainless steel container was also found. (Any C seems to be lowered). A comment was made concerning the ratio of the lithium isotopes (see paper from NRL). The lithium appears to vary with depth into the Pd cathode using $D_2O$ but there is a lesser amount of Li with depth using $H_2O$.

The conclusions found that excess heat is definitely measured. No comments were made concerning the production of tritium.

In the question period, Bockris stated that excess heat was observed in all successful (about 80%) experiments but that more heat per cu cm of Pd occurs with smaller diameter cathodes. It was also noted that tritium production was not significant in these short experiments. If helium is produced and the effect is a surface effect then the helium would escape with the evolved gases.

**CALORIMETRY-HUTCHINSON**

D.P. Hutchinson, C.A. Bennett, R.K. Richards, J. Bullock IV and G.L. Powell, (ORNL), "Initial Calorimetry Experiments in the Physics Division at ORNL", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Eight calorimetry experiments were performed with palladium cathode electrolysis cells to investigate the possibility of cold fusion heat production based on the reported results of Fleischmann and Pons. Six of the cells contained 6.35-mm-diam x 10-cm-long palladium cathodes in a 0.2-M $^6$LiOD electrolyte solution; and one cell used a cast 1.27-cm-diam x 10-cm long palladium rod in a 0.2-M electrolyte. All eight cells were constructed with platinum wire anodes. Five of the cells exhibited an apparent power excess from 2 to 9 W for a period of approximately 1500 hours of a total operating time of 1800 hours; each of the remaining three cells remained in power balance.

REPORTER'S COMMENTARY

The authors noted that when the temperature of the water bath was changed that some effect was noted on the amount of excess heat produced. Experiments run over

long periods of time generated excess power of the order of 10 megajoules per mole of Pd. Although the actual percent of excess heat was low, the amount of excess power was much larger than could be accounted for by chemical means.

At one period in the experiment a large heat pulse of about 40 watts was measured. Many experimenters observe these bursts of activity. When the $D_2O$ electrolyte was changed to $H_2O$, the excess heat fell from 1.5 watts to 0 watts.

In a discussion of whether the phenomena is a surface or volume effect, it is noted that there is conflicting data.

**CALORIMETRY-SCHREIBER**

Martha Schreiber, T.M. Gur, G. Lucier, J.A. Ferrente, J. Chao and R.A. Huggins, (Stanford), "Recent Measurement of Excess Energy Production in Electrochemical Cells", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Excess power has been observed over long times in several experiments involving the electrolytic insertion of deuterium into palladium. After a short period, the overall energy balance becomes positive, leading to the generation of significant amount of excess energy.

REPORTER'S COMMENTARY

Dr. Martha Schreibner presented an excellent review of previous work at Stanford and emphasized that excess heat is never obtained using $H_2O$ but is usually observed in experiments using $D_2O$ under proper experimental conditions.

The Stanford group uses coin-shaped ("fat dime") Pd cathodes. The cells are closed with a recombiner and the isoperibolic calorimeter is used. Under learned experimental conditions the probability of measuring excess heat is high but is not always of the same value. Typically, excess heat ranges from 5% to 20%.

One data slide showed that over 200 hours, the excess power produced was 22.5 megajoules per mole which is about 200 times the invested energy to start the excess heat production. Obviously, there is neither a battery nor chemical process involved. Dr. Wilford Hansen (USU) observed that 22.5 megajoules per mole equals 5,000 kilogram calories per mole which is 10 to 100 times the sublimation value.

**INSTRUMENTATION-CHECK**

Graham T. Cheek, (U.S. Naval Academy), "Quartz Crustal Microbalance Study of Palladium/Hydrogen Interactions" *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Thin palladium films (5000 Angstrom) deposited on quartz have been loaded with hydrogen (deuterium by electrochemical reduction of 0.1 M LiOH (LiOD) in $H_20$ ($D_20$). Coulometric measurements during both the hydrogen deposition and subsequent removal steps have shown that Pd:H(D) ratios of 0.7 are reached under these conditions, in accord with accepted values for bulk samples. The frequency decrease, usually attributed to a mass increase, observed at AT-cut crystals during hydrogen (deuterium) loading is larger than that expected for the mass of hydrogen deposited into the film. Considering that palladium undergoes a substantial increase in volume upon hydrogen uptake, the role of the resulting film stress in influencing the observed frequency must be addressed. It has been found that such film stresses at an AT-cut crystal produce frequency decreases and that these effects can be accounted for using techniques which are well-established in the frequency control field. Measurements at BT-cut crystals, the stress/frequency response of which is opposite to that of AT-cut crystals, have confirmed that stress plays a major role in the present work and have allowed the determination of a quantitative value for this stress. The details of the frequency/time dependence during deposition and stripping processes at both types of crystals are also interesting and will be presented. Investigations of mixtures of $H_20$ and $D_20$ have also been carried out and shed some light on the effect of small amounts of $H_20$ in determining the H/D content in the palladium.

REPORTER'S COMMENTARY

The author noted that the sensitivity of the device described is about 9 nanograms per Hz. Some clever adaptations may be made of this instrument so that the amount of deuterium being loaded into a classical FP cell can be measured by volume increase.

**EPRI WORK-SANTUCCI**

J. Santucci, B. Chexal, T. Passell, J. Chao, D. Cubicciotti, R. Jones, (EPRI), " Investigation of Nuclear Processes in Deuterated Metals", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The Nuclear Power Division of the Electric Power Research Institute (EPRI-NPD) has been following closely reported observations of "Cold Fusion" in deuterated metals, and is conducting independent investigations to ascertain and gain an understanding of the phenomena involved. The EPRI-NPD program of investigations started shortly after the initial announcement by M. Fleischmann and S. Pons. The program includes in-house activities and laboratory work, the latter primarily at three contractor facilities: SRI International (Menlo Park), Stanford University (Palo Alto) and Lockheed Nuclear Research Laboratory (Palo Alto). The experimental investigations have focused on:

* Developing a good understanding of the electrochemical, thermal and hydraulic behavior of Pd-$D_20$ cells, to permit adequate characterization of unexpected results, such as excess heat.

* Measuring excess heat with a very high degree of confidence in closed cells and in flow calorimeters.

* Developing an understanding of the materials processing variables that affect reproducibility of the phenomena being investigated (both the cathode and the electrolyte materials).

* Determining which nuclear products are characteristics of the phenomena investigated and devising proper monitoring protocols.

* Determining whether certain conditions are conducive to initiating the phenomena under investigation.

This paper provides an outline of the work completed and in progress. Various elements and portions of the work are described in more detail in subsequent presentation by M. McKubre (SRI), M. Schreiber (Stanford University), T. Gur (Stanford University), and J. Chao (EPRI). Many valuable insights have been obtained performing limited, but highly instrumented and characterized, experiments.
Dr. Santucci stated that the experiments funded by EPRI have conclusively shown that the results cannot be explained by chemical processes. However, the nuclear fuel has not been unquestionably identified nor has the "ashes" of such fuel.

On-line diagnostics are needed. For example, the Pd cathode resistivity varies with deuterium loading. The curve increases to a peak and then decrease as the D/Pd ratio increases.

The threshold current in the cathode (current level at which excess heat can be expected to occur) appears to lower after one or more bursts of heat have occurred.

Autoradiography of a used cathode can be used to identify if the heat-producing reactions are spotty or uniform. [Note: Some work at BARC indicates that the results are more spotty using Titanium than when using Pd. Ed.]

It is important to design experiments so that low-level (under 2.2 KeV) X-Rays can be measured. This should be a high priority. The current work in process is emphasizing the study of reproducibility, the measure of D/Pd ratio, the precise role of temperature, and the understanding of what parameters effect the sudden initiation of nuclear events.

**INDIA-IYENGAR & SRINIVASAN**

P.K. Iyengar and M. Srinivasan, (BARC), "Overview of BARC Studies in Cold Fusion" *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Investigations to verify the cold fusion phenomenon commenced at Trombay within a week of the first announcements from Utah. Several groups having expertise in various areas such as electrochemistry, metal hydrides, electrolytic hydrogen generators, isotopic exchange processes in $D_20$ concentration and deuterium plasma pinch experiments, devised and set up a variety of electrolytic cells and $D_2$ gas loading facilities. The measurements of tritium levels in the electrolytes were carried out by specialist groups of the isotope and Health Physics Divisions.

Report BARC 1500 published in December 1989, summarizes the cold fusion studies carried out at Trombay during the first six months of the "cold fusion era".

The main findings of the BARC experiments to date are (1) Neutrons are produced in bursts lasting from tens of seconds to tens of minutes. (2) However, it is tritium which is the primary product of cold fusion reactions, with the neutron to tritium "yield" ratio being $10^{-8}$. Some available evidence indicates that neutron and tritium generation is temporally concomitant. (3) In spite of the wide disparity in their design, most of the electrolytic cells produced their first neutron burst when a charge of a little over an ampere-hour/$cm^2$ had been deposited on the cathode. The fact that this approximately corresponds to the number of deuteron required to load the Pd associated with 1 $cm^2$ area of cathode surface to a D/Pd ratio of approximately 0.6 is a significant finding. (4) Once initiated, the cells produced ~$10^5$n/$cm^2$ and approximately a micro curie of tritium/$cm^2$ of cathode. (5) With a view to shed some light on the mechanism of neutron production, the multiplicity spectrum of neutron

detector counts in 20 ms intervals was measured. Analysis of these data reveals that while 80% of the neutrons generated follow Poisson statistics, implying emission of one neutron at a time, between 10 to 25% of the neutrons are produced in bunches of a few hundred neutrons each. (6) Generation of tritium in gas loaded Ti and Pd samples has been established through the technique of autoradiography, analysis of K X-ray emission (in case of Ti) and isotopic exchange with ordinary water (in case of Pd). (7) Over a dozen "aged" (8 to 18 years old) deuterated titanium targets (on copper backing) some procured from Amersham Laboratories of U.K. and the rest fabricated in BARC have been found to contain unexpectedly high tritium levels (~100 u Ci). This corresponds to a T/D isotopic ratio of $10^{-5}$ to $10^{-6}$. The manufacturers of these targets have indicated that inadvertent tritium contamination of this high degree appears highly improbable. Cold fusion over the years appears to be a plausible explanation.

All in all, the BARC studies have confirmed the occurrence of nuclear fusion reactions at ambient temperatures in deuterium loades Pd and Ti samples.

REPORTER'S COMMENTARY

Dr. Iyengar showed an aerial view of BARC which has one of the longest laboratory buildings in the world. The BARC facility employs 3,000 scientists and over 10,000 technical staff. He also observed that it may be some time before we can expect commercialization of cold fusion. The project needs not only monetary support but also moral support.

Dr. Srinivasan presented a summary of the BARC work. [Note that the 20 papers comprising the BARC report were summarized in the February issue of Fusion Facts. Ed.]

The work at the Indira Ghandi Atomic Research Centre was also summarized. Tritium has been observed to be produced simultaneously with neutrons. Events seem to occur after about 1 ampere/sq cm of Pd surface has been achieved. Neutrons are often produced in bunches. Electrolytes using both LiOD and NaOD have been used successfully. Current replications are about 70% successful.

An interesting use of a plasma-focus device to "inject" deuterium into the end of a metal rod was mentioned.

**CALORIMETRY-GUR**

T.M. Gur, M. Schreiber, G. Lucier, J.A. Ferrante, J. Chao and R.A. Huggins, (Stanford), "Experimental Considerations in Electrochemical Isoperibolic Calorimetry" *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

A new design of calorimeter has been constructed and employed with both open and closed electrochemical cells in "cold fusion" experiments. The basic underlying concepts and important experimental characteristics will be presented.

Other important experimental considerations, such as sample preparations and calibration methods will also be discussed.

REPORTER'S COMMENTARY

One of the design advantages of this calorimeter is that it has a higher temperature operating potential. The power output is equal to K delta T, where K is an easily-obtained calibration constant, and delta T is the measured temperature difference in two parts of the calorimetry.

**THEORY-PREPARATA**

Giuliano Preparata, (University of Milano), "Some Theoretical Ideas on Cold Fusion", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The usually neglected interaction between the quantized radiative electromagnetic field and the elementary systems (nuclei, electrons, etc.) of condensed matter is shown to provide possible dynamical mechanisms for:

(a) coherent plasma oscillations of peripheral electrons that substantially screen the Coulomb repulsion between the deuterons absorbed in the metal lattice;

(b) a coherent electromagnetic cooling, where the coherent electron plasma absorbs the excess energy of the DD fusion process in a very short time (~10-21 sec), thus enhancing the fusion rate over the incoherent (vacuum) mechanism by some ten orders of magnitude.

It will be shown that much of the phenomenology so far reported can be interpreted adequately within the above theoretical framework.

REPORTER'S COMMENTARY

Dr. Giuliano Preparata presented one of the most interesting theory papers of the conference. The theory involves QFT-superradiance. Briefly stated, there may occur coherent domains within the Pd lattice in which the clouds of electrons surrounding the Pd nuclei are in coherent oscillation. Under such a condition, an itinerant deuteron would be thrown into deep potential wells. As these coherent domain wells become filled the probability of d-d fusion greatly increases. The paper shows that this probability can be increased 20 to 30 orders of magnitude. The author suggests that the F-P type of fusion is this coherent type of fusion while the Jones type of observed fusion is of the incoherent type and is observed at lower D/Pd ratios. Under conditions of coherent fusion, the energy developed must be transferred. Preparata provides some equations that relate the energy transfer into the swarms of electrons and shows that this energy transfer can be expected to occur in about $10^{-21}$ seconds.

Because the claims made by Preparata for his model can account for nearly all of the observed experimental evidence (including those who have not found excess heat) and because he develops his model from basic known physics, the paper is highly recommended.

**THEORY-HAGELSTEIN**

Peter L. Hagelstein, (MIT), "Status Report on Coherent Fusion Theory", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Nuclear reaction which may exhibit coherent effect have been studied as a candidate explanation for cold fusion effects.

An analysis of a general class of two-step coherent reactions involving charged nucleons has been performed, and very small reaction rates are found. This result is due to the small tunneling factors associated with coulomb repulsion.

We are investigating two-step coherent reactions which begin through weak interaction mediated electron capture, which in hydrogen isotopes would produce off shell (virtual) neutrons. No coulomb repulsion occurs for virtual neutrons. Virtual neutron capture by deuterons would yield tritium, and virtual neutron capture by protons by a factor of 5000 on a per nucleon basis, and corresponds to a heat-producing reaction. The nuclear reaction energy would be coupled into the electrolysis process, with the final reaction products stationary.

We have found that the weak interaction process can in principle be superradiant in the Dicke sense. If so, then considerable acceleration of this type of coherent reaction may occur.

REPORTER'S COMMENTARY

Dr. Hagelstein presented an earlier paper [1] which has attracted considerable interest. This earlier paper was reported in *Fusion Facts* in the December 1989 issue.

In this presentation the author suggests that there can be a magnetic dipole coupling to a magnetic or an electric field. Hagelstein shows that by using the equations for a non-linear LC circuit that one can expect the following:

Heat is due to slow virtual neutrons or protons. Slow neutrons would be emitted. It may be possible to replace the electrolysis process with other voltage processes.

As one of the few theoretical papers based on the experimental evidence, Hagelstein's work is highly recommended.

[1] Dr. Peter L. Hagelstein, M.I.T., "Coherent Fusion Theory.", presented at COLD FUSION - A STATUS REPORT session in conjunction with the ASME Winter Annual Meeting held in San Francisco, CA December 12, 1989.

**THEORY-CHUBB**

Scott R. Chubb and Talbot A. Chubb, (NRL), *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Cooperative ionic fluctuation, which become energetically favorable in stoichiometric Pd-D when the associated lattice remains sufficiently ordered, provide a means for an entirely new form of nuclear interaction, "cold" or "solid state" fusion. As a consequence, 1) nucleons separated by macroscopic distances may interact in a nuclear fashion, 2) nuclear fusion may occur in which unfamiliar products are released, and 3) the periodic solid significantly alters the ioncity and effective electrostatic volume of each deuteron in a manner that is very different from expectation based on conventional theory associated with free space nuclear physics. In a periodic lattice, the evolution of such an ionic fluctuation, which we have named a Bose Bloch Condensate (BBC), becomes favorable as the concentrations of D and Pd become comparable because of large energy costs from lattice strain at individual lattice sites that result from coulombic

repulsion associated with the occupation of a site by more than one D. These strain energy costs are removed through the evolution of long-ranged, periodic, ionic fluctuations in which equal (though small) amounts of excess charge are distributed uniformly to unit cells throughout the crystal.

This paper provides the prerequisite quantum mechanical theory that underlies the origin of these fluctuations and the associated selection rules that govern the resulting nuclear interactions. Because these Fluctuations become energetically favorable through the overcharging of Pd electrodes during the prolonged electrolysis of LiOD, it is reasonable to assume that they are responsible for the associated heating[1], and this heating[1] is the result of a new form of nuclear interaction.

We also use known quantum mechanical effects associated with the behavior of D dissolved within metallic hosts to explain recent experimental observations of three-MeV protons and one-MeV $^3H$ that accompany the acceleration of clusters of $D_20$ molecules at moderate energies into a Ti-D target. These experimental results, derived from the "cluster impact fusion" method, reflect a second type of solid state fusion, which we will call "not-so-cold-" fusion, and which involves chemically bonded D. The nuclear reactions associated with "not-so-cold" fusion do not require the periodic order associated with BBC formation that is necessary in "cold solid state" fusion and can be explained within a framework that more closely resembles the physics of conventional collision-induced nuclear fusion.

As a consequence, this new form of fusion involves familiar nuclear products, such as free neutrons, $^3H$, etc., unlike the products found in "cold" fusion.

REPORTER'S COMMENTARY

Note that the authors deal with the issue of "that result from coulombic repulsion associated with the occupation of a site by more than one D". Many previously published papers dealing with probabilities of fusion have dealt with interactions between two deuterons located in adjacent sites within the crystalline lattice. Experimental evidence supports the idea that it is the itinerant deuteron moving through a lattice that is highly populated with deuterons that would be involved in nuclear fusion.

The authors develop the idea that a D+ BBC (Bose Bloch Condensate) is formed as the ratio of D/Pd approaches unity. The authors state [1], "Fusion is a result of three D+ BBC properties: screening by the lattice for $c << 1$ (where c = the ratio of condensate bosons to number of unit cells in the host crystal); the resulting large zero point motions associated with this screening; and the multiple boson occupation of single lattice sites." The authors also note that the large zero point motion spreads out the D+ charge density within a unit cell. They state further: "In the evaluation of the transition matrix element associated with fusion, the initial state wave functions and fusion-inducing changes in the potential result from non-number conserving, many-body fluctuations associated with multiple occupation of Wannier states at a given site. Site multiple occupations cause deuteron wave functions to overlap, inducing fusion."

In a final note in reference [1], the author's state: "Coupling between the chemically bonded D and the lattice could result in momentum transfer to the lattice as a whole. The result could be heat release without any high energy particle generation." Both papers are recommended for more careful study.

[1] T.A. Chubb (NRL) and S.R. Chubb (Bendix), "Nuclear Fusion in a Solid via a Bose Bloch Condensate", NRL Memorandum Report 6617, Naval Research Laboratory, Wash D.C. 20375-5000, March 5, 1990.

**THEORY-SCHWINGER**

J. Schwinger, (UCLA), "Nuclear Energy in an Atomic Lattice", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

REPORTER'S COMMENTARY

Dr. Julian Schwinger, Ph.D. and Nobel Laureate (UCLA) was the Thursday evening special lecturer. His theoretical treatment is based on known physics. The slides used for the presentation were vigorously endowed with complex equations. We look forward to the publication of his paper.

Within the limits of ones note-taking ability, the following presents some of the points made by Dr. Schwinger:

The mathematical approach starts with the development of an oscillator of mass and frequency from which is developed an average of the potential energy. A photon Hamiltonian is developed and treated with additional energy. In the equation there is a vector R energy and a displacement vector r energy. The vector r energy can be considered as the mean free (thermal) vibrational energy. By using the formulas developed, it can be shown that a 25% change in vector r produces a change of $10^7$ in the fusion probability. Dr. Schwinger made the comment, "No wonder it is difficult to reproduce cold fusion!"

Further mathematical treatment is provided in terms of Einstein oscillators to represent two deuterons. The end

result is the calculation of the probability of fusion (with a very sensitive term in the equations) of about $10^{12}$ per second (per some unit of volume which didn't get into the notes). Dr. Schwinger's article is highly recommended.

**EXPERIMENTS-BOCKRIS**

J.O'M. Bockris, G.H. Lin and N.J.C. Packham, (Texas A&M), "Nuclear Electrochemistry Among the Hydrogen Isotopes", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Pd cathodes are used to evolve $D_2$ from LiOD solutions for up to 4-1/2 months. Excess heat has been observed form 4 electrodes out of 28, tritium in 11 out of 47. Some degree of correlation between excess heat and tritium production has been observed. The production rate of T was c. $10^{10}$ atoms $cm^{-2}$ $sec^{-1}$. The branching neutron/tritium ratio was $10^{-8}$. A dendrites enhanced surface fusion model was suggested which gives quantitative consistency with the experiment.

REPORTER'S COMMENTARY

Subsequent to the visit by the DoE Cold Fusion committee at Texas A&M, it appeared necessary to do some intensive work proving the production of tritium in an electrolytic cell. The end result has been some excellent papers [1] and a unequivocal affirmation of the production of tritium in a lithium/heavy water electrolytic cell using a palladium cathode.

This paper reviews the intensity of the effort to prove that there was no tritium contamination. Out of 47 cells, tritium production was measured in 11 of the cells. Other labs that have also produced tritium are BARC (India), Wolf (TAM), and Schoessow at Florida. [See the BARC review by Srinavasan].

The author discussed the role of the dendrites (whiskers) in promoting tritium nuclear events. Also it was noted that the branching ratio of tritium to neutrons is about $10^{8}$. In the question period, Bockris reported that the production of tritium accounted for about one percent of the excess heat observed in the few cases in which both tritium and excess heat were being measured.

[1] N.J.C. Packham, K.L. Wolf, J.C. Wass, R.C. Kainthla, and J.O'M Bockris (Texas A & M), "Production of Tritium From $D_2O$ Electrolysis at a Palladium Cathode.", *J. Electroanal. Chem.* vol 270 (1989), pages 451-458.

**TRITIUM-STORMS**

Edmund Storms and Carol Talcott, (Los Alamos National Lab), " A Systematic Study of Electrolytic Tritium Production", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Tritium production is being investigated using cathodes made from palladium and its alloys (with Li, C, S, B and Be) to which are applied various surface treatments. Three anode materials (Pt, Ni and stainless steel), and various impurities in the electrolyte have also been used. Tritium has been produced in about 10% of the cells studied, but there is, as yet, no pattern of behavior that would make the effect predictable.

REPORTER'S COMMENTARY

Dr. Storms stated that at least 25 laboratories have achieved positive results in experiments with cold fusion, therefore, the question about the reality of cold fusion can now be put aside.

The studies with palladium alloys indicated the following:

Lithium alloy increases the takeup of deuterium; a carbon alloy slows down deuterium uptake; sulfur alloy increases the reactions of the deuterium with oxygen (in the air); and rhenium alloys alAso increased the deuterium uptake.

It was also found that a PdC rod could be treated to burn out the C and leave a porous Pd. Tritium was produced using both Pt and Ni as anode materials. When Stainless Steel was used as an anode the results were poor.

The authors' conclusions were that tritium can be produced by electrochemical cells but that there is, as yet, no consistent method that ensures replicability. In the question period, it was stated that about 10% of the cells tried produced tritium. Dr. Will stated that the D/Pd ratio is critical for tritium production (range of 0.5 to 0.8).

**EXPERIMENTS-SCOTT**

Charles D. Scott, John E. Mrochek, Milica Petek, Timothy C. Scott, Gordon E. Michaels and Eugene Newman, (Oak Ridge National Lab), "Measurement of Excess Heat and Apparent Coincident Increases in the Neutron and Gamma Ray Count Rate During the Electrolysis of Heavy Water", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

A research group at the Oak Ridge National Laboratory has achieved some extremely interesting results during the investigation of "cold fusion" via the electrolysis of heavy water. Experimental tests have been made with electrolytic cells utilizing 0.1 to 1.0 N LiOD in $D_20$ as the electrolyte and a palladium cathode surrounded by a wire-wound platinum anode operating at cathode current densities of 100 to 600 $mA/cm^2$. The electrolyte temperature was controlled and heat was removed by flowing water in a cooling jacket, and the cell was insulated. Cooling water and electrolyte temperatures were determined by thermocouples, neutron and gamma-ray spectra were measured and the electrolyte was periodically monitored for tritium.

Recent tests have included the long-term (approximately 2000 h) operation of a closed electrolysis cell with internal recombination of the evolved $D_2$ and $O_2$. The generation of excess heat was observed in several tests, and it was shown that certain system perturbations could initiate and extend the incidence of excess heat. Neutron count rates exceeding three standard deviations of background were detected and there was an apparent increase in the neutron count rate coincident with heat generation in one of the closed system tests.

REPORTER'S COMMENTARY

Dr. Scott reported that the hardware being used has evolved but that currently they use a closed cell with a Pt/Pd black as the recombiner. The accuracy of the measurements of heat are within 0.2% and that data is automatically taken every six seconds. The cathodes are made from Pd that is cast, cold-worked, and annealed at 900 deg C for several hours. They have measured excess heat for over 200 hours.

Slides of data have shown two or three bursts of excess heat that continued well above background for several hours. Also neutrons and gamma radiation was measured at 2 to 3 sigma above background.

At the end of test $H_2O$ was added and the excess heat slowly dropped (over a 100 hour time period). In all test that ran over 200 hours, excess heat has been measured.

In conclusion the authors observed: Excess power is being produced. System perturbations cause excess heat such as when the current is abruptly changed or when the electrolyte has its chemical composition changed dramatically. It was noted that it appears that more than one type of interaction may have been observed. Also, different palladium may produce different results.

**EXPERIMENTAL-SCARAMUZZI**

Franco Scaramuzzi (Frascati National Laboratory), "Search for Nuclear Phenomena by the Interaction between Ti and D", *Proceedings of the First Annual Conference on Cold Fusion*, March 28-31, 1990, University Park Hotel, Salt Lake City, Utah.

REPORTER'S COMMENTARY

Dr. Scaramuzzi and associates were the first to publish results of nuclear activity in a titanium lattice following the gas-loading of deuterium. See *Europhysics Letters*, Vol 9, No. 3, pages 221-224, 1 June 1989).

In a second series of experiments neutron flux was monitored and measured. In addition, a search for tritium production was made a part of the experiments. The emphasis was not on looking for total energy produced but on discovering more about bursts of activities. Experiments were conducted using a variety of gas-loaded metals of different types. The hypothesis that tritium in produced and is absorbed into the metal lattice is being tested. Deabsorption of tritium is expected when the metal is heated to 1,000 degrees C. Future work will continue working with the fracto-fusion measurements in titanium.

**NEUTRONS-JONES**

Steven E. Jones, (B.Y.U.), "Cold Nuclear Fusion in Condensed Matter Recent Results and Open Questions", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

We have observed clear signatures for neutron emission during deuteron infusion into metals, implying the occurrence of nuclear fusion at very low rates near room temperature. The cold fusion phenomenon has been demonstrated in collaborative experiments at Brigham Young University, Provo, Utah, at the Gran Sasso Laboratory in Italy, and at the Los Alamos National Laboratory. We have shown that cold fusion can be induced in metals using both electrochemical and variational temperature/pressure means to generate non-equilibrium conditions. Observed average neutron emission rate are approximately 0.04-0.4 n/s.
Current efforts focus on trying to understand and control the cold fusion phenomenon. In particular, we wish to understand the correlation of fusion yields with parameters such as temperature variations, hydride phase changes, hydrogen/metal ion ratio, pressure (induced, for example, electric fields or gas pressure or mechanical pressure), and surface conditions (e.g., a palladium coating in titanium).

We have recently established that neutron burst emissions occur with highest probability in certain deuterated Ti alloys when the sample temperature is approximately -30° C. The observed correlation between the neutron bursts and the sample temperature is highly suggestive. It has been established that hydrogen in dilute solution in Ti alloys forms a hydride at a rate which peaks in the range 0 to -80° C. The physical basis for this effect is clear: the hydride formation rate is diffusion limited at low temperatures, while at high temperatures the hydride is no longer stable. Hydride formation is accompanied by restructuring of the metal lattice, a volume increase of about 18% and, frequently, by crack formation in the brittle hydride. There is also Martenistic shear transformation in $TiD_x$ near -30° C. It seems likely that such dynamical changes in the partially-deuterided metal are associated with neutron bursts since both effects occur with highest rates in the same temperature range.

REPORTER'S COMMENTARY

Dr. Jones mentioned that his work in measuring neutrons from deuterium loaded metals goes back to 1986. In their work, they are aware that the background rate of neutrons is a function of atomospheric pressure and is taken into account in their experimental measurements.

A slide was shown in which increases in measured atmospheric tritium were found in the vicinity of active volcanoes. A current DoE contract is funding further studies of the measurements of nuclear byproducts that may result from nuclear reactions in geologic activity. During the question period it was suggested that such increase (over a 90-day period) may have come from a nuclear submarine that surfaced. [Note: Possibly the same sub that is responsible for anomalous levels of $^3He$ measured at Yellowstone Park. Ed.]

It was reported that when $D_2$ is loaded at high temperatures and high pressures no neutrons were observed. [Note: Dr. Cravens has reported that Los Alamos finds that better results are obtained when the Titanium is loaded with $D_2$ at low temperatures and allowed to rise to room temperature. Ed.] The level of gas-loading was reported to be about D/Ti = 0.4 for these experiments. The $D_2$ goes slowly into the Ti. Bursts occur during cooling (or warming) and also at room temperature. Metallic deuterium may be produced.

Dr. Jones reported that measurements for tritium have just begun.

Further work will stress the measurements of both neutrons and protons to get branching ratio measurements. Work will continue on geologic production of tritium.

**NEUTRONS-SRINIVASAN**

M. Srinivasan, A. Shayam, S.B. Degwekar and L.V. Kulkarni, (BARC), "Statistical Analysis of Neutron Emission in Cold Fusion Experiments", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The various mechanisms proposed to explain the cold fusion phenomenon can be classified under two categories. (a) those that lead to (d-d) fusion reactions taking place one at a time in which case one can assign a certain probability per second per (d-d) pair for the reaction rate and (b) those that result in neutrons being emitted in bunches following a cascade or chain of fusion events. Catalysis by muons or other particles or "fracto fusion" could give rise to such bunches. Statistical analysis of the neutron detector pulses issuing from a thermal neutron detector embedded in a hydrogen moderator (which temporally separates pulses caused by simultaneously incident neutrons during their slowing down) can give valuable information on the origin of neutrons. If neutrons are emitted one at a time, the detector pulses will obey Poisson distribution whereas in the case of bunched emission there will be significant departure from Poisson statistics.

With this view, the multiplicity distribution of neutron detector counts registered during 20 ms gate intervals, issuing from the neutron detector viewing the cold fusion source, was measured using a PC based data acquisition system. There were 1000 sampling intervals during a real time of 5 minutes.

Data was simultaneously recorded from a similar detector placed at a distance of ~1.5m serving as background monitor. Analysis of the accumulated data indicated that ~80% of the neutrons generated in cold fusion obey Poisson statistics, i.e., they are emitted one at a time. However, it was also found that occasionally 4 or more and at times even up to 20 neutron counts were registered in a single 20 ms interval. The background monitor never yielded such high multiplicity events even once. These observations led to the conclusion that about 10-25% of the neutrons were produced within the gate time of 20 ms.

REPORTER'S COMMENTARY

Dr. Srinivasan observed that high multiplicity events (neutron bursts) cannot be due to cosmic ray showers. In summary, he stated that 10 to 25% of the neutrons produced (in both electrochemically loaded and in

gas-loaded metals) were bursts. In comparing these burst measurements with other observations where tritium production was 1,000 to 10,000,000 times as frequent as neutron production it may not be logical to conclude that bursts of neutrons are associated with several orders of magnitude more tritium production. The neutron bursts may be due to fracto-fusion events.

Note: Jones, Scaramuzzi, and others who have been measuring neutron events are now modifying experimental procedures to observe the tritium (or proton) events. It is expected that improved data will be obtained that will more clearly establish the tritium/neutron branching ratio for fusion events in a crystalline lattice. Ed.

During a special question period, Dr. Srinivasan provided the following additional information:

The BARC work began immediately after hearing about the Fleischmann-Pons work. They found tritium being produced in the first day of electrolysis rather than after a few days length of time as some other experimenters have reported.

Dr. Menlove (LANL) mentioned that his gas-loading experiments appeared to be consistent with the BARC experiments.

Dr. Srinivasan showed a slide of the plasma focus gun which can produce a burst of $D_2$ ions. The gun was used with about 80 bursts to load $D_2$ ions into the end of a Ti rod. This method of ion implantation was later (4-5 weeks) found (by autoradiography) to produce tritium. After discussion, Dr. Srinivasan offered to produce a number of Ti rods and make immediate measures for tritium after the ion implantation. The scaling laws of the plasma focus gun are well understood and could be enlarged. It was noted that ion implantation of hydrogen did not produce any evidence of nuclear reactions.

Note: John Marshall later stated that the plasma focus gun was very similar to a device that his father made (Marshall Gun) while working at LANL. Ed.

**THEORY PAPERS-KIM etal**

Gary S. Chulick, Yeong E. Kim and Robert A. Rice, (Purdue), "Low Energy D-D Fusion Experimental Cross-Sections", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

A major criticism of electrochemical fusion experiments has been that the extracted deuterium-deuterium (D-D) reactions rates from these experiments are 40-50 orders of magnitude larger than the calculated reaction rates. However, the reaction rate calculations are partly based on the assumption that the D-D reaction cross-section at extremely low energies (i.e., a few eV) is of correct form. Since the D-D cross-section has not been measured at energies below 2 keV (center-of-mass), it is naively assumed that the trends in the cross-section above that energy are automatically valid below that energy. Close examination of the available lowest energy D-D cross-section data, and the results of the recent Brookhaven cluster fusion experiment, which potentially allows us to extract the D-D cross-section down the eV range, indicate that this assumption is not valid. The low energy cross-section (~100 eV) appears to be 10-20 orders of magnitude larger and appears to behave differently than the cross section at higher energies.

Robert A. Rice, Gary S. Chulick, Yeong E. Kim and Jin-Hee Yoon, (Purdue) "The Effect of Velocity Distribution on Cold Deuterium-Deuterium Fusion", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Reaction rates from recent electrochemical fusion experiments have been found to be as many as 70 orders of magnitude larger than those obtained from simple calculations involving an extrapolated low-energy D-D cross section (Fig. 1) and a sharp velocity distribution. However, if an appropriate Maxwell-Boltzmann velocity distribution is used in place of the conventional sharp velocity distribution, it is seen that the calculated reaction rate increase by as much as 50 to 60 orders of magnitude. This result for the fusion rate per D-D pair is shown in Fig. 2 (the upper curve uses a Maxwell-Boltzmann velocity distribution, the lower uses the conventional distribution).

Furthermore, the center of mass energy at which the D-D cross section is evaluated for given D-D energy is much larger than that used in the conventional calculation due to the higher energy components in the Maxwell-Boltzmann distribution. Finally, the above results are not significantly affected if a reasonable high-energy cutoff $E_e$ is included in the velocity distribution. This is shown in Fig. 3, with fusion rates per D-D pair being given in terms of both cutoff energy $E_e$ and D-D center of mass energy.

Yeong E. Kim, (Purdue), "Surface Reaction Mechanism for Cold Fusion with Electrolysis", *Proceedings of The First*

*Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

A surface reaction mechanism is described for tritium production and excess heat generation above that due to the electrode reaction reported by Fleischmann, Pons and Hawkins (FPH) and others in their electrolysis experiments. In the surface reaction mechanism, deuterium (D-D) fusion takes place in the surface zone of Pd cathode where whiskers of metal deuterides (PdD and/or LiD) are formed in electrolysis experiments. These whiskers are known to occupy the surface zone of greater than or approximately equal to 10 mm thickness, where most of the $D_2$ and $O_2$ gases are formed from the dissociation of $D_2O$. Depending on electrolysis conditions, many spherical and hemispherical $D_2$ gas bubbles of varying sizes (radii ranging from few mictrometers to few mm) will be produced continuously in the surface whisker zone and will stay there for certain time durations before they move out of the electrolysis cell. Most of these $D_2$ gas bubbles in the surface whisker zone will have whiskers protruding into the bubbles creating field emissions potentials around the tips of whiskers. The average potential in each $D_2$ bubble is expected to be approximately that of the applied potential of the electrolysis cell, but the electric field near the whisker tips can be several orders of magnitude larger than the average, as is well known from field emission studies. Due to this electric field, $D^+$ ions in the bubble will gain kinetic energies with a statistical distribution which depends on the bubble size and values of the varying electric field inside the bubble. When the applied potential is 1 to ~10eV, which may be sufficient to achieve the observed reaction rates of $10^{-10\text{ to}} \sim 10^{-23}$ sec $^{\sim 1}$ per D-D pair. Experimental tests of the proposed mechanism for cold fusion are discussed. Other nuclear reactions including neutron-induced reaction, which may occur subsequent to and concurrent with the D-D fusion during electrolysis, are also discussed.

REPORTER'S COMMENTARY

Note: The above three papers from Purdue with Professor Yeong Kim as the author or co-author were all scheduled to be presented within a thirty-minute period. Prof. Kim summarized the three papers with the emphasis being on "Surface Reaction Mechanism for Cold Fusion with Electrolysis".

During the past year there have been many papers calculating the probability for adjacent deuterons in a crystalline lattice to "tunnel" or fuse. In all cases, the results obtained showed that such fusion events were improbable -- as would be expected by experimenters. Professor Kim et al have been working with more realistic approaches. They have calculated the probabilities for the "hopping" or itinerant deuteron to fuse with deuterons already located in interstitial potential wells in a lattice. In addition, they have investigated the validity of using high-energy reaction rates extrapolated to the low-energy environment of a crystalline lattice at near room temperatures. Their findings clearly show that higher probabilities of fusion is expected and that it is invalid to expect the branching ratios of low-energy cold fusion to be the same as previously observed in high-energy plasma physics. These papers and their references are highly recommended due to the strong criticisms that have been leveled against cold fusion because of the lack of observation of equal numbers of neutrons and tritium reactions.

This last paper by Dr. Yeong Kim appears to support the view, advanced by Bockris, that the dendritic structure on a cathode can support nuclear events. In his summary statement, Dr. Kim made the point that the electron screening effect (in promoting fusion) is the savior of the physicist. This electron screening effect may explain the suppression of the neutron/tritium branching ratio so well known in plasma physics. Kim urges more careful measurement of the d + d reaction cross sections at low temperatures in the cold fusion environment.

**RESEARCH DIRECTION-MILEY**

George H. Miley, Magdi Ragheb and Heinrich Hora, (Univ. of Illinois/Urbana), "On Aspects of Nuclear Products", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

An ultimate goal for nuclear product diagnostics is the simultaneous measurement, in real time, of the product emission rates. A correlation with heating rates should then be possible. This information, when combined with theory should lead to a clear understanding of the mechanism involved in various cold fusion cells.

In this presentation, we consider a number of possible reaction products that should be considered. The various combinations proposed are justified by a review of current experimental data as well as predictions from various theoretical models. Experiments to date have generally focused on tritium and neutron measurements. Some work has also begun to examine possible palladium isotopes transmutation. Definitive measurements of possible helium production as well as X-ray and gamma emission are badly needed. The implications of these various observations relative to current reaction models will be discussed.

REPORTER'S COMMENRARY

Dr. George Miley, the esteemed editor of *FUSION TECNHOLOGY*, suggested that the continuing interaction between experimental data and theory should continue and will lead to maturity of this new field of science. The great advantage of the low-entry cost and the relatively low cost (in time and money) for additional experiments leads to lots of experimental data (as compared to the cost and difficulty of obtaining data in plasma physics).

Further measurements are need to measure neutrons, gamma rays, X-Rays, protons, helium 3, helium 4, etc. In addition, some careful measurements should be made concerning the suggested lithium and palladium transmutations. Autoradiography is suggested as extensions to current measurements.

The experimental data suggest that the nuclear events which produce either tritium or neutrons account for less than 3% of the observed excess heat (heat not generated by the input electrical energy). It is important to more closely identify the nuclear reactions and the rate of each type of nuclear reaction. Specifically, D or neutron tunneling needs more experimental investigation as does the possible D + D + ? --> $^{4}$He + ?. The role of lithium, such as in a D + Li reaction needs careful study. Are reactions surface or bulk or both? If the reaction D + D --> $^{4}$He plus energy is real, how is the energy dissipated? Is there a consistent reaction of the type D + $^{n}$Pd -->Pd $^{n+1}$ + ? that is causing the change in palladium isotopic ratios?

In summary Miley relates that there is no consistent picture. There seem to be multiple mechanisms as reported in various carefully performed experiments. New diagnostic techniques are strongly needed.

**THEORY-BUSH**

Robert T. Bush (Cal State Ply Tech.), "Isotopic Mass Shifts in Cathodically-Driven Palladium via Neutron Transfer suggested by a Transmission Resonance Model to explicate enhanced Fusion Phenomena (Hot and Cold) within a Deuterated Matrix", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The transmission resonance model previously presented by the author to explicate cold fusion phenomena is now extended to treat the full range of **enhanced fusion phenomena**, from **"hot" to cold"**, within a deuterated matrix. Such seemingly disparate experiments as those involving neutron emission, electrolytic cold fusion, and "cluster-impact" fusion (i.e., hot fusion within a lattice), may share transmission of de Broglie waves within a deuterated matrix. A new phenomenon is suggested: **"transmission resonance: assisted neutron transfer"**, which, in its effect, is essentially equivalent to **Teller's hypothesized "catalytic neutron transfer"**, and gives added support to a research suggestion of Teller.

REPORTER'S COMMENTARY

Dr. Bush's presentation is an advance over his first cold fusion theory paper [1]. Much attention has been given to the particle nature of possible cold-fusion nuclear reactions. Bush's approach in dealing with the wave nature of such reactions in the presence of the regularities of a crystal lattice has considerable merit.

His suggestion that the following reactions should be considered is challenging:
$^{6}$Li + D --> 2$^{4}$He + energy
$^{7}$Li + D --> $^{6}$Li + T + energy
D + $^{n}$Pd --> $^{n+1}$Pd + proton.

Dr. Bush's paper is highly recommended to experimenters. Bush has come up with several ideas that can be tested experimentally.

[1] Dr. R.T. Bush (Cal State Polytech, Pomona), "A Transmission Resonance Model for Cold Fusion.", Presented at COLD FUSION - A STATUS REPORT session in conjunction with the ASME Winter Annual Meeting held in San Francisco, CA December 12, 1989.

**PELTIER-EFFECT CALORIMETER-DROEGE**

Thomas F. Droege and Lee John Droege (Batavia, Ill.), "A Zero Gradient Calorimeter for the Measurement of Anomalous Heat from the Electrolysis of Deuterated Metals", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

A calorimeter has been constructed using Peltier devices which measures integrated energy through a null balance technique. Two insulated concentric thermally conductive shells are servoed to the same constant temperature. A Peltier device pumps a constant amount of heat between the inner and outer shells. The inner shell is servoed by a balancing heater. The outer shell is servoed by a second Peltier device which removes heat to a water cooled heat sink. Heat applied to a test device in the inner shell can be observed as a drop in the balancing heater. Anomalous heat is observed when the EI power

of the cell does not match the loss of balancing heater power.

The entire experiment is operated by an automated control system. A first level analogue computer controls the calorimeter servomechanisms. A second level digital computer monitors the experiment and collects data.

The test cells are run as closed systems. A sensitive servo controlled gas burette continuously measures the gas evolution. A four point resistance probe measures the resistance of the Palladium cathode at several current levels at ten minute intervals. A one-inch NaI(TI) photomultiplier counter system measures radiation. Fifteen other parameters are continuously recorded.

At Santa Fe, Garwin proposed that there may be a problem in measuring cell power. We have tested this hypothesis.

The cell can be operated so that an energy balance can be maintained through the entire run. Figure 1 is a typical run. The upper curve is the applied current. The lower curve, in Joules, shows the energy balance through the run. Negative numbers on this curve are excess energy. The data is shown as collected without any corrections.

The paper will discuss the calorimeter design, measurements of anomalous heat, sample resistance, net gas, and a test of the Garwin hypothesis.

REPORTER'S COMMENTARY

The use of the Peltier devices appears to be an excellent method for measuring energy flows in a calorimeter. The whole paper is recommended to those who do not have suitable calorimeters for performing experimental investigations in cold fusion.

**Pd MODEL-BUNCH**

K.J. Bunch and R.W. Grow (U/U, National Cold Fusion Institute), "Electric Field Distribution of the Palladium Crystal Lattice", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Palladium has always been a metal of interest for its hydrogen absorption qualities and, more recently, for its use in cold fusion experiments. An atomic model of the metallic crystal would give a better overall understanding of the palladium based on solving the three-dimensional Scrödinger equation is a major undertaking that is probably unnecessary for calculating many useful characteristics of palladium. A simpler approach, based on the Thomas Fermi model for palladium, is proposed by the authors. This semiclassical model averages the effects of all the electrons within an atom to approximate the electric field distribution everywhere. Overlapping these distributions approximates the electric fields within the palladium crystal. This model predicts a crystal that is a bit too stiff, but overall it gives reasonable results; it is also simple to use. It is expected that this model will broaden the understanding of the interaction of hydrogen with palladium.

REPORTER'S COMMENTARY

This model will probably be improved. To those interested in atomic models, the following 4 papers previously mentioned in Fusion Facts are recommended.

[1] Norman D. Cook (Oxford) and Valerio Dallacasa (Parma U.), "Face-centered-cubic solid-phase theory of the nucleus", *Physical Review C*, Vol 35, No. 5, pages 1883-1889, May 1987.

[2] H. Aspden (The Univ, Southampton), "The No-neutron Deuteron?", *Fusion Facts,* Vol 1, No. 9, pages 1-6, March 1990.

[3] H. Aspden, "The Theoretical Nature of the Neutron and the Deuteron", *Hadronic Journal*, Vol 9, pages 129-136, 1986.

[4] H. Aspden, "The Supergraviton and its Technological Connection", *Spec. Sc. Tech.* Vol. 12, pages 179-185, 1989.

**STATUS REPORT-WORLEDGE**

David H. Worledge (EPRI), "Technical Status of Cold Fusion Results", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Experimental results in cold fusion research up to the end of 1989 are reviewed to gain a perspective on the credibility of the phenomena. The review does not attempt to be comprehensive but concentrates on the highest quality experiments claiming to give results. The results are used to formulate a strategy for continuing to support cold fusion research in 1990.

REPORTER'S COMMENTARY

Dr. David Worledge reviewed the results of cold fusion research in general and especially that funded by EPRI at Texas A&M, Stanford, and SRI.

Research work funded by EPRI began in April 1989 at Texas A&M and at SRI. Tritium at high levels was reported by seven labs in over 22 cells and in many more experiments at low levels above background. The tritium evidence is strong.

Neutrons have been measured by Frascatti, BYU, LANL, Texas A&M, BARC, and others. Many cells have produced some neutrons above background. The evidence for neutron production is not as robust as evidence for tritium.

Excess heat has been observed by McKubre (SRI), Huggins (Stanford), Appleby (Texas A&M), Hutchinson (Oak Ridge), Oriani (Minnesota), Yeager (Case Western) and others. Too many questions have been raised to heighten confidence.

In all cases, the major problem is the lack of reproducibility. **The lack of reproducibility destroys the confidence of the scientific community.**

Worledge suggested the following:

* Quit trying to verify the Fleischmann-Pons Experiment.
* Focus on reproducibility.
* Improve the nuclear measurement diagnostics.
* Pay especial attention to surface chemistry and to metallurgy.
* Provide benchmark measurements for excess heat -- exchange promising materials.
* To conserve funds well planned short experiments are favored.
* Look beyond the electrolytic phenomena.
* Increase collaboration with Universities and National Laboratories.

In summary, the bottom line is:

* Nuclear reactions are not PROVED.
* Don't quit.
* Don't hold your breath for commercial applications.
* Do good science.

During the question period the following comments were made: Some palladium is delivered with helium in the palladium. Evolved helium may escape in the evolved gas if it is a result of surface reactions.

EPRI expects to spend $1-2 million in 1990 on cold fusion. No one is aware of any industrial results that would change the current review of cold fusion as presented. Dr. Hoffman, Rockwell, emphasized that the detection threshold for helium is about $10^{11}$ atoms per gram of Pd.

Dr. Worledge's comments about the lack of reproducibility destroying the confidence of the scientific community touched off a vigorous discussion lead by Dr. Giuliano Preparata of Milano, Italy. Dr. Preparata stated that if reproducibility was required to be good science, that biochemistry would not exist as a science. See editorial comments on Scientific Facts and the Scientific Process.

**EXPERIMENTS-ADZIC**

R. Adzic, D. Gervasio, I. Bae, B. Cahan and E. Yeager (Case Western Reserve Univ.), "Investigation of Phenomena Related to $D_2O$ Electrolysis at a Palladium Cathode", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Measurements have been performed to check on the Fleischmann-Pons phenomenon. They involved calorimetric measurements in a glass cell of the type used by Fleischmann and Pons and also a battery-type Tronac calorimeter, determination on the D/Pd ratio by coulometry, Li determination in the Pd electrode and neutron radiation measurements. The total energy balance of a closed cell obtained with the Tronac calorimeter showed small excess heat production over an extended period for Pd in LiOD in two cells. No excess heat was found with Pd in LiOH and Pt in LiOD. A large excess heat, 20-45%, was found over an extended period of time with one open cell with Johnson-Matthey Pd rod 4mm in diameter. Experiments are in progress with several new cells with LiOD and LiOH in order to obtain satisfactory statistics. Enhancement of tritium was found in this cell, as well as in four other cells, three with Ni anodes. The largest enhancement factor of 40 (calculated as the ratio of the electrolyte sample and $D_2O$ net count rates) was found with 0.5 mm Pd wire in a cell with 0.1 M LiOD and Ni anode. The D/Pd ratio was 1:1 for 0.25 mm wire. Li was found to penetrate 200 nm into Pd bulk. The neutron measurements were inconclusive. (Research supported by grants from NASA, Lewis and ONR.)

REPORTER'S COMMENTARY

The author mentioned the use of Prototech and Chalk River catalysts for the recombining of the evolved gases in their closed cell experiments. Data was also given on the daily measurements of tritium which was well above

background or above the levels expected by electrolysis in several cells.

SIMS (secondary ion mass spectrometry) measurements of the cathode found both nickel and lithium in the near-surface region.

In a conversation with Prof. E. Yeager, he stressed the importance of and the capability of Case Western in doing experimental work on cathode surface effects.

Dr. M. Fleischmann noted that the largest production of tritium can be expected in the 30 to 40 degree C region of cell operation.

**ANALYTICAL-ROLLISON**

Debra R. Rollison, William E. O'Grady, Robert J. Doyle, Jr. and Patricia P. Trzaskoma (Naval Research Lab), "Anomalies in the Surface Analysis of Deuterated Palladium", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The surface and near-surface analytical characterization of thin palladium foils after the electrolysis of $H_2O$ or $D_2O$ was performed with X-ray photoelectron spectroscopy (XPS), high resolution mass spectrometry, time-of-flight secondary ion mass spectrometry (TOF-SIMS), and scanning electron microscopy (SEM). These surface characterizations revealed a number of anomalous results, as summarized below.

All electrolyses were performed, with one exception, in 0.1 F $Li_2SO_4/D_2O$ or $H_2O$, as appropriate. The one exception was a solution of 0.1F LiOD in $D_2O$ prepared from dissolving lithium metal $D_2O$. All electrolyses were performed with 99.9% Pd foil, 0.127-mm thick. The foils were acid etched in 1:1 HCCL:HNO3 to remove surface oxide, rinsed well, and then sonicated in the appropriate solvent prior to electrochemical use. The anode was 99.999% Pt wire wound around a glass-rod cage so as to concentrically surround the Pd cathode. The Pd foils were cathodically charged at 10 mA/cm$^2$; higher current densities were then usually applied.

Atomic emission analysis of the stock Pd foils showed significant concentrations of the following metals: Ni (200-300 ppm); Pt(200 ppm); Rh(50 ppm); Cu(50 ppm); and Si (20-40 ppm). These metals are present at a concentration below the limit of detection by XPS, yet after electrolysis of $D_2O$ or $H_2O$, Rh and Ag were found to be present at the surface maximizing at concentrations of 3 and 1 atom%, respectively. It was shown that the Rh and Ag were not electrodeposited, but rather concentrated towards the interface as a function of the long duration and high accumulated charge of the electrolysis. As Ag and Rh were apparent at the surface of Pd charged in either $D_2O$ or $H_20$, a mechanism based on electromigration and forced diffusion as the Pd lattice is filled with H· or D· seems more probable than one relying on known neutron activation reactions of Pd isotopes which yield stable Ag and Rh isotopes.

TOF-SIMS measurements of the Pd blank (the Pd starting material prior to electrolysis) and PD electrolyzed in $H_2O$ yielded mass-to-charge vs. amu intensities which mirrored the expected sequence for the stable Pd isotopes (neglecting the 1.02% abundant $^{102}$Pd). The ideal abundances are:

$^{104}$Pd ..... 10.97%
$^{105}$Pd ..... 22.23%
$^{106}$Pd ..... 27.33%
$^{108}$Pd ..... 26.71%
$^{110}$Pd ..... 11.81%

Two samples electrolyzed in $D_2O$ exhibited greater than 20% enrichments in m/z 106 intensity and diminuations in m/z 105 intensity. This result is provocative because of the implication that $^{105}$Pd obtained a neutron to generate $^{106}$Pd. The more startling enrichment/diminuation was observed for the one sample electrolyzed in LiOD; an enrichment of ~45% was observed for one sample electrolyzed in $Li_2SO_4$. It was shown using the Pd blanks and the sample used to electrolyze $H_2O$ that the conditions of the TOF-SIMS measurements were not responsible for the enrichment/diminuation phenomena.

Subsequent fast-atom bombardment, high-resolution mass spectrometric measurements on the LiOD sample replicated the TOF-SIMS results, however, mass selecting the ions at m/z 106 and using collisional-induced dissociation (with He neutrals) showed a loss of oxygen atoms indicating that the intensity at m/z 106 was compromised by the presence of polyatomic ions. It was shown that the species was $^{90}Zr^{16}O$, a species with a nearly coincident mass to $^{106}$Pd. The $Li_2SO_4$-derived, $^{106}$Pd-enriched sample was Zr-free according to TOF-SIMS data, unfortunately, it no longer existed in a form compatible with surface-sensitive high resolution mass spectrometry. Other Pd foils used to electrolyze $D_2O$ have shown a normal Pd isotopic distribution by the high resolution mass spectrometry. The source of the anomaly in the Pd isotopic distribution of the one $Li_2SO_4$-derived sample remains unexplained.

SEM has been used to explore Pd foil (sufficiently etched to leave visible crystal grains) and the foils obtained after electrolyzing $H_2O$ and $D_2O$ from pieces of the etched stock. The surface morphology changes, as expected, after electrolysis, however, the resulting morphologies are quite

different between H- and D-exposed Pd. Cracks and fissures do not appear to be part of the morphology after electrolysis for either system. In addition, again using a common starting piece of etched Pd foil, the differences in the surface morphology as a function of total accumulated charge and the number of outgassing events after $D_2O$ electrolysis has been studied.

REPORTER'S COMMENTARY

Dr. Debra Rollison also reported an increase of Ag with electrolysis with the possibility of Ag coming from the Pd and perhaps migrating toward the surface. There also appears to be an enrichment of the Rh near the surface.

Photographs were shown of active grains in the Pd being uplifted. The uplift appear to result with the first outgassing event from the Pd.

Dr. Nate Hoffman says that Dr. Rollison's work is some of the most important work being done to better understand this new technology. He also related that the Rh is found "on top of a lot of crud" on the Pd surface.

The author stated that more work would be done, especially in determining the true nature of any isotopic changes in the palladium. It is important, for these investigations, to determine the isotopic ratios of palladium prior to the use of the Pd as an electrode for later comparative measurements. The isotopic ratios of both Li and Pd vary greatly with the source of the materials.

Note: This was one of the best professional presentations given at the conference. Dr. Rollison's work will be following with great interest. Ed.

**EPRI OVERVIEW-SCHBEIDER**

Thomas R. Schneider (EPRI), "Anomalous Effects in Deuterated Metals" *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Since last March, EPRI has been working to understand the "cold fusion" phenomena originally reported by Fleischmann and Pons of the University of Utah and Steve Jones of Brigham Young University. This effort has led to EPRI sponsorship of ongoing research at Texas A&M and Stanford Universities, SRI International and Rocketdyne ETAC. The anomalous results of experiments on deuterated metals conducted by these and other organizations prompted EPRI and the National Science Foundation to hold a joint research workshop on cold fusion October 16-18 in Washington, D.C.

Drs Edward Teller and Martin Fleischmann served as keynote speakers for the workshop, which was attended by about 50 scientists actively involved in the studies of the cold fusion phenomena. Dr. John Appleby of Texas A&M and Dr.Paul Chu of the University of Houston served as Co-chairmen. The purpose of the meeting was to identify research issues essential to understanding the phenomena. Conclusions reached by workshop participants were summarized by Appleby and Chu in a brief announcement, excerpted below:

"New, positive results of excess heat production and nuclear product generation were presented and reviewed in a logical, frank, open, and orderly manner. Based on the information we have, these effects cannot be explained as a result of artifacts, equipment, or human errors. However, (their) predictability and reproducibility...and possible correlations among (them)...are still lacking. Given the potential significance of the problem, further research to improve reproducibility... and to unravel the mystery of the observations is definitely desired.

"This paper will review the results of the conference and highlight the key research issues identified during the discussion at the conference."

* * * * * * *

**PANEL DISCUSSION - NUCLEAR PHENOMENA**

This panel was moderated by Dr. H. Rossi (U/U) and included the following: Dr. Padmanabha K. Iyengar (Director of BARC), Dr. Nate Hoffman (Rockwell), Dr. J. O'M. Bockris (Texas A&M), Dr. Steven Jones (BYU), Dr. Tom Schneider (EPRI), Dr. Charles D. Scott (ORNL), and Dr. Howard Menlove (LANL).

INTRODUCTORY REMARKS

Dr. Iyengar stated that there are many nuclear phenomena that cannot be explained. Small plasmas internal to the cathode may be part of the phenomena. The electron stream in the Pd cathode may be responsible for some of the phenomena observed. It will proably require a new theory in nuclear physics to be developed.

Dr. Nate Hoffman noted that there was much information and data that has now been obtained. It is important to achieve the state where the observed reactions can be

produced at will. Some palladium cathodes were found to have micron-sized holes that penetrated the surface thought to be associated with helium 4. Due to lack of precise knowledge of the palladium cathodes before experimentation began, some of the experiments have been flawed for lack of suitable pre- and post-data comparisons.

Dr. Harold Menlove noted that the nuclear events for cold fusion are reproducible but not predictable. Large excursions are rare events but there are lots of small events. The observed processes apparently involve non-equilibrium transient behavior.

Dr. Scott stated that it is obvious that the electrode preparation is very important. Various experiments have measured excess power, tritium and neutron production, and even gamma and soft X-Rays. It is important to establish the coupling between the observed measurements and the reactions. It is important to initiate and extend the measurements of these and new phenomena with each being studied individually. It is useful to look at many phenomena at the same time. The appearance of excess power or energy is important and must be looked for in all experiments. It is useful to look for tritium on a periodic basis. Other possible reaction products (particles) should also be looked for. Closed systems are desirable, the tritium effects last longer. There is a potential for enhancing the production and measurements for $^{3}He$ and $^{4}He$ in understanding the surface reactions.

Dr. Jones displayed a chart where tritium was measured over the course of a year. Data for two years were shown (1972 and 1976). Especially significant was the strong increase in tritium over a ninety-day period in the vicinity of an erupting Hawaiian volcano (Ulu). In 1986 Jones and Palmer discussed the possible existence of cold fusion under geological conditions. Since then, they have taken samples of volcanic-produced tritium. They now have a DoE funded study underway.

Dr. Schneider observed that more than a deuterium reaction may be occurring. Lithium and tritium may also be involved in nuclear reactions that are involved with the production of heat.

Dr. Bockris noted that the continuation of the production of heat for some time after the $D_2O$ was replaced with $H_2O$ was an important observation. This observation suggests that the excess heat is a bulk effect and not a surface effect. In the discussion of the potential large voltages (unbelievable to some) that can occur in the vicinities of dendrites on the surface of the cathode, Dr. Yeong Kim has provided calculations indicating the validity of this effect. Bockris suggested the importance of making long-term measures for tritium, neutrons, and heat. Cells may need a considerable time before these reactions are observed. Correlation of observed nuclear products are important.

QUESTIONS TO THE PANEL:

Has the tritium/neutron branching ratios been measured in volcanic activities. Jones said no. Experiments are now being devised to measure tritium and protons at the same time to answer that question. It was also suggested that in earth-related studies that the water below the ocean thermocline might have a different oxygen isotopic ratio than rain water as has been shown for magmatic water.

John Marshall suggested that the same type of etching used in the study of meteorites might be of use in the study of volcanic rock. Dr. Wilford Hansen (USU) asked

1. Can we say that tritium has been produced? and
2. Is it true that the excess heat cannot be explained by chemistry?

Dr. Bockris said that it is very probable that the answer is yes to the production of tritium. Dr. Menlove stated Yes to 1. and observed that 15 labs have now produced tritium in electrochemical cells. Bockris stated that the excess heat cannot be explained by chemistry. Dr. Iyengar asked, "Who has proved that tritium cannot be produced by cold fusion?" Dr. Hoffman stated that nuclear reactions are highly probably.

In a discussion concerning the measurment of nuclear "ashes" or byproducts Bockris noted that they had not measured gamma or X-Rays simultaneously with other events. It was noted that if the production of heat versus tritium was a bulk versus surface phenomena that there could be a large difference to be noted as a function of the cathode radius. It was asked if anyone had noted that excess heat was a function of cathode radius. Bockris stated that the thinner cathodes appeared to be better heat producers than cathodes of larger diameter.

Steven Kellog of Cal Tech noted that he had heard so many impossible things and that some were conflicting and asked, "Which of you is wrong?" No experimentalist volunteered.

In discussions about the $H_2O$ quenching of cold fusion events, Dr. Scott said, "Don't be so severe on experimnetalists so early in the game." There have been some experiments that shown a rapid queching of excess heat with the addition of $H_2O$ while at least one has measured continuation of excess heat for hours after the $D_2O$ was replaced with $H_2O$. It may be a function of electrode size.

Dr. Preparata (Milan) urged that we do not compare things are incomparable. The system is very complicated. We don't really know what reproducibility means. We cannot expect surface and bulk phenomena to be compared together. The presence of tritium (or heat) clearly cannot be chemical [after viewing the numerous careful experiments]. Preparata suggested that the world is looking at us in this conference. The panel should tell the world that cold fusion (as defined by J. Swinger (nuclear processes in an atomic lattice) has been proved to be real. The evidence is ample. **The world should be informed that cold fusion is real beyond reasonable doubt.**

Dr. Richard Petrasso (MIT) asked about the simultaneous measurements of tritium and heat. Bockris answered that tritium is measured periodically (once a day or every few hours) and that bursts of heat occur unexpectedly. So far they have not made simultaneous measurements. Dr. Rossi (U/U) stated that careful time analyses are needed.

## CONTROL THEORY-BASS

Robert W. Bass, (Registered Patent Agent), "On Empirical System ID, Possible External Electromagnetic/Electronuclear Stimulation/Actuation and Automatic Feedback Control of Cold Fusion", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

### ABSTRACT

This paper reviews some basic results from modern systems theory, which may prove useful to experimenters researching the cold fusion phenomenon from the point of view of attempting to learn how to stimulate, initiate, regulate, control by command at will and terminate excess enthalpy, rate of tritium production, neutron count, etc.

Empirical System ID Technology regards an unknown system, to which information-theoretic signals or inputs may be injected, and from which responding outputs may be recorded, as an "arbitrary black box". There are many procedures for performing systematic input-output testing from which the internal dynamics of the unknown processes in the box may be inferred. There are available System ID software packages for processing the data produced by input-output experiments, and then using other software packages in the CACE (Computer Aided Control Engineering) category to design automatic feedback control systems which can be implemented by means of a Controller or Control Computer that converts the system into a closed-loop system by means of processing the output signals to generate appropriate input signals which will regulate the state of the process at a given set-point, or drive it toward a varying state in response to dynamic commands.

This procedure can be applied to a Fleischmann-Pons electrochemical cell as follows. Introduce in proximity to the cathode one or more actuators selected from the category of all possible external physical stimuli whose effects are to be studied. Such a stimulus might be electrical (e.g., additional resistive heating of the electrolyte and/or electrodes, or an external electrostatic field, or external radiant heating), or magnetic (e.g., an external static magnetic field), or electromagnetic (e.g., ion or electron cyclotron-resonant heating), or electronuclear (e.g., high-voltage, fast-switch-triggered neutron flashers), etc. The system inputs will be the signals controlling such an actuator suite.

Now install a sensor suite comprising one or more measuring instruments selected to monitor the cell's physical properties of interest. Such monitors might include a continuous measurement of excess enthalpy, temperature of either electrode or electrolyte, rate of tritium production, neutron count, etc. The signals from these sensors constitute the system's output.

Suppose that the system is near a steady state ("autonomy"), and that small inputs give small outputs ("linearizability near equilibrium"). Suppose there are I outputs, m inputs, and that in addition to the preceding hypothesis the unknown process dynamic is either "finite dimensional" or adequately so approximable. Then according to the Ho-Kalman Lemma there must exist a finite integer n, and constant matrices F,G,H of dimensions respectively nxn, nxm, Ixn such that the unknown process can be characterized for control purposes by the Ixm matrix of scaler transfer functions $T_{ij}$ or transfer matrix $T(s) = H(sI_n - F)^{-1}G$.

This paper by a systems engineer will outline to experimenters available automatic data-reduction procedures (e.g., the MATLAB State Space Identification Toolkit) for determining the matrices (F,G,H) from records or systematic input-output experiments and available automatic synthesis procedures (e.g., the MATLAB Robust Control Toolkit) for designing an optimal controller C(s) to close the loop via feedback control.

### REPORTER'S COMNMENTARY

As future engineers and scientists review the papers presented at this conference, they will find Dr. Bass's paper to be of considerable interest. One may think that the discussion of feedback servo-control system technology at this state in the development of cold fusion is premature. However, in light of some of the rapid events that are being made, we suggest that it is most

appropriate that some of our best minds start devoting time and talent to this important subject.

The knowledge that the Ho-Kalman Lemma exists as a powerful tool for the development of servo-control systems is an important contribution to control system engineering. The information presented by Dr. Bass concerning the MATLAB State Space Identification Toolkit is also of considerable importance. We hope that Dr. Bass will provide us with some future specific examples for Fusion Control Systems where such parameters as temperature, pressure, electrolyte level, etc. are used as inputs to control a desired energy output of a cold fusion power system.

**GAS-LOADING EXPERIMENTS-MENLOVE**

H.O. Menlove, (Los Alamos National Laboratory), "High Sensitivity Measurements of Neutron Emission From Ti Metal in Pressurized $D_2$ Gas", *Proceedings of The First Annual Conference on Cold Fusion,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

Recent measurements of neutron emission from Ti metal in pressurized $D_2$ gas have established the multiplicity distribution of neutron bursts emitted from the samples. A new $^3$He detector system with high sensitivity has been used to lower the detection limit so that small bursts emitting from 2-10 neutrons can be distinguished from the cosmic ray background. The frequency distribution of the neutrons indicate that the lower multiplicities occur much more frequently than the higher multiplicities.

The improved sensitive in our new detector system was obtained by using low radioactive background stainless steel tubes, a small detector volume with high efficiency, and additional cosmic ray shielding. The detector consists of two independent segments making up inner and outer rings of $^3$He tubes. The inner detector has nine $^3$He tubes (2.5 x 30 cm) and the outer detector has forty-two $^3$He tubes 2.5 x 50 cm). The combined total efficiency is 44%. The low background inner detector has singles count background of 97 counts/h and a coincidence count background of only 0.67 counts/h. The corresponding singles efficiency (2.3 MeV neutrons) is 19% and the coincidence efficiency is 3.6%. This system has been used to detect low multiplicity neutron emissions from samples where the yield is 5-10 times larger than the background level for intervals of many hours. This improved sensitivity makes it possible to monitor the neutron yield characteristics of samples at much lower level than was previously possible. We have shown that the most frequent events emit neutrons with 1-10 n and the larger burst events 20-200 n occur much less frequently. The data is useful in establishing a physical model for the neutron emission mechanism.

REPORTER'S COMMENTARY

Dr. Menlove reported that the best results have been obtained when the titanium chips were loaded with deuterium at liquid nitrogen temperatures and then allowed to warm up slowly over a period of two days. Many single neutron events occur but the results show considerable multiple bursts of neutrons.

This work at LANL definitely confirms the previous work of Jones et al. The summary noted that most of the events occur at about -30 deg C (as predicted by Bush's theory). The mechanism for the nuclear events has not been identified. Future work will use D + T, and H + T in the gas loading.

**THIN FILM FUSION-CHAMBERS**

George Chambers, Graham Hubler and Ken Grabowski, (Naval Research Lab), "An Investigation of Cold Fusion in Thin Titanium Films", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The source of heat in the cold fusion experiments of Pons and Fleischmann has been hypothesized to arise from an as yet unidentified nuclear reaction. If this is the case, it must involve the emission of charged energetic particles (such as protons, tritons or $^3$He), since the traditional reaction paths would all produce great amounts of easily detectable neutrons, and gamma rays. With this in mind, an effort has been made to create cold fusion in thin films of titanium under low energy (300-400 eV) deuterium ion bombardment in a vacuum chamber. Deuterium ions are produced by extraction from a plasma produced in a Microscience electron cyclotron resonance (ECR) source. The sample is monitored during bombardment with a silicon particle detector in order to detect possible charged energetic reaction products. The films are deposited by vacuum evaporation onto thin (3.8 um) nickel foils. Full spectra will be presented, including background and control experiments, along with an analysis of possible causes of both real and spurious counts.

REPORTER'S COMMENTARY

In his presentation, George Chambers stated that both hydrogen and deuterium were used in the bombardment of the Ti films. Meaningful results were obtained only when deuterium was used. In one case a measured 9,020 counts occurred in the channel representing 2.9 MeV. It was reported that the measurements made were a function

of the bias voltage on the instruments. See the full paper for more details.

**THEORY-HANDEL**

Peter H. Handel, (Univ. of Missouri), "Reformulation of the Cold Fusion Problem", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The cold fusion problem is reformulated in a way which allows for a qualitative understanding of both the unexpectedly large fusion rate, and its observed intermittency in electrolytic cells. The new notions introduced allow us to predict a class of optimal electrode materials, and to develop an understanding of the absence of neutrons and y-rays.

REPORTER'S COMMENTARY

The author reformulates the cold fusion problem with emphasis on 1. the surface tension barrier in the bubbles of the evolved gases from the electrodes. 2. To consider the heavy fermion contribution to fusion rate and the increased effective contribution of the electrons. and 3. Neutron tunneling in the collective mode. The author shows that his approach provides large equivalent pressures.

**THEORY-ANDERMAN**

G. Andermann, (Univ. of Hawaii), "A Theoretical Model (Nu-Q) for Rationalizing Electrochemically Induced Nuclear Events Observed in Deuterium Loaded Pd Cathodes", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

To date theoretical treatments of high energy nuclear events in electrochemically induced cold fusion in deuterium pressurized Pd cathodes have relied on a wide variety of models involving deuteron-deuteron fusion in spite of the forbidding Coulomb repulsion. No detailed nor satisfactory theoretical explanations have been offered for the low energy phenomena. The theoretical model proposed here is based on the formation of a new neutral particle, namely two bound neutrons, designated as Neutrium (Nu). It is postulated that Nu, under favorable conditions, may be absorbed by a deuteron to yield quatrium (Q), where Q decays to produce various high energy nuclear events. Nu can be shown to provide plausible explanations for the achievement or non-achievement of various high energy events. The model also calls for the possibility of Nu being absorbed by Pd or other heavy nuclei.

REPORTER'S COMMENTARY

The interesting speculation that palladium could absorb a Nu or a Q and produce a higher number isotope of Pd is subject to some experimental measurements. It will be interesting to follow the expected increased series of measurements of pre- and post-experiments ratios of Pd isotopes. Ed.

**ANALYTICAL-THOMPSON**

D.R. Coupland, M.L. Doyle, J.W. Jenkins, J.H.F. Notton, R.J. Fotter, and D.T. Thompson, (Johnson Mathey Technology Center), "Some Observations Related to the Structure of Hydrogen and Deuterium in Palladium", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Analysis of palladium rods returned to JMTC from Utah by Fleischmann and Pons will be described:

Techniques used include Temperature Programmed Absorption/Desorption, SEM, XPES, TOF/SIMS, ICP Mass Spectrometry and Metallography, Complementary electrochemical experiments were performed to establish the influence of lithium on the palladium hydrogen system.

REPORTER'S COMMENTARY

Dr. Thompson reported that Fe, Cu, Pt, and Zn were all detected in performing surface analysis on Pons-Fleischmann Pd cathodes subsequent to their use in electrolytical cold fusion cells. He also noted that there appeared to be some isotopic depletion of $^{6}Li$ with respect to $^{7}Li$.

**COMPUTER MODEL-CHAO**

J. Chao, W. Layman, C. Kang, Gur, M. Schreiber, R. Huggins, G. Lucier, J. Ferrante, (EPRI), "Three Dimensional Computer Simulation of an Isoperibolic Calorimeter for Cold Fusion Experiments", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The three dimensional heat conduction computer code HEATING was used to simulate the isoperibolic calorimeter being used for cold fusion experiments at Stanford University. The simulation results confirm the measured temperature distribution in the calorimeter. Computer analysis also demonstrates that temperature measurements for this particular calorimeter are independent of the heat source position in the calorimeter. A numerical procedure was developed to derive the transient behavior of the heat generation in the cold fusion cell from the transient temperature measurements. This procedure was exercised using a measured temperature pulse. The transient behavior of the power pulse was in the form of square-wave and its magnitude was slightly higher than the on-line calculation based on steady-state approach.

REPORTER'S COMMENTARY

In his conclusions Dr. Chao stated that the three-dimensional simulation confirms the following:

1. The steady-state 3-D temperature distribution in the calorimeter, and

2. That the transient response of the calorimeter is being properly simulated.

Chao stated that they have built a library of over 100 temperature styles for use with the calorimeter. These library programs are useful to make rapid calculations under various input heat events in the calorimeter.

**ANALYTICAL-GURUSWAMY**

S. Guruswamy and M.E. Wadsworth, (Univ. of Utah, NCFI), "Metallurgical Aspects of Cold Fusion Experiments", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Deuterium loading of palladium cathodes in Pons-Fleischmann type electrolytic cells has been observed to result in generation of excess heat on several occasions. Metallurgical examination of some of the electrodes show extensive damage associated with deuterium loading. Surfaces have been found to be covered with large number of impurities. Initiation and sustaining these heat bursts, monitoring of nuclear products and materials aspects of these electrolytic cells have been the focus of our current efforts. As D/Pd loading appear to be critical, the measurement of deuterium loading using dilatometry as a function of current density, surface and heat treatment of the cathode and poisoning are currently being investigated.

REPORTER'S COMMENTARY

The report by Dr. Guruswamy was a welcome addition to the conference as the paper provides some insight into the current studies being conducted at the National Cold Fusion Institute.

Dr. Guruswamy reports that the current focus in on the following:

* The use of quartz cells with an acrylic jacket.

* Laser doppler measurements for velocity of the evolved gases.

* The close monitoring of temperature excursions of a working cell.

* The modification and/or monitoring of variables such as current density, temperature, electrolyte composition, cathode "poisons", and events that initiate bursts of nuclear activity in the cell.
* Electrode purity including
-- Use of primary and recycled palladium
-- Interstitial impurities (C, O, N. H)
-- Electrolyte (C, S, Cu, etc.)
-- Electrode microstructure (grain structure, dislocation density and distribution.
-- The possible role of a third element in nuclear reactions.
-- Cell Design - electrode geometry, spacing, etc.

Guruswamy showed various slides and graphs including photos of damage in spent cathodes.

**EXPERIMENTS-MILES**

M.H. Miles, K.H. Park and D.E. Stilwell, (Naval Weapons Center), "Electrochemical Calorimetric Studies of the Cold Fusion Effect", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

Several types of calorimetric cell designs were used in attempts to measure excess enthalpy during the electrolysis of LiOD/$D_2O$ using palladium cathodes. Control experiments were run by using $H_2O$ in place of $D_2O$, platinum cathodes in place of palladium, or by reversing the direction of the cell current. Initial experiments using thin palladium cathodes of an unknown purity gave no

significant differences between the $Pd/D_2O$ cells and the controls. For example, the ratio of heat out to Joule heat in was 1.00 ±0.04 for another study in $LiOD/D_2O$ compared to 1.075 ±0.07 in $LiOH/H_2O$ much thicker palladium rod (99.96%, d = 0.635 cm) from Johnson Matthey, however, resulted in calorimetric evidence for excess enthalpy. The excess rate of heating averaged 0.39 $W/cm^3$ over a 9-day period. The total excess enthalpy observed was 110,000 J. This excess enthalpy is difficult to explain by chemical reactions. Similar experiments conducted in $H_2O$ did not produce significant amounts of excess enthalpy. Possible experimental errors in these calorimetric studies are being investigated.

REPORTER'S COMMENTARY

Dr. Miles reported that over a nine-day period, they measured excess heat of about 18%. This excess heat was equivalent to about 110,000 Joules. If the entire Pd rod had been oxidized the amount of heat generated would be about 6,200 Joules. Therefore, it would be difficult to assign the observed excess heat to chemical processes.

Miles calculated that 1 Watt = $1.55 \times 10^{12}$ fusions per second. The number of atoms of palladium per cubic centimeter is $6.97 \times 10^{22}$, therefore it would require 11 years for one percent of the palladium atoms to be converted from one isotope of Pd to another isotope if all of the neutrons theoretically resulting from classical fusion were to be absorbed in such a Pd transmutation.

**THEORY-CHENG**

Yi-Chen Cheng, W-Y P. Hwang and Shin Nan Yang, (National Taiwan Univ.), "Thoughts on Warm Fusion Versus Cold Fusion"†, *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

We propose a mechanism that may allow for the understanding of the cluster-impact fusion experiment of Beuhler, Friedlander and Friedman (Phys. Rev. Lett. 63, 1292 [1989]). Specifically, it is assumed that d+d nuclear fusion reactions take place through atom-atom collisions without ionization of both atoms, instead of simple Coulomb-barrier tunneling following the formation of $D_2$ molecules. It is also assumed that, upon impact, the deuterium atoms in the cluster projectile evolve according to the Boltzmann transport equation and, as the zeroth-order approximation, the distribution function is locally Maxwell-Boltzmann, i.e.,

$f(r,v,t) =$
$(M/2 \pi \times \theta)^{3/2} \exp[-M/2\theta (v-u)^2]$

with theta and **u** slowly varying functions of the position **r** and the time t.

REPORTER'S COMMENTARY

This theoretical paper by Dr. Yang was of interest in computing the expected values for the ion-cluster fusion experiments. Dr. Yang reported that clusters of 150 molecules of $D_2O$ were assumed as reasonable values. Data shows that the collisions gave more counts/minute than had been measured in similar experiments. It was especially strange that some counts were obtained at 100 eV, the author reported.

**CONFERENCE SUMMARY-FLEISCHMANN**

M. Fleischmann, (U. of Utah, NCFI), "Overview of Cold Fusion Phenomena", *Proceedings of The First Annual Conference on Cold Fusion*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah.

ABSTRACT

The generation of excess enthalpy (both at a steady state and in "bursts" of variable duration and amplitude) has now been observed in the Pd/D system by a variety of calorimetric techniques. This is also true for the generation of tritium and neutrons; the balance of evidence points to a branching ratio for these products which differs markedly from unity. The amounts of these nuclear products are normally extremely low compared to those corresponding to the enthalpy generated; a start has been made on the search for the missing nuclear reaction paths.

The bulk of the work on the Ti/D system has been concerned with gas loading experiments. Here again, the careful work on neutron counting (especially neutron bursts) points unequivocally to the operation of nuclear mechanisms.

A start has been made on the comprehensive theoretical description of both the ingoing and outgoing channels. The theories are already at the stage where useful predictions can be made.

The time is opportune to devise new experiments to explore the scope of these new nuclear phenomena.

REPORTER'S COMMENTARY

Dr. Martin Fleischmann thanked one of the conference participants for his apology to the conference for giving out incorrect information to a member of the press (N Y Times) on a misunderstanding of the manner in which Dr. Pons had been making calorimetric measurements.

Dr. Fleischmann noted that there had been historic presentations in noted journals that incorrectly labeled some new discoveries as being less than feasible. Nature has been previously incorrect in its editorial assessments of reality.

As a special summary of the meeting Dr. Fleischmann commented on the following:

* Excess Enthalpy -- has been observed by many laboratories who have taken great care to provide accurate data.

* Bursts in Enthalpy -- is noted by nearly all experimenters who successfully create a working cell.

* Tritium -- well proven to exist especially at TAM and BARC.

* Bursts in Tritium -- were observed by several experimenters.

* Neutrons -- well proven to exist by Jones and many others since.

* Bursts in Neutrons -- shown by many experimenters.

* X-Rays -- now being detected by experimenters.

* Bursts in X-Rays -- have been detected but more work is needed.

* Gamma-Rays -- have been observed.

* Bursts in Gamma-Rays -- Should be looked for by others.

* Nuclear Reaction Products -- an area that should receive additional investigation to determine more precisely the number and type of the nuclear reactions that are involved in cold fusion. The theory, especially coherent phenomena, should also be developed to be consistent with experimental data. Dr. Fleischmann also added two well-demonstrated nuclear particles:

The DUBIONS -- These particles seemed to be specific in energizing an attendee from Cal Tech and one from MIT to respond to most of the papers in order to point out perceived errors of science and judgement.

The MORRISONS -- [These energetic particles have been most helpful in touting the idea of pathological science to the extent that Dr. Morrison of CERN has almost single-handedly squelched any favorable work on cold fusion in any of the CERN countries. Ed.]

Richard Petrasso of MIT suggested that the SKEPTISON be added to the list of noted particles. The SKEPTISON is so powerful that it can completely mask the presence of the REALITON except in the presence of very large REALITON flux densities or when supported by the DENYITON.

**Dr. Fleischmann received a standing ovation for his dedication and perserverance.**

* * * * * * * * * *

**C. IMPORTANT CONFERENCE CONCEPTS**
By Dr. Dennis Cravens, Vernon College, Vernon, Texas.

The First Annual Cold Fusion Conference was filled with practical points and new ideas. The following items represent concepts gleaned from the conference that may not be easily found in conference abstracts or proceedings. These concepts may be helpful to readers who were not able to attend the conference.

1. LiOD readily absorbs $CO_2$ from the atmosphere to form lithium carbonate. This chemical change can be quickly monitored by measuring the pH of the electrolyte. NaOH/NaOD solutions can be used to scrub $CO_2$ out of the air to avoid $CO_2$ contaminations. With $Li_2SO_4$ as the electrolyte carbon dioxide absorption does not seem to be a problem.

2. For some unknown reason there has been a greater level of cold fusion successes using the Johnson-Matthey palladium than Pd from other suppliers. This result is a puzzle - as most of the Pd come from the same South African mining districts except for Pd stemming from recycled metals. There appears to be no large differences in the metallic elemental analysis of various Pd samples, however, the non-metallic contents may have small differences.

3. Oak Ridge National Laboratory (Dr. Scott) reported that after about 1,000 hours of no excess heat that thermal triggering used on a cell caused initiation of the production of excess heat. The temperature "trigger" was about 20 deg C (40's to 20's).

4. Several individuals indicated that the excess heat effect went away when $H_2O$ was exchanged for $D_2O$. The time lags ranged from minutes to several hours and seem to indicate times commensurate with diffusion of H into the metal lattice. This evidence suggests that the heat production stems from the bulk of the Pd cathode as contrasted with being a surface phenomenon.

5. McKubre (SRI) using a differential calorimeter witnessed difference between a solid Pd rod and a Pd coated Cu rod. This difference seems to indicated that

the excess heat is a bulk effect (or at least does not occur within the outer micron surfaces of the cathode).

6. Higher $D_2$ loading can be achieved by using over pressures of $D_2$.

7. Lithium has been found in working Pd cathodes at depths of several microns.

8. As received Pd rods often have Ca, O, Cu, and Fe on the surfaces.

9. At least one working fusion cell seemed to indicated that the $^6$Li isotope is consumed in the fusion cell processes. The $^6$Li appeared to have been depleted with respect to $^7$Li. The levels of the lithium found in the spent cathode were 4%. This measurement may be the result of a diffusion effect because that large a change due to a fusion reaction would have produced a large amount of energy.

10. Data in some Oak Ridge National Laboratory cells continued for almost 2,000 hours. The excess heat started at about 9 W and lowered to about 2 W near the end of the run.

11. Typical energy levels for "good cells" are in the range of 20 megajoules per mole of Pd.

12. Neutron to tritium branching ratios are still found to be in the $10^{-8}$ to the $10^{-9}$ ranges. About 10% of the neutrons come in bursts of over 100 neutron events.

13. Several separate theoretical works indicate that coherent areas of Pd atoms (or the size of microns or at least consisting of several lattice sites) are required to explain the modeled fusion reactions.

14. Be patient in early work. Several experimenters have reported the elapse of a month or more before the cells "switch on".

15. Separate the gas recombination catalyst(s) from the cell so that possible contamination of the electrolyte will be avoided.

16. In work with Pd alloys used as cell cathodes the following were observed:

* Li in Pd or in Ti increases the rate of $D_2$ absorption.
* C slows the uptake of $D_2$.
* Rh increases rates and increases the D/Pd ratios.
* Cd slows D recombination. It was noted that slow recombination of the D within voids of the metal lattice may be desirable.

17. Use high current densitites when looking for excess heat. There may be a current threshold near 500 mA/sq. cm. of the Pd surface. It was suggested that this critical current range may be the most important factor in achieving success.

18. Neutrons are detected from Ti (chips, etc.) when loaded with gaseous $D_2$ as the Ti is warmed from liquid nitrogen temperatures up to -30 degrees C. Gas loading at the lower temperatures appears to increase the neutron emission during warming.

19. Two theoretical models for cold fusion predict that the percent of excess heat should increase with increasing temperatures (assuming that the temperatures are not sufficiently high to cause large losses of $D_2$ from the cathode due to diffusion).

20. Droege & Droege have witnessed oscillating changes of cell impedance. These oscillations appear as swings of several ohms with periods on the order of seconds. It would be appropriate to monitor supply voltages on an oscilloscope as the voltage would change with impedeance in the constant current sources normally used in fusion cell experiments.

21. Rh appears to be concentrated near the surface of the Pd rods after use in a working fusion cell.

22. Dr. Thompson (Johnson-Matthey) reported that used Pd rods showed local areas (at terminal end) of crystal structure changes indicating temperatures exceeding 100 degrees C.

23. The largest problem in the acceptance of the cold fusion process is the lack of byproducts of nuclear fusion. Anyone having long-running cells or cells producing large amounts of excess heat should try to collect quantities of any such byproducts for analysis. For example, helium may be produced near the surface of the Pd cathode and be removed with the evolved gases.

24. The work that has been accomplished in measuring changes, if any, in the isotopic ratios of Pd or Li has shown some anomalies. More detailed pre- and post-testing should be performed.

25. Experimenters are urged to communicate directly with other researchers. The press reports are responding to only a few individuals (both pro and con). Many press reports were written only during the first day of the conference and featured more of the pre-conference skepticism. Few of the press waited to report on the informed view of the attendees after the end of the conference.

26. Deuterium plasma (plasma focus devices) using titanium cathodes results in the production of considerable amounts of tritium. Workers using MPD thrusters may wish to examine such reported effects.

* * * * * * * * * * *

**D. SCIENTIFIC FACTS AND SCIENTIFIC PROCESS.**
By Hal Fox

The remark by Dr. David H. Worledge, EPRI, that the lack of reproducibility of cold fusion phenomena destroys the confidence of the scientific community deserves further comment.

The scientific process involves seeking for and establishing scientific facts. A scientific fact (as contrasted with an historic fact) is best defined as **the close agreement of a series of observations of the same phenomena**.

The scientific process (or method) involves the cycle of prediction (hypothesizing, modeling, theorizing) and testing (experiments). Much of the scientific process involves failures to achieve desired results. Such failures are often learning steps and provide information to augment the prediction-testing cycle.

If the lack of reproducibility destroys the confidence of the scientific community, then the scientific community is due for re-education concerning the scientific process.

It is more probable that members of the scientific community, aided and abetted by a media that (in America) seeks more for controversy than for factual reporting, are voicing human skepticism and sometime human frailities. Personal vituperation against a fellow researcher is never a part of the scientific process but may stem from a sometime scientist acting out human frailties. An excellent example is given us by the editor of Nature magazine. Acting not as a scientist but as an arbitrator of his personal belief, the editor of Nature has allowed his prestigious publication to stoop to personal attacks rather than the reporting of scientific facts. These relapses of human behavior should be granted sympathy, understanding and hopes for rapid recovery.

The discovery that fusion can occur in a metal lattice by Jones [1,2], through the use of electrochemistry by Palmer [3], and to produce excess heat by Fleischmann and Pons [4] must rank as the most important discoveries of science. That such important discoveries could be made and that, in all cases, such discoveries could be reported and replicated by many laboratories is the mark of excellence in the scientific process.

Constructive criticism (such as that resulting from the recent First Annual Cold Fusion Conference) is the appropriate part of the scientific process that is leading to the rapid acceptance of cold fusion as a scientific fact. That the experiments are difficult and hard to replicate is not reason to condemn the process nor to condemn those who have been the pioneers in furthering the facts of cold fusion.

Excellent progress is being made toward establishing the scientific fact of nuclear processes in a metal lattice. The year 1990 will not end before wide spread replication of such nuclear processes is attained and with excellent theory to explain such observations. Happy fusing.

[1] J. Rafelski & S.E. Jones, *Scientific American*, 267, pp 84-89, (July 1987).

[2] S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne, S. F. Taylor, and J. Rafelski, "Observation of cold nuclear fusion in condensed matter.", *Nature*, 338, pp 737-740 (1989).

[3] E.P. Palmer, Personal communication and copy of notarized laboratory notebook pages.

[4] M. Fleischmann, S. Pons, and M. Hawkins, "Electrochemically induced nuclear fusion of deuterium." *J. Electroanal. Chem.*, 261, pp 301-308, and erratum, 263, p187 (1989).

* * * * * * * * * * * *

**E. CONFERENCE PROCEEDINGS AND FORTHCOMING CONFERENCES**
**SIXTH INTERNATIONAL CONFERENCE ON EMERGING NUCLEAR ENERGY SYSTEMS.**

This Conference will be held in 1991 in California.

**THE FIRST ANNUAL CONFERENCE ON COLD FUSION**
**UNIVERSITY PARK HOTEL**
**SALT LAKE CITY, UTAH was held**
**MARCH 28-31, 1990**

The *"Proceedings of The First Annual Conference on Cold Fusion"* are available for $55.00. For more information about obtaining this document please contact:

National Cold Fusion Institute
390 Wakara Way
Salt Lake City, Utah 84108

or send $65 to Fusion Facts to cover postage handling.

CONFERENCE AND CALL FOR PAPERS
**WORLD HYDROGEN ENERGY CONFERENCE #8**

Abstracts should have been submitted by February 28, 1990. Send abstracts (250 word limit) to:

Program Chairman, WHEC8
Hawaii Natural Energy Institute
University of Hawaii at Manoa 2540 Dole Street, Holmes 246
Honolulu, Hawaii 96822 USA

Conference is sponsored by International Association for Hydrogen Energy, U.S. Department of Energy, the University of Hawaii, and others. Sessions on Cold Fusion are scheduled to cover Experiments, Physics of Cold Fusion Reaction, and Calorimetry - Spectroscopy.

Conference will be at Honolulu at Waikiki on Oahu for the July 23 through 25. The July 26 session will be at Wailoloa on the Big Island. Conference costs are $395 to $595 depending on where you stay and when you register.

For further information:
Telephone: (808) 948-8890
FAX: (808) 946-4235
Telex: 65027 82483 MCI

**Fusion Products**

**FUSION CONCEPTS COURSEWARE COSTS**
2-Diskette Set IBM-compatible.$ 95
Specify 5 1/4" or 3 1/2" Diskette

**FUSION ANNOTATED BIBLIOGRAPHIES COSTS**
Published on 5 1/4" or 3 1/2" Diskettes. Includes **INFOFIND** search and retrieval program.
Three Volumes now available.
Each Volume.....$ 95

**CONSULTING SERVICES**
Consultation services can be used
to evaluate research proposals and also to define new business opportunities and/or declining markets for specific industries. (801) 583-6232

**Publications**
**The following publications have been helpful in furnishing latest fusion information:**

*FUSION ASIA*
C-9 Nizamuddin East
New Delhi 110013, India
$40 for 4 issues.

*21st CENTURY SCIENCE AND TECHNOLOGY*
P.O. Box 65473, Wash, D.C.
$20 for 6 issues.

*FUSION TECHNOLOGY*
Recently added new section on Cold Fusion
555 N. Kensingon Ave.
LaGrange Park, Illinois 60525
$310 for 2 volumes + 1 supplement.

**FUSION FACTS STAFF AND CORRESPONDENTS**

Hal Fox.....Editor-in-Chief
Michelle Luken....Associate Editor
Paul Prows.....Departmental Editor
Christine Marshall.....Circulation
Technical Correspondents:

Dr. Robert W. Bass, Registered Patent Agent,
Thousand Oaks, California
Dr. Dennis Cravens, Texas
Dr. Samuel P. Faile, Cinc, Ohio
Avard F. Fairbanks, Resident Snr. Engineer
Marsha Freeman, Washington, D.C.
Dr. Maurice B. Hall, Resident Snr. Physicist
Prof Wilford Hansen, USU Logan, Utah
Ramtanu Maitra, New Delhi, India
Dr. Takaaki Matsumoto, Hokkaido U., Japan
Dr. V.C. Noninski, Sofia, Bulgaria
Prof Edward P Palmer, BYU Provo, Utah
Dr. S.X. Jin, Beijing, China

FUSION FACTS SUBSCRIPTION COSTS

| | |
|---|---|
| FUSION FACTS EACH ISSUED MAILED FIRST CLASS. | |
| 12 ISSUES..... | $ 345 |
| 36 ISSUES..... | $ 900 |
| Single Evaluation Copy.... | free |

| | |
|---|---|
| FUSION FACTS SINGLE ISSUES | |
| CURRENT ISSUES EACH..... | $ 35 |
| LAST MONTHS ISSUE EACH..... | $ 20 |
| 3 MONTHS OR OLDER EACH.. | $ 10 |
| 3 MONTHS OR OLDER ANY 3.. | $ 25 |

**SUBSCRIPTION REQUEST**

PLEASE SEND ME THE NEXT 12 ISSUES OF FUSION FACTS (12 ISSUES - $345, 36 ISSUES - $900)

Send Fusion Facts to:

NAME:_____
COMPANY:_____
PO BOX, DEPT:_____
CITY:_____
STATE_____ZIP_____

*Your check or money order should be made payable to Fusion Facts and sent to:*

***Fusion Facts***
**P.O. Box 58639**
**Salt Lake City, Utah 84158**

Any questions or comments?
Call (801)583-6232, or write us.