FUSION facts

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Fusion Facts Now Reports on Both Cold Fusion and Other Enhanced Energy Devices.

VOLUME 3 NUMBER 2 FUSION FACTS AUGUST 1991

CONTENTS FOR AUGUST 1991

COMING IN SEPTEMBER 1991

Fusion Facts will continue its expanded coverage of **Enhanced Energy Devices**. An article is planned to explain, in more detail, how excess energy can be obtained by the creation of **electron beads and recovering energy by the use of a modified traveling-wave tube.** See the note at the end of this issue about an offer for the 80-page patent on computer diskette with **INFOFIND** search and retrieval program.

ENHANCED ENERGY DEVICES

By Hal Fox, Editor

An **enhanced energy device** (EED) is a device that provides more energy out than is put into the device and where the source of such energy is unusual. The cold fusion electrochemical cell which purportedly operates on the fusion of deuterium and is described by Fleischmann, Pons, and Hawkins [1] is not the only enhanced energy device. A second enhanced energy device is described by Randell L. Mills [2]. This device is similar to the cold fusion electrochemical cell but can operate with light water and can use potassium carbonate as the electrolyte. The source of excess energy provided is theorized to be the energy released when the orbital electron of a hydrogen atom collapses below its normal ground state.

Two other enhanced energy devices are disclosed in recent patents. The first patent by William W. Hyde of Idaho Falls, Idaho [3] is a device for creating electrical energy from mechanical motion. Reference [10] may have some bearing on this device. The device is a modified electrical generator. However the patent states, "It was therefore found that working embodiments of the present invention require less than ten percent of the electrical output energy for the mechanical input." Moray B. King, author of the book Tapping The Zero-Point Energy [4] in a recent paper with the same title as his book cites the following: "Experimental support that macroscopic, virtual charge pair production might provide energy directly from the ZPE [zero-point energy] arises from Hyde's fully disclosed invention [3]. It appears imperative that Hyde's invention be replicated, for only a repeating experiment could prove that it is possible to tap the zero-point energy as an energy source."

The second patent has recently issued and *Fusion Facts* received a copy of the patent in time to whet our reader's interest in the July 1991 issue, page 30. Dr. Hal Puthoff and Kenneth R. Shoulders have been working at the Institute for Advanced Studies in Austin, Texas. Dr. Puthoff is well known for his several papers on zero-point energy. Kenneth Shoulders is well known as a first-

class experimental scientist/inventor in the field of computer science. The patent [5] is unusual for its lengthy description of over thirty embodiments of electron bead technology leading up to the subject of the patent which is energy conversion. The patent describes how electron beads (dubbed EVs) are formed, guided, manipulated, and used in a variety of new high-speed electronic devices.

After a lengthy discussion of EVs and their uses, Shoulders provides considerable words and drawings to show how EVs can participate in energy conversion. In a basic device, an EV is formed and directed through the center of a traveling-wave tube. Normally one thinks of a traveling wave tube as a device that causes a stream of electrons to "bunch up" in a series of pulses to be used in the production of high frequency, high-energy electromagnetic waves. When the electron bead moves through this type of traveling-wave tube, the energetic EVs produce a high voltage output from the device. Under appropriate conditions, described in the patent, more electrical energy can be extracted than is used to generate or produce the electron bead(s). The patent states (page 69, lines 30 to 46) the following:

"As an EV moves along a guide, or a traveling wave device, the EV may be continually absorbing electrons and, at the same time, emitting electrons. Energy conversion may be occurring in either of these two processes. ... An EV passing along a traveling wave device, for example, may be both absorbing and emitting electrons. In this way, the EV may be considered as being continually formed as it propagates [at about one-tenth of the speed of light.] In any event, energy is provided to the travel wave output conductor, **and the ultimate source of this energy appears to be the zero-point radiation of the vacuum continuum.**" To our knowledge, this is the first time that a patent (not the claims but the descriptive words) suggests that an invention has tapped the zero-point energy.

Harold (Hal) Puthoff discusses the possible use of the zero-point energy in two articles in the *New Scientist* [6,7] and in *Speculations in Science and Technology* [8]. Another paper addresses the source of the zero-point energy [9]. In reference [8] Puthoff shows that with a high-frequency cutoff, the magnitude of the zero-point energy (mass-density equivalent) is on the order of 10^{94} gram per cu cm! This extraordinary high value of energy coupled with a desire to "tap" this source, has made zero-point energy a favorite concept for speculation.

Dr. Puthoff (personal communication) considers it likely that the measured excess energy (not accounted for by the production of other nuclear byproducts such as neutrons, tritium, & ^{4}He) in cold fusion electrochemical cells stems from zero-point energy. Even the work of Mills has some linkage to zero-point energy. It is theorized that the reason that the electron orbiting a hydrogen atom does not lose energy and fall into the nucleus is because at its "ground state" the electron is exchanging energy with the zero-point energy sufficient to stabilize the hydrogen atom (and similarly, all matter.)

Theoretical physicists, and others, who have been struggling to explain how two charged deuterons can get close enough to fuse, because of the great strength of the Coulomb barrier, will be challenged to explain the production of electron beads. A typical electron bead may have from 10^8 to 10^{12} electrons. Measurements have indicated that if there are positive charges associated with an electron bead there can be no more that 10^5 such positive charges. **It would appear feasible to get two charged deuterons together if one can keep a hundred million electrons together.**

The electron bead must be characterized by highly energetic circulation in order for the electron bead to be dynamically stable for the time period that has been experimentally observed. These ultra-miniature specks of ball lightning are typically of the order of 1 to 25 microns in size. A single bead creates a hole or crater in specially prepared witness plates that vary from 1 micron up. At higher energies a string or vortex of electron beads are formed and creates a ring of craters about 20 microns in diameter.

In his most recent paper, Moray King [4] states: "Since vortex ring plasmoid pair production is observed in turbulent plasmas, modeling the ZPE (zero-point energy) as a turbulent, virtual plasma supports the vortex ring model for elementary charge and the vortex filament model for electric field lines. Such a model predicts that the abrupt rotation of electric field lines would manifest virtual charge from the vacuum energy."

Puthoff [8] points out: "Yet another feature of the ZPF (zero-point fluctuations) spectrum, related to its Lorentz invariance and again unique in comparison with all other competitors, is the complete lack of a drag force on a charged particle passing through it. ... On the other hand **accelerated** motion through the vacuum can in principle reveal the presence of the ZPF energy density directly."

Two questions that could be considered, in view of Moray's and Puthoff's statements are the following: Can the highly dynamic (therefore accelerated) electron bead qualify as a candidate entity to exchange energy with the structure of space? Properly manipulated, can the electron bead provide a net output of energy by its interaction with ZPE?

The various descriptions provided by Shoulders in his patent [5] suggests that the electron bead is highly

energetic, propels itself along a dielectric by a vigorous interchange of energy (electrons) with the dielectric material, moves at about one-tenth of the speed of light, and exists long enough to be useful in a variety of devices including RF generators, flat-panel displays, logic elements, and in energy conversion devices.

It is of considerable interest that these four enhanced energy devices have been tied to zero-point energy by one or more investigators. *Fusion Facts* welcomes your thoughtful consideration of these new methods of producing clean, inexpensive energy. Hot fusion physicists will, of course, welcome these new devices and urge the funding of further studies by DoE much as they have urged the funding and study of cold fusion.

We welcome serious letters to the editor on these (and other?) EEDs.

REFERENCES

[1] 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).

[2] Randell L. Mills, Steven P. Kneizys, "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte and the Implications for Cold Fusion', *Fusion Technology*, Vol 20, No 1, pp 65-81, (August 1991), 10 refs.

[3] William W. Hyde, "Electrostatic Energy Field Power Generating System', U.S. Patent Number 4,897,592, Date of Patent: Jan. 30, 1990, 19 claims, 3 drawing sheets.

[4] Moray B. King, Tapping The Zero-Point Energy, 170 pages, Paraclete Publishing, P. O. Box 859, Provo, UT 84603 (1989) [$10 from Paraclete.] See also paper of the same title c1991 (available from the author.)

[5] Kenneth R. Shoulders, "Energy Conversion Using High Charge Density", U.S. Patent Number 5,018,180, Date of Patent: May 21, 1991, 42 claims, 38 drawing sheets.

[6] Harold Puthoff, "Everything for nothing', *New Scientist,* pp 52-55, (28 July 1990).

[7] Harold Puthoff, "Where does the zero-point energy come from?', *New Scientist,* p 36, (2 December 1989).

[8] Harold E. Puthoff, "The energetic vacuum: implications for energy research", *Speculations in Science and Technology,* Vol 13, No 4, pp 247-257, (1990), 33 refs.

[9] Harold E. Puthoff, *Phys Rev A,* **40,** 4857, Errata, *Phys Rev A,* **44,** in press, (1 Sept. 1991).

[10] Bruce dePalma (DePalma Institute, 1187 Coast Village Road, Suite 1-163, Santa Barbara, CA 93108), "Magnetism as a Distortion of a Pre-existent Primordial Energy Field and the Possibility of Extraction of Electrical Energy Directly from Space", Presented at the 26th Intersociety Energy Conversion Engineering Conference, Boston, MA, August 4-9, 1991, 4 pages, 1 Fig, 18 Refs.

B. FINAL REPORT FROM NCFI

The final report from the National Cold Fusion Institute (NCFI) has been published in four volumes. Most of the report consists on papers prepared by NCFI staff and some of them have been published elsewhere.

Note that this final report was published by and copyrighted by the National Cold Fusion Institute, The University of Utah, Salt Lake City, Utah, June 1991.

Copies of the four volumes are available from National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road,
Springfield, Virginia 22161
Ref: Technical Information Series PB91175885.

This report will provide readers with the authors, titles, and abstracts of papers. Readers may order copies of single papers from *Fusion Facts* at $10 each to cover copying and mailing costs.

FINAL REPORT - VOLUME I

Overview, Executive Summary, Chemistry, Physics, Gas Reactions, Metallurgy.

OVERVIEW AND EXECUTIVE SUMMARY

F. G. Will, "Overview and Executive Summary", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 1-64, (1991), 504 refs.

EDITOR'S COMMENTS

No abstract. Contents: Status of Cold Fusion; Executive Summary of NCFI Work; Conclusions; and Bibliography. Under the Status of Cold Fusion, Dr. Will covers the following topics: Political and Financial Climate in the United States; Climate of Cold Fusion Abroad; and Technical Status of Cold Fusion (Excess Heat, Nuclear By-products, Theoretical Aspects, Conclusions, References, and Cold Fusion Review Articles.) Table I on pages 6-8 is an alphabetical listing of investigators with their institutions. Table headings also include System, Heat, ^{3}He, n, Other, and Report Type. One hundred entries are

given from 14 countries. The extensive bibliography on pages 32 through 64 provide a list of general publications and media reports.

TRITIUM ANALYSIS IN PALLADIUM

K. Cedzynska, S.C. Barrowes, H.E. Bergeson, L.C. Knight & F.G. Will, "Tritium Analysis in Palladium With an Open System Analytical Procedure", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 65-93, (1991), 4 Figs, 6 refs.

AUTHORS' ABSTRACT

In 45 palladium samples, produced by three different manufacturers in various lots and sizes, we found no evidence for tritium contamination. Within the maximum error of our experiments, that is +/- 3 DPM/ml, the palladium samples gave tritium counts identical to the background of 26 DPM/ml. The major factors leading to possible errors in applying this technique are discussed. Falsely high readings may be caused by chemiluminescence, photoluminescence, colored solutions, and chemical reactions. But such false high readings were not obtained when automatic quench control and other standard precautions were employed. On the other hand, falsely low readings can result from the escape of dissolved tritium gas. Closed system analytical procedures are, therefore, preferred.

AUTHORS' CONCLUSIONS

We have developed a closed-system analytical technique for the analysis of tritium in palladium which features high reliability and accuracy. This technique employs a distillation and catalytic gas recombination procedure which leads to the quantitative determination of the tritium content of palladium with an accuracy and sensitivity of 5 x 10^7 tritium atoms. Application of this technique to 90 palladium wire samples of various lots and sizes, manufactured by two different suppliers, yields no tritium contamination in any of these samples. While our results do evidently not exclude the possibility of rare spot contamination of Pd with tritium, such contamination is exceedingly unlikely both in view of our results and the details of the Pd manufacturing process. The closed-system analytical procedure, described here, is not affected by the shortcomings of open-system procedure for tritium analysis of Pd prior to use in "cold fusion" studies is advisable to ascertain that there is no possibility for tritium contamination.

COLD FUSION IN HIGH PRESSURE

Fritz G. Will & Ming-Chang Yang, "Cold Fusion Studies In A High-Pressure Sealed Cell", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 94-130, (1991), 25 Figs, 4 refs.

AUTHORS' ABSTRACT

A novel electrochemical cell has been designed and employed in a high-pressure sealed vessel, featuring continuous and automatic loading ratio determination, fast temperature response and no oxygen evolution. This cell design avoids several of the difficulties encountered in standard cell designs. Maximum deuterium to palladium loading ratios of up to 0.84 and 0.93 were obtained for deuterium and hydrogen, respectively. The cell design allows power measurements with a sensitivity of 0.56 milliwatts, corresponding to a temperature sensitivity of 0.2 °C. In one long-term experiment, we have found small, but definite, tritium generation is the Pd electrode and anomalous temperature excursions that are, very tentatively, interpreted as excess power excursions of up to 30 per cent.

AUTHORS' CONCLUSIONS

A high-pressure, sealed cell with continuous automatic loading ratio determination was applied to cold fusion investigations. D_2 and H_2 were successfully loaded into Pd foils employing fuel cell anodes and electrolyte-wetted battery separators. In this new technique, oxygen evolution and anode dissolution were avoided. The maximum loading ratio was up to 0.84 with D_2 and 0.93 with H_2. In our cell design, the loading of H_2 and D_2 into Pd proceeds by a combination of gas phase process and electrochemical charging process. Among the four experiments conducted on high-pressure deuterium cells, we have detected evidence for very low-level nuclear reactions only in the one cell that was operated over a long period of time, namely 12 days. In this experiment, we attained loading ratios D/Pd of 0.83 and small but definite tritium generation in the Pd electrode. As compared to a maximum tritium contamination level of 5 x 10^7 tritium atoms in fresh Pd, we find 1.4 x 10^9 tritium atoms in the Pd cathode after the 12-day experiment. We have also detected anomalous temperature excursions which are very tentatively assigned to excess power generation of levels up to 30%. We emphasize the tentative nature of the excess power finding pending a more detailed study of these effects.

TRITIUM AND NEUTRON GENERATION

F.G. Will, K. Cedzynska, D.C. Linton, "Tritium and Neutron Generation in Palladium Cathodes With High Deuterium Loading", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 131-150, (1991), 5 Figs, 18 refs.

AUTHORS' ABSTRACT

Tritium generation in palladium cathodes, highly loaded with deuterium during electrolysis of deuterated sulfuric acid is described. Tritium generation has been observed in four ordinary sulfuric acid control cells operated simultaneously. Total tritium analysis is performed on all cells before and after each experiment. Evidence is also presented for neutron generation from all four D_2SO_4 cells. A single anomalous heat excursion in one of the cells is mentioned as a tentative result.

AUTHORS' CONCLUSIONS

We have applied a novel procedure to attain D/Pd ratios in the vicinity of 1. When such high loading ratios are obtained, we have observed tritium generation on four out of four D_2 cells, whereas none of the four H_2 control cells shows any evidence for tritium generation. As we performed total tritium analysis on electrolyte, electrode and gas before and after each experiment, and as the cells are hermetically sealed, we conclude that the tritium can only have been generated by nuclear phenomena in the deuterium-loaded palladium during the experiment. The total tritium enhancement amount to factors as high as 50. The total amount of tritium generated is between 4.3×10^{10} and 1.1×10^{11} tritium atoms/cm^2 [sic] in typically 7 days. This corresponds to an average tritium generation rate from 5.8×10^4 to 2.0×10^5 T atoms/cm2/sec. Neutron generation has also been observed in these experiments. However, the levels are fairly small, amounting on very rare occasions to 4 neutrons counted in a time frame of less than 320 microsec. In one of the four D^2 cells studied, we have found evidence for a temperature excursion lasting approximately 70 minutes with excess power values in excess of 10W and an excess energy generation of approximately 5×10^4 Joules. Since this represents a single event in 4 experiments during two months, we regard this excess heat result as very tentative. The levels of tritium observed could only explain excess power levels of the order of 10^{-7} W.

DEUTERIUM-GAS PHASE REACTIONS

John R. Peterson, "Deuterium-Gas Phase Reactions on Palladium", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 151-184, (1991), 15 Figs.

AUTHOR'S ABSTRACT

An attempt was made to produce anomalous nuclear events in gas phase deuterium loaded palladium. Stimulation was achieved by applying a high voltage a.c. potential across two Pd electrodes. In some cases electrode cleaning was performed by using a similar high voltage discharge under vacuum. In others, electrode pretreatments of aqua regia etch or electrolytic palladization were performed. Of twenty valid experiments with palladium, nine or ten exhibited elevated levels of neutrons and/or tritium, representing a success rate of about 50%. These experiments and possible explanations will be discussed.

AUTHOR'S CONCLUSIONS

The tritium and neutron results obtained in this study show that anomalous nuclear reactions do occur when deuterium is loaded into palladium from deuterium gas. The problem was, and still is, the irreproducibility of the effects. As in many other laboratories around the world, the success rate achieved in this study is approximately one out of two. Neutron bursts have been recorded following high voltage discharge of deuterium loaded-palladium electrodes. The most dramatic of these were recorded using the high-quality facilities of Dr. Steven Jones at Brigham Young University. Four neutron bursts were observed in a time span of 80 hours. The most intense burst consisted of 280 source neutrons in the gate of 128 microsec. "Hot Spots" of tritium in used electrodes, far in excess to be accounted for in terms of contamination have been found using a highly sensitive and accurate "closed-system" analytical method, developed by Dr. Krystyna Cedzynska at the NCFI. The largest amount of tritium was found near the center of one of the electrodes which has produced the 280-neutron burst. A tritium concentration equivalent to 4.5 nCi/g Pd or 9.3×10^9 tritium atoms/g Pd was found. This compares to a maximum possible tritium contamination level of the Pd of 5×10^8 atoms/g Pd. The two most dramatic sets of results occurred in palladium that had been subjected to five-minute etchings in aqua regia. The effects of this etching on loading times was evident, however no chlorine was found during elemental surface analysis.

CALORIMETRIC MEASUREMENTS

Sivaraman Guruswamy, Raj K. Rajamani, Jun Li, Milton E. Wadsworth, "Calorimetric Measurements During Electrochemical Loading of Deuterium in Palladium and Palladium Alloys", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 185-262, (1991), 7 Tables, 32 Figs, 18 refs.

AUTHORS' ABSTRACT

The results of over 40 separate experiments on the electrochemical loading of palladium cathodes with deuterium are summarized. Extensive calorimetric measurements were made for these electrochemical cells. These results cover an 18-month period during which time a variety of parameters were considered. Initially, experiments were carried out using single wall quartz cells

with high heat transfer (HHT) constants suitable for resolution of rapid thermal changes. Large temperature increases were observed on several occasions. Cell design was subsequently change to double walled cells to increase cell sensitivity for detection of medium to low level heat transfer (MHT). Some of the key variables investigated were electrode preparation procedures, electrode composition, electrolyte composition, cell operating temperatures, cathode poisoning, current pulsing and introduction of transient conditions. The HHT cells had cell constants in the range of 2.5-5 watts/°C. Except for two of the early temperature excursion events in HHT cells, all heat bursts were explainable on the basis of intermittent recombination behavior resulting in thermal transients. The double walled cells had cell constants between 0.5 - 0.7 watts/°C. Excess heat below approximately 5% would be within experimental error for these cells. No evidence of excess heat above the level of 300 mW at 6-10 watt input levels were observed. A third series of tests were run on Fleischmann-Pons (FP) low heat transfer (LHT) cells having cell constants in the range of 6×10^{-10} WK^{-4} (0.1 - 0.2 WK^{-1} in the temperature range of interest, if heat transfer is assumed to vary linearly with cell temperature). Data were analyzed using a Kalman Filter Analytical Method. One cell experienced "boil off" of the electrolyte. A light water cell, operated in series with the heavy water cell, did not experience the "boil off event". Analysis of the thermal behavior of these FP cells is presented. The rapid heat excursion with "boil off" can be explained solely on the basis of the heat balance. The radiation heat transfer coefficient was measured separately in a FP light water cell. Apparent excess heat below 2 or 3 percent can be explained on the basis of cell chemistry, for example, partial recombination. All tests results using FP cells were within the 1 to 2 percent range in these experiments. Therefore, excess heat generation in FP cells was not verified.

HEAT ESTIMATION WITH KALMAN FILTER

Raj K. Rajamani & Florent Bourgeois, "Excess Heat Estimation With The Kalman Filter", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 263-276, (1991), 4 Figs, 3 refs.

AUTHORS' CONCLUSIONS

The Kalman filter algorithm was very suitable for the analysis of excess heat in electrolytic cells. Due to the very nature of the algorithm it can be used on-line and all the more off-line. Either it can be used to evaluate the radiation coefficient in H_2O cells or excess heat in D_2O cells. The filter was used in the analysis of a number of cell data provided by other researchers of the National Cold Fusion Institute. The excess heat values were in agreement with values determined by optimization programs.

EDITOR'S COMMENTS

As previously reported in *Fusion Facts*, Dr. Wilford Hansen (Utah State Univ.) demonstrated that Pons and Fleischmann's data showed significant levels of excess heat but using the Kalman Filter technique on data supplied by Pons and Fleischmann.

EXPLOSIVE COMPACTION

Sivaraman Guruswamy, Michael K. McCarter, & Milton E. Wadsworth, "Explosive Compaction of Electrode Materials and Metal Deuterides", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 277-291, (1991), 6 Figs, 9 refs.

AUTHORS' ABSTRACT

The objective of this investigation was to produce electrode materials, with unique composition or microstructures for cold fusion experiments, by explosive compaction. Compaction of metal powders, deuteride powders and metal matrix composites to cylindrical rod by contact explosive charge was studied. Materials compacted included Pd, Pd-Ti, PdD_X, Au-Pd-Pt and NiTi, metal matrix composite materials such as RiAl-SiC. Compaction of the powders, packed in a copper tube positioned centrally in a shaped vessel assembly containing perchlorate-aluminum-based liquid explosive, was performed inside a large explosive chamber in the IRECO explosives laboratory at the University of Utah. Limited microstructural characterization was performed using optical and scanning electron microscopy. Attempts to look for possible nuclear products due to piezonuclear fusion during explosive compaction of deuterides of Pd and Ti is described. However, no clear evidence of nuclear reactions was observed in the limited experiments performed. Additional experiments using large explosive charges and improved experimental arrangement in increasing the efficient absorption of neutrons, if any, in activation foil detectors are required.

DILATOMETRY MEASUREMENTS

Sivaraman Guruswamy, Jun Li, Narendran Karattup, "Measurement of D/Pd Ratio Using Dilatometry And Factors Influencing the Deuterium Loading Level", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 292-309, (1991), 13 Figs, 7 refs.

AUTHORS' ABSTRACT

Metallurgical changes that occur in palladium electrodes after short and long term loading with deuterium are summarized. Changes in microstructure, hardness, surface

condition and mechanical integrity are described. Factors that limit D loading of Pd above a critical D/Pd ratio at which all octahedral positions in Pd are occupied by D atoms are discussed as this may be a precondition to achieve nuclear fusion in solid state. In-situ measurements of D/Pd ratio using dilatometry technique under different conditions of electrolyte, current density, cathodic overvoltage and electrode composition are presented. Results indicate achieving D/Pd > 1 is difficult and D/Pd ratios measured lie between 0.7 to 0.97.

AUTHORS' CONCLUSIONS

Dilatometry measurements indicate that achieving loading levels of D/Pd ratio greater than 1.0, suggested as a precondition for nuclear reactions, is difficult to achieve. In all the experiments carried out under a variety of different conditions, maximum loading achieved was about 0.93 in pure palladium at a cathodic potential of -3.2 relative to Pt reference probe. Loading level varied with cathodic overpotential at overvoltages between -1.6 to -3.2. Plastic deformation resulting from D loading causes non-uniform dimensional changes. Diametral changes are larger than axial changes. Simultaneous measurement of axial and diametral expansion is required to accurately predict the D/Pd ratio. Addition of alloying elements in general reduced the maximum D/Pd ratio achieved and in all cases the D/Pd ratio obtained was less than 0.8. Microstructural studies indicate that at almost all practical current densities employed by different investigators, from few hundred microamperes/sq cm to 600 milliamperes/sq dm, plastic deformation of palladium electrode occurs. The resulting dislocation density is likely to result in an overestimation of D/Pd ratio. Extensive micro and macrocracking observed in palladium at high current densities or extended charging times lowers the maximum loading that can be achieved.

ULTRASONIC ENERGY EFFECTS ON PALLADIUM

Larry L. Anderson & Wisanu Tuntawaroon, "Ultrasonic Energy Effects on Palladium Electrodes in Cold Fusion Cells", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 310-323, (1991), 6 Figs, 3 refs.

AUTHORS' SUMMARY

The objective of this project was to determine if ultrasonic treatment of palladium electrodes could enhance their ability to take deuterium into their lattice where nuclear reactions could take place. A secondary objective was to determine if compositional changes actually took place in the electrodes and if so what the changes were. These objectives were not achieved although it was determined that ultrasound did influence cell temperature and power level.

AUTHORS' CONCLUSIONS

The operation of electrolytic cells assisted by ultrasonic energy input shows some possibility of enhancement to energy-producing reactions. No experiments were conducted which resulted in high energy (thermal) "spikes". Cells which were activated by the input of ultrasonic energy were always more active, i.e. had higher temperatures and cell power, than comparable cells operated at the same initial conditions.

NUCLEAR MEASUREMENTS

H.E. Bergeson, S.C. Barrowes, K.D. Crawford, Xuan-Ming Du, Lori Knight, Yong-Wing Li, Fariboz Lotfi, G.M. Sandquist, Shu-Xing WAng, Joseph West, "Nuclear Measurements on Deuterium-Loaded Palladium and Titanium", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume I, p 324-387, (1991), 14 Figs, 8 Tables, 7 refs.

AUTHORS' ABSTRACT

Nuclear detection capabilities have been built up and many cells observed for nuclear radiations or byproducts. The most firm positive result has been significant tritium production in at least five different types of experiments. No significant excesses of gamma rays nor X-rays have been found. Significant progress was also made toward setting up a charged-particle experiment and establishing an underground laboratory, where higher quality measurements would be possible.

AUTHORS' CONCLUSIONS

Looking for the nuclear products of an unknown nuclear reaction has involved many possibilities. ... One could not predict which experiments would be successful and which would not. In addition, for the successful experiments, one could not predict the time behavior. ... One exception is tritium measurements, since only the integrated production is measured. Our tritium measurements have been carefully calibrated and carefully done. Positive and significant tritium production has been measured in at least five different types of experiments. These amounts are solid evidence that some type of nuclear reaction has occurred. ...

Small but significant numbers of neutron bursts have been found in gas discharge experiments, in gas loading experiments, and in high-loading electrochemical cell experiments. ... our present results support others' finding of low levels of neutron bursts. No solid findings of gamma rays or X-rays can be reported. ...

VOLUME II - FINAL REPORT - ENGINEERING

FLOW CALORIMETRY

A.M. Riley, R.M. Winter, J.D. Seader, D.W. Pershing, "Flow Calorimetry and Related Experiments", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume II, p 1-84, (1991), 27 Figs, 2 refs.

AUTHORS' SUMMARY

In an attempt to observe the production of excess heat by the Pons and Fleischmann effect, 0.1 M LiOD in heavy water at near-ambient conditions of temperature and pressure, was electrolyzed with as-received Johnson-Matthey palladium cathodes and platinum gauze anodes in six different water-jacketed calorimeter cells. A seventh cell used an electrolyte of 0.1 M LiOD in heavy water to which D_2SO_4 was added to the lower the pH to 1.7. All cells used external catalytic recombination of the D_2 and O_2 produced, except cell 5, which was a closed cell with internal catalytic recombination. Current density varied from 40 to 550 mA/sq cm for cells 1 to 6, and was as high as 1600 for cell 7. The palladium cathodes were all 45 mm long, and were 4 mm in diameter for cells 1 and 3 through 6; 6.35 mm in diameter for cell 2; and 1 mm diameter wire to cell 7. Duration of cell operation was from 20 to 103 days.

A computerized data interface facilitated the recording and processing of all data. Net input power, Q_{JOULE}, to the cells was determined from the product of the measured cell voltage and measured cell current, corrected if necessary for the thermoneutral voltage. Output power, Q_{OUT}, was determined from measurements of the flow rate and temperature rise of cooling water flowing through the cell jacket. Although no calibration of the cells was necessary, because only well-known energy balances were needed to process the data, the energy balance was verified by measuring the power output from an immersed resistance heater in the absence of electrolysis and by electrolyzing light water.

At conditions where a near steady-state was maintained and coolant flow rate and coolant temperature rise were sufficiently high to achieve an accuracy of +/- 7% for the ratio of Q_{OUT}/Q_{JOULE}, this ratio was observed to be 1.0 +/- 0.1, except during an eight-day period for cell 5 when, for a cell current density of approximately 290 mA/sq cm and an electrolyte temperature of 29-34 C, an apparent, anomalous heat production occurred, varying from 9% to 28% +/- 7%, for an average of 17%. The cause of this apparent excess heat is not known, but it ceased when the current density was ramped up to 55 mA/sq cm, causing the electrolyte temperature to increase to 80 C over the next seven days of cell operation. During the production of apparent excess heat in cell 5, tritium concentration of the electrolyte was observed to increase by 20%, but this increase is many orders of magnitude too small to account for the apparent excess heat produced. During the course of the investigation, a number of ways to improve the operation and accuracy of water-jacketed cells based on flow calorimetry were developed and implemented.

EDITOR'S COMMENTS

The authors' state that platinum gauze anodes are as good as platinum wire anodes. Tritium was produced in several cells and especially in the cell that produced excess heat for several days. This calorimetry work does not report any cooperation from Pons and Fleischmann. It was unfortunate that the NCFI was established and managed in a manner that failed to elicit the friendly support of Pons and Fleischmann. Nevertheless, this and many of the other NCFI articles document the nuclear anomalies found in experiments with Pons-Fleischmann electrochemical cells.

SEEBECK CALORIMETRY

A.M. Riley, John Cook, R.M. Winter, J.D. Seader, D.W. Pershing,", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume II, p 87-122, (1991), 7 Figs, 4 refs.

AUTHORS' SUMMARY

In an attempt to observe the production of excess heat by the Pons and Fleischmann effect, under the modified conditions of Oriani, et al., 0.1 M LiOD (with added D_2SO_4 to bring the pH to 1.7) in heavy water at near-ambient conditions of temperature and pressure, was electrolyzed with palladium cathodes and platinum-gauze anodes in closed cells containing a recombination catalyst. Each cell was installed in turn in a Seebeck calorimeter, which was estimated to be capable of observing excess heat to an accuracy of +/- 2-3% at power input levels of one watt or higher.

Two of the five experiments were carried out under the same current-time conditions as reported by Oriani et al., who observed in less than three days of operation, up to 27% excess heat using an open cell with external recombination. In the experiments reported here, no excess heat was observed for electrolysis of these acid electrolytes, but this may have been due to the unusually high measured cell voltages, which caused electrolyte temperatures to exceed 60 C. Experiment durations were relatively short (less than 100 hours) and no measurable increase in tritium content of the electrolyte was observed. Atomic ratios, D/Pd, were observed to be greater than one. Two additional experiments were run with basic electrolytes of 0.1 M LiOD in heavy water for long time

durations of 33 and 74 days. Again, no excess heat was observed.

PALLADIUM ABSORPTION OF DEUTERIUM

A.M. Riley, J.D. Seader, D.W. Pershing, D.C. Linton, S. Shimizu, "Measurement of Absorption of Deuterium in Palladium During Electrolysis of Heavy Water", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume II, p 123-193, (1991).

AUTHORS' SUMMARY

Ever since the announcement of cold fusion by Pons and Fleischmann, it has been claimed that an atomic loading ratio of D/Pd in the palladium cathode of greater than one is necessary. Because of our success in developing closed cells with internal recombination, it was possible to develop a volumetric technique for making the loading measurement during and without disturbing electrolysis. Application of the technique is even possible during a calorimetric experiment. At the beginning of an experiment, the water level in a primary buret connected to the headspace of the cell, is lowered so that it has an empty volume of 50 ml. A vacuum pump is used to evacuate the air from the cell and the buret. After attaining a vacuum of 27 inches of Hq, deuterium gas is admitted to the cell and the buret at atmospheric pressure. This procedure of evacuation followed by filling is repeated a second time to ensure that the gaseous environment in the cell and buret is essentially 100% deuterium. The experiment is then initiated by switching on the flow of electrical current. Initially, most of the deuterium produced by electrolysis at the cathode is absorbed by the palladium cathode. This, oxygen produced at the anode reacts with the deuterium gas previously charged to the cell. Therefore, with time the amount of gas in the buret decreases. As the experiment proceeds, this volume decrease in the buret is periodically measured. Immediately prior to the measurement, the pressure in the call is equilibrated with the atmosphere. During the experiment, atmospheric pressure and the air temperature in the vicinity of the buret are constantly measured. Cell current and voltage are recorded every time a buret volume measurement is made. The system is regularly tested for leaks by moving the second adjustable buret and pressurizing the cell. By initially backfilling the gas space with deuterium gas, a suggestion made by Professor Cheves Walling of the Chemistry Department, an accuracy of better than 5% has been achieved. A total of 62 experiments were run under this procedure covering a wide range of variables, including: Pd-Cathode diameter, source, and surface treatment; electrolyte composition (acid and base); and current density (4 to 300 mA/sq cm). Except for 12 experiments, the atomic loading ratio of D/Pd was below 1.0, and typically in the range of 0.65 to 0.85. The steady-state loading ratio did not vary systematically with any of the variables, but the rate of loading did depend upon the current density up to a threshold value. In those cases where the ratio exceeded one, other tests at the same or similar conditions gave ratios below one. Thus, it is not known why some ratios attained or exceeded one. Within experiment error, no increase in tritium level above background was observed in any of the loading experiments.

HIGH PRESSURE CELL DEVELOPMENT

R.F. Boehm, Mark Case, Ti-Tung Chen, Xing Li, Barry Lloyd, "High Pressure Liquid Cell Development", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume II, p 251-278, (1991), 20 Figs.

AUTHORS' SUMMARY

This report has described the work performed related to the development of high-pressure liquid electrochemical cells. Described is the evolution in design from a massive configuration to small, cigar-shaped arrangements. Problems were encountered with the cell inner surface preparation, and these have been described. Efforts are still underway to develop a "fuel cell arrangement."

EDITOR'S COMMENTS ON VOLUME II

A binding error left out 100 pages of Volume II, therefore only a portion of the reports have been reviewed. In retrospect, it appears that much more useful work could have been accomplished if only someone had provided a "working recipe" for a cold fusion cell. Now that several groups have made excellent progress in creating reproducible cells (such as Miles et al. at China Lake, and some of the last work at NCFI), some of these engineering efforts could probably make significant contributions.

NCFI FINAL REPORT - VOLUME III
Theoretical and Collaborative Studies

REPRODUCIBILITY OF CELL CONSTANTS

Cheves Walling & Marvin Hawkins, "Temperature Dependence and Reproducibility of Cell Constants in FP Type Calorimetric Cells", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 1-13, (1991), 5 Figs.

AUTHORS' SUMMARY

A total of 16 calibrations at 100, 200, and 400 mA have been carried out on two typical Fleischmann-Pons type

calorimetric cells (10 x 0.1 mm Pd cathodes in D_2O-LiOD electrolyte) [Dimensions should be 10 x 0.1 cm]. Although the data scatter considerably, temperature dependence of the cell constants indicated that heat loss involves a combination of radiation and conduction. In these measurements, the experimental uncertainties in total cell power output, Q, or excess power, WX, was estimated as the larger of 0.05 W or 5% of Q. During the calibration, no evidence of excess power beyond experimental uncertainty was observed, but one cell subsequently operated at 800 mA and showed an apparent power surge of about 1 W (25%) for 2 hours.

Between October 11 and November 5, 1989, we carried out a series of 8 calibration measurements on each of two typical Fleischmann and Pons (F-P) calorimetric cells with the double objective of determining the temperature dependence of the cell constants and making an independent estimate of measurement reproducibility. The cells had 0.1 x 10 cm Pd cathodes in D_2O - 0.1 M LiOD electrolyte, had been running at 100 mA for several weeks, and were believed to be giving no excess power. Baths, electronics, data recording, and experimental protocol (except for some minor differences noted below) were those described by F-P as used in their previous work and in their subsequent matrix experiments.

DIATOMIC HYDROGEN

K.J. Bunch & R.W. Grow, "Diatomic Hydrogen in a Potential Well", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 14-36, (1991), 1 Figs, 10 refs.

AUTHORS' ABSTRACT

The equilibrium behavior of diatomic hydrogen in a potential well is explored. The amount of "squeezing" experienced by hydrogen in the well is calculated and compared to that expected for hydrogen within palladium.

AUTHORS' CONCLUSIONS

A model for H_2 interaction in a potential well has been presented. Details of the calculations made were explained. The results of a simple potential profile showed how hydrogen can be squeezed together, although the amount of reduction in internuclear distance is insufficient to explain the cold fusion phenomenon.

COLD FUSION REACTION RATES

Gary M. Sandquist, Vern C. Rogers, "Enhancement of Cold Fusion Reaction Rates", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 37-46, (1991), 7 refs.

AUTHORS' ABSTRACT

Although major controversy still remains as to the source of the excess thermal power output reported from diverse successful cold fusion calorimetry experiments, considerable independent evidence does exist that low-level, deuterium fueled, cold fusion reactions can occur based upon reported neutron and tritium measurements. Because the specific fusion power output may be very low in present cold fusion experiments, there are numerous features and conditions associated with cold fusion experiments which might enhance fusion reaction rates which are important to consider. The principal focus of attention in enhancing cold fusion reactions occurring in an electrolytic cell is the palladium cathode where deuterium is preferentially absorbed into the cathode. The cathode's physical, metallurgical and chemical characteristics such as purity, lattice cell size and orientation, and chemical, hydrodynamic and its electrical surface conditions and prevailing reactions are known to be important for maximizing deuterium loading. Even the geometrical size and configuration of the cathode and the crystalline grain size and conditioning are apparently important. The composition, pH, flow of the electrolyte, electrolysis employing rapidly time varying electrical potential and current and very high pressure and low temperature operation may also enhance fusion reaction rates.

LOW TEMPERATURE NUCLEAR REACTIONS

Gary M. Sandquist & Vern C. Rogers, "Low Temperature Nuclear Reactions by Deuterons in Metals", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 47-65, (1991), 2 Figs, 15 refs.

AUTHORS' ABSTRACT

Nuclear reactions between deuterons under ambient conditions have now been observed in a variety of physical settings generally classified under the title of "cold fusion" experiments. The claim that these reactions are nuclear in nature is derived primarily upon the experimental detection of tritium and low levels of neutrons (with energies of 2.45 MeV) presumably from the neutron branch of the deuterium fusion reaction. However, the estimated fusion energy yield associated with the neutron output is insufficient to account for the reported energy gain if the neutron and proton branch of the deuterium fusion reaction is about equal at ambient conditions. The excess energy gain must arise from an unobserved chemical reaction or an unfamiliar nuclear reaction. This paper explores these issues, attempts to provide physical mechanisms and explanations for the cold fusion

experimental observations, and suggests means for enhancing such nuclear reactions by deuterons.

EDITOR'S COMMENTS

This paper must have been written in 1989. The paper discusses branching ratios without citing any of the now extensive literature showing that tritium is produced far more often than neutrons.

FUSION IN METALS

Vern C. Rogers & Gary M. Sandquist, "Isotopic Hydrogen Fusion in Metals", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 66-83, (1991), 2 Figs, 15 refs.

AUTHORS' ABSTRACT

Nuclear fusion between deuterons under ambient conditions has been observed in the metal cathode of an electrolysis cell with an electrolyte of heavy water. The evidence for the fusion reaction is derived primarily from the detection of a low level of 2.45 MeV neutrons presumably from the neutron branch of the deuterium fusion reaction. However, the estimated fusion energy yield associated with the neutron output is insufficient to account for the majority of the reported energy gain if the neutron-proton branch of the deuterium fusion reaction remains about equal to ambient conditions. The excess energy gain may arise from an unobserved chemical reaction or an unfamiliar nuclear reaction. Reported evidence of an excess of ^{4}He in the vicinity of the cathode may indicate that a ^{4}He branch from the deuterium fusion reaction may proceed at ambient conditions through internal electron conversion without a large release of gamma rays. These issues are explored, and attempts are made to provide physical mechanisms and explanations for the cold fusion experimental observations.

[No references were cited showing that the neutron/tritium branching ratio is small, therefore this must be an early paper, circa 1989. Ed.]

VERIFICATION OF COLD FUSION

Gary M. Sandquist & Vern C. Rogers, "Evaluation and Verification of Cold Fusion", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 84-102, (1991), 1 Figs, 14 refs.

EDITOR'S COMMENTS

This paper provides three tabular listings of experimenters who have reported success in obtaining excess heat, neutrons, or tritium. The data is now outdated. See *Fusion Facts,* Vol 2 No 12 (June 1991) for a more complete list.

DEUTERIUM CONCENTRATION IN PALLADIUM

Vern C. Rogers, Gary M. Sandquist, & Kirk K. Nielson, "Deuterium Concentration And Cold Fusion Rate Distributions in Palladium", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 103-111, (1991), 8 refs.

AUTHORS' ABSTRACT

Cold fusion reactions and excess heat production have been reported in the electrolysis of heavy water with a palladium metal cathode. Solution of the standard diffusion equation for deuterium without fusion indicates that the deuterium concentration distribution rapidly becomes constant in the palladium lattice. Solution of the nonlinear diffusion equation for deuterium undergoing fusion also gives constant deuterium concentrations, suggesting that any fusion occurs uniformly throughout the palladium lattice. The hypothesis that fusion reactions occur predominantly at the palladium surface is shown to be inconsistent with experimental data.

[The latest reference cited is the Santa Fe Workshop, May 23-25, 1989. Whether cold fusion is a surface or bulk reaction, or both, is still not decided. Ed.]

LIMITS ON NUCLEAR EMISSIONS

M.H. Salamon, M.E. Wrenn, H.E. Bergeson, K.C. Crawford, W.H. Delaney, C.L. Henderson, Y.Q. Li, J.A. Rusho, G.M. Sandquist, S.M. Seltzer, "Limits on the Emission of Neutrons, Gamma-Rays, Electrons and Protons From Pons/Fleischmann Electrolytic Cells", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 112-126, (1991), 5 Figs, 17 refs.

AUTHORS' ABSTRACT

Emissions of gamma-rays from the cold-fusion cells used by Pons and Fleischmann were monitored in Pons' laboratory at the University of Utah by NaI detectors nearly continuously over a five-week period. No evidence of fusion activity was observed above power limits varying between 10^{-12} and 10^{-6} W for the known fusion reactions. In addition, neutron-track detectors indicated an integrated upper limit of approximately 1 emitted neutron per second from any of the cold-fusion cells over a period of 67 hours.

[Instrumentation was off line for 48 hours due to a lightning strike. No consistent correlation is provided to indicate that any excess heat was being produced by the

cells being measured. Therefore, the data has little value. Ed.]

POTENTIAL-ENERGY SURFACES

James Anchell, Maciej Gutrowski, Jeff Nichols, Jack Simons, "Self-Consistent-Field Potential-Energy Surfaces Of The DD Pair In The Presence Of Small Palladium Clusters", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 127-164, (1991), 16 Figs, 35 refs.

AUTHORS' ABSTRACT

An ab initio electronic structure study is presented on DD interactions in which the electronic environment is perturbed by the presence of palladium atom clusters. In particular, we investigated changes in the DD intermolecular potential when the deuteriums were separated from each other by a (111) plane of palladium atoms. The (111) plane was modeled with a cluster of three palladium atoms. Self-consistent field (SCF) level calculations were performed, and palladium atom pseudopotentials were employed to make the systems studied computationally tractable. For D_2 placed within the octahedral hole various lines of DD approach were considered {along the (100), (110), and (111) directions}. Lattice deformations and electronic excitations were examined for their effect on the DD intermolecular potential. In no instance did we find a D_2 intermolecular potential curve similar to those used in model studies which examined enhanced fusion rates at low temperatures.

AUTHORS' SUMMARY & DISCUSSION

Model intermolecular potentials have shown that if the DD interaction potential is substantially modified, presumably through electronic screening by the palladium lattice of neighboring deuteriums, then DD fusion rates at low temperatures consistent with those reported for CF are possible. We have investigated palladium-deuterium systems in an effort to find a palladium-deuterium interaction which might give rise to such an intermolecular potential. Our investigation, guided in part by chemical intuition, included a variety of singlet and triplet electronic states, anions and neutrals, with and without lattice deformations. We found no systems which gave a satisfactory modified intermolecular potential. For the arrangement of two deuteriums occupying the same octahedral hole it appears that the hypothesis that the electron density from the palladium lattice might screen the DD interaction is unlikely. This study suggests the opposite. Namely the palladium-deuterium bonding interactions in the octahedral hole results in a buildup of electron density between the palladium and deuterium atoms and subsequent depletion of density between deuteriums. As we have seen this de-screening of the DD interaction results in an intermolecular potential with a "harder" repulsive wall. For the system studied we found that simple DD fusion enhanced by lattice screening of deuterium atom interaction is not a likely mechanism. Of course, there are many more electronic states which could be investigated. Based on the previous work of others in this field, it is not obvious to us which, if any, of the manifold of excited states would be most likely to promote DD fusion. Other lattice deformations might be considered as well. There are, however, only so many distinct ways to stretch a bond, and our preliminary studies of Pd_2D_2 indicated that any palladium deuterium interaction will result in a less favorable rate of fusion.

FUSION RATE COMPUTATIONS

Jeff Nichols, Maciej Gutowski & Jack Simons, "Fusion Rate Calculations for Hydrogen Isotopes from 300K to 1 MeV", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 165-196, (1991), 8 Figs, 17 refs.

AUTHORS' ABSTRACT

Fusion rates for several hydrogen isotopes are computed within the Born-Oppenheimer approximation for collision energies ranging from 1 MeV to "room temperature", for various collisional angular momenta, and for various attractive interaction potentials. These potentials characterize binding of the two fusing nuclei by one or two negative fermions with masses ranging from the electron mass to 200 times the electron mass. Trends in the fusion rates thereby obtained as functions of collision energy, angular momentum, and binding fermion mass are analyzed. Two proposals put forth to rationalize how cold fusion might be taking place, one involving ^4He formation, the other producing tritium, are analyzed in terms of the fusion rates computed here and in light of available experimental data. Both models are found to have difficulties, but the tritium-forming model seems to be more plausible based on what is known experimentally.

AUTHORS' SUMMARY

In this paper, fusion rates for various collisional angular momenta, collision energies, and binding-fermion masses have been computed within the Born-Oppenheimer approximation. Possibilities of subsequent back-fragmentation and fragmentation to produce other nuclei have been examined via microscopic reversibility. Models for cold fusion which predominantly involve either ^4He or tritium formation have been examined; each is found to have weaknesses that are thus far unresolved. Given the recent data that seem to indicate the presence of tritium in the D_2O solution external to the Pd electrode, the latter model must be favored at this date. The tendency

of cells that are claimed to produce excess heat to undergo bursts of very strong heating followed by rather quiescent periods is not explained within either of these models. The analyses presented here are not, of course, able to resolve the many issues and questions surrounding cold fusion. They can, we feel, help us and other scientists think critically and imaginatively about possible interpretations of the available data.

A REVIEW OF COLD FUSION THEORIES

Giuliano Preparata, "Theories of Cold Nuclear Fusion: A Review", in Investigation of Cold Fusion Phenomena in Deuterated Metals, Final Report, Volume III, p 205-236, (1991), 6 Figs, 40 refs.

AUTHOR'S ABSTRACT

A review is presented of the main theoretical attempts to describe the phenomenology of cold fusion, whose general structure begins to clearly unravel. The main conclusion is that the approaches that are likely to be of relevance must invoke processes where the elementary components (nuclei and electrons) of condensed matter act in a coherent fashion.

EDITOR'S COMMENTS

Dr. Preparata's paper has a section on "How to Penetrate the Coulomb Barrier?" Now that Shoulders and Puthoff have shown that electron beads can be formed, directed, and manipulated (See article beginning on page 1 of this issue); a further theoretical challenge is to explain how 10^8 electrons overcome the Coulomb barrier to form a quasi-stable micron bead. If we can show how a hundred million electrons overcome the Coulomb barrier, maybe that will help explain how two deuterons can fuse.

C. NEWS FROM THE U.S.

EXCESS HEAT USING LIGHT WATER

Randell L. Mills (Mills Technologies, Lancaster PA, USA), Steven P. Kneizys (Academic Computing, Ursinus College, Collegeville, PA, USA), "Excess heat production by the electrolysis of an aqueous potassium carbonate electrolyte and the implications for cold fusion", *Fusion Technology,* Vol 20, No 1, pp 65-81, (Aug 1991), 9 Fig.

AUTHORS' ABSTRACT

According to a novel atomic model, the predominant source of heat of the phenomenon denoted Cold Fusion is the electrocatalytically induced reaction whereby hydrogen atoms undergo transitions to quantized energy levels of lower energy than the conventional "ground state." These lower energy states correspond to fractional quantum numbers. The hydrogen electronic transition requires the presence of an energy hole of approximately 27.21 eV provided by electrocatalytic reactant(s) (such as Pd^{2}+/Li+, Ti^{2}+, or K+/K+), and results in "shrunken atoms" analogous to muonic atoms. In the case of deuterium, fusion reactions of shrunken atoms yielding predominantly tritium are possible. Calorimetry of pulsed current and continuous electrolysis of aqueous potassium carbonate (K+/K+ electrocatalytic couple) at a nickel cathode was performed in single cell dewar calorimetry cells. **Excess power out exceeded input power by a factor greater than 37.**

EDITOR'S COMMENTS

The abstract for this paper was submitted for the Como, Italy conference (See *Fusion Facts* for July 1991), but was not presented. The experimental data detailed in the paper is presented in detail together with the electronic circuitry used to provide pulse control to the electrolysis cell. The results from over 30 "runs" are presented and include controls. The data is impressive. The reader may reject the unusual theoretical explanation given by Mills, but the data is difficult to reject. The authors note in their final paragraph, "Further work to enhance the power, to search for chemical species with shrunken hydrogen atoms, and to search for products of predicted subsequent nuclear processes (CAF) following the shrinkage reaction are in progress. Preliminary data indicate that the electrolysis of a heavy water potassium carbonate electrolyte at a nickel cathode produces significant quantities of tritium, but the amount is much less than can account for the heat observed."

We have heard that some attempts have been made to replicate this experiment but we have not communicated with anyone who has successfully reproduced Mills work. However, V.C. Noninski spent considerable time at Mills lab and apparently was convinced that a substantial effect occurs. The following abstract is from a faxed Abstract that was sent by the authors to Como, Italy for the cold fusion conference but was not given. See also the discussion on this and other enhanced energy devices in the article beginning on page 1.

NONINSKI ABSTRACT OF PAPER

V.C. Noninski, J.J. Farrell, W.R. Good (the latter two from Franklin and Marshall College, Lancaster, PA), "Observation of Excess Energy Effect During the Electrolysis of a Light Water Solution of K_2CO_3".

AUTHORS' ABSTRACT

It is well known that during the electrolysis of D_2PO with Pd cathode, production of excess energy is observed [Noninski, then in Bulgaria, was one of the first to replicate Pons and Fleischmann's work]. One of the authors (VN) can support the view that the published data is indicative of reproducible excess enthalpy and has concluded that objective analysis of the published data (even in the principal negative papers) leads to this conclusion [Noninski showed that MIT and CalTech both had produced excess heat in early cold fusion experiments but failed to recognize or report the fact]. Recently a further development in this area was reported. Studies carried out by Mills and Kneyzis revealed that during the electrolysis of light water solution of K_2CO_3 with Ni cathode the output energy significantly exceeds the input. According to these authors, similar electrolysis in Na_2CO_3 did not show such an effect. In view of the importance of this claim, we undertook studies to independently verify this observation. We carried out differential calorimetry measurements in two identical vacuum-jacketed dewars containing 153 ml K_2CO_3 and supplied with identical Ni cathodes, Pt anodes, resistor heaters, magnetic stirrer bars and thermal sensors. One of the dewars was used as blank, no processes being carried out in it. The temperature in the other dewar was increased in two different ways comprising two separate runs: 1) carrying out electrolysis at 0.083 A for about 14 hours and 2) heating the cell by the work of a resistor heater for same time period. The procedure was repeated with an interchange of the calorimeters. The analysis of the effect comprised the comparison of the heating coefficients of the electrolysis cell with the heating coefficient of the cell in which only the resistor works. There is no reason to expect that the mere exchange of the Ni/Pt circuit working as heater (1.48 V subtracted from the electrolysis voltage) with a resistor heater should cause the rise of temperature corresponding to unit input power to differ in the two cases; the thermal properties of the system are not affected by such an exchange. Indeed, when the experiment is carried out in Na_2CO_3 the observed heating coefficients in the two described cases behave as expected. Totally different is the behavior of the system when electrolysis of K_2CO_3 is carried out. In this [latter] instance the heating coefficient during electrolysis is about 60 °C/W. In contrast, the heating coefficient is about 30 °C/W for heating by the resistor only. It is not straightforward to interpret this significant difference of the heating coefficients by trivial causes. Attempts to assign this effect to the creation of temperature gradients were rejected by measuring the temperature of the cell during heating over space and time. [One sentence garbled in fax copy.] In view of the importance of this effect, its reality (non-triviality) should be further confirmed by additional independent researchers. The experiment is simple and yields a reproducible substantial effect.

[My personal acquaintance with Dr. Noninski and my high regard for his scientific ability leads me to put great faith in his preliminary work and the conclusion stated in the abstract. Ed.]

VIRGINIA - ION BAND STATE THEORY

Talbot A. Chubb & Scott R. Chubb (Research Systems, Inc. Arlington, VA), "Cold Fusion as an Interaction Between Ion Band States", *Fusion Technology,* Vol 20, No 1, pp 93-99, (Aug 1991), 16 Ref.

AUTHORS' ABSTRACT

A theory of solid-state fusion based on the interaction between D^+ and $^4He^{++}$ ion band states within a host lattice is presented. Formation of ion band-state deuterium is thermodynamically favored when lattice strain energy is greater than the incremental chemical potential of the band state. The key fusion step is a coalescence fluctuation that converts a two-fold occupation state of electrostatic zero-point-motion size into a state of nuclear dimensions. Rates are calculated using the Fermi Golden Rule. Fusion energy is shared between band-state members and subsequently transferred to the lattice.

AUTHORS' SUMMARY

We have postulated a new form of matter, namely, ion band-state matter within a metallic host solid. This type of matter can form when low concentrations of deuterium, helium, and possibly other light atoms are embedded as low-concentration impurities in a suitable metallic host. In the ion band-state configuration, the ions derived from these atoms assume a delocalized, standing-wavelike distribution, while the neutralizing electrons occupy a portion of the host's conduction electron population. An electrostatically stable ion band-state matter component forms if and only if the host + impurity system has a lower chemical potential with the distributed matter form than it has with a sparse, squeezed molecule population of discrete interstitial chemical occupations of scattered unit cells. The ion band-state configuration avoids the endothermic localized lattice strain term in the chemical potential but requires an endothermic ion-ion Coulombic repulsion term. The repulsion term is a result of multiple occupations of unit cells implicit in the many-body wave function description of bosonic band states. The coulombic repulsion term is concentration dependent and vanishes in the low-concentration limit. For this reason, ion band-state matter should be the stable matter form at very low concentration.

Ion band-state matter differs from chemical matter in its quantum-mechanical description because, in band-state matter, the dominant interaction is the electrostatic

interaction with the lattice. All other interactions are perturbations to this dominant interaction. The single-particle wave functions contain no explicit band-state-ion/band-state-ion interaction terms because without such terms the many-body wave function provides a minimum energy configuration of the total system. With chemical matter, all Coulombic interactions are explicit. The mass density of solids is determined by the relatively large deBroglie wavelength of the electron. When such structures are composed only of chemical matter, the core ion-ion Coulomb repulsion terms prevent nuclear wave function overlap. In contrast, for bosonic band-state matter, the algebra of the many-body wave function dictates wave function overlap. For a mix of D^+ and $^4He^{++}$ band-state matter, the resulting D^+ - D^+ overlap with $^4He^{++}$ leads to augmentation of band-state $^4He^{++}$ with an ultimate increase in system entropy at the expense of nuclear potential energy. This is the basis for the cold fusion heat effect.

At sufficient low temperature, the greatest overlap between initial and final states occurs when the final-state $^4He^{++}$ remains primarily ionically bound within the periodic (bulk) lattice and when energy release to the environment does not result from processes that destroy the periodic symmetry associated with either the final or the initial state. As a consequence, it is to be expected that ^4He will predominantly remain untrapped and in an ionic form within each solid crystalite and will be distributed uniformly therein. Thus, the model predicts (in agreement with experiment) that atomic (i.e., neutral) ^4He will primarily be found either in the surface regions, near interfaces and impurities, or in the outgases, where periodic order is disrupted, and not within the interior of the bulk solid crystals.

EDITOR'S COMMENTS

The model seems to work when the concentration of D^+ ions per unit cell is less than 0.0002. Experimental evidence seems to indicate that the concentration is usually higher than this number. The model is interesting in that it predicts that silver should be a potential cold fusion host. This prediction was made before the Como, Italy conference in which Bush and Eagleton presented data on Pd-plated Ag and Pons and Fleischmann related that they are having successes using a Pd/Ag alloy. The model does appear to predict that the ^4He will not be trapped in the Pd lattice. Miles (Naval Weapons Lab, China Lake, CA) has shown that ^4He is measurable in the fusion cell evolved gases.

UTAH - TRITIUM ANALYSIS

Krystyna Cedzynska, S.C. Barrowes, H.E. Bergeson, L.C. Knight, & F. G. Will (NCFI, U/U), "Tritium Analysis in Palladium With an Open System Analytical Procedure", *Fusion Technology,* Vol 20, No 1, pp 108-112, (Aug 1991).

[See page 4 for an abstract of this article. This same article appears in the NCFI Final Report, Vol I. Ed.]

WASHINGTON D.C. - H IN IRON HYDRIDE

J.V. Badding, R.J. Hemley, H.K. Mao (Geophysical Lab & Center for High Pressure Research, Carnegie Inst.), "High-Pressure Chemistry of Hydrogen in Metals: In Situ Study of Iron Hydride," *Science,* Vol 253, pp 421-424, 4 Fig, 33 Ref.

AUTHORS' ABSTRACT

Optical observations and x-ray diffraction measurements of the reaction between iron and hydrogen at high pressure to form iron hydride are described. The reaction is associated with a sudden pressure-induced expansion at 3.5 gigapascals of iron samples immersed in fluid hydrogen. Synchrotron x-ray diffraction measurements carried out to 62 gigapascals demonstrate that iron hydride has a double hexagonal close-packed structure, a cell volume up to 17% larger than pure iron, and a stoichiometry close to FeH. These results greatly extend the pressure range over which the technologically important iron-hydrogen phase diagram has been characterized and have implications for problems ranging from hydrogen degradation and embrittlement of ferrous metals to the presence of hydrogen in Earth's metallic core.

[As a result of this work, the authors compute that the earth's core may have 40% to 95% iron hydride. Ed.]

D. NEWS FROM ABROAD

CANADA - NEUTRONS FROM D-D FUSION

J.S.C. McKee, G.R. Smith, H.L. Johnston, J.J.G. Durocher, K. Furutani, C.B. Kwok, M.S. Mathur, J.K. Mayer, A. Mirzai, Y.H. Yeo (U. of Manitoba Accelerator Centre, Canada), K.S. Sharma, & G. Williams (Dept. of Physics, U. of Manitoba), "Recent Modifications to the Manitoba Deuterium Implantation Accelerator and a Study of the Properties of the Online Neutron Monitor Detector", Abstract provided at Second Annual Conf. on Cold Fusion, June 30-July 4, 1991, Como, It.

AUTHORS' ABSTRACT

Deuterium molecules have been implanted into Palladium, Titanium, and Indium targets in recent experiments [J.J.G.

Durocher et al., *Can J Phys.*, **67**, 624-631 (1989) & J.S.C. McKee et al., *Proc Int'l Conf on Anomalous Effects in Deuteron Metal Systems,* Provo, UT 91990).] by means of a 60 keV, 100 microampere D_2^+ ion accelerator. Neutrons from D-D interactions involving beam particles with previously stopped D atoms were detected by a large plastic scintillator viewed by two Photomultiplier tubes. We describe recent modifications to the accelerator made to improve the quality of the implanting beam, and the properties of the neutron detector used. Some recent experimental results will be discussed.

INDIA - D^+ MIGRATION IN Ti

K. Govinda Rajan, U. Kamachi Mudali, R.K. Dayal, & P. Rodriguez (Indira Gandhi Centre for Atomic Research, Kalpakkam, India), "Electromigration Approach to Verify Cold Fusion Effects", *Fusion Technology,* Vol 20, No 1, pp 100-104, (Aug 1991), 5 Fig., 11 Ref.

AUTHORS' ABSTRACT

Following recent announcements of the occurrence of nuclear fusion between deuterium nuclei in palladium near room temperature in an electrolysis cell, explanations for the incredibly large increase in fusion probability have been sought. Two pointers seem to emerge: the high density of deuterium ions sustained by the cathode material and, more importantly, the substantial screening effect produced by the conduction electrons in the host metal, which reduces the D^+ - D^+ barrier. This latter mechanism appears to be a function of the concentration of the D^+ ions.

It is well known that an electric field applied across a metallic bar produces a large concentration gradient of interstitial ions along the length of the bar. For hydrogen (or deuterium) in metals, ordinary electric fields can produce a concentration gradient of about 10^{20} between the ends. Thus, with the simultaneous application of an electric field along the length of the cathode in an electrolysis experiment, an elegant method of producing a nonequilibrium deuterium concentration becomes available. Hence, it is reasonable to expect an enhancement in the nuclear reactions occurring in the cathode in such an experiment.

To investigate this phenomenon, a two-compartment electrolysis cell is built. A titanium rod suitably shaped for the applications of the simultaneous electric field is employed as the cathode. Electrolysis of heavy water is conducted for several hours. Neutron counters are employed for continuous detection of neutrons. With the size of electrode used and for electric fields of up to 20mV/cm, neither a significant neutron emission nor any rise in the tritium level in the heavy water are detected. Faint traces of autoradiographs are, however, observed for the cathode.

EDITOR'S COMMENTS

It is suggested that the first step in this type of experiment would be to achieve fusion results with an electrochemical cell and then modify the successful experiment with this type of two-compartment experiment. Some experimenters, e.g. Pons and Fleischmann, state that it is important for the Pt anode to surround the cathode. The authors did find that there was evidence of tritium and that the nuclear reactions occurring in the titanium electrode [if any] are aneutronic. We would suggest that this group in India modify their experiments to replicated the success of Miles et al. who have not only replicated the Pons-Fleischmann experiment but have measured the amount of ^{4}He evolved. [M.H. Miles, G.S. Ostrom, B.F. Bush, & J.J. Logowski, "Heat and Helium Production in Cold Fusion Experiments" reported on in *Fusion Facts*, Vol 2, No 9, p 1, also in Vol 3, No 1, p 11; and accepted for publication in *J. Electroanal Chem.*]

ITALY - THEORY REVIEW

Giuliano Preparata (Univ of Milan, Dept of Physics), "Some Theories of Cold Nuclear Fusion: A Review", *Fusion Technology,* Vol 20, No 1, pp 82-92, (Aug 1991), 6 Fig., 40 Ref.

NOTE: See the last paper in Volume III of the NCFI Final Report (above). These two papers are essentially the same. Ed.

ITALY - EFFECTS OF D CHARGING OF Pd

N. Giordano, A.S. Arico, and V. Antonucci (Inst for Transformation and Storage of Energy, Messina, Italy), "Thermal Effects During the Electrolytic Charging of Deuterium in the Palladium Lattice", *Fusion Technology,* Vol 20, No 1, pp 105-107, (Aug 1991), 16 Ref.

AUTHORS' ABSTRACT

The formation of palladium deuteride during the electrolysis of heavy water is analyzed. This process is accompanied by thermal effects, such as local overheating, which can induce restructuring of the electrodes. The overheating depends on the size of the palladium-deuterium (Pd-D) clusters and the time scale for heat conduction. With the radius of the octahedral site occupied by deuterium in the Pd-D face-centered-cubic (fcc) lattice being similar or greater than the penetration depth of the temperature field for a single reaction of palladium with deuterium, Ruchenstein and Petty's

equation has been applied in the calculation of the local overheating. A value of about 2350 °C for the maximum average temperature rise has been calculated for the Pd-D cluster formation. Similar calculation for the TiD_2 fcc structure show that overheating probably depends also on the kinetics of D_2 absorption. The presence of these phenomena may play some role in the reproducibility of cold fusion experiments.

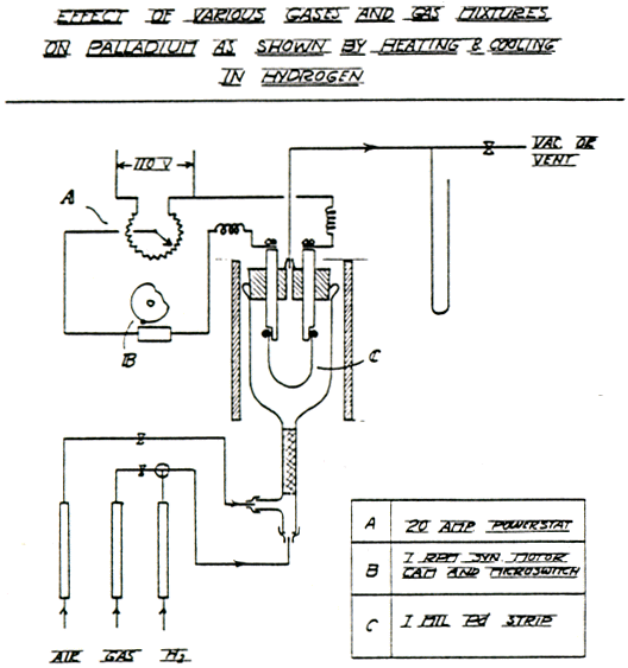
E. SHORT ARTICLES FROM AUTHORS

COLD FUSION AND PALLADIUM SILVER ALLOYS

Courtesy of Dr. James B. Hunter

Dr. Hunter is a retired vice-president of Matthey Bishop, Inc. of Malvern Pennsylvania. Dr. Hunter was the scientist who, in the late 1950s and early 1960s performed some of the important investigations that led to the development of the palladium-silver alloy that is used for hydrogen extraction. This article is a summary of information from Dr. Hunter.

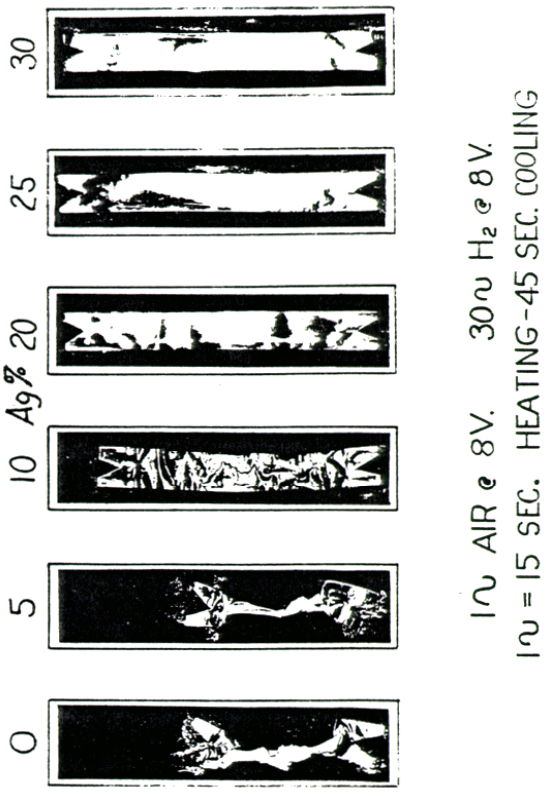
As depicted in Figure 1 below, Dr. Hunter exposed a thin



strip of palladium or palladium alloys to a stream of air, gas, or hydrogen. The metal strip, usually 1 mil in thickness, was electrically connected to a variable voltage source. The experimental arrangement allowed the experimenters to cycle the palladium alloy through various temperatures, by electrical heating of the strip, and observe how well the metal withstood the environment expected to be encountered in extracting hydrogen from a mixture of gases.

It is well known that hydrogen will diffuse through thin-walled palladium. It had also been found that the temperatures used caused some destruction of the palladium, probably caused by transitions between alpha and beta phases as the palladium was temperature cycled. The goal was to find a palladium alloy that would have improved performance. As a result of the experimental work done by Dr. Hunter, the now-standard $Pd_{77}Ag_{23}$ was determined as the alloy best suited for extracting hydrogen from a gas mixture. This alloy is now a standard Johnson-Matthey product. This alloy apparently does not undergo phase transitions even when being cycled from room temperatures to 400 C.

One of the curious anomalies found by Dr. Hunter was the following: When a strip of palladium was heated with voltages up to about 7 volts, there was no unexpected results. However, when voltages in the range of 7 to 8 volts were used, **and the palladium was cycled in hydrogen gas**, the palladium foil crinkled up like a dried raisin. See Figure 2 below. The cycles sustained were thirty cycles of 15 seconds heating, 45 seconds cooling. Thirty cycles at 8 volts resulted in the pictures shown in Fig. 2. Note that the strips begin with pure palladium and have an increased amount of silver alloyed with the palladium from 0 to 30 percent silver.



It is important to note that similar strips heated for a total of one hour did not suffer the severe crinkling unless cooled in hydrogen. Hunter reports that when the surface is scratched with a knife a very bright dense metal is found. Obviously this was not the result of the heating because all strips were heated the same way. He further reports that the strips did not melt (2800 F required) and that he did not observe any radiant hot spots.

The anomaly observed, the unusual crinkling of the palladium foil, suggests that some strong forces developed in the foil to pull together the metal foil as shown. It would be interesting to try this same experiment but to use deuterium instead of hydrogen gas.

Dr. Hunter writes the following: "The following are references to papers published in 1951 and 1953 involving hydrogen diffusion through palladium tubes charged negatively in an electrolytic experiment:

H.B. Wahlin, *J. of Applied Physics,* **24,** No. 2, p 42, (1953).

H.B. Wahlin, *J. of Applied Physics,* **22**, p 1503, (1951).

Hunter suggests: "This is only a suggestion that you might want to check on papers and patents of Dr. Earl Serfass of the Milton Roy Co. Dr. Serfass developed and sold a hydrogen generator using a bundle of silver-palladium tubes in a stainless steel section of pipe. The tubes were negatively charged and hydrogen was available at high pressures (as originally taught by Wahlin.)

"Serfass also developed and may have patented a method for treating the inner and outer surfaces of the tubing using molten sodium hydroxide at high temperature. This produced an adherent black coating on the metal that insured hat the hydrogen passed into and through the metal tube wall and did not merely form and bubble off the outside of the tubing.

"I hope you will contact me again if I can be of further help to you. It is certainly exciting to have even a very small part in such an important development. I also hope that Johnson Matthey can continue to help by supplying your needs for metals, metal alloys and/or metal fabrication."

MULTILAYERS OF PALLADIUM AND SILVER COULD PRODUCE MORE ENERGY.

By Dr. Samuel P. Faile

Chubb and Chubb [1] in the August, 1991 issue of *Fusion Technology* [page 93] indicate that even a fairly small amount of deuterium in silver could produce fusion. Several atomic layers of silver at a silver-palladium interface may have increased solubility. This solubility, even if small, may be significant according to Chubb and Chubb, since electronically one would have D^+ ions because in silver the d-shells are completed. If a lot of the excess heat production is taking place in the silver for Dr. Bush and Eagleton's [2] palladium-plated silver cathodes, one should consider increasing the palladium-silver interface area. This could be done by using a multilayer structure. For example, one could build up a structure by successive platings, consisting of layers 5 microns thick alternating Ag & Pd. Next, a rectangular cathode could be cut from this structure such that the planes of the plated layers would be perpendicular to the axis. Thus these layers would be normal to the cathode surface. Each layer of palladium would be accessible to the electrolyte and allow for loading of deuterium. Therefore, the palladium-silver interfacial areas would be accessible and greatly increased over present techniques. For example, a 5 x 5 mm rod 10 cm long would have its palladium-silver interfacial area increase by about 500.

An alternative could be an electrode that was first fabricated to have an open porous structure of palladium. This structure could then be infiltrated with silver. Another possibility would be to sinter or shock compress a mixture of silver and palladium powder. If palladium black was to also be deposited on such an electrode, as an addition feature; this feature could be improved by the co-deposition of palladium and silver.

Just before writing this short article, I mentioned the multilayer concept to Larry Wilbers. He asked me to forecast when there would be industrial applications for cold fusion. I stated that an important milestone would be a stand-alone capability for an energy producing apparatus that could power itself. If the multilayer design (or some other improvement) results in an output/input power ratio of ten or more, it should be relatively easy to use the excess heat and convert the heat into enough electricity to run the apparatus. Industrial uses could then follow within five years.

[*Fusion Facts* has used the figure of merit of 300% excess heat as suitable to create a cold fusion device that could power itself. We have been more optimistic in stating that commercial uses would be developed within two years after a stable cold fusion recipe is provided. Ed.]

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COLD FUSION - A Preliminary Scientometric Study

By Dr. Peter Gluck, Romania

AUTHOR'S ABSTRACT

The advent and further development of nuclear cold fusion proved to be an unbearable epistemological shock for many who prefer to deny its existence despite the growing evidence in its favor [1]. In the framework of a first scientometric study of this emergent field of research, the relevance of simplified statistical considerations [2,3] is questioned and rejected. A striking analogy for positive/negative results is presented. Despite the [early] dominance of negative experimental results and the lack of a sound theoretical basis, some articles [4,5] could contradict that nuclear cold fusion is a real phenomenon, the subject of conferences, and the source of hundreds of technical papers and other publications. The dynamics and the distribution of literature are analyzed as well as the evolution of "acceptance level" for cold fusion in different journals, countries, at specialized conferences, etc. The "geography" of acceptance emphasizes the importance of the modes of thinking in research. The public image of cold fusion has to systematically improved. The present and further scientometric studies will contribute to this.

INTRODUCTION

The advent and further development of nuclear cold fusion proved to be an unbearable epistemological shock for many who preferred to deny its existence despite the growing evidence in it favor [1]. It is yet questionable if this case will contribute to a epistemological revolution. The subject is dominated by incertitudes and evanescence, informational fogginess, the field is highly complex, immature, and dynamic. The situation is unclear (Dr. Appleby: "**NUCLEAR** or just **UNCLEAR**?" It seems that the negative results are dominant but this cannot be equivalent to a decision and even has no real truth value. Already Descartes has warned that scientific questions cannot be cleared by the number of notes. In this case, the weight or truth value of positive and negative proofs are different because:

* the negative proofs are always by absence,
* the positive proofs are always by the presence of some direct or intermediate signs of cold fusion.

QUOTATION: **"To see that it is not possible to observe the absence of things is a true, permanent vision."** (Chen Huei).

An intuitive analogy will explain better the mode of thinking on basis of which the first simple (if not primitive) statistic scientometric "studies" e.g. [3,4] have been carried out:

1. From 317 papers published [and read] on cold fusion only 56 present positive results.
Conclusion: Cold Fusion is statistically dead.

2. The Romanian dictator Nicolae Ceausescu was executed. The firing squad was scared and has used 302 bullets, but only 43 had hit him deadly.
Conclusion: Nicolae Ceausescu is statistically alive.

You have to consider all the results as you have to consider all the bullets. Right, Dr. Morrison?

This analogy seems to be a kind of a joke but actually the same rigid logic (paralytic logic as opposed to the stigma of pathologic science some try to attach to cold fusion) is acting in both statements. If number 1 is true, the Como, Italy symposium on cold fusion could not have been organized and if number 2 was true the author couldn't even think to come. Such statistics actually cannot tell if cold fusion is real or not, they can measure only the acceptance of this phenomenon.

A real professional scientometric study in an emergent, disputed, scientific field is a very daring challenge. This case is an unprecedented task - a genuine scientometric ordeal, it could be done only on a "Aquila non capit muscam basis." [Translation: You can't make an eagle out of a house fly.]

A real study cannot be limited to the description of facts. We want and have to explain and predict. It seems that in this case, temporary, transient mistakes and even blunders are unavoidable - but this is the high price you usually have to pay for creativity.

Beyond the limits of the problem "per se" we are very interested to extend our conclusions to a symptomatic situation - modes of thinking in research. Very important improvements are here both necessary and useful.

I have used two models for this work, two different scientometric studies [6,7]. Both use a much greater and completely developed database than our preliminary study.

* Solar power research - 8200 information units.
* Hydrogen energy and technology - 9597 information units.

[The author notes that up to April 30, 1991, he had obtained 570 papers published in 169 journals. He computes that these equal 2,162 information units.]

Due to the peculiar startup of this research field (its unconventional birth) a scientific publication unit referring to cold fusion is much easier to use than to define. Papers published in Financial Times, Wall Street Journal, etc. cannot be assimilated as scientific publications and

cannot be included in the database - but in the same time cannot be neglected because they are indicators of the acceptance, popularity, and funding expectations for cold fusion, i.e. can contribute to a research prognosis.

A great number of killer papers have been periodically published by some lower level scientific journals and in newspapers (mass media). These are only echoing publications from *Nature* or *Science*, the two prestigious (but dictatorial) scientific journals which have irreversibly correlated their prestige enhancement to the final disappearance of cold fusion. Their expectations are not at all fulfilled because **"news regarding the death of cold fusion are slightly exaggerated"**, as Mark TWain would say.
Another Ninja tactic, is to kill cold fusion by refusing to write anything good or wrong about it.

Three books on the subject of cold fusion have been published: 1. Kuzmin - Shvilkin. 2. Peat. 3. Frank Close. A fourth, Mallove and a fifth, Taubes, have been announced. [Mallove's book, Fire From Ice, Searching for the Truth Behind the Cold Fusion Furor", Wiley, 1991, has been published.]

As it appears from the data, the number of papers is steadily increasing. It is no similarity to the epidemic growth of papers regarding another breakthrough in physics - High Temperature Superconductivity. But advances in reproducibility as well as intensification of the cold fusion phenomena and a radical improvement of the public image will trigger an impetuous development of the research activity in this field. On the basis of the latest developments presented here [at Como, Italy cold fusion conference] we, all together, shall be able to determine more precisely when this will be the case.

LEVEL OF ACCEPTANCE

By comparing the number of positive, negative, and neutral papers on cold fusion it is possible to evaluate (as we have shown) not the reality but the level of acceptance for cold fusion. This isn't an easy problem as the basic terms are very difficult to define and measure -- in this incipient stage, a high degree of sloppiness must be admitted. The papers are roughly classified on a +1 (total acceptance), 0 (neutral), or -1 (total rejection) scale. Acceptance or rejection can be implicit or explicit. It is no place for finess yet.

Many research teams have abandoned the cold fusion work after the first failure in 1989, but there are notable exceptions such as Miles [8a,b,c]. This group has climbed on the acceptance scale from -1 to +1. The same attitude was evident at the Oak Ridge National Laboratory [9].

The acceptance data appear to contradict Langmuir's description adapted by D. Morrison for positive results are steadily increasing - as we could see at the Provo, Utah symposium - including an area outside the geographical zones defined by Morrison as good for cold fusion (euphemistically naive).

QUOTATION FROM MORRISON: "This regionalisation has continued with most of the world finding negative results (in phase three) and only Utah, Texas, India, and now Japan being in Phase two where both positive and negative results are reported."

Morrison has overlooked Hawaii, Colorado, Washington D.C., Oregon, New Mexico, New York, China, and Taiwan. To Dr. Morrison: If you will review your preferred database, i.e. the Britz bibliography on nuclear cold fusion, you will see that Part I has 22% positive results (82 of 368). Parts II and III have 43% positive results (71 out of 165). The explanation is complex but definitely anti-pathologic.

I dare to mention that Dieter Brits, a convinced skeptic is my friend on the basis of this statement, "Differences in opinion attract the people that are intelligent and repel only those who are not." On this basis, may we (the cold fusion community) call Dr. Morrison our friend. [Yes, he is intelligent, charming, and struggling to defend the turf that he too-early captured. Ed.]

A drastic change (improvement) will be registered after the discovery of the hidden parameters which generate the lack of reproducibility of the cold fusion phenomena. As we can see from [10] in a whole army of over a thousand quasi-identical titanium chips only four demonstrated an exceptionally high tritium generating activity. Due to unknown causes, all the other 996 remained inactive. This is a very simple situation as compared to electrochemical cold fusion. Conclusion: it may be a long way to reproducibility!

According to the interest and level of acceptance of cold fusion the countries can be classified between two extreme situations:

HIGH ACCEPTANCE: India, Japan, China, Italy
MEDIUM ACCEPTANCE: USSR and USA
LOW ACCEPTANCE: France, Germany, United Kingdom

What have the countries of the first category in common? What is the secret of their acceptance and the explanation? We cannot accept the concepts and the strange geography of Dr. Morrison. He always tries implicitly to demonstrate that the adepts of cold fusion are lacking intelligence.

In our scientometric experience, bibliometric measures are like IQ tests at the empirical level-- most agree that both

yield novel and useful information. At the conceptual level both pose difficulties.

QUOTATION: "**Citation data is subtle stuff.**" (Garfield, *Scientometrics*, **13**, 3-4, March 1988).

COLD FUSION AND THE MODES OF THINKING IN RESEARCH

Prelogical: At the startup of the research activity in different laboratories and later on due to:

* lack of essential information - both experimental and theoretical.
* impossibility to correlate causes and effects (both are not completely known).
* difficulty (major) in both measuring and calculating data.

Logical: Thinking step by step, without jumps or discontinuities. **"It seems that like other creeping things, pure logic isn't able to participate in the great intellectual ascensions."**

Supralogical: Creative thinking and lateral thinking as exemplified in the Upanishads (India), Zen (Japan, Tao (China), art (Italy), and lateral thinking (Italy).

We dare not to suggest a causal relationship (or a direct correlation) of cold fusion successes and oriental philosophy. It is merely a strong stimulating factor. But a tight correlation exists between the diligence of these people [Orientals], their philosophy assimilated in the deep subconscious, and distilled in thinking modes and their **interest** for cold fusion. The high acceptance (the way to positive results) is a product of their interest which includes a sympathetic attitude toward the problem. They can accept other answers than YES or NO. This is a creative attitude.

And Italy - our conference hosts? Why are they in the same preferential situation? The explanation is handy but complex. Their extraordinary aptitudes (talent) for art (i.e. right brain hemisphere thinking); affinity to both cultures; the open, clever scientific policy of ENEA; and lateral thinking. Lateral thinking is generative, provocative, discontinuous, and avoids negatives. Lateral thinking is an Italian invention (Edoardo de Bono).

We may wonder whether a book like "The Tao of Physics by Fritzof Capra, had a real influence on the thinking of the physicists in our generation or in the younger ones? This type of thinking is a valuable achievement of humanity. In its turn, the cold fusion saga, when truly told, will stimulate the development of the creative thinking, of the systematic scientific approach -- global, dynamic, relational, evolutionary. The mode of thinking is not quite a causal factor but it is strongly correlated to the success in reproducing and **improving** cold fusion claims.

In other counties - strong scientific personalities are working in a more hostile environment. There are those who are present at conferences and who dare to think and act creatively [regardless of the accepted dogma in their own country.] **"It seems that both women and creativity appeal for tenderness, but it is not clever at all to take both of these as quite serious."**

SOME PERTINENT QUOTATIONS:

"**We must in fact break away from the stranglehold of the scientific demigods who have served as inhibitors of intellectual development. We must try to build in this country a very broad base of highly informed individuals who will constitute a completely independent scientific community. At present this does not exist."** From a leading biophysicist talking on spotting and supporting good science. Quoted by Arunachalam & Manorama in "Measuring Science on Periphery", *Scientometrics*, **15**, 5-6, May 1989.

"In the early stages of any inquiry it is a mistake to lay down a hard and fast distinction between a scientific investigation of the facts and philosophical reflection about them. At the later stages the distinction is right and proper." H.H. Price.

"We need a different kind of human being, who is comfortable with the change; who enjoys change; who is able to improve; who is able to face with confidence, strength, and courage a situation of which he has absolutely no forewarning." Abraham H. Maslow.

"A chemist who isn't a physicist is nothing." Bunsen.

"People of superficial knowledge think they have enough when they happen to know only one way and do not realize that the true seeker will search unceasingly even after he has acquired some good formulas." Tao Philosopher, Ko-Hung.

"Any idea begins its career as a paradox, continues as common sense and ends as a prejudice." Grigore Moisil -Romanian mathematician.

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." Max Planck.

"The world is constructed designedly, just in order to fulfill the interest of the scientist, being infinitely complex and perfectible, providing an endless and eternal field of thinking and action for him." Y.H. Prum.

"The typical eye sees the 10 percent bad of an idea and overlooks the 90 percent good." Charles F. Kettering.

"It is impossible to distinguish between true and false on a purely logical basis." Steiner (Murphy).

"How knowledge can progress?
Why, it's easy to express.
You err, and err, and err, and err
But less, and less, and less." Piet Hein (Grooks)

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LESSONS FROM COMO
By Hal Fox, Ed.

Scientific papers on cold fusion can be grouped (for the convenience of this memo) into four groups:

1. Theory.
2. Instrumentation.
3. Experimental - nuclear byproducts.
4. Experimental - Excess Heat.

From the point of view of developing a science of cold fusion, good papers in all groups are valuable. Because neutrons and tritium are unquestionably a byproduct of nuclear reactions, many experimenters desire to produce and measure neutrons or tritium.

From the point of view of **developing a technology of cold fusion and future commercialization**, the experiments that produce excess heat are highly favored. For these scientists and technologists there are now three types of cold fusion devices (experiments) that produce excess heat (four if you count Mills of Lancaster, PA). The three are the Pons-Fleischmann electrochemical cell, the Liaw-Liebert molten salt electrochemical device, and the deuterium gas glow-discharge device (Karabut of Russia).

Ignoring, for the moment, the fact that all three devices have experienced problems with replication, consider the appropriate role of theory and experiment. In the practical world, experiment precedes theory. However, after the experiments have been understood and a reasonable theory developed, the technical papers are most often written as though the experiment was the outgrowth of the theory.

The desired linkages between theory and experiment is the following (and often given as the epitome of the scientific method):

1. An explanation of an experienced observation or of a "what if . . . ?" speculation as stated in precise scientific terms. This is the theory, model, or hypothesis.

2. An experiment is designed to prove/disprove the theory, model, or hypothesis.

3. A suitable experiment is tried, data is obtained, and the results analyzed.

4. The theory, model, or hypothesis is modified, replaced, discarded, or strengthened on the basis of experimental facts.

The cycle is repeated. Scientific progress results.

An important, but often unstated, condition is that item 3, the experiment, is expected to be replicable. The same experimental conditions are expected to produce the same experimental results. McKubre pointed out, that the problem is not replication of the results but the precise replication of the initial conditions.

THEORETICAL PAPERS

Considerable effort continues to improve theories and models to explain cold fusion. It is expected that a good theory or a good model will explain new results or form the basis for specific experimental tests. One of the figures of merit (but not proof) for a model is the experimental observations that are explained by the model. A stronger figure of merit is the number of new, unreported, experimental findings that are predicted by the model and later shown to be correct.

One of the earliest theoretical works, predicated on basic physics, has been the work by Guiliano Preparata. Some of his theory was developed at the NCFI during his 1990 in-residence work. Preparata's latest paper appears to be more involved with showing how other theories cannot be correct than with the development of details of his theory capable of being experimentally verified. Meanwhile, Peter Hagelstein, MIT, continues to refine, discard, and develop his model for cold fusion.

Dr. Robert Bass has been working on improvements to the model first proposed by Julian Schwinger (First Annual Cold Fusion Conference). Dr. Bass has now refined his model to the extent that it can be (and is being tested). In addition, some of the TRM (Transmission Resonance Model) developed by Dr. Robert T. Bush can be developed from the Bass model. Recently, Dr. Bass has been in communication with Dr. Hal Puthoff. It remains to be seen how this cross-fertilization may improve the modeling of cold fusion.

Bush and Eagleton (Cal Poly U., Pomona) have the best track record for their combination of theoretical and experimental work. The TRM has the best record for predicting results that are later found to be true. We commend Bush and Eagleton for their combination of theory and experimental work.

F. LETTERS TO THE EDITOR

FUSION IN THE EARTH

From Henry P. Dart, III
2048 East 7th St., Tucson, AZ 85719

Until recently it was believed that virtually all of the heat produced in the earth was "radiogenic" heat produced by the decay of uranium, thorium, and potassium 40 [1]. In recent years this hypothesis has been challenged, and there is a growing belief that U/Th/K can supply less than 5% of the earth's internal heat [2]. Concurrently the high ratio of Helium 3 to Helium 4 (one part in 10^5) found in volcanic regions, which cannot be explained by decay of U/Th/K, seems to substantiate the hypothesis that deuterium fusion is taking place within the earth, and that perhaps much, if not most, of the heat in the earth is being produced by fusion.

But some of those who are studying fusion in the earth are confused by the fact that, even in regions of volcanism, the ratio of Helium 3 to Helium 4 is only one part in 10^5. McHargue, et al. [3], for example, put a limit of 10^{-5} on the fraction of total heat in the earth contributed by fusion. They say: "Unlike the radiogenic production of Helium 4, fusion of deuterium to produce ^{3}He can only contribute a negligible amount (10^{-5}) of the observed terrestrial heat production". This statement is based on the assumption that the ratio of fusion heat to radiogenic heat is equal to the ratio of Helium 3 to Helium 4 released from the earth in volcanic regions, and this, in turn, is based on the belief that the only evidence of fusion in the earth is the amount of Helium 3 released at the surface of the earth.

This assumption is not correct. If a ^{3}He atom is produced by a fusion reaction deep in the earth, there is no compelling reason why it should ultimately emerge at the surface unchanged. Its residence time in the earth after its production, may be on the order of millions of years. During this time there is a high probability that it will encounter a neutron which will convert it to Helium 4, and create about 20 MeV of additional heat in the process. Thus it cannot be assumed that every Helium 4 atom that emerges from the earth is of radiogenic origin. Many, if not most of them, may originates from a fusion reaction. And this, in turn, means that a large part of the earth's heat, if not most of it, may come from deuterium fusion.

Palmer [2] has recognized the discrepancy between the heat requirements and the He3/He4 ratio. He says:

"If heat data and ^{3}He data are reasonably valid, fusion events analogous to muon-catalyzed fusion is not the dominant heat source because ^{3}He concentrations appear

to be too low to agree with heat data; other fusion processes need to be examined."

Palmer then goes on to discuss the Openheimer-Phillips reaction in which a neutron tunnels into a target nucleus producing a relatively large amount of heat and a small amount of ^{3}He "in roughly the observed ratios". Palmer does not discuss the possibilities mentioned above [of isotopic changes due to neutrons.] He apparently makes the same false assumption made by McHargue et al. [3], namely, that the number of ^{3}He atoms emerging at the surface is equal to the number of ^{3}He atoms produced deep within the earth.

It is submitted that most of the ^{3}He produced deep within the earth is converted to ^{4}He during its long residence time in the earth, and that the amount of ^{3}He emerging at the surface of the earth is not indicative of the total amount of ^{3}He produced in the interior. In that case fusion reactions deep within the earth can account for most of the heat of volcanism and other heat produced in the earth, and it is not necessary to resort to the Oppenheimer-Phillips reaction to explain the small amount of ^{3}He emerging at the surface of the earth, most of it having been converted to ^{4}He on the way.

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[1] John Verhoogen, "Energetics of the Earth", National Academy of Sciences, Washington, D.C., (1980).

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EDITOR'S COMMENTS

Henry Dart is a 74-year old retired attorney who, since retirement, moved to Tucson to study astronomy and geology at the University of Arizona. Dart suggested in 1950 that much of the heat of volcanism was caused by deuterium fusion but was not taken seriously. As Dart relates, "every physicist firmly believed that fusion in the earth is impossible because fusion requires 10 million degrees Kelvin." And some scientists still ignore the expanding literature of cold fusion. Suffice to say, after the announcement of Pons and Fleischmann discovery, Henry Dart was congratulated on being a prophet. We congratulate Henry Dart for his continuing interest in science in spite of his advancing years. Thanks for the letter.

G. CONFERENCES, PAPERS, & MISC.

FINAL REPORT FROM NCFI

The four-volume final report from the NCFI is available from:

National Technical Information Service
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The title: Investigation of Cold Fusion Phenomena in Deuterated Metals.
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Courtesy of Dr. Samuel P. Faile

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BOOK ON ZERO-POINT ENERGY

Moray B. King, is a scientists employed by Eyring Research Institute. In his spare time, King is an avid student of zero-point energy. His book: Tapping The Zero-Point Energy, contain 170 pages with some illustrations and is published by Paraclete Publishing, P. O. Box 859, Provo, UT 84603 (1989) [$10 from Paraclete.] This book contains many references to the literature and is recommended to our readers who want to learn more about the energetic structure of space.

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