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WHAT REALLY HAPPENED WITH COLD FUSION AND WHY IS IT COMING BACK?

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ABSTRACT

This paper is the result of a broad survey of original interviews with researchers who have been active in the cold fusion field for the past 16 years, their papers, and references to significant, previously undisclosed cold fusion experiments and audits.

This investigation shows that the claims of excess heat were never disproved, in contrast to the generally-held belief at the time. With the benefit of 16 years of progress and hindsight, cold fusion researchers have accumulated convincing evidence to establish the claims of a new, genuine field of science. This investigation shows that the original hope of cold fusion, a new source of energy without harmful radiation, remains.

This paper serves as a brief summary of some of the highlights of the field to date. Additionally, three experimental reports are referenced which review the micro- and nano-scale parameters of the research. A key remaining challenge to optimization of cold fusion relate to as-yet-unknown material science issues. Nanotechnology research may help answer some of these questions.

Key Words: cold fusion history journalism investigation condensed matter nuclear science.

1 HISTORICAL BACKGROUND

Martin Fleischmann, visiting professor from the University of Southhampton, and Stanley Pons, head of the chemistry department at the University of Utah, in a press conference organized by the university administration, announced the discovery of cold fusion on March 23, 1989. They disclosed the remarkable claims of 1) a sustained DD fusion reaction, 2) occurring in a low temperature experiment 3) without high levels of neutron emission and 4) without gamma radiation [1].

Numerous laboratories quickly challenged these claims. Within weeks, newspaper headlines announced that researchers at prominent laboratories, including Nathan Lewis (California

Institute of Technology), David Williams (Harwell Atomic Energy Laboratory), and Ronald Parker (Massachusetts Institute of Technology), had disproved cold fusion.

Later that year, John Huizenga (University of Rochester) was appointed to chair the Department of Energy's Energy Resources Advisory Board Cold Fusion Panel and tasked with the challenge of assessing the veracity of cold fusion. The bias[1] against cold fusion, an intruder in many ways to science and fusion energy research, adversely affected an objective, dispassionate assessment.

1.1 False Negatives

The hasty approach to cold fusion taken by many skeptical scientists was of great concern to 13 researchers in particular. These individuals were unsatisfied with the process and interpretations of the Department of Energy cold fusion panel and later conducted their own retrospective analyses of the work that supposedly disproved cold fusion. Their findings are summarized in Table 1.

Table I. False Negatives: Retrospective Analyses of Work That Supposedly Disproved Cold Fusion

Year	Analysts	Caltech	M.I.T.	Harwell
1991	1st China Lake Team [2]	Excess Power	Major Errors	Major Errors
1991	Noninski & Noninski [3]		Excess Power	
1992	Melich & Hansen [4]			Excess Power
1993	Noninski & Noninski [5]	Excess Power Major Errors	Major Errors	
1993	2nd China Lake Team [6]	Excess Power Major Errors		
1993	Swartz, Mallove [7]	Major Errors	Excess Power	
1994	Melich & Hansen [8]	Major Errors		Major Errors
1994	3rd China Lake Team [9]	Major Errors	Major Errors	Major Errors

[1] Huizenga later wrote in *Cold Fusion: The Scientific Fiasco of the Century* (Oxford, 1993) that he thought such a panel was ill-advised because he believed "the whole cold fusion episode would be short-lived."

Their analysis included interviews with some members of the original research teams as well as inspection of original raw data. Analyses indicated the findings of major errors as well as possible excess power in each of the prominent laboratories that supposedly disproved cold fusion.

None of the analysts who performed retrospective studies asserts that these laboratories showed proof of cold fusion. They did, however, state that these experiments were more likely to have replicated rather than disproved the claims of Fleischmann and Pons.

1.2 Unknown Positives

Table II displays results of several audits and analyses of studies that confirmed cold fusion. Results of several rigorously performed experiments which corroborated cold fusion are also displayed. Numerous instances of excess power and nuclear products including ^{4}He and tritium are reported. Three authors, including Richard Garwin, explicitly state that the anomalous energy is far too great to be the result of chemistry.

Table II. Unknown Positives: Early Successful Excess Power Experiments & Analyses

Analyst/ Experimenter	Fleischmann & Pons	U.S. Navy China Lake Team	Amoco Oil	Shell Oil	SRI International
W. Hansen [10] (1991 Analysis)	Excess Power Not Chemistry				
Bard, Barnes, Birnbaum [11] (1991 Analysis)					Excess Power No Major Errors
U.S. Navy - China Lake Team [6] (1993 Experiment)		Excess Power Correlated Heat and Helium-4			
R. Garwin & N. Lewis [12] (1993 Analysis)					Excess Power No Major Errors Not Chemistry
Melich & Hansen [8] (1994 Analysis)	Excess Power		Excess Power Tritium		
Shell Oil (DuFour, Foos, Millot) [13] (1995 Experiment)				Excess Power Helium-4	
Amoco Oil (Lautzenhiser, et al.) [14] (1995 Experiment)			Excess Power Tritium Not Chemistry		

1.3 Overview of Reaction Products

Figure 1 displays the known reaction products from cold fusion/condensed matter nuclear science experiments. They are grouped according to input materials, showing deuterium on the top left and protium on the top right. The reaction products measured in greatest quantities are listed in the top center; least occurring products are shown toward the bottom.

With deuterium, ^4He is reported at rates which imply 10^{12} nuclear events per second for a one-watt reaction and heat at 10^{11} events per second for a one-watt reaction. Tritium is reported at 10^4 events per second [15], and neutrons at 57 per hour [16].

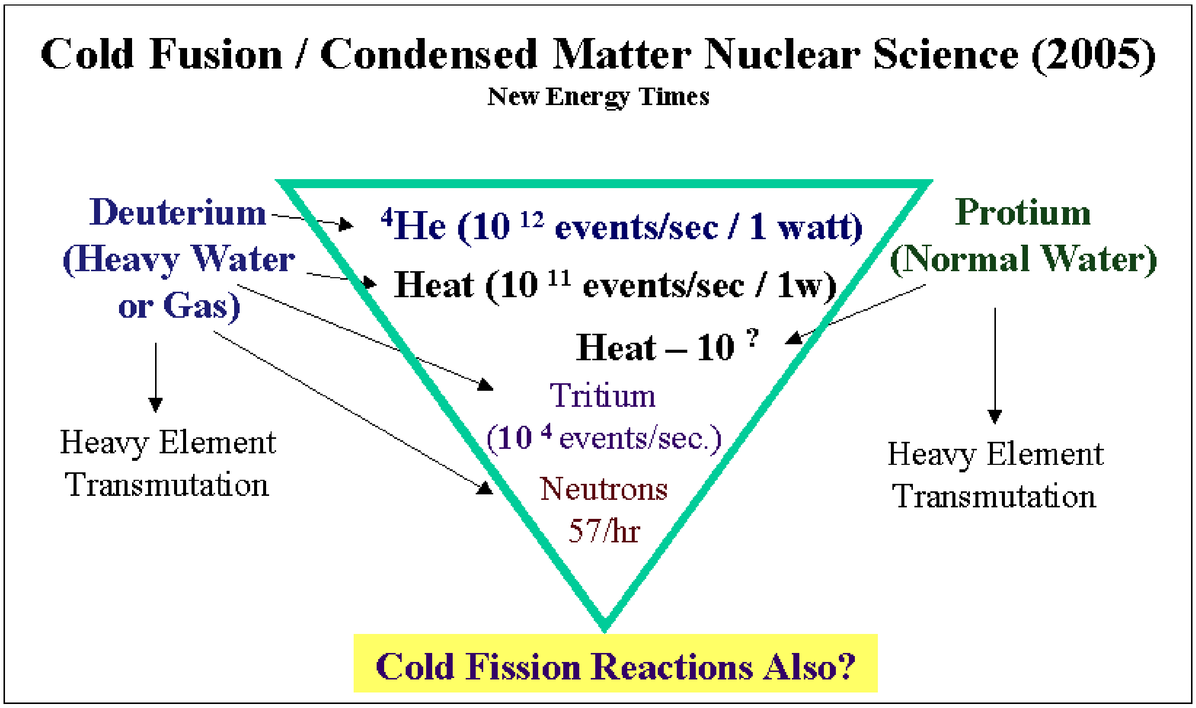

Figure 1. Overview of Reaction Products

Using protium, heat is reported at a lesser degree than with deuterium. Specific reaction rates are unavailable at this time. Both input products have been widely reported to exhibit heavy element transmutation, and some "cold fission" reactions are also reported [17].

1.4 Energy Production: Selected Reports of Excess Heat

Table III displays excess energy data from a few selected reports. Work by El-Boher of Energetics Technologies offers the most comprehensive data sets.

Table III. Energy Production: Selected Reports of Excess Heat

Researcher / Experiment No.	Year	Maximum Excess Heat	Percent Excess Heat	Time	Excess Energy
Arata [18]	1999	10w	No data	2000h	No data
Takahashi [19]	1992	130w	70%	1440h	No Data
El-Boher #56 [20]	2004	3.5w	80%	300h	3.1Mj
El-Boher #64a [20]	2004	34w (20w avg.)	2,500%	17h	1.1Mj
El-Boher #64b [20]	2004	32w	1,500%	80h	4.6Mj
Stringham [21]	2004	40w	No Data	No Data	No Data

Arata's work is noted because of the rigorous nature of the experiment and its subsequent replication by McKubre et al. at SRI International. Takahashi performed an early electrolysis experiment which was reportedly replicated by E. Storms as well as F. Celani. The Stringham work, while sparse in its data, is included because of its reported 100% reproducibility and early potential for commercialization.

1.5 Cold Fusion / Condensed Matter Nuclear Science Volumetric Power Densities

Several researchers in the cold fusion/condensed matter nuclear science field have calculated the volumetric power density of palladium when used in these experiments. M. Fleischmann & S. Pons reported in Physics Letters A [22] and J. Preparata et al. reported in J. Electroanalytical Chemistry [23] that their experiments showed significant power densities greater than that of uranium fuel rods (10^3 watts/cm^3) used in nuclear fission reactors. Fleischmann and Pons reported 10^4 watts/cm^3 and Preparata reported 10^5 watts/cm^3.

In recent years, some researchers speculate that the surface area of the host metal, (Pd), is exclusively responsible for the effect. This is in contrast to the consideration that the entire bulk of the palladium is responsible for the effect. Still others consider that in some circumstances, a host metal may not be required at all.

1.6 Heavy Element Transmutation in Cold Fusion / Condensed Matter Nuclear Science

G. Miley performed a survey of experiments demonstrating heavy element transmutation in condensed matter nuclear science. This survey says that 14 laboratories worldwide report claims of nuclear transmutations at low energies [17]. Work pioneered by Y. Iwamura of Mitsubishi Heavy Industries [24], reported first in 2002, is considered among the best in the field. T. Higashiyama of Osaka University [25] reported a replication of the Iwamura work in 2003. Both groups claim 100% reproducibility.

1.7 Cold Fusion Research Developments, a Brief Sample

1.7.1 Nuclear Hot Spots

Anomalous "hot spots" are measured on the Pd cathode using infrared imaging by Szpak et al. of U.S. Navy SPAWAR SSC, San Diego. [26, 27]. Data indicate that heat is produced on cold fusion cathodes in small, discrete loci and not the entire, broad surface of the cathode. This serves as a guide to further understand the exact nature of the nuclear active environment responsible for the reactions.

Plots of the infrared data display that the cathode temperature is in excess of 60C, while the surrounding electrolytic bath is 30C. This temperature difference is an inversion of the normal electrochemical effect of Joule heating. The effect cannot be explained by the assertion of local regions of higher resistance on the cathode. No known scientific explanation exists. These data indicate that new science is revealed. Related work displays unique morphology changes and surface deformations of the Pd/D structure [28].

1.7.2 Excess Energy and Helium Production

Megajoules of excess energy, ^{4}He and ^{3}He are shown in a unique experiment pioneered by Yoshiaki Arata and Yue-Chang Zhang of Osaka University. Called the "Double-Structure Cathode," the cathode contains a hollow chamber in which 20-nanometer-sized particles of Pd are placed [18, 29].

Results from the Arata/Zhang experiment show excess heat of 5 to 10 watts continuously observed over 2,000 hours. Total excess energy produced is estimated at 30Mj. Results from the McKubre et al. replication show a peak of 9.9 % ± 1.3%. The experiment exceeded the experimental uncertainty for a period of 86 days, and produced an integrated energy excess of 64 Mj ± 6 Mj. Experiments indicate a new source of clean nuclear energy [30].

1.7.3 Nuclear Transmutation at Low Energies using Gas Permeation

Using a substrate coated with a 40nm layer of Pd and a 2nm layer of CaO, Yasuhiro Iwamura et al. at Mitsubishi Heavy Industries transmuted Cs into the rare-earth element Pr. Experiments indicate a novel method to create nuclear reactions and atomic transmutation [24].

1.8 2004 U.S. Department of Energy Cold Fusion Review

Little insight evolved from the 2004 Department of Energy cold fusion review [31]. Storms [32] and Beaudette [33] wrote detailed critiques of the review, which, in their opinions, was poorly orchestrated and poorly executed. The most insightful reference is the reviewers' original comments [34].

1.9 Comparison of Hot and Cold Fusion

Table IV displays a comparison of key characteristics, and foreseeable qualities of each field are shown. Best values for hot fusion are displayed. Conservative values for cold fusion are displayed.

Table IV. Comparison of Hot and Cold Fusion

Government-Sponsored Research	**Hot Fusion**	**Cold Fusion**
Years Studied	54	16
Estimated U.S. funding to date	$16 Billion [35]	$25 Million [36]
Committed worldwide government funding	> $12 Billion	None
Experimental Qualities		
Shows potential for large-scale power generation	Yes	No
Potential for power production at point of consumption	No (too big)	Yes
Demonstrates self-sustaining nuclear reaction	Never	Yes [22,37-39]
Peak Experimental Power Levels		
Peak output power levels / Duration	16 Megawatt / 1 Sec.	10 watts / 2000 hrs [18,19,35]
Ratio of power out/power in (break-even =1.0)	0.67	> 1.1 [18,19,40]
Typical Experimental Power Levels		
Typical excess power levels	0	1 watt
Duration	n/a	5-600 hours [41]
Fuel		
Fuel required	D + T + Lithium	Deuterium
Dangerous and/or radioactive fuel	Yes	No
Commercialization Expectations		
Earliest estimated commercialization	2050	2010
Requires power distribution grid	Yes	No
Potential use: fixed, mobile, terrestrial, air, and space	No	Yes
Single point of failure for large service area	Yes	No
Security risk	Yes	Yes

The future of both fields of study is highly speculative. However, hot fusion likely will be appropriate for large-scale, centralized power generation, and cold fusion likely will be appropriate for smaller installations, at the point of consumption, eliminating the need for a power distribution and transmission network.

2 CONCLUSIONS

A retrospective review of cold fusion history shows many misunderstandings and diversions that impeded the progress of this field of science. Significant facts have been unreported to the general science community.

The nuclear active environment seen in successful cold fusion experiments remains to be fully understood. Certain variations and/or impurities in the cathodic material, at a nanoscale or atomic level, will cause one sample to work, and another to fail. These variations are not well-understood. Some experiments initially succeed, however, they often shut down when the cathode either melts entirely or undergoes severe deformation. Evidence of microscopic craters, unique morphology and molten metal has been reported. The commensurate high energy density required for such events can eventually be useful, but it presents an engineering problem. Nanotechnology research may help answer some of the materials science questions about cold fusion.

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