The most complete evaluation of the science of cold fusion so far
Frank Close, *Nature*

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To
DOLLY
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PREFACE

In the Spring of 1989, two electrochemists promised the world an energy Utopia – clean, cheap and abundant energy without harmful side effects to the environment. B. Stanley Pons of the University of Utah and Martin Fleischmann of Southampton University announced that they had successfully created a sustained nuclear fusion reaction at room temperature in a small jar on a laboratory tabletop. They had duplicated the process powering the sun. Their reported accomplishment had eluded fusion scientists for several decades, in spite of the fact that these scientists were experimenting with extremely high temperatures and large machines, and spending billions of dollars in fusion research. Fleischmann and Pons indeed made heady promises, which if fulfilled, are the stuff of Nobel prizes.

It was the scientific story of the century broadcast around the globe, and made network television newscasts on March 23. For example, the respected MacNeil/Lehrer News Hour devoted extended coverage to cold fusion and included interviews with both Fleischmann and Pons. Scientists around the country examined the videotapes of the MacNeil/Lehrer News Hour and other broadcasts to search for tidbits of information. However, the experimental details necessary for scientific evaluation were missing from the press release and early reports, leading many to be both upset by Fleischmann and Pons' "publication-by-press-conference" and skeptical of their claims.

The dream of cold fusion had a natural appeal because it was fueled by a very special set of circumstances. The environmental and political issues in the United States had focused our attention on a lack of a clear national energy policy. The almost coincident Exxon Valdez oil disaster was uppermost in the public's mind. Fears over gasoline shortages, price rises and lines at service stations were prevalent. The national consciousness concerning energy was rising dramatically. Furthermore, the burning of fossil fuels was known to produce large amounts of carbon dioxide in the air adding to the Earth's greenhouse gases and their predicted effect on global warming. In addition, the burning of our rather abundant high-sulfur coal was producing acid rain with its devastating consequences.

These highly destructive characteristics of fossil fuel on our environment led many to rethink the use of nuclear fission energy. However, the nuclear waste problem and the remembrance of the nuclear catastrophe of Chernobyl dampened the prospect of moving to large-scale usage of nuclear fission power in the near future. Others held nuclear fusion to be the energy source of the future. Billions of dollars had been spent already on controlled fusion research and development. Although considerable progress has been made in both magnetic and inertial fusion, no commercial power plants are projected to be operating, if at all, until well into the middle of the next century. It is against this rather dismal portrayal of the world's future energy supply that Fleischmann and Pons came onto the scene and stunned the world with their claim to have solved the controlled fusion problem. No wonder the promise of cheap, clean and abundant energy captured everyone's imagination.

In the early euphoric days of cold fusion, disbelief in the new energy dream was unpopular and viewed almost as an unpatriotic act. The *Wall Street Journal* compared Fleischmann and Pons with Ernest Rutherford, one of the giants of twentieth-century physics. However, with over four decades of experience in nuclear science, I was skeptical, as were most of my immediate colleagues, of Fleischmann and Pons' spectacular claims. Enhancing the probability of a nuclear reaction by 50 orders of magnitude (10^{50}) via the chemical environment of a metallic lattice, contradicted the very foundation of nuclear science.

Even so, many of us moved quickly to participate in the verification process. Surprises do occasionally occur in science. In scientific research it is always important to be on the lookout for an unexpected or surprising result. Our research group at the University of Rochester had state-of-the-art neutron detectors and associated electronics. This instrumentation was immediately mobilized by several of my colleagues to search for evidence of room temperature nuclear fusion. Experimentation is the final authority in science and experimental groups around the world immediately attempted to verify test-tube fusion on a bench top as viewed on the evening news. Electronic networks were saturated with open questions and unconfirmed rumors about cold fusion.

Early in April, 1989 I received a telephone call from John Schoettler, Chairman of the Energy Research Advisory Board (ERAB), asking me to serve as chairman of an ERAB panel on cold fusion. ERAB, an advisory committee to the Secretary of the Department of Energy, often formed study panels on issues of interest to the Secretary. I had served on ERAB since 1984 and felt some obligation to accept, but asked for a short time to consider the implications of such an appointment. The next week I was in Dallas and attended the first large public session on cold fusion organized by the American Chemical Society. This most unusual meeting, dubbed the "Woodstock of Chemistry", demonstrated the sharp division between scientists on the reality of cold fusion. All indications were that there would be no quick resolution of Fleischmann and Pons' extraordinary claim. A few days later, following discussions with colleagues at the spring meeting of the National Academy of Sciences, I agreed to co-chair the DOE/ERAB panel.

The panel members were appointed immediately by ERAB and began their work in late April.

For the next six months, I was completely immersed in the study of cold fusion. As the co-chair of the DOE/ERAB panel, I was in a unique position to participate directly in the day to day exchange of claims and counter claims and to experience the excitement and mystery associated with the cold fusion saga. Confirmations, retractions, new positive claims and null results were the order of the day and all had to be distilled and evaluated. It was the responsibility of our panel to gather up-to-date information from every group in the United States, as well as from many foreign groups, researching cold fusion. The amount of material was voluminous. Teams of panel members also made visits to selected laboratories working on cold fusion. Our panel completed its interim report in July, 1989 and final report in November, 1989. On speaking to a number of different groups and organizations about our panel's conclusions and recommendations, I learned firsthand that many people had a deep curiosity about the whole cold fusion episode and wanted to learn more about it. This motivated me to write this book on "cold fusion."

It is important for the reader at the outset to understand that the term "cold fusion" (or "room temperature fusion") has frequently been used for two very different phenomena. Firstly, the University of Utah claimed that Fleischmann and Pons had "successfully created a sustained nuclear fusion reaction at room temperature" producing four watts of power for each watt of input power. Secondly, Professor Steven E. Jones and his physicist colleagues at Brigham Young University (BYU) reported that they had produced very low levels of neutrons from fusion at room temperature. These two claims differed by thirteen orders of magnitude (ten thousand billion). Even so, both claims have been labelled "cold fusion" and are often erroneously interpreted as the same phenomenon.

This interchangeable use of "cold fusion" for these two very different claims has added considerable confusion to the cold fusion saga. The claim of watts of excess heat from nuclear fusion of deuterium at room temperature is completely inconsistent with reports placing very low limits on the intensities of fusion products. Jones' claim is not an independent corroboration of Fleischmann and Pons' claim. In this volume I focus on the more exotic claim of high fusion rates, first reported by Fleischmann and Pons. It is this claim that has excited the interests of everyone and has promised to solve our energy needs for all time. I do discuss also, however, the much more modest claim of very low levels of fusion products from deuterium fusion at room temperature. The reader, therefore, must always be aware of the fundamental difference in the two claims. From a scientific point of view, the latter claim, if true, is extremely interesting in its own right, but this phenomenon has no practical potential as an energy source.

The first six chapters deal with events through the second month of the cold fusion saga. Once the promise of room temperature fusion had been announced by press conference, without first passing through the normal processes of scientific scrutiny, the verification process entered the public arena. These chapters describe the early reports on cold fusion mostly communicated at several scientific meetings in the presence of the media. The clash between science and the politics of science is an integral part of the cold fusion episode. The University of Utah lobbied in Washington for major funding before the science had even been confirmed.

The second group of chapters (VII to X) describe and evaluate some of the pertinent scientific data. The University of Utah in its original press release called the experiment "extremely simple." In opposition to this, definitive calorimetric experiments turned out to be very difficult. This was especially true for open cell calorimeters. The positive reports were plagued by experimental uncertainties, inadequate controls and improper assessment of errors. One group of very strong proponents of excess heat summarized its results at the First Annual Conference on Cold Fusion by stating "There are enough calibration runs which show too much heat and D_2O runs which show little or no heat [so] that the whole process could be noise."

If fusion of deuterium is occurring there must be tell-tale fusion products. The detection sensitivity for fusion products is orders of magnitude larger than that for excess heat. Therefore, searches for neutrons, tritium, helium, etc. are the key experiments to validate cold fusion. These are described and analyzed in some detail. Proponents agree with skeptics on at least one aspect of the cold fusion saga. Namely, that there is an extremely large disparity between the claimed amounts of excess heat and fusion products even as reported by proponents. True believers in cold fusion have been frustrated by this incongruous result because it undermines the very foundation of the promise of a new "clean, virtually inexhaustible source of energy." In order to believe simultaneously in the claimed large amount of excess heat on the one hand and in its nuclear origin on the other hand, believers resorted to pseudoscience. Conventional nuclear physics was declared invalid in metallic lattices by fiat. This opened the door for a succession of miracles such as excess heat without fusion products and tritium without neutrons. Research teams obtaining negative results were often characterized as part of the "eastern establishment" and dismissed with the barb, "negative results can be obtained without skill and experience." The proponents' claim of "new physics in solids" has added intrigue and hype to the cold fusion saga, but unfortunately, it has in the final analysis led to confusion, scandal and deception. Fleischmann and Pons' underlying reason for investigating room temperature fusion was flawed from its very inception. They mistakenly asserted that the pressures attained during electrolysis were sufficient to drive deuterium nuclei close enough to fuse. The National Cold Fusion Institute has closed, careers have been damaged and many tens of millions of dollars have been squandered in time and resources. Still no verification.

How did cold fusion germinate and what fueled the whole episode? Is cold fusion pathological science? What are the hazards of going public with a far-reaching promise without sufficient experimental evidence? These subjects are explored in the final three chapters. A majority of scientists were unable to replicate Fleischmann and Pons' claim. Still, over a hundred groups reported excess heat and/or some fragmentary evidence for trace amounts of fusion products. On the basis of the sheer number of positive claims, it is tempting to conclude, as many believers have, that there must be some truth to cold fusion. Numbers of unproven claims alone, however, are not definitive in science. Hundreds of papers were published in support of both N rays and polywater, both classic examples of pathological science, which was defined by Irving Langmuir, Nobel laureate in chemistry, as "the science of things that aren't so." The paranoia of the advocates of cold fusion is illustrated by their charge that a highly vocal small group with hot fusion interests are sabotaging the future development of cold fusion. This is a case of self-deception, a characteristic of pathological science.

The University of Utah's handling of cold fusion is a striking illustration of what happens when administrators use potential royalties to force premature publication and when universities lobby for large federal funds before the science is confirmed. The chimera of cold fusion with excess heat is a striking illustration of what happens when research is done in isolation by scientists who are outside their field of expertise, when scientists circumvent the normal peer review process, when scientists require too many miracles to account for their results, when data are published by others through private communication rather than by the researchers responsible, when scientists distort the normal scientific procedures to protect patent rights, and when scientists use the press as a conduit to disseminate information about a claimed discovery in an unrealistic and overly optimistic tone.

The cold fusion fiasco illustrates once again that the scientific process works by exposing and correcting its own errors.

John R. Huizenga
Rochester, New York

The favorable reception of the first edition of my book has motivated me to prepare this updated edition. I am happy that the second edition is available also in paperback, making it accessible to a larger audience.

J. R. H.
July 1993

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I wish to thank publicly members of the Energy Research Advisory Board Cold Fusion Panel (see Appendix II for names) for their dedicated work during the six months that we studied intensively the voluminous literature on cold fusion coming from laboratories around the world. This group of twenty-two scientists from diverse backgrounds and with different fields of interest converged in their thinking on cold fusion to produce reports that were unanimously agreed on by all members. The following panel members deserve to be singled out for their special contributions to our final report: Allen J. Bard, Jacob Bigeleisen, Howard K. Birnbaum, T. Kenneth Fowler, Richard L. Garwin and John P. Schiffer. Without the support and encouragement provided by all the panel members during our study, I would not have later made the decision to write this book. However, I should emphasize that the opinions and conclusions expressed here are my own and are not necessarily those held presently by other panel members. My thanks also go to panel staff members Thomas G. Finn, David Goodwin and William Woodward who were very helpful to us in all phases of our work.

The panel also enjoyed the whole hearted backing from our parent body, the Energy Research Advisory Board. They were the authoritative body that unanimously approved our panel's final report for submission to the Secretary of Energy, Admiral James D. Watkins.

I am indebted to Tim Fitzpatrick for supplying photocopies of his stories in the *Salt Lake Tribune*, Bob Welk for placing cold fusion news clips from the *Wall Street Journal* in my mailbox, Bruce V. Lewenstein for sending me a copy of the University of Utah press release and numerous friends for calling particular articles to my attention. I am especially grateful to a large number of my scientific colleagues who supplied me with preprints of their articles and reports on cold fusion, as well as assorted bits of information by BITNET and FAX. The articles entitled "Cold Fusion News" written and electronically distributed by Douglas R.O. Morrison are classic pieces on cold fusion.

Several people have read early versions of this manuscript and provided helpful comments and suggested corrections. These include my daughter, Jann, my wife, Dolly, Nathan S. Lewis, Jack A. Kampmeier, Douglas R.O. Morrison and W. Udo Schröder. I greatly appreciate the help that each has given me. I also thank Dolly for sitting through the Hearing before the Committee on Science, Space and Technology on April 26, 1989 in Washington and taking prolific notes.

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ABBREVIATIONS

ACS	American Chemical Society
AIP	American Institute of Physics
APS	American Physical Society
BARC	Bhabbha Atomic Research Center
BITNET	electronic mail
BNL	Brookhaven National Laboratory
Bull. Am. Phys. Soc.	*Bulletin of the American Physical Society*
BYU	Brigham Young University
CAF	Coulombic annihilation fusion
Caltech	California Institute of Technology
CBS	Columbia Broadcasting System
C&EN	*Chemical and Engineering News*
CERN	Conseil European pour la Recherche Nucleaire (large particle-physics laboratory in Geneva)
CFRA	Cold Fusion Research Advocates
Coll. Jour. USSR	*Colloid Journal of the USSR*
COSEPUP	Committee on Science, Engineering and Public Policy
CSC	Clustron Science Corporation
DOE	United States Department of Energy
EPRI	Electric Power Research Institute
ERAB	Energy Research Advisory Board
Europhys. Lett.	*Europhysics Letters*
FAX	facsimile machine
GANIL	Grand Accélérateur National d'Ions Lourds
GeV	billion electron volts
HECTER	hydrogen emission by catalytic thermal electronic radiation
IBM	International Business Machines
ICCF3	Third International Conference on Cold Fusion
ICRR	Institute for Cosmic Ray Research
IMRA	Institute of Minoru Research Advancement
J. Electroanal. Chem.	*Journal of Electroanalytical Chemistry*
J. Electrochem.	*Journal of Electrochemistry*
J. Phys. Chem.	*Journal of Physical Chemistry*
J. Radioanal. Nucl. Chem. Letters	*Journal of Radioanalytical Nuclear Chemistry Letters*

keV	kilo-electron volts
mA	milli-amperes
MeV	Million electron volts
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NBC	National Broadcasting Company
NCFI	National Cold Fusion Institute
NCM	nucleon cluster model
NSF	National Science Foundation
NTT	Nippon Telegraph and Telephone Corporation
Nucl. Inst. Meth.	*Nuclear Instruments and Methods in Physics Research*
Phys. Lett.	*Physics Letters*
Phys. Rev.	*Physical Review*
Phys. Rev. Lett.	*Physical Review Letters*
PNL	Pacific Northwest Laboratory
Proc. Natl. Acad. Sci.	*Proceedings of the National Academy of Sciences*
Proc. Roy. Soc.	*Proceedings of the Royal Society (London)*
SDI	Strategic Defense Initiative
SIMS	secondary ion mass spectroscopy
Soviet Tech. Phys. Lett.	*Soviet Technical Physics Letters*
SRI	Stanford Research Institute
UCLA	University of California Los Angeles
WKB	Wentzel-Kramers-Brillouin approximation
ZETA	Zero Energy Thermonuclear Assembly
Z. Naturforsch.	*Zeitschrift für Naturforschung*
Z. Phys.	*Zeitschrift für Physik*

CONTENTS

I

Press Conference

On March 23, 1989, two electrochemists, Dr. B. Stanley Pons, Chairman of the Chemistry Department at the University of Utah, and Dr. Martin Fleischmann, a Research Professor at Southampton University, reported a major breakthrough in nuclear fusion research during a startling press conference in Salt Lake City. They claimed to have produced nuclear fusion in a test tube at room temperature in a high-school-type apparatus. If true, it was the type of discovery for which Nobel prizes are awarded! The accompanying press release (see Appendix I) was general in nature and contained virtually no technical information. Most of the major network and cable news programs carried positive stories about the Fleischmann-Pons phenomenon which has been dubbed "cold fusion." These media reports raised the hopes and expectations of many people. For example, Dan Rather led off the CBS Evening News that night with a fusion report, exclaiming, "What may be a tremendous scientific advance" (*Time*, April 8, 1989, p. 74). Journalists came to Salt Lake City from all over the United States and Europe to cover the story. The *Wall Street Journal* made cold fusion the top story in its worldwide news column on March 24. The page-one story flashed the headline, "Taming the H-Bombs?". This highly positive and detailed article in America's most prestigious financial journal suggested to the world that fusion of deuterium had actually been accomplished at room temperature. The *Wall Street Journal* article in explaining cold fusion stated that in the palladium metal lattice "the deuterium nuclei are brought close enough together to overcome their mutual repulsion and fuse." For informed readers this was one of the most extraordinary and bizarre claims made in the thirty-five-year-long effort to produce a controlled, sustained hydrogen-fusion reaction. Although most other news organizations emphasized the importance of the University of Utah discovery as a solution to the world's energy problems, some major news organizations did express skepticism and gave the story only a minor coverage. The *New York Times*, for example, relegated the story on March 24 to page A16 and wisely included reactions by physicists and fusion scientists who were skeptical of the University of Utah claims. *USA Today* for some reason ignored the story completely in its March 24 edition.

A very interesting story developed several hours prior to the University of Utah press conference. *The Financial Times* of London broke the cold fusion story on the morning of the U.S. press conference, surprising even the University of Utah press office. This occurred because March 24, 1989, was Good Friday, a bank holiday in England. Due to this holiday, *The Financial Times* would not be published on March 24, and if the paper were forced to wait until the March 23 press conference in Utah it wouldn't be able to run the cold-fusion story until Monday, March 27. This delay was apparently unacceptable to Fleischmann. According to one published report [*Science* **244** 422 (1989)] Fleischmann contacted an old friend, Richard Cookson, to ask him about the best way to get good coverage in Britain. Cookson, a former colleague of Fleischmann in the Chemistry Department at the University of Southampton, put Fleischmann in touch with his son Clive Cookson, who writes for *The Financial Times*. As a result of this contact, Fleischmann, with Pons' approval, provided *The Financial Times* with the information about their discovery for publication a day early. Hence, *The Financial Times* got the "scientific story of the year" one day before anyone else (*Science* **244** 422). The *Wall Street Journal* also had a story on the morning of March 23 entitled "Development in Atom Fusion to be Unveiled." However, its story provided only background information for its March 24 story which followed the University of Utah's press conference.

It has been known for many years that nuclear fusion occurs under exotic conditions of high temperature and pressure, such as are prevalent in the interior of the sun. Therefore, the harnessing of fusion energy for commercial use has been an elusive dream for many decades. The Fleischmann-Pons claim of cold nuclear fusion gave the world the promise of the century, namely, the promise of a virtually limitless supply of a cheap, safe and environmentally clean nuclear energy. If true, this would be an extraordinary accomplishment. Up to 1989, scientists in several countries, including the United States, USSR, Japan and a consortium of European countries had spent billions of dollars in fusion research, working on experiments with the extremely high temperatures believed necessary for inducing fusion. It is no wonder then that Fleischmann and Pons' claim shocked the scientific world and led the public to believe that the world's energy problems might be solved for all time.

The creators of the ensuing fusion frenzy first met in Southampton, England. Pons graduated from Wake Forest University in 1965, spent two years in graduate school at the University of Michigan, and left to join his family in the textile business. After eight years in business, Pons yearned to return to science and was accepted into the Electrochemistry Department at the University of Southampton to pursue his doctorate, which he obtained in 1978. It was there that he met Fleischmann, at that time a professor of electrochemistry. The two became friends and later, after

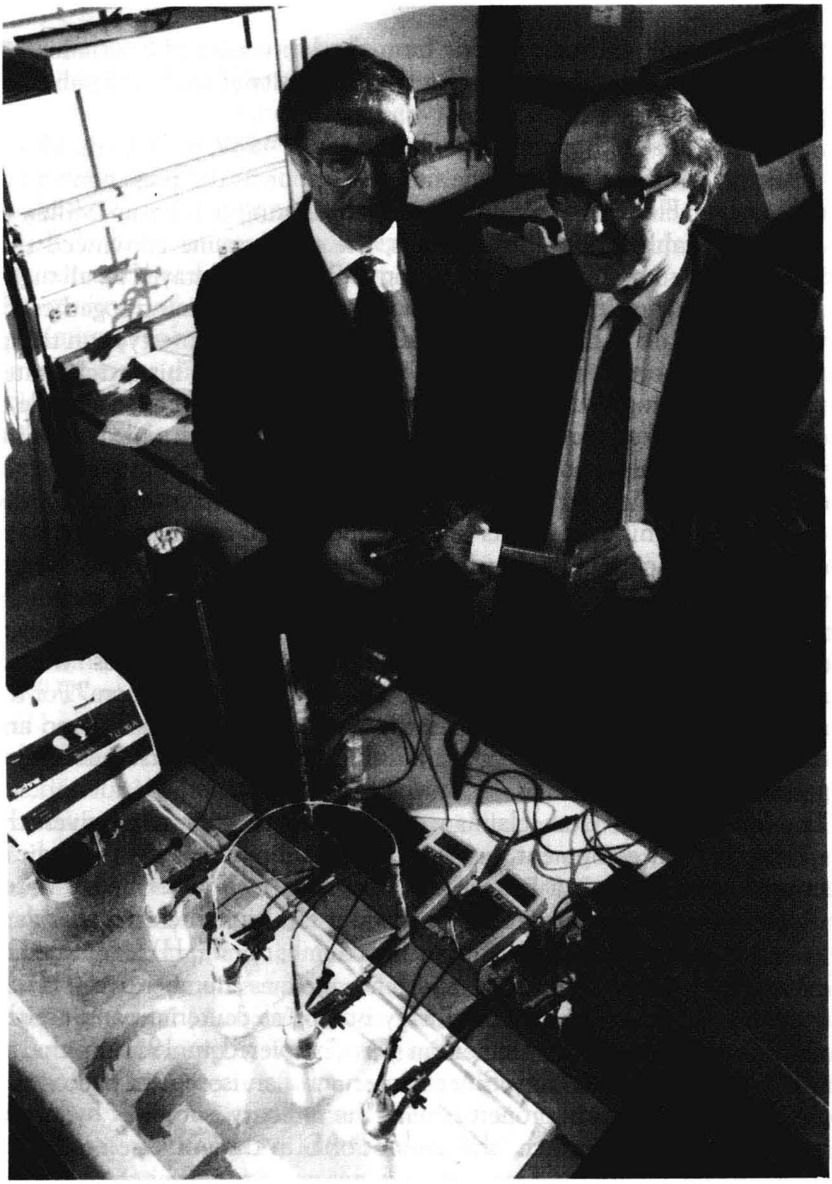

Figure 1. Professors Martin Fleischmann (right) and B. Stanley Pons in their University of Utah Chemistry Laboratory. Here they claimed to have successfully created a sustained nuclear fusion reaction at room temperature in a simple apparatus on a tabletop. Pictured are four of their small electrolysis cells in a constant-temperature water bath. At the Dallas American Chemical Society meeting (see Chapter III), Pons dubbed this bench-top experiment "the U–1 Utah Tokamak". (Courtesy of the University of Utah.)