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A Cold Fusion Primer

Cold fusion, 1994: What's it all about?

BY EUGENE F. MALLOVE AND JED ROTHWELL

What happened to cold fusion, the "miracle or mistake," announced at the University of Utah by Drs. Martin Fleischmann and Stanley Pons in March 1989? It would not be surprising if you thought that cold fusion were "dead," because, unfortunately, the scientific establishment, the hot fusion community, and many in the news media have ignored or maligned cold fusion research.

But cold fusion is far from dead. It is alive not only in dozens of laboratories in the United States, but in numerous foreign research centers, particularly in Japan.

Here are the basic facts about cold fusion as they stand in early 1994. For continuing monthly coverage of this rapidly expanding field, consider subscribing to this magazine, which every month will provide information unobtainable elsewhere, plus summaries of what is being reported worldwide in technical journals.

Hot fusion versus cold fusion

Hot fusion is the kind of nuclear reaction that powers the Sun and the stars. At temperatures of millions of degrees, the nuclei of hydrogen atoms can overcome their natural tendency to repel one another and join or fuse to form helium nuclei. This releases enormous energy, according to Einstein's famous $E=mc^2$ formula—the mass being lost in the reaction being converted to energy. Fusion is the opposite of fission, which is the release of energy by splitting heavy uranium or plutonium nuclei.

Scientists the world over have spent more than four decades and billions of dollars (an estimated $15 billion in the U.S. alone) to investigate the possibility of mimicking with devices here on Earth the fusion reactions of the stars. These are complex and large machines that rely on high magnetic fields or powerful lasers to compress and heat fusion fuel—typically the isotopes of hydrogen, deuterium and tritium.

The controlled hot fusion program has made enormous strides, but all agree that the earliest possible time when practical hot fusion devices may be available is about three decades away. Hot fusion is a very tough engineering problem. Many engineers—even those favorable to hot fusion—suggest that the "tokamak" reactor approach being followed by the U.S. Department of Energy will never result in commercially viable technology.

The U.S. hot fusioneers and their international collaborators now want to build a big, complex test reactor called ITER (International Thermonuclear Experimental Reactor), which might begin to operate in 2005. A commercial hot fusion power plant would not be on-line until at least 2040. The annual budget for hot fusion research in the U.S. regularly exceeds $500 million, and they now seek increased funding for ITER.

Mind you, the hot fusion program has never produced a *single watt* of power beyond the electric power that was put into each experiment. Occasionally, such as in December 1993 at the Princeton Plasma Physics Laboratory, "breakthroughs" in hot fusion are announced in which the power of hot fusion reactions reaches a record level, but the level has always been *below* the electric power put in.

You can't pinch it, but it's real

"Cold fusion" is a real but still incompletely explained energy-producing phenomenon, that occurs when ordinary hydrogen and the special form of hydrogen called deuterium are brought together with metals, such as palladium, titanium, and nickel. Usually, some triggering mechanism, such as electricity or acoustic energy, is required to provoke the "cold fusion" effects. Both ordinary hydrogen and deuterium are abundant in ordinary water—whether fresh water, ocean water, ice, or snow—so the process will likely end many of the world's energy concerns, if it can be developed commercially. Now, this seems all but certain. (The deuterium form of hydrogen is present naturally as one out of every 7,000 hydrogen atoms and is easy to separate.)

Cold fusion releases enormous quantities of energy in the form of heat, not radiation, as in hot fusion. This heat energy is hundreds to thousands of times what ordinary chemical reactions could possibly yield. If "cold fusion" is a heretofore unknown form of benign nuclear reaction—as most researchers in the cold fusion field believe—there is more potential cold fusion energy in a cubic mile of sea water than in all of the oil reserves on earth. Whatever the explanation—nuclear reactions, exotic "super-chemistry" perhaps requiring some modifications to quantum mechanics—or something even more bizarre (such as tapping of the zero-point energy of space at the atomic level), cold fusion seems destined to become a dominant source of energy.

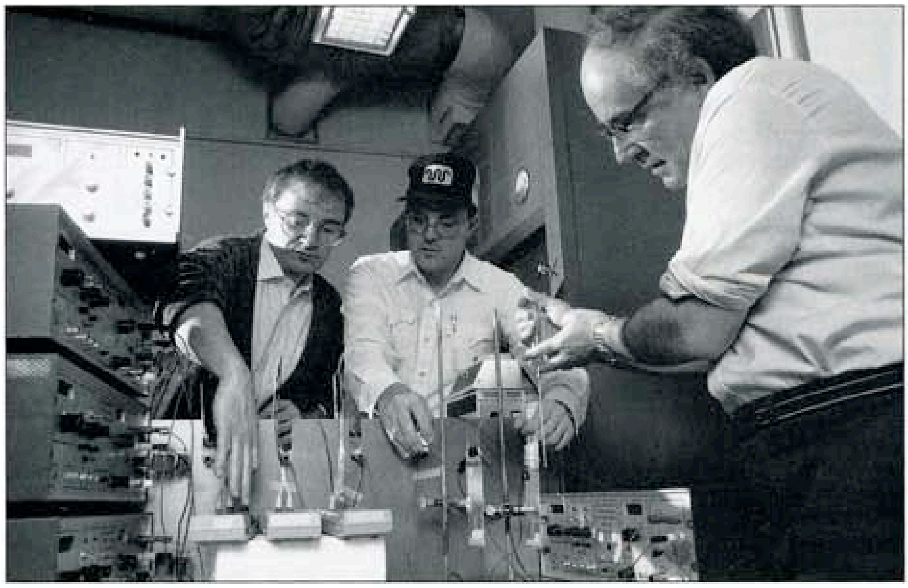
Cold fusion, in contrast to hot fusion, occurs in relatively simple apparatus, albeit not yet without some difficulties. Cold fusion reactions are not at all like conventional hot fusion reactions. If they were, cold fusion experimenters would have been killed by massive flows of radiation—neutrons and gamma rays. The continuing wonder of cold fusion is that it is apparently a very clean reaction that gives very little of the radiation common to fission and fusion reactions. In cold fusion experiments, low-level neutrons, tritium, helium-4, and isotope shifts of metal elements have been seen.

Cold fusion researchers have attempted to find theoretical models to explain the observed cold fusion effects—the large thermal energy releases, the low-level nuclear phenomena, and the absence of massive, harmful radiation, and other conventional nuclear effects. There is yet no single, generally accepted theory that explains all these phenomena. There is no doubt, however, that the phenomena exist and will eventually be explained—most likely in the next few years.

The cold fusion evidence

The most important evidence for cold fusion is the excess heat energy that comes from special electrochemical cells—much more heat coming out than electrical energy being fed in. Competent and careful researchers have now confirmed that under the proper conditions it is possible to obtain excess power output beyond input power anywhere from 10% beyond input to *many thousands of times the input power!* In fact, in experiments reported at the Fourth International Conference on Cold Fusion (December 1993), one researcher, Dr. T. Mizuno of Hokkaido University, reported an output/input power ratio of 70,000! Sometimes this power comes out in bursts, but it has also appeared continuously in some experiments for hundreds of hours, and in some cases even for many months. When this power is added up to give kilowatt-hours, the inescapable conclusion is that much more energy is being released than any possible chemical reaction (as we ordinarily understand such reactions) could yield.

And there is more. Neutrons, tritium, energetic charged particles, and other ionizing



(L. to R.): Prof. Stanley Pons, graduate student Marvin Hawkins, and Prof. Martin Fleischmann in University of Utah laboratory in 1989.

radiations have been detected in a variety of cold fusion experiments. In the past few years, there has also emerged a startling body of experimental evidence that elements have been *transmuted* in cold fusion experiments. Several laboratories have found helium-4, for example, and low levels of radioactive metal atoms. Isotopes of silver and rhodium have appeared in palladium electrodes from cold fusion cells where no such atoms existed before the experiments began. Moreover, many of these experiments differ significantly from one another in their approach and conditions.

So, there is no chance that the various laboratories are all making the same systematic errors in all these experiments. These nuclear effects are clearly the hallmark of nuclear processes of heretofore unknown character. By itself, this nuclear evidence points to an entirely new realm of phenomena of staggering scientific importance. The excess energy in some of these experiments is virtual proof that something very extraordinary and of enormous potential technological significance has been discovered.

In the early days of cold fusion research, when scientists were struggling and learning how to replicate the effect, there were many poorly done experiments, and many mistakes. In the weeks following the 1989 announcement by Drs. Martin Fleischmann and Stanley Pons at the University of Utah, large numbers of scientists tried to replicate the phenomenon, and failed—or *thought* they had failed. They actually might have obtained positive results, but for various reasons falsely interpreted and improperly reported their data.

The experiment is considerably more complicated and difficult to perform than originally reported in some scientific and popular news journals. Many scientists became disillusioned with the field after the initial "boom and bust," but a smaller number of determined scientists dug in and continued to work on the problem. Some of them continued, day in and day out, and finally achieved success. Soon after the discovery was announced, in the National University system of Japan, a low-key, long-term program was established, involving over 100 scientists in 40 institutions. The program was coordinated by Dr. Hideo Ikegami of the National Institute of Fusion Science in Nagoya.

Another long-term, well-financed program was sponsored by the U.S. Electric Power Research Institute (described below). These programs have gradually yielded a solid body of carefully replicated experimental evidence. Many of the experiments performed during the last five years produced so much heat, and used such accurate and sensitive instruments, that the results from them are certain. It is revealing that the only people saying that these experiments must all be in error either have never done cold fusion experiments themselves or have left the field of cold fusion experimentation, following their early and hastily-drawn conclusion that "cold fusion" was impossible.

Major research organizations

Several hundred laboratories around the world have obtained positive cold fusion results. A partial list, which appeared in "Fire from Ice: Searching for the Truth Behind the Cold Fusion Furor," in 1991 is already outdated. In the spring of 1991, a conference in the former Soviet Union revealed many more positive results; at the Second Annual Conference on Cold Fusion held in Como, Italy, in July 1991, much more positive evidence for cold fusion emerged. At the Third International Conference on Cold Fusion in October 1992, the evidence became overwhelming. At the Fourth International Con-

Excess heat: Count the ways

Many other methods of obtaining excess energy have been added to the roster since Pons' and Fleischmann's breakthrough five years ago. This is the current (and growing) list of apparent "cold fusion" processes giving excess energy:

1. *The original Pons-Fleischmann process*
   Heavy water solution with a current-carrying electrolyte such as lithium deuteroxide (LiOD). Current is passed between a palladium or palladium-alloy cathode and a platinum anode.
2. *Molten salt process*
   High-temperature molten electrolysis process typically involving a lithium chloride (LiCl) and potassium chloride (KCl) molten solution saturated with lithium deuteride (LiD). Electrodes are of palladium and aluminum.
3. *The Randell Mills process*
   Ordinary water solution with (typically) potassium carbonate (K_2CO_3) electrolyte. Electrodes: nickel cathode and platinum or even nickel anode.
4. *Deuterium gas discharge process*
   Low voltage electrical discharge onto various metals through a deuterium gas atmosphere—ordinary hydrogen gas too!
5. *Ultrasonic activation*
   Using ultrasonic frequencies, acoustic energy bombards palladium metal submerged in heavy water, producing excess energy and helium-4.
6. *Ceramic proton conductors*
   Certain ceramic materials related to high-temperature superconductors (such as strontium-cerium-oxide and aluminum-lanthanum-oxide), when very low current is passed through them in a deuterium gas atmosphere, give significant excess energy.
7. *Magnetic field and radio frequency stimulation*
   Magnetic fields and radio-frequency stimulation have now been proved to enhance the excess energy from other cold fusion processes, e.g. electrochemical cold fusion cells.
8. *Turbulent activation*
   An aluminum cylinder with a geometric hole pattern on its periphery rotates with close tolerances within a steel casing. Ordinary water is pumped through the interface and flashes to steam. The Hydrosonic Pump (of Hydro Dynamics, Inc., Cartersville, Georgia) has now

ference on Cold Fusion (Maui, December 1993), the field blossomed in many new directions: new methods of generating excess power, and new observations—especially *the apparent transmutation of heavy elements at low-energy*. Research facilities in the U.S. and elsewhere in the world reporting important cold fusion results include:

- Electric Power Research Institute (EPRI)/SRI International
- Los Alamos National Laboratory
- Oak Ridge National Laboratory
- Naval Weapons Center at China Lake
- Naval Research Laboratory
- Naval Ocean Systems Center
- Texas A&M University
- ENECO, Salt Lake City
- Hokkaido National University
- Osaka National University
- National Institute for Fusion Science, Nagoya
- Tokyo Institute of Technology
- Bhabha Atomic Research Centre, Bombay, India
- Technova Corporation
- IMRA Corporation
- NTT (Nippon Telephone and Telegraph company)
- And many other private research laboratories in the U.S. and abroad.

Major financial support for cold fusion research comes from these sources:

The Ministry of Education, Government of Japan. Research is coordinated through Japan's National Institute for Fusion Science, in Nagoya, and conducted in National University Laboratories. The Ministry of Education annually spends $15 to $20 million on cold fusion. In the Autumn of 1991, the Ministry of International Trade and Industry organized a research consortium of 10 major Japanese corporations to advance research in cold fusion. Prior to this, only the Ministry of Education was involved in this research. This consortium is called "The New Hydrogen Energy Panel" (NHEP). In the spring of 1992, as the activities of the Panel became widely known, Japanese newspapers reported that five other major Japanese corporations asked to be included.

In mid-1992, MITI announced a four-year, three billion yen ($24 million) program to advance cold fusion research. This money was to be spent on special expenses within the national laboratories, such as travel and extra equipment purchases beyond the usual discretionary levels. That sum did not include the money, salaries and overhead, which come out of separate budgets, and it did not count any research in the private sector, which we know to be substantial. In fact, the corporate members were expected to contribute at least $4 million more to the fund, for a total of $28 million. Both MITI and NHEP members emphasized that this fund is flexible, and could be expanded. The estimated present annual expenditure in Japan on cold fusion probably approaches $100 million.

The Electric Power Research Institute (EPRI), Palo Alto, CA., (the $500 million/year research arm of the U.S. electric utility industry) had spent as of the end of 1991 $6 million on cold fusion, and had budgeted as of January, 1992 $12 million.

Is it really possible that a revolutionary energy technology has been inappropriately cast aside in the U.S.?

The EPRI program continues to spend several million dollars per year. EPRI's sponsorship of the Fourth International Conference on Cold Fusion (December 1993) means that this powerful research organization is in the field to stay.

The public announcement in December 1993 that ENECO, a Salt Lake City-based corporation, had acquired worldwide licensing rights to the University of Utah's cold fusion patents is further indication of the increasing corporate interest in cold fusion R&D.

Recent Significant Developments

Here are some of the most extraordinary news happenings in cold fusion in recent years:

- The continuing research of Drs. Fleischmann and Pons is impressive. They are now working at a laboratory near Nice, France (in Sophia Antipolis) funded by Technova Corporation, an affiliate of Toyota which is headquartered in Tokyo. At the Como, Italy, cold fusion conference in July 1991, the cold fusion pioneers revealed that with 10 of 11 silver-palladium alloy electrodes they were able to bring their electrochemical solution to boiling. In fact, after a gestation period to reach boiling, they were able to boil away the entire liquid electrolyte in less than an hour in each positive case. In the May 3, 1993 issue of *Physics Letters A*, Drs. Pons and Fleischmann document the calorimetry with which they are able to verify the production of power at a level of 3.7 kilowatts per cubic centimeter in tiny pieces of palladium. They can now repetitively boil away the liquid contents of their cells. This is approximately the same power density of an operating nuclear fission breeder reactor.
- The Japanese government announced in 1992 that Fleischmann and Pons are senior scientific advisors for the five-year, multi-million dollar MITI cold fusion research program. They continue their work at the Japanese facility, IMRA, near Nice.
- Dr. Michael McKubre's group at SRI International has produced definitive proof of excess heat and energy production far beyond chemical explanation (200 megajoules/mole). In his Electric Power Research Institute-funded work, McKubre achieved reproducible excess power with four different palladium electrodes. His group now understands the conditions necessary to produce excess heat at will. Dr. McKubre stated categorically that the excess energy produced in his group's work cannot be explained by chemistry. Dr. McKubre's work was interrupted by a tragic, unexplained explosion on January 2, 1992. Dr. Andrew Riley, an electrochemist, died in the blast. Dr. McKubre and Dr. Stuart Smedley were also hurt. In 1993, the SRI work resumed, and will become more aggressive in its effort to identify the physical nature of the "cold fusion" process.
- The work of Dr. Robert T. Bush and Robert Eagleton and their colleagues at California Polytechnic Institute achieved one of the highest recorded levels of power density production for cold fusion—similar to that of Drs. Fleischmann and Pons. It occurred in a thin film of palladium that was deposited on a silver electrode: almost three kilowatts per cubic centimeter came out. This is 30 times the power density of the fuel rods in a typical contemporary fission nuclear reactor. The cell produced several watts of excess power for almost two months.
- On January 27, 1992 at the ISEM IEEE meeting in Nagoya, Japan, Dr. Akito Takahashi of the Department Of Nuclear Engineering, Osaka National University, reported spectacular results. Takahashi's device is a 1 mm thick x 35 mm x 35 mm palladium plate. Over a one month period, the device put out, on average, 70 watts of excess heat. About three times more heat energy came out of the device than the amount of electrical energy put into it. The total excess came to more than 200 megajoules of heat, or approximately 15,000 eV per atom. This is thousands of times more heat than any chemical reaction could possibly produce.
- Dr. Edmund Storms of Los Alamos National Laboratory announced on August 15, 1992 that he had successfully replicated the Takahashi cold fusion experiment. His experiments were conducted using a palladium cathode. Dr. Storms' success was published in *Fusion Technology*. Several other groups are known to have replicated the Takahashi experiment with varying degrees of success, including the group of Dr. Francesco Celani in Italy.

- The Subcommittee on Energy of the House Space, Science, and Technology Committee met on May 5, 1993 to discuss the status and funding of fusion energy. The hot fusion program was the focus of about two-thirds of the four-hour meeting, with the hot fusion ranks again coming to ask for further hundreds of millions to continue their work. After that, the heretofore outcasts—cold fusion and aneutronic hot fusion—was the subject. So for the first time since the House Science, Space, and Technology hearing of April 1989, cold fusion received an abbreviated but an open airing before an important congressional committee. After the very positive reception at this meeting, it appears likely that eventual Congressional exploration of cold fusion research will occur. The "ice has been broken."
- Dr. Randell Mills of Hydrocatalysis Power Corporation, of Lancaster, PA, whose heat-producing experiments with ordinary water-nickel-potassium carbonate cells are well regarded in the cold fusion field (but still questioned by some), made a presentation at the May 5, 1993 Congressional hearing. Mills's opening remarks concisely summarized what the Lancaster, PA effort is all about:

"Hydrocatalysis Power Corporation (HPC) has an extensive theoretical and experimental research program of producing energy from light-water electrolytic cells. HPC and Thermacore, Inc., Lancaster, PA are cooperating in developing a commercial product. (Thermacore is a well-respected defense contractor and its expertise is in the field of heat transfer.) Presently, all of the demonstration cells of HPC and Thermacore produce excess power immediately and continuously. Cells producing 50 watts of excess power and greater have been in operation for more than one year. Some cells can produce 10 times more heat power than the total electrical power input to the cell.

"A steam-producing prototype cell has been successfully tested . . . The [original] experiment has been scaled up by a factor of one thousand, and the scaled-up heat cell results have been independently confirmed by Thermacore, Inc. Patents covering the compositions of matter, structures, and methods of the HydroCatalysis process have been filed by HPC worldwide with a priority date of April 21, 1989. HPC and Thermacore are presently fabricating a steam-producing demonstration cell."

Dr. Mills and his colleagues believe that the energy source in their ordinary water experiments is technologically extremely potent, but they have adopted a very radical theory to explain the excess heat. These ordinary water experiments were first reported in May 1991, and have since been widely reproduced—in Japan, India, and in the U.S. Dr. Mills says that the source of excess energy is released in a catalytic process whereby the electron of the hydrogen atom is induced to undergo a transition to a lower electronic energy level than the "ground state," as defined by the usual quantum-mechanical model of the atom. Thus, stored energy in the atom is catalytically released. Mills views many of the nuclear effects in "cold fusion" to be real effects, which he thinks can be explained by his theory.

'Nothing is too wonderful to be true.'

—Michael Faraday

Balanced scientific evaluations and reference material

Several excellent scientific reviews of the cold fusion field are highly recommended. Those who want to learn more about the remarkable progress in this field should examine:

Dr. Edmund Storms (Los Alamos National Laboratory), "Review of Experimental Observations About the Cold Fusion Effect," *Fusion Technology*, 1991, Vol.20, December 1991, pp.433-477.

Dr. M. Srinivasan (Bhabha Atomic Research Centre, Bombay, India), "Nuclear Fusion in an Atomic Lattice: Update on the International Status of Cold Fusion Research," *Current Science*, April 25, 1991.

"A Review of the Investigations of the Fleischmann-Pons Phenomena," John O'M. Bockris, Guang H. Lin, and Nigel J.C. Packham, *Fusion Technology*, Vol.18, August 1990, pp.11-31.

BARC Studies in Cold Fusion (April-September 1989), Bhabha Atomic Research Centre, BARC - 1500, December 1989, P.K. Iyengar and M. Srinivasan; also in *Fusion Technology* Vol.18, August 1990, pp.32-94.

First Annual Conference on Cold Fusion (March 28-31, 1990): Conference Proceedings, by the National Cold Fusion Institute, Salt Lake City.

Anomalous Nuclear Effects in Deuterium/Solid Systems, American Institute of Physics Conference Proceedings 228, 1991, Steven E. Jones, Francesco Scaramuzzi, and David Worledge (editors), Proceedings of an International Progress Review on Anomalous Nuclear Effects in Deuterium/Solid Systems, Brigham Young University, Provo, Utah, October 22-24, 1990 (approx. 1000 pages).

Investigation of Cold Fusion Phenomena in Deuterated Metals (four volumes), by the National Cold Fusion Institute (Salt Lake City), June 1991, now available from NTIS.

The Science of Cold Fusion: Proceedings of the II Annual Conference on Cold Fusion, June 29-July 4, 1991, Como, Italy, published by the Italian Physical Society, Bologna, Italy, 1991, edited by T. Bressani, E. Del Giudice, and G. Preparata (528 pages).

Frontiers of Cold Fusion, Proceedings of the Third International Conference on Cold Fusion (Nagoya, Japan 21-25 October 1992), edited by Dr. Hideo Ikegami, National Institute for Fusion Science, Nagoya 464-01, Japan.

"Summary of the Third International Conference on Cold Fusion in Nagoya," by Professor Peter L. Hagelstein, MIT (available from Cold Fusion Research Advocates).

"The Third International Conference on Cold Fusion: Scrutiny, Invective, and Progress," By Drs. Victor Rehn and Iqbal Ahmad for the U.S. Office of Naval Research, Japan (available from Cold Fusion Research Advocates).

"Anomalous Nuclear Reactions in Condensed Matter: A Report on the Third International Meeting on Cold Fusion" by Dr. Iqbal Ahmad for the U.S. Army Research Office (AMC) - Far East (available from Cold Fusion Research Advocates).

The technical journal published by the American Nuclear Society, *Fusion Technology*, formerly was exclusively devoted to hot fusion. Since September 1989, under the editorship of Professor George Miley, this journal has regularly had an extensive section devoted to cold fusion. Other journals that have continued to carry cold fusion articles are the *Japanese Journal of Applied Physics*, *Physics Letters A*, and *The Journal of Electroanalytical Chemistry*, where the first cold fusion paper appeared.

Besides *"Cold Fusion" Magazine*, published monthly, which is the world's first magazine devoted exclusively to cold fusion R&D and investment, there are several newsletters, newspapers, and popular magazines now covering cold fusion regularly, or from time-to-time, including *The Wall Street Journal*, *Business Week*, *Cold Fusion Times* newsletter, *Fusion Facts* newsletter, *21st Century Science and Technology*.

Information is also available from *"Cold Fusion"* Magazine Contributing Editor, Jed Rothwell, who co-founded Cold Fusion Research Advocates:

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2060 Peachtree Industrial Court—
Suite 313
Chamblee, Georgia 30341
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The question of reproducibility

Cold fusion effects have not always been easy to reproduce, but that does not make them any less real. The difficulties with reproducibility, however, are rapidly disappearing as researchers discover the conditions required to provoke the phenomena, such as sufficient deuterium loading of metal lattices, specific metallurgical requirements, and peculiar triggering mechanisms. Some experimenters now report very regular appearances of cold fusion phenomena, such as tritium production and excess power as exhibited by heating, and even boiling.

Critics of cold fusion research have regularly dismissed positive results simply because the effects have not always been repeatable. Of course, there are many natural phenomena that are highly erratic, not repeatable, and definitely not predictable, such as meteorite falls, lightning strikes, earthquakes, and the elusive "ball lightning." There are also a host of modern technical devices that will not function if subtle, sometimes poorly understood composition parameters are askew; semiconductor electronic devices are good examples of this. It is not so surprising that the exotic cold fusion phenomena are subject to similar difficulties.

Negative results not necessarily negative

It is shocking but true. In the case of three major research groups that had supposedly negative results in the spring and summer of 1989—Caltech, the Harwell Laboratory in England, and MIT—there now appear to be significant questions about their work which the scientific community at-large has not addressed. Three scientists have found simple algebraic errors in the Caltech work, which invalidate the paper's negative conclusions. These scientists wrote many times to *Nature* magazine, but *Nature* refused to publish the corrections. A critique, however, was published in *Fusion Technology*.

In the MIT Plasma Fusion Center case, serious questions have arisen about the methods used to evaluate excess heat results. The unpublished data appear to show indications of excess heat, but the published version does not show these indications. Furthermore, analysis of the methodology employed by this group revealed fatal flaws—even *if* the data had been properly handled. (A technical discussion of the 1989 MIT Plasma Fusion Center cold fusion calorimetry appeared in *Fusion Facts*, August, 1992.)

In the case of the widely-touted and supposedly completely "negative" Harwell Laboratory (U.K.) calorimetry results, independent analysis of that laboratory's raw data show evidence of excess heat production. Details of the Harwell Laboratory problems have been published in both the Third and Fourth International Conference on Cold Fusion *Proceedings*.

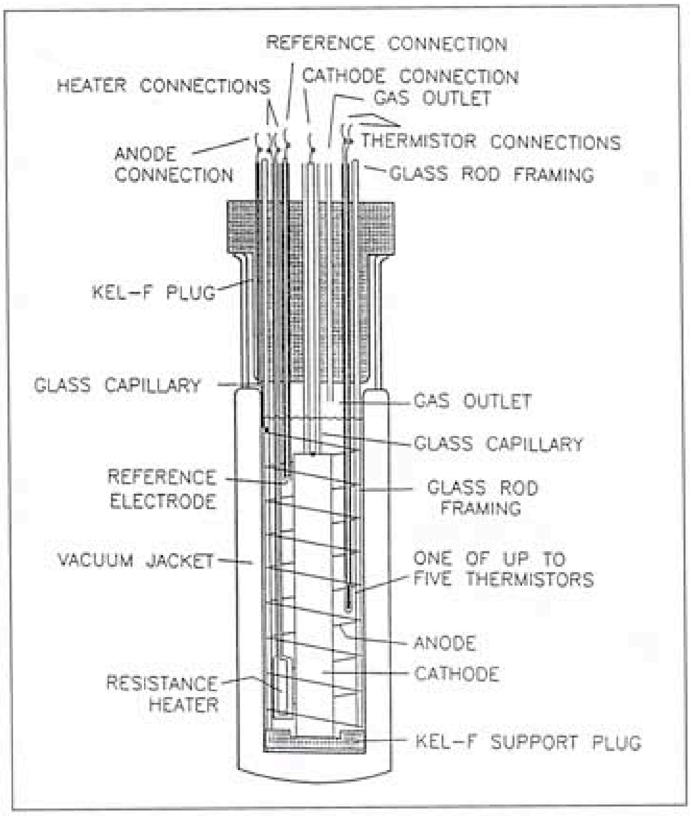
Theories of cold fusion

When conventional (low temperature) superconductivity was discovered accidentally in 1911, there was no physical theory that could explain it, nor was there any such theory for about the next half century. The much discussed high-temperature superconductivity, which appeared in 1986-1987, still has no satisfactory theory to account for it, yet industries and governments are bent on developing and commercializing it.

The same should be true for cold fusion. However, because cold fusion seems to be an even more radical departure from conventional physics wisdom than high temperature superconductivity, and because of the past reproducibility problems of cold fusion, the latter has not been accepted as readily as high-temperature superconductivity.

Cold fusion does not operate like hot fusion. That has been clear from the start. It must have some other explanation.

Happily, several scientists have proposed theories to explain cold fusion. Each of these theories might explain all or aspects of this astounding new physical phenomenon. Cold fusion theorists include physics Nobel laureate Julian Schwinger, Peter Hagelstein of MIT, Robert Bush of California Polytechnic Institute (Pomona), Scott and Talbott Chubb of the U.S. Naval Research Laboratory, Akito Takahashi of Osaka National University, Giuliano Preparata of the University of Milano hot fusion expert Frederick Mayer, Randell Mills of Hydrocatalysis Power Corporation (Lancaster, Pennsylvania), and many others.



Cross-sectional view of an early Fleischmann-Pons-type cold fusion cell. It is set up for heat-measurement as a dewar calorimeter with a glass vacuum jacket integral to the cell structure.

Notable cold fusion conferences

- First Annual Conference on Cold Fusion, Salt Lake City, March 1990.
- Anomalous Nuclear Effects in Deuterium/Solid Systems, Provo, Utah, October 1990.
- Conference on Cold Fusion under the auspices of the Soviet Academy of Sciences, March 1991.
- Second Annual Conference on Cold Fusion, Como, Italy, June-July, 1991.
- Japan Nuclear Energy Conference, cold fusion seminar, October 15-18, 1991, at Kyushu National University, Engineering Department, Fukuoka City, Japan. Part of an annual conference sponsored by the Atomic Energy Society of Japan.
- The ISEM conference on January 27, 1992. Principal sponsors were Nagoya University, the JSME, and the IEEE.
- The Third International Conference on Cold Fusion, October 21 25, 1992, in Nagoya, Japan. Principal sponsors were the Physical Society of Japan, the Japan Society of Applied Physics, Atomic Energy Society of Japan, The Institute of Electrical Engineers of Japan, The Chemical Society of Japan, The Electrochemical Society of Japan, and the Japan Society of Plasma Science and Nuclear Fusion Research.
- The Fourth International Conference on Cold Fusion, December 6-9, 1993, Maui, Hawaii, sponsored by the Electric Power Research Institute (Palo Alto, CA).
- The Fifth International Conference on Cold Fusion will be held in Nice, France in April 1995.
- The Sixth International Conference on Cold Fusion will be in Beijing, China in mid-1996.

The Future: Too good to be true?

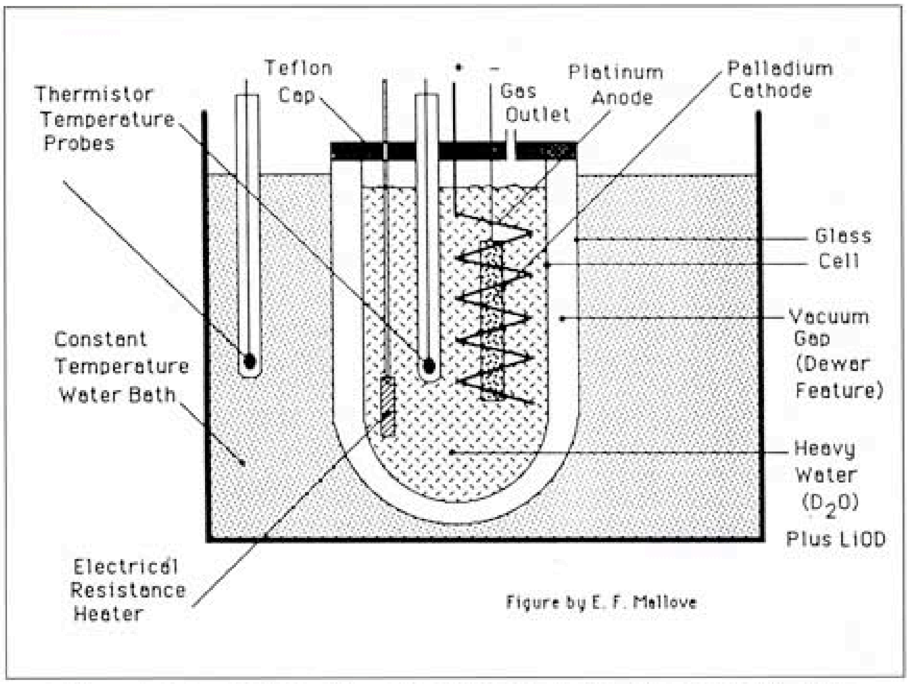
Cold fusion research is not "Big Science." It does not need massive installations, just relatively small-scale dedicated work at national laboratories, universities, and in private industries, which are already beginning to enter the field in the U.S.

Cold fusion does, however, require the talents of top scientists and engineers, combined with sophisticated analytical instrumentation. Federal laboratories, floundering in search of a new mission, are well-equipped to support cold fusion research. Cold fusion research could well become a major mission for scientists at these laboratories. Cold fusion energy development, however, will dominantly be the territory for private industry. There is no need for massive government investment. But government must smooth the path for private efforts.

Is it really possible that a revolutionary energy technology has been inappropriately cast aside in the U.S.? That is exactly what has happened, as scientific and engineering developments will show. This need not be true any longer. For the economic and environmental well-being of the nation and the world, every citizen must become aware of the facts about cold fusion, and help encourage funding for American research.

Probably the most difficult hurdle in trying to come to terms with cold fusion is that it seems too fantastic scientifically, and "too good to be true" economically and socially. But the same could have been and was said about many other technological revolutions as they began to happen.

Cold fusion will likely revolutionize the world in ways we can barely begin to imagine. We believe that before the year 2000 there will be cold fusion powered automobiles, home heating systems, small compact electrical generating units, and aerospace applications. These technologies will revolutionize the world as they speed the end of the Fossil Fuel Age.



Schematic view of a Fleischmann-Pons-type cell, showing the essential features. (From Fire from Ice, *courtesy John Wiley & Sons.)*

The stakes have never been higher. We should remember the sentiment of the famous scientist, Michael Faraday, in the last century, to whom we owe our revolutionary electrically powered civilization. He wrote, "Nothing is too wonderful to be true."

Calendar of Events

- National Workshop on the Status of Cold Fusion in Italy, University of Rome III, Rome, Italy, February 14-16, 1993
- Russian Conference on Cold Fusion, Abrau Durso, Russia, September 29-October 1, 1993
- Fourth International Conference on Cold Fusion, Maui, Hawaii, Sponsored by the Electric Power Research Institute December 6-9, 1993
- IAP Cold Fusion Seminar Series at MIT January 22, 1994
- "Renew '94," Stamford, CT, A Conference and Trade Show Promoting A Renewable Energy Future, April 11-13, 1994
- International Conference on Cold Fusion, Minsk, Republic of Belarus, May 24-26, 1994
- Fifth International Conference on Cold Fusion, Nice, France, March-April, 1995
- Sixth International Conference on Cold Fusion, Beijing, China, Mid-1996