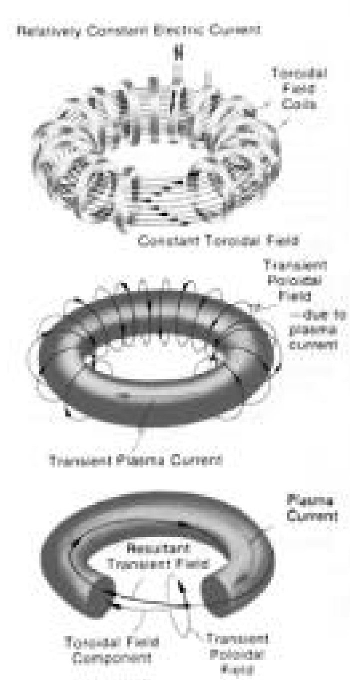
Cold Fusion
In search of Infinite Energy

George Heming

In his 1870 novel, *The Mysterious Island*, Jules Verne predicted an age of water-fuel. Soon after this assertion, black gold was discovered, and it started a new epoch in the advancement of our race, the Industrial Age. This age saw the development of most of our current technologies and was the precursor to our present information age; it was an era of inventions. We discovered ways of harnessing energy from our environment and putting it to work for ourselves. Energy gave us the power to dream and to make those dreams come true. The many inventions that came out of this age were soon so intimately woven into our lives that we could barely live without them. Ultimately, our need for energy became supreme to our existence and could only be surpassed by our need for food.



In the spirit of advancing, we sought better ways of generating energy after several eras of using coal and other fossil fuels. Our insights into nature revealed to us the limited capacity of these sources of energy and the harmful effects some of them had on our environment. We came to the realization that we needed not only more efficient ways of generating energy, but also new sources of energy that were economically viable and, more importantly, environmentally friendly. We had to search for newer sources of energy that were cleaner.

In the early twentieth century, developments in atomic theory, especially quantum theory, hinted at the possibility of harnessing the power of the atom for energy. But this radical idea, like most others that require a massive change in our view of the world, was met with strong opposition. Ernest Rutherford, one of the greatest minds of his time, and in 1933 is quoted as having said, "The energy produced by the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine." Only a year later moonshine became reality. In 1934, Enrico Fermi produced the first sustained nuclear fission reaction.

The 1950s had conquered nuclear fission, and man was ready for his next conquest. This time our dreams would took us to the stars. Scientists set out to tame the power of the stars, to produce controlled nuclear fusion reactions on Earth. If this were to be achieved, it would mean infinite energy from deuterium, a form of hydrogen, which is abundant in seawater. The potential was enormous, and the prospects exciting.

In theory, if we can get two hydrogen atoms close together so that they overcome the so-called Coulomb barrier, then they will fuse to form helium with the release of an enormous amount of energy given by the famous relation $E=mc^2$. This is conceivable theory, and, intuitively, the most feasible way of doing this would be to achieve the high temperatures, on the order of a billion degrees Celsius, of the core of stars. Scientists set out with enthusiasm to achieve their goal of re-creating stars on Earth with this intuition. Fifty years and billions of research dollars later, the enthusiasm hasn't waned, though the so-called break even point - a point when the output power of the reactor is equal to the input power- is yet to be achieved.

The implementation of theory has proved to be the greatest engineering challenge to man, with the two principal limitations being the confinement of the plasma and control of the enormous amount of neutrons that are produced, which tends to destroy the material of the reactor. Two techniques are currently being explored to tackle these problems. The first and more popular solution to the problem, called the "Tokamak," was first proposed by the Soviets and it seeks to solve the problem by magnetic confinement. It is on this model that two of the four currently running test reactors (Test Fusion Tokamak Reactor [TFTR] at Princeton and Joint European Torus [JET] in England) are built. The other two reactors, Shiva and Nova, both at the Lawrence Livermore National Laboratory, are of the Inertial Confinement species. The approach in these latter models is to fuse nuclei so quickly, using gigantic lasers or particle beams, that the nuclei do not have time to move apart.

Though these techniques have enormous prospects, the Department of Energy predicts that practical hot fusion reactors are at least five decades away. The quest is still on to tame the stars, but in the interim we have to find other alternative sources of energy to supplement the world's ever-diminishing supply of fossil fuels.

Electrodiffusion and "Cold Fusion"

In 1929, while all the excitement in physics was about the atom, quantum phenomenon, and the possibility of fission reactors, Alfred Coehn made a discovery that was seemingly tangential to the issue of energy generation. He observed that current flowing through a palladium (Pd) wire containing hydrogen (H) would move the hydrogen as if it had a positive charge. This simple phenomenon, electrodiffusion, suggested the presence of bare protons in the lattice of the Pd wire.

Seven and a half decades later, this phenomenon became the inspiration for two professors to tackle the fusion problem from another angle. Stanley Pons and Martin Fleischmann, both professors of Electrochemistry at the University of Utah, reasoned that if the proton concentration in Pd could be made high enough, then the nuclei would approach close enough to overcome the Coulomb barrier and produce unexpected nuclear reactions.

With funding from their own resources, they put their hypothesis to the test with a simple and cheap apparatus. The setup consisted of an insulated glass jar containing deuterium oxide, D2O (commonly known as heavy water), and lithium deuteroxide, LiOD (Lithium deuteroxide), in which two electrodes were immersed, one of them a coil of platinum wire, the other a rod of palladium. A small voltage between the electrodes decomposed the deuterium oxide into oxygen and deuterium (2H), some of which absorbed into the palladium. If the setup is run long enough, the deuterium gas produced at the Pd electrode saturates the electrode and fusion may occur in it. After five years of experimenting, they were ready to tell the world about their discovery.

On March 23, 1989, Fleischmann and Pons, galvanized by their university, held a press conference in Salt Lake City, Utah, where they made their claim of having discovered cold fusion. They had tamed the stars and were looking forward to a future of clean infinite energy.

In more ways then one, the two professors had broken the tenets of the scientific establishment: Thou shall not exaggerate your results. Yet, they had promoted their work with the hyperbole, "Breakthrough process has potential to provide inexhaustible sources of energy." Thou shall first report your findings in peer-reviewed journals, they held a press conference instead. Lastly, their claim was heretical. Added to the fact that their claim did not fit the current body of knowledge, their experiment was so basic and poorly documented that hot fusion physicists met it with the highest skepticism. Yet, while scientists were skeptical, investors were excited. The discovery had great economic prospects, so the announcement caused a stir on the financial market, which would last for only a few weeks.

In the heat of the controversy between physicist and the two professors, the Department of Energy set up a body of inquiry to corroborate the validity of the claim. Pons and Fleischmann refused to release information on their experimental setup until their university was granted patents on the discovery. Without specifications of the original experiment, the MIT team proceeded with its own version of the experiment, and five weeks later, they had a verdict. The MIT fusionists found apparent inconsistencies in nuclear effects claimed by the Utah group. Ronald Parker, director of the MIT fusion lab, dismissed the whole thing as "scientific schlock" and "maybe fraud." This was not the end, however. At the American Physical Society meeting that May, Steven Koonin and Nathan Lewis, speaking for himself and Charles Barnes, all three from Caltech, put forward a convincing argument that debunked cold fusion research, pointing to subtle problems with the experiment, which could have been mistaken for a new phenomenon, on which the claim was made.

The Years Between

With the controversy over just five weeks after the March announcement, mainstream scientists barely talked about the issue. But the subject was not dead yet. A few scientists worked on the problem independently. Pons and Fleischmann stepped down from their positions in Utah and moved to the South of France, where Technova, a subsidiary of Toyota Motor Company, had built them a lab to continue their research. In Italy, Professor Francesco Scaramuzzi, who is the head of a small low-temperature physics research group at a national laboratory in Frascati, decided to try the Fleischmann and Pons experiment. He reasoned that electrolysis wasn't really necessary. It served only to get deuterium to insert itself into the atomic lattice of the palladium electrode. He also thought that the system should not be in thermodynamic equilibrium. Together with his group of young scientists, he arranged to put some titanium shavings in a cell pressurized with deuterium gas (titanium also absorbs large quantities of deuterium into its atomic crystal lattice). Then they used some liquid nitrogen to run the temperature of the cell up and down, thus creating thermodynamic disequilibrium. This setup was to detect neutrons, which are produced in the proposed nuclear reaction, rather than to measure heat changes. When they installed a neutron detector near their apparatus, they observed very substantial bursts (much higher than is present in background radiation) of neutrons, which occurred spontaneously.

Back in the United States, Dr. Edward Storms, who worked 34 years with the Los Alamos National Laboratory developing nuclear motors for space applications, believed that the phenomenon was real and spent his retirement doing cold fusion research in his basement. He performed carefully controlled experiments, in which all potential sources of error were eliminated, and obtained data that suggested the phenomenon is real. He claimed that his apparatus produced excess heat for days.

Michael McKubre, a postdoctoral student of Fleischmann's at the University of Southampton and currently the Energy Research Center director at Stanford Research International (SRI), was program manager in electrochemistry when the announcement was made. He happened to be working with deuterium and palladium at the time, and managed to convince the Electric Power Research Industry (EPRI) to contribute $30,000 to fund his cold fusion research. Six months later, after several failed attempts at replicating the experiment, he obtained positive results. He had two identical cells, one with a large palladium electrode, the other with a small one, and he observed that heat was generated in proportion to the size of the electrode. Yet more evidence was needed to support the claim.

In New Hampshire, yet another experimenter was at work on the Pons and Fleischmann claim. Les Case, an MIT-trained chemical engineer with over 30 patents, was interested in finding the energy of the future. With money he had inherited from his deceased wife, he researched the cold fusion phenomenon, which he found curious. He successfully replicated the original experiment and then set out to amplify the effect by trying different materials for the electrodes. He discovered that a sample of palladium on carbon did indeed produce excess energy on a scale of 1.2 times the input energy. This was miraculous. Next, he went on to verify that what was really going on in his cell was a nuclear reaction. First he searched for neutrons that would suggest reaction A, but he didn't find any. He was probably looking at the wrong nuclear reaction, he decided, so he paid Geochron, a research lab in Cambridge, Massachusetts, to check for tritium, the presence of which suggested reaction B, but again the results were negative. Finally, he proposed reaction C, which was not considered by hot fusionists because it cannot occur in the plasma phase. To verify his hypothesis, he searched for gamma rays but found none. To be absolutely sure, he sent one of his devices to Lockheed Martin, at Oak Ridge, Tennessee. They reported that the device appeared to generate an astonishing and inexplicable 90 ppm of helium. At last, he had the confirmation he was looking for.

Besides the few scientists already mentioned, various groups in Japan and Europe, as well as some other U.S. scientists have either replicated the original experiment or reported observing seemingly nuclear effects in certain reactions at room temperature.

The Current State of Cold Fusion Research

Today, there is a sizable number of published research data that suggests the cold fusion effect, occasionally referred to as chemically assisted nuclear reactions, is real. Among researchers in the field, the reality of the effect is no longer in doubt and there are several well-corroborated ways in which the cold fusion effect has been observed. These include:

- Electrolysis of D_2O-based electrolyte using a Pd cathode (20-100°C).
- Various solid compounds in D_2 (700-800°C).
- Gas discharge using Pd electrodes in hydrogen.
- Gas reaction with Ni under special conditions (400°C).
- Enhanced reaction involving D_2O and various metals using an acoustic field.
- Enhanced reaction in H_2O using microbubble formation (20-100°C).
- Reaction of finely divided palladium with pressurized deuterium gas.

More recently, evidence supporting the claim of nuclear reactions at low temperatures has increased. The most significant one being the observed transmutation of the electrode material into metals that were initially absent in the cell, such as K, Mg, Fe, Cl, Al, and Ca, in addition to the production of tritium and 4He. This was first reported at Texas A&M University by Bokris and Menevski, who have studied the phenomenon for over a decade. New research done at the underground Gran Sasso research laboratory in Italy, using one of the world's best neutron counters, has given more credibility to the observed emission of neutrons in cold fusion cells.

Despite the increased reliability of cold fusion experiments, there hasn't been as much success at developing a working theoretical model that explains the gamut of observations. Among the successful theories is Trapped Neutron Catalyzed Fusion (TNCF), first proposed by Hideo KozimaShizuoka (University of Japan), which has been used to successfully explain the transmutations as well as the simultaneous production of tritium and helium. In this model, thermal neutrons, which are present in the normal environment, are proposed to be trapped in crystals where they can, under the proper circumstances, interact with nuclei. The neutrons are thought to be stabilized by forming neutron Cooper pairs and by acting as Bloch waves, which prevent both normal neutron decay and interaction with near-by nuclei until a large perturbation is suffered by the crystal. This perturbation is proposed to be caused by certain surface impurities, some of which subsequently react with the released neutrons. The approach is handicapped by the need to make several arbitrary assumptions in order for the model to be consistent with observation.

MIT Professor of Mathematics Peter Hagelstein provides this explanation: Thermal vibrations of individual atoms combine to produce pockets of higher energy (temperature). Energy is accumulated in phonon bands by non-linear frequency shifts involving fluctuations in the phonon spectrum. This enhanced energy is transferred to a few atoms by vibrational processes, which cause adjacent nuclei to approach each other with sufficient energy to allow various nuclear interactions including fusion and transmutation.

Barut (deceased professor at the University of Colorado at Boulder) and Vigier (University of Bari) have suggested that the observed "excess heat" in cold fusion experiments could be related to the new tightly bound states of the hydrogen atom. These states are caused by electromagnetic interactions at small distances. Another mechanism for the occurrence of deep energy levels could be a creation of the "anti-Born-Oppenheimer" states, corresponding to rapid motion of the heavy particles around almost-fixed electrons.

Preparata of the National Institute of Nuclear Physics (INFN), Italy, using an approach called QED (Quantum Electro Dynamics), proposes a model in which various coherent plasma fields exist in a crystal structure, i.e., the fields act like electron lasers that are completely contained within the structure. These fields are proposed to combine and provide sufficient screening of deuterium nuclei to allow fusion and other reactions to take place. The model requires the fusion process to occur at tetrahedral sites within b-PdD when the deuterium concentration has reached very high values. Released energy is absorbed by the coherent fields, which then emit X-rays. However, no evidence exists for tetrahedral occupancy by deuterium in b-PdD.

Despite the lack of a unified model to explain all the observations, many of the theories propose resonance processes. This agreement the plethora of theories may be the first step to finding a universally accepted model for cold fusion.

Jules Verne's Dream

"I know that most men, including those at ease with problems of the greatest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives."

—Tolstoy

Modern science has forgotten that our current body of knowledge is only a set of partial theories attempting to explain our universe. It is quite unfortunate that a discovery should be debunked as pathological science because we cannot explain it with our current theories, or because people who are not considered experts in a highly technical field made the discovery. Cold fusion, if it turns out to be real, has enormous potential for advancing science and the human race; therefore, we owe it to ourselves to give this phenomenon a thorough scientific evaluation. It is only then that we can advance toward the water fuel age, predicted by Verne, who is considered by many to be the father of modern science fiction.

References

1. www.altenergy.org/3/new_energy/coldfusion/ (Alternative Energy Institute Inc.)
2. http://www.its.caltech.edu/~dg/fusion.html (Dr. Goodstein, faculty member at Caltech and a friend of Scaramuzzi)
3. http://www.wired.com/wired/archive/6.11/coldfusion.html (*Wired* Magazine Online archives)
4. http://www.mv.com/ipusers/zeropoint/ (*Infinite Energy* Magazine online)
5. http://www.scientificexploration.org/ (Society for Scientific Exploration)
6. First reliable tritium data by Packham et al. analyzed by TNCF model, *International Journal of Hydrogen Energy*, Volume 25, Issue 6, 1 June 2000, Pages 505-507
   Hideo Kozima, Koki Yoshimoto and Kunihito Arai
7. Localized nuclear transmutation in PdHx observed by Bockris and Minevski revealed a characteristic of CF phenomenon, International *Journal of Hydrogen Energy*, Volume 25, Issue 6, 1 June 2000, Pages 513-516
   Hideo Kozima and Kunihito Arai
8. New quantum mechanical tight bound states and "cold fusion" experiments, *Physics Letters A*, Volume 265, Issue 3, 24 January 2000, Pages 163-167
   A. Dragi, Z. Mari and J. P. Vigier