*EXCESS HEAT & Why Cold Fusion Research Prevailed*, Second Edition, Charles G. Beaudette, 2002, Oak Grove Press, LLC, ISBN 9-9678548-2-2 (hard cover), 38.95 USD, ISBN 0-9678548-3-0 (soft cover), 27.95 USD.

This book tells the history of the strangest event in modern science. In 1989 the University of Utah announced a new experiment by electrochemists Professors Martin Fleischmann and Stanley Pons that demonstrates table top nuclear fusion at extremely low levels, and substantial anomalous (unexplained, excess) heat energy (power) with no dangerous radiation. This story, written for the college reader without scientific training, presents the abundant replication of excess heat results by many laboratories in several countries. Excess heat research, referred to as cold fusion research, is presently an empirical science known as low energy nuclear reactions (LENR). While the book illustrates much progress, the specific reactions that produce the heat energy still await discovery. Accused of being scientific heresy, this story parallels the famous story about Galileo whose academy fellows refused to look through his new telescope because the observations would contradict then current cosmic theory. Likewise, skeptics of cold fusion research refuse to go into the laboratory and measure the generation of excess heat in contradiction of current nuclear theory. Two future possibilities are presented: (1) a sustainable, plentiful, and portable source of energy for society, and (2) the transmutation of radioactive waste products into harmless elements (radioactivity remediation).

# EXCESS HEAT

## *Why Cold Fusion Research Prevailed*

SECOND EDITION

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*An investigative report prepared for the general reader to explain how the most extraordinary claim made in the basic sciences during the twentieth century was mistakenly dismissed through errors of scientific protocol.*

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## CHAPTER ONE

# *The Significant Claim*

The French Academy printed a brief report by Pierre Curie and his collaborator Albert Laborde in 1903 to announce that the newly recognized metal radium was always a little warmer than its surroundings.[1] The metal gave off heat continuously without suffering apparent change. In a later memoir, Marie Curie, Pierre's widow, offered her appraisal.

> More striking still was the discovery of the discharge of heat from radium. Without any alteration of appearance this substance releases each hour a quantity of heat sufficient to melt its own weight of ice. This defied all contemporary scientific experience.[2]

In 1989, a certain chemistry experiment, by its claim to run a little too warm, "defied all contemporary scientific experience." Two reputable chemists at the University of Utah, Salt Lake City, in March of that year, claimed that an electrochemistry experiment generated a large amount of power in the form of an excess of heat, an amount of power that could not be accounted for by science. This phenomenon happened in an experiment consisting of a water solution in a flask with two metal electrodes immersed in it such that when a considerable electric current was made to flow between the electrodes, gas formed on them and bubbled to the surface. They also set forth an hypothesis that the observed energy came from an unrecognized or unknown nuclear process, one that did not emit dangerous radiation.

Evidence for anomalous power emerged from their heat measurements and established a scientific observation not unlike that made by Pierre Curie, whose report was accepted even though the source of the warmth was not known to science and certainly there could be no understanding of it at that early date. The two Utah chemists presented their experimental observation of excess heat to the scientific community that it might be recognized and evaluated in the same way.

These two chemists also claimed achievement of sustained nuclear fusion in their experimental flask. That announcement flew in the face of the world's hot fusion physicists. The scientific community reacted in a frenzied and skeptical manner. Shortly, knowledgeable scientists declared that their measurement of nuclear activity was severely flawed and did so with good reason. The scientists properly dismissed the measurement as a mistake.

That evaluation of the nuclear fusion claim followed proper protocol (formal procedure) in that it was evaluated simply as a measurement. Observational science offers a cosmic supernova (exploding star) or the phenomena of electrical superconductivity (electrical conductivity with zero resistance). These interest science enormously, even if their cause or mechanism is unknown. For example, the 1911 discovery of superconductivity presented a scientific question: How was it possible for a metal to conduct electricity with zero resistance? The claim to have discovered anomalous heat power presented the question: What was a possible origin of the heat power? The first question, about superconductivity, was not answered for forty-six years.

How many years of scientific study must pass before the source of anomalous heat has been determined? The process of validating a thermal measurement is properly held completely separate from its consequent questions. This separation enables the scientific community to do an evaluation in accordance with historically established procedures.

In that manner, conventional protocol calls for the scientific community to accept each well-measured observation as a *stand-alone* datum. Each, after validation, is admitted into science to begin a new field of study. Science will elucidate afterwards, as its *raison d'etre,* the underlying mechanism thus engendering further understanding of matter and energy. Scientists will bend their backs to answer the questions: what causes a supernova, and what enables superconductivity. When the process of answering the causal questions has been completed, something that may take a generation or more, science will have acquired the understanding that was missing at the first observation or discovery. In this way, the routine procedures of science provide for that understanding which is often missing at the moment of discovery.

Over the years 1989–1994, meticulous measurements were made of anomalous power. That was done with a wide variety of experimental arrangements and instrumentation, and it was done in many different laboratories. The measurements continued for a decade and were essentially without scientific challenge. They were reported in more than one hundred full-length technical articles in a number of scientific journals and constituted the field's source of intellectual motivation for the first decade.

Unfortunately, physicists did not generally claim expertise in calorimetry, the measurement of calories of heat energy. Nor did they countenance clever chemists declaring hypotheses about nuclear physics. Their outspoken commentary largely ignored the heat measurements along with the offer of an hypothesis about unknown nuclear processes. They did not acquaint themselves with the laboratory procedures that produced anomalous heat data. These attitudes held firm throughout the first decade, causing a sustained controversy.

The upshot of this conflict was that the scientific community failed to give anomalous heat the evaluation that was its due. Scientists of orthodox views, in the first six years of this episode, produced only four critical reviews of the two chemists' calorimetry work. The first report came in 1989 (N. S. Lewis). It dismissed the Utah claim for anomalous power on grounds of faulty laboratory technique. A second review was produced in 1991 (W. N. Hansen) that strongly supported the claim. It was based on an independent analysis of cell data that was provided by the two chemists. An extensive review completed in 1992 (R. H. Wilson) was highly critical though not conclusive. But it did recognize the existence of anomalous power, which carried the implication that the Lewis dismissal was mistaken. A fourth review was produced in 1994 (D. R. O. Morrison) which was itself unsatisfactory. It was rebutted strongly to the point of dismissal and correctly in my view. No defense was offered against the rebuttal. During those first six years, the community of orthodox scientists produced no report of a flaw in the heat measurements that was subsequently sustained by other reports.

The community of scientists at large never saw or knew about this minimalist critique of the claim. It was buried in the avalanche of skepticism that issued forth in the first three months. This skepticism was buttressed by the failure of the two chemists' nuclear measurements, the lack of a theoretical understanding of how their claim could work, a mistaken concern with the number of failed experiments, a wholly unrealistic expectation of the time and resource the evaluation would need, and the substantial *ad hominem* attacks on them. However, their original claim of measurement of the anomalous power remained unscathed during all of this furor. A decade later, it was not generally realized that this claim remained essentially unevaluated by the scientific community. Confusion necessarily arose when the skeptics refused *without argument* to recognize the heat measurement and its corresponding hypothesis of a nuclear source. As a consequence, the story of the excess heat phenomenon has never been told.

A few basic notions about the atom are needed if the components used in cold fusion experiments are to be recognized. The atom's center is the nucleus, a tiny object relative to the atom, that may hold two kinds of objects, the proton with a positive electric charge and the neutron with no charge. Hydrogen gas is the lightest element with one proton in its nucleus and one electron orbiting about it. It has three forms (isotopes) each of sufficient importance to have its own name. Hydrogen (H), the most common type, has no neutrons, deuterium (D) has one neutron, and tritium (T) has two neutrons. Because most of the atom's weight is in the nucleus, deuterium with its two particles has twice the weight of hydrogen. When water consists of deuterium instead of hydrogen, as in $D_2O$, it is about 10 percent heavier than ordinary water and is referred to as heavy water.

The two Utah chemists were Martin Fleischmann, electrochemist and Fellow of the Royal Society, and Stanley Pons, Chairman of the Chemistry Department at the University of Utah. By March 1989, they had been experimenting with the generation of anomalous (unaccountable) heat power for about five years.

Their experiment in its most general form is familiar to chemistry students. The cell, as the apparatus is called, is tightly configured. The glass flask itself has a Dewar, double walled (thermos), construction with a hard vacuum between the walls. Its content consists of heavy water ($D_2O$) with lithium dissolved in it to form an electrolyte (an electrically conductive solution) that fills the flask up to its neck. Inside the flask, immersed and centered near the bottom, is the cathode electrode, a palladium metal rod. Wrapped against the inside wall of the flask is the anode electrode, a platinum wire. The flask is usually submerged to its neck in a cooler bath of temperature controlled (plain) water for heat measuring purposes.

To operate the cell, a direct current is passed between the two electrodes from an external power supply. The electric current causes the water to break down into its constituent parts. Oxygen gas bubbles off at the anode (+) and deuterium gas bubbles off from the cathode (−). Some of the deuterium atoms enter directly into the body of the palladium. The temperature of the cell's liquid electrolyte, and the voltage across the two electrodes are the two measurements that tell an experimenter what the cell is doing. Because the electrolyte is slowly bubbling away, it has to be replenished at regular intervals.

## *Anomalous Power*

Figure 1.1 is an advantageous starting point for an introduction to anomalous power.[3] The illustration is taken from an informal article Fleischmann wrote for an electrochemical society journal. In it he shows *qualitative* evidence for the existence of anomalous power. The drawing has two tracings, (the central

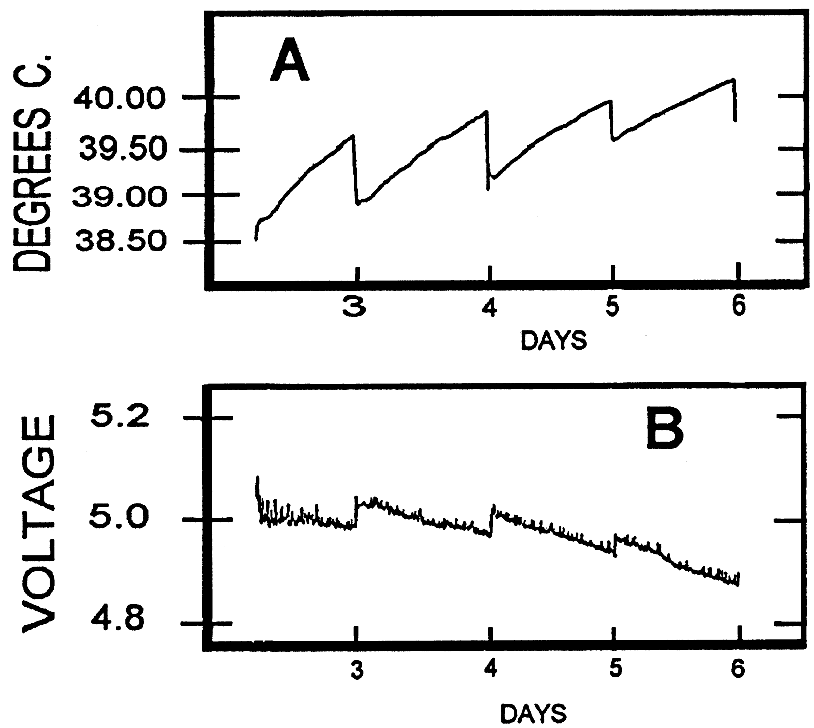


FIGURE 1.1 Fleischmann offers a qualitative display of excess heat power. When the cell voltage decreases, the cell input power decreases, but the cell temperature continues to increase.

lines in the graphs): A is a sequence of cell electrolyte temperature measurements and B is a sequence of cell electrode voltage measurements.

Tracing A shows temperature in degrees Celsius (Centigrade) as marked on the vertical axis. It is shown for one cell operating during days three through six, after the electrical current from an external power supply was turned on. The temperature climbs continuously during each 24 hour interval. A precipitous temperature drop occurs when the cell's liquid level is replenished. The temperature also increases from one day to the next. After replenishment on day three, the temperature is just under 39.00 degrees.* At the end of the subsequent 24 hour period, the temperature has climbed up to 39.75C. At replenishment, it drops to 39.20C and starts to rise again.

* The temperature and voltage numbers come from the experiment's database that was used to draw the tracings in Figure 1.1.

Tracing B shows electrical voltage as plotted on the vertical axis. The voltage across the cell electrodes decreases during each of these daily intervals and also decreases from day to day. At day three, the potential starts at about 5.08 volts, and decreases to 4.98 in 24 hours. With replenishment, the voltage jumps to 5.05 volts, and begins to descend again. Since the cell operates with a constant current from its power supply, the voltage decrease means a decrease of power delivered into the cell.*

After each addition of water, the cell ought to achieve an equilibrium temperature in ten hours, which would result in the temperature and voltage traces leveling into horizontal lines until the next electrolyte addition. How is it possible for the temperature to get hotter while the electrical input power is reduced? The experiment displays no attainment of equilibrium.

Fleischmann states, "The conclusion that there is excess enthalpy [heat power] generation is inescapable and we note that this conclusion is independent of any method of calibration which may be adopted to put the study on a quantitative basis."[4] The data demonstrate *qualitatively* that there is within the cell a hidden source of additional energy that causes the temperature to rise even as the input power decreases.

It is possible at this point to see how some scientists came to the conclusion that within the cell there was a source of anomalous heat generation that was unrecognized or unknown to science. Their source of motivation during the first ten years was to confirm and explore this now well-measured, anomalous-heat observation. The esteemed hot fusion physicist Franco Scaramuzzi states from his own laboratory experience that, "It is my conviction that some of the phenomena known with the name of CF [cold fusion] are real, in particular, the production of excess heat and its nuclear origin."[5]

Evaluation of a measurement (observation) claim proceeds in ways that might at first seem strange, or at least counter-intuitive. The protocols of science† require that the scientific community evaluate a significant measurement claim. If the two chemists' claim is sustained, then the community will be obliged to study that phenomenon until an understanding of it is achieved, no matter how long that might take.

* For the experiment of Figure 1.1, details include a solution of lithium sulfate ($Li_2SO_4$) in heavy water, the cell current was 0.4 amperes, the Faradaic efficiency was virtually 100% (there was no significant amount of recombination), and the coefficient of heat transfer from the cell (using a Dewar flask with a hard vacuum) was independent of time. The rate of power generation at the end of each day was reported as 45, 66, 86, and 115 milliwatts for days 3 through 6 respectively. (These calculations allow for the energy used in separating the water molecule into the two gases that then leave the cell.)

Fleischmann's cells usually have a relaxation time of about ninety minutes (with nine hours allowed to realize equilibrium), a silvered top/neck area to mask liquid level changes, and 95% radiant cooling (5% conduction cooling) to the water bath.

† Protocol means an explicit step-by-step procedure. A doctor follows the appropriate protocol in the treatment of a patient for a disease.

CHAPTER NINE

# *The Critics: II*

After the Utah announcement, severe criticisms arose about the presumed lack of suitable control experiments in the Fleischmann and Pons paper. These criticisms came both from individual physicists and from publications. Each demanded an experiment substituting light water for the heavy water because the deuterium supplied for the claimed fusion was presumably provided by the heavy water.

As was mentioned earlier, a dichotomy was implicit in the complaints because two situations needed to be tested. The control test for nuclear fusion required substitution of light water. The test for anomalous power required substitution only of an exhausted palladium or a platinum rod for the cathode.

In April 1989 the *New York Times* wrote an editorial in authoritative tones, "But the two [Fleischmann and Pons] apparently neglected a basic caution that scientists have learned to impose on themselves for fear of being carried away—a control experiment, like repeating the test with ordinary water instead of heavy water."

Dr. Huizenga was emphatic about the need for this control experiment. He said,

> Pons and Fleischmann failed to carry out a number of even the more elementary tests and cross-checks. When questioned about their results with ordinary light water, their answers were non-informative and subject to ambiguous interpretations.[1]

perature had not dropped. He put the cell in a bucket of water, and after an hour its temperature had dropped to 60C. On Saturday, he came in to check the cell and found the water had evaporated, the bucket empty, and the temperature up to 80C. He found a larger bucket and put 15 liters of water in it so as to completely submerge the cell. He checked three days later, on April 30, to find that this water had evaporated too.

Mizuno refilled the bucket with another 15 liters, and on each of the next two days he added 5 liters to it. Four days later, on May 7, the water was half gone and the temperature subsided to 35C. He calculates that from April 30 to May 7 the cell evaporated water to the tune of $8.2 \times 10^7$ Joules. That energy would keep our 1500 watt stove burner running on high for 15 hours.

This example of Mizuno's is the only occasion in this book where we have presented a limited type of experiment. The data was not sufficiently well documented to be published in a journal.

Giuliano Mengoli, Instituto di Polarografia, CNR, IPELP, Padova, Italy, by operating his cells at 95C, responded to an earlier Fleischmann note that higher temperatures facilitate the onset of anomalous power generation. He operated the cell and its bath at that temperature initially to enable cell temperature excursions above 95C allowing a measure of excess heat generation.[15] His design was similar to Fleischmann's, it being of similar size with a Dewar cell and palladium sheet cathode in a heavy water electrolyte. One difference was that Dr. Mengoli used an external source of gas bubbling through the cell to assure adequate mixing when the current was set at values much lower than those used by Fleischmann and Pons.

Figure 15.2 shows, partially, the result of one such run in 1995. The figure is labeled in watts of excess heat and in minutes from the point at which, after five days of electrolysis, the current was reduced to 1.5 mA/cm$^2$. After about 45 minutes the current was switched off. The amount of generated (excess) heat then increased to a level of 0.82 watts, about double its earlier value. The cell continued at that power level for 3.3 hours as shown in the figure, and for an additional 24 hours that are not shown. During these 27.3 hours, there was no electrical excitation applied to the cell. Furthermore, the excess energy generation stopped only because the experiment was shut down by turning off the thermostatic bath and letting it assume room temperature.

Dr. Mengoli reports one run in which the excess heat after current cut-off continued without cell excitation for 150 hours.[16]

Dr. M. Miles, China Lake, CA, received an appointment to the New Hydrogen Energy (NHE) Laboratory, Sapporo, Japan, where he performed an experiment that ran for 70 days, from December 1997 to February 1998. The cathode for his cell was an alloy of 0.5% boron in palladium made at the Naval Research Laboratory, Washington, DC, especially for this purpose. The

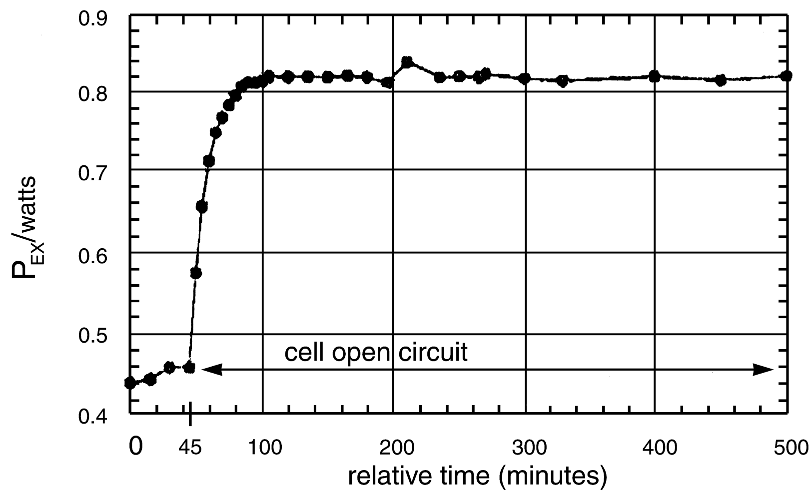


FIGURE 15.2 Mengoli observed his cell, operating at 95C, to continue to generate heat for 27 hours after the current circuit was interrupted.

data acquired during the run was thoroughly evaluated in a report published by the NRL[17] from which this summary is prepared.

The cell was allowed to run dry on day 69 to produce, afterwards, the phenomenon of heat-after-death (or posthumous heat) that lasted for approximately one hour during which time the excess heat being generated by the cell increased from 1 watt to approximately nine watts.[18] Fleischmann and Pons, Mizuno, Mengoli, and Miles all obtained a substantial increase of power after excitation was turned-off. Oriani found that excess heat could be generated from the start without electrical excitation.

This display of posthumous heat enables a more intuitive appreciation of the Fleischmann and Pons phenomena. *No longer is it necessary to subtract the input from the output power to determine the amount of excess heat.* The measured heat is all excess heat.

With this chapter, we end our devotion to anomalous power, the principle presenting symptom of an unknown nuclear reaction in solid matter. From the beginning of this episode, some scientists, correctly convinced that the excess heat announced by Fleischmann and Pons in March 1989, would prove true, started to search for the nuclear products that must be produced by that reaction, no matter what the nature of that reaction might be. Part Four is committed to that purpose.

CHAPTER TWENTY-TWO

# *The Skeptics*

It was a surprise for me to realize that the skeptic, as herein defined, does not often contribute to the advancement of science. In Chapter 10, p. 133, I quoted Beveridge in support of this view. The skeptic is one who will not accept an assumption that is fundamental to a field of study thereby leaving him blind to the research. Consequently his "criticisms" are not useful to those to whom they are directed.

The world accepts the implication of Magellan's ship's journey circumnavigating the globe, but Beveridge's flat-earther does not. A cartographer puzzles over the paradox of how to design a flat map to depict the spherical Earth. The distortions implicit in his finished map are ridiculed by the skeptic as error. The skeptic thus imagines himself a critic. The skeptic, believing the world to be flat, does not recognize that the cartographer's mapping problem exists. His "criticisms" do not help the cartographer.

The data of interest in cold fusion studies imply the existence of anomalous power in the Fleischmann and Pons experiment. Those committed to the field strive to assess that data with increasing rigor while the skeptic ignores that same data. The skeptic can criticize them; he can not help them. His "criticism" is sterile. Nevertheless, skeptics have played a significant, possibly formative, part in the cold fusion saga. Their part in it must be thoroughly considered.

The field of cold fusion research suffered from the armchair skeptic. He was supremely confident of his nuclear theory and so did not venture into the chemistry laboratory. He somehow knew, *a priori,* that anomalous power did not exist.

The source of motivation for the cold fusion researcher as seen by the