Cold Fusion – The Energy Balance Sheet

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The Correct Energy Balance Sheet was missing from the initial 1989 and subsequent pronouncements of cold fusion, or nuclear fusion at room temperature, or low energy nuclear reaction (LENR).

Three weeks after the March 23, 1989 news of cold fusion, *my alma* mater, the George Washington University (GWU), asked me to give a lecture on cold fusion on the UNET, the University Satellite Network. Everyone was hungry for definite news about the process. The first Item in my Lecture was "A Correct Energy Balance Table in Cold Fusion." The coast-to-coast telecast course was then canceled. On May 12, 1989, the Continuing Engineering Education Program (CEEP) administration at GWU wrote me to "*confirm the scheduling of your new course no. 1600DC, "The Heat Mechanism in Cold Fusion" for presentation in Washington, DC- - -*" That 3-day course was also canceled. Around the same time, my course on the Space Shuttle Challenger Investigation, which received the highest ranking in more than 1,500 CEEP courses, was also canceled (see Shuttlefactor web page). My Energy Balance Table for cold fusion would have focused federal, private and academic effort, which was getting out of hand then.

In April 2009, the CBS 60-Minutes ran a piece on cold fusion. That created a tiny burst of reaction from reputable science groups, but nothing like the 1989 ruckus. The 60-Minutes program and the reactions show that the "Correct Energy Balance Sheet" for cold fusion remains obscure. Here, I will describe how everyone ignored the most important energy term in cold fusion. If you have seen a daily balanced budget, you will instantly recognize the Correct Energy Balance Sheet in Cold Fusion.

In their initial paper and statements on cold fusion, Pons and Fleischmann (P&F) vaguely claimed that they achieved 1,000% of break-even and projected that their process could achieve 1,000,000% (one million). Let's unravel these claims. P&F write, "*this* (heat generation) *is maintained for experiment times in excess of 120 h during which typically heat in excess of 4MJ* cm^{-3} (four million joules per cubic centimeter) *of electrode volume was liberated*." The latter number was the most dramatic claim in the P&F paper.

This says that a small palladium (Pd) cube, roughly the size of a chicken or beef flavored bouillon cube you find in the supermarket, produced 4 million joules (about one million calories). This is dramatic. Why? A similar small wooden cube releases less than 10,000 joules. You can fill up a living room with logs of wood that contain the same energy released from the tiny metal cube. P&f, and then others, reported that it took a meager electric current, e.g., from a battery, to light up deuterium, or heavy hydrogen, in the palladium.

To Pons and Fleischmann and everyone else, the Energy Balance Sheet for Cold Fusion looks like this:

Table 1 – Cold Fusion Energy Balance Sheet That Amazed the World in 1989

Energy In	Columns intentionally left blank		Energy Out	% Break-even
400 joules			4,000,000 joules	1,000,000%

The dramatic break-even percentage, which was widely reported in 1989, is simply obtained as follows: ((4,000,000/400) x 100) = 1,000,000 (one million).

Anyone with the above Energy Balance Sheet deserves a Congressional Hearing, and that was what P&F, the University of Utah, and cold fusion got on April 26, 1989.

I sat in the last row of the hearing room with my cold fusion Energy Balance Sheet on my lap. I had spoken with the staff of the Congressional Committee about it, but, at the time, the staffers were weary from my Challenger accident input and the barrage of dismissals from NASA. I had hoped that by 1989, NASA would have told the Congress about the massive "excess" forces that I identified in Space Shuttle design in 1986. That would have given my word some credibility with the Congress. But that did not happen. You can read about the "excess" forces in my report, "The Problem with the Space Shuttle and the Space Program," Section 7, Measurement of the "Dynamic Overshoot" in the Shuttle. There, I write how "*…experts were literally bewildered by the excessive dynamic overshoot force component, which they labeled* "**EXCESS** UPWARD FORCE*," or surplus upward force!*" The "excess" heat in cold fusion was greater than the "excess" forces in the Shuttle. I was overwhelmed by the colossal mistakes and by the colossal opposition to my effort to clarify the blunders.

From the outset, 'cold fusion' faced two critical questions: (1) is there really nuclear fusion in the process? And, (2) how do you explain the reported "excess" heat? Professor Ronald G. Ballinger from MIT pinned down the two points in his testimony before the Committee, *"From our standpoint, the key point of verification is the detection of neutron radiation. From an engineering point of view, however, the importance of excess heat production is critical."* The scientists complained about the scarcity of data from P&F, Ballinger testifying, *"And so the scientific community has been left to attempt to reproduce and verify a potentially major scientific breakthrough while getting its experimental details from the Wall Street Journal and other news publications."* I was also getting my input from the *WSJ* and science and general media reports. Everyone recognized the importance of energy balance in cold fusion, Ballinger testifying, *"it is critical that a* ***total energy balance*** *over time be done,"* (my emphasis). How do you do total energy balance in cold fusion over time? Well, you take all the energy that goes into the process and all the energy that comes out of the process. Ballinger summarized the mood of the scientists as *"excited," "skeptical,"* and *"frustrated."* The primary reason for the frustration was that no one took all the energy input in cold fusion into account, including, Pons and Fleischmann.

The Committee listened to others, including Pons and Fleischmann. Perhaps, the most dramatic testimony was delivered by a non-scientist, Ira C. Magaziner, who began with the blunt words, "*I am not from Utah Nor would I recognize a piece of palladium or a fusion reaction even if I were staring right at them*." Ira lambasted everyone for many great inventions and discoveries and nearly zero follow-up on production, jobs creation, and economic benefits. The decorum of congressional hearings prevented me from putting my Energy Balance Sheet for Cold Fusion in front of Magaziner to have him give an impromptu dramatic description of the situation to the Committee. Nothing was resolved in the Hearing.

The Department of Energy (DOE) started several initiatives to deal with the cold fusion subject. DOE and the Los Alamos National Laboratory (LANL) arranged "A Workshop on Cold Fusion Phenomena" for May 23-25 1989 in Santa Fe, New Mexico. About 500 experts attended from around the world, including me. I had written 4 papers on the subject by then. I submitted two papers, "Cold Fusion – The Heat Mechanism" and "Cold Fusion – Engineering Perspectives" to the organizing committee. My papers were accepted as poster papers. I tried to include the first paper in the oral presentations at the Workshop, so that everyone could hear about the Correct Energy Balance Sheet in Cold Fusion, but I was not successful. My papers described how hydrogen-embrittlement, or deuterium-embrittlement could account for the "excess" heat in cold fusion. I had done extensive research and tests in these and related subjects in the early 1970s.

In the Workshop, many experts described errors they found in the work of P&F. Some called for "**a correct energy balance**" (my emphasis), but everyone seemed to have a different idea about "correct energy balance" in cold fusion than I did. Anticipating the frosty atmosphere, P&F did not attend the Workshop. I had sent copies of my papers to Dr. Pons to apprise him and the University of Utah of my work.

The Workshop atmosphere can be best described with one word; "uncertainty." Some scientists reported heat from the cold fusion process, but many scientists did not detect any heat at all. Those who detected heat measured varying amounts. Most papers concentrated on nuclear byproducts, and these were more variable and uncertain than the heat measurements. Some scientists reported detecting neutrons, protons, tritium, helium, gamma rays; and many scientists did not detect any of these at all. Some papers in the Workshop were authored by 10 or 20 scientists; one paper authored by more than 25 experts. Unless you were a member of the physics thermonuclear community, you had no idea where was the Workshop going. To me, one number stood out: 4 million joules per cubic centimeter, 4MJ in a bouillon-sized cube. It takes tens of donkeys to haul that much energy in the form of logs of wood. I concentrated on this number.

I prepared a Flyer for the Workshop, and I discussed my work with other experts. Many were amazed at the possibilities I raised. The Workshop facilities could not keep up with the demand for the Flyer. I arranged with a local shop in Santa Fe to produce hundreds of copies; "all went," I wrote in my notes. The last paragraph in the Flyer contains my "correct energy balance sheet" for cold fusion in plain words.

> "The heat liberated in palladium-deuterium is considerable. Professors Pons and Fleischmann projected 1000% excess heat from their process and expect one million per cent thermal yield. The confident figures are based on the small energy input to the electrolytic cells, but do not consider the substantial energy required to process (melt), or recycle, palladium. In this paper, I show that less than 50% of break-even has been attained, and that break-even may not be possible. The heat mechanism and other parameters are described. Though the process may be better described as Metal Burning or Rapid-Corrosion, and not Nuclear Fusion, it leads to vital scientific and technical studies and applications, some of which are identified by this author.

I thought that I could bring a halt to the "uncertainty" in the Workshop. The buzz was primarily about the 1,000,000% of break-even that P&F announced. I drafted a 'Motion' for the Workshop to declare that (1) cold fusion did not achieve break-even, and (2) the process could not even achieve break-even. I spoke with many physicists about it. They were fascinated, but declined to second (sign) my Motion because they were not acquainted with the hydrogen-embrittlement phenomenon. I then spoke with metallurgists, who should be familiar with the hydrogen- and deuterium-embrittlement subject. Even Robert Huggins of Stanford University did not know enough about the phenomenon to sign my petition. The Workshop concluded. Everyone went home. There was no consensus on what cold fusion was. There was no "correct energy balance sheet," even though it was the simplest thing to do (see below).

Before and after the cold fusion Workshop in Santa Fe, NM, I spoke with executives and experts in energy, and with others involved in the subject. I spoke with Robert Park of the American Physical Society (APS), David Lindley, editor with *Nature*, Robert Pool of *Science* and others whose coverage was followed closely by experts and non-experts. Lindley wrote me about my paper on July 20, 1989, "*it certainly represents an aspect of 'cold fusion' that I have not seen discussed elsewhere with any authority*." It took a year and a half before my papers were published in the Journal of Fusion Energy. Still, no one has come forward with a clear-cut energy balance sheet for cold fusion. So, let's do it together here in plain language.

Look again at the Energy Balance Sheet for cold fusion that I reconstructed from the P&F's words:

Table 1 – Cold Fusion Energy Balance Sheet That Amazed the World in 1989

Energy In	Columns intentionally left blank		Energy Out	% Break-even
400 joules			4,000,000 joules	1,000,000%

The first column gives the tiny electric current that the researchers apply to the electrolytic cells. As I show in my papers, hydrogen and deuterium can light up a transition metal, like palladium or titanium, without any current at all. Some scientists went as far as to invent new methods and instruments to accurately measure this value. We are not going to split hairs over this tiny number.

The "Energy Out" column is the excess heat reported by P&F from their 5-years of experiments. Unless there was outright deception on the part of P&F (which I categorically reject), this number must be taken seriously. Even if this value was measured in only "one" of "thousand" runs, it must be accepted. P&F describe a dramatic event that happened in their tests relating to this item, which is discussed in my papers.

We now come to the two columns that I intentionally left blank in Table 1. Column 2 contains the most important energy term in 'cold fusion.' It was the negligence of the scientific community to incorporate this energy term for 20 years that led to the message of the CBS 60-Minutes program in the first place.

The Energy Balance Sheet of Table-1 is correct *if, and only if*, the palladium samples that P&F and others use in cold fusion experiments grow on trees or sprout out of the ground in gardens immediately adjacent to the laboratories. In that case, the energy of walking to the garden to pluck the Pd rods can be ignored. But palladium, like all the other metals, requires considerable energy to find (energy), mine (more energy), transport (energy), process, especially by melting (lots of energy), reprocess, form and transport to the labs. P&F wrote the following short Acknowledgement in the 1989 paper, "*We thank Johnson Matthey PLC for the* <u>*loan*</u> *of precious metals for this project*," (my emphasis). The reader will agree that the loan, or gift, of metal samples does not mean that the samples were developed energy-free.

It takes considerable energy to mine, gather heaps of dirt to extract the ore, transport, melt, form, re-melt, and reform the metal to produce the final samples that are used in the labs. How much energy? I calculated it takes about 10 MJ to produce 1 cm^3 palladium cube. From published energy values required to produce one metric ton of titanium, a transition metal like palladium, I found that it takes more than 8 MJ to get 1 cm^3 titanium cube. I do not know if the latter value includes the energy needed to transport dirt and metal on ships, trains, trucks, and, maybe, airplanes. Also, palladium is rare and can only be found in the State of Montana in the U.S., potentially requiring more energy to produce than the more abundant titanium.

The energy consumed in producing the Pd, or other metal, samples for cold fusion must be part of the Energy Balance Sheet. We are not cheating nature when we pretend that the palladium samples came energy-free; we are cheating ourselves. The 10 MJ needed to produce a small Pd cube comes from burning oil, gas, coal and wood. Nature spent considerable work (energy) and time to develop these fuels that we use. And the energy from oil, gas, coal and wood that is used to produce the laboratory Pd samples must be taken into account in any Energy Balance Sheet.

And so, my Correct Energy Balance Sheet for cold fusion, in 1989 and in 2009, looks like this:

Table 2 – The Correct Cold Fusion "Energy Balance Sheet" 1989, 2009

Energy In	Processing Energy	Total Energy In	Energy Out	% Break-even
400 joules	≈10,000,000 joules	10,000,400 joules	4,000,000 joules	≈ 40%

The Table is dramatic. It shows that P&F did not exceed break-even and could not even achieve break-even with the cold fusion process. It shows that the 'Motion' I drafted for the Workshop in Santa Fe in 1989 was a valuable contribution. It should have been considered and adopted.

In the DOE and LANL Cold Fusion Workshop in 1989, Professor Robert Huggins of Stanford described a process that he used to produce heat from his palladium samples. His process consisted of melting the Pd samples 10 (ten) times. That was widely discussed in the Workshop and widely reported in the media. It can be seen from the above Correct Energy Balance Sheet that the efficiency in this case was less than 5% (less than five percent) of break-even.

Some advocates of cold fusion might argue that after the fusion of deuterium two or three times in the Pd samples, break-even is reached, and that subsequent fusion will produce extra, or excess, heat. Not so. My papers show that the formation and propagation of cracks in the palladium samples is itself the mechanism responsible for the heat produced in cold fusion. One complete highly successful cold fusion run (4MJ), a completely cracked palladium sample, and then back to the oven (10MJ) to melt and reform the metal for the next run – a complete loss of 6MJ energy from oil, gas, coal and wood!

By the end of 1989, researchers from the U.S., Japan and elsewhere began to find cracks in the palladium samples used in cold fusion. Professor Nobuhiko Wada of the Nagoya University in Japan reported that he detected neutrons in his cold fusion setups. Most importantly, Wada said that after examination, he found *"many cracks and holes"* in the Pd rods. Other centers in the U.S., Europe and elsewhere also found *"cracks"* in the Pd samples used in the cold fusion process. These widely reported results were crucial "peer review" verifications of my 1989 proposed solutions of the cold fusion process. You see, the cracked (or spent) Pd must be melted again to get rid of the cracks and rebuild the crystallographic structure to start another round of random metal burning, metal cracking, or metal rusting and heat generation.