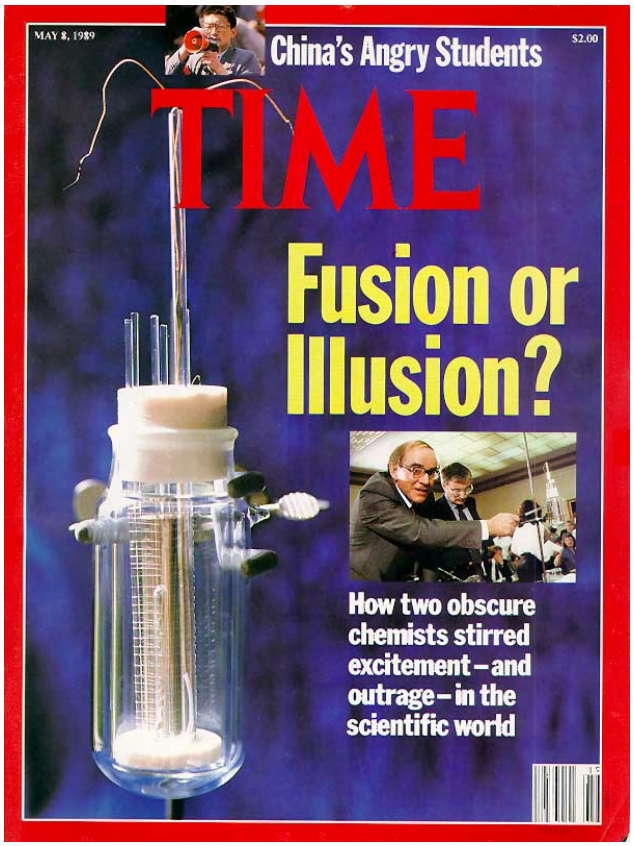
COLD NUCLEAR FUSION
from Pons & Fleischmann to Rossi's E-Cat

by Martin Bier

Twenty-two years have passed since Pons and Fleischmann held their legendary press conference. Presumably, they had realized cold fusion. But it became a classic case of pride before the fall. A few months later, after the results appeared irreproducible, the American Physical Society and the authoritative journals declared it pseudoscience. Nevertheless, cold fusion never totally disappeared. Money has continued to be poured into it and researchers are still working on it. Recently, there has been commotion over an alleged "breakthrough" by Andrea Rossi with his E-Cat. But there are indications that Rossi's E-Cat is a sham.



The front cover of *Time* on May 8, 1989.

PONS EN FLEISCHMANN

Martin Fleischmann (1927) was an accomplished British elektrochemist. He had been president of the International Society of Electrochemistry for two years. In 1986, he was allowed to join the Fellowship of the Royal Society. After 1983, he no longer had any teaching duties at the University of Southampton and started spending a lot of time doing research at the University of Utah.

Stanley Pons (1943) was from Valdese, North Carolina. He interrupted his chemistry studies for eight years to help run the family business. But in 1975 he picked it up again and in 1978 he received his Ph.D. from the University of Southampton. In 1989, he was head of the chemistry department at the University of Utah in Salt Like City.

The two scientists would have preferred to just publish their results in a scientific journal. But for the University of Utah this was too big of a PR opportunity to simply let pass. So on March 23, 1989, cold fusion became world news.

HOT VS. COLD NUCLEAR FUSION

Atomic nuclei are positively charged. Therefore they repel each other when they get too close to each other. Thanks to this so-called Coulomb force, a hydrogen atom remains a hydrogen atom under normal conditions. A large amount of energy, however, can be released if the Coulomb barrier can be overcome and nuclei can be made to fuse.

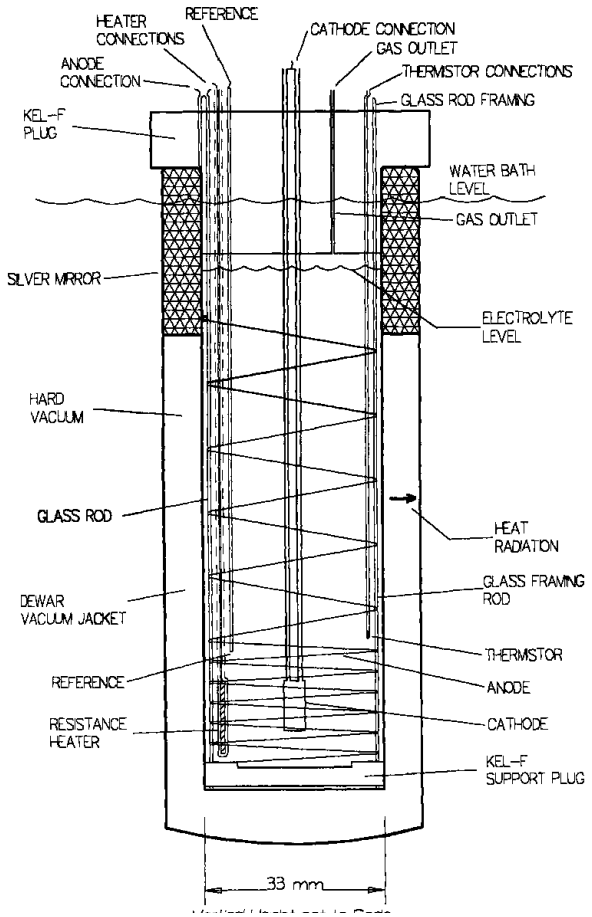
Nuclear fusion is why the Sun shines. In the interior of the Sun the temperature is about 25 million degrees Fahrenheit. At such high temperatures the thermal motion (sometimes called "Brownian motion") of the individual protons is fast enough to overcome the Coulomb repulsion. Protons fuse on a massive scale in the interior of the Sun and because of the released energy, the temperature stays at 25 million degrees. That chain reaction has been going on now for about 5 billion years.

It is possible to make atomic nuclei fuse here on Earth. But the energy that is released in a chain reaction when even a small amount of nuclei fuse can be very large. This is what happens in the hydrogen bomb, which was developed soon after World War 2. For less destructive applications, like a power plant, the explosion needs to become a contained and controlled burning. Containment and control is fairly easy in the case of a combustion engine and that technology is already more than a century old. In the case of the Sun, it is the large pressure of the outer layers on the inner layers that prevents the interior from blowing up. On Earth, however, it is almost impossible to generate the forces that are required for the containment of nuclear fusion. At the temperatures that are necessary to make hydrogen nuclei fuse, no material remains in solid form.

Nothing would be nicer than having a trick to bypass the Coulomb barrier and get a nuclear-fusion chain-reaction at a much lower temperature. At normal temperatures atomic nuclei and electrons are at Ångstroms (1 Ångstrom = 10^{-10} m) away from each other. Interaction energies are of the order of an electron volt (1 eV= the change in energy of an electron when the electric potential changes by 1 Volt). In order to get nuclear fusion, one has to go from the world of Ångstroms and electron volts to the world of femtometers (1 fm = 10^{-15} m) and mega electron volts (1 MeV = 10^{6} eV), i.e. distances that are 100,000 times smaller and energies that are a million times larger. The behavior of matter on the atomic level is generally described with quantum physics. The world of quantum physics contains a lot of counter intuitive surprises. But a factor of a million can't be easily fudged away, not even with quantum physics.

THE HYPE AND THE HANGOVER

Neither the press conference, nor the subsequent articles made clear how, on a basic physics level, Pons and Fleischmann had achieved their nuclear fusion. But with a very simple setup (see illustration), hydrogen had been turned into helium. That was the claim.



The setup with which Pons and Fleischmann observed the alleged cold fusion. The palladium cathode is in the center of the test tube. (from: Charles G. Beaudette, *Excess Heat: Why Cold Fusion Research Prevailed*, Oak Grove Press, 2000)

Physicists had generally been surprised by the discovery, in 1986, of superconductivity at temperatures much higher than had been considered possible. However, that superconductivity turned out to be real and reproducible. In the years since, theoreticians have formulated explanations for the phenomenon.

With the high temperature superconductivity in the back of their minds, physicists initially hesitated to vocally challenge cold fusion. Wishful thinking may also have been behind the lack of appropriate skepticism. After all, the Chernobyl disaster had only occurred three years earlier and one day after the press conference of Pons and Fleischmann, the Exxon Valdez ran aground in Prince William Sound in Alaska (which led to 25 million gallons of crude oil flowing into the sea). The need for a source of cheap and clean energy became ever more urgent.

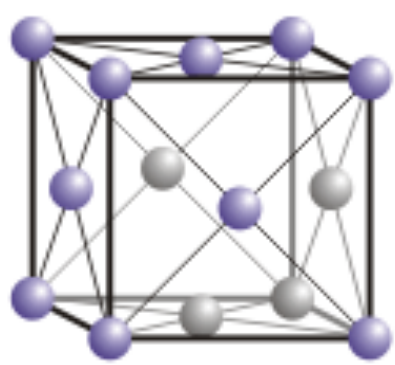
Many laboratories tried, but the experiments of Pons and Fleischmann turned out to not be repeatable. It took only a few months for the dream to fall apart. Physics as a discipline had been humiliated and cold fusion had become a tainted subject.

THE PALLADIUM CATHODE

Palladium (Pd) is a noble metal. It is number 46 in the Periodic Table of Elements. "Colored gold" is actually an alloy of gold and palladium. Palladium is a catalyst for many chemical reactions and it is, for instance, commonly used in catalytic converters. In pure palladium the atoms are nicely positioned in a lattice at a distance of about 4 Ångstrom from each other (see figure). One of the most striking characteristics of palladium is its ability to chemically split ($H_2 \rightarrow 2H$) and store hydrogen. At room temperature and at normal atmospheric pressure, 900 gallons of hydrogen gas can be absorbed by just one gallon of palladium. Absorbed hydrogen nuclei move freely and easily in the open spaces between the palladium atoms. When the palladium is heated, it will release the absorbed hydrogen again. There has been a lot of discussion in the last few years about hydrogen gas as a possible fuel. A "palladium tank" would be the ideal way to store a lot of hydrogen relatively safely, were it not for the fact that palladium costs about $12,000 per pound. That is about half the price of a pound of gold.

Water (H_2O) can be split up into its basic elements, hydrogen (H) en oxygen (O), through so-called electrolysis. To perform such electrolysis, one simply puts a positive electrode (anode) and a negative electrode (cathode) in the water. Already before World War 2, it had been discovered that a palladium cathode can absorb large numbers of protons. Fleischmann himself had been involved in researching this phenomenon. He published an article in 1972 about the diffusion of hydrogen nuclei in a palladium cathode[1]. A hydrogen nucleus can be a single proton (H). But it can also be a proton bound to a neutron. In that case we have a so-called deuteron (D). In his 1972 article, Fleischmann described how protons and deuterons behave differently in a palladium lattice.

To jump from all this electrochemistry to ideas about cold fusion is not that awkward. In a palladium lattice, deuterons are in relatively close proximity to one another. The electric repulsion between the positively charged deuterons is reduced because they are in the midst of a screening gas of negatively charged electrons. After the possible fusion of two deuterons we would have a helium nucleus and a lot of released energy.



Palladium atoms arrange themselves in a lattice. The open space in the center of the cube leaves room for protons or deuterons.

It is hard to build an intuition for what is going on the basis of the aforementioned Ångstroms and with energies that are expressed as powers

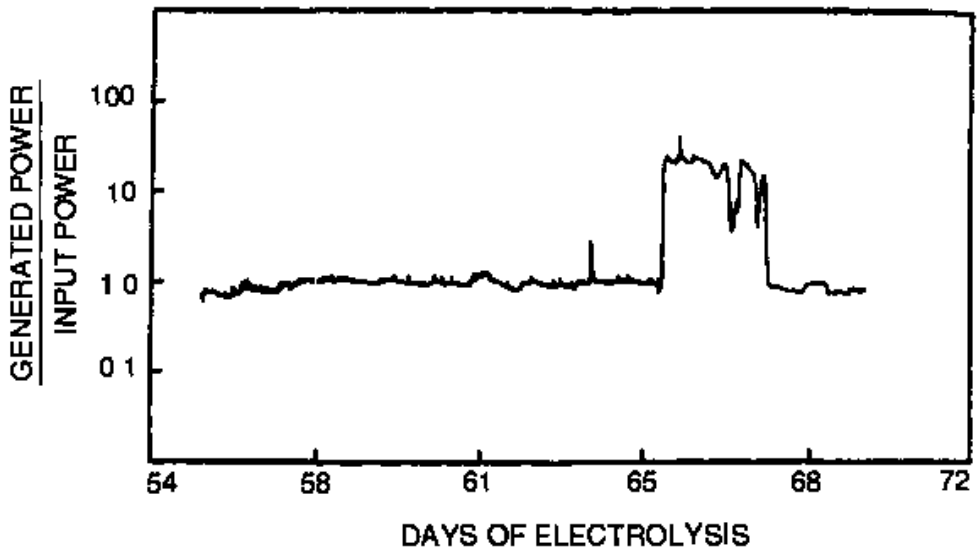
of ten. To get an idea of the scale one should think of protons and deuterons as mosquitoes that are repelling each other - they fly at 100 yard distances away from each other and at such distances the repulsive energy and the kinetic energy are about equal to one another. For two mosquitoes to touch each other, an amount of energy is required to overcome the repulsion that is a hundred thousand times as large as the average kinetic energy.

THE POSITION OF A THERMOMETER AND THE FORMING OF A SECT

In 1987 there was an article titled "Cold Nuclear Fusion"[2] in the *Scientific American*. An article like that would have been impossible after the subject matter got tainted in 1989.

"Polywater"[3] is commonly offered as the archetypal example of science having gone wrong. This more dense and more viscous form of water was presumably discovered in the late 60s. There was a lot of excitement, but nobody wasted any more serious thoughts or money on it after 1973. By then, it had become clear that polywater had been a big misunderstanding[4]. History, however, took a different course with cold fusion. A hard core remained faithful and vocal after 1989.

That there are still so many "believers" in the case of cold fusion has a lot to do with the capricious and unpredictable behavior of Pons-Fleischmann systems as in the drawing on page 3 The graph on page 6 shows how the heat production in such a system behaves over the course of 15 days. A constant electrolytic current is permanently running through the system. That current constitutes the input of energy. The heat production is the output of energy. Oscillations or large fluctuations are very common and natural in systems that transfer and convert energy[5]. It is likely that a kind of snowball effect, a *positive feedback*, is the cause of the big fluctuation that starts on day 66 in the graph on the next page. The generation of a small amount of heat somewhere in the cathode can cause protons and/or deuterons to move to the surrounding water. There these protons and/or deuterons would chemically react and that would cause the production of more heat, etc. etc. This "snowball" could continue until the cathode is almost empty. After the system has cooled down the cathode can start again with the uptake of protons and deuterons. The unpredictability arises from the fact that a small fluctuation on a molecular level can set the "snowball" in motion. When a lot of heat is generated at the cathode it is, moreover, no longer likely that heat is spread out evenly in the liquid. Temperature differences within the liquid will develop and convection currents can occur. If you then continue to assume that the temperature that you measure at a specific location in the test tube applies everywhere throughout the test tube, then you can indeed easily come to the conclusion that the system has more thermal energy output than electric energy input. "Tens of millions of dollars at stake, dear brother, because some scientist put a thermometer at one place and not another" said Stanford nuclear physicists Walter Meyerhof in May 1989[6].



The output/input power ratio over the course of 15 days as measured by Pons and Fleischmann. The input of energy derives from the electrolytic current. The output energy is the heat production. For a long time, the ratio fluctuates around one, but then it suddenly shoots to a value of more than ten where it next remains for two days. (from: Charles G. Beaudette, *Excess Heat: Why Cold Fusion Research Prevailed*, Oak Grove Press, 2000)

Hundreds of millions of dollars have still been invested in cold fusion R&D after 1989. In 1992 Pons and Fleischmann moved to Southern France. There they continued to work on cold fusion in a lab that had been set up by Toyota in Valbonne, halfway between Cannes and Nice. Officially, Fleischmann retired in 1995, but he is still going to conferences and writing about the subject. In 2002 he was a co-author on a US Navy report about cold fusion[7]. In 2006, D2FUSION, "a California-based solid state fusion energy firm," hired the meanwhile 79-year old Fleischmann as a senior scientific advisor[8]. But it looks like this company has meanwhile ceased to exist. Stanley Pons has shown himself to be less assertive. In 1998, Toyota closed the Valbonne lab for lack of results. Pons then took early retirement and choose to remain in Southern France. He has meanwhile adopted French citizenship.

BETWEEN PSEUDOSCIENCE AND THE SCIENTIFIC MARGIN

It is at MIT, one of the most prestigious technical universities in the world, that Peter Hagelstein is passionately trying to turn cold fusion into industrial reality[9]. There is a handful of researchers like Hagelstein - working seriously on the subject and publishing about it in peer reviewed journals. Mainstream science generally derides them as neo-alchemists. However, that scorn is precisely what has made

many conspiracy theorists and counter cultural characters from outside the academic world jump the cold fusion bandwagon.

MIT was also the affiliation of Eugene Mallove. He was a journalist and a scientist. In 1991, he left MIT and wrote a book about cold fusion and the Pons-Fleischmann affair: *Fire from Ice: Searching for the Truth behind the Cold Fusion Furor*. According to Mallove, the work of Pons and Fleischmann was all bona fide and correct. But it was vested interests, with MIT prominently among them, that had deliberately discredited the work. For ten years, Mallove ran the magazine *Infinite Energy - The Magazine of New Energy Technology*. The magazine is not just about cold fusion - perpetuum mobile's and devices that extract "free energy" from a vacuum also feature prominently. In 2004 Eugene Mallove was murdered while he was cleaning his parents' house. The house had been put up "For Rent." At first it was suspected to be a robbery-murder. It is now thought that a conflict with a former renter got out of hand and there have been arrests. It is no surprise that the tragic homicide has fed conspiracy theories. Mallove's New Energy Foundation is still very active and maintains an extensive website[10].

The professional organization of cold fusion researchers is the International Society for Condensed Matter Nuclear Physics[11]. This club runs a peer-reviewed, electronic journal: the *Journal of Condensed Matter Nuclear Science*. It is an "open access journal," which means that all articles are freely accessible online[12]. Already since 1990 the Society also organizes the ICCF conferences. ICCF16 took place in India in February 2011 and attracted about a hundred scientists. Although the old acronym is still used, the conference is now officially called International Conference on Condensed Matter Nuclear Science[13]. The terminology "Condensed Matter Nuclear Science" is characteristic. The words "cold fusion" carry stigma. New descriptions have been put forward. "Condensed matter" includes liquids and solids. So the expression "Condensed Matter Nuclear Science" implies cold fusion as the with normal "hot" fusion any material evaporates to become a gas. Other neologisms that are now substituting for "cold fusion" are "Low Energy Nuclear Reactions (LENR)," "Chemically Assisted Nuclear Reactions (CANR)," and "Lattice Assisted Nuclear Reactions (LANR)."

A very prominent personality is the science-journalist Steven Krivit[14]. The aim of his New Energy Institute is education, analysis and reporting. He is an untiring blogger, editor, and writer of articles. He maintains a very readable blog on his website that always sparks lots of reactions. He is at odds with just about every other cold fusion personality and his coverage of the intrigues between a variety of characters is often very amusing.

The large professional umbrella organizations, such as the APS (American Physical Society) and the ACS (American Chemical Society), face a dilemma here. For a long time, everything that smacked of cold fusion was systematically kept out. But cutting off the debate has only reinforced the cold fusion community in its paranoia and elitism. Government and private funding of cold fusion research had meanwhile

continued. So about five years ago, the APS and ACS opened the gate to the cold fusion community. There are now cold fusion symposia within the large bi-annual conventions of the APS and ACS. Cold fusion researchers, furthermore, are presently bundling their "proceedings" in books that carry an ACS seal of approval[15]. The ACS and the APS claim to persist in skepticism towards the possibility of cold fusion and to just want to open a critical dialogue. But the new approach does not appear to be very successful. In conventional science new names of new people pop up all the time within the different branches and there is a healthy turnover. The field of cold fusion, however, has been spearheaded by the same small group of authorities for two decades.

About every few years a cold fusion "breakthrough" is announced. Below the most recent "breakthroughs" will be discussed. These "breakthroughs" involve press conferences and patent applications. Companies are started up and investors are attracted. The excitement generally remains limited to the internet. Scientific journals, popular scientific magazines, and the mainstream media are ignoring these "breakthroughs" rather systematically. Justifiably so far, as none of the "breakthroughs" has ever lived up to its promises.

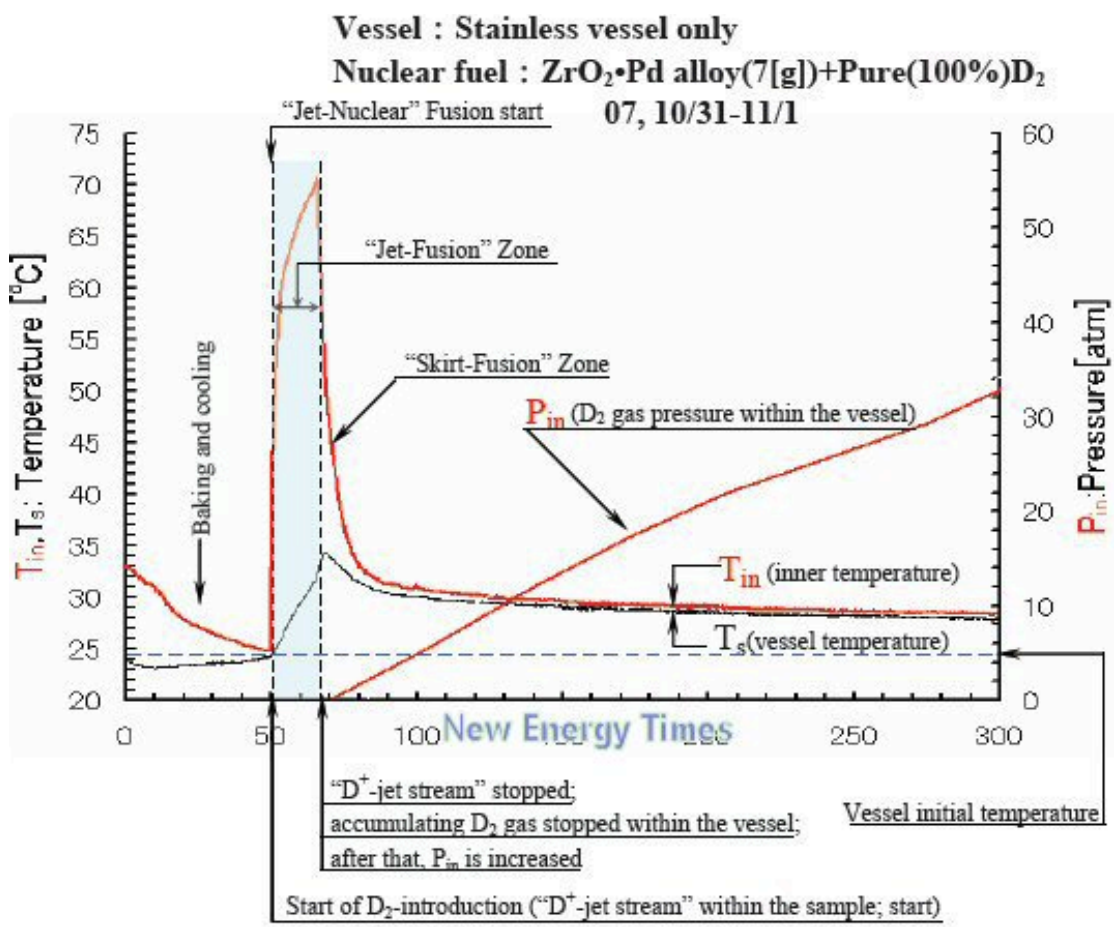
THE ARATA PHENOMENON

By grinding a piece of metal down to a powder, one can increase the surface area while keeping the volume the same. With a larger surface area the metal should be able to more rapidly absorb hydrogen nuclei. This is precisely what Yoshiaki Arata did. In the end, his setup is simpler than that of Pons and Fleischmann. There is no electrolysis anymore. There is 7 grams of pulverized metal in a small container. Instead of pure palladium, he uses different alloys of palladium, zirconium, and nickel. The graph on the next page shows how pressure and temperature behave in the course of an experiment. After 50 minutes, hydrogen gas is pumped into the container. The absorption of hydrogen by the metal generates heat. After a maximal amount of hydrogen has been absorbed, the further supply of hydrogen gas increases the pressure. The temperature is then going down again as heat escapes the container. The relaxation of the temperature back to room temperature holds the alleged proof: that relaxation is slower when deuteronic hydrogen gas (D_2) is used instead of ordinary hydrogen gas (H_2).

On May 22, 2008, journalists and academics attended a demonstration of Arata's setup[16]. The day coincided with Arata's 85th birthday. Arata is a staunch Japanese nationalist, so everything was handled in Japanese. He claimed that he had been using the demonstrated procedure for already half a century to make helium. But he just had not been showing it, because the world was not ready for it.

We have already seen that protons and deuterons behave differently when in a metal lattice. They have different binding energies and diffusion speeds. Fleischmann had already established that in the 1970s. Different relaxations for H_2 en D_2 are therefore not unexpected and they are not a proof of nuclear reactions.

Even within the cold fusion community it was noted that Arata's data were not convincing[17]. Arata claimed to have established the presence of helium gas after the experiment. But questions were raised about the way it had been measured. There had, furthermore, been no attempt to detect radioactivity.



The temperature and pressure in Arata's experiment. After 50 minutes hydrogen starts being pumped into the reaction chamber. After the "nuclear fuel" is saturated with hydrogen, the pressure increases while the temperature is going down. The fact that the temperature eventually lingers a few degrees above the ambient temperature is "proof" of nuclear fusion.

After the demonstration, the alleged nuclear reactions got the name "Arata Phenomenon." This was not meant ironically.

THE PHENOMENON ROSSI

Andrea Rossi and Sergio Focardi gave a press conference at January 14, 2011. The conference was by invitation only. There were journalists, physicists, and also the

Italian state television (RAI 3) was there. In a room adjacent to the conference room, an alleged cold fusion reactor was started up. The reactor had been named "E-Cat" - from "Energy Catalyzer." A few small tables sufficed for all the equipment. As the reactor was presumably operating, Rossi and his co-workers were answering questions. A video with English subtitles of the entire 41 minutes long conference is meanwhile available on YouTube[18].

Andrea Rossi was born in 1950. He is an inventor and businessman with no significant academic qualifications and somewhat of a tainted past. At the end of the 70s he started a company. With "Petroldragon," Rossi was going to extract fuel from organic waste on a large scale[19]. But it never really came off the ground. Criminal and civil litigation ensued because tens of thousands of tons of toxic waste had not been transported, stored, and processed according to legal guidelines. In the 90s, Rossi was arrested twice for money laundering and gold smuggling.

Sergio Focardi is a nuclear physicist at the renowned University of Bologna. He was already 75 years old and an emeritus when, in 2007, Rossi attracted him as a partner in the enterprise.

The procedure of Rossi and Focardi is very similar to Arata's. Hydrogen gas is pumped into a 3 cubic inch reaction chamber that contains some pulverized nickel. Pressure and temperature are increased and, at some point, heat starts being produced. The claim is that a fusion reaction, $Ni + H \rightarrow Cu$, is occurring. So it is no longer palladium or some other metal that is catalyzing the fusion of deuterons. A nickel nucleus with 28 protons and 34 neutrons (^{62}Ni) would absorb a proton and turn into copper (^{63}Cu). The superscript denotes the total number of protons and neutrons in the atomic nucleus.

As was to be expected, the press conference of January 14, 2011, did not lead to any coverage in the world press. But heated debates followed in newsgroups and in forums on the internet. Physicists and engineers started to play detective and analyze the video frame by frame in order to figure out what was going on. From already a year before the press conference, Rossi maintains his own weblog on http://www.journal-of-nuclear-physics.com. The title "*Journal of Nuclear Physics*" suggests that we are dealing with a scientific journal. However, right below the title it is written "nuclear experiments blog." The site also contains a report that was issued to accompany the January 14 press conference. Rossi, furthermore, answers questions on this weblog on an almost daily basis.

MENTAL MASTURBATIONS VS. SATISFIED CUSTOMERS

In regular science, it is customary to describe setups and procedures in such a way that the obtained results are reproducible. Rossi, however, appears unconcerned about reproducibility. He has, for instance, caused major irritation with his "secret catalyst." A catalyst is a substance that enables or accelerates a reaction, but that

itself is the same before the reaction as it is after. Even in his patent application, Rossi has not revealed what this "secret catalyst" is or does. He claims that he does so in order to protect the interests of his investors. Even Focardi appears not to know what the "secret catalyst" is and he could only speculate about it in a radio interview in March 2011.

It is obvious that Focardi is the co-pilot in the venture. However, he has actually worked on cold fusion and the nickel-hydrogen reaction. In November of 1998, he was the first author of a scientific article in the well-respected in *Il Nuovo Cimento A*: "*Large excess heat production in Ni-H systems*"[20]. The observations made in this report would actually become the basis for the E-Cat. The final form of the article is characteristic for the ambivalent attitude of mainstream science. On the first page we see that the article is categorized as being about "Fusion and fusion-fission reactions." However, nowhere in the article is there an explicit suggestion that nuclear fusion would be behind the heat production that is observed. Instead, the authors write about an "excited state" with "anomalous heat production." On the whole, it is a fairly straightforward and actually rather dull article - it is just a description of an experiment. Nevertheless, on the title page, right under names of the authors, it is written "ricevuto il 9 Marzo 1996; revisionato il 16 Settembre 1996; approvato il 30 Giugno 1998." In other words, before the publication there was two years of wrangling between authors, editors, and referees. Most likely that wrangling was about the wording. An interesting fact would have been the presence or absence of radioactivity associated with this so-called "excited state." It would have been easy to measure the radiation, but no attempt in that direction had been done. One of the co-authors on this article is Francesco Piantelli. A few years earlier, this Piantelli had accidentally discovered the phenomenon that is being studied in the article. On that occasion he had already registered patents.

From the beginning Rossi has primarily focussed on industrial and commercial development more than on gaining credibility in academic circles. Two days after the January demonstration in Bologna, he writes on the blog of the *New Energy Times*: "In this field the time of mental masturbations is over. Now is time for facts, and facts are operating reactors of satisfied Customers."

DOMESTIC DISPUTES

Even the cold fusion establishment has been irritated by the way in which Rossi brushes off technical and scientific inquiries. The aforementioned Steven Krivit has been working hard for years to make cold fusion respectable again within mainstream science. In a March 2011 blog, Krivit expresses his dissatisfaction with the fact that a lot of ado is made without any results ever having been reported through formal scientific channels like journals and scientific conferences[21]. He also finds it annoying that a mere weblog is posing as a scientific journal.

On the 14th and 15th of June, 2011, Steven Krivit actually visits Rossi in Bologna. He watches an E-Cat in action and he interviews Rossi, Focardi, and their co-worker

Giuseppe Levi. Everything is recorded on video. On June 16, Krivit writes a preliminary report on his *New Energy Times* blog. It appears that everyone had behaved politely and professionally during the visit (see illustration). But a big brawl erupts because of what Krivit writes in his preliminary report. Krivit had questions about the way the output energy of the E-Cat is measured. There had already been some disputes about this, but apparently Krivit really pressed the issue in his interview with Giuseppe Levi. The E-Cat's output energy is used to boil water and the amount of evaporated water is supposed to tell how much energy is produced. This method, however, is very inaccurate. Because of drops of unevaporated water in the vapor, the method can overestimate the produced energy with a factor ten. Krivit was unhappy with the way his queries had been answered and said so in his preliminary report. Rossi got angry over this and does not mince his words when he next writes on his *Journal of Nuclear Physics* blog: "THIS IS A SNAKE, NOT A JOURNALIST."

Andrea Rossi (l) and Steven Krivit (r), while apparently still on good terms, on a patio in Bologna in June 2011. A few days later Rossi characterized his guest as a "SNAKE."

Steven Krivit has meanwhile published his more extensive reports on his *New Energy Times* website. He has also put a very illuminating video on YouTube[22]. The Swedish physicist Peter Ëkstrom has based some impressive physics-detective work

on this video[23]. Ëkstrom's conclusion is that the E-Cat does not put out any more energy than is put into it.

THE ISOTOPE CONUNDRUM

On March 29, 2011, two prominent Swedish physicists, Sven Kullander en Hanno Essén, attended a six hour long demonstration of the E-Cat. Several internet blogs mentioned that the two were "skeptics." The Swedes wrote a report[24] and declared the E-Cat to be bona fide: "Any chemical process should be ruled out ... there is some kind of a nuclear process that gives rise to the measured energy production." Kullander and Essén were also given the opportunity to analyze the fuel. Rossi brought two samples to Sweden - one from before and one from after the "burning."

The sample from before the "burning" was pure nickel. In nature, nickel has the following isotope composition: ^{58}Ni - 68%, ^{60}Ni - 26%, ^{61}Ni - 1%, ^{62}Ni - 4% en ^{64}Ni - 1%. The patent application states that, in a working E-Cat, it is ^{62}Ni that absorbs a proton to become ^{63}Cu. On April 11, 2011, Rossi wrote on the *Journal of Nuclear Physics* website that he uses enriched nickel for his fuel. Here "enrich" means that the lighter isotopes are partially removed to end up with more than 4% ^{62}Ni. Enrichment is generally difficult and expensive. Rossi indicates that he has found a easier and cheaper method, but he refuses to give any information about it. Nevertheless, when the nickel sample was analyzed in Sweden, it was found that the isotope composition does not differ from the natural one.

The "spent fuel" (sometimes called "nuclear ash") contained, in addition to nickel, 10% copper and 11% iron. Copper has only two stable isotopes: ^{63}Cu (69% in nature) and ^{65}Cu (31% in nature). In the "spent fuel" copper was present in its natural isotope ratio. It is absolutely impossible that fusion of the ^{62}Ni in natural nickel (4%) leads to a spent fuel in which there is 10% copper with the natural isotope ratio! First of all, if the copper in the spent fuel were the result of ^{62}Ni+H, then that copper would be 100% ^{63}Cu. Secondly, even if all the copper in the spent fuel had been ^{63}Cu, it would still be impossible to get 10% Cu out of a fuel with 4% ^{62}Ni. It has been suggested that ^{65}Cu could be the result of the reaction ^{64}Ni+H. But it would an incredible coincidence if the reaction rates of ^{62}Ni+H and ^{64}Ni+H are exactly those that lead to the natural isotope ratio 69:31. Moreover, ^{64}Ni is only 1% in the original fuel - add that to the 4% ^{62}Ni, and you still don't have enough for the 10% copper in the nuclear ash. So maybe, it has been suggested, the lighter isotopes of nickel undergo a chain of reactions: ^{58}Ni would absorb a proton and turn into ^{59}Cu. This would decay to ^{59}Ni and then absorb a next proton, etc. etc. But it is really practically impossible that such a complicated chain would, after some arbitrary time in reaction chamber, lead to a non-radioactive nuclear ash with precisely the natural 69:31 isotope ratio for copper!

The measured isotope ratios are in agreement with the hypothesis that the nuclear ash isn't nuclear ash at all. The involved metals have, instead, simply been bought in a regular hardware store. They were turned into powder and mixed. In the end,

the composition of these samples constitutes one of the clearest indications that deliberate deceit is taking place.

BUSINESSMAN IN AMERICA

"Defkalion Green Technologies" was founded in 2010[25]. For a long time the intention was that, in the course of 2011, Defkalion would open a small power plant in Greece. In this power plant, about a hundred E-Cats were to produce about a megawatt. That is an amount of power that is sufficient for between a hundred and a thousand households. The manufacturing of the E-Cats for the Greek plant was initially planned to take place in the United States.

In 1996, when the Petroldragon affair was largely over, Rossi moved to the United States. At first he worked on biodiesel technology at the Bio Development Corporation in Bedford, New Hampshire. But already in 1997, he registered his Leonardo Corporation.

It is hard to figure out Rossi's network of companies. Leonardo Technologies, Inc (LTI) is not the same company as the Leonardo Corporation. LTI was started a little later in order to bring Rossi's thermoelectric inventions to market. The idea of the thermoelectric generator is straightforward. Two electrodes are held against points that have different temperatures. The device then turns the temperature difference directly into a voltage or current. Thermoelectric devices are not practical and economical for power plants because of their very low efficiency. Rossi, however, claimed to have upped the efficiency from the usual 2% to an incredible 20%. He had supposedly developed equipment that would make large-scale thermoelectric conversion economically interesting. The American military got interested and went into business with LTI. What happened next can be read in a 170 page US army report from 2004 that is accessible on the web[26]. The report recounts how LTI had purportedly done successful tests of its thermoelectric generators at the University of New Hampshire in Durham in 2000. However, a fire next destroyed Rossi's laboratory in Manchester, New Hampshire. Rossi then left for Italy. Twenty-seven thermoelectric generators were sent from Italy to the US army. Nineteen of these did not work at all and the remaining eight gave only 1 Watt instead of the anticipated 800 to 1000 Watt. The army has since spent significant effort and money to start a new thermoelectric lab in New Hampshire. But the efficiencies that Rossi claimed have remained out of reach.

On his *Journal of Nuclear Physics* blog, Rossi gives the following answer when he is asked where in the United States the E-Cats are manufactured[27]:
"2- there is noreason why I have to disclose where we manufacture our reactors. Our Customers will receive the reactors in their factories, they are not interested about the manufacturing sites. Our NON-Customers have no reason to know anything at all.
3- The reactors are manufactured by Leonardo Corporation, while LTI (Leonardo Technology Inc.) is the company with the exclusive commercial license of Leonardo

Corp. in the Americas and Caribeans. For any info about LTI, please coontact them directly: ccassarino@lti-global.com".

In interviews and on his blog, Rossi let it be known that he is doing all his efforts, not in order to get rich, but as a service to humanity[28]. He also indicates that profits of his venture will go towards aid for children with cancer[29]. Rossi apparently likes to present himself as a simple and honest inventor who just wants to work for the benefit of humanity. But the professed humble and charitable spirit seems at odds with the convoluted network of companies that has been established around the development and financing of the E-Cat.

PRESIDENTS' MEN

LTI has its headquarters in Ohio. The website www.manta.com holds a large database of American companies. A visit there reveals that LTI also has an office in Bedford, New Hampshire. According to the Swedish popular-technology magazine *NyTeknik*, LTI co-founder Rossi had himself bought out of LTI at the end of the 90s[30].

LTI got out of thermoelectric generators and went into the vague "consulting" business. Head of the company is now Robert Gentile[31]. In the early 90s, Robert Gentile served for 16 months as Assistant Secretary of Energy in the cabinet of George Bush Sr[32]. LTI's website lists Jeff Jarrett as "LTI Senior Policy Advisor." This Jeff Jarrett served for 14 months with George Bush Jr as Assistant Secretary for Fossil Energy[33]. LTI's vice-president is the Craig Cassarino to whom Rossi, in the above quote, refers the questioner. Craig Cassarino operates from the same Bedford, New Hampshire, address where we find all of Rossi's American companies being registered. In a short biography of Craig Cassarino we read[34] "LTI provides consulting services to the US Government on evaluating and testing emerging technologies. Clients include the Department of Energy, the Department of Agriculture and the Department of Defense." Despite the vagueness of its activities, the company realizes millions of dollars of revenue[35]. Strangely enough, there is nothing about Rossi's E-Cat on LTI's website[36].

NUCLEAR FUSION AND REAL ESTATE

In April of 2009, Craig Cassarino and Robert Gentile, both of LTI, were also among the four founders of a new company: "Ampenergo." In an interview with the aforementioned Swedish magazine *NyTeknik* Craig Cassarino says[37]: "We formed Ampenergo, because Ampenergo and LTI involve different people and they are separate companies that do completely different things. LTI is an energy engineering and consulting firm, while Ampenergo will be focused on developing and commercializing the Energy Catalyzer." In other words, Ampenergo is going to take care of marketing and royalties. From that interview it also appears that Ampenergo is looking for money and for investors. It, furthermore, becomes evident that the company has already paid money to Rossi. Another co-founder of Ampenergo is Karl Norwood. Karl Norwood is a real estate agent, who brokers

internationally in business premises[38]. His "Norwood Group" has been doing that since 1968. The headquarters of the Norwood Group are located in Bedford, New Hampshire. The address and phone number of the Norwood Group are the same as those of the New Hampshire branch of LTI. Ampenergo's website (http://ampenergo.com/) is meager and not very informative. But the State of New Hampshire maintains a very well organized website with information about all registered companies. There it appears that Ampenergo is also located at that very same River Road address in Bedford, New Hampshire[39]. All in all, the facts invalidate Craig's claim about LTI and Ampenergo being "completely different." It's the same people in the same building.

Leonardo Corporation is the company that is to eventually manufacture the hardware, the real E-Cats. The company's website (http://leonardocorp1996.com/) does indeed look promising. It actually shows factory halls and equipment. However, for the address of the company we are referred once again to the River Road in Bedford, New Hampshire - the very same address that already houses Norwood Group, LTI, and Ampenergo. There is an aerial photograph of the River Road premises on the website of the Norwood Group[40]. This is clearly an office building and it is impossible that mass production of E-Cats is taking place there! Leonardo Corporation also maintains a branch in Florida[41]. But the Florida address is that of a residence in an apartment building - again there is no sign of a factory[42]. Ampenergo and the Leonardo Corporation, just like LTI, make no mention of the E-Cat on their website.

On the website of the Leonardo Corporation there is mention of EON srl. EON srl is an Italian company that was founded by Rossi in 2002 and sold in 2008[43]. Also Italian is EFA srl - this company is 70% owned by Rossi's wife and it manages the patents and the rights of the E-Cat technology. In April of 2011, an Italian patent was issued for the E-Cat. As yet, no international or American patents have been issued for the E-Cat. Stumbling blocks are the overlap with existing patents of Arata and Piantelli, the secret catalyst, and the general skepticism toward cold fusion.

A PHANTOM, A COVERT AGENT, A SOCIALIST, AND AN OFFSHORE COMPANY

The internet blog *Journal of Nuclear Physics* has already been mentioned. This "journal" has an eight person Board of Advisors. Among them is listed a George Kelly from the University of New Hampshire. However, a visit to http://www.unh.edu/directories/facstaff.html reveals that there is no George Kelly associated with the University of New Hampshire. Another American member of the Board of Advisors is Michael Melich. The DoD (Department of Defense) is given as his affiliation. He appears to be a faculty member at the Naval Postgraduate School[44]. There we see that "war" tops his list of teaching interests. Among his research interests there is more military stuff, but at the very bottom we indeed find "Condensed Matter Nuclear Physics." On January 20, 2011, Steven Krivit blogs about Melich's role in the E-Cat venture[45]: "Some background on Melich may be helpful. Melich is not a researcher, and his fundamental relationship with the LENR

field is unclear. For many years, Melich has gone out of his way to give people in the LENR field, including me, the impression that he is a covert intelligence agent, specifically tasked by the U.S. government to promote and keep an eye on 'cold fusion.' Many people in the field have believed this and consequently have responded to him deferentially and with unusual openness. One problem with his methods is that true covert operators never try to give people the impression that they are covert operators."

Four of the eight "Advisors" of the *Journal of Nuclear Physics* are from the University of Bologna. The most notable is Christos Stremmenos. He is a former collaborator of Focardi. There are a few articles of Stremmenos' on the *Journal of Nuclear Physics* website. The Department of Industrial Chemistry of the University of Bologna categorizes the meanwhile 80-year professor as "fuoro roli," i.e. emeritus. Four decades ago, while working in Italy, he was involved in the opposition against Greece's military dictatorship. He was good friends with Andreas Papandreou, the founder of Greece's socialist PASOK party. In 1981, Papandreou became the prime minister of Greece. At present, his son is the prime minister. In the 1980s, Stremmenos served as the Greek ambassador in Italy.

Christos Stremmenos is also on the Board of Directors of Defkalion. On June 23, 2011, Defkalion gave a press conference where Stremmenos was one of the three company representatives on the stage[46]. An extensive new company website was also launched on that date. In the course of 2012 the company intends to start with the production of 300.000(!) E-Cat units annually in Xanthi, a town in northern Greece. A 1 megawatt reactor is still planned to become operational in 2011. Defkalion Green Technologies is owned by Praxen Defkalion Green Technologies. The latter company is registered in Cyprus. Such registration makes it possible to create a new smoke screen. Cyprus is a kind of Switzerland within the European Union. Business there can be done incognito. Legislation in Cyprus makes it possible for investors to remain anonymous. So it is unknown where the money for the Xanthi operation is coming from.

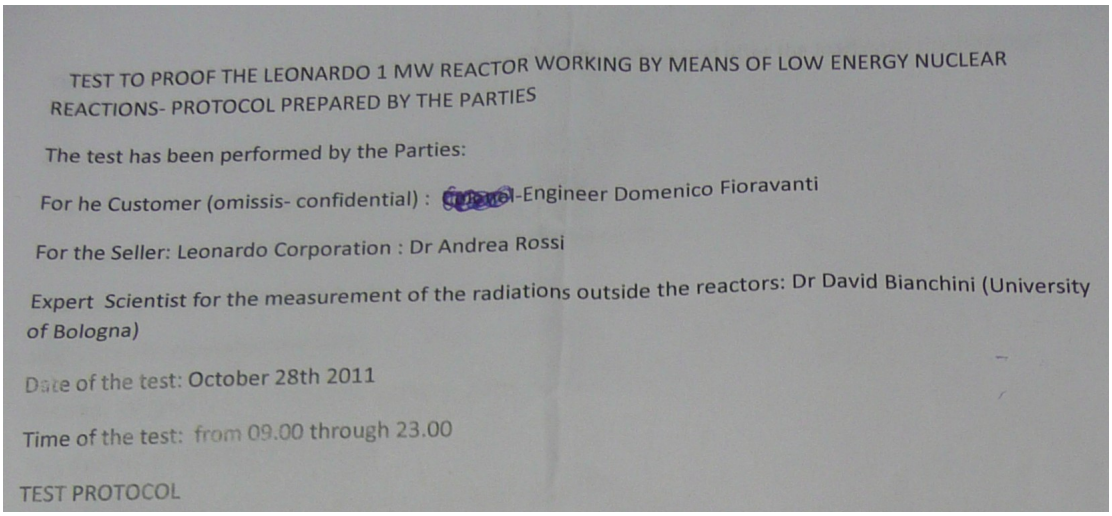
THE NOT-SO-COVERT, BUT PROBABLY FAKE, COLONEL

Defkalion did not pay Rossi the millions that he wanted for the E-Cat technology. So in August of 2011 it came to a breach between Rossi and Defkalion. Defkalion still plans to move ahead with the Xanthi operation. The erstwhile collaboration has now turned into a battle over rights and money.

Rossi, meanwhile, forged ahead by himself and put together the promised power plant - a large container where several tens of E-Cats produce about a megawatt. On October 28, 2011, there was a test run with this container[47]. This was Rossi's twelfth demonstration in the course of 2011 and, once again, it was for invitees only. There appears to be a customer in the picture with this container, though the identity of the customer is not disclosed. Official looking reports of the test run were rapidly put on the internet and can be downloaded via, for instance, a

NyTeknik article[48].

In a report in regular science or business, it is often the stuff that has been crossed out that is most revealing. But Rossi takes this to a whole new level: it is the stuff that they want you to believe they tried to cross out that is most interesting. On the first page of the report, the title before the name of the customer's representative is crossed out with blue ink (see illustration). It takes little effort, however, to discern what they have crossed out - it is the word "Colonel." One does not have to be a pathological skeptic to start suspecting that Rossi is trying to make us believe that his customer is the military; he is trying to attach military prestige to his product.



TEST TO PROOF THE LEONARDO 1 MW REACTOR WORKING BY MEANS OF LOW ENERGY NUCLEAR REACTIONS- PROTOCOL PREPARED BY THE PARTIES

The test has been performed by the Parties:

For he Customer (omissis- confidential) : Colonel-Engineer Domenico Fioravanti

For the Seller: Leonardo Corporation : Dr Andrea Rossi

Expert Scientist for the measurement of the radiations outside the reactors: Dr David Bianchini (University of Bologna)

Date of the test: October 28th 2011

Time of the test: from 09.00 through 23.00

TEST PROTOCOL

The first few lines of the three page report of the October 2011 demonstration of the 1 megawatt reactor. The customer is supposed to be an undisclosed organization. The word "Colonel" in front of the name of the customer's representative is very noticeably crossed out. It is hard to escape the impression that Rossi wants to send a message into the grapevine: the military is interested.

PART OF A PATTERN

Rossi's venture is not the only megadollar spin-off of the cold fusion turmoil of 1989.

In 1991 Randall Mills presented a theory to explain the observations of Pons and Fleischmann. He asserted that there was no nuclear fusion taking place at all. Instead, Pons and Fleischmann had created an environment in which hydrogen could transition to a state with less energy than the well known ground state. This, according to Mills, was what produced the heat.

Clean and cheap energy were now presumably within reach. So, concurrently with the presentation of his theory, Mills started a company to turn his insights into money. The parallels with Rossi's venture are striking. Rossi associated himself with the University of Bologna by donating large amounts of money. In a similar vein, Mills "bought" academic credibility at Rowan University in Glassboro, New Jersey. In both cases there are rumors and indications that NASA is interested. And in both cases there is chronic bickering about patents.

Mills' theories have meanwhile evolved to become a huge, pretentious, and freakish absurdity. He claims to have united all of physics and in 2008 he completed his brazenly titled book "*The Grand Unified Theory of Classical Physics*." The book is "self published" and can be downloaded for free via the website of Mills' company BlackLight Power[49].

CONCLUSIONS

In summary, three reasons can be put forward for why the E-Cat is an unwise investment.
(1) The principle behind the E-Cat is not supported by generally accepted science. Questions about the technology are evaded and the demonstrations raise more questions than that they answer. The working of the E-Cat has not been verified by an independent party. There are strong indications of outright deceit.
(2) Rossi's past as a businessman and inventor is not encouraging. Twice before he got into the large-scale development of technologies that are too good to be true. There is a history of promising a lot and delivering nothing. There have been criminal convictions and prison sentences.
(3) A confusing network of companies has been constructed. There is movement of documents and money, but there is no indication that actual factory space exists or is being set up - factory space that is imperative for the manufacture of the promised large amount of tangible products.

Even the cold fusion establishment has turned away from Rossi and watches with disquiet as con men and botchers appear to once again give the field a bad reputation.

Ventures like those of Rossi and Mills are ultimately set in motion and kept going by investors with deep pockets and shallow scientific knowledge. In the course of about two decades Randall Mills has raised ten of millions of dollars without ever having generated a single kilowatthour. This is probably how things will fare with Rossi's cold fusion. Whenever new money is needed, there will be a press conference with demonstration where it will be announced that the final realization is just around the corner. A more promising investment would meanwhile be one in the direction of a film studio that is planning a biopic about Rossi's career as an inventor and businessman.

The puzzling behavior of protons in a metal lattice justifies scientific research. It would be great if such research could result in, for instance, a way to safely and compactly store hydrogen for use as a fuel. But that genuine nuclear fusion might occur in those proton filled lattices, that is very unlikely. In spite of that, charlatans appear to keep succeeding in selling cold-fusion-pipe-dreams to wealthy ignoramuses. And that is an unfortunate waste.

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