Mario Menichella

# SECRETS OF E-CAT

Consulente Energia

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# Preface

*I wrote this book because I am an inquisitive physicist.*

*I had read of the potentially revolutionary reactor invented by Rossi and Focardi – better known as the "Energy catalyzer", or E-Cat – only a few days after its first public demonstration on January 2011 in Bologna. At first, I did not give too much weight to the idea, even though I wrote to Rossi to compliment him and give some tips on how to communicate such sensitive news to the public. But fate, evidently, had much more in store for me.*

*Quite unexpectdly, I was contacted a few months later by the co-founders of a cultural association operating in Viareggio to organize a major*

*popular conference there on cold fusion, inspired by the novelty of the E-Cat. So, I also arranged a long interview with Sergio Focardi, one of the protagonists of the story that led Andrea Rossi to make the "quantum leap", and to invent the E-Cat in its current form. Moreover, this event allowed me to get to know many of the other people mentioned in this book.*

*More importantly, I was forced to significantly deepen my knowledge of the topic so as to be able to prepare the event in a professional way; I soon ended up by becoming passionately involved in it. An extra element I discovered right away was that, in the two decades following the announcement in 1989 by Fleischmann and Pons of "their" cold fusion – prematurely labeled as a "hoax" – this area of research, despite a thousand obstacles and prejudices, had begun to make great strides forward, independently of the validity or otherwise of the E-Cat.*

*The aim of this essay, therefore, is not to determine whether the E-Cat is an amazing product or the scam of the century – this verification and the scientific validation is only a secondary theme of the book, although it is treated in some depth – but to bring an understanding of how it works to all those who, like me, would like to try to replicate it.*

*When, more than twenty years ago, I enrolled in the Faculty of Physics at the University of Pisa, I was attracted by the idea I had formed as a child, of an "eighth-century" physics – a kind of physics that allows you to make an important discovery in a one-room laboratory while spending only a little money – exactly the opposite of today's physics, which requires research*

*machines that are increasingly large and expensive, and have to be run by ever-larger teams of scientists.*

*In this scenario, "cold fusion" stands out as a remarkable, fascinating exception. Testing the concept is relatively affordable for everyone, from someone who works as an amateur to small and medium companies. And, as we shall see in this book, this also applies to the Energy catalyzer, which has always struck me by its incredible simplicity, which characterizes at least 90% of the whole project.*

*The issue of its "secret catalyst", then, is very interesting. In fact, one can look forward to enjoying the experience of setting up the rest of the machine with the help of this book, or can try – as I did in this volume – to work patiently at putting together the many "pieces of the puzzle" so as to be able to reach a logical conclusion, as a detective would do when facing the enigma of a crime in which the murderess is unknown. Luckily, after all, there are no perfect crimes...*

*So, all I need to do now is to say goodbye to you, and – of course – wish you a good read!*

*Mario Menichella*

# Chapter 1 – What E-Cat is

The E-Cat, or *Energy catalyzer*, of Rossi-Focardi is the first and (so far) only system in the world able to obtain, according to its two inventors, large amounts of energy from nuclear fusion reactions, processes that do not normally take place on Earth, but inside the stars, thanks to the very high temperatures and pressures present in them.

In addition, the process of generating energy that is the basis of an E-Cat uses as "ingredients" the only *nickel* (Ni) and *hydrogen* (H), both very abundant and cheap: nickel, in fact, is an important component of the Earth's core and is commonly used to produce steel, while hydrogen can be extracted from water by simple electrolysis.

Therefore, devices such as the E-Cat – and the *low-energy* nuclear reactions, as we shall see, allowing the operation of this machine – could be a source of almost unlimited energy for humanity, characterized by a cost close to zero and no environmental pollution.

Although this may seem "too good to be true", the E-Cat is not just a dream or a laboratory prototype: it is already a reality, being in the pre-start marketing in the U.S. (for the American market); now it is going to do the same in Europe (for the European market), and has already attracted proposals of investment for a total of tens of millions of euro.

What makes the E-Cat very suitable for a widespread use, both industrial and domestic, are its small size and high production of energy, produced in thermal form – i.e. as heat – but easily convertible into electricity (which is almost always produced from thermal energy).


*Andrea Rossi with behind his potentially revolutionary invention, the E-Cat.*

In fact, the ideal use of an E-Cat is "cogeneration": that is, providing high-quality and high-temperature heat to produce electricity and/or for certain industrial processes, and waste heat at a lower temperature more suitable for space heating and/or sanitary water heating, etc.

## What are *low energy* nuclear reactions

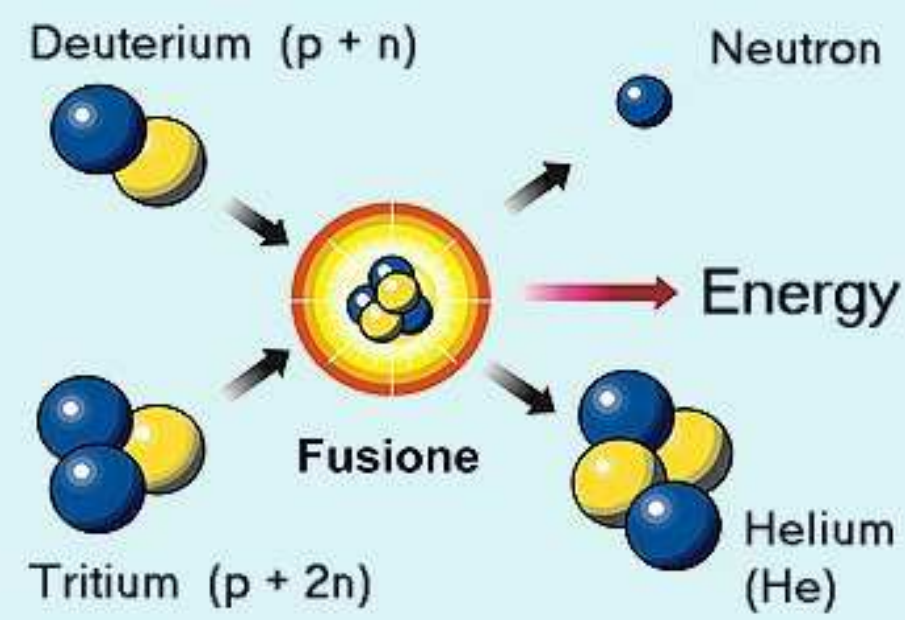
The operation of an E-Cat is based – as we shall see throughout this book – not on the common chemical reactions, but on "low energy" nuclear reactions, so named to emphasize the fact that they are the result of interactions which can occur under conditions of temperature, pressure, etc., not extreme, i.e. similar to those existing on Earth.

In nature, there are two types of well known nuclear reactions able to provide energy: those of *fission* and *fusion*, while the "low energy nuclear reactions" – often referred to, especially by Americans, with the acronym of LENR (Low Energy Nuclear Reactions) – represent a new and still little known type of nuclear reactions.

Nuclear *fission*, which consists in "splitting" the nucleus of a heavy element (e.g. Uranium-235) into smaller particles accompanied by the release of energy, is used in reactors of nuclear power plants. Because the fission reactions release about a million times more energy than chemical (and are self-sustaining), a 1,000 MW nuclear power plant consumes in his lifetime

only a few tons of uranium, but always requires an adequate cooling of the reactor core and produces radioactive waste difficult to store.

Nuclear *fusion*, on the contrary, is the physical fusion of two "light" nuclei (i.e. characterized by a low atomic number) in a heavier, and is accompanied by the release of energy. There are two types of fusion: "hot" nuclear fusion, which is well known and understood for a long time, and the "cold", whose reputation is much more recent.




*A well known "hot" nuclear fusion reaction between two isotopes of hydrogen.*

The hot fusion is the process that allows stars to radiate light and energy and not collapse on themselves, through nuclear fusion reactions of various types, the simplest of which sees two protons ($^{1}H$) merge into a deuterium nucleus ($^{2}D$), with emission of a positron and a neutrino. Man tries to reproduce a similar process on Earth, in machines called "tokamak",

trying to recreate the conditions of extremely high temperatures and energies needed for this type of reactions. However, the complexity of these machines and their exorbitant costs mean that even the only real demonstration of the feasibility of fusion will remain a dream for many decades.

*Cold fusion*, instead, is always a fusion reaction – from this point of view is very similar to hot fusion – but differs because it does not need high temperature (or energy). Thus, the terms "cold fusion" and "low energy nuclear reactions" indicate the same thing: the first is the historical name with which the relevant experiments are widely known and is now mainly used by the media; the second is especially widespread among scientists, which in Europe for ten years identified studies on cold fusion with the broader expression *Condensed Matter Nuclear Science* (CMNS).

## Twenty years of research on “cold fusion”

The modern history of cold fusion begins with the premature announcement made in the United States by the two electrochemical Martin Fleischmann and Stanley Pons, who in 1989 convened a press conference – without having first published an article in a journal with *peer review* – to illustrate the success of an experiment done with palladium and deuterium in an electrolytic cell, where they produced a very slight excess heat.

There were numerous attempts to replicate this result, but for some years had little success, so that soon the question of cold fusion was labeled

by the media and mainstream science as a "hoax". As a result, there have been numerous other studies that have focused not only on the palladium-deuterium line of Fleischmann and Pons (which led in recent years some interesting result), but have also explored a new line – the nickel-hydrogen – which instead uses a dry cell, with the metal in gas atmosphere.


*At the beginning, the cold fusion seems to be a "hoax", especially for the media.*

The probably better experimental work in this second line of research has been carried out in Siena since the early Nineties, by a group of physicists composed by Sergio Focardi (University of Bologna), Francesco Piantelli (University of Siena), Roberto Habel (University of Cagliari), but it

did not lead to a system capable of generating useful amounts of excess energy for normal industrial or domestic applications.

In Siena, in fact, the three scientists – using hydrogen and nickel as the two only "ingredients" of the reaction, plus an appropriate amount of heat supplied to the system – manage to get out a double thermal energy than the electrical energy provided in input. Obviously, if there were no some "unknown" reactions to produce this little but detectable result, you would get a lower thermal energy, due to the significant losses that you always have turning a form of energy into another.

Focardi and Piantelli collaborate in research on cold fusion – exploring not only the main line Ni-H, but also other involving the use of different metals and alloys – until 2005, when Focardi is distracted by serious health problems and abandons the search, ending a valuable partnership. Focardi was therefore, from the beginning, the protagonist of a long journey that finally, surprisingly, has led to the invention of the *Energy catalyzer* by Andrea Rossi, so this machine has also Focardi's name.

But who is the "scientist" Sergio Focardi?

Born in Florence in 1932, once graduated he won the competition at the Scuola Normale Superiore in Pisa, where a few years later graduated *cum laude* in Physics with 110. There he began his academic career, which continues in Bologna and led him to become, in 1977, full professor, and to teach general physics, experimental physics and superior physics. In his research, he deals with processes involved in the 4 major forces: strong,

weak, electromagnetic and gravitational. Highly regarded by colleagues from the Italian *National Institute of Nuclear Physics* (INFN) – he directs the INFN Section of Bologna in the years 1973-76 – and in 1980-89 he was dean of the Faculty of Sciences, at the University of Bologna, who appointed him, in 2005, Professor Emeritus of Experimental Physics.

*The physicist Sergio Focardi, professor emeritus at the University of Bologna.*

## The disruptive innovations brought by Andrea Rossi

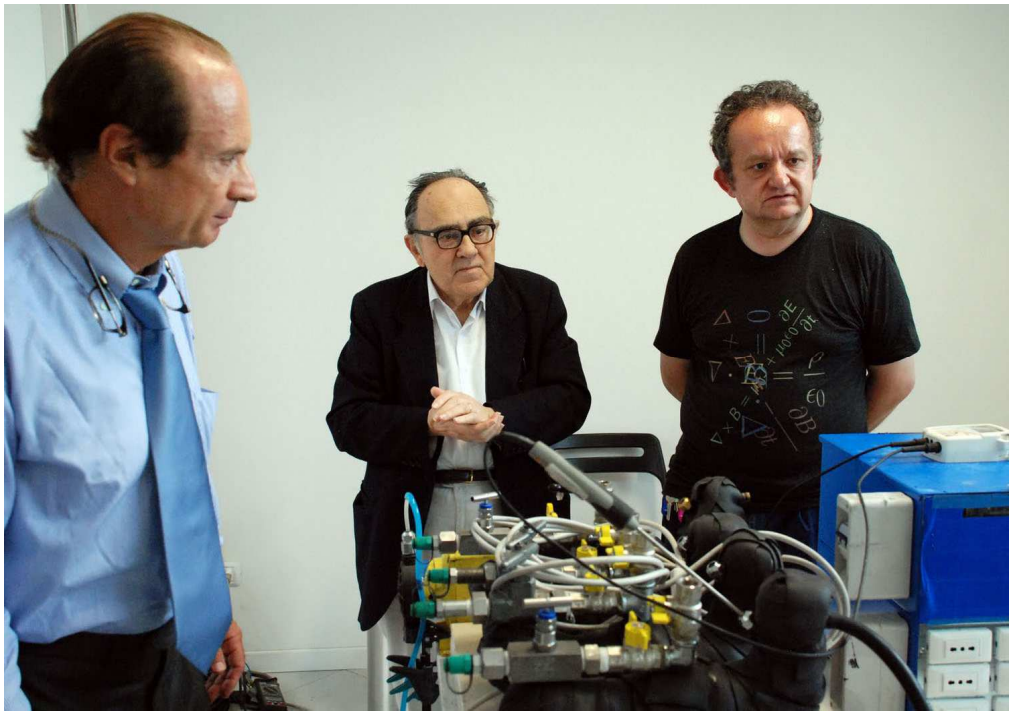
Just when Focardi is relieved from teaching assignments and by concerns about his health – because, meanwhile, he has retired and has undergone a successful surgery – it comes into play Andrea Rossi, an Italian chemical engineer who worked since 1997 in the United States, where he concentrated on innovative technologies in the energy field.

In 2007, Rossi contacts Focardi to develop a cold fusion reactor, and the two meet in Bologna. Rossi illustrates his ideas, like the one he wanted to use nickel in the form of powder, to increase the surface area and thus encourage the "loading" of hydrogen inside the metal and the subsequent reactions. Being on the same wavelength, the two establish a partnership and carry out many experiments, which are made in Bondeno (Ferrara), in the industrial building of EON, a company of Rossi.

The two focus on the reactions between nickel and hydrogen – while not neglecting other possible metals – as it was the most promising line of research from previous Focardi's work, and they soon get the first important results that led to the prototype of the E-Cat. In this experiments, Focardi is more concerned with the "nuclear" aspects, such as ensuring that there is no emission of neutrons or gamma rays, which are dangerous to health. Rossi, instead, focuses mainly on how we can increase energy production of the apparatus, facilitating the reaction in some way: he is looking for a "catalyst", in the strict sense (i.e. of a chemical substance) or not.

They built the first apparatus, and in just a few months Rossi gets surprising results. In practice, the arrival of Rossi, with his background and practical skills, in research with Focardi brings a tremendous innovation in the experiments, previously conducted with simple nickel-hydrogen cells characterized by a very limited excess energy production. Rossi is able to "activate" the system through a catalyst still secret – even if, as we shall see, there are different assumptions about it – which allows the old Focardi's

reactor to move from a production of excess heat of watts (of the same order as the electrical power input) to an order of kW.



*Rossi, Focardi and the physicist Giuseppe Levi near some E-Cats. (Photo by D. Passerini)*

Once they realized the reliability of the invention, Rossi and (especially) Focardi push to publish on a scientific journal with peer review an article on their sensational results. So, the two publish the article online and, under pressure from Focardi, Rossi decided to make also a public demonstration of the functioning *Energy catalyzer* (just renamed, for convenience, E-Cat), which held in Bologna, on January 14, 2011 at the presence of an audience composed by several University and/or INFN physicists, and journalists from various Italian newspapers and televisions: RAI, Repubblica, etc. So, the news about the E-Cat, in a few days, goes around the world.

## The findings of a “skeptic” to the presentation of E-Cat

It may seem surprising in part thus far, but the only real attempt to understand really, during a test, what there is inside the reaction chamber of an E-Cat – and, therefore, to have information on the secret catalyst – was made by Francesco Celani, precisely on the occasion of the first public presentation of the machine, on January 2011.

Celani is not a common experimental physicist. He works, from practically a lifetime, at the Frascati National Laboratories of the Italian *National Institute of Nuclear Physics* (INFN), where he is first researcher, and some twenty years agostarted working on cold fusion with the idea to show that it was a "scam". Then, with time and the experiments he made, he changed opinion and dedicated to the development of cold fusion: he began a systematic study of various experimental setups, employing sophisticated techniques to promote the reactions, collaborating over the years with some of the best world scientists working in this area.

So, animated by his usual critical spirit, on January 14 he comes curious but also scared at the appointment with the E-Cat, because he knows that Focardi is a reliable scientist but also of advanced age, while Rossi wants to make a presentation "of effect". So, he is worried that the machine can produce some strong gamma emission that can do serious damage to health. Thus, he arrives on site with a bag full of over 20 kg of equipment!

Before the experiment begins, Celani leaves and goes to the bathroom – which, fortunately, is adjacent to the room where you can find the E-Cat –

bringing with him three small portable instruments: a Geiger counter, a microwave detector and a detector of ELF electromagnetic waves, i.e. *Extra Low Frequencies*, to measure the noise on the power grid frequencies around 50 Hz. The idea is that Rossi, if wants to play some "joke", has two options: either put a power cord (possibly hidden under the table leg) to power at the appropriate time, or have a radioactive source hidden somewhere, so that he can pull it off at the appropriate time.


*Francesco Celani, one of the major Italian experts of cold fusion and LENR.*

Well, the measurements carried out secretly in the bathroom prior to ignition of the reactor show that the situation is quite regular: the environmental background near the E-Cat is the same as in the farthest room. Good sign. At this point, Celani pulls out of the suitcase its various tools, puts them on the table – under the gaze of the very surprised Rossi's

wife, who perhaps believes him a spy – and turns them on. In addition to the already mentioned instruments, there is a wide range spectrometer and a EMP detector, i.e. of electromagnetic pulses.

The idea is that, if Rossi wants to cheat, he could start the test creating the equivalent of a strong electromagnetic pulse, so instrumentation would detect something, making people believe that there is a "signal". So, if the ELF and EMP detectors report something, it's a bad sign. If, instead, they remain silent while the nuclear detectors (Geiger and spectrometer) – powered exclusively by battery – reveal anything, it is a good sign: it means that in the experiment there is something of serious.


*Rossi shows the current absorbed from his E-Cat during a public demonstration.*

And things go like just that. At one point, both detectors show for about a second (or less) a signal, a sort of "flash", which according to Celani corresponds to the instant when the reactor reaches the critical temperature for starting nuclear reactions. He understands this because, shortly after, an happy Rossi comes out of the room saying: "We made it". Even at shutdown Celani detects a signal, albeit smaller. Therefore, it can be concluded that the phenomenon is genuine, i.e. it is not a hoax.[1]

[1] In fact, it's hard to believe that an electromagnetic disturbance has been able to start two independent battery-powered instruments, or that a cosmic ray, entered in the room with the right angle and just prior the Rossi's announcement of the start of reactions, has passed through both detectors.

# Chapter 2 – How much energy it produces

Among all the features characterizing an E-Cat, the generation of a remarkable energy, as reaffirmed on several occasions by both its inventors, Rossi and Focardi, is what most distinguishes it – and, indeed, makes this machine unique compared to the previous (always experimental) equipment which tried to produce "excess energy" in research on cold fusion.

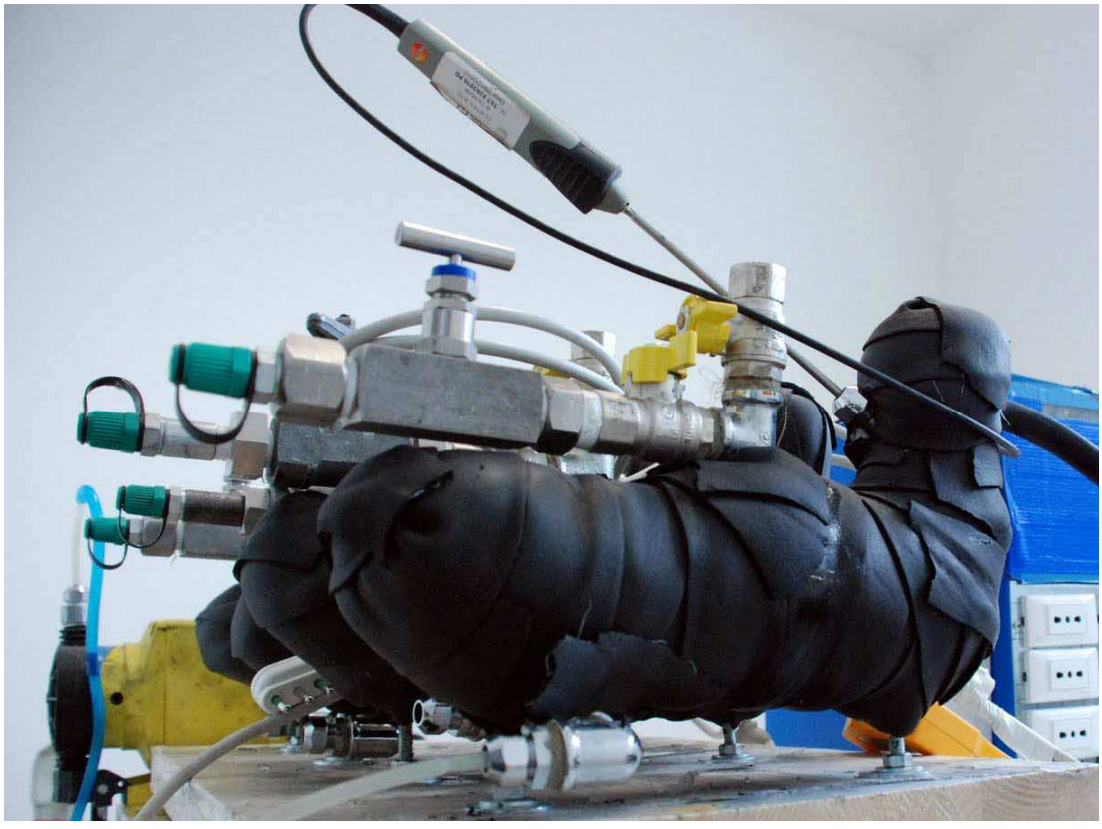
But how much energy is produced, in practice, by an E-Cat?

Before giving quantitative data, it is important to make here some assumptions useful for non-expert reader, which are:

- A machine like the E-Cat is powered by electricity and produce thermal energy, so they are two different forms of energy: the first measurable with a simple and common power meter, while the second form is considerably more complex and indirect to assess.
- Electricity is measured in electric kWh ($kWh_e$), while the heat is measured in thermal kWh ($kWh_t$). However, they are not equivalent,

that is 1 $kWh_e$ is not equal to 1 $kWh_t$: for practical purposes, at about 500 °C there is a ratio of about 1:3 between the two different energies. That is, if I produce 100 $kWh_t$, these are roughly equivalent to about 30 $kWh_e$: the exact value depends on the transformation method to convert the heat into electricity (Stirling or others).

- The energy *E* produced by the E-Cat is the so-called *excess energy* generated by the system, i.e. the outgoing energy (thermal) less input energy (electricity). Then, using the just showed equivalence, we have: $E = [0.3 \times E_{\text{thermal output}} (kWh_t)] - E_{\text{electric input}} (kWh_e)$. So, the energy produced can be expressed in terms of electric kWh.



*Some E-Cats lined up one behind the other on a table. (Photo by Daniele Passerini)*

- More useful of the electric energy in $kWh_e$ produced by an E-Cat is the *energy amplification* factor *A*, which answers to the question: if I provide 1 kWh of electricity to the machine, how many thermal or electric kWh (between the two types, at 500 °C there is a ratio of 1:3) I get out? Obviously, the necessary condition for a cold fusion reactor to generate excess energy is that $A > 1$, at least.

At this point, we can try to answer the question with which we began: how much energy produces an E-Cat?

## The first methods used to calculate the excess energy

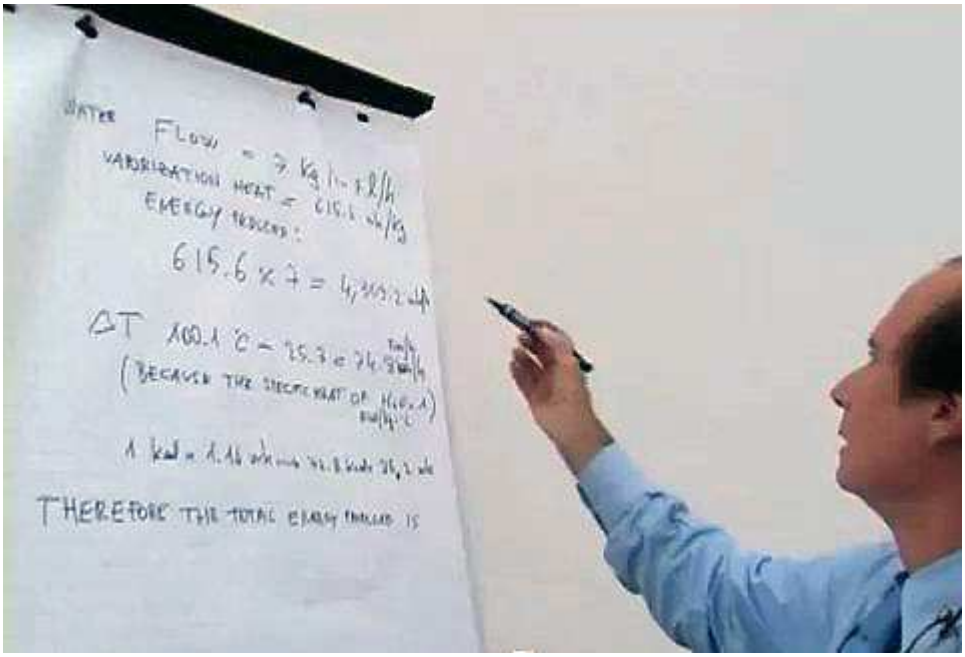
The maximum temperature achievable with the E-Cat of Rossi-Focardi embraces – as stated by its inventors – a wide range of values, and it can therefore be used not only to heat a fluid appropriate for various uses, but also for the same estimate of the produced energy.

In fact, the sealed cell which represents the chamber where the reaction between nickel and hydrogen occur is in close contact with an external tank (thermally isolated with the surrounding environment to minimize heat loss), which can be filled with water or another appropriate fluid that acts as a carrier to get out the heat produced in the E-Cat.

Due to the high heat produced from the system, if you use the water as a fluid, it reaches the boiling point, and therefore the pipe containing the water is under pressure. Since the steam pressure cannot exceed a certain

limit, its value is maintained within a safe range – corresponding to a pressure of 3-6 bars – through the appropriate opening of a valve.

When the valve opens, water enters to replace the old gone in the form of steam. Since the water supplied to the system is measured, it is possible to calculate, retrospectively, the thermal energy produced in the E-Cat, which in steady state turns out to be much larger than the electricity supplied in input (measured with a simple power meter).




*Andrea Rossi calculates the energy produced from his E-Cat. (Video by S. Krivit)*

In the initial development of E-Cat, Focardi and Rossi have used three different methods to measure – or at least to have an estimate of – indirect thermal energy generated by the device (and thus of the amplification factor of the latter), which is one of the most critical aspects of these experiments. We call the three methods, respectively, A, B and C.

*Method A* consisted of a "fast" measurement – as the E-Cat has been kept in operation only for about 1-1,5 hours – carried out by measuring the amount of water introduced into the tank surrounding the reaction cell, and knowing that water boils when it reaches 100 °C. The pressure has been kept under control to a fairly constant value thanks to the safety valve, as I have explained in the previous part.

*Method B*, instead, has evaluated the thermal energy in an appropriate way by forcing the circulation of water heated by the E-Cat through some radiators connected in series, and having the unit in operation for about 10-20 days in a row. The energy produced in the machine was estimated by measuring the energy required to reach the same temperature of the radiators with a normal heating system.

*Method C*, finally, used a closed circuit in which water was forced to circulate through a pump. As usual, inserted in the circuit is the E-Cat, properly insulated to minimize heat exchange with the outside world. Two thermocouples placed before and after the E-Cat has allowed to measure the water temperature in continuous mode, which has been so recorded by a computer. Knowing from moment to moment the difference between the two temperatures, it was possible – for Rossi and Focardi – calculate the thermal energy transferred by the *Energy catalyzer* to the water.

## The experimental results obtained at the beginning

In the scientific paper *A new energy source from nuclear fusion* – written in 2010 and the only source of detailed information on the production of thermal energy obtained with the E-Cat in its first phase of tests, carried out between 2008 and 2009 in an industrial shed at Bondeno (Ferrara) – Focardi and Rossi summarize the results of their experiments.

A new energy source from nuclear fusion

S. Focardi[1] and A. Rossi[2]

[1]Physics Department Bologna University and INFN Bologna Section

[2]Leonardo Corp. (USA) - Inventor of the Patent

April 22, 2010

**Abstract**

A process (international patent publication N. WO 2009/125444 A1) capable of producing large amounts of energy by a nuclear fusion process between nickel and hydrogen, occurring below 1000 K, is described. Experimental values of the ratios between output and input energies obtained in a certain number of experiments are reported. The occurrence of the effect is justified on the basis of existing experimental and theoretical results. Measurements performed during the experiments allow to exclude neutron and gamma rays emissions.

**1. Introduction**

It is well known that in chemical reactions, and more specifically in processes used to obtain energy, as for example oil, gas and carbon combustion, only some electronVolts (eV) can be obtained for every couple of atoms involved. This depends on the fact that binding energies of external atomic electrons are in the eV range.

On the other hand, in nuclear transformations, the energy quantities that can be absorbed or released are of the order of mega-electronVolts (MeV) for every couple of nuclei involved in the process. As a consequence, for every given amount of energy obtained, the mass to be transformed by a nuclear process is about a millionth of that necessary for a combustion.

It is a general rule, valid for all stable compounds, that the mass for a compound is lower than the total mass of all constituents. In such conditions, the mass-energy conservation principle guarantees stability against the spontaneous disintegration into the components. As a consequence, for the nuclei, the mass of every stable nucleus turns out to be lower than the sum of the masses of all its components (protons and neutrons).

If we denote by $m_p$ and $m_n$ the mass values of free protons and neutrons, and by $n_p$ and $n_n$ the numbers of protons and neutrons belonging to a given (stable) nucleus N, the nuclear stability is insured by the always positive difference

$$\Delta = n_p m_p + n_n m_n - m_N \qquad (1)$$

1

*The paper of Rossi-Focardi about the E-Cat, published on the "Journal of Nuclear Physics".*

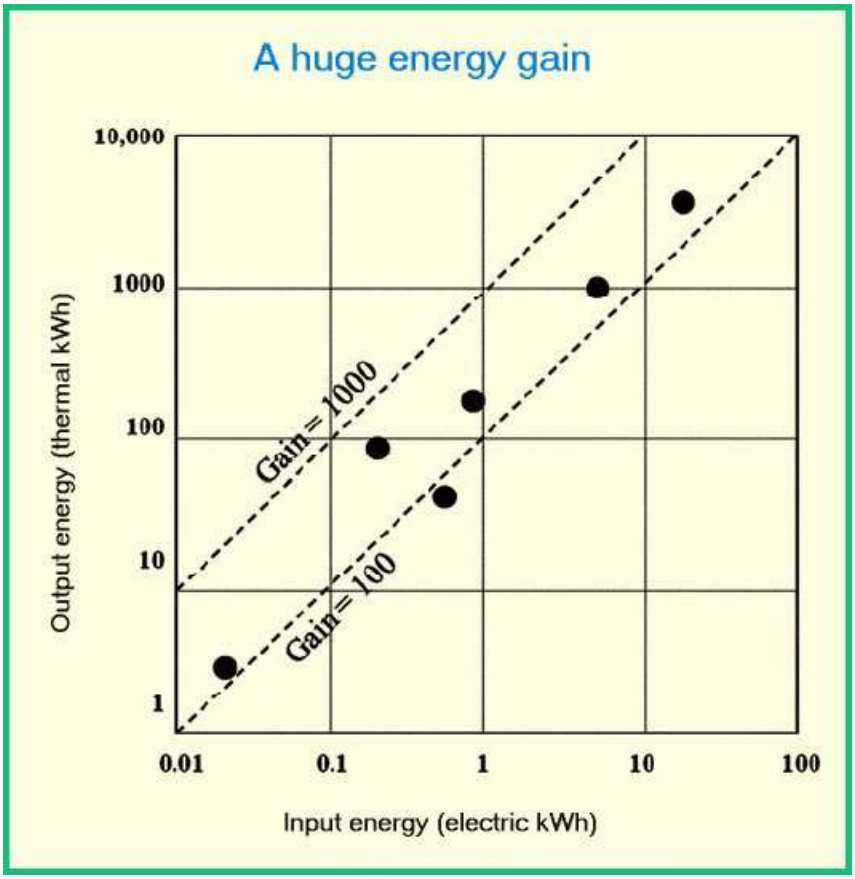
The data are summarized in the table below, and refer (1) to measurements of the thermal energy produced with the E-Cat obtained by

one of the three methods described above, and (2) to measures of the energy supplied to the machine made with a common power meter. The first column shows the time (in days) for which the E-Cat has been kept running continuously. The second column shows, instead, the electricity supplied in input (expressed in $kWh_e$), while the third column refers to the energy provided as thermal output in the apparatus (in $kWh_t$).

| *Days* | *Method* | *Input Energy* | *Output Energy* | *Output/ Input* |
|---|---|---|---|---|
| 2008-5-28 | A | 0.2 | 83 | 415 |
| 2008-6-11 | A | 0.806 | 165 | 205 |
| 2008-9-2 | A | 0.5 | 40 | 80 |
| 2009 (2-17, 3-3) | B | 5.1 | 1006.5 | 197 |
| 2009 (3-5, 4-26) | B | 18.54 | 3768 | 203 |
| 2009-10-22 | C | 0.018 | 3.23 | 179 |

*The first "official" tests made by Rossi and Focardi on the Energy Catalyzer.*

The last column of the table shows the *amplification factor* of the E-Cat, i.e. the ratio between energy output (in this case, heat) and energy input (electricity), or between the energy produced by the machine and that supplied to it. Recall that, to estimate electric-power amplification, you have to divide by about "3" the values in this column: so, the thermal-electric amplification of 200 times reported in the table corresponds, at 500 °C, to an electric-electric amplification of about 70 times.




*The energy gain of the E-Cat resulting from the first experiments performed by Rossi and Focardi. The graph shows the thermal energy in output as a function of the electrical input.*

The amplification factor of the E-Cat – as you can see – is remarkable, with all three different measurement methods: just around 200 times (70 if we consider the electric-electric factor). Only in two cases the amplification was "anomalous": in one, it was lower (and equal to "only" 80 times), due to "contamination of the fuel", while in the other case (with amplification of 415 times!) Focardi and Rossi cannot provide an explanation.

The amplification of the E-Cat depends, of course, from various initial and "boundary" conditions used in the experiment and, being these equal, depends on the functioning time of the machine. Since the anomalous

amplification efficiency – of about 415 times – refers to a short running time (about 1-1,5 hours), it is likely that reflects only a transient phenomenon of high-energy production to stabilize before the start of the nuclear reaction, and therefore it is not indicative of the performance characterizing the apparatus on a long time, i.e. it is not an appropriate "medium" value.

## The public demonstrations of the *Energy Catalyzer*

From January 14, 2011, the date of the first presentation to the press of an E-Cat, the Rossi-Focardi reactor has been the subject of various "proofs" in public, or at least tests where there was an enough detailed information, as it also results from the numerous and precise "chronicles" made by Daniele Passerini in his blog *22 passi*, that I invite you to read.

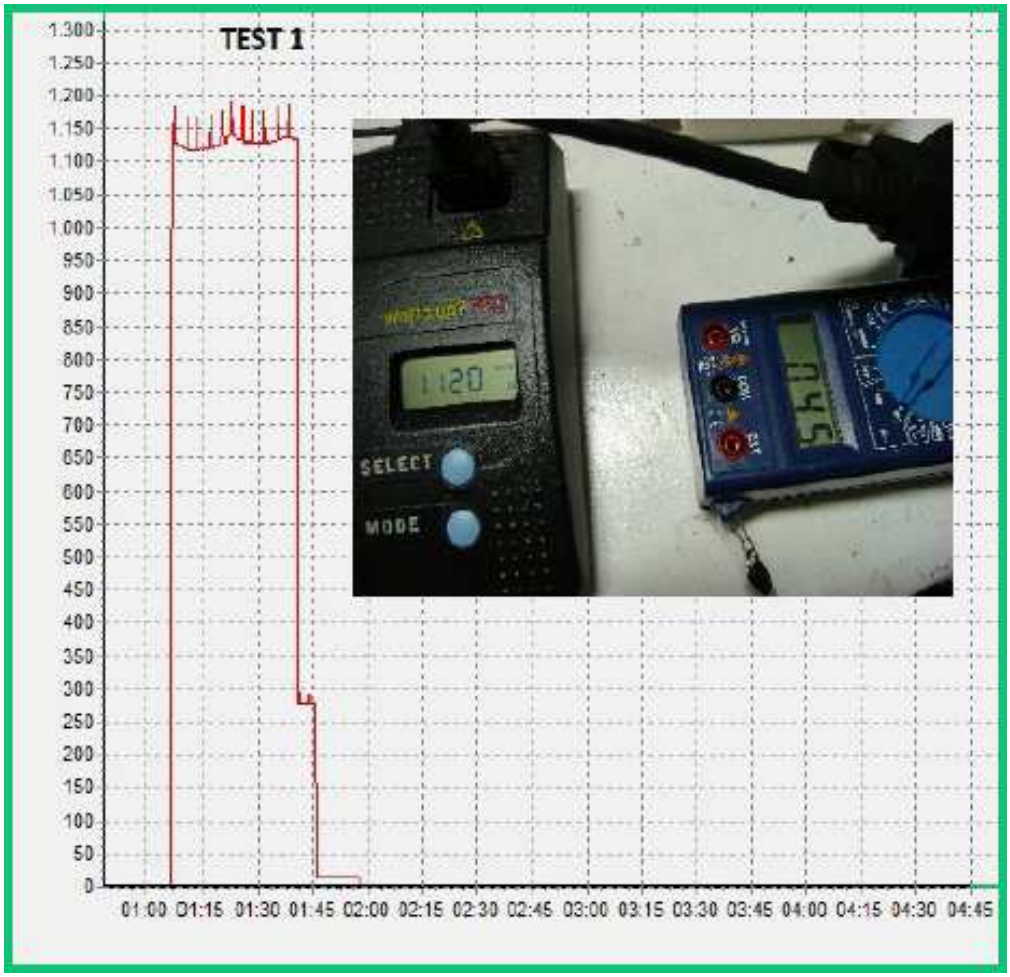

*The blog "22 passi" (left), edited with patience by Daniele Passerini (right).*

Below, I will summarize the main tests of which we are aware:

1) *Demonstration of January 14, 2011.* In an industrial building near Bologna, in front of an audience of invited experts and journalists, it was held for about 45 minutes a functioning test of the E-Cat carried out under not fully controlled conditions. One of the organizers of the event – Giuseppe Levi, a physicist at the University of Bologna and for a long time collaborator of Focardi, associated to the Italian *National Institute of Nuclear Physics* (INFN) – has, subsequently, provided a report of the experiment (which also illustrates a previous test done on December 16, 2010, in which it had been reached the state of a self-sustaining reaction), while a report on the gamma radiation produced was made by Dr. Mauro Villa. The reactor is heated by providing an average of 1 kW of electrical power, would produce 12.7 kW of power, therefore, with a gain of more than 10 times.

2) *Demonstration of February 10-11, 2011.* The just mentioned Giuseppe Levi was able to rule out a possible chemical origin of the phenomenon thanks to this additional test, performed by him and Rossi in Bologna from 10 to 11 February 2011, and that has lasted continuously for 18 hours. On this occasion, the reaction was triggered by providing 1.2 kW of power for about 10 minutes, then reducing the value of about 100 watts, giving so enough power to keep running the electronic apparatus intended for the supervision of the process. The excess output power was 15 kW, thus corresponding to a power gain of about

15 times. In the test it was also measured the total consumption of hydrogen, that resulted of about 0.4 grams.




*The electric power absorbed by the E-Cat during private testing of December 16, 2010, as illustrated from Giuseppe Levi in his report on the experiment of January 14, 2011.*

3) *Demonstration of March, 29, 2011*. Following the publication, on the Swedish magazine *NyTeknik*, of an article on the E-Cat, it was held in Bologna a new test at the presence of two physicists rather well-known in Sweden: Sven Kullander, Professor Emeritus at the University of Uppsala, and Hanno Essen, a professor of theoretical physics at the

University of Stockholm. For the first time, the E-Cat has been shown "naked", but in a smaller version (by just 4.4 kW, compared with more than 10 kW of the first prototype). The energy input was 330 W and output of 4.7 kW. Both the calculation of the produced energy and the calibration of the flow of water necessary to estimate the heat produced were made by two Swedish scientists, who were totally free to control everything (but not to open the reactor). A few days after the experiment – which lasted 4 hours – they wrote a long positive relationship on the machine, available on the Web.

*Rossi shows the reduced version of the E-Cat to the Swedish physicists Kullander ed Essén during the demonstration of March 29, 2011. (Photo by Daniele Passerini)*

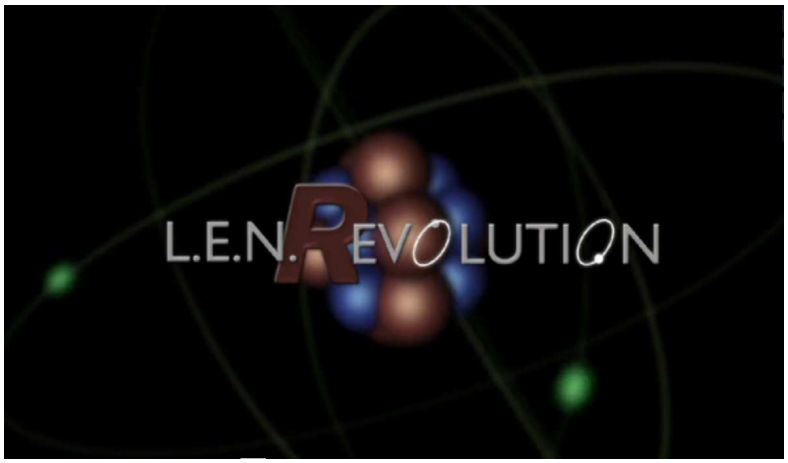
4) *Demonstrations of April 19 and 28, 2011*. In the month of April, two further demonstrations of an operating E-Cat, which lasted respectively 2 and 3 hours, were held in Bologna. Mats Lewan, a science journalist sent from *NyTeknik*, has been actively involved – in order to exclude the most obvious possibilities of a fraud – in such tests and in the measurements needed to estimate the heat produced. The test showed a power gain of 2.3 to 2.6 kW against a given input electrical power of 300 W. As in the previous tests, the power output was calculated from the amount of vaporized water and depending on the flow of liquid water, this time reduced compared to previous demonstrations.

## Uncertainties related to the amplification factor

As you see, therefore, the power gain of an E-Cat (the one from electric to heat, no electricity-electricity) fell with the time from the value of about 200 of the first experiments of Rossi-Focardi to that of 10-15 in the tests of 2011 and, more recently, Rossi has pledged to sell the E-Cat with a gain of at least a factor of 6. Which is the reason of these differences?

The most likely explanation is that the power produced by the current E-Cat is a compromise between energy gain, stability and reliability of the system (and perhaps even some form of "manageability" of the secret catalyst). In other words, in the experiments mentioned by Focardi, the

machine was running "at full" power or nearly so, which is not generally desirable, since this regime has not yet been explored – such as Giuseppe Levi explains in an interview – and could produce damage. In the public tests, therefore, the E-Cat has been used more appropriately "detuned" with respect to its true potential, for trivial reasons of safety.



*The E-Cat has not yet been studied in his "critical" regime , as Giuseppe Levi tells us in an excellent documentary by Giacomo Guidi (right): see it with English subtitles on the web.*

It seems, indeed, unlikely that the "power loss" of the E-Cat from the beginning to now depends on an erroneous measurement of the previously accomplished excess heat, as the three different methods used by Rossi and Focardi in the first experiments gave results consistent with each other, and one of them was a "comparative" method (in which they heat up radiators at the same temperature using two heaters, in one case the E-Cat and in the other an electrical resistance, and then compare the electrical energy supplied in both cases), therefore a crude method but somewhat more reliable. The fact remains, however, that their measurements were not made directly from

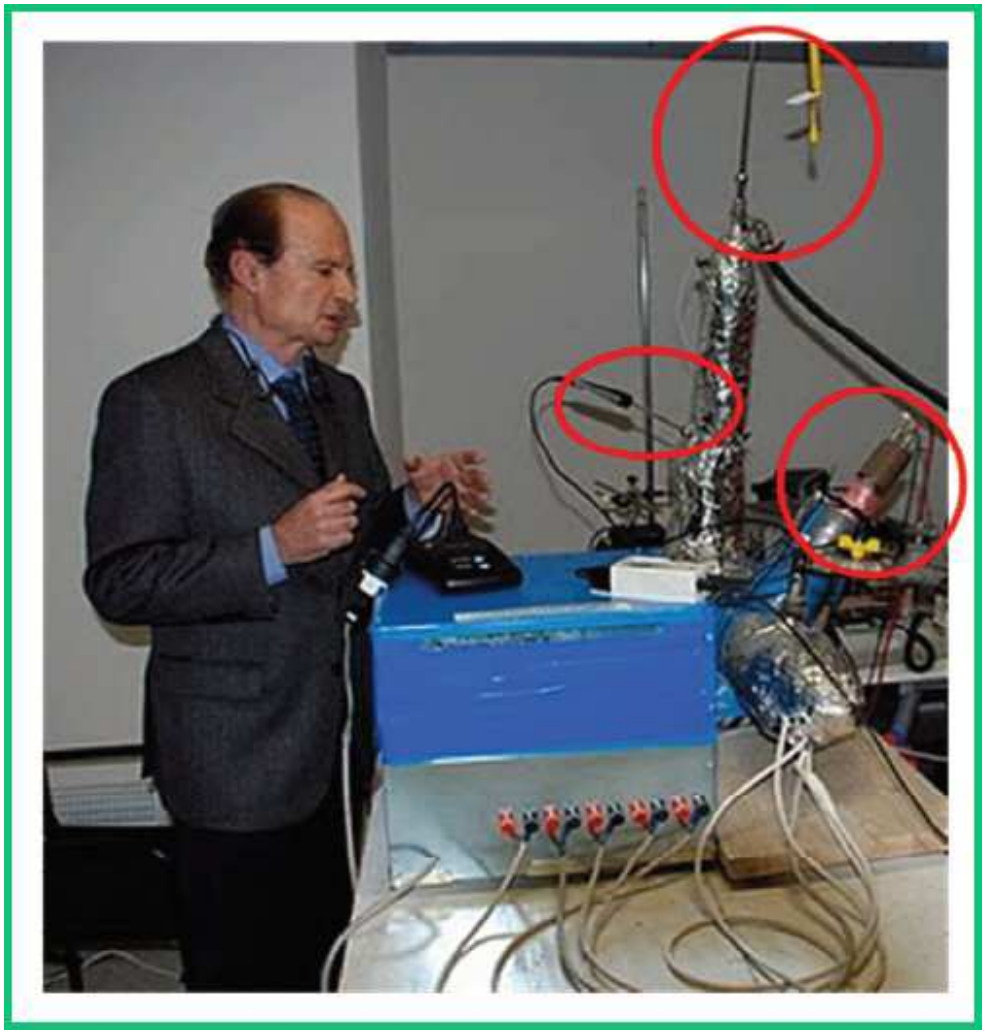
Focardi, who told me he had done personally this type of job only at the time of the old experiments with Piantelli.

However, we must also take note of the fact – on which much has been written on Internet – that all measurements of the excess heat produced by the E-Cat made in the various demonstrations listed above were executed using a procedure which provides water to the reactor that is then heated up to 100 °C, a temperature at which it turns into steam; but the calorimetric measurements in which the steam is involved are inherently subject to very high errors, which feed inevitably understandable criticism (for example, in the USA by Steven Krivit, science journalist and editor of *New Energy Times*, and in Italy by Ugo Bardi, chemistry professor at University).

As explained on several (even public) occasions by Francesco Celani – one of the leading experts in Italy in this kind of measurements on cold fusion reactors – to determine the excess heat it is important that the water does not produce steam, because the so-called *enthalpy* associated with the formation of steam is about 7 times greater than the energy needed to bring the water temperature to 100 °C, and therefore, even if only a small amount of water evaporates, the obtained measure is "distorted".

To avoid this, it is sufficient that the water temperature does not exceed, for example, 90 °C, which is achieved by circulating water in a circuit so that it does not exceed this threshold. The best method for making correct calorimetric measurements of excess heat on the E-Cat has a name: that of

*flow calorimetry in liquid phase*. Celani said he is ready to carry out his own measurements on the heat to validate the machine.



*In the experiment of January 14 were measured (from the bottom upwards) the gamma rays, the temperature of the cooling water, the "quality" of the steam (from a report presented by Francesco Celani to the ICCF-16 Congress in Chennai, India, on February 6-11, 2011)*

To address both the mentioned problems – the study of the critical regime and the exact measurement of the excess heat produced – Rossi concluded, in June 2011, a contract worth € 500,000 with the Physics

Department of the University of Bologna. It is an agreement for *research and development*, so they can test for long periods the E-Cat, possibly improving its performance, and give a scientific validation at an academic level.

# Chapter 3 – How is an E-Cat made?

When, in June 2011, I interviewed Sergio Focardi for the first great popular event in Italy on cold fusion and on the E-Cat that I was organizing in Viareggio (Lucca), beyond the words recorded in the public part of the interview, I had from him the distinct feeling of what I had thought preparing the interview after reading a lot of material and hearing the same Focardi in previous interviews: namely, that the E-Cat is a very simple machine, at least for the part developed by Focardi-Piantelli in their old experiments, and this seems to me to be a very good thing.

Probably, it is worth reporting directly here his words: «In Siena, we used some containers called “cells", measuring about 30 cm (he indicates the size with his hands). In this closed volume we put the gas, hydrogen, a metal and then we applied a voltage. Therefore, these cells have always been objects small, manageable, which provided some electricity and then you could see if you get more energy as a result of what had been given».


*The author interviewing Sergio Focardi for the meeting held in Viareggio, on July 23, 2011.*

As Focardi explains to me, when in 2008 he met Andrea Rossi, they immediately put to work in the shed of Rossi in Bondeno (FE), resulting – a few months later – in a huge leap forward for the excess energy produced. And this from a device similar to that of the old experiments with Piantelli in Siena, but using nickel powder and, above all, with the addition of a "catalyst" made by Rossi, a secret and very important part of the machine which will be discussed in more detail in one of the next chapters.

There are many sources from which we can draw more explicit information on how the E-Cat is made, and these range from the first patent application made by Rossi in 2008 to the latest artwork for advertising issued

by Defkalion, a Greek company which should have produced in the Hellenic country machines developed from the E-Cat. Therefore, it is possible to have a pretty good idea of this object, although the individual construction details are obviously covered by industrial secret.

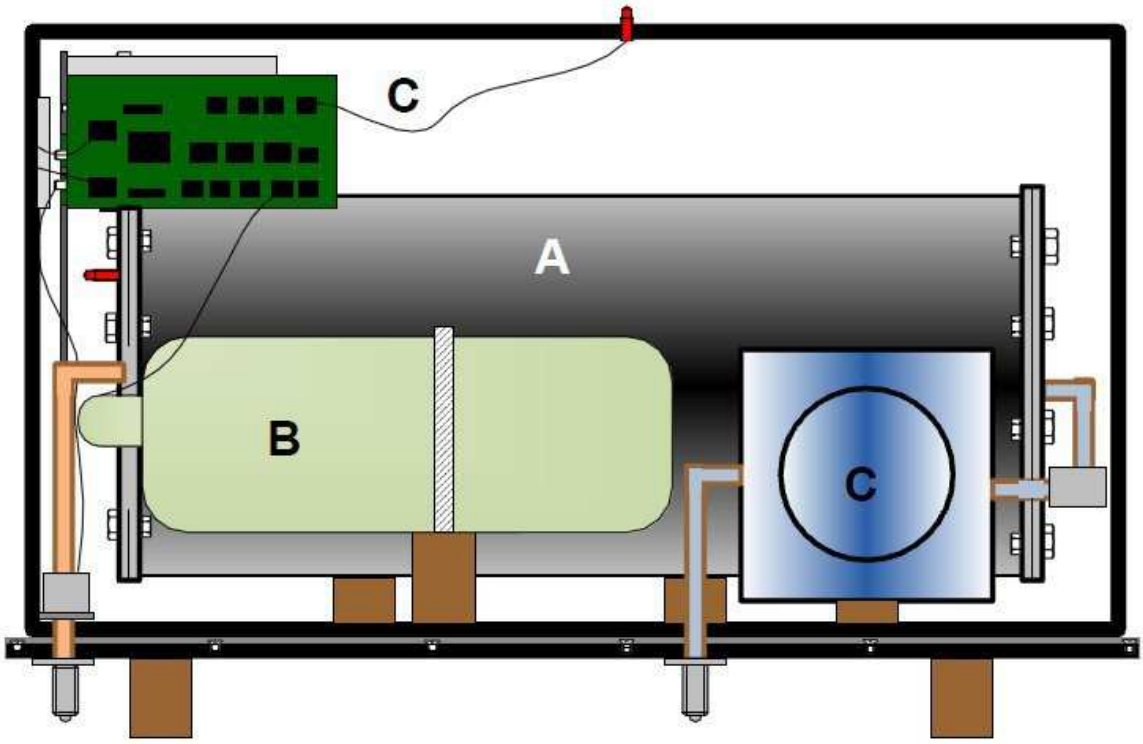
## The architecture of the commercial version

The brochure on the products *Hyperion* by Defkalion – equipment for the production of heat with a thermal output ranging from a few kW to MW thermal – is, in fact, a good starting point to understand in more detail the structure of an E- Cat. According to this document, the architecture of a few kW Hyperion includes three different parts (marked A, B and C):

A) It is the “real” E-Cat, in practice the "black box" containing the reactor, the catalyst with its components and appendages covered by industrial secret. The E-Cat, then, is the "heart" of the Hyperion.

B) It is a pressurized tank of hydrogen, used as a main switch of the module. A *module* is a unit that contains one or more E-Cat in parallel, thereby producing more energy.

C) It is the electronics that, through a "smart" autonomous and real-time connection with the operations center at Defkalion’s headquarters, monitors and ensures the smooth functioning and that there is no an unauthorized use of the product, and in particular of the reactor.




*The structure of a Hyperion. "A" is the core of the product, and basically consists in an Energy Catalyzer like the E-Cat, "B" is the hydrogen tank under pressure, while "C" is the electronic that monitors the operation of the reactor.*

The E-Cat, seen as the core of an Hyperion as just illustrated, is an object that is, in turn, made by the following components:

- A metal pipe "loaded" with a nickel catalyst. The reaction with hydrogen takes place inside the tube, producing a quantity of heat between 5 and 30 thermal kW.

- A thermal closed-circuit utilizing a fluid (typically glycol) to bring the heat from the reactor cooling module out of the tube. This circuit is

integrated with a pump for circulating the coolant, which is controlled by the C – that is, from the "smart" electronic – part of the machine.

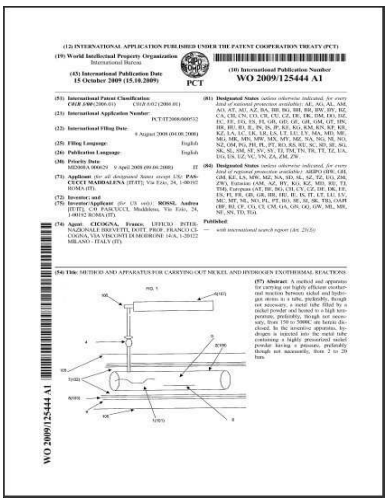
- A "box" watertight, which is thermally isolated from the external environment and shielded with lead.

- An electric heating element to heat the tube, which triggers the nuclear reaction by consuming less than 0.5 kW.

Therefore, Defkalion provides a fairly clear description of the E-Cat – albeit quite simplified and not so detailed – that, along with pictures of the prototype shown in public by Rossi, gives us a first idea.

## What are the internal components of the E-Cat

More detailed information on the apparatus named "E-Cat" can be found in the international patent application made to the *World Intellectual Property Organization* (WIPO) by Andrea Rossi and his wife, Maddalena Pascucci, on April 9, 2008 and published in 2009.


(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 October 2009 (15.10.2009)

(10) International Publication Number
WO 2009/125444 A1

PCT

(54) Title: METHOD AND APPARATUS FOR CARRYING OUT NICKEL AND HYDROGEN EXOTHERMAL REACTIONS

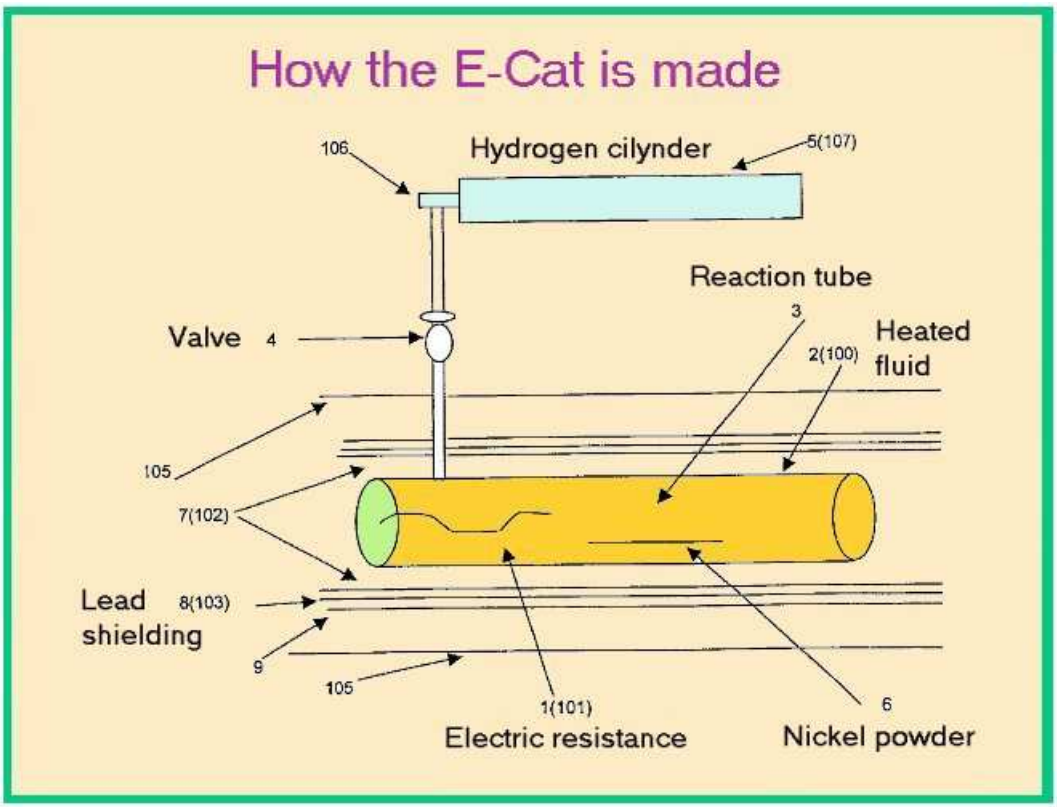
(57) Abstract: A method and apparatus for carrying out highly efficient exothermal reactions between nickel and hydrogen atoms in a tube, preferably, though not necessary, a metal tube filled by a powder of nickel and of a catalyst, preferably, though not necessary, from 150 to 5000C an heater disclosed. In the invention apparatus, hydrogen is injected into the metal tube containing a highly pressurized nickel powder having a pressure, preferably though not necessarily, from 2 to 20 bars.

WO 2009/125444 A1

*The patent application made by Rossi and his wife in 2008 for the "Energy catalyzer", containing an interesting description of the apparatus and of its operation.*

As clearly stated already in the summary of the cited document – which also contains a useful schematic drawing of the E-Cat which shows many constructive details of the invention – the machine is «an apparatus for achieving highly efficient exothermic reactions between atoms of nickel and hydrogen, preferably (but not necessarily) in a metal tube filled with nickel powder and heated to high temperature».

It then describes the various components of the system, starting with the metal tube (2), containing an electric heating element (1) and nickel powder (3). An electromechanical valve (4) - such as the so called "solenoid", that is controlled by an electric current through a solenoid – adjusts the pressure at which hydrogen (5) is introduced into the tube.




*The E-Cat description reported in the patent application by Rossi (we added some colors).*

The nickel powder is placed inside a copper tube (100), together with an electric heating element (101) whose operation is regulated by a thermostat (not shown in the picture), which detects when the machine is producing heat because nickel has been "activated" by the hydrogen gas contained inside a special container (107) – that is, the nuclear exothermic reaction is triggered – and will shut down this resistance.

Thus, both the temperature of the electrical resistance and the injection pressure of hydrogen in the reaction chamber can be easily maintained at constant values or, conversely, "pulsed" in time.

In the patent, which also contains many small errors in the theoretical parts, is done only a quick nod to the *secret catalyst* – or the '"additive", as usually Focardi calls it in his interviews since the public presentation of the E-Cat in January 2011 – a component, of course, fundamental.

The above mentioned catalyst is cited in two part of the patent, that we show here with italics: (1) page. 6, where it says: «In applicant exothermal reaction the hydrogen nuclei, due to a high absorbing capability of nickel, therefore are compressed about the atom nuclei, while said high temperature generates inter-nuclear percussions which are made stronger by the *catalytic action of optional elements*», (2) page. 17, in the "Claim 2", «A method that differs from that described in the claim 1 for the fact that *catalytic materials* are used», and the "Claim 6": «A device equal to the claim 5, characterized in that said nickel powder contains *catalytic materials*».

Of course, it is quite likely that Rossi has not provided details of the catalyst in the patent application to protect the secrecy of his invention, but in this way he has so far prevented the international patent could be issued, as a necessary condition is that the device is replicable by others, and it is obviously impossible if you do not say the key "detail".

## How the external part of the E-Cat is made

The whole system containing the electrical resistance and the copper tube with nickel inside, but also the container of hydrogen (107) and its connection system (106) with the pipe itself – as you can continue to read so clearly in the patent application by Rossi – is protected, and in turn appropriately shields the products created in the reaction tube (or camera), while preserving the environment, through two layers:

a) an inner lining (102) – e.g. steel – containing water and boron or boron only (presumably to absorb any neutrons produced by the machine, since these are two typical materials used for this);

b) an outer layer of lead (103) – it may be also covered with a layer of steel – with the function to absorb the gamma radiation produced by the exothermic reactions and transfer the heat to the medium, either for the civil or industrial appropriated uses.

In practice, the heat generated by the nuclear transformations and decay of particles can be transferred to a medium for the applications you want –

heating, electricity production, mechanics, etc. – directly through the layer of lead and aluminum, or perhaps better, at first heating a primary fluid (e.g. containing boron and water) contained in an outer steel tube (105), then the fluid exchanges heat (and so thermal energy) with a secondary circuit.


*The output of an E-Cat without its typical black outer layer of insulation.*

The apparatus just described was installed on October 16, 2007 in the shed of Rossi's EON, and working 24 hours on 24 provided for several months, during the winter, enough heat to heat the structure. This was later confirmed to me by Focardi – at that time he went in Bondeno by train almost every day as part of cooperation with Rossi – in his interview.

As already emphasized in the patent of 2008, the E-Cat can be used as a single unit "pipe" to provide thermal energy, but you can also put more E-Cat *in series* (e.g. making modules with multiple pipes) to increase the total thermal power of the device, or *in parallel*, so that we can raise the output temperature within certain limits: in practice, up to about 450° C (note that the melting point of nickel is well higher: 1453 °C).

## A reconstruction of the heart of the reactor

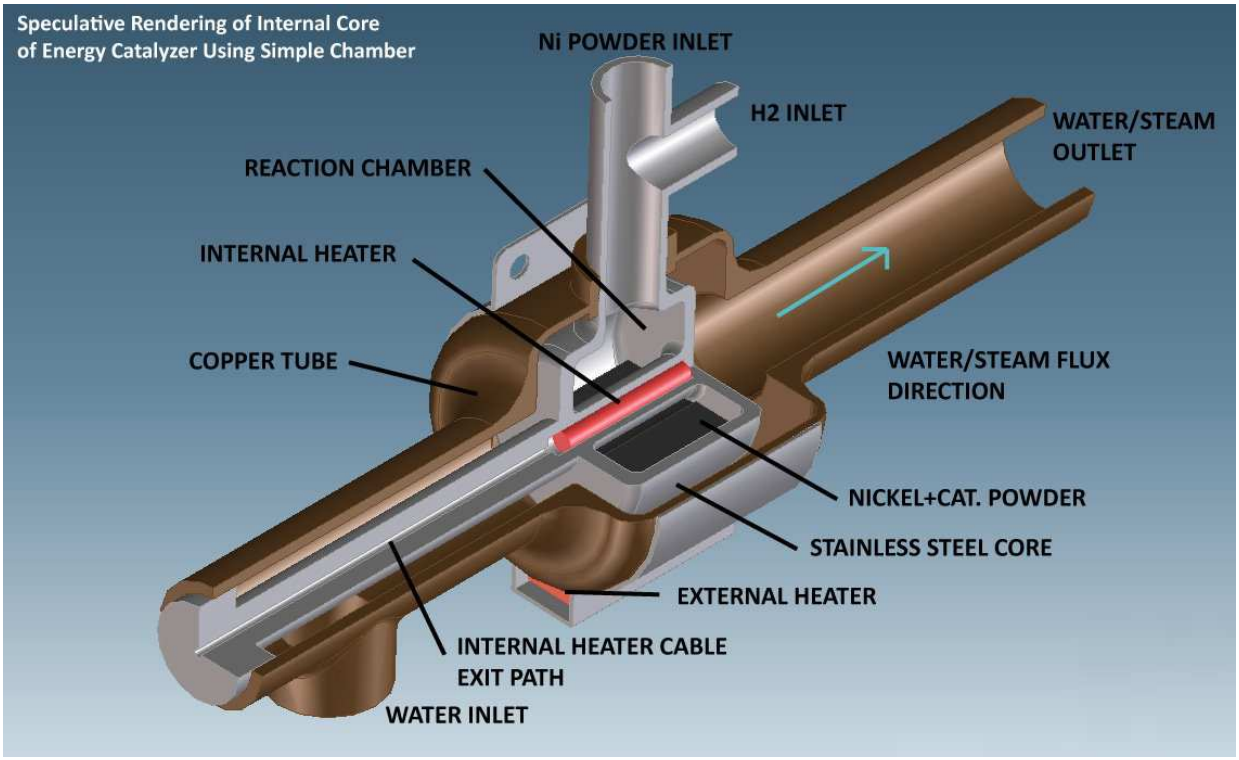
After the public presentation of the working prototype of an E-Cat by Rossi and Focardi, which took place in Bologna on January 2011, there have been many suggestions from experts or simply passionate about how the reaction chamber is made, i.e. on the secret "heart" of an E-Cat, which – as stated by the same Andrea Rossi – «does not exceed the size of a walnut».

Of course, there are no sketches or official pictures beyond those we have here shown and described, since the machine is protected by industrial secret, and even when the E-Cat will go on sale there will be no less than 12 levels of security and countermeasures designed to protect the intellectual property, so you cannot think to take it apart and analyze its components, because – in doing so – this action automatically triggers a mechanism of self-destruction, although not dangerous for people.

On the other hand, all the information filtered until now confirm that the description of an E-Cat made in the previous paragraphs is correct, while

still little is known on the *secret catalyst*, i.e. to what permitted to make the "big leap" over the older Focardi-Piantelli's equipment.

The best graphic reconstruction of the "core" inside an E-Cat, made on the basis of information available is, in my opinion, a three-dimensional drawing by Giacomo Guidi, an experienced R&D engineer in nuclear medicine working at the company *Phizero*, and author of the already mentioned excellent documentary on the LENR and E-Cat.

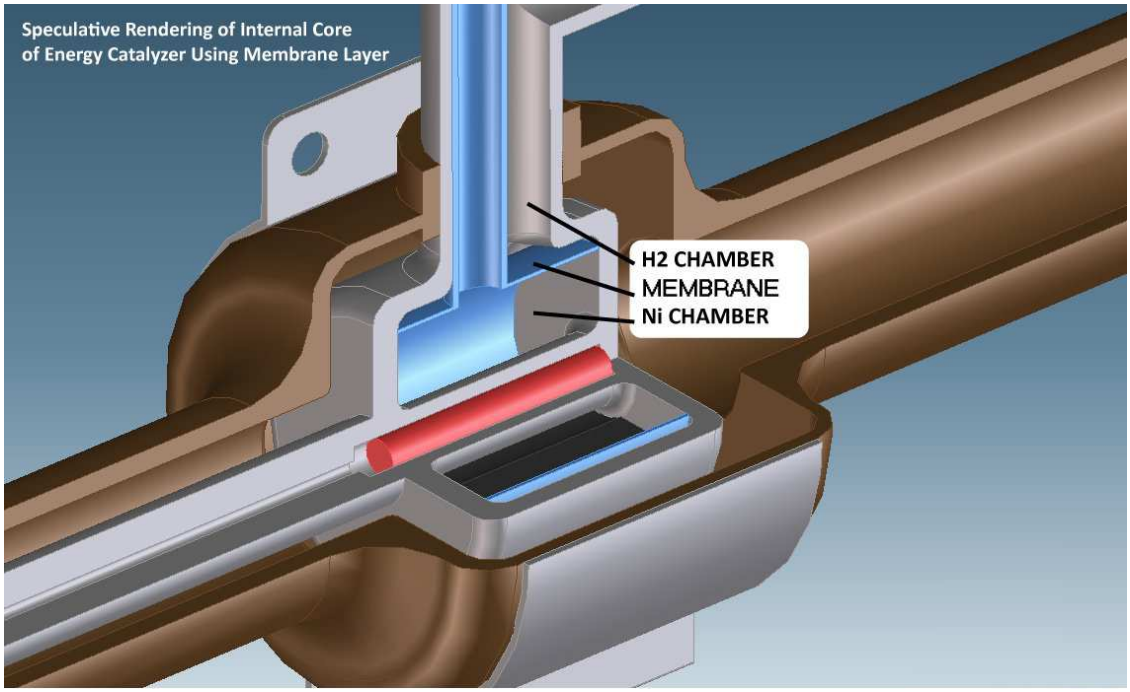



*The "heart" of an E-Cat in a 3-D reconstruction proposed by Giacomo Guidi.*

As you can see from Guidi's drawing, there is an internal reaction chamber, which in its reconstruction shown here – based on a statement made by Rossi himself – is made of stainless steel, while in the patent the

same chamber appears to be made of copper, even replaceable with another metal. It has two thermometers, one internal and one external that surrounds the reaction chamber throughout its length according to a cylindrical geometry (in the public test made on January 2011, one of the two resistors did not work but the machine could start thanks to the second). The rest of the sketch is consistent with what we previously described.

Guidi has also suggested, in another 3-D artwork, that the catalyst may be simply a "physical object", instead of an additional chemical and/or a pre-treatment of the reagents, etc.




*A clear sketch in which the catalyst is a membrane. (3-D drawing by Giacomo Guidi).*

Guidi deduces this – i.e. that the catalyst can be some solid substrate – by the fact that, as we shall see better in Chapter 6, in the spring 2011 Rossi

has made available to two Swedish "skeptics" physicists some exhausted material coming from experiments performed with the E-Cat: therefore, if the catalyst was a substance mixed with nickel or hydrogen, it would have been very difficult to extract so that people cannot find it.

However, to make hypothesis on what could be the secret catalyst is a very important issue if you want to understand the E-Cat, and therefore it constitutes the main theme of a later chapter.

# Chapter 4 – Discovering the setup

When I made the long interview to Sergio Focardi on the research that led him and Andrea Rossi to invent the E-Cat, I had a dual purpose: to create an original and interesting document for the specific commissioned event (the popular conference held in Viareggio on July 23, 2011 on the cold fusion), and to achieve a better understanding of which the experimental setup behind the operation of the machine is.

In fact, as a physicist I was deeply interested in *understanding* the details, and I put in the shoes of other researchers who had wanted to try to replicate such an apparatus, or at least to begin experimental studies in this direction. I assumed that Focardi wouldn't tell the secret part on the catalyst, so I wanted to know better the other "boundary" conditions (temperature, pressure, etc..): then, I tried to have by him as more as possible elements about the most important aspects regarding the rest of his experimental apparatus, since they were not covered by industrial secret.

My reasoning was, basically, very simple: as we have a machine that has a "public" and a small secret part – albeit crucial – if I want to replicate it, I have to know and understand the public part, in this case virtually I have already done, let say, "half of the work", in the sense that I have clearly reduced significantly the number of free parameters of the problem, leaving to explore mainly those relating to the secret catalyst.

*The long list of questions prepared to understand more on the setup of an E-Cat.*

Therefore, some of my questions in the interview to Focardi – which, in reality, only for a small part was later published online on YouTube – was aimed at understanding, on the one hand, the various crucial conditions to

permit the operation of the experimental prototype of the E-Cat and, on the other hand, any difference compared to the setup of the old experiments performed earlier by Focardi and Francesco Piantelli in Siena, and from which the research with Rossi was started in 2007.

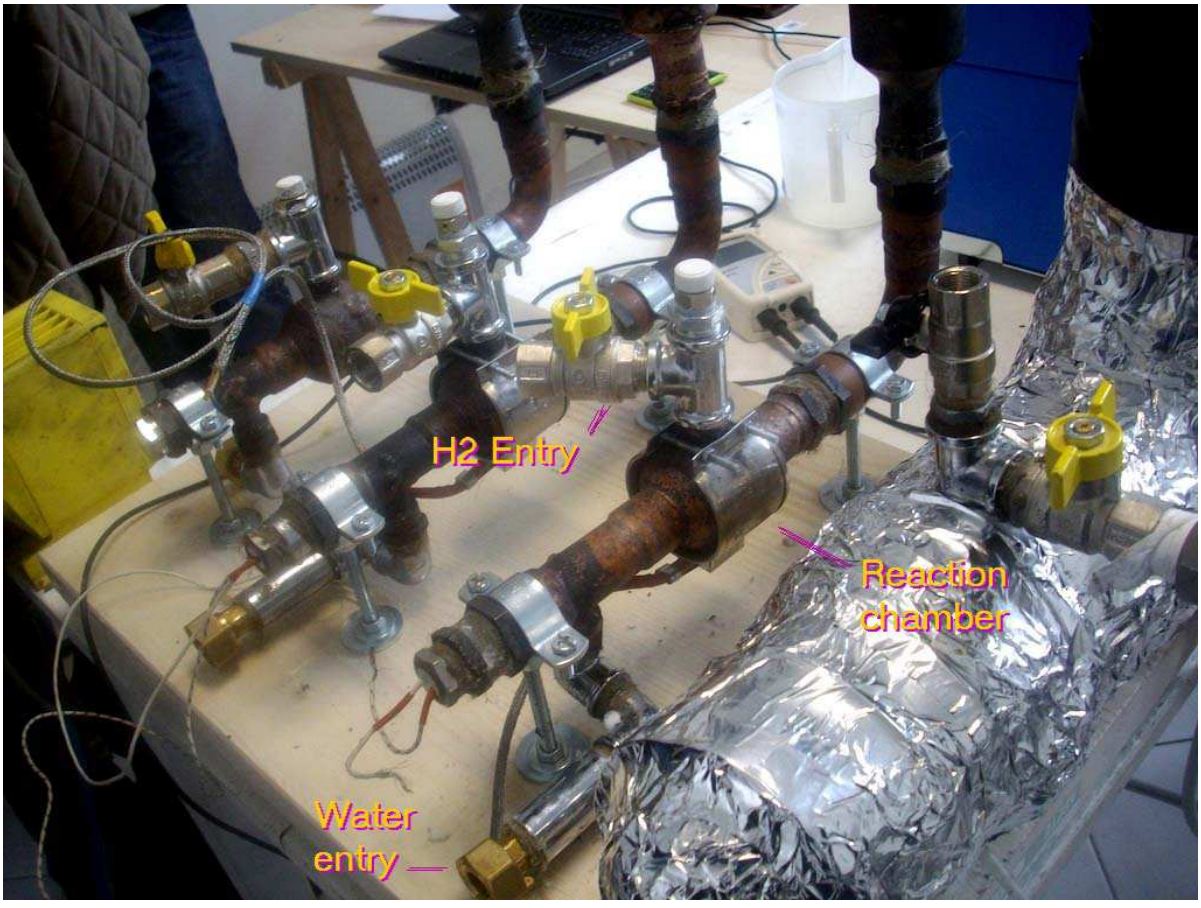
Obviously, the information on experimental setup gathered in the interview had to be crossed with all the others at my disposal, so as to better focus the individual issues and to have a control (and possibly a redundancy) of data. And this is also the aim of this chapter.

## The source of hydrogen and its pressure

If you want to do an experiment involving nickel powder and hydrogen gas, you have to worry – just to begin to reduce the "free parameters" of the problem – about the gas: which source to use for hydrogen? And at what pressure should it be injected into the reaction chamber?

I then turned these questions directly to Focardi, also trying to figure out any differences with previous experiments made in Siena with Piantelli, receiving a very interesting answer and, in part, unexpected: «The pressures of today and those of the experiments we realized in Siena are more or less of the same order of magnitude: in practice, although I do not remember the exact values because we have made several experiments, they are in the order of 1-2 atmospheres, or something like that».

So, rather low pressures (in fact, 1 atmosphere is the typical air pressure at sea level) and easily accessible without the use of an expensive or complex equipment. To confirm this, I asked him if he and Rossi had tried to use, as a source of hydrogen, electrolyzers instead of the gas cylinders used in the first public presentation of the E-Cat, getting this answer: «Yes, hydrogen was also produced by electrolysis directly into the device and we used it without having to compress. If you want to stop the machine, you just turn off the power of the electrolysis, so you can easily control the process».




*The E-Cats seen "naked", with the entry for hydrogen. (Photo by D. Passerini)*

Rossi, however, has just recently wrote on his blog, the *Journal of Nuclear Physics*[2], that, despite having previously used electrolysis to produce hydrogen, now prefer to use pressurized hydrogen – i.e. gas cylinders – for various reasons that has refused to specify.

It is interesting to compare the information on the hydrogen pressure provided by Focardi with those contained in the patent application made by Rossi in 2008, which says on the front page: «The hydrogen is injected into the metal tube containing a highly pressurized nickel powder at a pressure, preferably but not necessarily, between 2 and 20 bars». Note that the bar is a unit of measure whose value is about one atmosphere (1 = 0.987 atm), 2 bar is the pressure to which the tires of cars are inflated, while 10 bar is the typical power of common compressors on the market today.

It should also be emphasized, since it seems relevant and not derived from other sources, an information contained on page 12 of the Rossi's patent: «The unit mentioned has shown that for proper operation, the release of hydrogen must be done under a variable pressure». It is not clear what is exactly meant by "variable pressure", but a clue comes from the fact that on page 17 the same document says, in the "Claim 7": «A device identical to that of Claim 6, but characterized in that said hydrogen is injected into said tube under a non-constant pulsating pressure».

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[2] Accessible at the following address http://www.journal-of-nuclear-physics.com. This is an electronic journal – founded by Andrea Rossi and having a *peer review* made by experts – which contains several interesting articles and contributions on the *Energy catalyzer* and its nuclear reactions.

So, the "variable pressure" seems to be interpreted as a pressure pulse, which seems entirely reasonable, since it is one of many possible methods of excitation used in modern cold fusion experiments. It must be said, however, that Focardi never talks about it in his interviews, although he has never received an explicit question about that. One thing is certain, however, because Rossi says in another interview: «By modulating the parameters related to the injection of hydrogen, we regulate the power of an E-Cat».

## The ignition temperature of the nuclear reaction

Another important aspect to consider, for those who want to try to replicate the reactor of Rossi-Focardi, is the temperature that must be provided to the reagents to start the nuclear reactions.

Responding to a my question, Focardi says what is the value of the temperature at which the E-Cat begins to produce excess energy: «We found that the reaction is triggered early, without having to go much up with temperature: it starts at 60 or 70 °C. We tried to change the threshold triggering the phenomenon: indeed, once we have a mixture of nickel and hydrogen, the working temperature can be fixed from the outside with a thermostat, and heating the mixture we can see at what temperature the reaction begins. However, exploring the change in the value of the ignition threshold has not provided us important information about the physical process: only the "recipes" for using the machine».


*The growing temperature of the steam produced from water heated by the E-Cat in the public demonstration of January 14, 2011. (from the report by Giuseppe Levi).*

Then, I asked Focardi which differences he noted, in the ignition temperature, compared to his previous experimental apparatus developed with Piantelli, and he told me: «There was an improvement over the old experiments of Siena, in which the threshold temperature was of the order of 600 °C. In the first article we wrote, there was this value of 600 °C, because we did not want to contradict with our very recent past, but in reality it is enough just a temperature much lower: at 60-70 °C the reaction is triggered, then it goes alone without any problems».

In fact, the temperature values that are reported in the patent application made in 2008 are much higher than the 60-70 °C which would trigger the reaction with the catalyst of Rossi. This document, indeed, speaks of a «metal tube filled with nickel powder and heated to a temperature between 150 and 500 °C». If we give credit to the words of Focardi in my interview, we must assume that the temperatures mentioned in the patent are a legal caution or an elegant way to be as vague as possible.

As regards, instead, the wait time required for the beginning of the reaction, Focardi explains that «the process starts by itself after 20-30 minutes, once it reaches the threshold temperature». Andrea Rossi definitely confirms this fact in an interview with *ECatReport* blog: «The start time of the E-Cat is about 20-30 minutes, and that is the period between when you press the button and when the reactor produces 5 kW. The stopping time, however, is about 20 minutes».

In the patent, finally, we read that «the thermostat to control the temperature of the electric heater is designed to power down after 3-4 hours of operation, when the machine generates with no doubt – and continuously – more thermal energy than that provided by the resistance, self-sustaining the reaction». However, it seems that the E-Cat, in its commercial version, will continue to use the electrical resistance, because in this way you have a much better control of the reaction.


*In the foreground, the external resistance enveloping the reaction chamber of an E-Cat.*

Note that the reactions encountered in the E-Cat are not only triggered by the temperature when it exceeds a certain threshold level, but – as explained by Rossi – they "control themselves" also reducing the reaction rate as the temperature increases: an effect, this, very interesting observed several times in the experiments on *Energy Catalyzer.*[3] It seems, then, that the electrical power to be supplied initially to the two resistors is around 1,000 W, which drops to about 80 W when the reaction starts.

[3] The commercial version of the E-Cat has a very sophisticated control system, which automatically turns off the machine – turning off the heating elements and reducing the hydrogen pressure – when you reach dangerous levels of temperature or pressure, i.e. thresholds set at the factory, but that can be modified within certain limits depending on the needs of the customer. In any case, if the nickel reaches the melting temperature, the reactions will stop by themselves, so the system is intrinsically safe.

## Nickel powder: the quantity and the ideal size

Nickel, being an abundant element on Earth, can be easily purchased in powder form and at a low price: just go online and do some research on possible suppliers, or go directly to the Italian company which has provided it to Rossi, that will be indicated at the end of this chapter.

We don't need so much nickel: Rossi says that, to operate continuously for 6 months, its prototype at the power of 10 kW has used (i.e. he has put into the reaction chamber) only 100 grams of nickel, though obviously it's quite convenient to buy more than a few hundred of grams, in order to do various experiments without using the same dust.

As regards nickel *consumption*, Rossi explains that, after 6 months of operation with an E-Cat in the experiment just mentioned, «about 30% of nickel has been transformed into copper» (also the amount of hydrogen consumed in that occasion was very small). It is interesting to note that, as we will show by simple calculations in Chapter 8, with 1 gram of hydrogen an E-Cat running at a power of 5 kW can be operated for at least 5 days. So, with 30 grams you can make it work for at least 150 days, which correspond to exactly 5 months. Therefore, what Rossi said is perfectly in accord with what I expected on the basis of my estimates.

As we saw earlier, it is the same Focardi to tell that the use of nickel in the form of powder is, with the catalyst, one of two main changes made by Rossi compared to the old experiments with Piantelli in Siena, which are otherwise substantially similar. The advantage of the powder compared to a

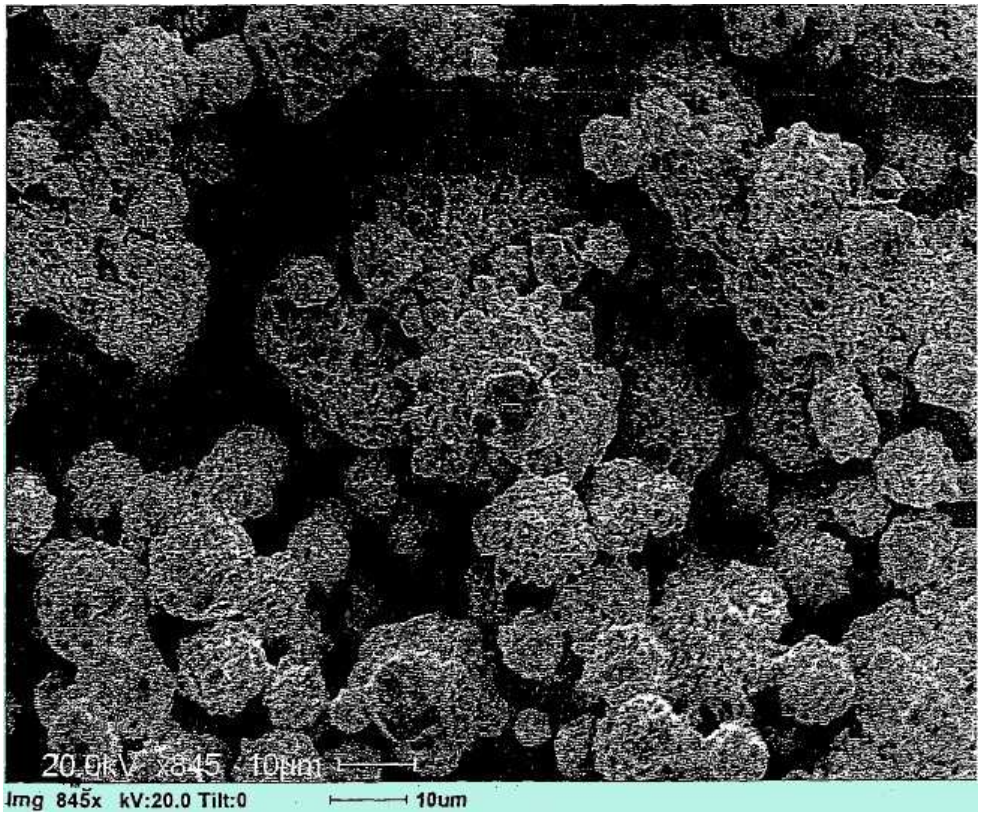
wire, a cylinder or other solid surface, is that it amplifies and maximizes the "cross section" of the nuclear reactions in a nickel-hydrogen system, i.e. in practice it increases the likelihood that, for example, reactions between the protons and the nuclei of nickel occur.


*A common package of nickel powder available on the web.*

Not surprisingly, the greek chemist-physicist researcher Christos Stremmenos, who in the Nineties teached at the University of Bologna (where he remained until his retirement) made research on cold fusion reactions independently from Focardi's work in Siena, was among the first persons to have the idea of using the *powder* metal.

But, if we do a search on the web, we find that the nickel powder may have granules with an average size of various types: what is the average size of nickel powder used by Rossi and Focardi?

To answer this question, it is very valuable to read, once again, the patent application, showing a photo of the nickel powder coming from the experiments of Rossi-Focardi, as seen through a powerful electron microscope of the Department of Physics (University of Bologna), at a magnification of 845 X. The image we are referring to was taken on January 30, 2008, under the supervision of Focardi.




*An electron microscope image at 845 X of nickel powder used in the early experiments of Rossi-Focardi. (from the Rossi's patent application).*

This picture allows us to see the small grains of nickel to form aggregates of "flakes", which facilitate the absorption of hydrogen atoms from the nuclei of the metal; but, more importantly, shows the scale of reference, and thanks to the latter, we see that the average size of the granules does not exceed 10 microns. Keep in mind that the photo shows the nickel not first but after the reaction, when it is exhausted and the starting particles may have aggregated into larger flakes eventually only for the process of metal "loading" with hydrogen under pressure.

## The isotopic composition and metal treatment

At this point, you might think that everything is clear enough, with respect to the nickel. But it is not so, because a chemical element, in nature, is a mixture of different *isotopes*, i.e. atoms of the same element but differing in the number of neutrons in the nucleus. And we have not considered what is the *isotopic composition* to be used: if the natural for nickel or, instead, a different mixture, with one or more of its isotopes "chosen at the table" and assembled together in a laboratory.

The issue is far from negligible, for the Energy catalyzer. In fact, Rossi says about this subject, in a response to a reader on his blog: «We buy a regular nickel powder, whose isotopic composition is well known: $^{58}$Ni (67,88%), $^{60}$Ni (26,23%), $^{61}$Ni (1,19%), $^{62}$Ni (3,66%), $^{64}$Ni (1,08%). After that, we do a treatment that changes the isotopic composition».

The reason for this change is soon told. On several occasions, Rossi explained that the most abundant isotope of nickel, $^{58}$Ni (68%), according to him, did not "work" in producing heat – although he is not entirely sure – and he said that the rates of reaction of $^{62}$Ni and of $^{64}$Ni are much higher (indeed, in the analysis made by the Swedish physicists of post-reaction powders provided by Rossi, as we shall see, two peaks were found for copper right at the isotopes $^{63}$Cu and $^{65}$Cu, which are formed respectively by $^{62}$Ni and $^{64}$Ni). This makes these two isotopes the major contributors to the process of heat production by the E-Cat, despite their abundance in natural nickel being, respectively, of 3.6% and 0.9%.

*A sample of native nickel, which has the natural isotopic composition.*

Therefore, it is likely that the nickel powder "treated" (according to Rossi's words) consist mainly – though not exclusively – of the two isotopes $^{62}$Ni and $^{64}$Ni (which can also be purchased separately and then combined). And, in response to a reader who asked him who will provide nickel to recharge the commercial version of the E-Cat, Rossi replied: «We provide it, because it must be treated in a proprietary manner». He adds that a cartridge of treated nickel (probable price around 30 €) allows uninterrupted operation of the E-Cat for 6 months, then it must be replaced and the contents of the cartridge can be recycled and reused as fuel up to 90%.

We are not aware if nickel is subjected to other types of "treatment" before being used in the reaction, but it is not possible to exclude it at all. Moreover, it is certainly not the first time that nickel powder is used in Ni-H experiments, and usually a treatment to facilitate the "loading" of hydrogen in the crystalline matrix of metal and/or the subsequent nuclear reaction is needed in order to get some results.

For example, the previously mentioned chemist Stremmenos, at the time of Focardi's research in Siena, developed a technique for loading the gas in the nickel quite effectively, in an experiment that allowed him to pick up very rapidly the temperature of the Ni-H cell: from the initial 500 °C up to 1,000 °C and beyond, so that – as told by him in an interesting interview – it scared a lot and stopped everything. The trick used to achieve this was to purify the nickel powder holding it at low pressure ($10^{-6}$ bar, but much less is probably sufficient), and at a temperature of 500 °C for as long as a week, so that all the oxides on the surface of the metal were removed.


*The chemist-physicist Christos Stremmenos and (right) a machine for creating vacuum.*

## A simple list of what you need

For those who want really to try, at this point, to set up an experiment similar to the Rossi-Focardi, the patent of 2008 provides a list of what they used in the prototype of their invention, and of the suppliers of materials.

Here follows the list of such parts or equipment:

- ✓ Electric resistance: Frei, Brescia
- ✓ Thermoadjuster: Pic 16- cod- 1705, Frei
- ✓ Lead shields: Picchi Srl, Brugherio (Milan)
- ✓ Hydrogen: Linde Gas Italia, Arluno (Milan)
- ✓ Pressure reducer: Linde Gas Italia

✓Nickel powder: Gerli Metalli, Milan

✓Boron: Danilo Dell'Amore Srl, Bologna

✓Copper tube: Italchimici, Antezzate (Brescia)

✓Laser beam temperature measuring device: Raytheon, USA

✓Pressure gauge: Department of Physics, Univ. of Bologna

✓Neutron measuring device: Department of Physics, Univ. of Bologna

✓Chemical-physical analyses: Department of Physics, Univ. of Bologna

For the sake of curiosity, I asked Focardi if he had an idea of the cost of their prototype, and here is his answer: «No, I never thought about it, because in the machine there is also the cost of the invention. The material part has been cured by Rossi, so he can get an estimate. He has purchased or has built the things with his company. But it cannot cost much».

In fact, if we look with some care the list just presented, we find that the vast majority of the used components have a relatively low cost, and therefore are affordable for an amateur loving scientific hobbies.

# Chapter 5 – The secret catalyst

The "secret catalyst" making so interesting the reactor of Rossi-Focardi is, certainly, one of the most interesting topics with which I have had to deal with in my numerous science books.

In fact, we are primarily talking about a potentially revolutionary invention, which in a few years could change the world energy scene, on the one hand dramatically lowering energy costs and, secondly, by facilitating the transition from our current system of centralized electricity production in a popular and widespread system, where private industries and cities can all be partially or totally independent.

Therefore, it is a type of invention rather full of promise for mankind but, at the same time, "uncomfortable" for the traditional and powerful energy *lobbies*, for the politicians that cannott gain on it, etc. Not to mention the fact that every powerful technology can have useful civilian applications but also uses less edifying, like in the military field.

In addition, to make fascinating for me the theme of the catalyst – as a physicist curious and open to "disruptive" new things – is the purely scientific aspect, with the various technical questions unanswered, some of which merge with the "mystery" that, for obvious reasons related to the enormous interests at stake, surrounds the story.


*The reaction chamber of an E-Cat, containing inside the secret catalyst.*

The secret of the catalyst, in short, most likely – as almost always happens in such cases – involves persons, places, episodes, events that go beyond what most people imagine, although it is not hard to understand given the “money on the table”. In this chapter I will discuss only what is

already of public domain, trying to put together some of the many "pieces of the puzzle" to see what emerges, leaving out information obtained from "hearsay" or undisclosed for reasons of opportunity.

## The importance of an “additive” in the E-Cat of Rossi-Focardi

During the interview for the conference organized in Viareggio, Focardi tells me very clearly that the difference between an E-Cat and the apparatus he used in previous experiments with Piantelli is that «in the new experiments nickel particles are much smaller in size, so the input surface for hydrogen in metal is much larger; moreover, among the ingredients of the reaction there is an "additive" whose formula is kept secret by Rossi, and that is important for the process to occur. So there are two main differences, and the second is probably more important than the first; however, also increasing the surface area represents a significant advance».

In the old experiments of Siena, as Focardi tells me, the energy gain achieved was very modest: «We had some small results, but sure: doubling the energy. That is, we started with a certain power, the system worked well for months and doubled the energy output, which was in the form of heat. This result did not help, in the sense that it had no a possible commercial application, because if one took this thermal energy and converted it into electricity, he went back to the starting point, even if there was at least a factor 2 of gain from the electric input to the thermal output».

The catalyst of Rossi, however, completely revolutionizes the things, as the Focardi clarifies: «He had the idea of using an additive whose composition is unknown – it will be revealed when the patents will be approved – which, in fact, allows an high degree of efficiency. Without this additive, in my opinion there is no efficiency. I refer to our previous experience: we did not have the additive, and therefore could not get the gain factor that we observe now. I have no proof of what I say, I rely only on experimental facts: without the additive, we could earn only a factor of 2, with the additive much more, therefore it has an essential role».


*Focardi while speaks of the secret catalyst during our long interview in Bologna, Italy.*

As we saw in the previous chapter, in the patent application of 2008, Rossi talks about – albeit "en passant" – the catalyst in the following terms:

"catalytic action of the optional elements", and "catalytic material". Thus, the catalyst could mean a physical object or an added substance. The above-mentioned self-published scientific paper by Rossi (probably written by Focardi) seems officially narrow the field as, in reference to the catalyst, we read on page. 3: «The system on which we work consists of nickel in hydrogen atmosphere and in the presence of additives placed in an airtight container and heated by a current passing through a resistance».

This is indirectly confirmed by Rossi, who on March 18, 2011, to the question of "how many mixes/versions of the catalytic materials have been tested before the current one", made to him on a chat organized by the Swedish magazine *NyTeknik*, replies: «Tens of thousands of combinations». This answer surprised me very much, because it is a very large number, that in my opinion can be explained only by the fact that we speak of multiple chemical substances, and by the possibility that some their parameters have been varied (including, surely, the size), rather than try many different chemical elements, which on Earth are only a few dozen.

On the other hand, in the comments on his blog, Rossi wrote in recent months that the catalyst is not a precious metal, is not radioactive, is common and inexpensive, while more recently, to a reader who asked if it was copper, he said “no”. So, while usually not citing specific substances, Rossi has virtually excluded all the chemical elements leading candidates for the role of catalyst, which is very strange, making it hard to believe.

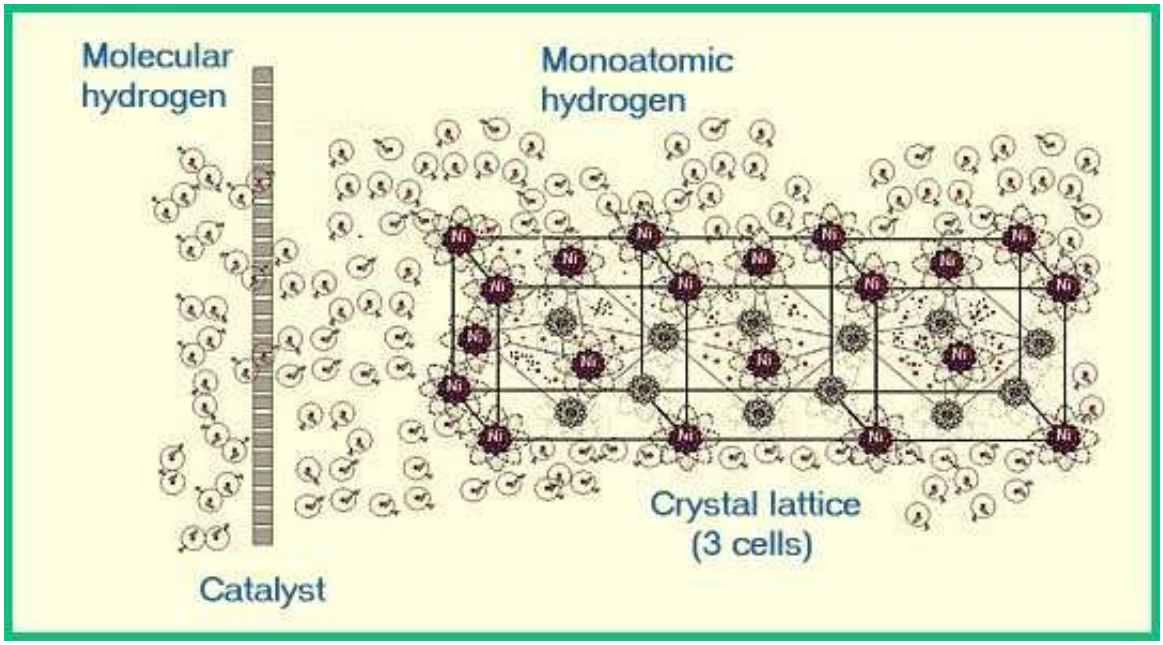
## What is the function of the catalyst in a reaction?

One of the main questions regarding the catalyst of the E-Cat invented by Rossi-Focardi, once clarified its importance in enabling this machine its remarkable production of excess energy, is what is its function, because this could be useful to understand what it might be.

In this sense, it may be partially illuminating an interview given by Focardi, in April 2011, to a small local radio station, during which the scientist said, with reference to the secret catalyst: «I I do not know what constitutes the additive of Rossi, I did not ask him. But I have a my idea: I think that it is intended to facilitate the reaction favoring the formation of monatomic hydrogen with respect to its molecular form».[4]

This, in effect, is quite plausible, because, as it is well known to anyone involved in cold fusion, the reaction between hydrogen and nickel powder occurs between nuclei that make up the crystalline matrix of the metal and the protons, i.e. individual hydrogen nuclei, whereas normally the hydrogen gas is in a molecular form ($H_2$), that is diatomic. So, if you find a way to turn at least partially from diatomic to monatomic hydrogen, it goes in the direction of favoring the final reaction.

[4] According to Lino Daddi (a nuclear physicist and former professor at the University of Pisa), in the experiments of Siena made by Focardi and Piantelli – which used only nickel and hydrogen, without the addition or use of any catalyst – it may have been nickel itself to disassociate, at least in part, the molecular hydrogen. However, in those experiments the excess heat produced was much lower.




*One of the possible functions of the catalyst: to split the diatomic hydrogen.*

Obviously, it is possible that the catalyst of Rossi has also other functions. After all, I am convinced that Focardi really do not know what constitutes the famous "additive" and, on the other hand, from over twenty years of research on cold fusion is now known that the *necessary* conditions for triggering a low energy nuclear reaction are: (1) the achievement, through the so-called *loading*, of a minimum density or "threshold" of the reagent – in this case, hydrogen – within the crystalline matrix of the metal, and (2) the excitation of the system with one or more possible techniques to bring it in a state of forced non-equilibrium.

In particular, the catalyst could help to solve the fundamental problem of cold fusion: the fact that protons – that is, the monatomic hydrogen – are unable to fuse with the nuclei of nickel due to mutual electrostatic repulsion. The normal protons have low energies, in the order of electron volts (eV),

totally insufficient to overcome this repulsion even if we heat the hydrogen to hundreds of degrees. Since the probability of a nickel-hydrogen nuclear fusion depends on the energy of protons, for making it significant the energy should be about 7-15 MeV, i.e. in the order of millions of electron volts.

As a physicist, then, the first system that comes in mind to go in the direction of increasing the energy of the protons, is to add to the nickel (or put around) one or more *radioactive* elements.


*A small sample of radioactive material stored in its protective container.*

In fact, each radioactive decay of atoms releases an energy of millions of electron volts (while the atoms in a chemical reaction don't release more

than a dozen of eV). Focardi himself, moreover, told me in the interview that with Rossi they have experienced not only the nickel-hydrogen reactions, but also reactions with elements of the periodic table for which he did not possess the authorization by the Department of Physics, therefore it is not difficult to imagine what types of elements may be.

Then, the mysterious catalyst could have a dual function: to separate the atomic and molecular hydrogen and so strongly boost the number of mergers between the nuclei. In practice, it could favor the "loading" and/or subsequent reactions by facilitating the formation of monatomic hydrogen and/or excitation of the system, or in some other way that we can now only speculate, but probably related to the *composition* or the *physical properties* of this additive (including, potentially, the size, geometry, etc.), or to *advanced treatments* that have been made, or, finally, of course for an appropriate mix of all these factors.

## The possibility that it may *not* be an added compound

As we noted two chapters ago, it is quite illogical to think that Rossi has added an "additive" to nickel powder, because he has later supplied to some Swedish scientists the exhausted post-reaction powders" for being completely analyzed. And so, this would not have been possible if the catalyst was composed of some chemical elements mixed with nickel.

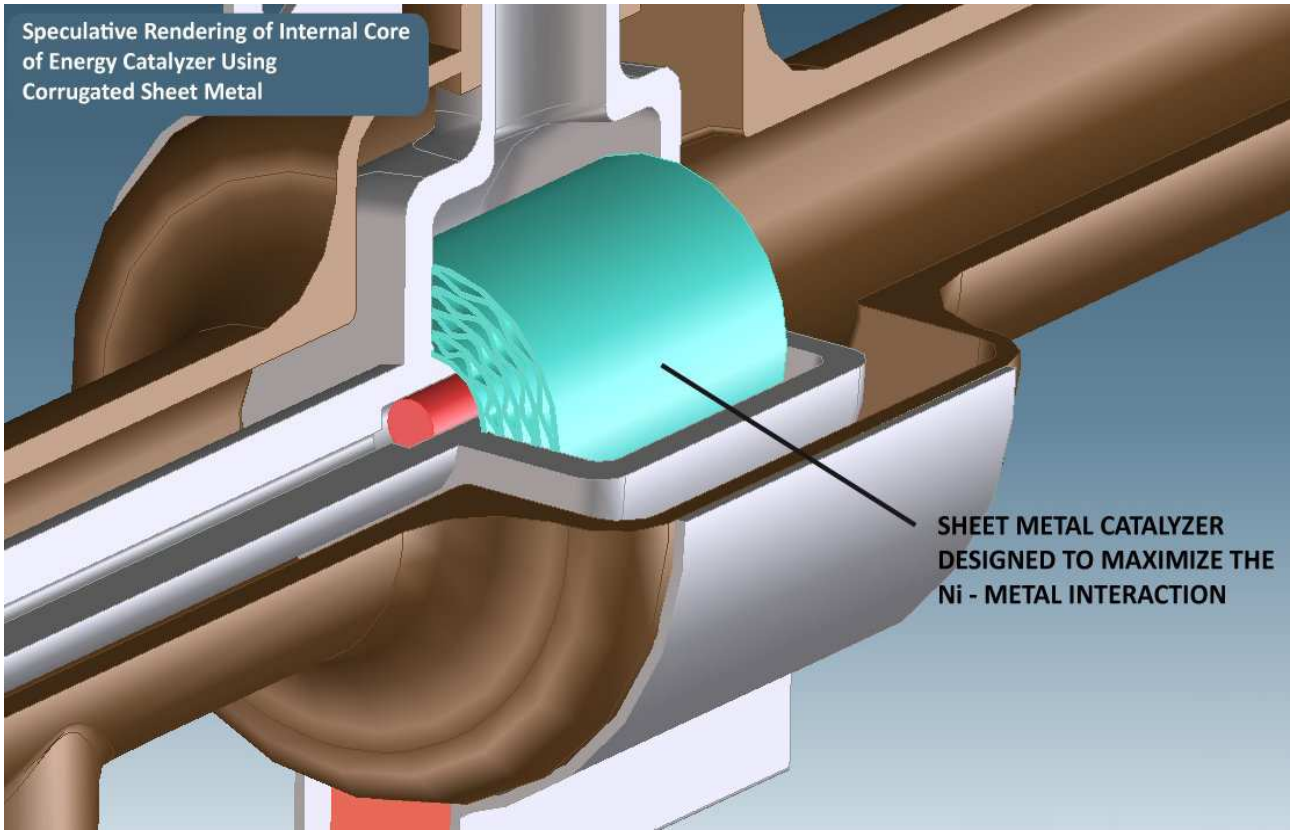
This reasoning, not easy to "dismantle", leads to the idea that: (a) the catalyst is *a physical object* – a bit like the metal catalyst for cars, which uses a substrate with honeycomb texture, made from different metals than those needed in our case – or that (b) the catalyst is the *nickel itself*, thanks to an appropriate preliminary "treatment" of such a metal.

If the purpose of the catalyst in an E-Cat is really to facilitate the transition from molecular hydrogen ($H_2$) to monatomic (i.e. $H^+$ ion or proton), you need a material capable of fostering the splitting of the hydrogen molecule. Among the possible candidates – as already suggested by the engineer Giacomo Guidi in the blog “22 passi” edited by Passerini – there are *palladium* or *platinum*, two expensive elements used in "fuel cells" to dissociate the $H_2$ molecules, and to allow the protons obtained to penetrate inside the PEM (*Proton Exchange Membrane*), an organic polymer membrane, whose purpose is to conduct protons while remaining impervious to gases such as hydrogen (!) or oxygen.

In this hypothesis, platinum or palladium – or their alloys – could be not in the form of grains, but of a substrate that separates hydrogen from nickel. The substrate might be, e.g., a simple flat membrane which divides in two parts the reaction chamber, or perhaps a substrate with a more complex geometry, to maximize the contact surface with the nickel. Guidi has imagined in a 3-D reconstruction a possible example.

The idea that Rossi might have used such material is made even more reasonable and probable from the fact that he previously, during his career

(e.g., with *Leonardo Technologies Inc.,* a company he founded, providing technologies and systems to the U.S. Department of Defense, DOD, and to the Department of energy, DOE), widely met these technologies and materials related to fuel cells. On the other hand, Rossi, who has to his credit several important patents, has always tried to develop innovative technologies in the energy field– e.g. a process that enabled him to obtain oil from waste – sometimes so uncomfortable for the lobbies to pay the consequences (it is very instructive to read his biography at www.ingandrearossi.com).




*A possible version of the catalyst in the reaction chamber, in case it is a solid substrate. (3D drawing realized by Giacomo Guidi)*

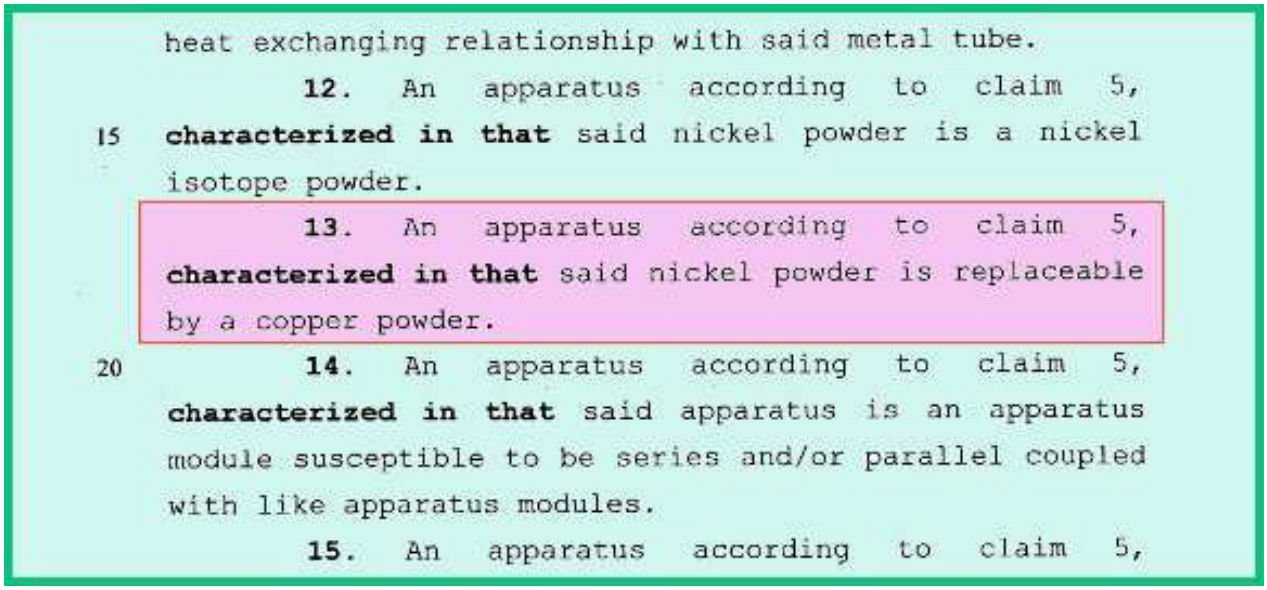
As Guidi notes, an alternative to platinum/palladium could be iron, since, as published on April 3, 2009 in the journal *Science*, a group of Canadian researchers led by Jean-Pol Dodelet has found a way to realize a catalyst based on this transition element. Used in fuel cells, in the laboratory tests the catalyst based on iron was found to provide performance similar to platinum. The use of iron would explain also its presence – otherwise difficult to justify – in the exhausted powders analyzed by the Swedes.

As regards, finally, the possibility that the catalyst is nickel itself – as it happens, e.g., in the reactor of Piantelli in Siena – it could be justified, probably, by the fact that in this kind of experiments to find the best size of powder grains is crucial. Therefore, at a certain *range of sizes*, the metal could play a catalytic action. This could be improved through appropriate (but unknown to us) preventive treatments of the metal, like that once made by Stremmenos: today, they can be done with more sophisticated techniques. The same *selection* of nickel isotopes used for the powder favors the reactions, and is therefore "catalytic" in a broader sense.

## Some valuable and... totally unexpected clues

As often happens, even to resolve (albeit partially) the puzzle of the catalyst, we need a little luck. And I think this has assisted me in identifying a possible candidate that, for various reasons, is very credible in the role of catalyst, alone or together with other elements.

It all started with reading the here repeatedly cited patent application made by Rossi in 2008. For the purposes of this book, I read with some attention the text once and, then, a second time. But I had not noticed large "oddities". It was the third or fourth time that I was looking through, and I analyzed the content, that I realized one thing. Namely, that in the entire document there was only one note “out of tune", which is at page 17, in one of the "Claims" (No. 13), which calls for the protection of intellectual property not only for the already described apparatus, but also for another in which the «nickel powder is replaced by a *copper* powder».



heat exchanging relationship with said metal tube.

**12.** An apparatus according to claim 5, **characterized in that** said nickel powder is a nickel isotope powder.

**13.** An apparatus according to claim 5, **characterized in that** said nickel powder is replaceable by a copper powder.

**14.** An apparatus according to claim 5, **characterized in that** said apparatus is an apparatus module susceptible to be series and/or parallel coupled with like apparatus modules.

**15.** An apparatus according to claim 5,

*The part of the Rossi’s patent with the “claim” inconsistent considering the context.*

To many people, this request may at first sight not to hit, as happened to me the first few times. But then, rereading carefully the text of the patent, I realized that it never mention copper, if not as a reaction product (and the fact that, for the reaction chamber, in the patent is used as material the

copper is another "curious" aspect, although far less). Now, as in cold fusion literature do not results that copper-nickel experiments have obtained an even minimum result, I do not understand why Rossi wrote this "claim". I thought for two days, and the only plausible explanation I found is that copper is among the "ingredients" present in the reaction chamber: in other words, it would be one component of the catalyst.

To confirm it, surprisingly, shortly after was the totally random discovery made on Internet, while looking for information on other aspects regarding the E-Cat, of a very interesting email written in May 2011 by Brian Ahern – a mature expert researcher of materials science, author of 26 patents, who works at AMES National Laboratory, a research centre of the U.S. Department of energy (DOE) – on a list of internal discussion of hundreds of scientists and professionals (CMNS), where people is pretty careful before you write something. The email was published, due to its huge potential significance, by a great number of blogs in the world.

In this long and rather detailed letter entitled "performance of Zr-Ni-Cu" (i.e. copper, nickel and zirconium), Ahern said, in practice, that an attempt to replicate the experiment of Rossi-Focardi made from his lab, following a complex procedure employed since Japanese Yoshiaki Arata and others – including the creation, after appropriate treatment of a metal powder with granules of the average size of about 40 μm – has been successful, obtaining for a few days an excess energy of 5 W using 30 grams of powder alloy that was then "loaded" with hydrogen at a pressure of (initially) 13.8 bar.

From: Brian Ahern, Boxborough MA
Re: Zr-Ni-Cu alloy performance

Ames National Laboratory processed metal alloy foils via arc melting followed by melt spinning. This is the Yamaura process employed by Arata and others. The foils were baked in ordinary air at 445C for 28 hours.

The brittle, oxidized foils were placed in a tumble mill for 24 hours.

This resulted in 30 grams of black powder with a median grain size of about 40 microns.Presumably, each grain has about one million nanoscale islands of NiCu inside.

The 30 grams occupies about 7 ml inside the 50 ml dewar. The system was vacuum baked at 220C for 24 hours and cooled to room temperature.

H2 gas was added at 200psi. The pressure dropped only to about 185 psi over twenty minutes. In these replication experiments the exothermic reactions have had peak temperatures above 220C with substantial loading above 3.0 H/M ratios. This time the temperature only rose by 2 degrees C.

The system was heated with a band heater to high temperature. There was no controller. A rheostat was set at an arbitrary position and the system comes to a an arbitrary temperature.The average power input was 90 watts.

After several hours the hydrated system was evacuated overnight at a constant high temperature at 530C. The next day H2 gas was again added at 100psi and the temperature rose by 40C to 570C and came back down to 530C after two hours. At the end of the day the dewar was again evacuated while still at 530C overnight.

The third day repeated the same procedure. H2 gas was added at 100psi and the temperature rose by 44C to 574C. However, this time it did not come back to the initial temperature. It remained at the elevated temperature overnight.

On the fourth day H2 gas was again added at 100psi and the system rose by 50C to 580C and again stayed at the elevated temperature indefinitely.

A rough calibration suggests that the 30 grams of hydrated nanopowder is putting out 5 watts of excess power.

Yesterday Peter Gluck suggested that the relationship between loading and excess power may be a myth. This seemed to be true for electrolysis with Pd and heavy water where loading levels exceeding 0.9 D/M were a prerequisite for observing excess power.

My loading level with this nanopowder sample as less than 0.1 H/M.

This 5 watt excess is very much less than Rossi, but it is a real and repeatable experiment There was no radiation above the background level.

Other alloys from Ames NL are expected within ten days

*The letter with which Brian Ahern announces the success of his Rossi-like experiment, that allowed him to get 5 watts in excess for a few days, and describing the procedure.*

Later, Ahern said to be already able to improve the outcome with a longer grinding of the metal alloy, obtaining 8 W in excess with only 10 grams of powder, and that he is working to increase the power obtained up to the levels of Rossi. He said to be very confident in the ability to achieve such a goal. He also stated that the alloy used is composed of zirconium for 66%, of nickel for 21% and of copper for 13%, and that his machine does not generate any type of radiation.

The importance of this document, coming from a source considered authoritative in the environment of LENR, is remarkable, as twofold: (1) on the one hand, it shows how copper is a likely component of catalyst, together with the *zirconium*, which is an element used in 2005 by Arata – with the function of "sink" – in his experiments with the palladium (used instead of copper) in the combination Ni(30%)-Pd(5%)-Zr(65%); (2) on the other hand, this partial replication of the experiment of Rossi-Focardi removes the complete fraud scenario that some non experts – often paid in some way by the competitors or by various types of "lobbies" – supported. The main question about the E-Cat of Rossi, therefore, is no longer *whether* produces energy, but *how much* power it produces.

## What are the conclusions that can be drawn?

At this point, in summary, we have for the secret catalyst three different kinds of possibilities, if you exclude a quarter quite trivial, i.e. that it does not

actually exist (a hypothesis that, likely, would mean being in front of a scam, while it doesn't seem the case):

a) *Solid substrate or nickel hypothesis*. The main points supporting this explanation are that: (1) it justifies the fact that Rossi has published the analyses of some post-reaction powders in his scientific article and, especially, has provided them to Swedish scientists; (2) it is based on technologies well-known, mainly to Rossi, thanks to his professional activity in his American "second life"; (3) in the case of nickel, it explains why Rossi excludes as possible catalysts used in his E-Cat all the other more "obvious" chemical elements.

*A typical example of a catalyst consisting of a solid substrate, used in cars.*

b) *Hypothesis of copper (alone or not).* The main points supporting this explanation are that: (1) copper is mentioned as a possible alternative

to the nickel in the already cited patent application; (2) the replication of the Rossi's experiment made by Brian Ahern shows that can be used with some success a powder made of an alloy including copper and nickel, and a "sink" like zirconium, following in part what has been previously done by Arata in Japan; (3) it explains why in the Swedish analysis of the exhausted powders has been found a high percentage (10%) of copper, and in the natural isotopic composition.

c) *Hypothesis of radioactive elements*. The main points supporting this explanation are that: (1) it explains, at least in principle, how the protons can reach the high energy required to overcome the Coulomb barrier of nickel nuclei, and provides a form of "excitement" to the system, usually a necessary condition to trigger reactions in cold fusion experiments; (2) it is not necessary that the radioactive isotopes are mixed with nickel powder: therefore this latter, once used, can be given to third parties for analysis in specialized laboratories; (3) it is almost certainly a road that has been explored by Rossi and Focardi in their various tests, as can be deduced from the words of Focardi that we reported previously in this chapter.

I would like to stress that, in summarizing the three possible hypotheses, I did not follow a particular criterion in the order. Each reader is invited to make his own free opinion on what might be the most likely according to him, taking into account the fact that, in reality, it is also possible to formulate a whole series of "mixed" hypothesis: as an example, a nickel-

copper-iron mix, although this is only a completely imaginative hypothesis, just to give you an idea of what I mean.

Interestingly, Francesco Celani, when – as mentioned at the beginning of the book – attended the presentation of the E-Cat on January 14, went very close to the "discovery" of the substances which would compound the secret catalyst, or otherwise to solving the mystery. In fact, with its sensitive spectrometer ranging from 25 to 2000 keV, which he had brought with him from Rome, after having started to do the "integral" measures of the gamma radiation emitted by the E-Cat, at one point "moved" the detector from measurement counts to the spectrum, but Rossi shortly after realized that, not allowing the measurements. So, Celani found himself forced to delete the data he had registered for a period of 3 minutes.

*Francesco Celani while, after the demonstration of the E-Cat held on January 14, 2011, talks to Andrea Rossi, explaining to the public what had just happened.*

Celani himself tells this anecdote at the end of the test, speaking to Rossi in front of a crowd of journalists and experts: «I have asked to take measures as spectrum, to understand how great was the energy of the emitted gamma, and you said that in this way I can understand everything and so you prevented me». Rossi replies: «Professor Celani, you are too skilled and too clever not to understand that with that instrument you was able to "read" within the reactor. Pity, because if those measures were undertaken, very probably today the catalyst would not be a secret!

In the meantime, therefore, it does not remain that read and maybe – why not? – try to do some experiments. But for this we still need to know and understand many things about the E-Cat and the reactions that take place, which will be discussed in the following pages.

# Chapter 6 – Products of the reactions

To know what are the new chemical *elements* and – by analyzing the products in more detail – the new *isotopes* that are created by reactions occurring within an E-Cat, is useful not only to understand what the secret catalyst could be but also, and above all, to at least sketch out some theoretical explanation of the phenomenon.

In this chapter and in the next we shall refer to arguments just a bit more technical and we will often use terms such as isotopes, neutrons, decays, etc. Therefore, it is appropriate to give here in a few lines, to the not expert reader, some very simple notions of atomic and nuclear physics.

In nature there are, at the natural state, 96 different *chemical elements*, which are classified (along with 21 other artificial man-made chemicals) in the famous *periodic table* designed by the Russian chemist Dmitri Mendeleev in 1869: a simple scheme in which all the elements are sorted according to their atomic number ($Z$). The *atomic number* is, simply, the number of protons which are in an atomic nucleus.

The smaller part of each chemical element that exists on Earth is called *atom*. An atom is composed of three different types of subatomic particles: *protons* (positively charged) and *neutrons* (no charge), both of which form the atomic *nucleus* (positively charged) and are called "nucleons"; and electrons, much smaller and negatively charged particles "moving" around nucleus and confined to the so-called "electron shells" (or energy levels).

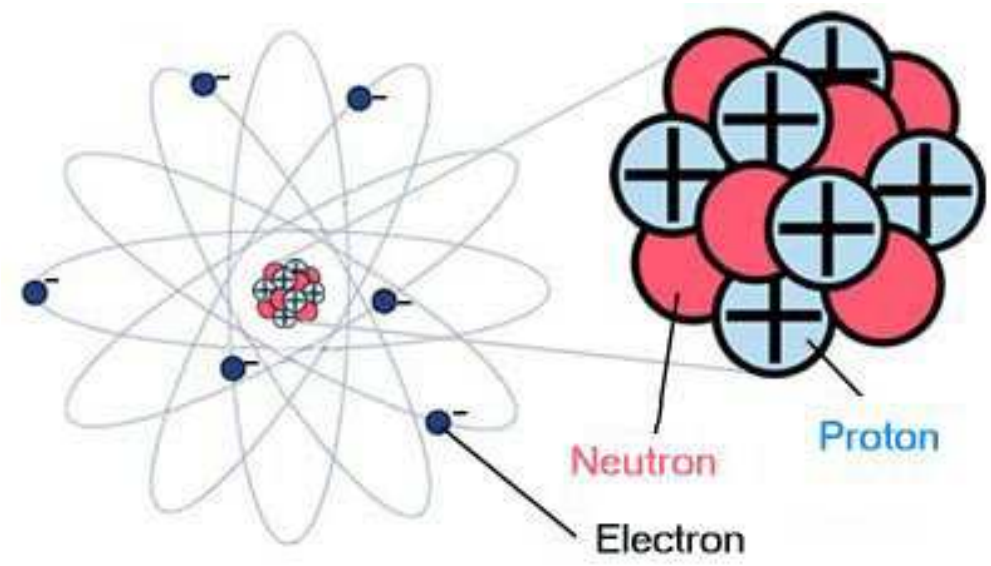



*Illustration of the structure of an atom (left) and its nucleus (right).*

Atoms of the same element, although have all the same number of protons in their nucleus, can have different numbers of neutrons, thus identifying many *isotopes* of the atom, which are indicated by a number (the so-called *mass number*, *A*, equal to the number of nucleons – i.e. “protons + neutrons" – present in the atom), and that is usually placed in the top left of the chemical symbol for the considered element.

For example, nickel is an element that has atomic number (i.e. protons in the nucleus) amounting to 28 and is present in nature in the form of 5 different *stable* isotopes: $^{58}$Ni (the most abundant, 68%, which has 58-28 = 30 neutrons), $^{60}$Ni (26%), $^{61}$Ni (1.25%), $^{62}$Ni (3.66%), $^{64}$Ni (1.16%). Nickel has also 18 radioactive unstable isotopes, which "decay" over time – is the *radioactive decay* – and so turn into other (stable) elements.

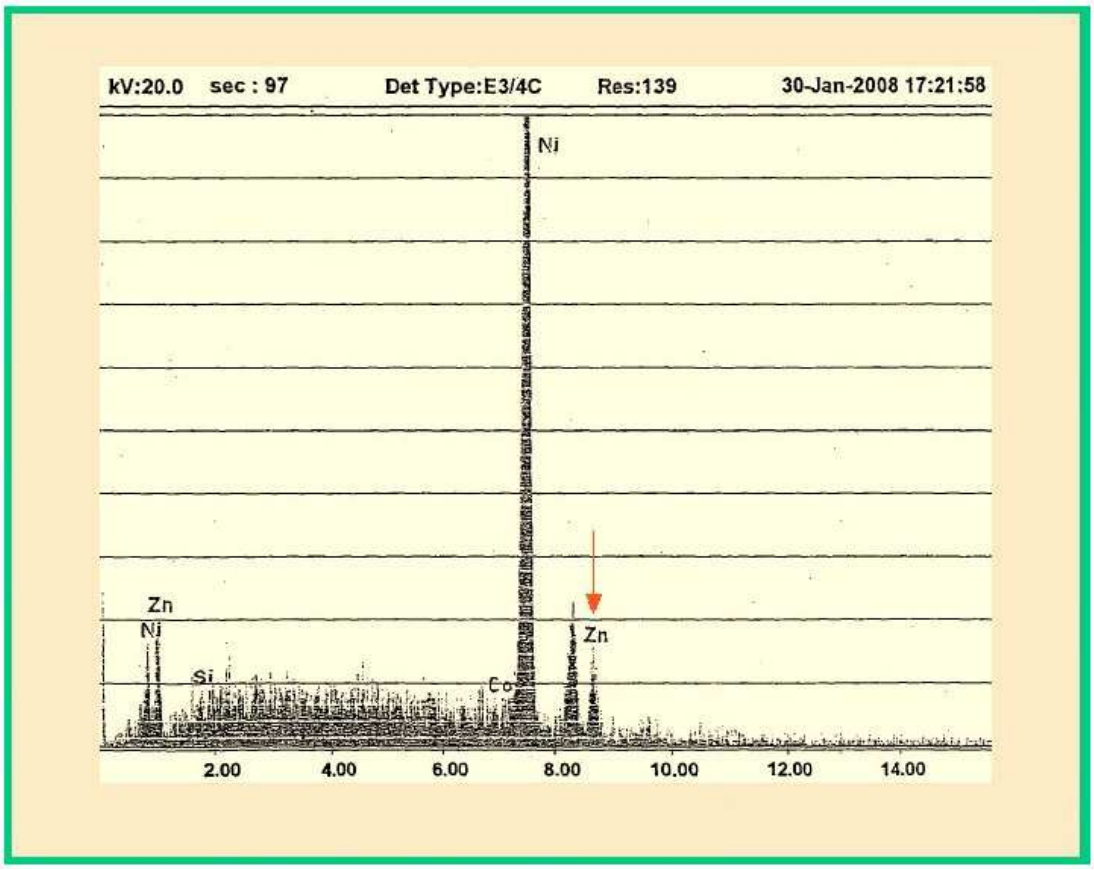
## The substances observed in the post-reaction powder

To get an idea of what are the products of nuclear phenomena taking place in the *Energy catalyzer*, we once again refer to the patent application by Rossi in 2008, where (on page 6) it is said that the reactions produce the "processing of nickel in *copper*".

Moreover, in the same document, there are two graphs representing an analysis, performed on January 30, 2008 at the Department of Physics, University of Bologna, of the atomic composition of two powder samples collected by the E-Cat *after* the nuclear reactions between nickel and hydrogen in experiments for producing excess energy.

Well, as underlined in the patent, both graphs show that the phenomenon also produces *zinc*, an element not present in the nickel powder inserted in the apparatus at the beginning, and this product is justified, according to Rossi, by the fusion between a nickel atom and two hydrogen atoms. The patent goes on to say: «Additionally, we found atoms

of elements lighter than nickel (such as sulfur, chlorine, potassium, calcium), which shows that, in addition to the fusion, *fission* phenomena also occur in the core of nickel that create stable lighter atoms».




*Analysis by mass spectrometry made in Bologna on January 30, 2008, of post-reactions powder samples collected from the E-Cat. (From Rossi's patent application)*

In my interview, Focardi confirms: «Looking at the powder we found the copper, and the relationships between the various isotopes of copper other than natural ones, which is an indication of the nuclear nature of reactions». In fact, the post-reaction analysis shows a ratio of isotopes of copper equal to $^{63}Cu/\ ^{65}Cu \sim 1.6$, while the isotope ratio that is found in nature is about 2.24,

and from the statistical point of view it is a significant difference, which allows you to exclude *contamination* as a possible explanation for the presence of copper in post-reaction powder.

The cited information on the isotopic ratio of about 1.6 found in post-reaction powder lies in the scientific article of Rossi and Focardi *A new Energy source from nuclear fusion*, self-published in Rossi's blog on April 22, 2010, explaining that two different samples of the material used in many different experiments described in this paper were analyzed at the University of Padua with a mass spectrometer, using a technology synthetically called SIMS (Secondary Ion Mass Spectroscopy).

*Another phase of the long interview with Focardi. This time we talk about some "details".*

The cited article also says: «in the samples analyzed, the mass spectroscopy showed the presence of three peaks in the region of 63-65 u.m.a mass (atomic mass units), which correspond respectively to $^{63}$Cu and to elements ($^{64}$Ni and $^{64}$Zn) resulting from the decay of $^{64}$Cu and $^{65}$Cu. The peak in the mass spectrum to 64 u.m.a., due to $^{64}$Ni and $^{64}$Zn, requires the existence of a $^{63}$Ni that, being absent in the natural composition of nickel, must have been previously produced from lighter nickel isotopes».

## The issue suddenly become more complicated

Already at the end of 2010, thanks to the patent of 2008 and to the article by Focardi and Rossi, you could have at least in broad terms an idea about the main products of the reactions taking place within an E-Cat. But, in reality, it was going to get a little "cold shower".

In spring 2011, Rossi provides two samples of powder – one pre-reaction and one post-reaction – from a long experiment with the *Energy Catalyzer* lasted two months and a half, to professor Sven Kullander, a well-known physicist of the Swedish Royal Academy of Sciences who was interested since February to Rossi's invention together with his colleague Hanno Essén, head of the *Swedish Skeptics Society*. This samples were provided so that it could be carried out an independent analysis, accomplished with cutting-edge equipment, in order to determine their composition (i.e. the elements and their isotopes, as well as the amount percentage).

Kullander make to analyze a part of the samples to the Ångström laboratory of Uppsala (Sweden). Here the analysis is performed by Dr. Erik Lindahl using a sophisticated equipment for *x-ray fluorescence* (a modern spectrophotometric technology known with the initials XRFS). In addition, a second part of the samples is sent for examination to the Biomedical Center of the same Swedish city. In this case, the analyses are carried out by professor Jean Pettersson, using a technique of advanced mass spectrometry, the *Inductively Coupled Mass Spectrometry* (ICP-MS).

The result of these measurements, as reported by Kullander in an interview on April 2011 to the Swedish magazine *NyTeknik*, was that «both show the sample of pure nickel (i.e. pre-reaction) is composed primarily of nickel, while the composition of the post-reaction sample is different, as here are also present different elements: especially *copper* (10%) and *iron* (11%). Furthermore, isotopic analysis carried out by ICP-MS shows no deviation from the natural isotopic composition of nickel and copper».

And always with reference to this isotopic analysis, Kullander adds: «Assuming that copper is not one of the "additives" used in catalyst, $^{63}$Cu and $^{65}$Cu detected isotopes may have formed only during the reactions in the E-Cat. However, it is surprising that the $^{58}$Ni and hydrogen can form $^{63}$Cu (70%) and $^{65}$Cu (30%), because this means that in the nuclear transmutations the original $^{58}$Ni would have had to grow, respectively, of 5 and 7 atomic mass units. However, our analysis shows there are two stable isotopes of nickel with low concentrations – $^{62}$Ni and $^{64}$Ni – that can possibly contribute to the production of copper».


*Swedish physicists Kullander and Hessén during an interview in their Italian short stay.*

However, something does not convince the Swedes, and probably for this reason the idea discussed with Rossi of installing an *Energy Catalyzer* in a laboratory of Uppsala for more detailed measurements – or even an official test of the functioning machine – does not realize, at least for the moment: Essén and his "skeptics" look back and change idea, blaming the poor Kullander for his excessive enthusiasm. What had happened?

## Involuntary assistance for all the skeptics

We don't know exactly what are the reasons that have led the "skeptical" of the Swedish Association to reverse opinion, but we can envisage. Here is

what might be the principal reasons, in relation to the results of the analysis of powders carried out in laboratories at Uppsala:

- In addition to what has already been reported, Kullander publicly declares that: «according to what has been reported by Rossi, post-reaction powder was used by the E-Cat continuously for two months and a half with a power output of 10 kW. This corresponds to a total of 18 MWh energy, and a direct calculation shows that – to produce it – a considerable proportion of nickel would be "burned" in a nuclear process, so it is strange that the isotopic composition of the post-reaction powder does not differ from that natural».

- The fact that the isotopic post-reaction compositions of nickel and copper does not differ from those natural is in blatant contradiction with what was reported, in 2010, in the article of Rossi-Focardi *A new Energy source from nuclear fusion*, where at page 7, with respect to copper, the authors claimed – as already reported in our book – exactly the opposite: «the $^{63}Cu/^{65}Cu$ ratio is 1.6, which is different from its natural value (2.24)». In Swedish analysis, instead, $^{63}Cu$ is present at 70% and $^{65}Cu$ at 30%, so their ratio is (= 70/30) 2.3, in agreement with the natural ratio, within experimental error.

- The fact that, as noted by the Swedish nuclear physicist Peter Ekström on magazine *NyTeknik*, the presence of 10% of isotopes of copper in the post-reaction powder is difficult to understand, mainly because only stable isotopes ($^{63}Cu$ and $^{65}Cu$) were detected. The fact that the isotopic

ratios of stable copper present in the post-reaction powder are the same of the natural copper is highly unlikely if the copper is produced by fusion reactions as Rossi says».

*A sample of native copper, which has a natural isotopic composition*

- The fact that the Swedish analysis shows a very high percentage of iron (10%), while in Rossi's patent application on page 13 we read: «charts (of the atomic analysis of post-reaction powders of two samples) clearly show that formed zinc, while zinc is an element not present in original nickel powder placed in the apparatus». Therefore, in one case you note the iron but not zinc, in the other case zinc but not iron: a new contradiction. In addition, it is difficult to explain iron as a product of a merger – being "nuclearly" very far from nickel – or as a result of erosion of the reaction chamber used, which is of stainless steel.

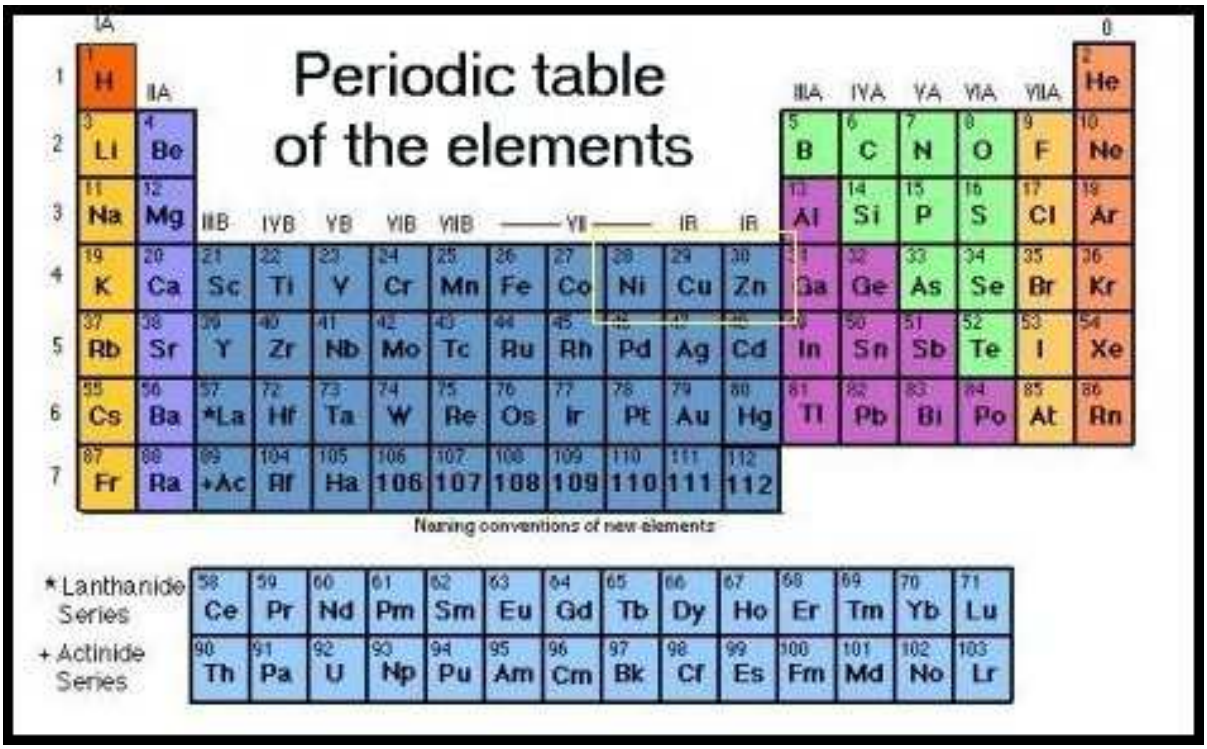
It should also be noted that on January 20, 2011, Rossi stated on his blog that a charge of "fuel" (pure nickel) was used in the E-Cat for 6 months uninterrupted, 24 hours on 24, and then, at the end of the operation, the percentage of copper – which, of course, is related to the amount of energy produced – was more than 30% (almost certainly Rossi does not refer to the same experiment from which come the powders provided to Swedes). And he stated that the isotopes of nickel resulted significantly changed.

## Looking for a plausible explanation

Initially, I was puzzling over the possible explanations: the possibility that Rossi had not provided a sample of the true post-reaction powder, but one obtained by mixing "natural" nickel, copper and iron; the possibility it had been used catalysts and/or nickel pre-reaction powders different in the two cases; the possibility that the reactions had taken place in a not spatially homogeneous manner in the about 100 grams of powder, etc.

Then, during my interview – made two months after the Swedish data on their analysis were in the public domain – I mention to Focardi the issue relating to such analysis, and he tells me: «I read something *en passant*, but I did not follow the analysis. I have done analysis on material that Rossi gave me at the time, where we see weird things, such as mergers and more. However, in Sweden the analysis has been done with systems more accurate than those used by us. Probably, Rossi gave me only a part of the samples,

because a part must have be given to the Swedish professors. But I did not go to the bottom, otherwise I should quarrel with him (laughing) because he had not said to me he was giving only a part of the powder».




*The periodic table of elements with the main elements involved in the reactions of an E-Cat.*

Then, to my observation that iron found by the Swedes might also be due to the mysterious catalyst, Focardi replies: «No, sometimes in the residues may be included other elements, we have always seen something of similar. Sometimes the results of the analysis are produced by various rubbish, even if I have not ever made personally the analysis: they were conducted by experts of electron microscopy, I just look at the pictures, I read what is written, so I am not able to make assessments in that field».

Finally, he agrees with me that, if reactions really produce iron, its presence would require a more complex explanation of the phenomenon.

Also Francesco Celani, that I consulted on this issue, thinks the result of the Swedish analysis may be due to the "pollution", or "dirt", present in the reaction chamber (he didn't know the thought of Focardi, since his opinion was in the long piece of my interview to him ever made public).

Andrea Rossi, instead – which is the main protagonist of the story – replying on the subject to a reader of his blog, says on May 25, 2011: «to answer these questions I should enter in reserved details regarding the cartridge used by me and its operations. Therefore, your comments are correct in the absence of further explanation».

In fact, as noted by the Swedish physicist Kjell Aleklett – professor at the University of Uppsala and President of ASPO, the *Association for the Study of Peak Oil* – «if the original sample of powder is made from natural nickel, then the isotope $^{62}$Ni and $^{64}$Ni, together, account for 4.5% of the sample. And if all these isotopes of nickel are converted into copper, 4.5% of the post-reaction powder should be copper. Moreover, if $^{62}$Ni and $^{64}$Ni isotopes are converted into copper, their isotopic ratio would be 80/20, which is close to the 70/30 measured natural ratio».

Since we know from other statements made by Rossi – always on his blog – that the most abundant isotope of natural nickel, $^{58}$Ni (68%), does not appear to contribute significantly to the production of energy in the E-Cat, this would explain (at least in large part) the observed isotopic ratio of

copper, while the percentage of copper found in the analysis is of relative utility, because this percentage depends on the length of the reaction and the initial amount of fuel, so the 4.5% mentioned by Aleklett represents only a theoretical value, which may not have a practical feedback.


*The notable Swedish physicist Kjell Aleklett, University professor and President of ASPO.*

Therefore, with these simple observations, we can understand the various Swedish analysis results, except the presence of iron. The latter, however, might actually be only a *contamination* of the sample – as suggested by Focardi and Celani – and, in this case, also the last "piece of the puzzle" would place, dissipating the remaining doubts.

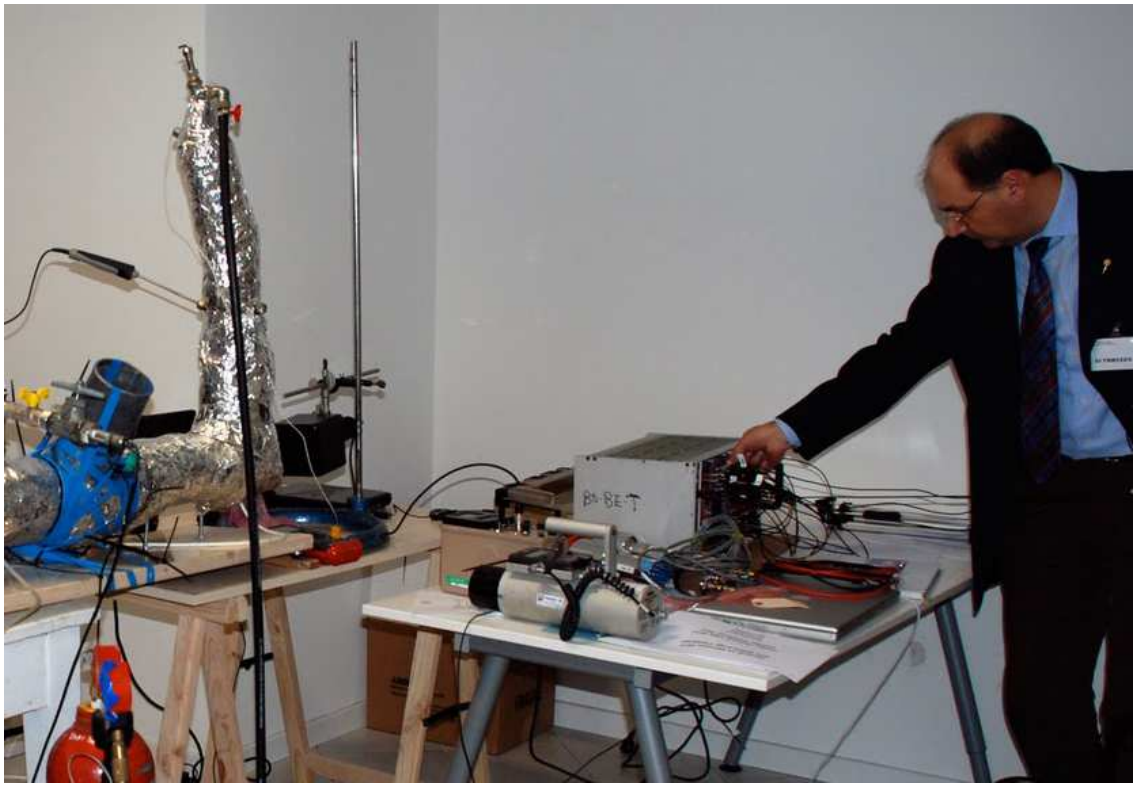
# Chapter 7 – The controls on radioactivity

Another important aspect concerning the "products" – in the broadest sense – of the reactions taking place within the E-Cat, is the presence or not of *radioactivity*, or of "emissions" dangerous to humans.

This type of information, in fact, it is not only important for the security of those who work on this kind of experimental equipment – or intend to buy in future an E-Cat – but represents a further small step in trying to unravel the mystery of the catalyst and to understand which are the reactions that occur within the reactor.

In general, a cold fusion experiment can only create weak "dangerous" emissions (in the absence of shielding) – e.g. *gamma rays* and sometimes *neutrons* – so all information relating to such products and their energies are very valuable. Since gamma rays penetrate easily in the human body and can damage tissues, we have to absorb them with a layer of lead.

Note that so-called "high-energy neutrons"[5] – *if* created – can produce gamma rays interacting with the cooling water surrounding the reaction chamber, but these secondary gamma rays are different from those produced by the fusion event itself, because the "secondary" have much less energy and interact with water in a detectable mode.



*A part of the equipment for determining the absorbed dose of gamma radiation. It was used in the presentation of the E-Cat on January 14, 2011. (Photo by Daniele Passerini)*

It should also be noted that the low-energy nuclear reactions that occur in the "cold fusion" using non-radioactive materials do *not* produce

[5] The types of interaction that neutrons have with matter depend on their initial energy (Eo). Therefore, we distinguish different classes of neutrons: thermal neutron, Eo < 1/10 eV; slow neutrons, 1/10 eV < Eo < 100 keV; fast neutrons, 100 keV < Eo < 100 MeV, high energy neutrons, Eo > 100 MeV.

radioactive waste like nuclear fission, emitting *lethal* particles and radiation – especially for inhalation or ingestion through air, water and contaminated food – with enormous difficulties for the storage of the waste themselves once decommissioned the nuclear power plant.

## Radioactivity levels outside the machine

What are, therefore, the levels of radioactivity outside the E-Cat? Can we rest assured and operate – or even sleep – without problems next to the machine or, conversely, there are invisible dangers?

Focardi and Rossi tell, in their scientific article of 2010, that «during their experimental tests in the immediate vicinity of the apparatus, carefully shielded with lead, were carried out continuous checks on radioactivity levels using a *gamma ray* detector and three passive *neutron* detectors – "bubble" type, made by Canadian Bubble Technologies – one of which intended to measure the thermal neutrons. Well, not any radiation has been observed at higher levels of natural background, and has not been found radioactivity in the residual nickel from reactions occurring in the E-Cat».

The cited article continues stressing the absolute harmlessness of the apparatus: «on March 10, 2009, during various experiments with our E-Cat, the Health Physics Unit at the University of Bologna has verified that the emission of ionizing radiation around the *Energy Catalyzer* did not differ significantly from natural background. And also the water that enters in the

system and, once heated, emerges, had the same concentration of natural radioisotopes of tap water, so there is no difference between the two».


*A typical Geiger counter, an instrument that allows you to measure radioactivity.*

Focardi, who in the experiments with Rossi was responsible – as a nuclear physicist – of the protection from any dangerous emission of particles or radiation from the reactor, confirms to me in the interview the total absence of radioactivity outside the E-Cat, and adds: «without the lead, there is a small emission of gamma rays: I measured them in the first tests with a detector. I also measured the radioactivity around the apparatus without shielding, and a little further on in the room, and I compared with the natural background. In that case, there was a radioactivity of one and an half times the natural background. Small, but it must to be not even 1% more. However, just use a small thickness of lead and the system is safe».

## The absence of neutrons in the Ni-H reactions

Focardi explained on several occasions that, in the experience made with nickel and hydrogen, he has never observed neutrons, which would be very dangerous to humans, so we must avoid them in all ways.

But, in the interview granted to me, he clarifies that only with nickel it has always been so: «in our experiments performed in Siena once we found the neutrons, and I wondered why. In my opinion, we found the neutrons because in that experiment it has been used a steel finger instead of nickel. The steel contains boron, whose nucleus has a shallow "potential hole" from which neutrons can be extracted».

The fact that has never been the nickel to produce neutrons is only a reconstruction made *after*, as Focardi explains: «Unfortunately this is a piece of information that I miss. I had to think about the data that I knew. And I knew that there were neutrons because I also attended the measures, we published an article – and then they were cited – but I also knew that several experiments have been made at that time. Among other things, in such a period, in Siena there were two cells in function, so it was one of the two that had the finger of steel. I knew that sometimes Piantelli had used steel and in fact he had told me: "Mah, it also works with the steel". And this is not surprising, because the steel contains nickel».

Obviously, Focardi is aware that this may create doubts in the people, and confesses: «In the scientific articles, that we were able to publish thanks to the fact I was a friend of the Director of the Italian science magazine

*Nuovo Cimento*, among the things we talk about there are the neutrons we saw in Siena for several days, and this gives me a little bit of discomfort. In fact, I do not know if in one paper we wrote that instead of nickel there was the steel... Today, I would prefer we had not ever published that article, because it leads people to suspect that sometimes we say the right things and sometimes we invent them. But now things have gone so...».

## Temporary emissions in the reaction chamber

Almost certainly, the "heart" of the E-Cat in all experiments of Rossi and Focardi is surrounded, in addition to the lead, also by a shielding formed by a layer of boron and by the cooling water.

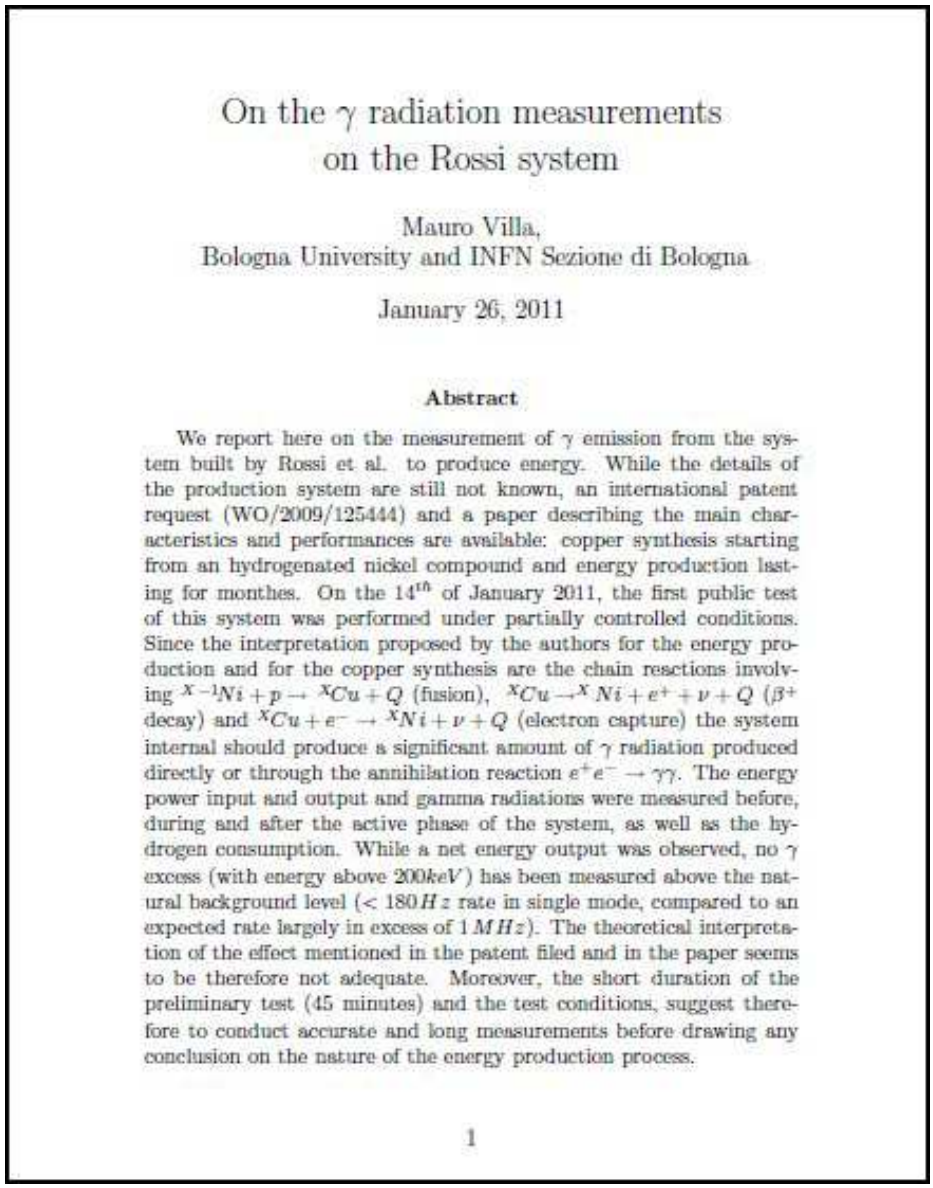

*Blocks of lead used to shield radioactive materials.*

In fact, not only we read about this shielding in the patent of 2008, but Rossi himself declares in an interview that the commercial version of the E-Cat will have a «shielding including lead, boron and cooling water». The lead is meant to absorb gamma rays, while the boron and water are the typical absorbers used for the far more dangerous neutrons.

Therefore, it is not surprising that out of the machine – which is shielded in the appropriate manner: the reaction chamber of an E-Cat for sale will be surrounded, to guarantee maximum safety, by 50 kg of lead! – we do not look dangerous emissions, and therefore we can conclude there is no danger to humans. This, however, does not mean there are no emissions *inside* the reaction chamber, where the nuclear reactions occur.

To clarify very well the thing is the answer given by Rossi to the Swedish nuclear physicist Peter Ekström, who, in the cited videochat organized by the magazine *NyTeknik*, poses the following interesting question:

«In the fusion of a proton with $^{58}$N (the most abundant isotope of nickel existing in nature) you should create a considerable activity due to the formation of $^{59}$Cu, which decays with a half-life of 82 seconds through a so-called "beta decay". In their scientific article, Rossi and Focardi say that "no radioactivity was found in post-reaction residuals of nickel". But this is surprising, given the very high activity of the produced $^{59}$Cu: even 10 mean lifes after the end of the reaction the activity should be of the order of 1013 Bequerel, a value not only easily detectable, but also deadly if such radiation is not adequately shielded».



On the $\gamma$ radiation measurements
on the Rossi system

Mauro Villa,
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January 26, 2011

**Abstract**

We report here on the measurement of $\gamma$ emission from the system built by Rossi et al. to produce energy. While the details of the production system are still not known, an international patent request (WO/2009/125444) and a paper describing the main characteristics and performances are available: copper synthesis starting from an hydrogenated nickel compound and energy production lasting for monthes. On the $14^{th}$ of January 2011, the first public test of this system was performed under partially controlled conditions. Since the interpretation proposed by the authors for the energy production and for the copper synthesis are the chain reactions involving ${}^{X-1}Ni + p \rightarrow {}^{X}Cu + Q$ (fusion), ${}^{X}Cu \rightarrow {}^{X}Ni + e^{+} + \nu + Q$ ($\beta^{+}$ decay) and ${}^{X}Cu + e^{-} \rightarrow {}^{X}Ni + \nu + Q$ (electron capture) the system internal should produce a significant amount of $\gamma$ radiation produced directly or through the annihilation reaction $e^{+}e^{-} \rightarrow \gamma\gamma$. The energy power input and output and gamma radiations were measured before, during and after the active phase of the system, as well as the hydrogen consumption. While a net energy output was observed, no $\gamma$ excess (with energy above $200keV$) has been measured above the natural background level ($< 180\,Hz$ rate in single mode, compared to an expected rate largely in excess of $1\,MHz$). The theoretical interpretation of the effect mentioned in the patent filed and in the paper seems to be therefore not adequate. Moreover, the short duration of the preliminary test (45 minutes) and the test conditions, suggest therefore to conduct accurate and long measurements before drawing any conclusion on the nature of the energy production process.



*The detailed report made by the physicist Mauro Villa on measures of gamma radiation produced by the E-Cat during the presentation of January 14, 2011.*

Rossi explains the apparent paradox saying: «Yes, it is true, no radioactivity was found in metal residues, but the measures were made the day after we stopped the E-Cat. In any case, you are correct: If the $^{59}$Ni is formed from $^{58}$Ni, due to the beta decay we should observe pairs of 511 keV gamma rays in opposite directions, but we have never observed, while we

have seen gamma rays in the range 100-300 keV (as shown in the report on the January 14 experiment written by Mauro Villa: *On the gamma radiation measurements on the Rossi system*). I think then that $^{59}$Ni is not produced and I suppose the only stable copper is produced by transmutation of the nickel isotopes $^{62}$Ni and $^{64}$Ni. I can infer this conclusion from the products we found at the end of the reactions».

In practice, in the case (entirely hypothetical) in which the container of the E-Cat where the reactions occur broke, outside you might measure – potentially – a short sudden increase in the levels of radioactivity. However, the escape of hydrogen gas from the reaction chamber would quickly stop nuclear reactions and the production of radioactivity.

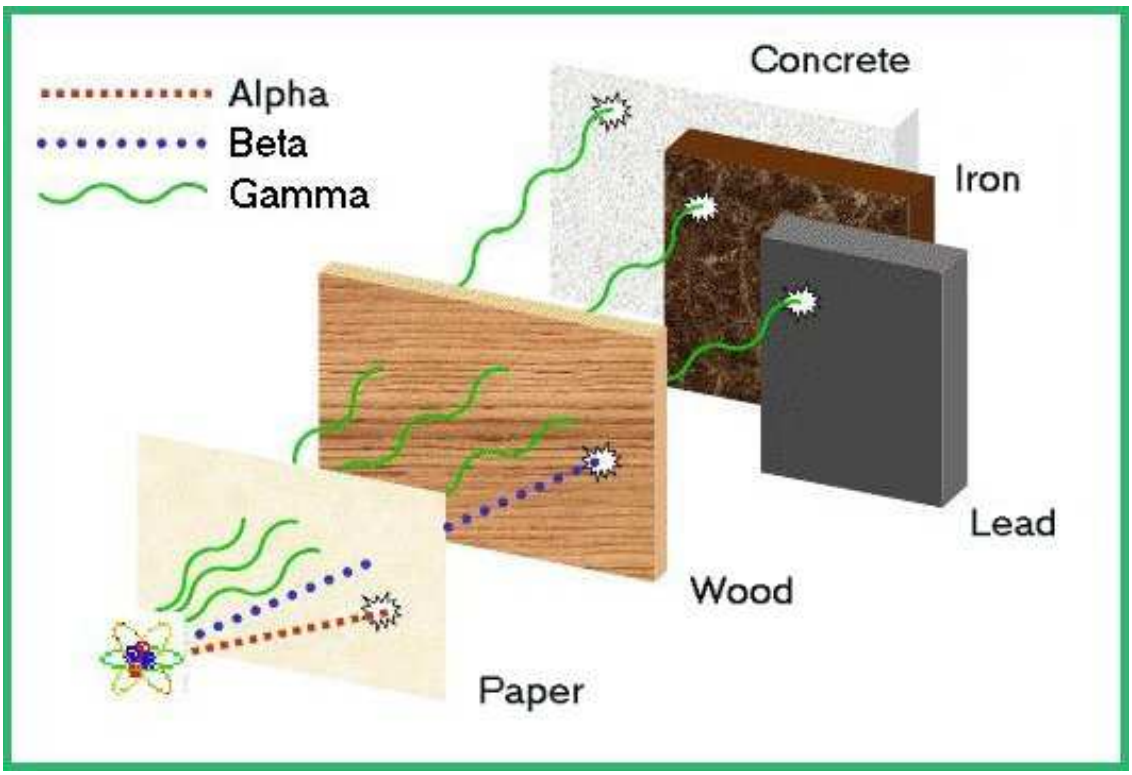
## The shielding from low-energy gamma rays

No one knows why the main product of the cold fusion reaction – it is not, therefore, only the case of the E-Cat – is the heat and not, instead, large amounts of highly lethal radiation, or a "rain" of neutrons, or both. However, it is obviously a good thing, because otherwise the shielding would be quite complex and therefore machines of this type would be difficult, costly and dangerous to commercialize.

One possible hypothesis is that the energy produced is somehow absorbed by the metal lattice, for example through high-frequency vibrations or consistent processes that involve many delocalized vibrations. This would

also explain why none of the low-energy nuclear reactions that we know seems capable of producing "chain reactions" (as happens with the chemical reactions in *explosions* and nuclear fission in *nuclear bombs*), which are able to release large amounts of energy in a very short period of time, an essential requirement if one want to fabricate a bomb.

In the case of the E-Cat, as we have seen, the gamma rays with higher energy are those at 300 keV or less (which seems reasonable, since gamma rays from radioactive decay usually have energies of a few hundred keV): so, we are talking about *low-energy* gamma rays, but they can still pass through the skin without difficulty and, once in cells, create extensive damage to Dna, with potential risks of developing cancer and leukemia.




*To absorb the gamma rays, high-density materials are needed.*

In general, the higher is the energy of gamma rays and more, of course, they are penetrating and more thick is the layer of lead (preferred to other materials because of its high density and high atomic number, for which its electrons absorb and disperse the energy) that we need to put around the reactor to absorb them completely. However, since the probability that matter could absorb gamma rays is proportional to the thickness of the absorbent, we observe a decrease of *exponential* type in the intensity of radiation when the thickness increases.

In practice, with a layer of 2 cm made of lead – the thickness used in a prototype of the E-Cat – we have an attenuation of nearly $2^{20}$ times of the gamma rays at 200 keV, so it is reasonable that outside the machine[6] radiation are not different from those of the natural background.

[6] The attenuation of gamma rays, however, varies greatly depending on their energy. At 100 keV, with 2 cm of lead is $2^{60}$ times, while at 500 keV to mitigate them 10 times a thickness of 1.4 cm is needed (therefore, 2 cm are not sufficient to shield the possible gamma at 511 keV initially expected from theory). In addition, the amount of radiation is inversely proportional to the square of the distance.

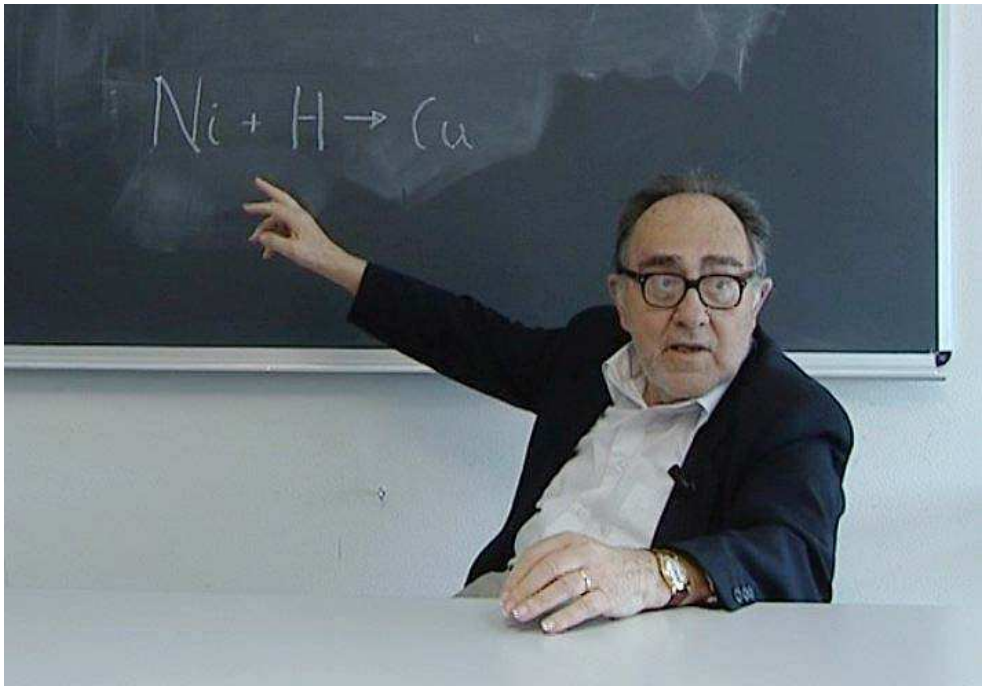
# Chapter 8 – Nuclear nature of the reactions

The process that, in the *Energy Catalyzer* of Rossi-Focardi, gives rise to the clearly observable excess power generation cannot be – according to the Focardi – chemical, due to the amount of thermal energy produced by the device, greatly larger than you can get, for example, by burning.

As the components, or the starting materials, used in the reaction chamber are nickel and hydrogen, and the main product of the reactions – except, of course, the excess energy – is given by copper, Focardi believes that it is a process of "fusion", albeit a *cold fusion*, i.e. at low temperature, completely different from the "hot fusion", which occurs at very high temperatures and pressures in the stars and that scientists try to reproduce in laboratory within expensive machines called *tokamak*.

When Focardi, at my request, during the interview made to him in June, wrote on the blackboard the equation at the base of an E-Cat (which

appeared as follows: “Ni + H —> Cu”), he commented: «this is an equation that would horrify any chemist… but it is what we see!».




*Professor Focardi shows a… little chemical equation!*

According to Focardi, the explanation at the conceptual level of what happens inside the reaction chamber of an E-Cat is, in practice, the following: «the *nucleus of hydrogen* in monoatomic form – which is simply a proton – penetrates inside the *nucleus of nickel* (which contains 28 protons and a variable number of neutrons) and this causes a variation of such nucleus, which with a proton plus than usual becomes *copper*, an element following the nickel in the periodic table of elements».

This explains the process, but of course remain the difficulties of interpretation related to the fact that this phenomenon is not expected from

physics that we know – which, however, explains the hot fusion – and therefore, to justify from a theoretical point of view the phenomenon and observed products, seems necessary to formulate a new physical theory.

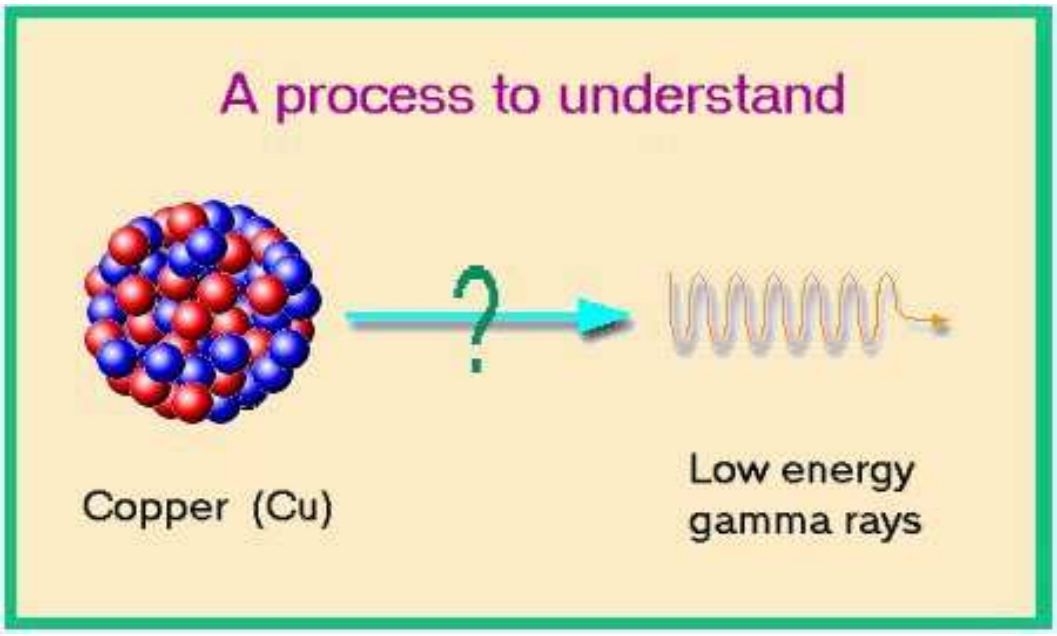
## A self-sustaining exothermic reaction

The monatomic hydrogen – i.e. the proton that forms its nucleus – must overcome, to penetrate the nucleus of nickel, a strong repulsive electric field that opposes such a motion: the so-called *Coulomb barrier*. However, it is difficult to understand how a similar nuclear process happens: there is not, in fact, a simple justification of this phenomenon.

The experimental fact is the proton capture oby the nucleus of nickel, resulting in the formation of copper, which is found in "excited" nuclear levels – i.e. not in the normal steady state – from which, according to Focardi, decays emitting low-energy *gamma rays*, low frequency electromagnetic radiations (the frequency of a wave is linked to its energy $E$ through the relationship $E$ = *constant* x *frequency*) responsible for the thermal energy output that characterizes an E-Cat.

In fact, as Focardi explains very well, «at the issuance of each gamma ray, the nucleus of copper recedes a little, like the barrel of a cannon when the bullet is launched, and so the nucleus of copper gives energy to the medium, heating it. This is very important because it allows other similar processes – that require a certain minimum temperature so that hydrogen

can penetrate the nucleus of nickel – to occur, and so inside in E-Cat the reaction, once started, can self-sustain».




*Despite the words of Focardi, we still need to understand how from the copper (or other products) you arrive to the production of low-energy gamma rays, i.e. heat.*

In fact, the exothermic reaction that runs the E-Cat – both in prototype and commercial versions – continuously uses electricity supplied from outside. In principle, you could use the heat generated by the machine itself to implement the cycle of self-sustenance of the process, but as the heat produced by such apparatus is neither constant at every new startup nor easily controllable in a "fine" way, the system results much more stable if is operated by heating fuel with an electrical resistance.

Of course, this applies to versions of the E-Cat intended to produce only thermal energy. For models that also produce electricity in cogeneration

or not, in fact, it is conceivable (and cheaper) to use, as a source of electricity for heating the resistance, part of the electric power generated by the system, as the latter can be easily stabilized with an electronic circuit, at the voltage required for the proper functioning of the machine.

For sake of chronicle, this kind of operation, seeing an E-Cat prototype functioning in a "self-sustained" mode, has been tested by Rossi many times for a period of several hours. However, to achieve the self-sustaining status, it is important that the nuclear reactions become much energetic, in which case the energy output can become so high to cause an explosion. Therefore, in normal use, the E-Cat uses only a small part of the energy that could provide when working in a full power self-sustained mode.

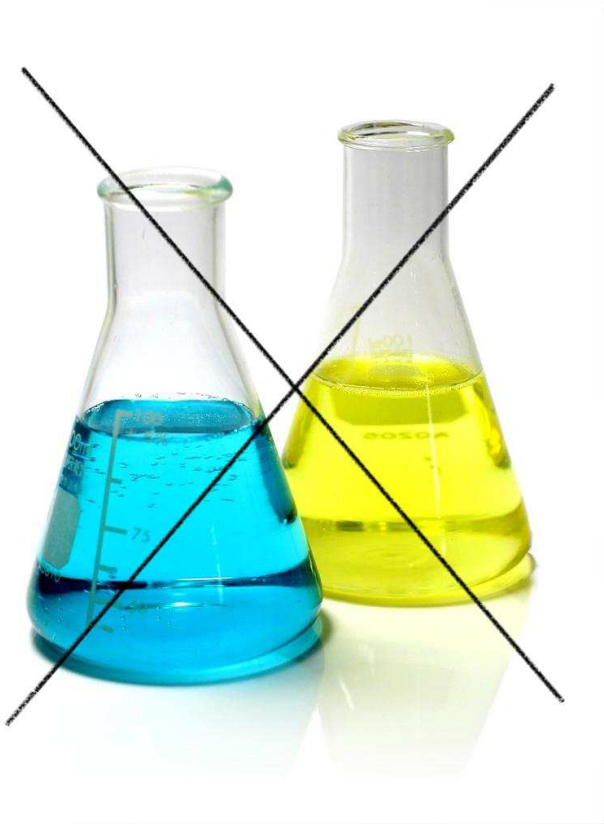
## The main nuclear "signature" of the phenomenon

There are various proofs (or "signatures", as we say in the jargon), each of which is sufficient by itself to prove the thesis of the nuclear, rather than chemical, nature of the reactions taking place within an E-Cat.

The main proof[7] – very obvious if you make some simple calculations, as now we'll see – is the fact that the production of thermal energy in excess by the catalyst of Rossi-Focardi is absolutely too high to be explained by any

[7] The other proofs are the observed production of low-energy *gamma rays* – because gamma rays are produced only by nuclear or subatomic transitions – and the always observed formation of *copper*, because it is not among the initial ingredients of the reaction.

process of chemical nature (including *combustions*, i.e. strongly exothermic chemical reactions that propagate with a certain slowness, and *explosions*, chain chemical reactions and therefore discontinue in time, but able to release large amounts of energy).



*The excess energy produced by the E-Cat cannot be of chemical nature.*

In fact, assuming that every atom of nickel can achieve, in optimal conditions, a chemical reaction – that, as we know, releases an energy of a few eV, since that is the binding energy of the electrons in the outermost atom – to get the same amount of energy produced by the E-Cat in an experiment, it would take at least $10^{28}$ atoms, as it is easy to prove.

In fact, there is the following equivalence between units of energy: 1 eV = 4.4 x 10-26 $kWh_t$, so equivalently 1 $kWh_t$ = 0.22 x $10^{26}$ eV, and hence to obtain e.g. the 1000 $kWh_t$ produced from E-Cat in the long experiment of the spring 2009 – when it was operating for 2 consecutive weeks – it takes approximately (1000 x 0.22 x $10^{26}$ =) 2 x $10^{28}$ atoms, where we can ignore the factor "2" considering an energy of some eV for each atom, resulting in the need of about $10^{28}$ atoms for two weeks.

But how much is $10^{28}$ nickel atoms?

Well, it is something like a million grams: 1,000 kg or, if you prefer, a ton! In fact, a so-called *mole* of nickel, or of any chemical element present in the periodic table, contains 6.0 x $10^{23}$ atoms of that element (this is known in chemistry as "Avogadro's number") and has, by definition, a mass – expressed in grams – almost identical to the atomic weight of the main stable isotope of the element that interests us.

The stable isotope of nickel most abundant in nature (68%) appears to be the $^{58}$Ni, which has atomic weight "58", having 28 protons in its nucleus and (58-28 =) 30 neutrons. So, a mole of nickel contains 6.0 x $10^{23}$ atoms and weighs about 58 grams (if we take another isotope of nickel, the weight changes of a few grams, not more). Therefore, $10^{28}$ nickel atoms are approximately ($10^{28}$ : 6.0 x $10^{23}$ =) 0.2 x $10^5$ moles, and then weigh (0.2 x $10^5$ x 58 =) 1.2 x $10^6$ grams, i.e. 1200 kg. Consequently, since in reality Rossi did not use 1200 kg of nickel but about 100 grams, only a nuclear reaction may explain the long operating time reached by the E-Cat.

*If the E-Cat worked with chemical reactions, would consume hundreds of kilograms of nickel.*

## Different energy levels in chemical and nuclear reactions

An interesting question is: how much energy can the *Energy Catalyzer* produce with a gram of "fuel", i.e. with a gram of nickel? Or, if you prefer, how long can this device operate with only one gram of fuel?

To find an answer to this question we must, on the one hand, make general assessments of *theoretical* type and, on the other hand, execute *experimental* measurements with the machine kept running for a long time, evaluating after this kind of test the actual "consumption".

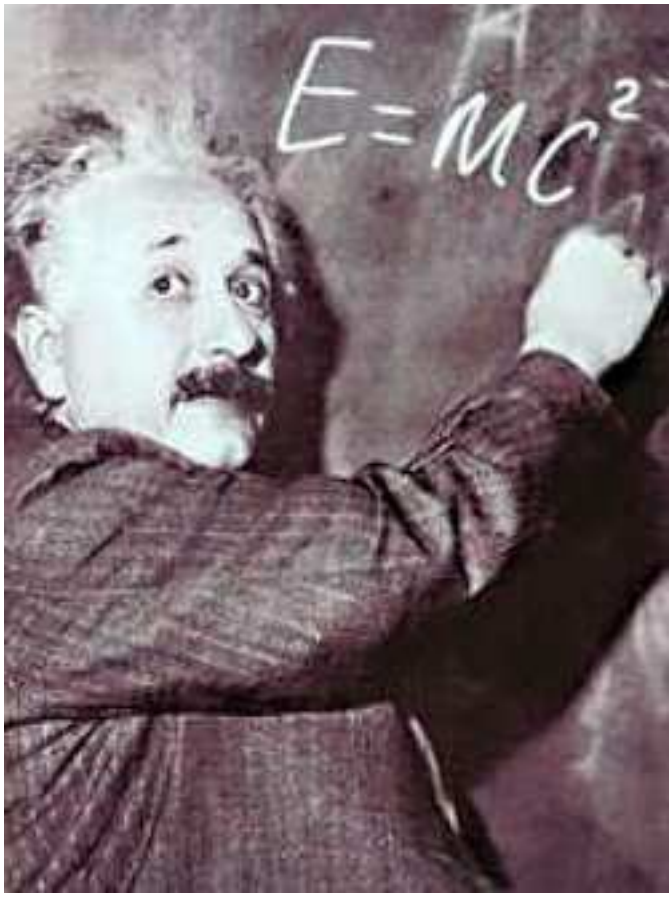
In *chemical* reactions – particularly in processes that aim to derive energy, e.g. through the burning of oil, gas or coal – you can extract very

small amounts of energy, of the order of a few electron volts (eV) for each pair of atoms involved in the reactions, a value that reflects the binding energy of the electrons in the outermost atom.

On the contrary, in *nuclear* reactions involving the transformation of a chemical element in another lighter, the amounts of released energy are in the order of a million electron volts (MeV) for each pair of atoms involved, as it is valid the famous "law of conservation of energy" $E = mc^2$ (it reads: *energy* = *mass* x *velocity of light squared*).

This law, formulated by Albert Einstein in his *Theory of Relativity*, ensures that the difference in mass between the "starting constituents" of a nuclear reaction (atoms and/or components of their nuclei, i.e. *protons* and *neutrons*) and the mass of the atom – or of the "new" stable and lighter compound – formed at the end of the reaction itself, does not "disappear into the void", but is liberated in the form of energy.

Therefore, even a relatively small mass difference between the "starting ingredients" and the final products of a nuclear reaction, may result in a significant production of energy. Just to give you an idea, the difference in mass between that of a stable atom of helium (final product) and the mass sum of its separate components (2 protons, 2 neutrons, 2 electrons) – that is greater – is equivalent to an energy of 28.3 MeV, which may eventually be easily turned into the most common unit of thermal kWh, knowing the equivalence: 1 MeV = $4.4 \times 10^{-20}$ $kWh_t$.




*The famous law of energy conservation by Albert Einstein.*

Since the energy produced by nuclear reactions, as just shown, is at least 100,000 times greater than that achievable with chemical reactions, with the same produced energy the fuel needed to power nuclear reactions is at least 100,000 times lower, or – if you prefer – with nuclear reactions a fixed amount of fuel can produce the same amount of energy of that produced with chemical reaction, but for a time at least 100,000 times *longer*.

Consequently, already at the mere theoretical level we can see as a chemical reaction such as at the base of the E-Cat is able to consume very little fuel and go on for a long time before it is necessary to provide new "fuel" or replace the previous because "exhausted".

## A theoretical estimate made by orders of magnitude

Let try to estimate, at least in broad terms, how much energy can be provided by a *low-energy* nuclear reaction, i.e. the kind of reaction that is responsible for interaction between nickel and hydrogen in an E-Cat.

So, we start from the reactions we all know very well because a man of the 21° century still use, directly or indirectly, in his daily life – the *chemical* reactions – and let imagine to have some of them at our disposal, e.g. firewood in a stove. How much energy can provide 1 kg of wood?

The rather dry wood – as indicated by any table concerning the various possible fuels – has a "caloric power" of about 3,000 Kcal/kg, significantly less than that of any other *solid* energy source, such as coal (7,000 Kcal/kg), and that of *liquid* energy sources of fossil origin, such as crude oil or diesel fuel (both, give about 10,000 Kcal/kg).

However, it is convenient to measure the thermal energy in kWh. Well, to switch from the unit Kcal/kg to $kWh_t$, just use the equivalence 1 Kcal/kg = 1.16 x $10^{-3}$ $kWh_t$. Therefore, 1 kg of wood can provide about (3,000 x 1.16 x $10^{-3}$ =) 3.5 $kWh_t$/kg, while the coal can provide approximately 8.1 $kWh_t$/kg, and the crude oil or diesel around 11.6 $kWh_t$/kg.

Although there are light petroleum distillates (e.g. gasoline, used in transportation) which provide about 10% more energy, you can consider the diesel as the chemical fuel with the greater energy yield, so it is widely used for heating. If, as unit of measure, we use $kWh_t$/gr (i.e. the "thermal watts

per gram") instead of $kWh_t/kg$, the yield from diesel is about 0.012 $kWh_t/gr$, while that from dry wood is only 0.0035 $kWh_t/gr$.

*The great energy of a lightning is released as heat and light, but is not exploitable.*

As – we told it earlier – a nuclear reaction can supply energy at least 100,000 times larger than most chemical reactions, we expect that 1 gram of fuel in an E-Cat can provide thermal energy 100,000 times greater than that produced by diesel, i.e. at least (x 105 = 0.012) 1,200 $kWh_t/gr$.

Therefore, a 10 kW E-Cat, fed with just 1 gram of fuel, according to our simple reasoning should be able to produce energy in an uninterrupted way for at least (1200: 10 =) 120 hours, equivalent to 5 days. Similarly, 5 grams of fuel are more than sufficient to operate the device for a month, while 70

grams should allow it to work for over a year. And indeed, from what the same Rossi told, we know that, with 100 grams of nickel, the E-Cat has worked continuously for two months and a half.

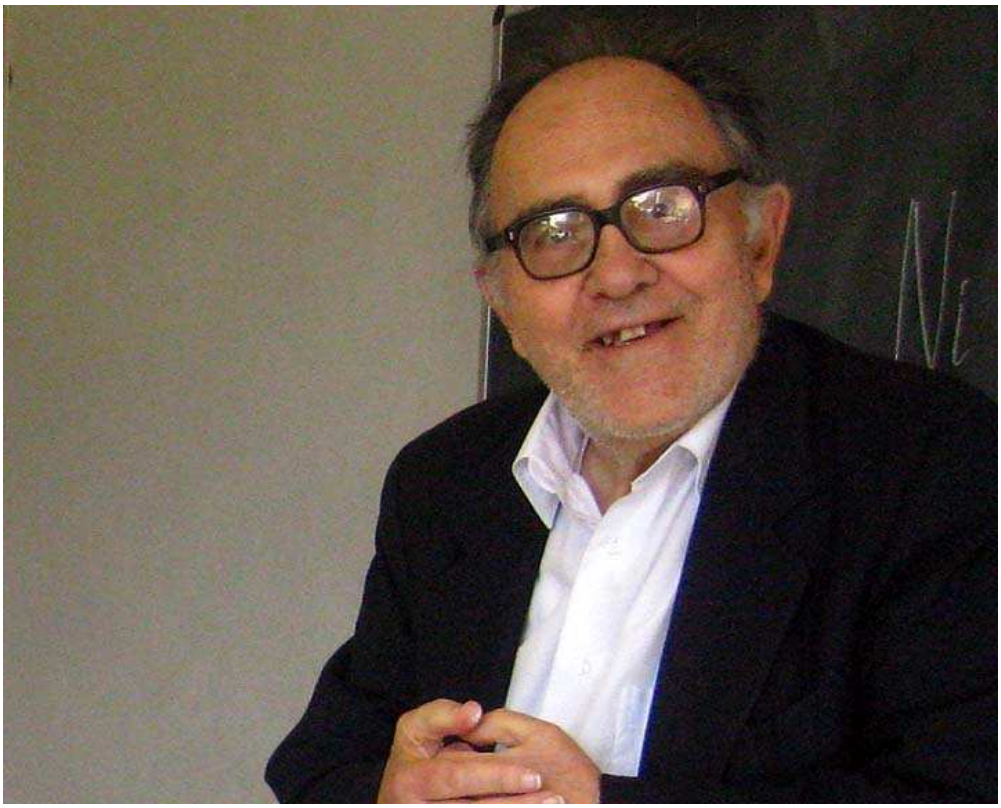
# Chapter 9 – Towards a possible theory

The process underlying the functioning of an E-Cat is currently far from being understood. Sure, we have an idea of how things can go: the proton – i.e. the hydrogen ion ($H^+$) – penetrates into the atomic nucleus of nickel, then some subsequent decay reaction of products created by this initial reaction generates low-energy gamma rays that heat the surrounding medium and thus provide an high excess heat.

But the details of the issue – in particular two: how can the proton enter the nucleus of the nickel, and what are the exact nuclear reactions that lead to the experimentally observed products – are not yet clear, and therefore it will take much more accurate experimental research, on which to formulate subsequently theoretical explanations.

It made me remember that once Focardi, in one of our long and pleasant conversation by phone, confided to me, not hiding some fun: «The theoretical physicists, scientists who have not believed in what we discovered,

in future will be forced – almost a sort of "punishment" – to find a detailed explanation, to formulate a consistent theory of the phenomenon that allows the *Energy Catalyzer* to produce so much energy».

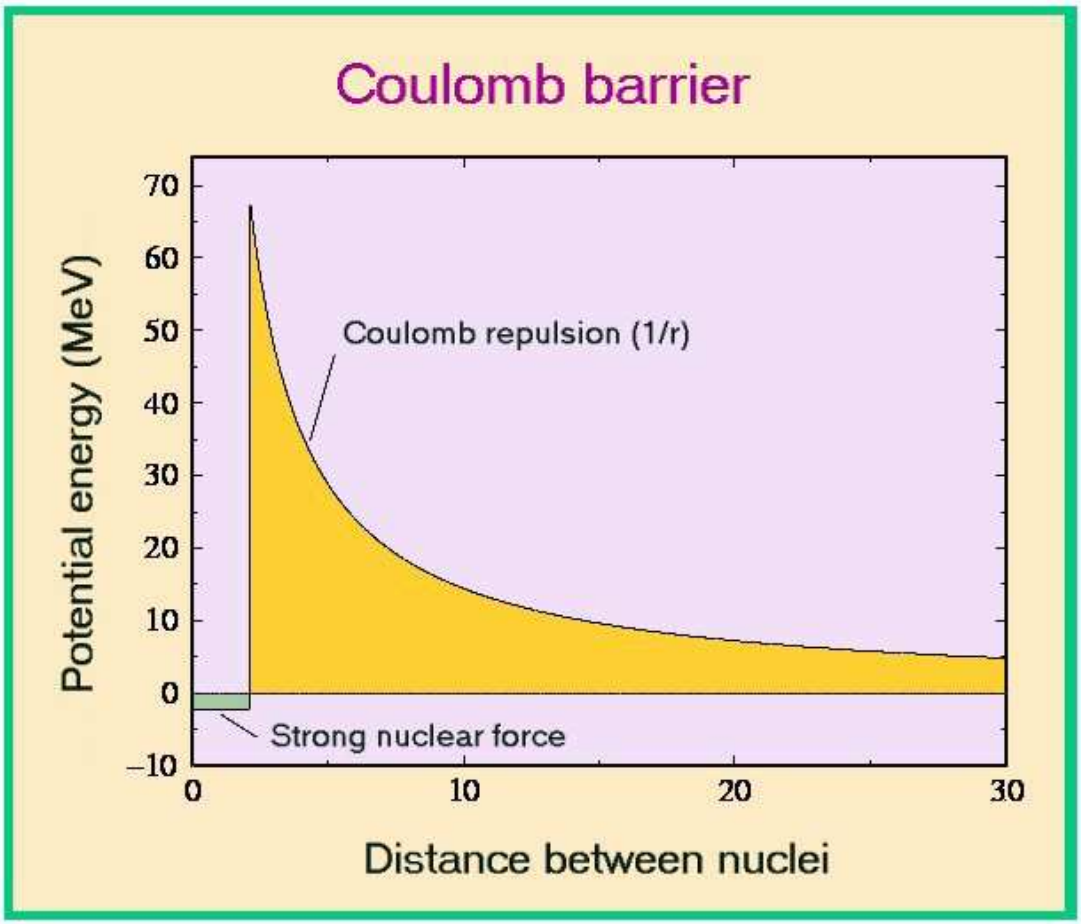



*Focardi in an amused expression during my interview. (Photo by Claudio Puosi)*

Rossi and Focardi, in their old article *A new Energy source from nuclear fusion*, provide some elements for a first theoretical interpretation of what is happening. Here I will give you a popular version of what they tell, integrating the material with basics, additional information, trivia and with possible theoretical explanations proposed within the more general field of low energy nuclear reactions (LENR).

## Overcoming the Coulomb barrier

The capture, by the nickel nucleus, of the proton (which constitutes the nucleus of the hydrogen atom) represents an unexplained process – at least in appearance – for a physicist, due to the strong positive repulsive electric field exerted by the nickel nucleus, which obliges the proton (which also has a positive charge, and we know that charges of equal sign repel each other) to overcome a major repulsive force that opposes the motion of approach, and that in physics is known as the *Coulomb repulsion*.




*The classical "potential barrier" between two atomic nuclei.*

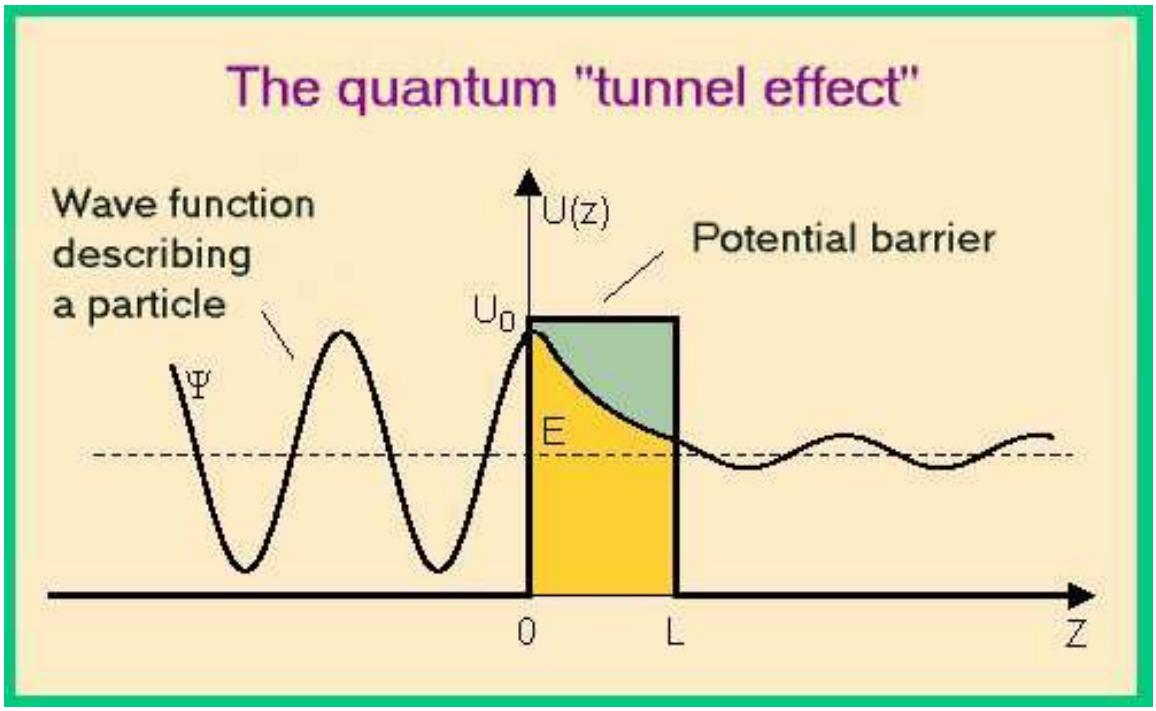
Even if I do not want boring you with the details of calculation, for the most common isotope of nickel, the $Ni^{58}$, the greatest Coulomb repulsion is, theoretically, at a distance between the center of the nickel nucleus and the center of the proton of about 7.2 fermi or "femtometer" (fm), thus – as, by definition, 1 fm = $10^{-15}$ m – it is equal to 7.2 x $10^{-15}$ meters. If the proton is able to approach the nickel nucleus at a distance less than this value, then the merger is inevitable, because prevail the nuclear attractive forces (the so-called "strong interaction"), which unlike the electrostatic forces act only on very small distances, where are dominant.[8]

The energy that must be provided to allow the overcoming of the Coulomb barrier, i.e. the energy that a proton should have to approach the nickel nucleus to the point of maximum repulsion, is about 5.6 MeV while, as we know from the *kinetic theory of gases*, the average kinetic energy ($K$) of a proton in a monatomic hydrogen gas at a temperature $T$ – given by the formula $K = 3/2\ kT$ (where $k$ is the so-called Boltzmann's constant) – even assuming a high temperature, e.g. 700° C, is just 0.13 eV.

Therefore, according to classical physics, a particle having a low energy can never pass through a so high potential barrier. In contrast, the modern physics provides, under the well-established theory of *quantum mechanics*,

[8] In nature there are 4 types of "fundamental interactions (or forces)", which are the basis of the energy exchanges between the particles: (1) *gravitational* forces, which are very weak and are carried by particles with mass; (2) *electromagnetic* forces, that are exerted by the particles with electric charge, and like the previous act at any distance; (3) the *strong* interactions, nuclear forces with a range of 1.4 x $10^{-15}$ m; (4) *weak* interactions, nuclear forces with a range of $10^{-18}$ m.

the possibility of the so-called "tunnel effect": in practice, it says that a particle has a chance, small but finite, of crossing a barrier of arbitrarily high potential, which is instead forbidden by old classical mechanics.




*The "tunnel effect", in quantum mechanics, is the penetration of a particle through a potential barrier of higher potential energy of the particle itself.*

However, the formula which expresses the probability *P* that a single particle can overcome the Coulomb barrier of the "target" nucleus (as a result of the *tunnel effect* predicted by quantum physics) was determined by the physicist George Gamow. And, applying it in our case of a proton having an average kinetic energy of 0.13 eV (thanks to a temperature of 700° C to which the reactor has been heated) and of an element as the nickel having a number of protons in the nucleus equal to 28, after a bit of calculations

which you can find in the article of Rossi-Focardi, provides as a result: $P = 4.7 \times 10^{-1059}$, a probability value so small that the "occasional" merger of a proton with a nickel nucleus is an event that almost *never* occurs.

## A look at the main types of possible reactions

Once that, in a way that we do not yet know, the proton represented by monatomic hydrogen has outperformed, despite the theoretical difficulties, the hurdle of the Coulomb barrier and is penetrated inside the nickel nucleus, must take place a series of reactions that – for the classical physics – are not particularly difficult to speculate.

In fact, the proton capture process by the nickel nucleus produces a nucleus of copper, according to the simple scheme (applicable to various isotopes of these elements, indicated with the generic *mass number*, *A*, equal to the number of "protons + neutrons" present in the atom):

$$^{A}Ni + p \rightarrow {}^{A+1}Cu$$

The copper nucleus, with the exception of the two stable isotopes of this element, $^{63}$Cu and $^{65}$Cu, can transform into nickel – so, at first sight, you go back to the initial situation, but in reality, of course, you get different isotopes with respect to the initial – through one of the following two possible processes (which have a different probability of occurrence):

1) *A "beta+" decay*. In practice, the copper nucleus decays into a nickel nucleus emitting two new particles, a positron ($e^+$) and a neutrino ($\nu$), according to the scheme:

$$^{A+1}Cu \rightarrow {}^{A+1}Ni + e^+ + \nu$$

2) *A so-called "electron capture"*. It consists in the nuclear capturing by the copper nucleus in an excited state – and thanks to this excess energy – of an orbital electron *K* of its atom; capture that gives rise to the following process, which involves the creation of a neutron (n) and an antineutrino ($\bar{\nu}$):

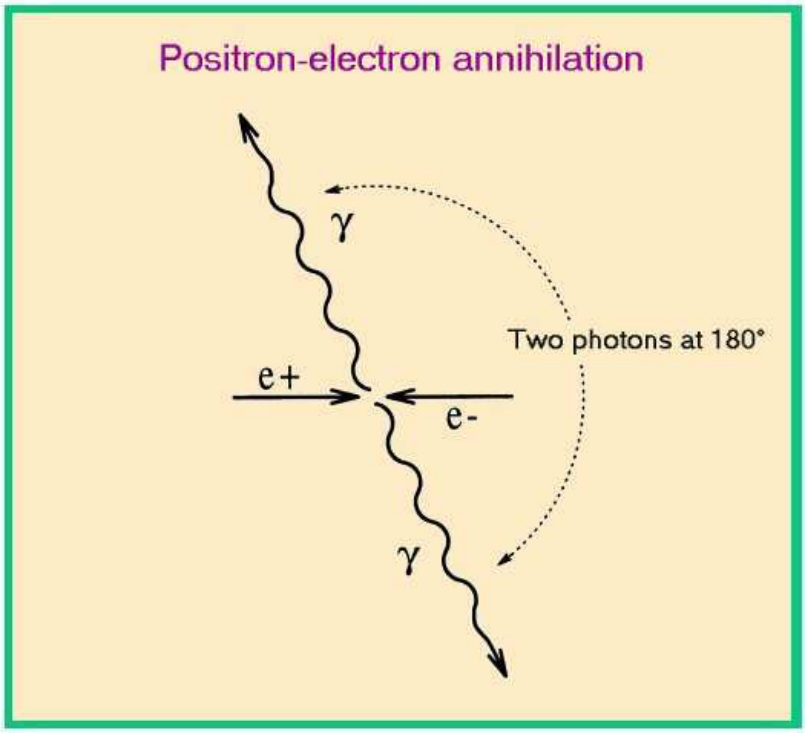
$$p + e^- \rightarrow n + \bar{\nu}$$

so the copper nucleus loses a proton becoming nickel and the copper-nickel reaction of process 1) is replaced by the following:

$$^{A+1}Cu \rightarrow {}^{A+1}Ni + \bar{\nu}$$

The *relative frequencies* of these two decay processes now illustrated – 1) beta+ decay and 2) electron capture – for the various copper isotopes are, generally, unknown. However, both processes allow to produce heat in the reactor, albeit in a different way. In fact, in the case 1), i.e. the beta+ decay, positron collides with an electron, producing two 511 keV gamma ray; while, in the case 2), i.e. the "electron capture", you have a chain rearrangement of electronic shells in the copper atom (going to occupy inner layers that remain free), with emission of low energy gamma rays.

The final result of the reactions is that, starting from the nickel isotope most abundant in the natural isotopic composition of this element – i.e. the $^{58}$Ni – through the two previously described processes " $^{A}Ni + p \rightarrow {}^{A+1}Cu$ " and then " $^{A+1}Cu \rightarrow {}^{A+1}Ni + something$", the formation of copper and its subsequent decay into nickel produces the isotopes $^{59}$Ni, $^{60}$Ni, $^{61}$Ni and $^{62}$Ni. The chain stops necessarily at $^{62}$Ni because, as we know, the $^{63}$Cu isotope of copper is (like the $^{65}$Cu) stable. The $^{64}$Ni, instead, is formed by the decay of $^{64}$Cu, which is an unstable copper isotope.




*The diagram of electron-positron annihilation, a phenomenon that produces a pair of photons at 511 keV of energy, headed in opposite directions.*

In summary, the proton capture – i.e. the capture of the monatomic hydrogen – transforms the nucleus of nickel isotopes in nuclei of copper

isotopes immediately below, as clearly shown in the following table (kindly provided by Lino Daddi, a physicist expert of LENR), where the stable nuclei are in black and the red characters distinguish the radioactive isotopes, i.e. unstable. The half-life of the latter is short, so as to enable them, decaying, to contribute to the heat produced in the reactor.

| | | | | | | |
|---|---|---|---|---|---|---|
| $^{58}$Ni | $^{59}$Ni | $^{60}$Ni | $^{61}$Ni | $^{62}$Ni | $^{63}$Ni | $^{64}$Ni |
| 67,6 % | $8\ 10^4$ y | 26,2 % | 1,25 % | 3,66% | 8 y | 1,16 % |
| $^{59}$Cu | $^{60}$Cu | $^{61}$Cu | $^{62}$Cu | $^{63}$Cu | $^{64}$Cu | $^{65}$Cu |
| 51 s | 24 m | 3,3 h | 9,8 m | stabile | 13 h | stabile |

*The table shows in which copper isotopes are transformed the isotopes of nickel, existing in nature or artificially produced, with mass number between 58 and 64.*

## A theoretical prediction later proved wrong

Focardi and the physicists collaborating with him were convinced that, being the most abundant isotope of nickel the $^{58}$Ni (68%), the latter, through the "obvious" reaction " H + $^{58}$Ni –> $^{59}$Cu ", created the unstable isotope $^{59}$Cu, which – decaying sometimes into $^{59}$Cu plus a *positron* and a neutrino through the cited reaction of beta+ decay – explain, at least in part, the production of excess thermal energy in the E-Cat.

In fact, the positron (also called "antielectron") is a particle of antimatter: into practice it is like an electron, which has the same mass but

positive charge while the electron has a negative charge. Since antimatter in our universe is completely unstable, almost immediately after being created any positron "annihilates" with an electron, producing two gamma rays (γ): i.e., the mass of the proton and of its anti-particle – the electron – is converted into energy in the form of two photons, each with an energy of 511 keV, which propagate in opposite directions.

Of course, we speak here either of gamma-ray and photons because, as is taught in high school, the *electromagnetic radiation* (an example of which are visible light, X-rays, gamma rays, etc.) has a *wave-particle* behavior, so in practice it can be seen, either as a wave or radiation of frequency $\nu$ or as photons, massless "messenger" of the electromagnetic force.

Rossi and Focardi have wished to test for the first time this theoretical prediction – the decay of the copper through a reaction involving the emission of two positrons – during the famous public demonstration of an operating E-Cat held in January 14, 2011.

Therefore, the collaborators of Focardi have made two holes in opposite directions on the lead shielding protecting the reaction chamber and have put, in such points, the probes of an instrument measuring the gamma rays, in order to reveal the possible peak of radiation at 511 keV, which would represent a "signature" of that reaction. However, no peak was observed, and this is why... probably it does not exist!

In fact, as explained by Focardi a few months later in a television interview: «Viewing better the literature, we found that the assumed reaction

is, in reality, very rare for copper: having an extremely low probability, normally it is not observed nothing». He confided to me later: «Our mistake was to make publicly that measure we had never done before».

*One of the detectors used to reveal the gamma rays at 511 keV. (From the report by M. Villa)*

This suggests there is still much work to do on the theoretical and experimental plan to arrive at finding the actual reactions that allow the *Energy catalyzer* to produce so much energy. And, of course, a theory for the E-Cat – or, more generally, for the Ni-H systems – can only be based on an extensive and accurate set of nuclear measurements (in particular, gamma

spectrometry and mass spectrometry), performed both during operation of the machine and also at the end of the reactions.

## Which theories on LENR are applicable to an E-Cat?

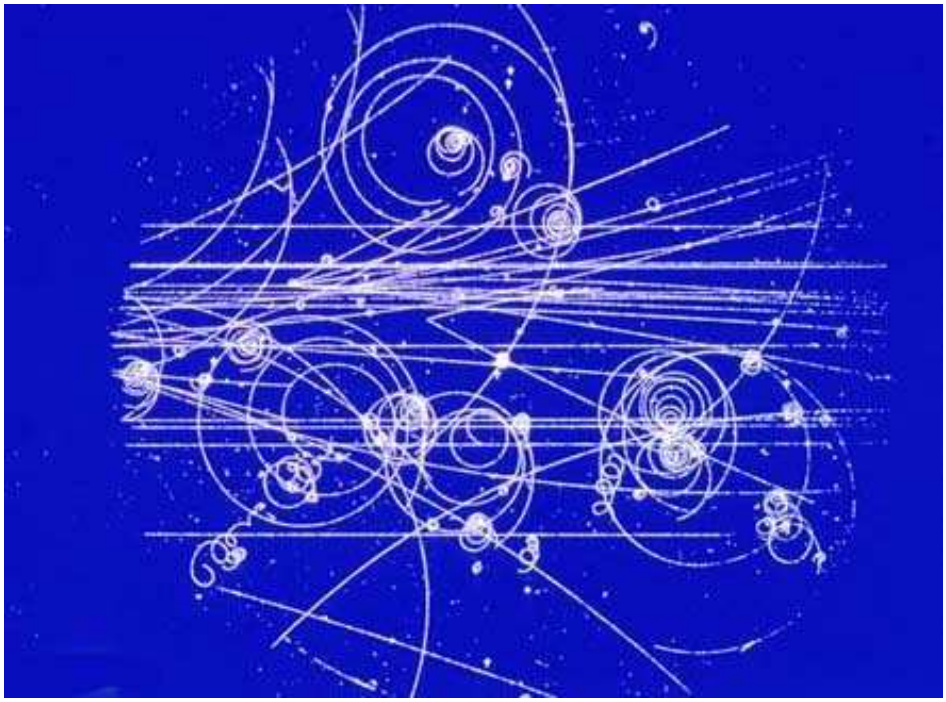
While waiting for future precise measurements on the reactor, some possible explanation of the reactions taking place within the *Energy catalyzer* may come from the numerous theories that have been formulated to explain cold fusion, or – as is more correct to say, because according to some of these theories there would be not a "merger" but a "transmutation" – the *low energy nuclear reactions* (LENR), or "lattice assisted".

After all, by many scientists around the world, dealing with nuclear reactions in condensed matter, have been proposed so far even over 150 different theoretical explanations, which must also explain – or at least should do, otherwise they are quite useless – the so-called "three miracles" of cold fusion, namely: (1) the lack of strong emission of neutrons, (2) the mystery of how the Coulomb barrier can be penetrated, (3) the lack of strong gamma-ray and X-ray emissions.

Among all these theories, that considered the best[9] – because it does not require any new or "exotic" physics and explains the "three miracles" – is the

[9] Not all the scientists, of course. According to Francesco Celani and some other physicists in the field, for example, the explanation of cold fusion is to be sought by applying to the metal lattices the *Paradox of Fermi-Pasta-Ulam*, discovered in 1953 through pioneering numerical simulations made with the computer MANIAC of the Manhattan Project. It describes the birth of a new class of solutions localized in time –

*Widom-Larsen theory*: a fascinating theory published in a peer-reviewed scientific journal, according to which the phenomena occurring in what is now vulgarly called *cold fusion* in reality are neither fissions nor fusions, but processes of nuclear "synthesis", which in any case occur only if there are very high energy density (of about $10^{11}$ V/m): this explains why they occur more easily in the small gaps created on nanoscale inside the materials.



*The collisions produced in particle accelerators, which advance our theories.*

The Widom-Larsen theory states that, in the excited hydrated metals, originate some special oscillating waves of electrons, called *plasmons*. These

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and, more generally, the onset of a behavior much more complicated than expected – for an anharmonic lattice subjected to localized non-linear excitations. This discovery has led, in fact, to the birth of non-linear physics, from which the theory of solitons, chaos theory, etc. will later derive.

are absorbed by the protons (monatomic hydrogen) and transformed into neutrons by weak nuclear interaction, a force acting on very small distances. Having no electric charge, these neutrons are easily captured by an atomic nucleus through the *strong interaction*. Then, it produces a cascade of unstable isotopes via beta decay, which releases gamma rays that, when hit the plasmons, are largely transformed into infrared radiation, i.e. heat.

However, when asked recently on the subject in some interviews, Rossi explained that it had, for the E-Cat, «a theory completely different from the Widom-Larsen, which is taking shape everyday thanks to the experience accumulating with the Energy catalyzer». He added: «when I'll be sure, I will write this theory, but for now I need to get more experience». And finally, he expressed appreciation for the recent article *Generalized Theory of Bose-Einstein Condensation Nuclear Fusion for Hydrogen-Metal System* by professor Yeong E. Kim (Purdue University, Indiana), «as it reflects an understanding of the basic principle behind the E-Cat better than the now prevalent theory of Widom-Larsen».

# Chapter 10 – Update: Recent developments

After I released the first edition of this book, many events happened and some of them deserve to be told, being relevant to the main theme of my essay. Not to mention that Prof. Focardi, here cited many times, on June 22, 2013 passed away, leaving on all of us who knew him an heavy legacy.

Meanwhile I knew personally Andrea Rossi and I encountered him sometimes: I was allowed to attend one of his rare private demonstrations with an E-Cat working in a totally self-sustaining mode and I was very impressed by his invention. Also Nobel Prize for Physics Brian Josephson encountered privately Eng. Rossi and appreciated him and his revolutionary apparatus, making later a public endorsement.

After a third party test on a high-temperature E-Cat made in the early 2013 by an international team of physicists, engineers and experts of electric measurements, a detailed scientific paper describing the results was released soma months later, “demonstrating” the not conventional nature of the

reactions involved in the machine and putting substantially an end to the last doubts around their reality or not.

*The Nobel Prize Brian Josephson, one of the best estimator of Andrea Rossi.*

We are entering in a new energetic Era, so the amount of documents and events regarding E-Cat and LENR are almost exponentially increasing. I cannot in this chapter enter in the details about all the many facts and results achieved in the last two years, but I will try to give the reader information needed to orientate himself.

## Towards the unveiling of the secret catalyzer

All of us would like to know the secrets of an E-Cat. In this book we discussed many aspects and information available on July 2011. But what is changed in the last two years? Have we new valuable information about the secret catalyzer?

The answer is «Yes» and «No» at the same time, in the sense that probably the answers to the previous questions are under our nose, but they could be not so easy to use for a not experienced research team trying to replicate the results. So, it is highly improbable that an amateur researcher with only a little of luck could obtain a huge energy gain, not having the help of a sophisticated equipment.

I don't know exactly which is the secret catalyzer used by Rossi in his E-Cat, but at least now I have a more clear idea about the possible nature of the chemical element constituting the catalyzer "added" in some way to the nickel powder in hydrogen atmosphere. My idea is based in part on facts publicly known but underestimated by the media, in part on private exchange of opinions with experts working in the field.

In the middle of 2011, the relationship between Andrea Rossi – and his Leonardo Corporation – and Defkalion GT (buyer of a regional license for E-Cat production) abruptly broke up: according to the well informed Christos Stremmenos, later author of many letters condemning the ethic of his countrymen presented to Rossi, the economic agreement had not been honored. But Defkalion had already come into possession of some secret Intellectual Property (IP) held by the inventor Andrea Rossi, as confessed by one of the protagonists himself in a telephone conversation with Eng. Mats Lewan, who published the relevant content on his magazine *NyTeknik*.

Well, on June 23, 2011 Defkalion presented publicly his Hyperion technology (originally developed in connection with the E-Cat and now as a competitor) for the first time. And the Power Point used to illustrate it showed in background, on the cover slide, the empirical formula for benzene ($C_6H_6$) and carbon rings of some benzene like molecules. Some careful observers found this fact quite interesting, because "officially" – and also in the following slides – carbon and benzene had nothing to do with the E-Cat or Hyperion technology. Other people interpreted this fact as a free imaginative choice made perhaps by a graphic.


*Defkalion's CEO (left) and the presentation with the molecules containing carbon (right).*

But surprisingly, in January 2012, NASA released a video reporting on how researchers at its Langley Research Center were working on developing energy from LENR: indeed, in the video – also posted on YouTube – NASA appeared for the first time publicly involved in researches on LENR. More surprisingly, nickel, carbon and hydrogen were mentioned by the speaker,

Dr. Joseph Zawodny (Langley Research Center), as possible materials for creating a reaction that NASA said was capable of providing enough energy to meet the needs of the modern world.

When I saw such a video and the word “carbon”, I literally made a jump on my chair. Indeed, it was the first time that carbon was mentioned by experts in connection with nickel and hydrogen. I was sure, because I followed the topic very carefully since one year, and I soon checked on the web, where I did not find such association. So, how could NASA know that carbon is an important element for LENR? How could NASA know something that did not appear on the web and in the scientific literature? And if, alternatively, it was a secret discovered by NASA itself, why make it public? The other interesting thing was that no one media noticed that: all had the unexpected name of a catalyzer under their nose, but nothing...

## When all the pieces fit in the puzzle

This sort of “outing” by the NASA is not at all strange. Indeed, it is quite reasonable that it was one of the many companies and/or institutions to which Rossi showed his E-Cat working in private tests in the course of 2011 or before, even if none of these led to a commercial agreement judged interesting by Rossi.

Moreover, according to some rumors that I received privately and probably reported also on the web by others, in the same year some US

scientists, presenting them officially as civilian researchers, came in Siena, Italy, to visit the laboratory of Francesco Piantelli (who had previously worked with Focardi on Ni-H reactions), because he had just claimed publicly new interesting results. And in 2012 Michael Nelson, a NASA researcher specialized on LENR, tested the Hyperion at Defkalion headquarter, in Vancouver (Canada), obtaining positive results illustrated in a report. On September 22, 2011 NASA held also a LENR workshop at its Glenn Research Center in Cleveland, Ohio, where many scientific contributes were presented.


*The NASA researcher who publicly cited the carbon in connection with Ni-H reactions.*

Ok, I imagine your main objection: these "coincidences" regarding the carbon are very interesting but they are not a proof, i.e. not enough, for example to start an extensive research. I could partially agree, but surely they

are already two important pieces of the puzzle. And there is a third piece of this part of the puzzle which is not public, so I can only make a short nod.

After I published the first edition of this book, I got in touch with some researchers on LENR and private companies who contacted me. So, I know directly that there is at least one good research group in the world that obtained a clear better performance using carbon in some (common) form in a nickel-hydrogen environment, in experiments carried out before that NASA made its surprising announcement. These results have not been published by the group of research, so they are not – and will not be – in the scientific literature. I cannot say more because I am not authorized, but this should be enough for a reader.

Finally, I would like to remark that, in June 2011, Rossi promised to publish a paper by Wladimir Guglinski in his blog *Journal of Nuclear Physics*, but then did not fulfill his promise. He also deleted the post from Guglinski and his promise to publish the paper too. Some people theorized that the paper may have not been published due to the fact that Guglinski mentions carbon as a possible – if not the best – catalyst for the E-Cat. Following this line of reasoning, Rossi could not publish the paper because he would had revealed the secret of his catalyzer.

So, the fact that the catalyst (or one of the catalysts) is a form of carbon is probably, at this point, something more than a mere speculation. However, no one appears to really know without a doubt the identity of the exact catalyst/s. Indeed, the carbon is an element that we can found in many

chemical compounds natural or artificial, thus the information about the possible presence of such element is surely useful, but not so much.

Guglinski himself thinks that probably the catalyst is a mixture of some elements, and he consider carbon one of them. So, there is need to know what is the correct percentage of each of such elements. According to the LENR expert Edmund Storms, Rossi hit upon this compound somewhat by accident: he was using a nickel catalyst to explore ways to make a fuel by combining hydrogen and carbon monoxide and, apparently, observed that his apparatus was giving extra energy; then, he explored the effect amplifying it in one or more years.

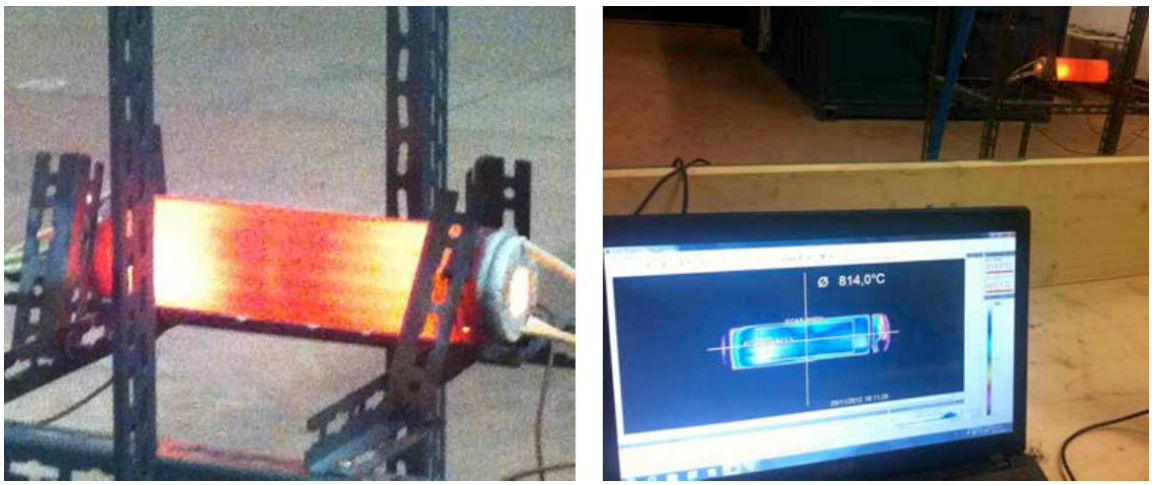
## Secrets of E-Cat: another brick in the wall

In these years Rossi, with only the already mentioned exception of his previous partner Defkalion, has well protected the Intellectual Property of his invention, also thanks to many public false leads he deliberately conceived to complicate the life to the competitors, as once he revealed in a private conversation.

So, little solid information has been provided by Rossi in the last years regarding the E-Cat technology. But a notable – and public – exception to this extreme secrecy is the very detailed and informative scientific paper entitled "*Indication of Anomalous Heat Energy Production in a Reactor Device Containing Hydrogen Loaded Nickel Powder*", by Giuseppe Levi et

al., published in May 20, 2013 on ArXiv. It is also remarkable that, among the seven signatories of the paper, there is also Hanno Essén, a theoretical physicist professor at the Swedish Royal Institute of Technology and surely skeptic par excellence, having been until 2011 president of the Swedish Skeptics Society.

The paper is the report of two long run tests (96 and 116 continuous hours, respectively) on an high-temperature version of the E-Cat, called "Hot Cat". In one of the two tests, the reactor produced 160 thermal kWh with only 35 electrical kWh provided in input, corresponding to a Coefficient of Performance (COP) equal to 5.6. The document showed also that the power density of the reactor was 530 kW/kg and the energy density 61,000 kWh/kg: compared to the conventional (i.e. chemical, not nuclear) energy sources, it was then easy to conclude that an E-Cat is an invention based on reactions completely different from the chemical, and at least 1,000 times more energetic.



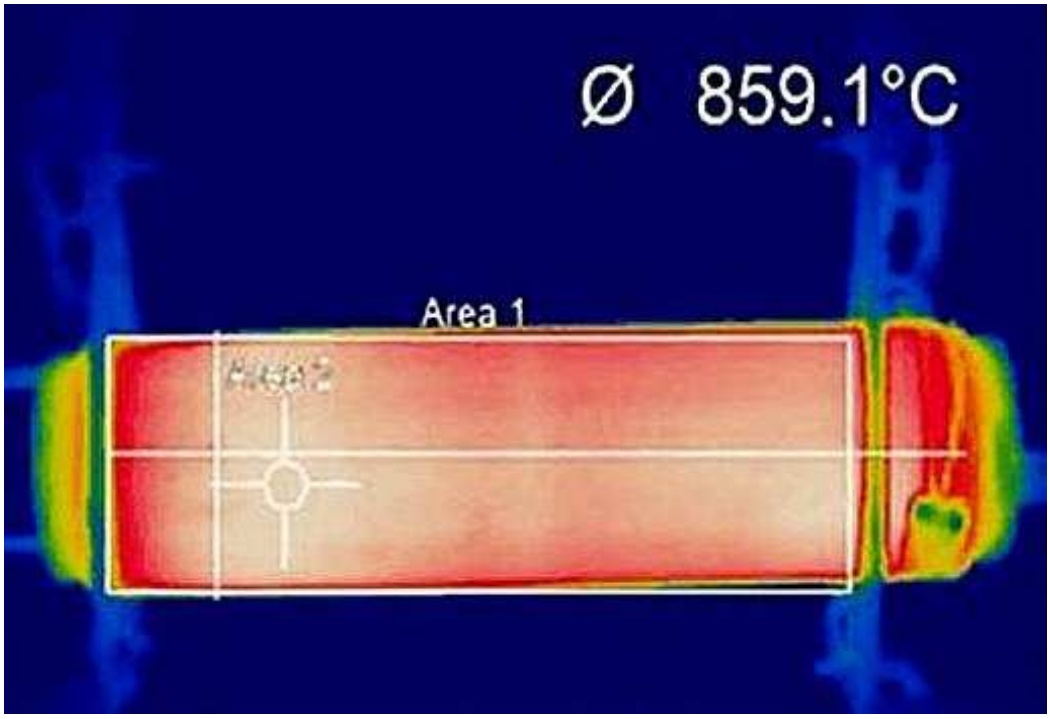

*Images from the tests of an high-temperature E-Cat performed in early 2013.*

Well, this third party research and the following article were probably authorized by Rossi as a sort of last "gift" to the friend and collaborator Prof. Focardi, already seriously ill. But the scientists involved were left free to write what they want in the paper, and this was an error: a researcher is not the best guardian of confidential information! So, the document contains many details on this new type of technology that normally would have been kept secret. If you want to make an idea of what I mean, I suggest to read the entire paper, but if you are busy don't worry: I have already done the work for you and I will show in the following lines what I found more interesting.

The first surprise is that the reactor is even simpler than the low-temperature version: a steel cylinder charged internally with a small amount of hydrogen loaded nickel powder plus some unknown additives kept as an industrial trade secret, for a total weight of the powders estimated (on page 22) in only 0,3 grams. The hydrogen is contained in patented tablets that release very small quantities (nanograms) as the temperature increases. The steel tube is surrounded by two ceramic layers – the innermost of which containing the electric heating resistors – and by a larger external steel cylinder. The reaction is primarily initiated by heat from the 16 spiral-wire resistor coils inside, and once the operation temperature is reached, it is possible to control the reaction easily by regulating the power to the coils.

On page 3 of the paper, we find a new relevant information: "The resistors are fed by a Triac power regulator device which interrupts each phase periodically, in order to modulate power input with an industrial trade

secret waveform"[10]. As the authors themselves specify, "this procedure is needed to properly activate the E-Cat HT charge". Well, this is an important news, because it is the first time that officially appears on the scene a waveform generator, although this kind of device had been noted on previous public E-Cat tests by some careful observers, as reported by the related detailed chronicles, easy to find on the web.




*Thermal image of an high-temperature E-Cat (said also "Hot Cat") in operation.*

[10] As pointed out on page 15 of the cited paper by Levi et al., the second E-Cat tested has been powered not by a tree-phase and Triac power supply as the first E-Cat, but by a single-phase power input: the Triac has been replaced by a control circuit having a three-phase power input and a single-phase output, mounted within a box, the contents of which were not available for inspection, being part of the industrial trade secret.

## A detailed recipe for a revolutionary technology

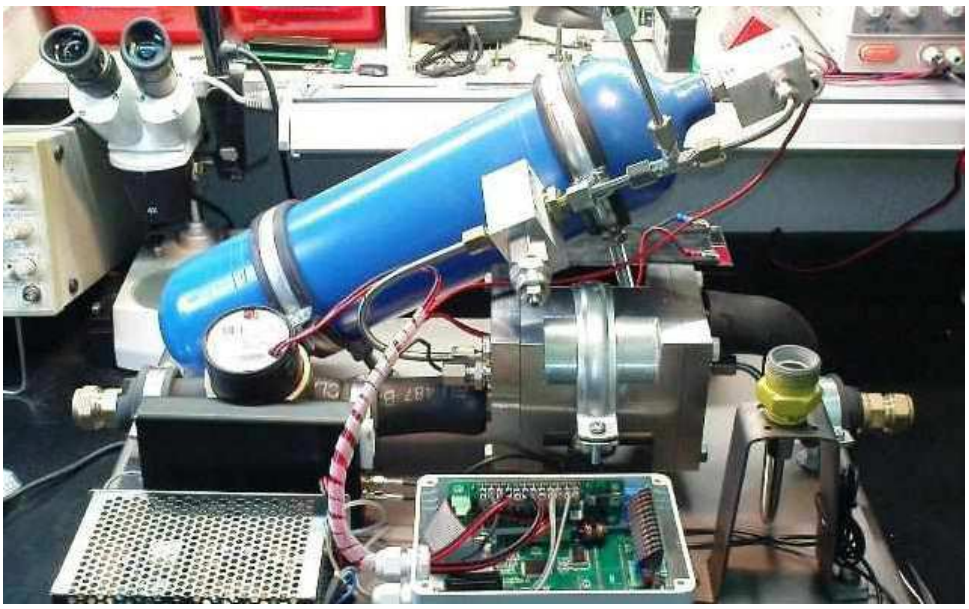
If these written leaks seem interesting and surprising, they are absolutely "nothing" compared with the amount of technical details and insights provided in the last two years by Defkalion GT, mainly in official documents like product datasheets, Power Point presentations, public tests and so on.

Due to the vastness of materials and themes, here I will only summarize the main points and the related sources of data. I would like to stress that, even if an E-Cat and an Hyperion are in some little aspects different devices, they have a common origin. Moreover, while Rossi has always created false leads, the cited scientific paper and the many documents released by Defkalion seem to be, on the contrary, completely genuine, and thus a valuable source of information for all the teams interested to replicate such technology. In my opinion, providing many confidential data to increase its credibility, Defkalion adopted a virtually suicidal "I-have-nothing-to-lose" strategy.

In the 21 pages long specification datasheet of 5-45 kW Hyperion pre-industrial prototypes, published online by Defkalion on November 2011 (you can download a backup of the file from PESN), we find already important information about the reactor and its many subsystems. Moreover, the document mentions, but not disclosing further details: (1) a proprietary method for (mono)atomic hydrogen generation embedded within the reactor's structure; (2) proprietary catalysts involved in the reaction; (3) an electric power preheating (phase I) but also a chemically assisted preheating

(phase II). As you can note, points (1) and (3) deserve attention because they are a partial "news".

But, in my opinion, the most interesting part of this datasheet regards the row material used for the nickel powder. Just some weeks before, I came to the conclusion that Rossi had probably used filamentary nickel, which has a well defined dimensionality. So, you can imagine my big surprise when I read in the datasheet that the sub sieve particle size was 3-7 microns, thus partially overlapping – regarding dimensionality – my hypothesis: it was the first time we had an official and precise info about this aspect! In the same document, you can find also the chemical composition of the nickel powder used by Defkalion. It is prepared with a balance using a proprietary method, then chemically cleaned ($CHCl_3$) and later thermal and vacuum cleaned.



*One of the first images released by Defkalion of an Hyperion - 5 kW basic unit.*

In August 2012, at the NI Weeks organized in Austin (Texas) by the National Instruments, Defkalion GT released a technical presentation signed by John Hadjichristos, Defkalion's Chief Technology Officer (CTO). It was a Power Point, entitled "*Defining a New Source of Energy*", stressing on LENR as a geometrical and a material problem, and extraordinarily rich in confidential details. For example, in slide 15 it mentions – for the first time – the use, in their Hyperion reactor, of a Plasma Ignition Method (DC pulsed at 24 kV/22mA at some kHz) to produce glow discharges in a high pressure (2-8 bar) hydrogen envelope, by special shaped tungsten and Titanium-Zirconium-Molybdenum (TZM) electrodes.

The "experts", however, will find many other relevant information in this precious Power Point: (1) the glow discharges serve to break $H_2$ into atoms and to "excite" them to their Rydberg State (RSH), so that behave like a dipole; (2) for a period of $10^{-13}$ seconds, each RHS proton is very close to its electron, then the RSH nucleus is a masquerade neutron and can easily penetrate the Coulomb barrier of a nickel nucleus; (3) the RSH dipoles can be polarized and "guided" intact to the target, a "Nuclear Active Environment" (NAE), through the magnetic fields created by the plasma current; (4) at the end of the slides, are shown the results of a transmutation analysis before reaction and after run.

Finally, it results clear why the multistage reaction cycle depends on geometry. According to the Power Point, the Nuclear Active Environment – characterized by a surface of 48 $m^2/gr$ – is created by: (1) a nickel foam

obtained by the raw material previously cited in the datasheet; (2) several layers of other "agents" (ZnO, MgO, $ZrO_2$, etc.), whose function is to help RSH atoms to survive in the journey towards the NAE; (3) the agents are coated around a Si-Al ceramic surface surrounding the nickel foam. So, in an Hyperion the (2)-(3) are likely the "chemical" catalyzers, which in a E-Cat (or in a simpler reactor) could be replaced by carbon-based materials, supposedly nanostructured with appropriate techniques. Thus, now the circle is virtually closed.

## A New Physics and the quest for a Nobel Prize

But the surprises were only at the beginning. In practice, it was the opening of Pandora's box. Andrea Rossi and especially his new big American partner – to whom he had sold in autumn 2012 the intellectual property of his invention – had been warned.

On July 23, 2013, Defkalion performed on an Hyperion the first real public test that could be followed by streaming. During the very long continuous commentary made by Hadjichristos, lasted several hours, he revealed other confidential details that I wrote on my notebook. Among them: (1) the preheating temperature before the triggering with the plasma-glow discharge method was 175 °C (≈ the Debye temperature for nickel); (2) the characteristics of the high voltage used were 10 kV and 119 mA, and the discharge absorbed about 1 kW every time, but only 200 W as average value;

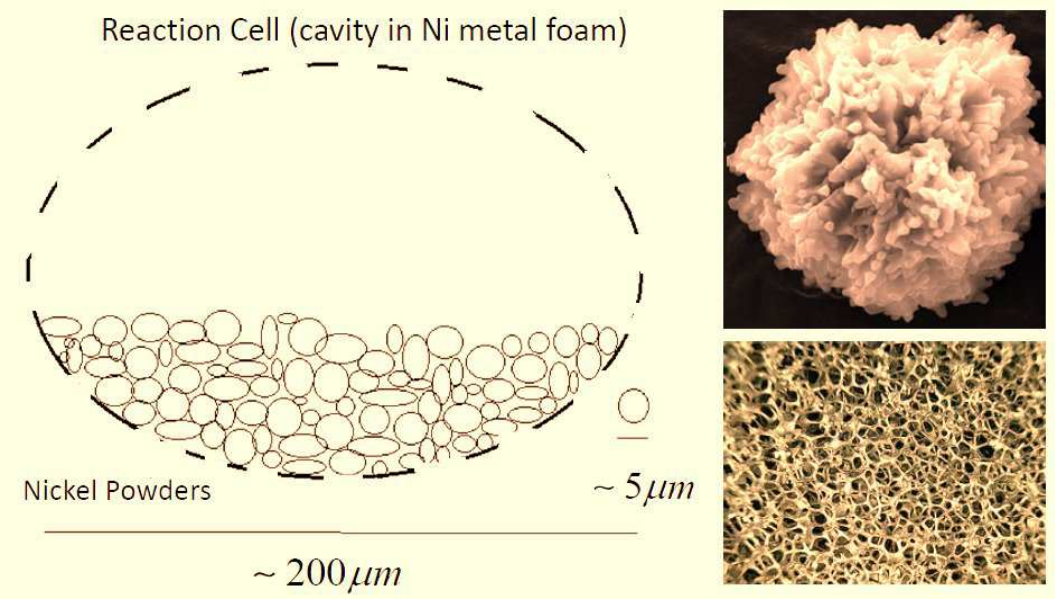
(3) the hydrogen pressure in the Hyperion was, at the beginning, of 1-2 bars (so, Focardi-like values), but then rose to 3-4 bars due to the temperature increasing inside the reactor.


*The public test of an Hyperion performed by Defkalion on July 23, 2013.*

Only a few days later, professor Yeong E. Kim (Purdue University) and Hadjichristos put online a scientific paper entitled "*Theoretical Analysis and Reaction Mechanisms for Experimental Results of Hydrogen Nickel Systems*" and also a summary Power Point presentation with the same title, prepared for the ICCF-18 Conference held at the University of Missouri. Here, we read other interesting information: (1) the thermal output is modulated by varying the duty cycle of the trigger pulse; (2) the transmutations reactions involving nickel may not be dominant reaction mechanisms but could be only part of much weaker secondary reactions; (3) the excess heat was

observed in Hyperion only with the even isotopes of Nickel ($^{58}$Ni, $^{60}$Ni, $^{62}$Ni, $^{64}$Ni), not with the odd isotope $^{61}$Ni.

The authors explain that the reactor contains a nickel foam with many empty "cells" or chambers, each with average diameter of ≈200 μm, whose function is to protect the reacting nickel powders from the high temperatures around the glow discharges. Nickel powders consisting of "modified" nickel crystals of about 5 μm are inserted into these cells prior to the normal operation of an Hyperion. The lattice of the nickel crystals has been previously restructured, through a proprietary technique, to convert the normal Ni face centered cubic crystals to a C4 or a Pm3m structure, removing all of the face atoms and some atoms in the edges: this nano-restructuration makes the nickel crystals less "dense", allowing them to act in a LENR reaction as wished.




*The "Nuclear Active Environment" formed by both the nickel foam and powders.*

According to their work, the magnetic fields generated by the internal triggering could provide magnetic alignments of nickel atoms on localized surfaces of nickel powders. So, these external magnetic fields could provide, for a short lifetime, localized magnetic trap potentials for Boson clusters. Indeed, Hydrogen Rydberg atoms, trapped in a localized magnetic trap due to their magnetic moments, are paired to form Bosons, thus aiding the formation of Boson Cluster States at temperatures higher than Debye's. Thanks to some evaluation about the observed reactions rate, it has also been argued that the self-sustaining reactions rate could be improved by increasing the deuterium density.

Finally, the scientific paper resumed by the Power Point detail the important discovery of very strong magnetic fields (≈1,5 Tesla at 20 cm from the reactor) correlated to the excess heat generation. They are probably created by super-currents and open up a possibility of direct conversion of excess heat generation to electric power. This super magnetic field is a completely new phenomenon and represent a new scientific discovery. It had been observed also in the E-Cat reactor by Andrea Rossi, who publicly mentioned the topic on his blog only in the early 2013, and in 2011 – as I know through private information – by another first class researcher operating in USA on LENR (but he has not made public his discovery, so I will not unveil the name).

At this point, it should be very clear to the reader that we are on the edge of a big revolution in two fields – the first theoretical, the second practical: the physics of condensed matter and the energy production. So, being the "super-nanomagnetism" a discovery not less important than the superconductivity, it is not difficult to predict one or more Nobel Prizes in the next years. I don't know who will be the winners, but one thing is sure: the E-Cat is an Italian invention, and the name of Andrea Rossi will probably remain in the History like Leonardo da Vinci, Galileo Galilei, Alessandro Volta, Antonio Meucci, Guglielmo Marconi and many others brilliant Italian inventors.

# Acknowledgments

At the moment of the acknowledgments, the first goes to a protagonist of our story on the E-Cat, Sergio Focardi, who not only granted me a long interview on a hot and muggy summer day, but he has also been generous with his explanations and clarifications in several private conversations.

I had the pleasure to know, even if at the beginning only by e-mail and phone, also Andrea Rossi, who has always been extremely helpful in spite of the little free time that his work leaves him, so I thank him for this.

I am also grateful to the likeable Francesco Celani, which is not only an excellent experimental physicist appreciated at international level – so much that he has been Vice-President of the *International Society of Condensed Matter Nuclear Science* (ISCMNS) – but he is above all a valuable source of news, anecdotes, curiosities, etc., on the cold fusion. In numerous pleasant telephone conversations, as well as in person in Viareggio, I could clarify and exchange views on many of the topics covered in this book.

Another unexpected help, particularly for information regarding the nuclear reactions, was provided by Lino Daddi, former University professor and expert in reactor physics, neutron and nuclear measurements, who has been involved in cold fusion and low energy nuclear reactions since 1989, signing some scientific articles with Focardi.

I would like also to extend a sincere appreciation to Daniele Passerini, for how he conducts its useful work of blogger specialized in following the events regarding the E-Cat, often sacrificing hours of sleep; and even Roy Virgilio, for his book *Cold Fusion*, which has been a valuable source of information when I approached the topic for the first time.

Also, I have to give a special thank to Claudio Puosi, Vessy Nikolova, Fabiano Pallonetto for allowing me to undertake the adventure that, from the conference in Viareggio, has led me to this essay, and in particular for having, indirectly, "forced" me to explore these issues.

Finally, even if this book took only a few months of work compared with my longer and more complex previous essays (I am a physicist but also a science writer), I would like to dedicate it to one person and real friend, whose name is Jovy.

# The author

**Mario Menichella**, physicist and writer on science, after graduating with honors as Master of Science Communications, for which he attended the International School for Advanced Studies (ISAS) in Trieste, Italy, worked in Rome as press officer at the headquarters of the National Institute of Nuclear Physics (INFN). He is currently working on spreading the various highly innovative energy technologies that will allow the transition of our society towards a so-called *green economy*. He has published several papers in international journals and has written, in Italian, over a dozen essays and popular books, including: *Interstellar Travel* (Cuen, 1999), *Searching for E.T.* (Avverbi, 2002), *Profession Scientist - Parts I and II* (SciBooks, 2005), *Future Worlds* (SciBooks, 2005) and *Profession Popularizer* (SciBooks, 2006).

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