FACES OF LENR

Part 5A: Design and Operation Principles of LENR Reactors

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Introduction to Part 5A

Parts 5A (herein) and 5B (forthcoming) discuss the dominant types (faces) of LENR reactors:

1. Heat generating reactors, triggered mainly by fission, induced by cracking (hydrogen corrosion) of the lattice. The Pons-Fleischmann cell belongs to this group. (Part 5A)
2. The second reactor group is dominated by transmutations of even heavy elements; it is marked by rotating charged dust particles. (Part 5A)
3. The third face of LENR is dominated by electric energy generation by surface plasmon and condensed plasmoid-based reactors. Their technical layout and energy extraction methods are also discussed. This is applied physics and engineering. (Part 5B)

All this will hopefully give readers a firm grip on the methods of catalytic fusion. The final aim is to provide skill for readers to design and operate their own reactors. (Part 5B)

By then, the diligent reader will grasp the fundamental physics of catalytic transmutation machines and processes. It will enable readers to design and operate cold fusion reactors, though the rotating ATP-ase enzyme and proton pump complexes can't be surpassed—ever. (It is self-reproducing as well.) Heat generating and transmutation reactors will be discussed in Part 5A, because the list of LENR reactor types is long. Type 3, electric energy generation reactors, will be discussed in Part 5B, due to the length of this subject.

Part 5A and 5B are the culmination of this series of papers. Four major unexplored/unknown auxiliary effects of LENR have already been discussed in the previous parts.

In Part 1, the extension of electrodynamics was accomplished by including rotation. Thus the formation mechanism of condensed plasmoids as torus-like heavy quasi-particles was described. (The engineering aspects will be discussed in Part 5B.)

In Part 2, rotating charged dust particles were described as a means of the most simple LENR processes in nature; it is the means of energy production in the solar corona, and the ATP synthase, to turn deuterium and carbon into nitrogen.

In Part 3, electrodynamics was extended to include a generalized Lorentz force, capable of teleportation. This may explain transmutation/fusion of heavy nuclei, and the Hutchison effect.

In Part 4, the rich features of ether were described. It was claimed that ether consists partly of neutrinos as a frictionless superfluid at macroscopic distances. At subatomic distances, ether is a randomly oscillating high-density medium, made of electromagnetic oscillations. No isolated system can exist due to its high penetration capability. Therefore the rules of thermodynamics are just approximations, not laws.

It was shown that weak interactions, the cause of radioactive decay, were due to the change of vacuum fluctuation intensity. Further, the Cook-Dallacasa model shows the binding forces of nucleons are due to magnetic forces just as magnetic dipoles attract each other. Consequently, there is no need for separate weak and strong interactions.

Myths of LENR

The field of LENR research today is based on four tacit assumptions:

1) LENR is restricted to bulk condensed crystalline matter, and is a lattice enabled phenomenon. Semiconductors, amorphous matter and high mass elements like tungsten, bismuth and their alloys are ignored in these considerations. This notion is restrictive and counterproductive.
2) The faces and aspects of LENR processes can be addressed within (advanced) textbook physics. The first four parts hopefully discredited this hideous idea.
3) Transmutation in biology does not need to be researched as earnestly as in inanimate nature (physics). In my opinion, the boundary between physics and biology is artificial due only to our ignorance. The study of biological transmutation adds to our understanding of nature.
4) LENR generates excess heat only, mainly by fusing deuterium into helium. Part 5A and Part 5B will show that LENR appears on a much wider area having important practical applications.
5. The other, broader and most dangerous tacit social assumption is that "market capitalism" in R&D will always bring forward the most economical technical solutions and the best ideas due to fierce competition in industry and science. This has never been true. The financial and political might of the incumbent technology usually killed or made nearly impossible the replacement of the old solutions.

James Watt, who invented the rotary steam engine in 1782, was unable to draw any investment to develop a proper seal to make this product ready for mass production. The small company LiquidPiston solved the sealing problems of rotary Wankel motors, but struggled for R&D funds for the internal combustion engine (ICE). (See Figure 1.) There are several similar inventions, like opposed piston engines.

Tens of thousands of research and design engineers have mass produced piston-based ICEs based on steam engines. Hundreds of millions were manufactured. The rotary ICE offers five to ten times more power density, with less production cost, and less gas consumption. It demands much less oil, thus makes less pollution.

This is the problem: any threat to high oil consumption is met with an immediate, stiff reaction.

Hot fusion in any form is not a threat, because it will never work for fundamental reasons, so will never compete with oil. LENR is the only real threat due to its economic potential.

The physics in all previous four parts will be used because LENR reactors cannot be understood, designed and operated without them.

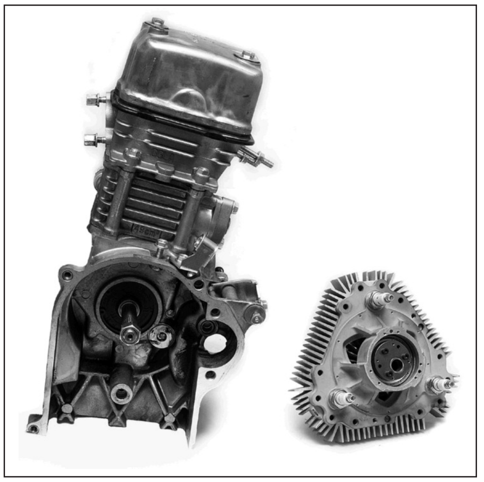


Figure 1. Comparing a rotary internal combustion engine to the usual piston and crankshaft type 4 stroke engine of the same power. The power density is 1:10!

The erratic, unpredictable behavior of most LENR reactions definitely demands an insight into the details of their operation.

Good questions are the first step on the path of enlightenment. We have a list of the most relevant ones. They were collected by David Nagel, the living conscience of the field, in *IE* 118.[1] Nagel listed twelve important questions which will be among the guiding lines through Part 5A and Part 5B.

The first major question: Is there only one or *more than one* physical mechanism active in LENR experiments?

In the first four parts of this paper we explored the necessary auxiliary effects needed to comprehend LENR. There might be more of them, but we attempted to explain LENR within this extended framework. Edmund Storms has criticized the existing numerous theoretical models (all within the limits of textbook physics) as being inadequate.

The rest of the questions will be discussed later, when detailing specific LENR reactor designs and operations.

The parochial narrow-mindedness and hostility of the hot fusion community, and the stiff censorship of LENR publications/patenting backed by the interests of the oil industry, is a problem too. Therefore we must find answers for Nagel's question ourselves, without external help.

This is apparent for us, but unknown to the taxpayer. The ban of publications and patenting is well organized; only Italy managed to avoid it—partially. Likewise, electric vehicles have successfully been crushed by piston ICE engines for a century, just by sheer muscle.

So the remark, "If LENR were so good, we would have already seen it as a product" is just plain wrong! Capitalism is optimized for generating maximum profit, not for efficiency. (The same is true for any industry.) This is very dangerous for the environment.

In contrast to this, there is a real competition for new solutions in life to carve out an edge, a method for survival in biology. This is the seldom told background of LENR research.

Researchers frequently err by falsely mixing the *discovery* of a new effect with an *invention*. A newly discovered effect always lacks the perfection or sophistication of an invention, which is required in industry.

Pons-Fleischmann, Correa and Shoulders rushed for the patent office. The effects were not yet reliable and/or competitive in the market. The high efficiency, reliability and know-how was simply not yet there.

Yes, this is a "catch-22" situation: there is less chance for R&D investment without a secure patent.

Tesla, Moray, Papp, Jekkel and Gray passed this first trap but other further traps prevented their progress. The careful design and operation of LENR reactors opens vast new opportunities to improve upon the catalytic fusion effects to make marketable products.

LENR Reactors Based on Light or Heavy Water

There are many electrolysis-based LENR reactors (cells), but only the most interesting ones will be discussed. Most experiments and patent applications are based on this method.

Liquid water-based LENR methods are summarized and compared in Table 1. Note that the bulk of transmutation methods/efforts has been devoted to this area. Not all experimenters and results are mentioned, because there were more than a hundred high quality tests to replicate the heat

Table 1. LENR methods based on water.

Inventor	Electric Voltage	Isotope of Hydrogen	Cathode	Yield	Parkhomov's Limit?
Pons-Fleischmann	DC < 10V	D_2O heat	Pd	COP<50%	no
Patterson	DC	H_2O heat	Pd	COP>50%	no
Meyer	AC pulses	H_2O oxygas	Fe	COP>50%	no
Horvath	AC pulses	H_2 oxygas	Fe	COP>>50%	no
Graneau	AC pulses	H_2O + D_2O mixture	C	COP>50%	yes
Ohmasa/Brown	AC pulses	H_2O + D_2O	Cu	COP?	yes
Biological transmutation	AC pulses	H_2O	not applicable	?	no

generation/transmutation results.

It is apparent that there are a wide variety of physical processes and engineering designs in LENR reactors, and it is difficult to make order in this chaos. One must make order along the reactor design purposes and physical processes as well; all of them are different faces of LENR. (Part 5B will compare plasma-based technical solutions known by the author.)

There are two major hidden parameters in Table 1, as noted before. When overpotential is used in electrolysis, there is a possibility of tiny local *spark formation* as well, around local tips on the surface. This is a trap, because this hidden parameter may explain the success or failure for Patterson, Meyer, Horvath, etc.

None of the above inventors thought that small protrusions of the cathode, due to the preparation/manufacturing, is a decisive factor. Small sparks around peaks inside H_2O bubbles may form condensed plasmoids, and thus catalyze transmutations, but this is not visible during operation.

John Bockris warned that *overpotential* was necessary for transmutation and excess energy. Giuliano Preparata also warned the LENR community to use pulsed current at ICCF6.

However, no one considered surface quality or tensile strength, ductility or brittleness as an influencing factor. This "engineering data" approach is unknown to the most influential researchers in the field. For example, Peter Hagelstein *et al.* approached LENR as a bulk cathode phenomenon based on phonon modes (WO/2006/055294). I wonder if they ever built the reactor described in the patent application. R.E. Godes has a more practical approach along the above lines as well (U.S. Patent 2011/0122984). It seems he did build this sound driven reactor, but he made sure that no useful data would appear in the patent description.

The handful of people in the nuclear research area who learned anything about LENR are familiar only with the Pons-Fleischmann process. In the past 30 years it has remained only a research area, not a dream machine of green energy. This has a fundamental reason. The process, which is electrochemistry below the boiling temperature, is not fit for economic application, just like hot fusion, though the former is a much better stepping stone. In general, the issue of spin-based selection of hydrogen diffusion into the lattice is absent. The influence of ortho and parahydrogen (spin alignment) never appears in LENR related papers. (See Part 1 for details.) These spin-based features were forgotten both in physics and in biology, although their strikingly different physical properties were discovered in the 1930s. S.B. Chambers invented a method to make them separately (U.S. Patent 2000/6,126,794). This method is based on pulsed electrolysis, similar to some LENR reactors of Stephen Horvath or Stanley Meyer.

There is a striking difference between LENR reactors and fossil fuel, nuclear fission or hot fusion reactors. The latter are all controlled chain reactions (boilers, furnaces, ICEs, etc.)

The Fundamental Difference Between Hot and Cold Fusion: Catalysis

Physicists, the designers of hot fusion reactors (both inertial and magnetic confinement), took it for granted that a chain reaction would work for fusion. This was so obvious for them that they never even considered catalysis as a matter worthy of consideration. They couldn't be persuaded otherwise. Consequently, they were already doomed at the very first step of their designs without catalysis, and the rest is eternal agony.

All LENR reactors have one common feature: they are based on catalytic effects. That is, an LENR reactor is more similar to fermentation reactors, for example to a beer brewery, than to a furnace fired by oil or gas. The principles of microbiology (enzymes) are more relevant for us than those of the standard power engineering based on a chain reaction. *These design views are worlds apart*, inmiscible. This is why all hot fusion reactors will always fail, no matter how one increases the confining magnetic field, or the symmetry of pellet compression. A fundamentally flawed design concept cannot be corrected with proper engineering or better parameters. Nature has a storehouse full of plasma instabilities. There will always be a new, unexpected one.

The fact that the H-bomb works has nothing to do with the controlled fusion, as the H-bomb is *not* a controlled process. There is *no controlled hot fusion in nature* at all, as shown in Part 2 regarding the mechanisms of stars.

It is possible to produce alcohol from scratch, in principle, from hydrogen and carbon, though it would be very difficult and expensive. Inorganic alcohol can be produced with discharge plasma, but at a staggering cost. All kinds of alcohol are produced organically in practice, with yeast as catalyst.

The art of LENR reactor design starts with selecting and refining catalytic phenomena. There are a handful of them fortunately, shown in Parts 1, 2, 3 and 4 (the neutrino flux).

Three Different Faces of LENR Catalysis

Three major groups of catalytic processes will be described:

1. Neutron-catalyzed fusion in a lattice: Metal lattice vibrations caused by cracking due to hydrogen diffusion, or hydrogen corrosion, led to fission. Fission yields neutrons participating in fusion.
2. Rotating charged dust as a catalyst: Dust fusion, when rotating, charged particles generate electric, magnetic and spin fields as a catalyst. (See Part 2.)
3. Condensed plasmoids and plasmons as a catalyst: Quasiparticle catalyzed fusion characterized by the combination of surface plasmon waves and condensed plasmoids. (The latter is not known in textbook physics.) They are formed only in transient plasma microdischarges, a barely researched area of plasma physics. (See Parts 1, 2 and 3.)

What are our tacit assumptions from now on? Some of them are: energy and electric charge are conserved, though linear and angular momentum may change slightly due to meddling with ether.

There is a dire warning to the readers though: the above three catalytic fusion processes require more sophistication and more know-how than hot fusion reactor design (based on textbook physics). This area is the home of multilevel, nonlinear phenomena, making mathematical simulations impractical.

Ignition, and self-sustained energy production, has already been achieved by several LENR reactors, but never by hot fusion ones. All the nitty-gritty know-how was lost for the best catalytic LENR reactors during the last century. This makes it so hard to re-create these lost reactors.

A personal note before we start in earnest. This author had the motivation to write this paper because of his 30 year experimental background with all major LENR reactor types:

— Lattice fusion by the Patterson-type floated bed electrochemical reactor and underwater sparking-arc reactors.
— Dust fusion reactors, published in several *IE* papers.
— Quasi-particle driven LENR reactors, like Correa, Chernetzky and early (too early) attempts of the Moray-Tesla experiments.

I spent 20 years in pressurized water reactor (PWR) nuclear research. The judgment summarized in this paper is based on my own experience. Other researchers may come to different conclusions. At the beginning I spent about 20 years reading and selecting forgotten patents and tracking down strange inventions. This work has been published in three volumes, in Hungarian.

Practical Applications

There are three major areas of technical applications for LENR reactors:

1) Heat production by hydrogen and heavy hydrogen fusion.
2) Transmutation of lighter elements into heavy ones (dust fusion, alchemy, biological transmutation).
3) Electric/chemical/mechanic energy production by hydrogen fusion.

There are no sharp boundaries between the applications. Namely, electricity generation devices, or transmutation reactors, may produce some heat as a side effect. Further, the three different physical LENR mechanisms discussed previously may appear together.

Heat Production

The Pons-Fleischmann (P-F) electrochemical reactor, along with others, shows that several processes contribute to heat production. So it is a series of effects, not a single step event.

The Patterson cell beads were analyzed by George Miley, who found a host of transmutations. As stated before, this method lacks the necessary neutrino flux due to the low temperature (restricted by boiling of the electrolyte), and therefore its thermal output (thus its commercial capability) is negligible.

It is the firm, personal opinion of this author that the electrolysis-based development path is a "dead-end street." In some instances when the electrolyte evaporated, and electric current was stopped, there was a runaway, self-sustaining effect termed "heat after death." Certainly, as heat inside the core increased, neutrino flux increased, too. This could lead to a positive feedback loop, leading to the melting of the core. This could have been a warning about the importance of the temperature, but it fell on deaf ears.

Another thing that is much harder to recognize is the physical and mechanical state of the core.

Edmund Storms correctly felt that cracks somehow took place, and had an essential and maybe a catalytic role in the fusion part of the process. Nevertheless, he missed the importance of lattice acceleration.

The transmutation products clearly show that there is a fusion process at least by fusing a proton. This process was aided by the "Parkhomov bottleneck," the enhanced thermal neutrino flux. (See Part 4.)

What makes protons and electrons fuse in the presence of thermal neutrinos? Because their presence alone is necessary, but not enough. Otherwise all tungsten lighting bulbs would act as fusion reactors, as there are always some protons there due to the diffusion of water through the glass of the bulbs!

It is likely that lattice oscillations aid, and catalyze, this process in the form of charge waves, or surface polaritons. The lattice oscillations were suspected behind LENR by Peter Hagelstein and Mitchell Swartz, beside others, but it was left to nature to do it.

Pons-Fleischmann Type Electrochemical Cells

The Pons-Fleischmann process has both faces of LENR: fission and fusion.

Fission is due to the fission of palladium, as a consequence of the diffusion of hydrogen into the lattice. Carpinteri *et al.*[2] proved that the cracking of any solids, amorphous and crystalline, yielded very high frequency, mechanical lattice vibration, which in turn resulted in nuclear fission. This is surprising, counterintiutive and not widely accepted, but is based on solid experimental evidence. However, there are no mighty hydraulic presses anywhere in LENR. Further, why do lattice vibrations cause fission of a stable nuclei well under the mass number of uranium?

One may speculate that this is due to the excitation of the vacuum spectrum, from extremely high accelerations induced by cracking. Pons and Fleischmann, and nearly all researchers, assumed that deuterium nuclei got so close to each other in the palladium lattice that they were ready to fuse. That means the lattice acted as a shielding for the Coulomb charge. It was assumed that the deuterium loading ratio must reach a high threshold value of 0.9, accompanied by a phase change in the lattice, then fusion would start. Therefore steady electrochemical loading was preferred to gas (plasma) loading. This textbook physics, single step process has turned out to be wrong, and too simple. Experiments based on this simple model failed. Skeptics denied the very existence of LENR due to this failure. However, most experimental know-how originated from this electrochemical process. Transient plasma and hot fuel processes are latecomers. The fission releases neutrons, and they are the catalyzers. This model has other consequences, too.

The original bulk-cathode Pons-Fleischmann experiment offered too little surface volume for this mechanism, where vibration amplitude can be high. The bulk metal, the material inside of the massive Pd cathode, dampens the amplitude of the oscillation.

There are good design solutions for this problem: It needs a large surface, and a thin layer cathode, for example, as a pebble bed cathode, with loosely coupled little balls. The pebbles and the plastic balls are covered with a micron thick palladium layer protected by a more flexible nickel coating. Pulsed, high voltage power is provided to the cathode. Figure 2a-c shows a comparison of cell designs. The foil cathode is the best for research purposes (Figure 2a), compared to the bulk cathode (Figure 2b). For practical applications Patterson's "pebble bed" type reactor (Figure 2c) is the most suitable.

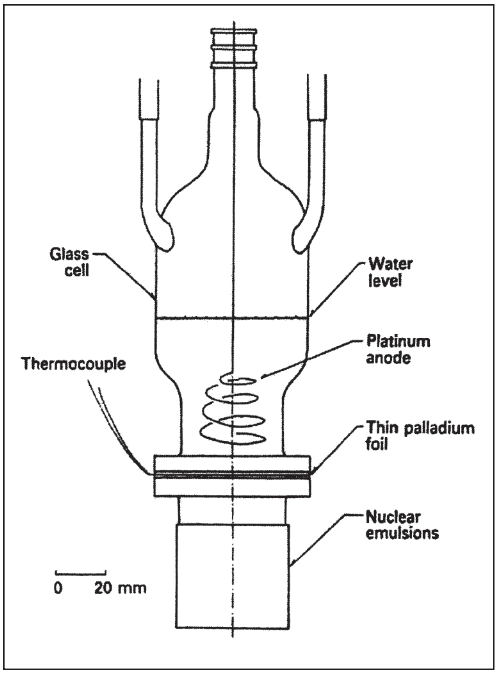


Figure 2a. Matsumoto's thin foil cathode design. There is hydrogen flux through the foil. Excellent for research purposes.

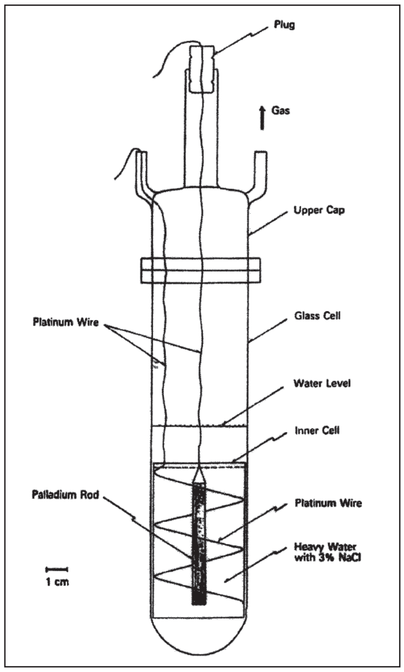


Figure 2b. The usual Pons-Fleischmann layout with the bulk palladium cathode in the middle. The hydrogen/proton flux is initially high. High loading ratio is difficult to attain.

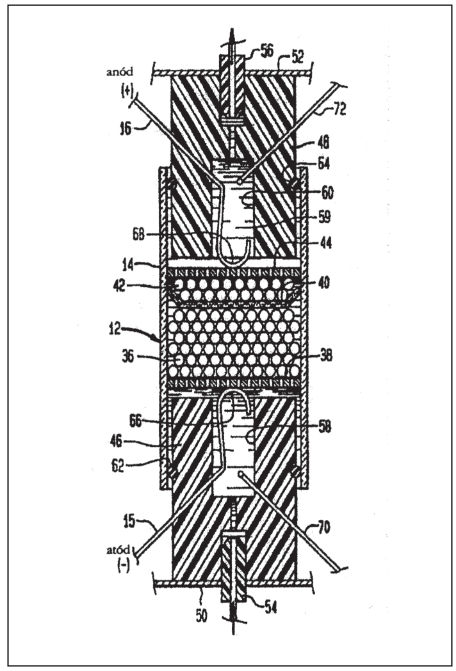


Figure 2c. The Patterson bead cathode reactor. It has a very large cathode surface, and it is easy to saturate the palladium layer under the external nickel layer. Deuterium or hydrogen diffusion flux is regulated by the changing current for Figure 2a.

***The Thin Layer Patterson Ce*ll**

An outstanding feature of the Patterson cell (Figure 2c) is that distilled water and a salt solution of $LiCO_3$ is suggested as electrolyte instead of heavy water. This author has hands-on experience with this device. It was easy to load the micron thick cathode layer (vapor deposition or electroplating is suggested). Our pellets were 5 mm diameter plastic foam spheres. They were covered with graphite, then copper. The palladium layers were all very thin, about 1 µm. They were covered finally with an equally thin nickel layer, where hydrogen can diffuse through, yet it is a continuous layer. This cell had many problems. Any pollution of the electrolyte covers the cathode surface with an insulating layer, stopping electrolysis/hydrogen deposition into the lattice. The coating is sensitive to the physical stiffness of the palladium layer. The stiffer the layer is, the more it is prone to cracking, thus vibration, and therefore fission occurs. It is difficult to reproduce the same quality Pd deposition under the Ni coating. Our three different batches diverged widely in quality for no obvious reason. The thin layer technology apparently requires extreme measures in quality control.

Patterson himself fell into this trap. The first, decades old batch of his catalytic palladium balls was quite reliable and successful. When he ran out of them, he was unable to repeat it despite his best efforts.

The preparation of the balls proved to be a tough challenge. Therefore we abandoned this line of research quite early. About 50 - 80% excess heat was measured only for some hours. Then the excess diminished due to surface contamination. We blamed the impurities of the anode deposited on the pebbles and the $LiCO_3$.

The existence of a high surface area packed bed Patterson cell (U.S. Patent 1994/5,372,688) came as a surprise to the LENR community. Until then the necessity of deuterium (heavy water) had not been questioned, nor that a bulk palladium cathode is necessary—based on the Pons-Fleischmann cell. This is the answer to Nagel's third question (are protons and deuterons interchangeable in some heat producing experiments). Indeed, it is possible to have cold fusion with light water, because the diffusion of hydrogen, and thus the cracking of the lattice can be efficient for thin layers. In this case, the bulk of the heat production is due to fission, and neutrons reacting with the palladium and the nickel lattice. There was a steady hydrogen diffusion through the thin metal cathode layers into the plastic spheres in the Patterson cathode. Thus the metal volume was thoroughly utilized.

Arata-Zhang Microcrystal Cell

At ICCF6 (Lake Toya, Japan), Patterson presented his results based on a light water electrolyte, and a thin layer cathode. At the same meeting, Arata and Zhang presented another R&D path: to use high pressure deuterium (200 bar) and Pd nanoparticles, another form of packed bed reactors. They discovered this remarkable effect before the Pons-Fleischmann effect was published, as noted in 1999.[3] They used deuterium and electrolysis, but the cathode was made by composite microparticles—DS cathode. They measured continuous heat without the need of input energy, a sort of "heat after death" effect. This was rarely observed, but was by Tadahiko Mizuno and Kitamura *et al.*

It is clear by now that reactors based on electrolysis will not reach economic viability due to their erratic behavior and low power efficiency. It was not known, and is not generally accepted even today, that the main initial effect is the diffusion of hydrogen into the lattice, and the consequent embrittlement, and vibration of the lattice. Fission as an LENR process was not considered, only fusion. Therefore hydrogen, or protium, as a fusion reagent was rejected at the beginning.

Light water was used only in control tests, and fusion/fission trace elements were not sought or tested. This mistake was admitted by Storms only decades later.

I strongly recommend reading J.P. Biberian's 2009 review.[4] (In the same book, the chapter by Mahadeva Srinivasan is also important.[5)] Biberian clearly expressed: "The use of gas phase instead of the original electrochemical system is certainly the future of the field…This method has many advantages…There is no longer the low temperature operational limitation as exists with electrolysis in water…Gas phase is a much cleaner environment that permits better control of the materials…"

The expensive palladium-deuterium system is an interesting choice from the research point of view, but not very applicable to practical devices. Biberian also noted, "I believe the most interesting system is the nickel hydrogen pair."

In fact, the LENR mechanism is described in the reviews by Biberian and Srinivasan, but it was not written down in a definite way. These steps are the followings:

1. Metal lattice (Pd at low temperature, Ti or Ni at higher temperature) is loaded with hydrogen or deuterium, and it diffuses into the lattice. This is a slow process; therefore the large surface area of Patterson or micro-nanodust of Arata and Zhang are superior to the P-F cell. Ni or Ti (maybe Fe) can't be loaded at room temperature, because diffusion into the lattice is negligible.

2. Due to the phase transition by hydrogen diffusion into the metal lattice, swelling (thus strain) appears in the lattice, and microcracks are formed. Previous cold work, with a buildup of internal mechanical stress, is important as a "hidden" parameter, but it is unmeasurable. This factor in itself may be responsible for the notorious unrepeatability problem. The lattice cracking is the same for hydrogen and deuterium, so they are interchangeable up to this part (Nagel's third question). The neutrons released by the fission are more likely to interact with deuterium than with hydrogen, thus deuterium will yield more heat.

3. When the external pressure drops, the hydrogen or deuterium suddenly diffuses out of the lattice. This is a faster process than loading. This causes more mechanical stress, and causes local mechanical lattice vibrations as a nonlinear cracking process. This causes local "hot spots," which are nuclear active sites where LENR is intensive.

4. Lattice vibrations in turn smash the nuclei due to extremely high frequencies and acceleration (THz order of magnitude), which in turn excite the surrounding ether. The high acceleration, thus much higher vacuum fluctuations, tear apart previously stable nuclei. This effect is not within textbook physics, but ether has this weird property. (See Part 4.) How does it take place? What is the tentative physical mechanism? Acceleration of the lattice shifts the spectrum of vacuum fluctuation as noted before. The effect of the modification of the vacuum spectrum was noted by Hawking for black holes, and Davies and Unruh for accelerating systems. Note, this is a departure from the "usual" cubic; invisible vacuum fluctuation spectrum appears only at extreme accelerations, which happens only during the cracking due to the loading of the lattice. (Timothy Boyer also noted the vacuum oscillation spectrum changing effect of acceleration.)

5. Previously stable nuclei become unstable at more intense vacuum fluctuations, disintegrating into fragments. This is a mechanical stress-induced nuclear instability. This is called a piezonuclear effect by the Italians, and mechanofusion by the Russians. Biberian listed many independent, but forgotten observations. Nuclei fall apart amidst releasing low energy neutrons due to the cracking of a lattice. Mechanical stress on the lattice is usually induced by mechanical hammering, temperature transient stress and deloading. Thus the energy release is a function of the brittleness of the lattice. A soft lattice—like copper, lead or aluminum—is useless, even if hydrogen diffuses into them. Their brittle alloys, however, are likely candidates. (Note: pig iron is very brittle. Stainless steel is annoyingly ductile.) Thus LENR controlled by diffusion and cracks has a limited duration: neutrons are produced as long as there is enough material to crack. This is a non-uniform time scale, and unpredictable. Lattice swelling is generated after saturation. Nevertheless, continuous cracking cannot be maintained for years. This is the ultimate bottleneck of diffusion controlled LENR reactors.

6. Neutrons released in the above LENR fission process take part in fusion as well—like forming deuterium and tritium when the absorbed gas is hydrogen or deuterium. This is an unusual process. Most of the released neutrons are captured in the neighboring nuclei and only a few escape the lattice. The neutron/tritium ratio is about 10^{-7} in Srinivasan's estimations. They are definitely released in uneven bursts in time and space as well. However, LENR activity stops after a short period, termed "poisoning." In fact, this further indicates the importance of annealing the lattice. LENR ceases when all available cracking volumes are consumed.

The importance of the existence of ether (as a long range effect, by Parkhomov and Schnoll) was noted in Part 4 of this paper. Now we just extend it with the practical applications of the Davies-Unruh effect as well. (Hawking and Boyer also found it.)

The most extensive experimental investigations of neutron emission effects related to mechanical stress were done by Carpentieri *et al.*[2] Srinivasan *et al.* examined nuclear effects related to quenching stress, when a hot, thin palladium foil is thrown into cold liquid deuterium. They found tritium in the sample foils. (A similar example is metal glass manufacturing.) There was a Russian experiment as well, indicating the importance of mechanical stress. B.V. Derjaguin and later Andrei Lipson started to shoot a steel slug into LiD and D_2O ice. The steel slug had about 200 m/sec velocity before impact. There were low efficiency neutron detectors behind the samples. The test results clearly showed neutrons above the background radiation. They call this effect "nuclear mechanofusion," while Carpenteri termed it the piezonuclear effect. However, the mechanical properties of brittleness have not been investigated, like Vickers hardness, etc. This is possible only for surfaces like thin foils.

Takaaki Matsumoto did just that.[6] He switched from the "classic" bulk rod cathode to a thin foil, shown in Figure 2a. No correlation has been searched for mechanical properties of the foil, and time variability of the hydrogen/deuterium flux through the foil. The pressure under the foil was not changed, a sadly missed opportunity. He found traces like circles of condensed plasmoids under the Pd foil!

To summarize: it is not worth designing LENR cells based solely on liquid electrolysis of bulky cathodes. They are limited by their low temperature and low surface/volume ratio. No intensive crack formation or lattice acceleration can be achieved. Therefore their practical application is useless in the present form, as daily practice has borne out.

"Hot" Cold Fusion: The Rossi-Parkhomov Line

One or two million ºC is considered hot on the temperature scale of nature. Anything below it is warm at best. Most of the visible mass of the universe is in a "warm" plasma state. Cold, solid planets and interstellar dust are the exceptions and not the rule. Anything is rightly considered "cold" under the melting point of tungsten. All technical devices are expensive where a plasma is contained above this limit. They are commercially worthless and any effort to portray them as a breakthrough area is very dangerous propaganda. (All branches of hot fusion, including spheromaks, stellators, inertial confinement, z machines, focus fusion etc. belong to this group.)

There is another branch of cold fusion devices termed "hot," as they are still under the cracking, or melting, points of heat resisting ceramic materials, that is, under about 2000ºC.

Piantelli, Celani, Rossi, Scaramuzzi and other Italians started the "hot" nickel-based line of research and were joined later by foreign researchers. There are arguments for and against this line of research. These devices operate around or above 1000ºC (the Parkhomov threshold), so an important bottleneck is overcome. The main design insight of Parkhomov is that the element producing neutrinos, the heating element, can be separated from the fusion core. This is an advantage from the viewpoint of design and operation, because different metals are suitable for ohmic resistors and others as crackable fusion alloys.

Rossi did not recognize the importance of this separation, but employed another important step, the catalytic splitting of the hydrogen molecules to help the diffusion of hydrogen into a nickel lattice. In the case of a plasma, like glow discharge, protons and ionized hydrogen molecules are readily available. Simple heating of hydrogen is less effective, because it yields only a very diluted plasma. It is just not enough for lattice loading at normal, atmospheric pressure, or above it. (See U.S. Patent 2011/0005506, Piantelli WO/2010/058288)

The electrically heated nickel-based core has only a thermal output. Thus they compete with heat pumps, which have about 500% efficiency as long as the outside temperature is above freezing.

The cost of electric energy is always more than the cost of heat energy (for the same kilo Joule).

How much energy is generated by the fission of Ni, Pd or Ti? Is it 1% or 99%? Is the fusion by released neutrons and deuterium/hydrogen the dominant effect generating heat? What is the dominant energy production effect? Fission or fusion?

There is no clear answer today, as there are no test data on energy balance, or material degradation/transmutation analysis.

The continuous cracking of Ni, Pd and Ti (and consequent fission as a catalyst) by supplying neutrons probably yields a lower amount of heat generation than fusion. However, this is just a guess.

Parkhomov assumes the following fusion reaction:

$$p + \nu + Ni^{60} + e^- \rightarrow {}^4He + {}^{57}Fe + 0.57 \text{ MeV},$$

a reaction involving a nucleus of Ni. In fact, a neutron from the fission of another Ni nucleus is the source of neutrons.

However, the fusion reaction of p + ν + Ni → yields less energy than fusion between light nuclei, like: $H_1^2 + H_1^1 \rightarrow H_1^3$ or the $n_1^0 + H_1^1 \rightarrow H_2^1$ type reactions. Of course thermal neutrons must be generated, and this is the bottleneck reaction, the key to "cold" fusion. Unfortunately the Rossi-Parkhomov "hot" cold fusion method is not on this path, because their source of neutrons is limited.

It is apparent that slow (thermal) neutrons act as catalyzers for LENR reactions. They are able to penetrate any nucleons at thermal speed. In fact, ultracold neutrons already react at the next atom (Widom-Larsen model). Therefore they are impossible to detect. In the heated, atmospheric pressure, with hydrogen loaded systems, neutrons leave the splitting nuclei at higher speeds. The cross section of their reactions is smaller, and less eager to react with hydrogen isotopes. The sweet spot is that relatively little preparation is needed to have them, only to crack the metal lattice. However, there are no test data on the mechanical properties of fissionable Ni alloys at high temperatures, a sorely missing data.

The general design problems on the crack-based piezonuclear reactions are twofold:

a) The neutrons do not always interact with protons or deuterons, but mainly with heavier nuclei of the lattice. These reactions yield less energy than fusion with deuterium.
b) Cracking a lattice cannot be a steady-state process, and it cannot be a homogeneous one, uniform in the whole lattice. Neither the physics, nor the design, of these reactors have been properly explored.

All in all, the practical potentials of the "hot" version of cold fusion is better than the methods based on electrolysis.

Now we are in the middle of the debate: What sort of cold fusion reaction paths/engineering methods are the most lucrative solutions?

The Paths of Transmutations

All LENR processes are based on transmutation, as fission or fusion. Transmutations do happen in fission and in fusion, too. We shall not discuss fission induced by lattice cracking and vibration further in any detail. (Unfortunately most researchers of this area are either ignorant about this form of fission or reject this possibility out of hand.)

We shall move into an uncharted LENR area from now on, where theory, test results and inventions are sporadic. There are some general remarks before we discuss these reactors.

Fusion may take place with the following methods (to the best knowledge of this author):

— Generation of ultracold, slow neutrons by charge waves (resonant plasmon polariton waves). This process requires input energy though at later steps it will turn into a net gain, yielding deuterium and tritium. These charge waves are considered quasi-particles, though very short-lived ones. See the three-part paper from this author in *Infinite Energy*.[7]
— Generation of long lived, nearly stable quasi-particles (under the names of EVO, condensed plasmoids, strange radiation). (See Part 1. We shall discuss the physics of condensed plasmoids further in Part 5B.)

Condensed plasmoids are not yet accepted into textbooks of plasma physics. Only Von Engel[8] mentions stable plasma vortexes in a single sentence in his book (page 109, Figure 6.5 there): "A toroidal plasma (of vortex ring or smoke ring shape) can be produced by using a tube…a special type of spark plug." It is a coaxial hollow cathode pulse discharge device.

Note that this vortex is formed from the plasma of the positive column, and thus is electrically neutral. Further, it quickly vanishes by recombination, not like condensed plasmoids. Therefore one cannot refer to this on a patent application as a catalyst of LENR.

Today condensed plasmoids do not appear in textbook physics, therefore they are nonexistent from the viewpoint of patent applications. Most probably a patent application will be rejected if condensed plasmoids are explicitly quoted as an explanation for the catalytic LENR effect. This ignorance is killing a whole class of LENR devices!

It is not certain that transient plasma induced by cavitation, or bubble collapse, will make the same condensed plasmoids as microdischarges, like a corona. This area, sonofusion, was initiated by R.P. Taleyarkhan *et al.* and Roger Stringham and was endorsed by Julian Schwinger as well.

Condensed Plasmoid Production by Cavitation

The cavitation method for generating plasmoids is less efficient then sparking, nevertheless it is worth mentioning.

The tentative process is shown in Figure 3 (A-E). The best case is when there are hydrogen (deuterium) bubbles due to electrolysis in water, with oscillating pressure. This system is not the Pons-Fleischmann electrolytic cell because there the pressure is steady. (However, the two systems can be favorably combined, although nobody has tried it so far.)

The sequence of events during the pressure oscillation is as follows (see figure):

(A) The hydrogen bubble has a definite spherical volume, just off the cathode.
(B) When the ambient pressure drops in the bubble it expands, and water vapor diffuses into the bubble. Note, the bubble is not stable; it oscillates spatially as well. The pressure waves are driven by a vibrating plate (Ohmasa) or piezoelectric crystal (Suhas Ralka). Thus the bubble undergoes a spatial oscillation and a radial (volumetric) oscillation as well.
(C) The hydrogen bubble is back to its original volume, but saturated with water vapor.
(D) The ambient pressure is increased, and the hydrogen/vapor bubble is compressed in an adiabatic manner, then overheated, and plasma appears.

Due to a spatial pressure difference, ions and lighter electrons are separated, and an electric gradient appears. As this is a short transient, spin field is generated, as rot $S(t) \approx \partial E(t,r)/\partial t$.

The plasma is compressed into a condensed plasmoid of toroidal shape due to the same process as during a sparking, described in Part 1. The preferred frequency of the pressure oscillation is in the order of 50-500 kHz.

When a bubble undergoes several pressure cycles, plasmoids may accumulate in the gas and may diffuse into the water as well. There they may catalyze transmutation, as Ohmasa and Brown observed.

(E) The bubble is back to its original volume. If it is allowed to leave the liquid, the gas is filled with catalytic plasmoids. When this oxygas is burned, it has a cool flame, but reacts with metals, and the transmutation is significant.

The process may take place even without hydrogen bubbles, just with vapor bubbles, because it also splits to hydrogen and oxygen. However, it is less economic, since oxygen is less useful in condensed plasmoid formation.

Spin fields and electric fields must be present simultaneously to overcome the Coulomb threshold shown in Part 2. Even a magnetic field is required for the transmutation of heavy nuclei, also considered a catalyst. Though the "hyper-

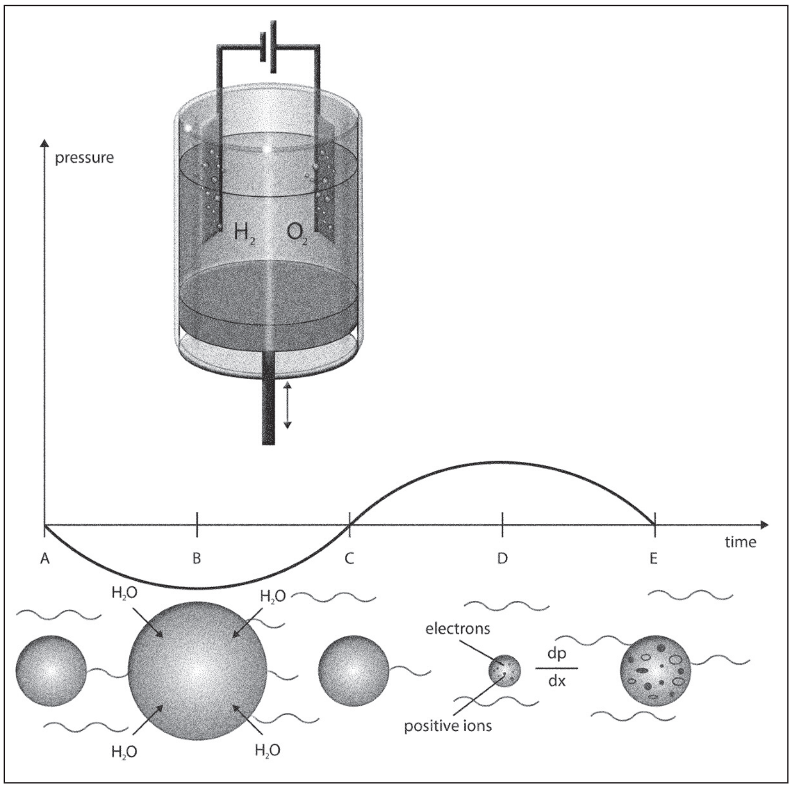


Figure 3. (A-E) Phases of hydrogen bubble swelling and compression. It is a high frequency transient process. Formation of condensed plasmoids due to cavitation, and pressure gradient inside a bubble.

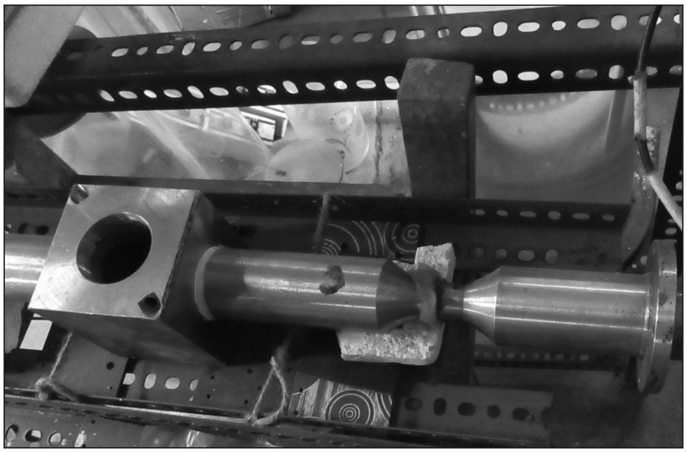


Figure 4. Suhas Ralka's ultrasound driven fuel preparation device based on watery tungsten sludge. Note the three sonotrodes, the sound conductors. They conduct the ultrasound waves to the treated sludge.

space jump" seams to be a far fetched assumption, the Hutchinson experiments seem to verify that there is a causal relationship between them. Local atomic sized hyperspace jumps seem to be the (unwanted) condition for fusion. (Otherwise the fusion of massive nuclei without significant X-ray radiation is hard to explain.) This double problem was discussed in Part 3.

This is hopefully all the background physics necessary to describe LENR inventions, and the practical applications of the above processes. This background knowledge is much more than classical or quantum physics textbooks can offer today.

Reviews of LENR reactors and processes take us up to this point. Eugene Mallove (*Fire from Ice*), Charles Beaudette (*Excess Heat*), J.P. Biberian (*Fusion in All Its Forms*), Steven Krivit (*Fusion Fiasco*), Edmund Storms (*The Explanation of LENR*) and Tadahiko Mizuno (*Nuclear Transmutation*) do not take us beyond this point. From now on, we shall be in no-man's land.

Conservation of mass, and energy, is still considered valid, as well as angular and linear momentum. Appearance of magnetic charges as quasi-particles is assumed and magnetic currents as well, discussed in Part 1.

Suhas Ralka's Heat Generating LENR Reactor

This method of heat generation is a mixture of two mechanisms: dust mediated and condensed plasmoid driven. This process has two consecutive steps:

1. Generate as many condensed plasmoids as possible in heavy metal fuel grains. There will be a number of transmutations in the grains as a side effect.
2. When the fuel grains are placed in a discharge tube, in a hydrogen atmosphere, the periodic discharge pulses are aided simultaneously with ultra-sound acoustic pulses in the order of 1 MHz. That is, fusion of hydrogen into deuterium, tritium and helium takes place, as well as fusion of neutrons into heavy elements, and piezonuclear fission reactions.

The C.O.P. was measured around 8 by the inventor of this technologically demanding process, which is already commercially viable. All faces of LENR have been found here again by luck and perseverance.

The Martin Fleischmann Memorial Project (MFMP) funded two visits for independent measurements, but both failed. (An editorial was devoted to these visits in *IE* #135.)

The novelty here was the preparation of the "fuel," which was high density metal grains, mainly tungsten. They were treated by a powerful 3-beam ultrasound device for hours in a watery sludge. The frequency of the ultrasound ceramic generator was very high, around 1 MHz. (See Figure 4.) The metal powder mixture was heated due to the dissipation of the ultrasound, but the temperature was not measured. Apparently, the fuel grains were filled with condensed plasmoids, ostensibly due to cavitation.

Suhas Ralka had life-long experience with ultrasound devices and had off-the-shelf devices of sound conducting sonotrodes, ceramic piezoelectric disks and proper power supplies. It took him years to achieve this impressive technological background in ultrasound technology.

He applied it to various mixtures and materials, and he stumbled into transmutation just by accident, as is typical in this field.

The open question is: how did transmutation happen in the tungsten grains without transient spark discharge? How does ultrasound treatment of the fuel sludge happen?

First of all, even a watery sludge acts like a cavitation site when overheated due to the high amplitude oscillation. This may lead to the simple version of condensed plasmoids made by the same process as in the Brown gas and Ohmasa gas. These condensed "hydrogen crystals" are also catalytic agents, just like the toroidal condensed plasmoids. Moreover, neutron generation due to lattice oscillations may appear as well, creating neutron-rich, unstable isotopes, and "polyneutrons," or other catalytic quasi-particles too. A rich reward awaits the inquiring mind in this area!

Ralka noticed the transmutation that hundreds of other engineers doing ultrasound applications failed to recognize or just were afraid to report. This is called serendipity, and a very important one.

Robert Greenyer of MFMP analyzed the "fuel" compositions before and after the ultrasound treatment and found significant differences in material compositions due to the transmutation.

Ralka found an unusual side effect as well. When the "fuel" metal grains were removed after treatment, and put into small plastic bottles, they fell apart after some weeks. Apparently slow, "creepy" LENR had just changed the composition of the plastic walls.

The heat production method was simply to place the "crystal plasmoids" saturated by metal powder into alumina tubes and then into a hydrogen atmosphere. The rest is familiar (dust fusion, discussed in Part 2), except again the ultrasound driven gas discharge. This latter is useful to move the catalyst (condensed crystal) inside the tube. Thus the efficiency of catalysis is greatly enhanced. Moreover, the metal powder in the oscillating plasma acts as a dust fusion process as well.

Ralka's two-step process is better than the Pons-Fleischmann process by an order of magnitude. In his method the fusion of hydrogen is likely the dominant process for producing energy, not LENR fission.

This method has the highest technical potential in the category of heat producing devices, but hard test results are not available, as usual. The piezonuclear fission reactions are better in heavy elements (Pb, Ra, W) than in Pd, because there are more escaping "surplus" neutrons after fission. One may think about alloys as well, not only in terms of pure metals. The carbides and nitrides of heavy elements are promising, because their mechanical brittleness is essential for fission induced by vibration. It is worth noting that semiconducting alloys of Pb and Si are more prone to hydrogen diffusion than pure metals. Further, fine grains with their better surface/volume are needed for piezonuclear fission.

The electrolytic Pons-Fleischmann cell, the Patterson cell and even the more sophisticated Ni-hydrogen heated cells of Focardi, Celani, Piantelli, Rossi, Arata-Zhang or Parkhomov have no known published design criteria. They were all assembled by "gut feeling" or trial and error.

They are not inventions yet as such (despite patents granted), but discoveries with useful applications (Piantelli WO/2012/147045A1; Celani *et al.* U.S. Patent 2012/0134915A1; Rossi U.S. Patent 2011/0005506A1).

Their operations were also not well established. For example, Bockris always noted that roughness of the electrode surface was essential for better efficiency, as well as overpotential. Both of them make sparking possible under the surface of the electrolyte. Further, Preparata always emphasized the importance of transient electric pulses, which in turn caused hydrogen loading/de-loading into the cathode lattice. This transient de-loading mode enhanced crystal fragmentation, and thus more vigorous lattice oscillations, leading to fission.

This method works only with thin films, as in the pebble bed cathode of Patterson. The thin wires of Celani, Swartz or the Arata-Zhang Pd nanodust serves the same purpose in hot cells.

The importance of a thermal neutrino flux was considered only by Parkhomov, because he separated the heating element (thermal neutrino production) from the fission/fusion nickel reactor core. Thus this is the first LENR reactor where an engineering design was based on a physical insight.

The Arata-Zhang nanodust reactor was used at a very high steady pressure, at about 200 bars, under D_2.

Again, there were no engineering considerations in the design and operations. This type of LENR reactor has not been investigated in detail due to the prohibitive cost of Pd/ZrO_2 grains, and the manufacturing problems.

The mixture of Parkhomov's insight (separate neutrino production heating element) and Preparata's insight (transient loading/de-loading to help lattice oscillations) seem to unite the advantages.

The separate electrical heater allows transients and the creation of de-loading transients. Rossi's idea to use a chemical catalyzer to split hydrogen atoms to ease lattice loading is also a bright insight, worthy of considering during design.

Parkhomov recognized that his reactor stopped yielding excess heat after about half a year despite the available hydrogen supply. Apparently the nickel completely cracked, and thus the available supply of neutrons ceased to induce fission.

A more advanced heat generation reactor may combine the following design features: Parkhomov's heater in a transient mode, Ralka's heavy metal grains and preferably alloys of heavy elements. The operation is preferably based on simultaneous ultrasound and gas discharge pulses in a hydrogen/deuterium atmosphere.

Unfortunately, Suhas Ralka is no longer active in this field, and most likely he will take this advanced technology to his grave.

The CO_2 Smasher of Valentin Cesa

The plasma-based dust fusion device of Valentin Cesa is also the result of serendipity. Cesa was a man of brick-and-mortar. He built wood fired open fireplaces at first (U.S. Patent 1977/4,006,729). Later he covered them with heat resistant glass doors. He noticed that when the inlet air flow mass flux was fine tuned, the combustion became oscillatory, even resonant. In this condition the flame became white and the fireplace radiated an unusual amount of heat. He also noticed a strange result: in this condition the CO_2 output was reduced, and sometimes vanished completely. He recognized the significance of his test results, and started to develop a resonant combustion device which received a U.S. Patent (2007/7,201,882). Dust fusion was discussed in Part 2. Cesa developed a more complicated set of resonant combustion systems described in WO/1992/004973A1.

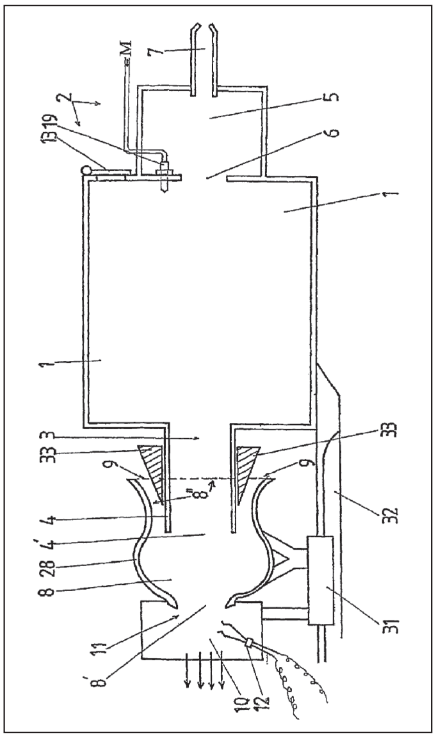


Figure 5. The tunable resonant combustion system in Cesa's patent. The tunable length of the oven is visible, thus acoustic resonance is maintained.

Several devices were built and tested with the help of British angel investor Geoffrey Galley. The device in Figure 5 is a tunable combustion system.

Cesa used his experience in fireplace building to build his resonant furnace (just like Pons and Fleischmann electrochemistry). Thus he always thought in terms of cubic meters for the combustion chamber.

His device used either a whistle, or a tunable vibrating metal tongue, for acoustic wave generation, as shown in Figure 5. The resonant cylindrical combustion chamber (1) became tunable by two means. The air inlet chamber (5) itself was a resonant unit driven by a tunable whistle (7).

The fuel (heavy oil) entered at the nozzle (19) with a high pressure spray. On the other side of the resonant combustion chamber, the length of the exhaust assembly was also tunable, moving along a rail (31).

There was a nearly spherical afterburner (8) to burn the leftover dust. The air was sucked in via the whistle (7) and secondary burner opening (9).

It was noted by Galley that the combustion was white hot, radiating an extreme amount of heat.

The resonance capability of large industrial boilers/furnaces was known before, and a subject of university curriculum. Engineering students, future designers of furnaces, are warned about its dangers, and to avoid it at all cost. Indeed, there have been a number of severe industrial accidents, where huge boilers simply jumped off from their concrete bases despite being screwed down by dozens of 10 cm diameter bolts.

Yet these forces are simply unstoppable. Flames themselves are inherently a turbulent source of oscillatory combustion—seen in a candle flame, or a torch. When they are properly designed to match the frequency of a resonant acoustic cavity, loud combustion is achieved.

Cesa built several huge tunable furnaces. Their size was in the order of 2x5 meters. The fuel was oil, sometimes used tires. They burned well without a trace of CO_2 and CO, though with some NOx due to the unusually high flame temperatures. The carbon didn't disappear; half of it was turned into fine separable soot, the other half into carbon nanotubes (industrial grade).

In fact, this exhaust led to the demise of the invention; authorities were unwilling to give permission due to the NOx exhaust content.

Cesa was over-ambitious in the patent application. He assumed the same resonant combustion method is applicable for piston driven internal combustion engines, and gas turbines as well. He didn't recognize the essence of the fundamentals in the above cases: resonant combustion of carbon dust plasma.

This can't be achieved in a moving piston due to its variable volume, or within the rotating blades of gas turbines lacking permanent boundaries. However, it is possible in the combustion chamber of a rocket or ram-jet, when the fuel contains alcohol, which may turn into carbon dust in rich (oxygen starved) fuel ratios.

This device is a showcase of sloppiness in science and technology.

Several fellow fireplace builders also noticed the extra heat of resonant combustion (as many other users of fireplaces), but never bothered to check out the CO_2 content for resonant operation.

Industrial designers, and a host of university departments in the combustion research and development area always avoid this operation mode, because it is mechanically detrimental. (The Russian Moon rocket also failed due to unusual, unexpected oscillations in the Laval nozzle, and consequent mechanical resonance at a given low pressure in the upper atmosphere.)

Had oscillatory dusty combustion been investigated thoroughly, LENR reactors could have been built earlier, but at far away places, as thermal power plants, where noise is not a problem.

Dusty plasma researchers also avoid this parameter range: the atmospheric, high temperature, chemically reacting resonant plasma. Their range of interest is restricted to the parameters of interstellar plasma: very low pressure, with no combustion, and no resonance. Combustion is not touched in the papers on dusty plasmas. Soot is mentioned in combustion research papers and textbooks, but resonant sooty plasma has never been studied.

Where is LENR here? Simple. In this type of three-phase medium (solid dust particles in the micrometer range, dilute plasma and non-ionised gas) dust particles are charged and rotate randomly. The rotating, charged dust particles create a spin field. There is an electric and magnetic field around the rotating particles, and the flames of carbohydrates contain hydrogen atoms in an ionized form: protons. All ingredients are here for LENR fusion, just as in the solar corona discussed in Part 2 of this paper.

Thus heat producing, dusty fusion has always been right in front of our noses, though in an unexpected form. Coal fuelled industrial boilers could have been fusion rectors in principle, in an acoustically resonant mode. Of course, existing furnaces are not suitable for this purpose, because they are designed to avoid acoustic resonances, and oscillations at all.

Laminar and Turbulent Flames for LENR Fusion

This author has "hands-on" experience with the design and operation of these resonant dusty plasma systems. I briefly describe my approach, because the ideas leading to the actual inventions are also interesting.

After reading Tesla's carbon button experiments, gas discharge-based, excess energy systems became my keen interest. I was aware of inevitable cathode erosion and generation of dust and evaporation, when leading the research program on the Correa and Chernetzky projects. Further, the study of the missing rotation symmetries in electrodynamics led me to the test results of Felix Ehrenhaft and Mikhailov. It became clear that rotating charged particles have novel, unexpected physical features.

After that, simple resonant dusty plasma experiments in microwave ovens showed remarkable transmutation, and possible heat energy generation. I turned my attention to dusty plasma research. However, I found nothing suspicious in the voluminous published literature of combustion and dusty plasma, except: the parameters of fusion regime were clearly omitted.

There were two separate paths for research: (a) combustible carbon dust, where oscillating plasma was generated by chemical process with little external power; (b) non-combustible dust, where oscillating plasma was generated by variable amplitude and frequency microwaves.

I followed both paths. The first inexpensive combustion tube oven was built based on the principles of a turbulent Ranque-Hilsch tube. This tube is fed tangentially with compressed air in the middle, and the fuel was a propane-butane gas mixture from a cylinder. The exhaust was analyzed in a commercial gas analyzer, used for measuring car exhaust. Later we switched to a furnace exhaust gas analyzer.

The Ranque-Hilsch tube was chosen because it is a tunable, rotating gas tube even without combustion.[9] (It yields cold air on one end, and warm air on the other end.) Usually it is not used for combustion experiments, only as a light, and inefficient, heat engine in trucks, where heating or cooling are necessary. (See Figure 6.) Note that this tube is not a Maxwell's demon, the simultaneous heating and cooling is at the expense of inlet pressure. This is a very counterintuitive device. It was chosen because it has a self generating pressure oscillation. It has never been used for combustion, let alone for burning dusty plasma. We omitted the cold exhaust, used only the hot exhaust, regulated by a rotating cone. (See Figures 6a, 6b.)

The first "furnace" was a 20 mm diameter, 50 cm long quartz tube, with a 1 m long steel exhaust pipe. The inlet air and exit outlets were spiral channels, the usual feature of Ranque-Hilsch tubes. It took some time to learn how to tune it to resonance.

Even the first experiments were encouraging. The CO_2 content was reduced to half of the usual value when tuned into a howling-resonant mode. The fuel/air ratio was carefully adjusted and measured, and the input air was dried to a degree. Due to this success we got shoe string funding from the management of the Bakony Thermal Power Plant for two years. Thus a better device was built with a 40 mm diameter quartz tube, with even better results. It was quite apparent that the surface/volume ratio was important; the excess heat appeared only above 1200ºC.

The quartz tube withstood both the thermal and mechanical stresses. (Funding was soon cut due to the government restriction on innovations. Then we were awarded a 2 million Euro research grant, but the host company, Aqua, immediately stole all the money. Later Swiss private investors funded the project also in a shoestring manner. After a steady progress, they were unable to get private investors for CO_2 reduction and excess energy. Therefore they stole all the equipment and closed the lab.)

Nevertheless, to cut a very long technical description short, it has been experimentally shown that transient resonant dusty plasma can produce excess energy due to transmutation, and it appears first in the form of reduced CO_2 emissions, along with increased NOx emissions.

This setup is not viable for household furnaces, because compressed air is necessary. Besides, methane is not a good fuel, as it does not readily form soot. Results were better when we used fine carbon dust as fuel. (See Figures 7a, 7b, 7c.) This approach was technically viable even 150 years ago to save coal, but it was unknown.

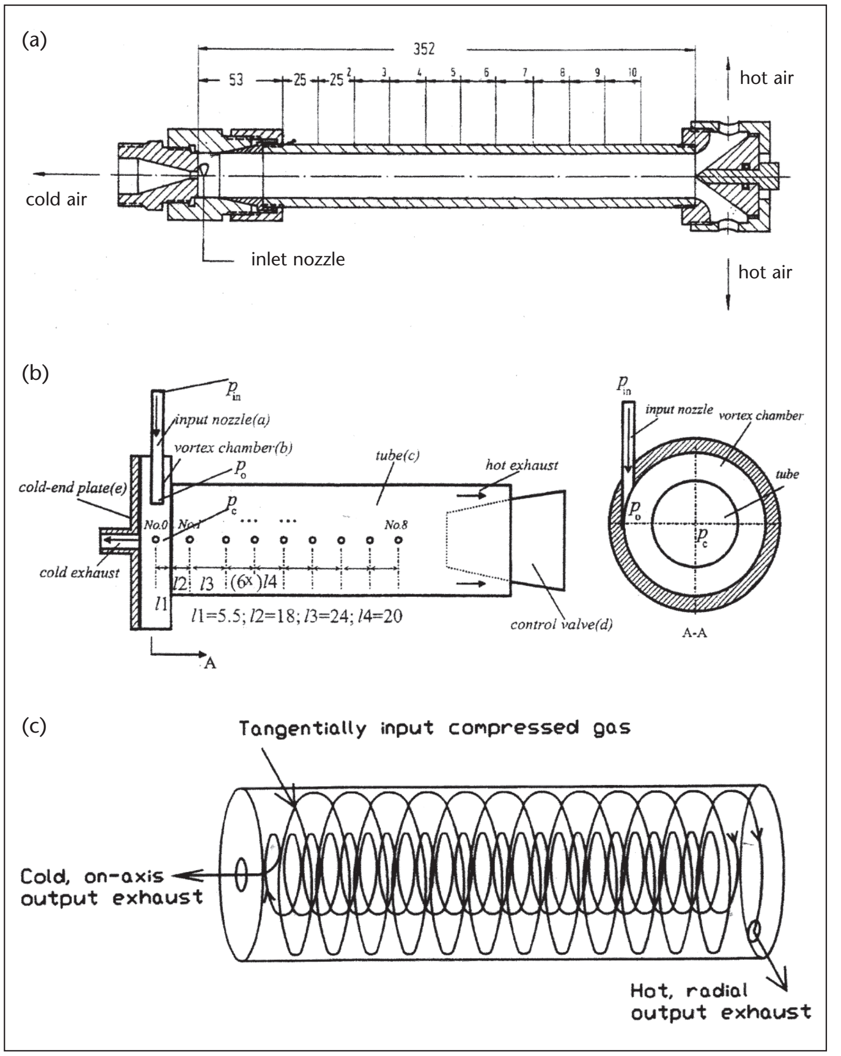


Figure 6a-c. Ranque-Hilsch tube for temperature separation; their flow pattern. In 6a and 6b, the cross sections are shown; in 6b and 6c the flow pattern is shown. The dusty plasma rotates and oscillates in the whole volume.

Another drawback of this technology is the acoustic noise of oscillations, but no efforts were made to insulate it due to the low budget.

Calorimetric tests for a 60 mm diameter quartz tube have also shown excess heat in the order of 20-25%. The efficiency clearly improves with better surface/volume ratios. It is quite feasible that the excess heat can be significant, and commercially viable above 30-50 cm diameter acoustic resonators.

This resonant carbon dust fusion based on combustion is an unknown face of LENR, very far from the electrochemical Pons-Fleischmann cells. It uses the available hydrogen in carbohydrates since all of them are combustible.

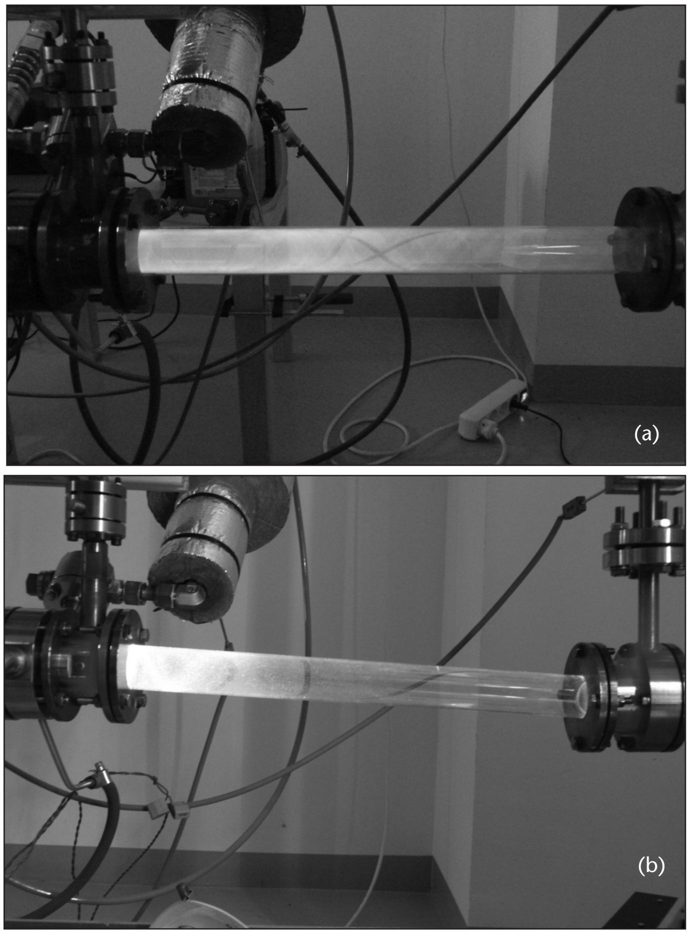
Design and Operational Considerations for Coal Dust LENR Reactors

We used propane, butane, acetylene (C_2H_2) and carbon dust as fuel in our resonant combustor devices. An extensive know-how was developed over the years about different whistle designs. Apart from the Ranque-Hilsch tubes, the design of musical instruments (such as organs, trumpets, etc.) has been carefully studied for years. The inlet air was always tangential with variable angles, because it turned out to be important. An axial whistle of the siren type with rotating blades was also developed to yield input air with pulsed pressure. (See Figure 7d.) Preheating of the inlet air and fuel was important. The real improvement came when the inlet fuel gas was injected periodically to enhance resonant, high pressure combustion.

The method was developed both for turbulent, high power density, and nearly laminar combustion. The efficiency of the latter is higher, because it is more suitable for high amplitude oscillations during laminar combustion. This method may produce so much excess heat that CO_2 and CO molecular bonds are broken. A careful upper temperature limit may reduce NOx emissions as well.

The resonant combustion, LENR based boilers are the most suitable for the elimination of CO_2 emissions from thermal plants fueled with coal or heavy oil. However, by the time dust fusion is acceptable to the mainstream, hopefully other, simpler energy production means will be available.

Several coal fired power plant owners were approached in the U.K., Germany and Hungary to help with R&D, but they were not interested in CO_2 reduction, because it required investment.



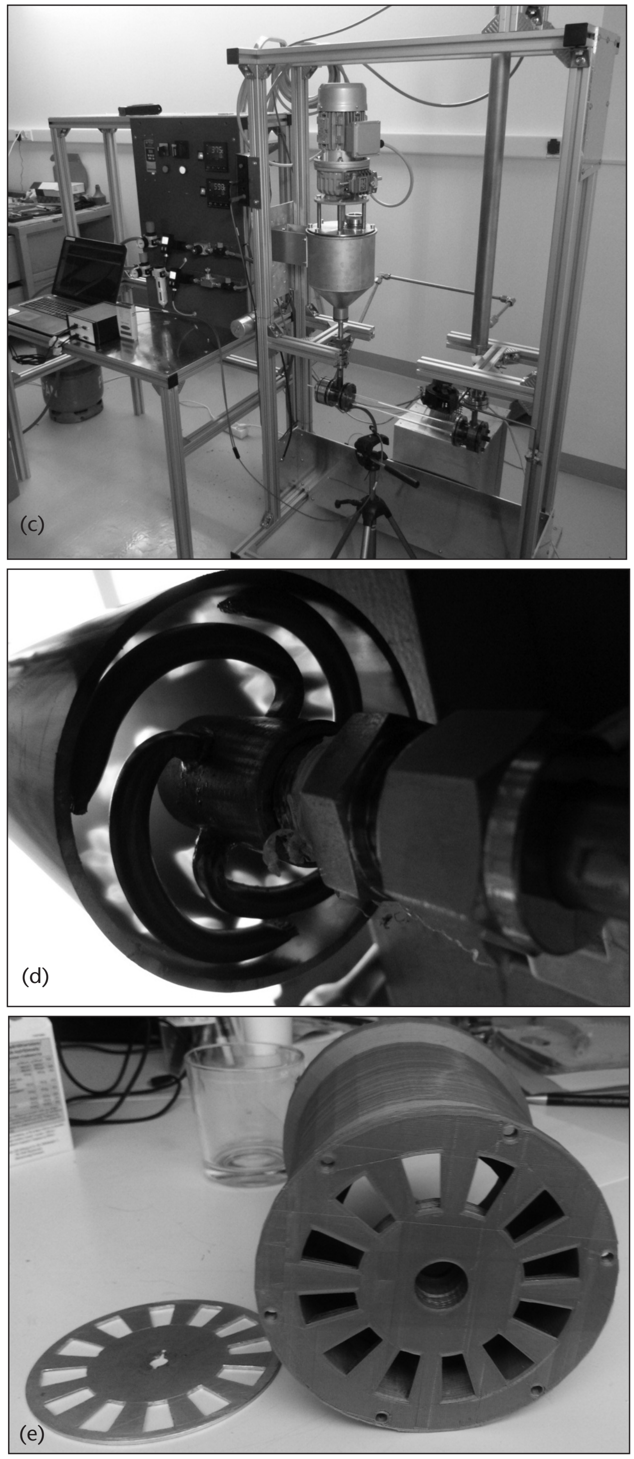


Figure 7a-e. Different experimental resonant combustion devices. The axial high pressure siren oscillator is in Figure 7e. It made possible the turning to resonant acoustic condition for each pressure and temperature. Figures 7a-d are based on the Ranque-Hilsch resonant, oscillating tubes.

Resonant Plasmon Polariton Based Heat Production

Yet another face of LENR is when neutrons are manufactured by resonant plasmon polariton waves.

The plasmon-polariton wave model requires some explanation. There are coupled charge wave propagations above a metal surface in a plasma. Hence the name is plasmon polariton. When a polarization wave moves in a metal, a quasi-particle is generated, just like a surface wave in a pond.

Plasmon polariton waves are known in the plasma above conducting metal and semiconducting surfaces in plasma. Their electric field amplitudes are small when studied above a conductive plane, because they spread, and therefore soon fade. The situation is better along a one-dimensional wire. This method is championed by Celani in Constantan (Ni based alloy). Here the voltage amplitude is constant, but will decrease due to dissipation. Swartz also made a very successful demonstration experiment on thin wires at MIT. The electric field, and accumulated wave energy, can be very high in a coupled plasmon polariton wave when the spreading of the wave is precluded, *e.g.* by spreading the wave only on a thin wire.

The electron wave amplitude can be increased if metal covered fine dust particles are mixed with a number of insulating particles. Thus the metal covered particles are not in electric contact with each other. In principle, a floating bed fits this condition, when about 60% of the bed consists of inert, insulating fine grains (or a floating insulating surface). See Figure 8b, where a mixture of metal covered and insulating spheres are shown. When immersed in a transient plasma, resonant plasmon polaritons may form. It requires tuning-matching the parameters of grain size, pressure and excitation frequency.

This plasmon wave has inertia due to the mass of the ions of the plasma, hence a high virtual mass, like a liquid wave. This is indeed a quasi-particle, acquiring electric charge and a high virtual mass. Most probably this is the notion of the "heavy electron" in the long descriptions of the Widom-Larsen patent applications (U.S. 2008/0296519; 0232532). (There is no experimental evidence that their proposed technical apparatus works.) Evidently, they were not aware of the self-generation of these waves by thermal transients, nor the uselessness of flat plane metals. A similar application was filed by Zawodny (U.S. 2011/0255645). Their theoretical concept seems valid, and worthy of realizing in practice, for example in floating bed reactors. In fact, the Arata-Zhang nanodust bed Pd/Zr reactor is a practical application of this concept. (However, diffusion based piezonuclear fission is also present!)

There is simply no diagnostic tool to measure these waves by probes, or optical methods. They don't even leave traces on surfaces, like condensed plasmoids. This is a fundamental difficulty when these catalytic properties are to be judged. It is highly probable that these waves behave as muons (or pions) and thus are able to catalyze LENR reactions. This is achieved by their high intensity electric fields, and high virtual mass, comprising millions of protons. Further, there is spin field generation due to the relation of rot $S(t) \sim \partial E(t)/\partial t$.

Thus, very sharp electric field transients generate such "heavy electron" quasi-particles, where even a proton + heavy electron wave + neutrino yields neutrons, provided the collective wave energy (0.78 MeV) is enough to squeeze one or more electrons from the plasmon wave into a proton. The thermal neutrons, even if several of them are slow, have a high effective nuclear reaction cross section. They readily react with any nuclei in their vicinity.

It is the task of the reactor designer to generate these waves efficiently, and at the highest intensity.

Tiny sparks or ultrasound acoustic waves may do this job on a conductor/plasma interface, as lucky/brave inventors have recognized.

Even thermal or loading/deloading transients will do this job in a plasma. Neutron formation is the bottleneck of most LENR reactions. Their usual absence outside of the LENR reactors is due to their slow speed, and high fusion capability.

This model gives hints to the design and operation of some LENR reactors. This principle can be combined with condensed plasmoids, because both of them appear under the same technical condition, and amplify each other—a lucky coincidence. The design criteria are clear by now. Use thin wires (mesh) or a dust bed for LENR reactor design, and operate it with transients of heat or electric sparks. Sparks are especially well suited to generate plasmon polaritons and condensed plasmoids at the same time.

These fusion reactors work more favorably with deuterium, but not exclusively. Moreover, the deuterium + neutron reaction yields more energy (about 4.9 MeV) than the proton + neutron fusion (about 1.9 MeV).

The real engineering advantage of plasmon based wave generation appears only for zero dimensional, isolated, small objects, where the energy of the waves persist in resonance. With plane waves, the invested energy quickly dissipates into wasted heat. Apparently these engineering considerations escaped the attention of the handful of people making LENR reactors.

Then the system is flooded with hydrogen isotopes. It is "ignited" by two methods:

1) Transient plasma: then it can't be a closely packed bed, because transient plasma must appear above the metal surface.
2) Heat up the system just above the Parkhomov limit of about 1200ºC and let plasmon waves appear. They can be enhanced acoustically, just like with the solution of Suhas Ralka using an acoustically excited dust bed reactor.

The electric field waves are restricted to the thin metal surface. Their current density electric field amplitude is higher than when a full metal dust particle is used. (See Figure 8b.) A practical realization is shown in Figures 9a and 9b, in a spark discharge between metal electrodes,

We had some limited, first-hand experience with this system. We made a vacuum metal evaporation/condensation system with our small team, where falling micron-size particles became covered with a submicron nickel layer. Unfortunately, the research fund was embezzled by a consulting firm, so we were unable to test the thin metal covered beds. However, there was a semi-successful test series when industrial grade (double and triple layer) carbon nano

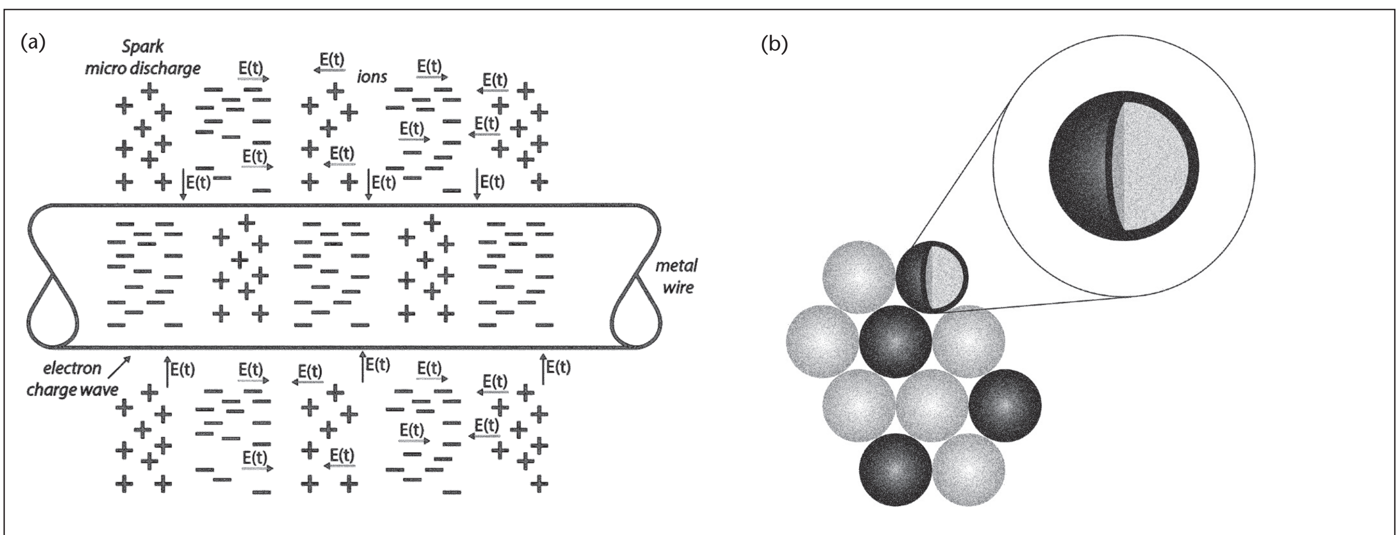


Figure 8. (a) Drawing of a coupled polariton wave (polarization wave) along a wire, and a coupled plasma wave around it. There is no standing wave for a wire, only for a "dot," shown in b. (b) Small beads in a plasma bath. Only some of the grains are covered with metal.

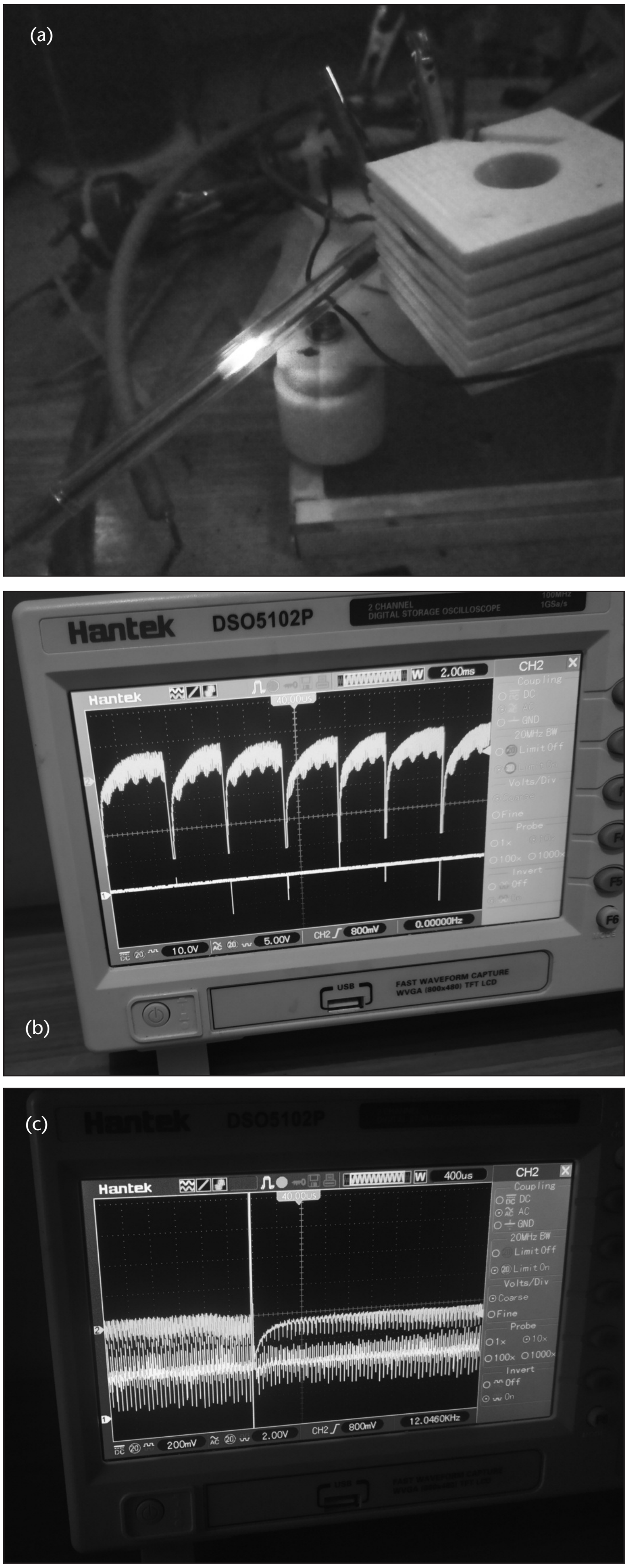


Figure 9. (a) Photograph of a plasmon-polariton wave along a wire. (b) Current and voltage along the wire on the oscilloscope screen. The oscillation has an increasing amplitude only in hydrogen. It has a steady amplitude in air. The spark gap is driven by relaxation oscillator, that is, discharging a capacitor. (c) Note gradual increment of the voltage oscillations (above) and current oscillations (below).

tubes were smeared on a ceramic textile in a hydrogen atmosphere, in a pulsed electric field. The calorimetry yielded about 20% excess heat. Then the remaining R&D funds were stolen again and the project closed.

This is too thin experimental evidence to draw any conclusions. The only conclusion is that charge wave based (heavy electrons in the terminology of Widom and Larsen) fusion works. But considerable R&D efforts are required to assess its merits. (See the author's patent application: WO/2012/164323, U.S. Application 14/118,458. See Figures 10a-d as a practical realization. The plasmon-based reactor was built by the author's team.)

Based on the above brief outline, Suhas Ralka's two step technology seems technically the most promising, and the electrolysis based Pons-Fleischmann cell seem the weakest. It is in fact a discovery, but not a full-fledged invention. Due to its low temperature, there is no room for further substantial technical development.

We shall continue the discussion with "classical" transmutation, or alchemy, though the separation of the two phenomena is somewhat arbitrary, because transmutation is the fundamental process in both of them.

Transmutation — Alchemy

The oldest forbidden area of science is alchemy. Now it is synonymous with "hoax." The fundamental statement of chemistry is: there is no transmutation of elements. It is indeed impossible within the energy range of chemistry of some electron volts, and with the usual test tube methods. Transmutation is a routine process in nuclear physics though at a much higher energy range, and with expensive experimental devices with ion accelerators and nuclear reactors.

Is it possible that transmutation was achieved as a technical process in Roman-Egyptian times?

Sir Isaac Newton devoted most of his writings, experiments and speculations to transmutation. His contemporaries noted that the alchemist's oven near his room was always hot. Was he a part time fool, or a full time genius? It is forbidden to talk about his activity as an alchemist, just as Leibniz witnessing a mechanical perpetual motion machine. Leibniz witnessed it and was convinced about the reality of the perpetual motion machine made by Orffyreus (Johann Bessler). In the early 1700s both alchemy and perpetual motion machines existed but both are vehemently denied now.

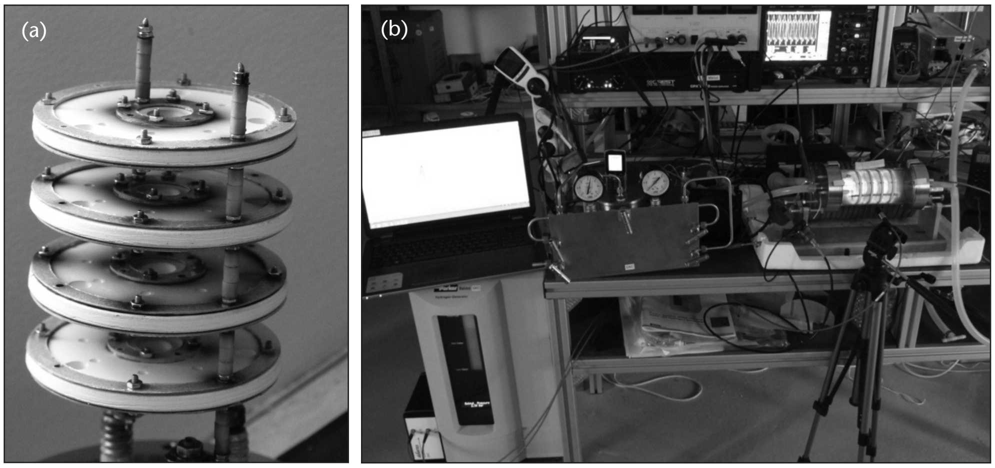
This author has some limited experimental experience with "classical" transmutation, guided by Peter Grandics.[10]

What is the process behind transmutation? Part 2 and Part 3 of this paper described biological transmutation and the necessary conditions to produce heavy elements, like Ca, or even iron. However, the technical setup is quite different, as well as the aim of the experiment.

The aim of transmutation was to make gold, and other noble metals, so the discussion will be focused on these super-heavy elements.

Transmutation is always a two step process:

1) Prepare a fine grain substrate. The size distribution must be uniform, and the grain size is around 1 μm.
2) Heat it to a high temperature, preferably above 1000˚C. The rest is shrouded in mystery, because this type of work has always been a secret. It was quite a usual practice that



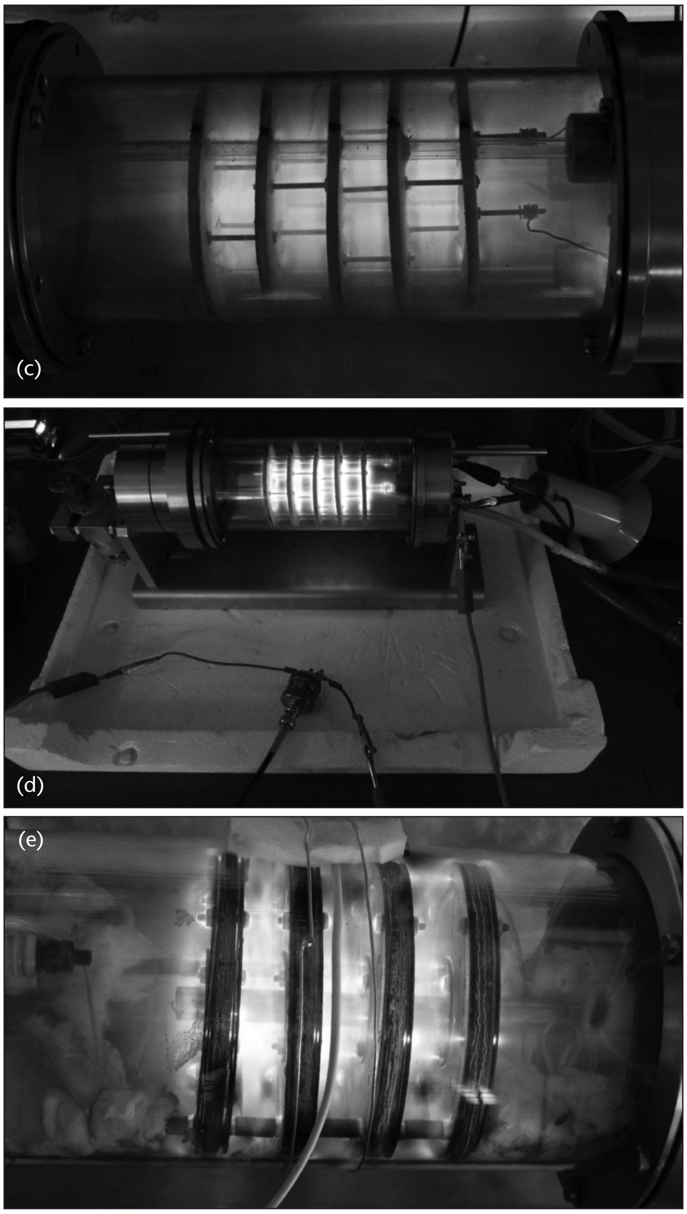


Figure 10. (a) The internal part of the plasmon resonance reactor. The blackish color on the white ceramic are the semiconducting carbon nanotubes. (b) The experimental test stand, heat exchangers removed, with pulsed excitation hydrogen plasma. (c) The reactor with low amplitude oscillation, no excess heat. (d) The reactor with high amplitude sharp voltage pulsed oscillations, in hydrogen plasma. About 20-30% excess heat appears. (e) Closeup of 10d.

successful and unsuccessful experimenters were beheaded.

Therefore there are a number of open questions in this area. No wonder most researchers in LENR consider this traditional method as a fantasy at best, or a hoax at worst. The most likely missing element in the technology might be acoustic oscillations. It has potentially two sources:

1) Thermoacoustic oscillations due to thermal gradients. (This effect is behind the Rijke tubes.) This is a low intensity source due to the damping of the grain bed.
2) The sound of flames (oven system; audible sound). The shape of the oven, its temperature and wood/air inlet ratio were also important. This is a more intensive acoustic effect.

Is the intensity of thermoacoustic oscillations plus oscillating flame intensity enough to create high amplitude oscillations of the plasma in the intergrain cavities?

Can local resonances enhance this amplitude? If so, we are back to the usual situation: an acoustic pressure difference will induce an electric gradient within the cavities of the grains. Thus an electric potential difference is generated because electrons and ions diffuse at markedly different speeds. This is the mechanism of sonofusion, which is LENR based on cavitation, discussed previously.

This is an interesting, exotic research area, because plasma acoustic pressure/electric fields were explored only for shock waves (explosions), where this effect is weaponized. (The purpose is to damage electric and electronic circuits.)

Suhas Ralka's research results took this area to the extremes, where success was obvious. Can the same effect happen at a much less extreme parameter range? This is a risky but exciting area of research. Interested readers are encouraged to enter this field, and to experiment in packed bed plasma.

Dust Fusion

Dust catalyzed fusion is the most ubiquitous in nature, because all the stars, and presumably quasars, function by this method. The dust/plasma volumetric ratio is high in alchemy. It is the reverse in dust fusion: most of the reactor volume is filled with plasma, and a small fraction is filled with solid or liquid droplets.

Dust particles are charged electrically even in a steady state plasma, as discussed in Part 2, because the mobility of electrons is far higher than that of ions. This is known in plasma physics. When dust particles are present in a plasma, they may form a regular hexagonal lattice structure due to their mutual repulsion, termed "crystal plasma." This charging effect is further enhanced by acoustic waves, due to the pressure gradient, as mentioned above in connection with alchemy.

The ultimate dust surface charge density is reached when the acoustic oscillations are in a resonant mode, in an acoustic resonant cavity.

The plasma is always diluted (weakly ionized) at low to high (above atmospheric) pressure under 5000ºC. At atmospheric pressures, the ion and electron temperatures are already equal, and thus the charge of a dust particle can be positive or negative depending on several factors, like the photoelectric effect, the temperature of the dust surface and quality of the material.

Dust mediated fusion takes place on the surface of a rotating, charged dust particle. Note that the dust can even be a liquid droplet, or molten metal because solid state dust is not an exclusive demand!

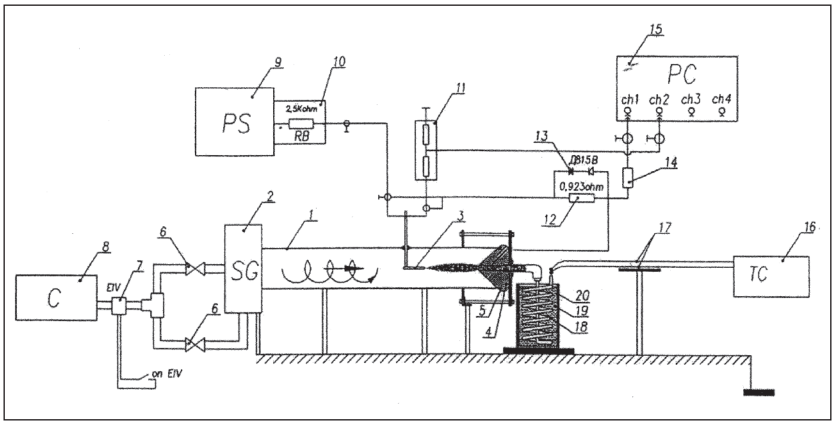


Figure 11. Klimov's rotating dust fusion reactor. The dust particles rotate around their own axis and around the axis of the reactor as well. It is driven by pulsed Tesla coils.

Though there is a growing list of textbooks and research papers on dusty plasma, researchers never consider the rotation of these particles as important. They do not know the work of Ehrenhaft and Mikhailov. Consequently spin field, general Lorentz forces and thus teleportation are also unknown. (It is also generally not known that stars are liquid, and their hottest, energy producing parts are outside their body, in the corona region, where interstellar dust particles are not yet evaporated—as found by the Parker space probe). See Part 2.

No wonder most transmutation effects, and devices with transmutation, have been found in connection with transient dusty plasma.

Nikola Tesla clearly noted transmutation in one of his high voltage tubes, in an interview in the 1930s.

However, the first peer reviewed paper on transmutation was published by the Transactions of the Royal Society[11] by the team of Norman Collie *et al.* (London College, 1910-1914). I have referred to this work as the most tragic missed opportunity in theoretical and experimental physics. Helium and neon were formed by fusion from hydrogen and ostensibly oxygen, diffusing through the glass walls of the discharge tubes!

The next independent serendipity observations were those of the Japanese George Oshawa during underwater arc-welding. (He was living in France at that time.) The Russian Mitkevich also observed an anomaly during transient arcing in 1905, when carbon electrodes were involved. Many subsequent observations noted it, but were duly censured/forgotten.

Recently dust catalyzed fusion tests were renewed from scratch again by:

a) The Quantum Rabbit team.
b) The Russian team of Anatoly Klimov,[12] where the revolving dust particles are also rotated. See Figure 11.
c) This author has built several resonant, acoustic, dust fusion reactors as well, published in *IE*.[13]
d) There were accidental observations of massive amounts of transmutations in India, in an arc smelter/kiln. In the hot, frothing pool of molten iron/silica liquid, graphite electrodes heated the scrap steel/silica and mixture for silica steel production, needed for transformers. The dust was produced here partly by the erosion of graphite electrodes and molten steel mist.

The daily amount of excess Si and Fe was 4.27 tons, coming from the transmutation of carbon electrodes. The yield of this method depends on the amount of molten droplets, that is, the gap between the graphite electrodes and the surface of the molten mixture of Si and Fe. Further, the shape of the kiln is also important due to acoustic resonance. Transmutation is apparent when the arc is in the focus of an acoustic resonance, otherwise it may not appear.

e) Another serendipitous discovery was made by a Russian researcher, M.I. Solin, in a high vacuum smelter, heated by a powerful electron beam. His patent (RU 1977/2,087,951) is not an improvement on dust fusion, just an observation of transmutation as a fact. (Again, a slight overheating, frothing, boiling metal is required. Electrons are supplied by the powerful electron beam of this smelter, not by a plasma.) This vacuum chamber is not even optimized for transmutation, because big chunks of solid metal to be melted are not needed for the process. The evaporating fine metal droplets are important. They fly off due to the intense electron beam. This is not an ideal method to produce a massive economic amount of transmutation. The best method would be a molten metal spray at atmospheric pressure, and acoustic resonance driven by ultrasound source.

Lessons to be Learned

Hands-on, personal experience is most important. Dust catalyzed fusion is the most reliable, least expensive experiment to achieve massive transmutation results. The simplest setup is described below. Only two new parts are required aside from a household microwave oven:

1. A quartz tube, about 15-20 cm long, 20-25 mm internal diameter. If possible, make a trumpet-like conical end (to improve acoustic efficiency) and a slightly larger diameter "belly."
2. An insulating stand to hold the above tube roughly in the middle of a kitchen microwave oven. See Figure 12a.

Preferably use a 1 kW microwave oven with variable power. It would be even better if the microwave oven was driven by a toroidal transformer, for better power regulation. A long incandescent tungsten wire lamp with two antennas at the end 3-4 cm long may help to locate the place of maximum power, and direction of the maximum electric standing wave. (See Figure 12b.) This is a helpful device. The toroidal transformer must be set at its minimum power when using this probe. Also, wet fax paper is suitable to locate the power maximum. Its color will turn dark where the microwave power is at maximum.

The following steps must be taken to prepare the dust fusion reactor:

1) Find the maximum electric field place in the microwave oven.
2) Place the quartz tube there and fill it with a quarter teaspoon of fine charcoal dust in the belly of the tube.
3) Put one end of a soft, thin graphite rod into this dust heap. (Pencil lead of maximum 0.5 mm will do, or even a thin copper wire.) This is for ignition only.
4) Turn on the power gradually until maximum power is reached. It will spark and a quite noisy plasma will fill the tube.
5) Leave the system humming for 3-4 minutes, until the tube becomes red or white hot.
6) Analyze the charcoal dust before and after.

This is the simplest construction for the "bare foot" fusion researcher, the first generation of a dust fusion device. (See Figure 12a.)

The author developed a fifth generation, variable power, variable frequency device with a spherical electromagnetic and acoustic resonator. The advantage of the spherical device is the minimum loss of heat and acoustic energy. (See Figure 13 for a spherical cavity electromagnetic resonator driven by microwaves.) The quartz acoustic resonators are shown in Figure 14. The "pot belly" trumpet-like resonator belongs to Figure 12, the spherical ones to Figure 13.

There is no textbook help for the design of the spherical coupled TE, TEM type microwave cavity resonator. It took three years of continuous R&D to optimize at first TE and TM cylindrical EM resonators, and then to develop the microwave power supply with tunable frequency for 1.5 kW magnetrons. The most demanding task is to design the iris separating the spherical EM cavity resonator from the waveguide. The location of the antenna of the magnetron is also an important design problem. (See Figure 13.) (All of these reactors were taken away from me by the "investors.")

Apart from the electronics, the most difficult part is to couple the magnetron to the spherical electromagnetic cavity, and to match the acoustic impedance of the oscillating plasma. The advantage of spherical EM cavity resonator (a spherical coupled acoustic resonator) is that it reflects heat. A small amount of input energy is enough to maintain the resonant condition, and thus continuous transmutation.

It is very hard to ignite dusty plasma in hydrogen, because it is a very good conductor. Therefore a slightly "polluted" gas must be initially ignited. Then let the system warm up, and pump the initial gas out of the resonators.

The acoustic resonator offers a number of possibilities for frequency tuning. Long tubes attached to a spherical acoustic resonator lower the frequency significantly. Simple holes on spherical acoustic resonators tend to increase the acoustic frequency because they act as Helmholtz resonators. Two holes of different diameters cause two different acoustic frequencies simultaneously.

However, plasma being nonlinear, the difference and the sum of these frequencies appear in harmonics, so a regular series of resonant frequencies appears.

A good ultrasound microphone (up to 100 KHz) and spectrum analyzer help find correlations between transmutation

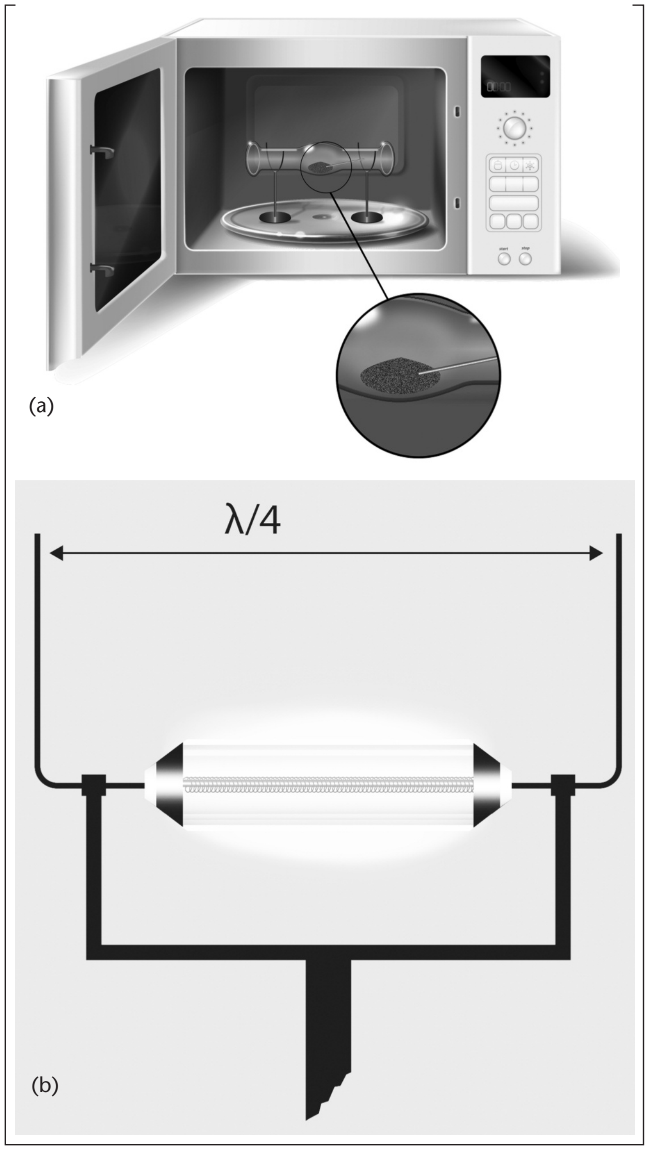


Figure 12. (a) Microwave oven as dust fusion reactor run with charcoal dust. The belly-horn structure keeps the oscillating plasma inside the quartz tube, and locks the acoustic energy in the tube up to 600Hz. (b) Tungsten filament lamp to detect λ/4 microwave standing wave. The best place for the quartz tube belly is where the light intensity is at maximum.

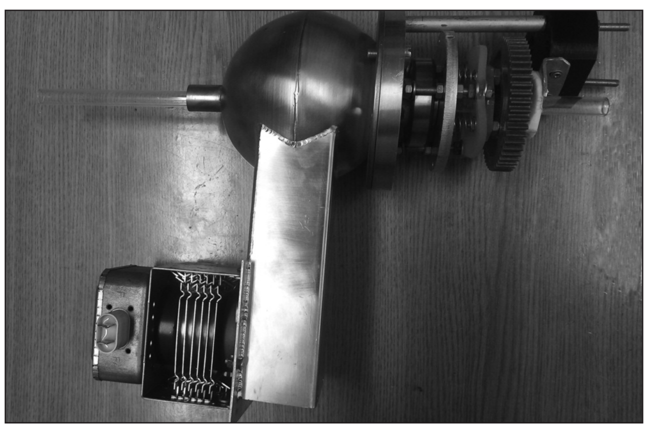


Figure 13. Spherical EM cavity resonator with attached dust dispenser for continuous operation. Note the wave guide between the magnetron and the spherical EM cavity resonator. The iris is between the sphere and the wave guide.

paths and yields as a function of acoustic frequencies and amplitudes.

Apart from the composition of initial powder, the most important parameters are the input power, the temperature of the quartz wall and the acoustic frequency spectrum induced by the variation of the microwave power. External acoustic excitation also enhances the output.

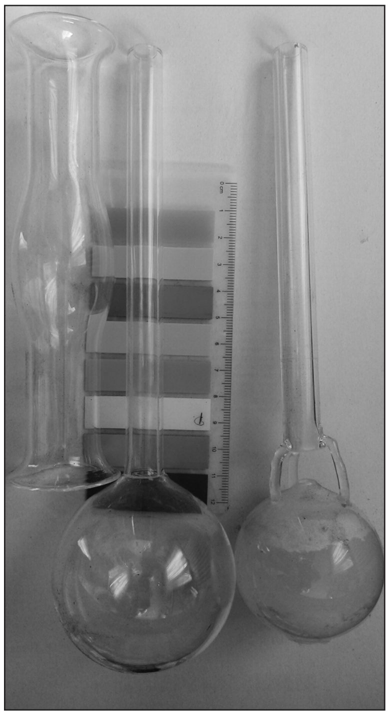


Figure 14. A simple spherical quartz acoustic resonators for the former microwave driven dust fusion reactor. Many other designs have been tested for cylindrical devices. A belly horn type of quartz acoustic resonator is shown, too.

An important note: don't expect much excess heat from transmutation of heavy elements. Szumski's rule restricts the net excess heat, because the energy released in a process is absorbed locally by an unfavorable endotherm process. Thus a new nucleus will be synthesized, requiring input energy. This is the "least action" principle, minimizing excess heat production, and helping isotope shifts and transmutations. Isotope shifts (neutron number enrichment) make this process difficult to understand, because only high resolution ICPMS machines can detect it. Simple chemical analysis cannot. There are only a few data available because these high resolution mass spectrometers are expensive.

Even a small amount of water vapor is able to cool the plasma, and then transmutation stops.

No harmful radiation was observed, only some soft X-ray when the magnetrons were above 1.5 kW power.

There is no emission of strange radiation in this process. We noted unusual, six-sided unexplained traces on the inner metal walls of electromagnetic cavity resonators. It is enigmatic, because we used closed quartz tubes during the tests. (This was noted by Robert Greenyer of MFMP.) It was strictly forbidden for us to study them by the Swiss "investors."

I won a 2 million Euro research grant to build a hydrogen powered home heating system. The awarded grant simply disappeared. Maybe the authorities recognized its disruptive nature. It disappeared even from the homepage of the state research grant agency, according to Sandor Vajda, who was a lawyer managing the application process. A number of test results were published by this author in the *IE* transmutation issue (#142).

The discussion of LENR reactors producing electricity will be continued in Parts 5B and 5C, in forthcoming issues of *IE*.

Acknowledgement

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