FACES OF LENR

Part 5D: Design and Operation Principles of LENR Reactors

George Egely

Introduction to Part 5D

Part 5D concludes Part 5 on the "design and operation" of LENR reactors. (Part 6 will be forthcoming in a few months and will be the last part of this series.)

Very little attention has been paid to cold Pd/D_2 and warm Ni/H_2 systems due to their marginal practical significance in this series, contrary to the usual treatment.

Dust fusion has also been treated briefly, but more attention has been paid to catalytic fusion based on plasmon polaritons (short-lived) and condensed plasmoids (long-lived). Both of them are barely recognized quasi-particles by mainstream physics.

Part 5D includes:

1) A brief section on "second rate" inventions, where even less is known about the design and operation parameters. Though hundreds of such inventions were patented during the last 150 or so years, all of them are buried on the shelves of patent offices.
2) Condensed plasmoid-based *mechanical* inventions "fueled" by the ambient vapor in the air. As usual, these spark-based rotary devices all resemble Wimhurst devices—electrostatic influence machines.
3) The similarity laws between discharges are briefly discussed, because they are needed to have a firm ground for LENR reactor design in transient gas discharge. The attitude and beliefs of inventors and academic researchers are in strong contrast to each other. There is no communication, no "bridge" between them. The forgotten inventions should be fertile soil for academic research. There is no communication even among academic researchers, *e.g.* condensed plasmoids were discovered (and forgotten) at least eight times.
4) Pulsed power supplies are not discussed in this paper; only some features and references are given.[1-4] However, they are a must for plasmoid generation since the work of Nikola Tesla. Though this omission is not fair, these references provide a stepping stone for readers to start their own inquiry.

Hopefully these four papers (Parts 5A-5D) on design and operation give readers enough information to start their own experiments, to be able to check the validity of the claims laid down in this series of papers.

Second Rate Inventions

Even the "first rate" inventions discussed in Part 5C were not detailed enough to reach the threshold of reproducibility, but this group is much worse. In that sense that there are no established power balances, eyewitness reports, photographs and technical parameters on materials, scales, pressures, etc.

The only reason to deal with them is they sometimes contain a grain of insight useful for further considerations.

For this part of the paper, I referenced a collection of water-related patents.[5] The book presents a simple search, restricted only to U.S. patents. Thus only English language patents were used, omitting the rest, the bulk of patents. Based on my crude estimation, because there are three Hungarian water/fusion related inventions (Joseph Papp, Steven Horvath and Janos Jekkel in Part 5C) for 10 million people, I expect the same ratio prevails at least in Europe, or through the industrialized world.

This subject has a powerful multiplication, cross fertilization or "pinball effect." This is the reason we deal with it so extensively. Tesla's invention of the poly-phase current, as a requisite of cheap and reliable electric power production and distribution, had a truly beneficial, transformative effect upon society. It made possible the utilization of hydraulic and coal power far from urban centers (Niagara Falls), thus helped urbanization to a significant degree. His motors, for example, made possible the electric elevator among other things, which made high-rise buildings feasible, even skyscrapers. It also made subways/metros possible. As remote coal mines as power sources became feasible, cooling and refrigeration became possible, too. Thus the food supply chain became longer, making food cheaper.

Aluminum manufacturing requires a large amount of inexpensive electric energy. Tesla's poly-phase system, among others, made aluminum manufacturing economic, thus building large airplanes became possible.

Sparking in water/hydrogen is of similar practical importance. It is quite unclear why Tesla (or any other inventor) was unable to make the last step—the mass production of his prototype.

Anyway, it is certain that dozens of other similar inventions are hidden, buried in Romanian, Czech, Serbian, Russian, etc. patent offices.

By now readers are familiar with the most important criteria of catalytic fusion by pseudo-particles. Therefore they are able to comb through the layers of patent histories. For now we will discuss only three patents.[5]

L.H. Wattles, Patent 583,104 (1897)

In this invention a zinc cathode is used, immersed into an acid. Even without electricity, zinc develops nascent hydro-

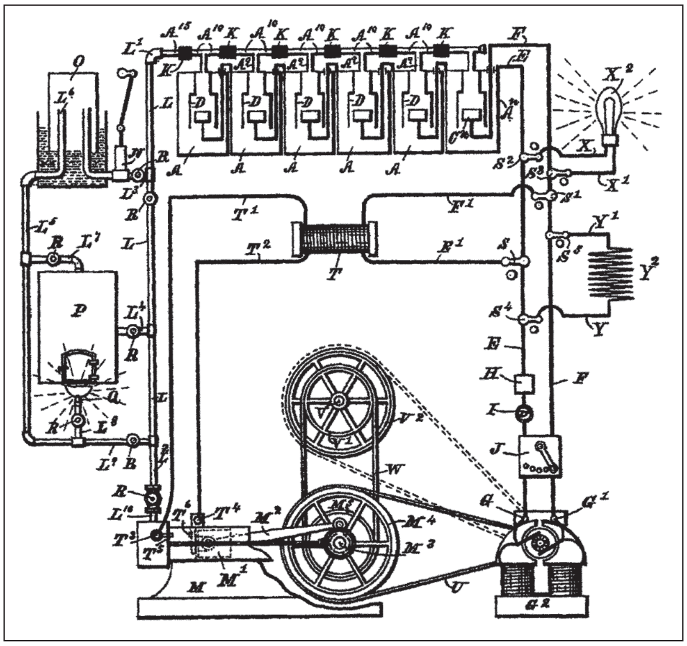

Figure 1. The Wattles device. Though an internal combustion device was used to generate electricity from hydrogen, the pulsed electric circuit is apparent. The system might have fed itself at some parameter range at the price of zinc consumption.

gen, useful in fusion. Wattles invented a closed, self-running system with pulsed generation of electric energy, as seen in Figure 1.

The device is based on electrochemical and pulsed electrical hydrogen generation. The inductive circuit is shown in Figure 1. Other figures (Figure 2 of the patent, not reproduced here) disclose sharp edges of the zinc electrodes, thus the pulsed electric circuit may generate profuse sparking in the acid. This in turn can lead to excess hydrogen generation.

H. Eldridge/J. Clark/B. Blum, Patent 603,058 (1898)

This invention has the same layout as the Parkhomov *et al.* patent described in Part 5C. The carbon rod cathode is above a liquid surface, and periodic pulses are applied. Even without it, the frothing liquid definitely interrupts the arc current with high frequency. (See Figure 2.)

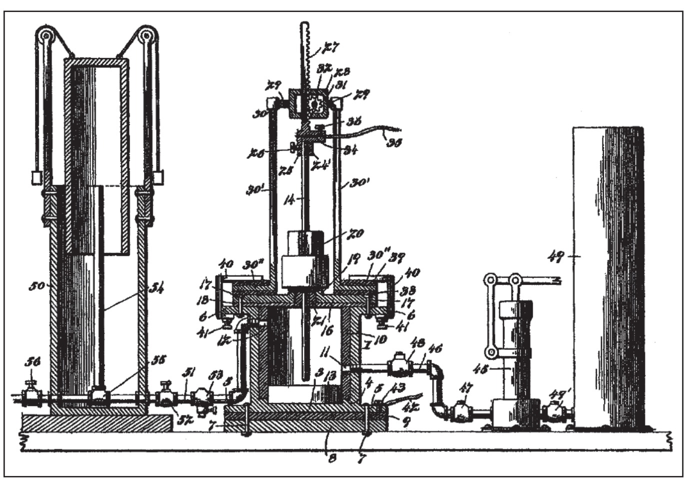

Figure 2. The Eldridge *et al.* device. Note the carbon rod above a liquid surface.

S. Ruben, Patent 1,431,047 (1922)

Ruben, the co-founder of Duracell, patented a pulsed electric water splitter. This patent (method) most probably has the technical potential to generate excess amounts of oxigas.

There are some unique and potentially useful features of this invention. As seen in Figure 3, there are two electrodes, E and E', immersed into an electrolyte. However, the hydrogen generated this way is led back into the porous cavity of the E' cathode. This cathode is also driven by electric pulses, emphasized in all seven claims.

The D power supply (B) is modulated with an AC part, regulated by a high frequency, rotating spark gap (20).

The high voltage, intermittent switching generates pulses on the sharp edges of the holes bored into the walls of cathode E'. The cup (11) is porous, thus electrolysis is possible. Though no parameters are provided, the electric circuit and the electrolytic splitting vessel seem to be reproducible. Finding the right parameters certainly requires patience. This is a good project for garage experimenters.

Mechanical LENR Devices

Thestatika, Hyde, Godin, Roschin

The common feature of these mechanical devices is that all of them used transient filament discharges. Mechanical devices use rotating parts of *highly charged disks* as a source of spin field.

This is bizarre indeed. They seem to be so far from the electrolytic LENR cells that no relationship was ever

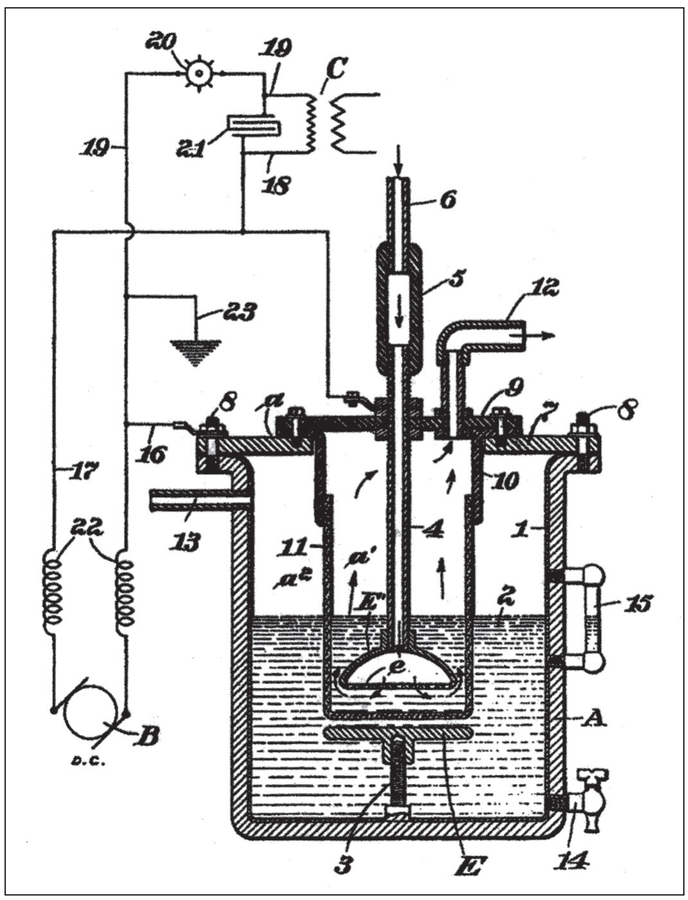

Figure 3. The Ruben device. The unusual, although useful, feature of this patent is that the DC generated hydrogen is led back into the cathode.

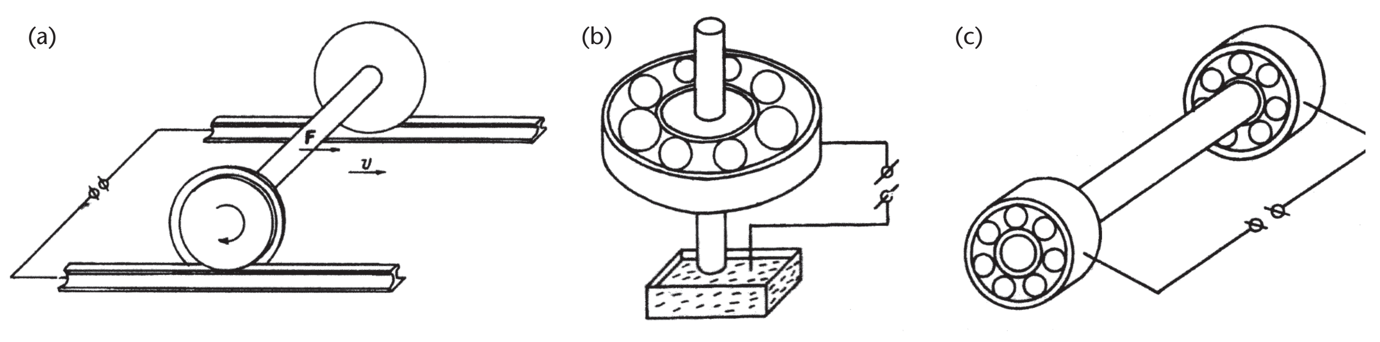

Figure 4. Sparky contacts with rolling metal contacts. (a) Wheels on rails; there are only two contact areas along lines. (b) A single ball bearing with several contact points. The mercury contact is not necessary at the bottom! (c) Two rotating ball bearings. This setup requires more than 10A, 20V DC power supply. It must be kick started, then it rotates at very high angular velocity.

assumed to them.

The Godin-Roschin Russian antigravity device is also based on transient spark discharge. (We will discuss those devices in Part 6.)

Ball Bearing as a Micro-discharge-based LENR Reactor

The title of this section may seem absurd at first sight, but not impossible. Swiss engineer Jakob Huber and Adolf Egloff of Bern found a strange effect in 1959. A ball bearing started to rotate when DC current passed through it, or even a pair of metal cylinders rolled along a metal rail. (See Figures 4a, 4b and 4c.) The rolling effect had very little torque, but it *worked for AC as well*, for any frequency and for DC regardless of polarity. This seemed to be at odds with Maxwell's electrodynamics.

A high level theoretical paper was published by Canadian H. Gruenberg in the *American Journal of Physics* in 1978.[6] This sophisticated theory explained the small torque and the apparent insensitivity to the nature of current type. This effect puzzled several Russian researchers because it seemed at odds with textbook physics.

We also tested this effect in Hungary, melting several pairs of spherical and cylindrical types of ball bearings. We noted the extensive sparking around the balls. After awhile the steel balls became bluish due to overheating, and perhaps transmutations, and finally welded into one of the inner rings.

However, Russian researcher N.N. Sinelnikov hit the nail on the head. He tested the rotating wheels in a pressure chamber. It turned out the effect was sensitive to pressure, that is sparking. Angular velocity correlated only with the intensity of sparking at the contact surface of balls or wheels, and *hot air caused the rotation*, in his opinion.

Steady sparking due to poor contact and consequent heating of the surface rolled the balls at high speeds. However, when sparking appears in a mechanical device (or any device), plasmon waves and condensed plasmoids may appear as well. When it happens in damp air (that is, hydrogen is present), a low efficiency LENR process takes place. Thus electrons ejected by the condensed plasmoids also contribute to the driving of ball bearings. In fact, this mechanism may appear in all electrostatic influence motors and generators, provided there is some humidity around.

The Thestatika (Swiss M-L Converter)

One of the most mysterious devices of the "free energy" world is the invention of Paul Baumann, a religious leader in the Mathernita community in Linden, Switzerland. See Figures 6a-e.

A host of German engineers witnessed several demonstrations, however they were never able to replicate it despite strenuous efforts.

The device itself looks like a Wimhurst machine, with counter-rotating plexi wheels. It is an electrostatic influence machine, creating static electricity not with friction, but by electric polarization of metal plates—and with sparks. Several influence machines were invented to generate high voltage static energy by polarizing metal objects, then grounding half of the charges. This made possible the generation and accumulation of high potential positive and negative charges. The Holtz (1856), Töpler (1866) and Wimhurst (1883) machines are usually high school physics demo machines. Sometimes even the belt driven Van de Graaf generators are demonstrated.

Their common and important part is the group of sharp needles, shown as S1 and S2 in Figure 5.

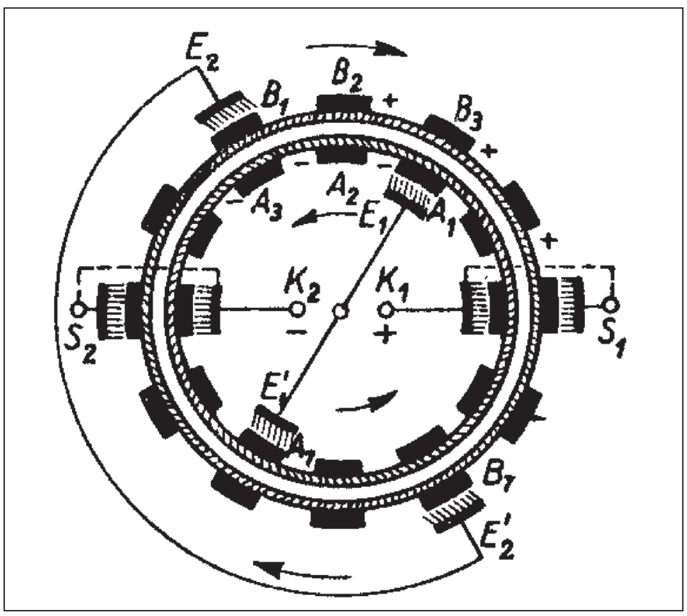

Figure 5. The scheme of an electrostatic influence machine. The input is mechanical energy by rotating the wheel. The output is high-voltage low-current electricity.

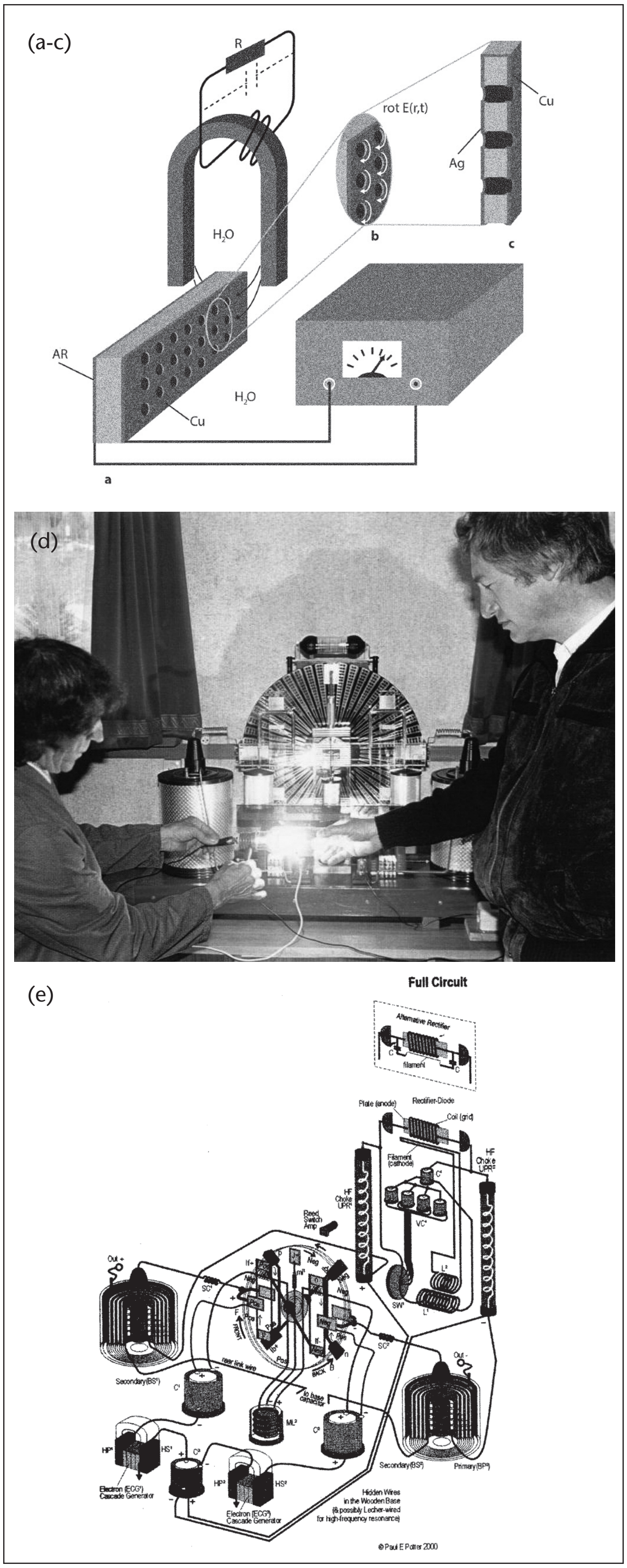

Figure 6. (a-c) The Linden demonstration device. (a) The setup with the movable perforated metal plates. (b) The induced electric vortexes around the perforations. (c) The enlarged cross section of the hole. Note the sharp metal edges at the perimeter of the holes. (d) Baumann with a Thestatika machine, 1984. (e) The likely wiring of the Thestatika device from the book by Keith Tutt.

They do not touch the "influenced" (electrostatically polarized) metal. They have a spark gap, and high voltage spark discharge—micro-discharges appear on their tips, creating condensed plasmoids. They carry the electrons, during polarization. The other contacts (E1, E2) are soft metal brushes, touching the metal lamellas, thus having a galvanic contact. In Figure 5, the difference is not apparent, but in fact they have quite different physical features, by now clear to the readers.

Are all the Wimhurst or Van de Graaf machines over-unity LENR reactors? Not at all, just like an ordinary electrolysis has no LENR at all.

In order to initiate LENR in the mechanical devices, further technical steps are required.

A curious fact was observed with the Thestatika machine by witnesses. It stopped rotating after one or two days in a closed room; in hindsight it seems they were using up all the vapor in the room—the fuel. (This casual remark of one observer hit my alarm bell, arousing my curiosity.)

The Thestatika device is described by Keith Tutt in his 2001 book *The Search for Free Energy*. German Engineer Sven Bonisch made most of the careful "reverse engineering" work—partly on Thestatika, partly on short gap electrostatic discharges. Unfortunately, he missed the condensed plasmoid work of Shoulders, and the catalytic fusion effects associated with them. Though he was an accomplished, careful researcher, he kept on thinking "inside the box." With coworkers he published some spark discharge models and test results, about short gap electrostatic discharges (ESD).[7]

Skilled engineers (over 100) missed the salient points of this machine (and the Hyde and Godin/Roschin devices to be discussed in Parts 6A and 6B).

The following tentative sequence of processes take place in all these mechanical LENR reactors:

1. Create condensed plasmoids with short bursts of corona discharges at metal tips, in a short (0.1 - 5 mm) spark gap.
2. Have an electrostatically highly charged rotating wheel, to generate spin field. (See Parts 1, 2 and 3.) The spin field will tear apart the chain of condensed plasmoid "pearls," thus making them capable of catalyzing.
3. Make sure to have damp air containing hydrogen. (These machines can make wonder in a box of atmospheric deuterium gas!) When sparks ionize vapor, hydrogen participates in several fusion reactions, releasing high energy electrons. (Remember the Tom Claytor experiments yielding tritium as a consequence of sparking in deuterium gas.)
4. Collect the high energy electrons, separate them from the plastic/metal interface. The influence machines are the right devices, they are made for charge separation and charge collection. This is one of the reasons LENR electric energy generation was found with these machines.

It must be noted: The Thestatika is not the usual Wimhurst machine! There are similarities, but also marked differences, in the construction. The most striking difference is the shape of the metal lamellas on the counter-rotating surfaces.

There are only some small-area radial metal foils on a Wimhurst machine without holes on the foils. On the Thestatika the mesh lamellas cover more than half of the areas. Thus more charge can be stored on the rotating surfaces, consequently the spin field is stronger, influencing the movement of condensed plasmoids.

The Thestatika Demo Device

The Thestatika device, a mechanical "perpetual motion" machine and a hacked Wimhurst electrostatic device, was demonstrated several times for engineers.

Several times they witnessed two large counter-rotating perforated wheels yielding about 1 kW of electric energy. The device had feedback, thus the 1 kW output was the net gain. The efficiency is meaningless in this case. However, various devices were built, but they were so complicated that the witnesses were unable to make sense of it. No wonder. The inventor himself had no scientific concept of what made its action possible. (There are a number of related videos, photos and reports on the internet.) (See Figure 7.)

Baumann invented the fundamentals when he served a jail sentence in a Swiss prison. When released, with a small team he built the invention based on the large counter-rotating disk. He gave several lectures about the principle of this device to curious engineers in the city of Linden. So the following description is an attempt to explain its principles, noting the important, although hidden, features of the demo device.

Knowing this, one can build a large influence machine device with direct electricity generation. Not only the Thestatika, but also the Hyde machine (U.S. Patent 4,897,592 - 1990) is based on similar principles: sparks are generated in humid air between highly charged rotating plates. (See Figure 8.) These machines are so efficient that the small amount of hydrogen found in humid air is enough to run them.

The Irreducible Demo Device

The demonstration device seems to be simple, devilishly simple. However, no one succeeded in replicating even this simple demonstration.

The device is shown in Figure 6a. It consisted of the following parts: a horseshoe magnet with some wire around it and a wire loop as an oscillating circuit with distributed parameters.

The other innocent-looking part was a plastic sheet with aluminum and copper plates on the opposite sites, both perforated with coaxial bore holes. These electrodes were soldered to wires, and connected to a sensitive galvanometer with high input resistance.

The perforated plate sandwich was pushed in and out between the legs of the magnet during the demonstration, and the galvanometer registered up to 700 V during these swings.

The witnesses, skilled German engineers, were shocked by the effect. This shouldn't have happened at all according to textbook physics. The metal plates, made of aluminum and copper, should generate only eddy current losses, but it shouldn't appear on the galvanometer. There is not even a closed circuit, therefore no voltage can be induced. Electric current was not measured at all, but even static potential difference, which is very hard to measure in absence of current, is clearly anomalous. (See Figure 6b.)

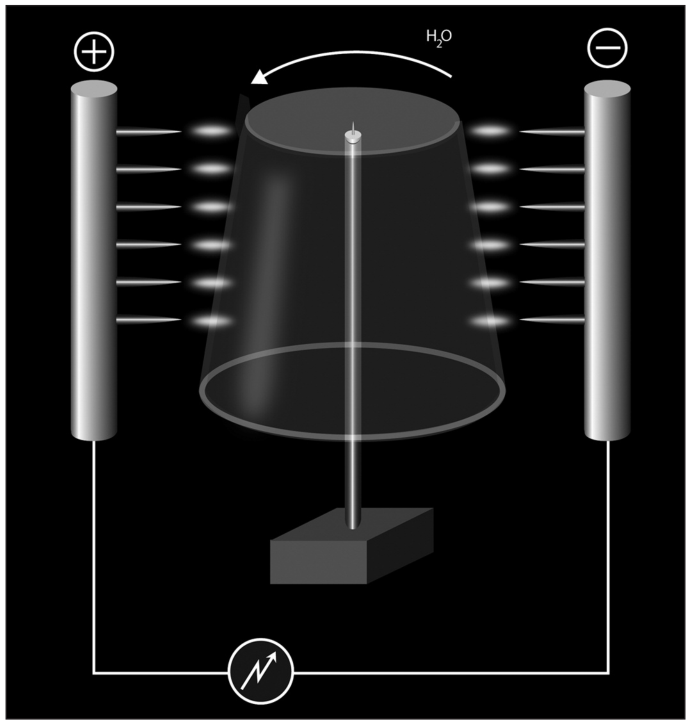

Figure 7. The scheme of a simple electrostatic motor based on sparks.

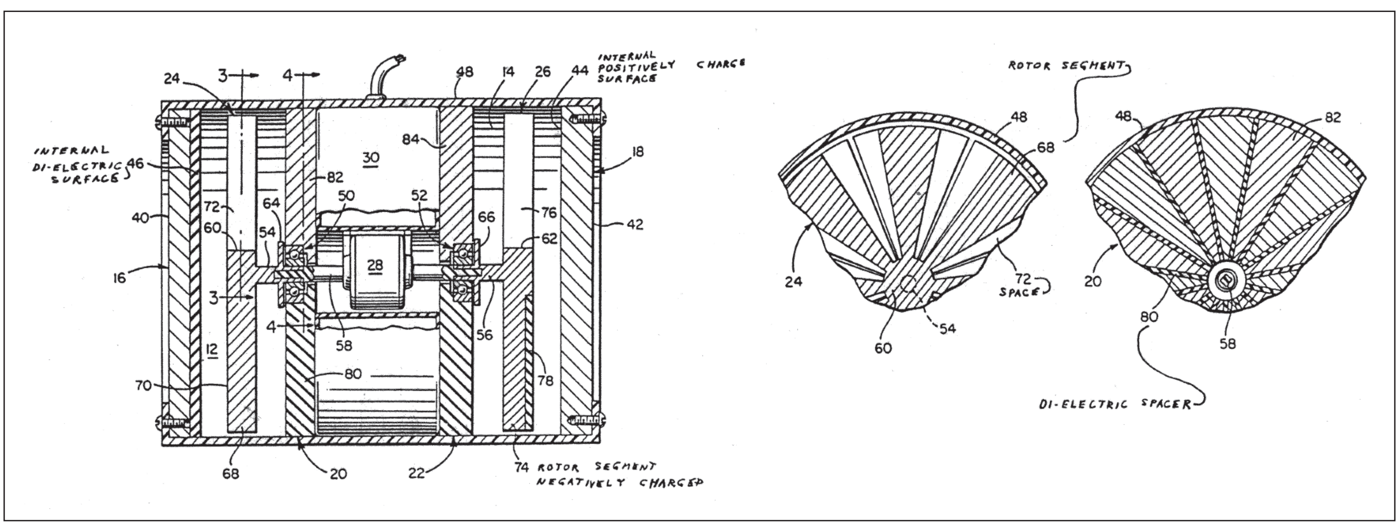

Figure 8. The patent drawing of the Hyde generator. Note the highly charged rotating lamellas.

What is the significance of the wire loop on the magnet? Why are there two different metals? Why are they separated by a plastic plate? Why are they perforated? There is no sensible answer to these questions, based on textbook physics.

There were several unsuccessful attempts to replicate this demo device. Therefore skeptics assumed some tricks, and "believers" thought some hidden know-how. Obviously, all attempts to replicate the more complicated device of double spinning wheels failed, too.

The Mathernita device demonstrations ceased after awhile, and this enigmatic device just faded away from actively pursued backyard research.

We shall try to give a tentative answer for the riddles based on the previous papers, especially Parts 1, 2, 5A and 5B.

The Hidden Know-how Behind the Demo Device

The Thestatika device was not built by the author, but the hands-on experience on sparking seems to be enough to indicate: it is possible that the device was run on *micro-discharges*. The hidden know-how is laid in the perforations: how the edges of the metal plates (electrodes) were formed, what was the condition of their surface and edges at the perforations.

These hidden features are essential to understand the principles behind the Hyde generator, and the Godin/Roshin antigravity invention (to be discussed in Parts 6A and 6B).

The following effects must be considered in order to explain the demo device:

1) The field of the horseshoe magnet is obviously inhomogeneous. Therefore, eddy currents are induced around the perforations when the "sandwich" plates are pushed through the legs of the magnet. This induces periodic changes in the magnetic flux. That, in turn, induces an oscillation in the wire loop wrapped around the magnet. Note that there is a resistance in the loop, thus the loop has an oscillation, because there is a small distributed capacitance between the wires. If the loop is of a proper size, even a resonant oscillation can be observed. (See Figure 6b.)
2) When there are two different metal plates, and there is a poor conductor (semiconductor) between them, a significant, observable amount of charge accumulates on their surfaces at about 0.3 Volts. (See Parts 3 and 4.)
3) When the edges of the metal plates at the perforations are sharp (see Figure 6c), a significant electric field is induced, enough to initiate a spark even for a static field. A micro discharge, a small spark, produces a condensed plasmoid at its head. This is not enough in itself; there is a need for an external transient field in order to catalyze fusion: electric, magnetic or spin field.

The formation of condensed plasmoids is necessary but not adequate, as discussed before in Parts 5A and 5B. A transient external field is required for the "white," active condensed plasmoid, for the catalytic condition.

The small demo device produces transient spin field, and transient magnetic field, via the electric vortexes around the perforation holes in the sandwich-type plates.

The induction equation is the following in vector formalism (though S field is a tensor) from the extended electrodynamics, which include charge rotation (Parts 1 and 2):

$$\text{rot } E(r,t) \sim \partial B(r,t)/\partial t + \partial S(r,t)/\partial t$$

This is the S spin field generated by two effects: the electric vortex field around the perforation holes and the changing magnetic field due to the oscillating circuit coupled to the horseshoe magnet. That is, the time dependent spin field after rearrangement is:

$$\partial S(r,t)/\partial t \sim \text{rot } E(r,t) - \partial B(r,t)/\partial t$$

What is the hidden know-how in the demo device? A number of invisible parameters, like:

a) The conductivity of the plastic. Maybe it was warmed and mixed with fine carbon dust to make it semiconductive. Thus it could generate/collect more charge, as a source for micro sparks.
b) The radius and density of perforations, holes.
c) The sharpness of the metal edges inside the holes.
d) The distance between the sharp metal edges.
e) The field data of the permanent magnet, inhomogeneity.

These data were never observed, let alone recorded.

It is important to note that the perforation/sharp metal edge combination is not always necessary. It is possible to catalyze LENR with sparks alone. However, these perforations are useful as auxiliary effects. The electric vortexes around sharp-edged holes in an inhomogeneous transient field help catalysis.

This engineering "booster" or power enhancement is invisible to the untrained eye, and they just look meaningless within textbook physics.

It is not known how Baumann came to grasp these steps in prison. Certainly the usual combination of luck, insight and perseverance was necessary, as well as the tolerance of the prison guards. Most bosses in academic and industrial research labs are far less tolerant to lab "underdogs."

The counter-rotating perforated wheels in the Thestatika device have all the elements discussed above. Such a detailed blown up drawing is shown in Figure 6e. The exploded diagram of the complicated wiring is shown on page 117 of Tutt's book. It is too complex for reverse engineering, but the above-mentioned demo device and the previous discussions of spark structure in Parts 5A, 5B and 5C help the reader to grasp the essential physics.

The periodically charged, counter-rotating wheels are shown in this figure, but the horseshoe magnets and the perforations with sharp edges are missing. There are several photographs on the internet of this device, of varying quality. (See Figure 6d.) There were a number of attempts to replicate the device. All of them failed due to the lack of comprehension.

The mere fact that highly charged rotating wheels generate a new symmetry, and therefore a new field, is unknown in textbook physics. This is not enough for catalytic fusion in itself, but an important side effect to activate the condensed plasmoids generated by the high voltage influence machines.

On the technical side, electrostatic motors are less known, because their energy density is far less than that of motors based on magnetic field.

The electric field intensity is severely limited by insulation capability, while this limit is less restrictive for magnetic motors, let it be any type.

It is very easy to make a simple electrostatic motor based on sparks generated on the tips of sharp needles.

There are dozens of simple constructions shown on YouTube. Their rotor is usually a plastic cup suspended in vertical position on the center by a needle. The high voltage (5 - 20 kV) is supplied usually with high-voltage, low-current, high-frequency resonant power supplies at a modest price. (See Figure 7.)

When such a device is put in a box where the atmosphere is water-vapor/air mixture, we have a modest LENR machine with little practical use. Considerable R&D is necessary to increase its efficiency, as was done by Hyde, or with the Thestatika machine.

The fundamentals are the same everywhere: generate condensed plasmoids by sparks efficiently, then make them catalyze fusion of hydrogen to higher mass nuclei, thus releasing high-energy electrons during this process. These high-energy, thus high-potential, electrons drive mechanical, electric and heat generating systems, or split water molecules to generate HHO oxigas.

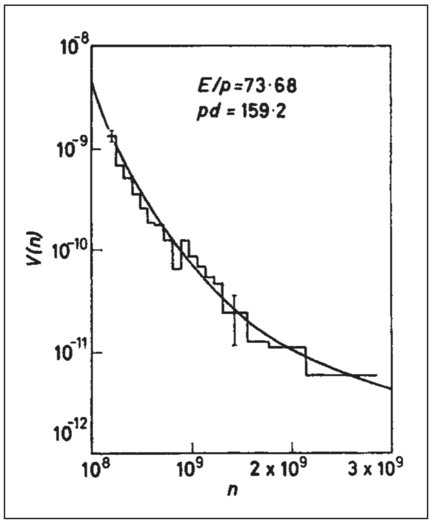

Figure 9a. Electrical charge distribution of charge clusters—condensed plasmoids in Raether's test. He used coplanar electrodes to study the discharges. Usually a cluster contained 10^6 - 10^8 charge electrons.

On Being Unusual

LENR is an oddity for mainstream researchers; most of them dismiss it out-of-hand. Only a small group accepts LENR de facto, but a mechanical fusion device exceeds even their tolerance level.

Though the sparks are essential, the means of high voltage generation is a secondary issue. (There are some patents on influence machines, like U.S. Patent 3,436,630 by B. Bollee.)

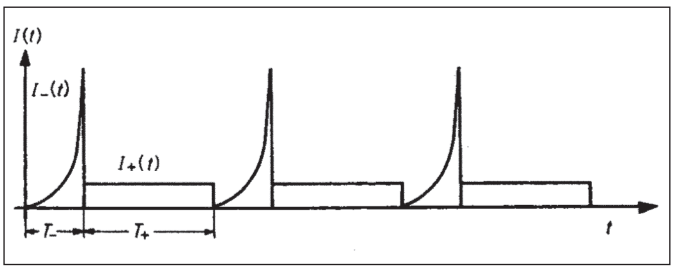

Figure 9b. The current as a function of time in a spark discharge. At first the condensed plasmoid arrives with a lump of negative charges. Then the positive ion trail arrives slowly, gradually.

There are a few academic papers on high-voltage influence machines. I recommend only one of them: M. Zahn *et al.*: "Self Excited, Alternating, High Voltage Generation Using a Modified Electrostatic Influence Machine," *American Journal of Physics*, Vol. 42, April 1974, pp 289-294.

Electrostatic motors in general are inferior to magnetic motors. Their only advantage is simplicity. However, they can generate a fairly strong spin field due to the rotating, uncompensated charges.

For this and only this reason alone they can be a useful research tool in the future.

The Missed Opportunities by Four Blind Men

There is a well-known parable about an elephant and four blind men. Each of them approached the elephant, and touched it for awhile at a certain location. The first, who touched the trunk, described it as a flexible duct. The second, who touched the belly, described it as a hairy, soft, warm sphere. The third, who touched the tusk, described it as a smooth, hard, cold, curved sword. The fourth, who touched the feet, said it was a soft column.

Each of them were correct, partially. This is the same with the observations about the features of condensed plasmoids.

Heinz Raether found that they were the agglomerate of an embarrassing number of uncompensated charges up to the order of several billions! His findings were published in *Zeitschrift Physics*, as early as 1935 (Vol. 94, p. 567). Several papers followed in *Zeitschrift Physics*, a leading theoretical and experimental journal of that time.

Yet no one raised, or answered, the question: why were these charges "glued" together? They are not nucleons so strong interaction is ruled out between them. He even plotted the distribution density of the charge clusters. (See Figure 9a.)

It turned out that most of these electron clusters have "only" 0.5×10^8 charges/plasmoids—depending on the gas pressure and material, electrode shape and electrode material. (See detailed review in Raether's book *Electron Avalanches and Breakdown in Gases*.)

Raether clearly missed other essential features of the "elephant," like the temporal stability, and of course the notion of quasi-particle as a theoretical concept. Concepts of quasi-particles—like the exciton, phonon, magnon, etc.—escaped him and his contemporary theoreticians. He measured the charge content of a plasmoid by measuring the current as a function of time. (See Figure 9b.)

No one recognized that this strange object could be as useful as fission of nuclei.

Raether missed again a second time, as in the second period of his life he studied surface plasmons—which are also quasi-particles.

He was a young physicist, age 25 in the 1930s, when he discovered the huge charge clusters. However, he became a seasoned experimenter by the time he made remarkable observations about the coupled charge waves in conductors, and even the plasma oscillations above them. See, for example, his 1988 book *Surface Plasmons on Smooth and Rough Surfaces and on Gratings*.

Raether never tried this wave excitation on closed (dust) surfaces, where resonant amplification is especially strong, but realized it on a rough silver or gold surface. Also, he never tried hydrogen plasma, because fusion seemed impossible at the 1 - 10 eV range (glow discharge).

Gennady Mesyats, a prolific writer, also discovered the existence of condensed plasmoids during spark discharges. He termed it as ECTON=explosive electron emission, which is correct in a restrictive sense. He published many papers, and two detailed monographs on pulsed vacuum discharge, worth reading even for the LENR community, as they contain many useful sub-effects, and description of pulsed power supplies.[4,5]

Despite his immense hands-on experience with charge clusters, Mesyats considered it a "short living electron avalanche" (XVII. Int. Symp. on Discharges, 1966, p. 720).

Do we talk about the same phenomena? Yes, as based on the formation criteria, pulsed power at high voltages, there is no doubt. Yet his notions of the "elephant" or condensed plasmoid is quite different from ours, especially concerning the duration of the charge clusters. Clearly, Mesyats and other experienced academic researchers did not expect "Ectons" to be so rich in useful features.

Even the small LENR community is unaware and apparently unconvinced about the catalytic nature of condensed plasmoids.

Ken Shoulders described the useful nature of these plasmoids in his patents and books (Parts 5A and 5B), that is, their mobility and long life in narrow channels, which Raether and Mesyats missed.

Matsumoto clearly outlined the causal correlation between these plasmoid traces (found on exposed X-ray films) and transmutations in his publications (Parts 5A and 5B). Yet he missed the conditions of the formation, because he always used electrolysis with high current, sparking in the electrolyte.

Inventors like Moray, Tesla, etc. used the condensed plasmoids, formed during spark discharge, without digging deep into the physical nature of the these catalytic quasi-particles.

This is a deep rooted problem in science and engineering, the fragmented "mosaic" knowledge. Each observer notes only one side of the "elephant." Yet there is deep mistrust built up between inventors and scientists, with a mutual disregard of the others' results.

Physicists seldom read old papers, especially old patents. Garage inventors never read academic research papers or monographs, because they are not specific about the practically useful, unused features of discharges in gas or vacuum.

The ignorance of patent examiners and research grant agencies on this area is of a tragic degree, leading to environmental degradation.

Lacking a seamless knowledge of all useful features of the self sustaining, catalytic cluster charges, inventions were based on luck only—a luxury we can no longer afford. We can't afford to be blind any longer. Hopefully this series of papers will connect the dots, as was promised in Part 1.

There is still need for more detailed know-how, and extensive material research for proper surfaces and materials, just like for battery research and development, which was dormant for nearly 100 years.

Raether, Mesyats and even Shoulders were three essential steps away from practical applications:

1) Economic formation of a large amount of condensed plasmoids.
2) Storage of condensed plasmoid groups around the cathode.
3) Enforce the nuclear catalytic actions of condensed plasmoids by external pulsed fields.

The ultimate difference between spark and glow discharge is the formation of clusters of charges, versus smooth distribution of charges in steady or transient glow. The dusty transient plasma has several similar features in charge cluster distribution to spark discharges, usually ignored or downplayed in large monographs on gas discharges.

It is worth noting here that there is a nearly 100 year long enigma in arc discharge as well: the *retrograde motion of cathode spots*. It is well known that arc discharge is maintained by the electron emission of hot cathode spots. However, contrary to expectations, the arc jumps off this nice hot cathode spot starting at a new cold spot, and so on.

There is a long debate on this surprising, counterintuitive jump series. Several models were proposed, but none of them withstood experimental tests.

In my opinion, electrons (near to the cathode spot) are to be blamed for the rotation of the charges. The visible rotation of the arc (hence the name) leads to the spin field formation.

This in turn with the electric field yields a Lorentz force type action, tearing off the arc plasma from the hot cathode spot.

Symmetries, like rotation of charges, in this case play a major but ignored role in gas discharge as well. The nature of retrograde motion and the stability of condensed plasmoids ostensibly has the same physical roots. Both of them are unexplained for the same reasons.

Similarity Laws: Design & Operation of Gas Discharge LENR Reactors

An airplane, a gas turbine, an internal combustion engine and an industrial boiler are all designed with the help of similarity laws. Turbulent flow has no firm physical foundations yet, though hopefully it obeys the major conservation laws. Yet all engineering devices involving flames (plasma) and especially turbulent plasma, and machine designs are based on similarity laws. Some selected groups of variables change together, and influence the characteristic of the flow. The Reynolds number, Froude Grashof number, etc. are such variables. They are derived from the dimensionless solutions of the Navier-Stokes equations.

They are very important, as they make it possible to test the design, *e.g.* a large ship, with the help of a small model. However, maybe another liquid like oil is used instead of water to make modeling possible on a much smaller scale. After testing the design in a small model, a huge cargo ship can be built; it will not fail. All flow problems can be modeled on a 1 m long hull model at the fraction of the cost of the cargo ship. This makes aerodynamic (and flame) design a science based on similarity laws.

Can we design LENR reactors based on the same principle: small scale models? Is LENR reactor design an art based on intuition, or is it a hard engineering science, where nomograms or computing software are usable?

Three (or maybe four) types of LENR reactors were discussed so far in this series of papers. Let's judge the feasibility of the design by similarity principles:

1) Lattice vibration-based devices, cold and hot
In my (subjective) opinion, as lattice cracking/deformation rules this area, it is possible to use diffusion equations (Poisson type equations) and related LENR effects. It is possible that this area will be (or can be) hard science, where coupled equations of diffusion and non-linear deformation (crack formation) can simulate exactly the outcome of LENR effects. So this area has all the criteria to become hard science with proper funding.

2) Dust fusion
Dust acoustic waves, even resonant ones, can be treated ana-

lytically, though some consecutive equations are more or less heuristic. This is standard engineering practice. We use, for example, tensile strength taken from reference books, for standardized industrial materials.

Oscillating dust in plasma requires much more heuristic data, like the distribution of dust diameter density function. It is strictly related to the electron accumulation capability of dust particles, which in turn can give a good estimation of LENR processes with the ion density of the plasma.

These coupled phenomena will be as complex as a climate model with a number of internal feedbacks because plasma temperature depends on the LENR reactions, the heat released by them.

Though hot fusion reactions can't be modeled in tokamaks due to the 23 types of known turbulences, and also the unknown ones, oscillating acoustically resonant processes do have a ray of hope to find useful similarity groups. (See the works of Tsytovich, Fortov, Morfill, Shukla, Ivlev, etc. under the subject of complex plasmas.)

3) Underwater cavitation, transmutation

Two-phase or three-phase flow (liquid, vapor + plasma)—that is, cavitating, turbulent flow—offers little hope for similarity laws, especially if the flow goes through divergent channels (widening channels).

This is turbulence at its worst. Frankly, this area is sincerely hopeless for any similarity laws. Each device must be tested, to be built fully at operation size.

Underwater sparking devices also belong to this area. This area is of little practical importance.

4) Spark based and plasmon/polariton based devices

Of all the above devices, this group has the longest history and most potential applications (see the devices discussed in Part 5C).

So the question is again reformulated: if small scale LENR reactors are studied/tested can we build bigger ones based on the experience gained on smaller ones?

My guess is no, based on hands-on experience with building small and larger devices. There are so many feedback loops in these systems that we can't spare the cost of building and testing the devices at all scales. Experience gained with one device can't be applied to a bigger device, due to the bewildering number of material properties (surface conditions especially hard to quantify) and geometric parameters, field transients.

When a sheet of paper is dropped from the same height, say 5 m, it never falls into the same position twice, out of millions of cases. Dropping a flexible paper sheet is an example of internal feedback loops. The distortion of the paper sheet will influence the air current around it, then the shape of the paper sheet at the next moment. Hopelessly chaotic phenomena. Spark discharge is similar, but a million times worse.

The cost of designing a new diesel engine (transient two-phase plasma) is about $1 billion USD, when all adjustment is done. This means the construction of the machine, plus the design of the operation—the combustion. Even this is possible only if there is experience gained previously on at least half a dozen engines.

Volkswagen, for example, chose to cheat with the software instead of redesigning its diesel engine, to spare costs.

Spark discharge reactor design (Tesla, Moray, Gray, Jekkel, Horvath, etc.) is not science, it is art, where only intuition leads us. It is practically done by trial and error.

The Fundamental Troubles

Sparks may create a number of condensed plasmoids, which in turn can't be described by textbook electrodynamics. Only an electrodynamics extended to involve rotation may handle them. (See Parts 1 and 2.)

In spark discharge all areas of "classical" physics and quantum mechanics meet, and that is the problem. The following short list sums up the far away fields of science required to describe it:

1. Polarization waves inside the cathode material.
2. Plasma waves above the cathode, thus acoustic waves also.
3. Field emission of electrons from the cathode, through a surface. The surface parameters (roughness) are as important as all other material properties, like conductivity, magnetic properties, etc.
4. Extended electrodynamics, which in turn describe the constrictive forces that keep the condensed plasmoid stable.
5. LENR – catalytic fusion.

Practically most of "classical" physics, quantum mechanics and extended electrodynamics is required here.

Mathematical models as a set of transient partial differential equations break down here.

There is a nasty habit amid plasma physicists, as a sort of pride: they often write nice equations, which are unsolvable, thus don't give any help to the reader. This is pseudoscience. It looks like science to the outsider, but has no predictive power.

Only test results count here, with little hope of finding those parameter groups that characterize the filamentary sparky discharge.

Even detailed monographs on plasma science, like Friedmann and Kennedy's 1000-page *Plasma Physics & Engineering*, does not make the fundamental difference between the avalanche-like Townsend discharge and pseudo-particle loaded spark discharge.

Moreover, as expected, they don't understand the fundamental physical difference between a stable quasi-particle and plasma waves, which are short-lived textbook physics objects.

Readers must be aware that the "head" of sparks (see Part 5B), condensed plasmoids, are spinning, highly charged objects capable of catalyzing LENR under favorable conditions. This happens when they are made of mainly hydrogen isotopes, and they are in hydrogen gas. They behave as magnetic monopoles, noted by Tesla first.

Contradictions Concerning the Similarity Laws

In biology, there are 1 mm long ants. There are even 2 cm long ants, but there are no 10 cm long ones. Fleas jump 1000 times compared to their own size, but they can't be magnified to elephant size.

Intuitively we know that there are severe limits to increase sizes for non-linear devices, because their operation parameters will change or cease altogether, especially when plasma transients are involved.

In weakly ionized plasma, we have the same problem. There are similarities in steady glow and arc discharges. It is possible to make 1 cm long, 10, 100 even 1000 cm long glow (neon tube) discharge devices.

In arcs, a 1 cm long welding arc or 10 km long lightning in a storm are possible with the plausible laws of similarity.

That is, we can design and operate glow and arc discharge devices within a fairly wide range of length parameters, as long as they are in steady state. (Micro discharges are different for other reasons.)

This similarity can be extended to low frequency harmonic (sinusoid) type discharges, up to about 1 MHz range, when something unusual creeps in.

It was noted quite early that *intermittent arc discharges* behaved in an unexpected, weird way. The arc always jumps off the hot cathode emission region, where emission is hard to maintain on a new, cold spot. Further, the direction of arc movement is annoying—the arc even moves against the direction of Lorentz force.

This is called the retrograde cathode movement of the arc. Dozens of new models were conceived to explain it, but all failed because all of them were within the framework of textbook physics.

The shape of an arc (hence the name) is "arc like," not linear. In the arc shape, charges are rotating at a considerable angular velocity, thus spin and electric fields yield a new type of Lorentz force. (See Parts 1 and 2.)

In intermittent, disrupted gas discharge, the inductive terms yield considerable spin field intensity (see Parts 1 and 2) that disrupts the familiar discharge pattern and yields new forces.

When the sharp transients interact with the charged plasma, quasi-stable particles (like condensed plasmoids) arise. Their interaction with the neighboring plasma may yield LENR—like fusion, resulting in a fundamentally new type of discharge.

Spark-based, hydrogen plasma-driven inventions, or LENR reactors, give the bulk of the practically feasible green tech future (Parts 5B and 5C). This is the reason we deal with these discharge regimes at some length. A usable monograph would be at least 2000-pages long on this subject, perhaps a project for the future.

The discharges involving cathodes and anodes are inherently nonlinear due to the finite value of breakdown voltage, and the field emission itself depends on the cathode surface quality.

This yields simultaneous processes, with vastly different time scales in oscillations. There are time delays in all emission phenomena as well. Their combination is called a "chimera" type process. See, for example, the 2020 book by A. Zakharova, *Chimera Patterns in Networks*.

Though they are still within the framework of textbook physics, this mix of different time (frequency) scales makes everything messy, unpredictable.

So experimenters must be prepared for very exotic behavior of their reactors, even without LENR, during control experiments.

Oscillations will change dramatically by changing size and operation parameters (like pressure, temperature).

There will always be the fear of unexpected appearance of weird new oscillations. This statement hopefully does not scare away future researchers; it is just a warning: the mapping of parameters will be troublesome. Two, three or four different types of oscillations appear from very low to very high electric and acoustic plasma oscillations!

I quote just three review papers on the similarity rules in gas discharges:

a) Y. Fu and J.P. Verboncoeur: "On the Similarities of Low-Temperature Plasma Discharges," *IEEE Trans. on Plasma Science*, Vol. 47, No. 5, 1994-2003, May 2019.

The authors mention 11 features that can be similar under favorable circumstances, like: gap dimensions, gas pressure, electric potential, discharge current, electric field, ion density, electron density, current density, ionization coefficient, species velocity and time interval (between sparks).

They note correctly that Paschen's law is valid only for the uniform electric field. Also, they emphasize that similarity laws are not valid when many-body collisions and field emission become important.

They are aware of Mesyat's work on explosive electron emission (condensed plasmoids), but there is no mention of quasi-particles as such.

This is a good review of the latest consensus on the field. Unfortunately, it is not deep enough for us.

b) O.V. Bolotov *et al.*: "Similarity Laws for Cathode-Directed Streamers in Gaps with an Inhomogeneous Field at Elevated Air Pressures," *Plasma Phys. Reports*, Vol. 36, No. 11, 1000-1011, 2010.

This paper is the closest to our area of interest. The authors are aware that the "nature of streamers are not yet clear" and there is no theory for streamer generation and propagation. However, they don't raise the need to extend textbook electrodynamics as a solution for the problem.

They assume that streamer discharge can be described by similarity relations, and emphasize the role of photo-ionization (ultraviolet radiation).

They skip over the problem of how streamer heads are formed, just neglecting all terms in their equations, describing only the intermittent streamers.

Simply, this kind of neglect is not permissible for us, because it skips the essence of quasi-particle formation.

c) G.A. Mesyats: "Similarity Laws for Pulsed Gas Discharges," *Physics Uspekhi*, Vol. 49, No. 10, 1045-1065, 2006.

Gennady Mesyats also independently discovered condensed plasmoids, after Tesla, Moray, Török, Raether, Shoulders, Matsumoto, Lewis, etc.

To disappoint readers: Mesyats is clearly unaware of the long lifetime, very high charge and catalytic properties of the explosive discharges. The emphasis on this long review paper is on the unifying concepts of discharges.

Mesyats, vice president of the Russian Academy of Sciences and leading researcher in gas discharges in Russia and the world, shows that even a skilled experimentalist misses the practical significance of pulsed plasma.

Though streamer and uniform glow discharge are clearly distinguished in his papers, the most important feature, the catalytic quasi-particle formation of pulsed discharge, is not mentioned.

Mesyats also notes the unknown glow to streamer discharge transition mechanism, but there is no clear answer to it. The whole field of academic researchers are completely unaware/ignorant about the past achievements of inventors discussed in Parts 5A, 5B and 5C.

His review paper doesn't mention at all the relevant inventions of LENR.

Mesyats mentions the importance of overvoltage in the streamer formations, even the essential difference between a rough and smooth cathode surface, but that's it.

So Mesyats and the whole field are not even close to the fundamentals of LENR. Even the similarity rules are not clear for experiments, and this makes for very annoying academic plasma research.

However, the conclusions of all the above review papers are the same: there are no similarity rules for spark or filamentary discharge, therefore the design and operation of spark-based LENR reactors must be based on intuition at first, then extensive testing later.

Is There a Smoking Gun Somewhere?

This whole issue of getting unlimited energy from water at modest technical parameters is met with utter rejection, and ridicule. Even raising this possibility is out of the tolerance range.

The first argument is that generations of gas discharge research never yielded anything suspicious of excess energy, thus any speculation about it is just sheer pseudoscience.

Well, there is (was) a smoking gun, coming out from academic research, as we shall see soon.

The other general consensus among scientific journal editors, patent examiners, green tech advocates etc. is that gas discharge is well mapped, covered in every aspect, with no fundamentally new and useful effect expected. Inventors just can't find anything new, because academic research preceded them in all areas.

Readers are hopefully aware by now that this is not true. Academic research covered only a small area of all possible spark discharges, even that mainly in inert gases. The pulsed, sharp cathode geometry remained unexplored. It seems to be a useless area from an academic viewpoint, yielding no further insight to the nature of spark or filamentary discharge.

Reading dozens of carefully written monographs, and hundreds of papers, the consensus among academic researchers is: though there are some tiny unknown areas in filamentary research, this area is already covered. There were about 200 researchers who spent most of their careers with gas discharge research, experiments and theoretical modeling. There were even more industrial R&D engineers in this area, but only in two areas: glow discharge for lighting (until LEDs made this area obsolete) and plasma etching for microchip manufacturing. These are steady-state processes. The same with welding/arc discharge.

On the other hand, there are thousands of backyard or garage experimenters. They are not as good as Tesla, Moray or Papp were, but their cumulated common experience is significant.

The (re)search pattern of academic and industrial researchers and garage inventors are different. Academic researchers do have a degree of freedom, in theory. In fact, a hard mentality, unwritten "dress code" is very strong. Dare to question a myth, like the impossibility of cold fusion, and you are out of the club. The same applies to industrial researchers.

Backyard inventors, however, are free to roam around, being quite ignorant about published reports, and "expectations." They read only patents, if they read anything at all. So when academic research stalls, as now, they are the only source of hope.

Janos Jekkel, for example, was literally employed in a "top job" at the National Technical Research Council of Hungary (OMFB). He was a stoker on the top floor of the building, though previously he was employed at the Electric Research Institute. He worked part-time in his hut, a run down garage.

Academic researchers don't read patents, so they don't have inspirations from "outside." Industrial researchers are not allowed to think outside the "management box." They may dream of making electric cars at GM, but if they do, their work is usually crushed.

Now here comes the tragedy of academic research: they are not allowed, or are not trained, to see the unusual, the "black swan"—only the white, usual swan.

Many physicists saw the trout in a fast creek, standing at the same place, defying the following conservation laws: energy, momentum and angular momentum. However, only a forester, Viktor Schauberger, went after this phenomena. (My list of similar cases is long.)

The same series of tragedies has happened with catalytic fusion related to pseudo-particles.

Condensed plasmoids have been discovered and forgotten, neglected immediately after their discovery. On the other hand, billions of dollars and countless lives were devoted to much shorter-lived "real" particles, like the "Higgs boson," and sold to the public as "real" science.

I have found a trail of discoveries of "black swans" which never made it to the mainstream. Here is my certainly incomplete list:

J.J. Török at Westinghouse, Pittsburgh in the 1930s noticed that the streak or filamentary discharges, in air, were quite different between spherical electrodes with pulsed discharge, as compared to the DC and flat plane electrodes. (In the latter there are no plasmon-polaritons, only in the spherical ones.) His papers are clear about this qualitative difference.

He made no reference to Tesla's experiments, despite working for Westinghouse Electric. High voltage filamentary-streak discharge was one of Tesla's research areas, with published qualitative results!

Then nearly at the same time, Raether again discovered condensed plasmoids, noting that the "head" carried sometimes more than 10^6 electrons. He made a simple electric circuit to measure the transient electric current with a cathode ray tube. He observed the sharp negative peak, a sign of a "lump" of electrons, shown in Figure 10a. (Source: *An Introduction to Plasma Physics*, S.C. Haydon, ed., 1964, lecture by G.A. Schroeder. Figure 5.2 on page 75.) See also Figures 9a and 9b.

Raether and his colleagues never asked the most exciting question: how is this huge lump of charge held together? What sort of extreme force keeps them together? Only 92 protons are held together in the nucleus of uranium at a price of 146 neutrons as "binding agents." Why are hundreds of millions of charges kept in a lump? How long are they stable? If and when is this lump stable? In what sort of interactions do they participate? Do they penetrate into metals, insulators? No questions; no answers.

These kind of relevant questions and answers were published decades later, in this magazine by Ken Shoulders, quoted in Part 5B.

Raether definitely saw the "black swan" and described it in clear terms, but did not move on to use this pseudo-particle. This is a big problem of the discharge herd mentality: thinking in terms of pseudo-particles is out of their mentality.

The same happened with Mesyats a generation later in Tomsk and later in Novosibirsk at the Academy of the USSR. He found and termed this pseudo-particle phenomena "explosive discharges." He found them even in vacuum discharges.[8]

He took photographs showing the evolution of the condensed plasmoids (explosive discharges), but no further interactions were examined (Shoulders and later Matsumoto looked closer). (See Part 5B.)

Mesyats clearly never read Raether's work, and never referred to either Tesla or Török.

Just as with the inventors, all of them started from scratch, never standing on "giant's shoulders."

The Black Swan

The odd, unusual "black swan" experiment on LENR was reported by J.D. Craggs, one of the best researchers in the gas discharge field.[9] He made these tests, but never dared to publish them. He was able to measure the temperature of sparks by calibrated spectroscopy, at very short resolution, on the order of picoseconds. (This is a very sophisticated test!) The essence is: Craggs realized that hydrogen sparks did not cool off immediately, like inert gases, but have a relatively long plateau, where the gas temperature does not cool off. This is unexpected, as hydrogen has a very high thermal conductivity, thus it ought to cool down more rapidly than other gases. (See Figure 10a.)

The thermal conductivity is related to the mean free path and the Maxwell energy distribution. Hydrogen has an unusually high speed, being just a proton mass.

Most probably the long plateau surprised Craggs, so he made a totally unexpected step: he tried the same temperature measurement in deuterium. That was even stranger. The temperature was even higher than that for hydrogen. See Figure 10b. Such a flat plateau does not exist with argon. (See Figure 10c.)

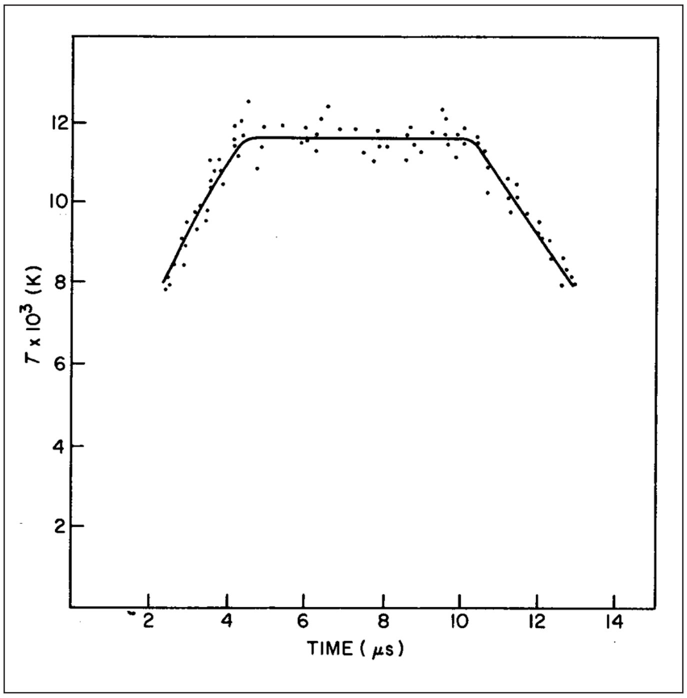

Figure 10a. The cooling of a hydrogen spark channel. The temperature has a flat platoon for about 6 microseconds; the heat losses are balanced by internal energy production. Pressure is at 200 Torr, temperature peak is about 11,000 Kelvin.

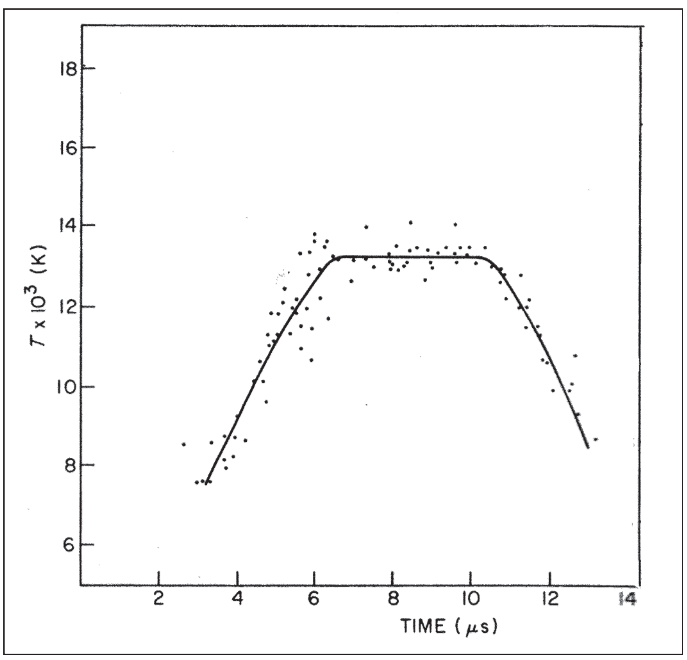

Figure 10b. The same experiment with deuterium. Note that the temperature is even higher, about 14,000 Kelvin. Pressure is 200 Torr, just like with hydrogen.

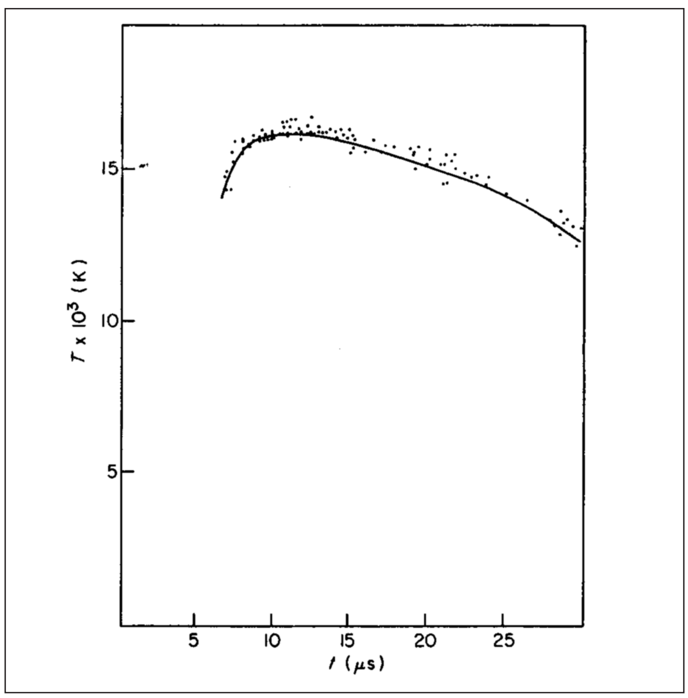

Figure 10c. Gas temperature in an argon spark channel as a function of time, at higher pressure. Note that it monotonously decreases after reaching the maximum value, lacking internal energy source.

This was definitely a "black swan" event. There is a choice of "fight or flight" at this point.

Craggs, having the highest reputation in the gas discharge research area, faced a dilemma. He didn't want to risk his reputation with publishing this controversial finding under his name, but left it to a younger colleague, Parkinson. Thus he didn't risk a loss of face.

Craggs noted (as in a self defense): "The calculation, from considerations of energy transfer, of this relaxation time is in practice not easy because of the simultaneous production of self shock wave from the spark and the complicated physical process occurring in the channel."[9,p818]

There is only a single sentence about this "black swan" phenomena of quasi-steady spark channel temperature: "The plateau (T gas constant) is of interest because here the energy content of the plasma is approximately constant so the energy input must balance the energy losses, such as thermal conduction."[9,p820]

Regarding possible experimental error, Craggs wrote the following: "Indeed, not surprisingly, the only notable exception is hydrogen which, because of its relative simplicity, particularly in the dissociated state, has received some attention. Even here direct measurement of T_e and n_e as functions of time and radial position in the channels provide virtually the only data of any accuracy."[9,p822]

These telltale data were taken well before 1978, so two decades before the Pons-Fleischmann re-discovery.

By the 1970s everybody in gas discharge research forgot the hydrogen sparking and transmutation results of Norman Collie, J.J. Thompson *et al.* at London College prior to 1914.

Craggs never thought of calorimetry tests, as Jacques Dufour made in the 1990s (see Part 5A). So these anomalous spark channel temperature measurements never made headlines as unexpected discoveries, and there was no follow-up to a broader range of investigation. It was duly forgotten, just like the transmutation tests of Collie *et al.*

There is a huge distance between a discovery and an invention. The notion that the excess heat effect was not found in gas discharge academic research is invalid.

However, the necessary distinction was not made between spark and glow discharge calorimetric tests, the role of hydrogen, deuterium vs. other gases, etc.

All in all, this "black swan" discovery never touched the nerve of either the gas discharge research community, academic and industrial, and never signaled the inventors about a valuable or "new" area. Of course, the idea of pseudo-particle related catalytic low-energy fusion didn't spring up from Craggs' discovery.

Academic gas discharge researchers have a quite different mentality from that of the inventors. Several qualitative, huge steps are necessary to move to practical applications, as inventors did, shown previously.

There is no exchange of ideas between researchers and inventors, which is a very harmful situation. This is the reason all inventions were done independently, and received with hostility, incredulity.

Craggs' sophisticated temperature measurement of the flat temperature plateaus means the excess energy generation in sparky hydrogen is a reality. This is a similar discovery to that of Becquerel and the Curies about radioactivity.

The parallel is that the darkening of photographic plates under some uranium salts was not considered a significant effect for the small community of physicists. Even a half century later, the possibility of using and releasing the hidden energy of nuclei totally enraged Rutherford (when Leo Szilard came up with the idea of chain reactions).

The temperature plateau of sparks in hydrogen could have been a similar watershed event, especially if someone digs up the transmutation results in hydrogen sparks by Norman Collie in 1914. The hydrogen-helium transmutation could clearly show the nuclear origin of the excess energy, that is, pulsed, sparky discharge in hydrogen is unique. Both discoveries were British, though two generations, two wars apart.

British physicists were among the most active in crushing the cold fusion revolution (at Harwell), and ridiculing a member of the Royal Society, Martin Fleischmann. (So much about the twists and turns of history.)

Craggs was familiar with Mesyats' results. Thus he was able to make the connection that pseudo-particles/excess heat/transmutation was within his grasp.

Leonard Loeb (Part A) of Berkeley was familiar with Raether's work, but missed interpreting it as a pseudo-particle, and was clearly unaware of Collie's transmutation work in sparky media. Due to this regretful ignorance, he clearly missed the opportunity to move toward tests of transmutation, excess heat, calorimetry. The most painful is, however, that none of the above authors were familiar with the pioneering intuitive work of Tesla and T.H. Moray. Both of them stressed the importance of brush or filamentary, streak discharge, the very subject of Loeb's investigation.

The whole subject was shunned from the twenty-second edition of *Encyclopedia of Physics*, from gas discharge results.

All in all, this is the reason inventors were left to themselves, and academic gas discharge research was (is) not any help to them.

Faces of LENR — A Conclusion

Following the questions of David Nagel,[10] we finish the brief incomplete tour of LENR devices, as a state of art in the 2020s. (The LENR antigravity connection will be discussed in Parts 6A and 6B.)

By now, we have found three distinct technical, physical methods to induce LENR:

1) a - Palladium cathode (light and heavy water) pulsed electrolytic cells. This turns out to be dominated by diffusion and mechanical cracking of the metal lattice, thus inducing fission of the metal. Most LENR work was concentrated on this small area.

b - Hot cells based on hydrogen, like Piantelli, Focardi, Celani, Rossi (the Italians) and Parkhomov, with Ni lattice.

Of the two approaches the diffusion based hot cell seems to be better, offering hope for commercial applications. The catalysis is done by neutrons released by high-frequency mechanical fractures. There are a number of separate observations stating that during mechanical cracking or ultrasound excitation (Suhas Ralka) there is a mixture of neutron emission, fission, even fusion of hydrogen isotopes. So this face is a mechanical vibration-induced LENR.

This area is still under-explored. There is a promising area of high mass brittle compounds, like tungsten carbides and nitrides, if they are able to absorb hydrogen. Semiconductors, like SiC, are able to absorb hydrogen to a degree.

Table 1. Physical principles of catalytic LENR reactors.

primary step	Loading of hydrogen by electrochemical and thermal method into a lattice (1)	dust generation in plasma (2)	transient sparking or micro-discharges (3)
first consequence	fracturing and oscillation of lattice due to diffusion	accumulation of surface charge on dust particles	polariton and condensed plasmoid appears
second consequence	LENR fission of lattice nuclei due to enhanced vacuum oscillations	rotation of charged dust particles, spin field appears	formation of plasmon waves and plasmoids as catalytic pseudo-particles
third consequence	release of neutrons from the split nuclei	spin field catalyzes fusion of hydrogen	induced LENR with hydrogen isotopes
fourth consequence	LENR fusion by neutrons into ambient material	LENR fusion via teleportation for high mass nuclei	emission of electrons

2) Rotating charged dust particles
This is the most ubiquitous energy generating fusion process in nature. All stars are driven by it, because interstellar dust is everywhere, though its distribution is uneven. Perhaps this process is the easiest to start with.

The Oshawa arc effect (Quantum Rabbit, Klimov and this author) demonstrated the feasibility of the process, especially the massive transmutation of large mass nuclei. During arc smeltering, a massive amount of transmutation was observed in an electric furnace in India.

Apart from transmutation, heat can be generated also in the presence of hydrogen (see solar corona). The ATP-ase rotating enzyme, life's power generator, belongs to this category, too.

The proton pump, as a means of biological transmutation via hyperspace jump, is a unique process demanding its own separate bracket or "dossier." Spin and electric fields catalyze LENR in this group.

3) Wave and condensed plasmoid catalyzed LENR
This process doesn't have any natural counterpart, it is "machine made." Most inventions, and all electricity producing devices, fall into this category. The cavitation (plasma collapse) devices are also in this bracket.

Generally, the corona discharge effects and inventions populate this group, as shown before.

It is clear by now that LENR is a multi-faced, rich group of phenomena. They are definitely outside the framework of

Table 2. Practical merit and main parameters of fusion reactors.

	Hot fusion confinement	Hot fusion confinement	LENR (catalytic) lattice oscillations		Dust fusion	Polariton condensed plasmoid
Main process	inertial (pellet)	magnetic field	cracking of lattice liquid	hot	rotating dust	pseudo-particle
Temperature ºC	$\sim 10^9$	$\sim 10^8$ °C	60 - 100	~1200	~1700	$50<T<1500$
Pressure (bar)	$\sim 10^{10}$	2	1	1	1	$0.5<p<2$
Design & construction period	10 years	30 years	3 months		6 months	2 years
Ion energy (eV)	~MeV	~MeV	1 eV	5 eV	10 eV	10 eV
Reactor size (m)	3	5 - 50	0.1	0.1	0.4	0.4
Aux (building) size (m)	500	500	0.2	0.2	0.5	0.5
Weight (kg)	$\sim 10^4$	10^5	2	1	2	2
Cost of R&D ($)	3×10^9	$\sim 2 \times 10^{10}$	10^3	10^3	$\sim 10^4$	$\sim 10^4$ - 10^5
Economic prospect	none	none	none	perhaps	yes	yes

textbook physics. One by one, the effects are questionable, as no concentrated effort was possible due to pride and prejudice of mainstream scientists. However, when viewed together, the identical patterns are apparent for the inquiring mind.

All in all, the universe—from bacteria to stars—can't be understood without LENR, and the necessary "auxiliary" effects surrounding the four faces of LENR.

Apart from it, no sustainable advanced technical civilization can miss LENR and related effects.

The present range of effects in textbook physics is too narrow for our survival.

Tables 1 and 2 sum up the current situation of effect ranges.

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