FACES OF LENR

Part 5B: Design and Operation Principles of LENR Reactors

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Abstract: *This is the second paper in the series about the design and operation of LENR reactors, to be followed by Part 5C on the same subject. While in Part 5A we mainly discussed the reactors based on electrolysis that were at the center of research for decades, a new field of reactors based on dusty plasma was also discussed. We move into a new area in Part 5B: LENR reactors based on quasi-particles.*

Though plasmon polaritons and condensed plasmoids were frequently mentioned in all previous parts, we shall move towards their practical applications. First the landscape of mainstream transient plasma research is shown. There the streamers of corona and spark discharges are known to produce heavy negative quasi-particles. However, they have never been tested for catalytic nuclear fusion, just as chemical catalysts. We shall review spark related research, as this area is shown to induce fusion effects. Most of the results have been published in peer-reviewed journals, like Fusion Technology.

The most important results have come from the papers of Matsumoto, Karabut and Dufour. The most important patents were granted to Shoulders. These results were published mainly in the 1990s, the "golden age" of LENR research.

Based on these results and insights, we move back a hundred years, to the research of Tesla. Judging by the shape of his discharge tubes, it is plausible that Tesla had a practical application of the results published 100 years later.

In Part 5C, inventions after the 1930s will be analyzed.

Extraction of Electrical, Mechanical and Chemical Energy from LENR Reactions

Heat generation is a relatively simple LENR process, and so is chemical (oxygas) energy generation. Other processes, like electrical energy generation, require additional steps to extract the generated excess energy.

Let's start with oxygas. The most widely known solution is that of Stanley Meyer's resonant, underwater coaxial oxygas cells and Stephen Horvath's similar solution. This latter invention has two useful features. An external solenoid and a star-shaped cathode are needed to enhance the local electric field for spark generation. There is no hint of how the eddy currents were eliminated on the electrodes. Otherwise it makes no sense. (See U.S. Patent 3,980,053; 1976.) See Figures 1a and 1b. The device was driven with sharp electric pulses. No yield data are available.

The fact that there is excess energy when sparking under water was already known by several arcing inventors, including Neal Graneau and Peter Graneau, who wanted to extract the excess momentum of water droplets after an underwater sparking, or arcing. They assumed that excess energy is hidden in the chemical bonds of water molecules previously irradiated by the Sun.[1]

Underwater sparking is theoretically a difficult, frustrating area due to its nonlinearity. There has been no attempt at theoretical description so far. No wonder. It is a transient *four-phase* effect: liquid, vapor, superheated steam and non-equilibrium plasma. Even if we disregard the theoretical problems of describing the formation of condensed plasmoids or dusty plasma, the far from equilibrium treatment of four phases and acoustic shock waves, this system is so complicated that computation-based science can't handle it.

Science as a method may deal with each phase individually, but it is unable to couple them due to the lack of constitutive relations. That is, to determine how energy and momentum are exchanged between boiling water droplets and saturated vapor. (This unsolved puzzle brought the safety calculations to a standstill for pressurized water nuclear reactors. It was not the lack of funding or effort, but the lack of test methods to measure the most important processes for dynamic cases.)

The experimental side of underwater arc and sparking is also hopelessly complicated due to the possible number of free parameters, like overpotential, pulse rise time and current evolution, etc. Sparking and arcing in saturated vapor (*e.g.*, H_2O) was barely studied, as it is easy to observe only for steady state. The transient regime has been an unexplored area so far. We are hopelessly lost, if we add the energy generation of LENR to this process, too.

Only cavitation was experimentally investigated to a small degree, endorsed by Julian Schwinger. In terms of Casimir forces, they demonstrate the extraction of vacuum fluctuation energy. The excess energy, or unusual chemical reactions (sonochemistry), were already noted in the 1930s, but ignored. Schwinger assumed the excess energy comes from the vacuum energy, which may be correct to a degree.

Meyer or Horvath's coaxial, resonant water splitter (using an electric circuit coupled to acoustic resonance) is a system where arcing and cavitation bubbles collapse during the same process. Its geometry is similar to the Pons-Fleischmann (P-F) cell, and its coaxial symmetry is not far-fetched, though the physics is quite different. The formation and catalytic action of condensed plasmoids are the dominant processes for the sparking, while for the P-F type cells the lattice vibration occurs.

In the case of underwater sparking inventions, the surface roughness of the electrode is also important, meaning the quality and density of high field inducing sparking edges. Many small sparks can be generated on the sharp edge of metal tips and needles, if the electrode surface finishing is rough, and not mirror smooth. (Meyer, Horvath and Andrija Puharich, etc. were lucky to stumble onto this effect, but they were not aware of this important fact.)

However, the edges disappear after awhile due to prolonged sparking, and the excess energy effect gradually ceases. (This led to the demise of both inventions, because the inventors were unaware of the cause.)

These inventors never explored the surface quality with a microscope, or the sparking with optical and/or acoustic probes. They were unaware of the fundamentals. On the other hand, underwater sparking is technically simple, even if it is combined with cavitation to make oxygas.

This is a typical backyard project, so technically interested readers are invited to try it. However, dusty plasma transmutation is more reliable! Success is immediate with little previous experience, while underwater sparking experiments are more difficult due to their erratic nature. There are a number of "hidden" parameters.

Underwater sparking, and arcing, have a common severe drawback. This process is of low efficiency due to enormous heat losses leading to boiling and evaporation. This problem is avoided only by Janos Jekkel's oxygas device, where superheated steam is used, and there is a corona discharge which does not harm the electrode surface. (See the forthcoming Part 5C.) Joseph Papp went one step further by exploding the oxygas in the cylinder right away to generate mechanical energy.

Nevertheless this is the area of eternal speculations, when cars are run on water instead of gas with the help of energy released in LENR processes.

The design and operation is straightforward, if we are aware of the catalytic LENR effects of condensed plasmoids, and polaritons formed during transient arc and spark discharges.

I will not describe each individual underwater sparking process. Note that tritium was observed during sparking in deuterium (due to β decay) by Thomas Claytor at Los Alamos. This was the result of transient corona discharge experiments in deuterium.[2] This sophisticated test is decisive, because tritium is unstable, and radioactive. It has a relatively short half-life and it doesn't occur naturally. Thus its presence is due only to transmutation during a corona discharge. The same transient plasma is generated in the underwater sparking (arcing) devices. The water acts as a transient generator (because it suddenly quenches the plasma), and as a source of hydrogen. Liquid carbohydrates could be better by the same token, but nobody has tried them.

The general features of early gas discharge LENR research of the 1990s are hidden in ambiguity, fog and ignorance, as usual in a new field. Norman Collie's hydrogen to helium transmutation work at London College of 1914 was forgotten by then.

Ignorance and curiosity are the essence of path finding research; it is not dangerous as long as it is acknowledged. There have been important discoveries on pulsed plasma LENR reactors without understanding the root cause.

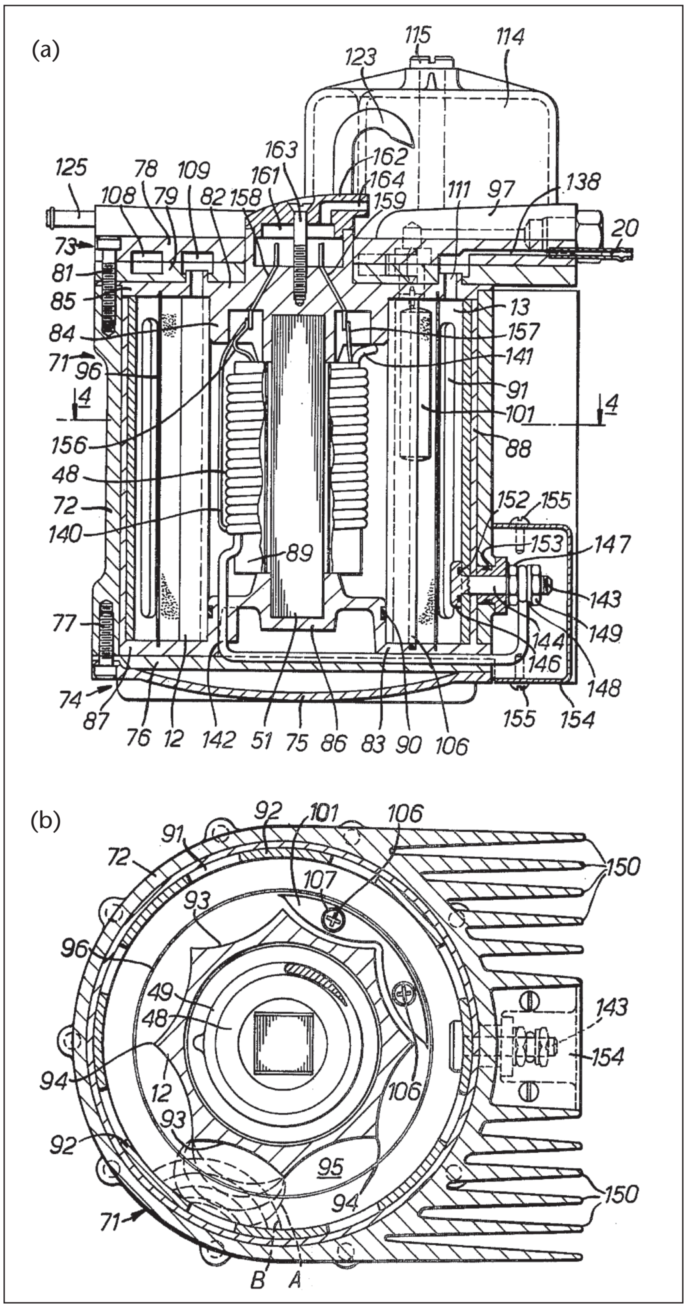


Figure 1a-b. Horvath's pulsed water splitter. Note the sharp edges of the cathode. Horizontal and vertical cut sections are shown.

Transmutation Tests in the 1990s

Experimental nuclear physicists are ignorant about the extreme richness and non-linearity of gas discharge processes. These areas are now far from each other on the map of experimental science. For example, there is not a single word about possible nuclear effects in the 900-page long "plasma bible" of Alexander Fridman and Lawrence Kennedy (*Plasma Physics and Engineering*, Second Edition), because they are not expected, and therefore not investigated. There are also other large ignored areas of plasma physics, like: hot fusion of fully ionized plasma, charge rotation, acoustic coupling, vacuum arc, quasi-particle generation, plasmons, etc. Also, there is no reference to LENR in the 900-page comprehensive book *The Physics of Energy* by Robert Jaffe and Washington Taylor. The peer-reviewed LENR papers in

Fusion Technology are not mentioned at all. (They do not mention that energy is a symmetry either.)

The most characteristic nature of gas discharges is its *richness of phenomena* due to its annoying nonlinearity—self-organization of pulsed plasma, sensitivity to the shape and quality of the cathode surface and other physical properties. (For example, permanent magnet cathodes are never mentioned in monographs of plasmas, nor liquid, flowing electrodes, etc.) A 50,000-page textbook would probably cover all areas already known and tested to some details, in my subjective estimation, and a ten times longer one may cover the known unknown areas. This is sobering, when we are zeroing in on the home of the narrow LENR-related area in this paper—pulsed, low-current, atmospheric, non-equilibrium cold hydrogen plasma. This kind of discharge is termed "filamentary," "brush," "corona" or "dielectric barrier" discharge. We shall use them as synonymous terms.

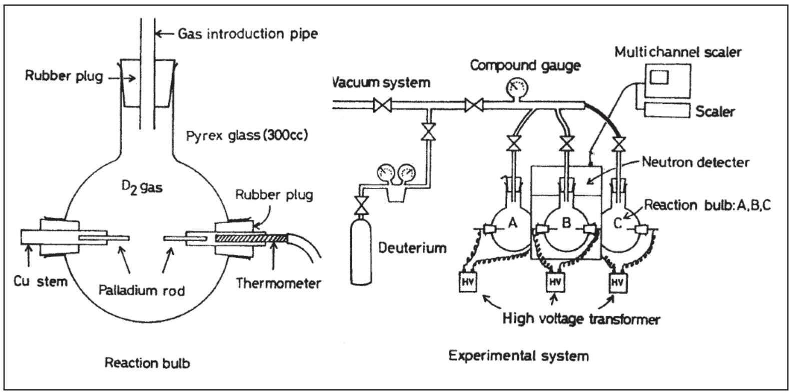


Figure 2a. Left: Wada's palladium-based gas discharge reactor. Right: The assembly of three reactors to enhance neutron emission. This is a good design both for fission and fusion. However, there were no sparks due to the low frequency (60 Hz), only glow and arc discharge. Consequently, there was only fission for awhile. The method of operation is plainly wrong.

Plasmas of any other materials (helium and above) are useless for direct electric energy generating LENR, though gases of mixed materials including hydrogen are not.

For example, Trichel pulses in corona discharge have been studied in detail by some authors in the 20th century, but never in deuterium. In general, academic research *never reached the area important for LENR* due to the vast range of possible plasma parameters. LENR belongs to "modern classical physics." However, the 1,500-page book *Modern Classical Physics*, written by Nobel laureate Kip Thorne and Roger Blandford, again fails to mention LENR. This subject belongs to the area of waves in cold plasmas, and nonlinear dynamics of plasmas. Though plasmons are mentioned on page 1129, their activity in LENR is omitted. Let's list some of the works where they came near but not yet fully to our area of interest.

Gas Discharge Results

L.B. Loeb noted in his vast monograph on coronas that sometimes "obscure oscillations" appeared.[3,p111] He examined pulsed hydrogen coronas only from the aspect of oxygen contamination. He noted that there was little sparking in hydrogen as compared to other gases,[3,p432] and that H_2O vapor inhibits streamer formation.[3,p225]

Y. Gosho[4] found the opposite, that an anomalous increase of pre-breakdown current takes place when H_2O vapor is added to any gas.

Also, C.G. Suits noted the inherent instability oscillations of high pressure hydrogen arcs, nevertheless, energy generation as a possible cause was not considered.[5]

The strange shape of Lichtenberg figures and corona sparks was also noted for H_2O vapor just as a side note. Quasi-particles, like condensed plasmoids or plasmons, as a cause of the spider web-shaped traces were not investigated.

The situation is analogous to early semiconductor studies. They were considered "third grade" problems from about 1860 to the 1930s. This was "the physics of dirt," as Wolfgang Pauli noted. Then crystalline semiconductors were studied in the U.S. but the inventions of Julius Lilienfeld (transistors) were ignored in the 1920s and 1930s. Later the amorphous semiconductors were dismissed in the same manner in the 1980s. Then an outsider, Stanford R. Ovshinsky, invented the coatings for CDs and DVDs despite the hatred of semiconductor physicists. (This will be discussed in Part 5C, as it is important for us.)

Corona and spark discharge in hydrogen, or water vapor, deserved no particular attention from the mainstream. There is a major difference in quality between corona and spark and arc discharges. Each of them are restricted to a narrow discharge channel, due to the self-constricting "pinch" effect. The corona discharge is always pulsed, while sparks and arcs are usually not. Coronas always have a cold cathode, while low current sparks and high current arcs usually have hot cathodes with thermal emissions. Once ignited, they are self-sustaining, while corona discharges never are.

The re-discovery of LENR in the narrow technical field of electrolysis gave new life to the field of transmutations induced by plasma discharges.

Four different plasma discharge reactors are shown in Figures 2a-2d, all born in the 1990s, to illustrate how they found a LENR effect, yet missed its significance.

Early Gas Discharge LENR Experiments

Wada

N. Wada and K. Nishizawa used the simple spark-based gas discharge reactor shown in Figure 2a. They had two small palladium rods as electrodes, and used them with an unspecified type of discharge at 12 KV, 60 Hz at 1 Pascal pressure. This set of parameters yields only a mixed spark plus a glow discharge, depending on the pressure and the tube geometry. The authors were unaware what sort of discharge they had. This operation method has a short "non-equilibrium," cold spark discharge at the very beginning of the discharge, and then a near steady glow discharge. As the usual mistake: they did not measure the discharge current with a coaxial 50 Ω shunt and an oscilloscope. They had some nuclear equipment on hand, and just "took a shot" at the problem. They counted neutrons well above the background level, and found gases with mass numbers 1, 2, 3, 4, 5 and 6. Most probably they were unstable He isotopes.[6] They activated the palladium electrodes for an undisclosed period, and then counted the neutron bursts. Then a 540 sec electric discharge "stimulation" was used after 55 hours, when the neutron counts increased significantly again.

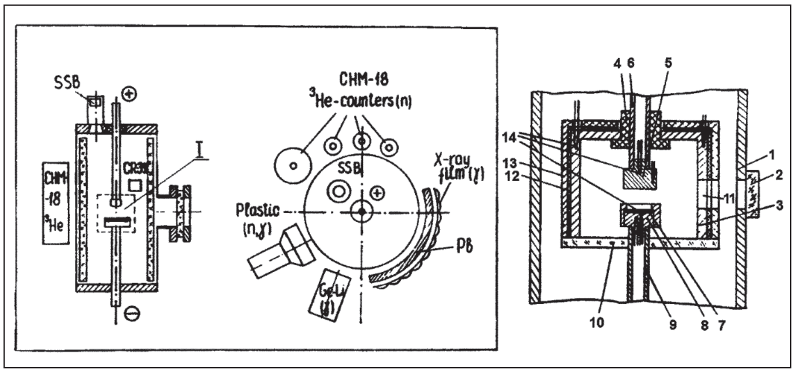


Figure 2b. Left: The setup of the Karabut reactor and nuclear detectors for particle and γ radiation. Right: The enlarged plasma reactor, with circular, parallel electrodes. This is in fact a glow discharge reactor. Corona discharge was achieved only by sheer luck due to surface craters.

This equipment seems to cause a mechanical lattice excitation due to longitudinal, contracting, squeezing Ampere forces at undisclosed current values. The palladium rods cracked after awhile but never showed neutron emissions again. The effect seems to be the same as with the Pons-Fleischmann cells. (See Part 4 and Part 5A.) This is a "finite yield" effect, a fission, induced by lattice vibration described by the Carpinteri team. This effect appears preferably with the expensive palladium that absorbs hydrogen even at low temperature. This effect is useless for commercial applications. There were no experiments with other cathode materials and gases, etc.

Karabut et al.

A better "shot" at this problem was attempted by Alexander. Karabut, Yan Kucherov and Irina Savvatimova.[7] Again, this was a team of experimental nuclear physicists with *no background in plasma physics* and diagnostics. The title of their paper is "Nuclear Product Ratio for Glow Discharge in Deuterium." This work is good on nuclear measurements, but sloppy with the plasma physics, thus causing trouble later. They claimed that their flat, circular Pd cathode sample was a "specially treated" Pd disc, where the excess heat and neutrons were found. They did not disclose what this special treatment was. In hindsight, it is an intermittent spark cleaning, a routine surface treatment to get rid of surface contaminants. The surface is thus covered with a number of sharp-edged molten craters after this treatment due to pulses of arc discharge. Paulo and Alexandra Correa also discovered their excess energy effect due to this cleaning! However, apart from the altered surface, condensed plasmoids were formed during the pulsed cleaning, and later during the power pulse applications.

Obviously, the Karabut team was not aware that their plasma had a corona discharge component. They assumed there was only a DC glow discharge. In fact, it was partly an intermittent corona+glow discharge. They failed again to measure the discharge current on an oscilloscope—a fatal error in this case. Their reactor was a parallel plane discharge tube (shown in Figure 2b), where they performed calorimetry tests, on a charged particle energy spectrum, γ spectrum, and found traces of high energy particles on CR-39 films, and 100-1000 Angström size "bubbles." (There were apparently traces of condensed plasmoids, the most likely catalysts of transmutations.)

When C.H. Ellison and J.A. Mahaffy attempted to replicate this experiment years later, it ended with utter failure.[8] Nothing was verified from the claims of the Karabut group—helping the skeptics of LENR. Obviously, Ellison and Mahaffey did not clean, or roughen, the Pd foil surface, did not degas or etch them, but "only fresh, new palladium cathode foils were used for the experiment."[8,p182] The authors sometimes described the discharge as a glow, and sometimes as an arc, and noted the erratic behavior of the plasma. Indeed, it is frustrating for the inexperienced researcher to hunt for a stable mode of operation and *missing the right kind of plasma discharge is a death trap*.

The high value of $\partial E(r,t)/\partial t$ is the consequence of the discharge itself in a periodic discharge, because it is a very fast avalanche ionization phenomenon. This fast transient then yields the vortex spin field (see Part 1, Part 2). The Wada and Karabut teams were not aware of this fact. The higher the rate of spark repetition, the more condensed plasmoids are produced for the catalytic transmutation.

Dufour

Jacques Dufour made a much better attempt at the phenomenon with *periodic spark discharges*. (A spark is a low current arc discharge.) His paper "Cold Fusion by Sparking in Hydrogen Isotopes"[9] is among the best ones in the successful LENR research; it is excellent, and unduly forgotten. The spark chamber is shown in Figure 2c as vertical and horizontal cross sections. Contrary to the previous sloppy publications, the plasma regime is clearly stated as a series of spark discharges. All necessary technical parameters are clearly laid down. This is real, repeatable path-finding science. The cathodes are thin, sharp copper wires and the anodes are cylinders. This work clearly identified the right kind of plasma that reliably yields LENR at the discovery

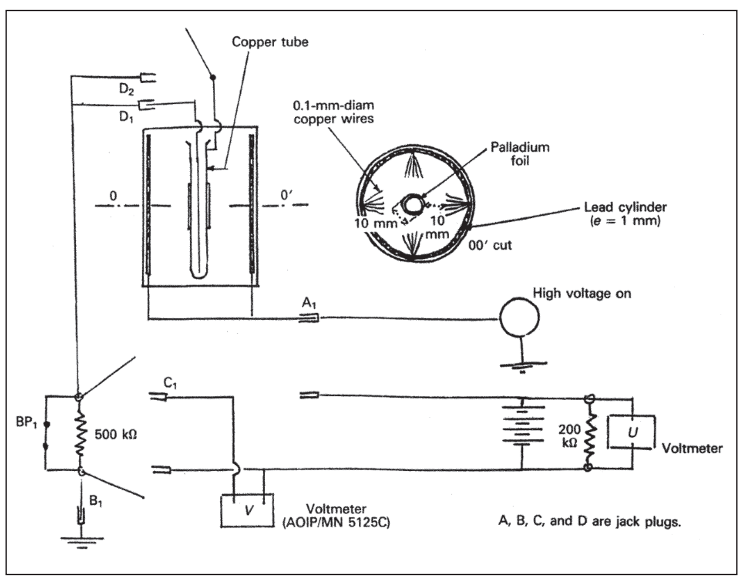


Figure 2c. Dufour's spark reactor. The vertical and horizontal cross sections are shown, with four groups of radial wires as cathodes. The anode is a palladium cylinder in the center. This reactor suits catalytic fusion. This is an appropriate design and operation to discover catalytic fusion.

level (but not at the engineering, commercially useful level). Unfortunately, this line of work was not repeated by LENR researchers in contrast to all the replication attempts of the P-F experiments. In his later published papers, Dufour noted that both fission and fusion may take place at a low energy range with different mechanisms. He suspected that electrons somehow got close to the nucleus, thus the charge of the protons is neutralized and they behaved like neutrons (a "deep orbit" model).

The main theoretical concern of Dufour, and the rest of the researchers, was how it is possible that the Coulomb barrier was overcome in the case of spark discharge. What makes pulsed discharges so special, and useful? What is the sequence of events that yields transmutation? It seems that Dufour did not consider muon-catalyzed fusion in liquid deuterium as an analogy to solve this puzzle. However, he noted that the energy production was *fully reproducible for hydrogen isotopes* during spark discharges. (Dufour was not aware of Collie's experiments on transmutation by sparking in hydrogen at London College during the 1910s.) Here is a list of Dufour's most relevant test results:

1) Excess heat energy is produced *only with hydrogen or deuterium* but not with other gases like nitrogen or argon. Pd electrodes are used in deuterium, but slightly *better results appear with stainless steel electrodes* in a hydrogen atmosphere.[9,Table2,p211] The combination of Pd/hydrogen also yields the same amount of excess heat as deuterium. Input energy/generated excess heat is roughly the same for hydrogen and deuterium, that is, the thermal excess efficiency is 100% ± 20%. The heat generation is carefully calibrated against an ohmic resistor instead of a spark (as a first reference test). Argon and nitrogen were also used as control tests. It was established that not sparking alone, but sparking in hydrogen or deuterium, was necessary to generate excess energy (called "active" experiments).

The rise of temperature in the calorimeter was clearly on a different linear curve when the "active" and reference or control tests were compared.[9,Fig17-20,p217]

2) Neutrons were also detected. There is a slight increase compared to the background value of $5 \cdot 10^{-5}$ to $1.3 \cdot 10^{-4}$ neutron/sec/cm^2 flux.

In a hydrogen/palladium system, the count rate is between $3 \cdot 10^{-4}$ to $1.5 \cdot 10^{-3}$, a nearly tenfold increase compared to the background.

In a deuterium palladium system, from $1 \cdot 10^{-4}$ to $7 \cdot 10^{-4}$ is the fluctuation of the neutron flux.[9,Table4,p217]

These values were obtained by neutron activation of gold, indium, dysprosium and europium. The γ spectrum was recorded with a germanium detector.

Also track etching was used on the usual CR-39 film. Further, γ and X-ray photons were measured with an Agfa X-ray film. These are difficult measurements, because they are just around the very low background flux. These values are so low that they do not possess any health hazard even for a long-term exposure, and are easy to shield. However, the neutron yield is ten *orders of magnitude less* than expected from a hot fusion reaction!

3) Protons and charged particles were measured inside and outside of the reactor vessel. The light-tight films were never blackened outside of the reactor, only in the deuterium/palladium system inside the reactor.[9,Table6,p221] There was no γ or X-ray emission at all!

4) The most relevant test result is that the electrodes emit electrons for about half an hour after sparking.[9,Fig24-25,p223] This happens *only for hydrogen and deuterium*, not for argon or nitrogen.

A further curiosity is that the temporal history of electron emissions of the electrodes is quite different for the two hydrogen isotopes. The electron emission of the electrodes appeared as a potential difference between the electrodes.

Two different half-lives were measured for deuterium palladium systems: a 20 minute and a 10 hour one. The activity declined steadily, but it was more intensive, reaching about 400 mV.

The temporal distribution is markedly different for hydrogen. The maximum intensity is much less, only 10 mV at its peak, but steadily increasing. This probably means that the character of fusion catalysis is different for the hydrogen isotopes. The catalysis sheds more electric charges in a decreasing manner for deuterium, while there is a lower but more steady value for hydrogen. The deuterium tests quickly decline into the "dark" mode. Hydrogen maintains a steady, but less intensive "white" mode.

These test results are the most relevant test results in the LENR research up to now, regarding direct electric energy production. It is detrimental that these tests have never been repeated. However, we shall see later in Part 5C that the forgotten inventions of LENR of Tesla, Moray, etc. might have been based on the hydrogen catalysis mechanism, yielding a steady outpouring of electrons due to catalytic fusion of condensed plasmoids in hydrogen or water vapor.

This sparking experiment was superior to the previous ones of Wada and Karabut. The Wada experiment was based on lattice vibration and fission, not fusion, with the known disadvantages. The Karabut tests were based on partial and low intensity corona discharges as an unknown, unintended side effect besides the useless glow discharge.

In the Dufour sparking tests, *all the conditions were met for catalytic fusion*. There is a very high rise in voltage (1 kV/μsec), and a high spatial potential difference due to sharp pointed wire cathodes, and hydrogen isotopes. The duration of the sparks is important and lasts about 30 microseconds. Though everybody desperately tried to show neutrons as a "hard proof" of hot fusion, it is clear that catalytic LENR (cold fusion) is not a modified hot fusion, because it has a different sequence of events.

Shoulders

The most abundant information on the formation of condensed plasmoids came from Ken Shoulders' patents. He intended to use condensed plasmoids for flat screen color TVs, and perhaps for memory chips, but never applied claims for nuclear catalysis in his patent. This aspect has been researched only indirectly (see the Introduction in Part 5A).

Shoulders wrote five very long detailed patents (all of them granted), and his instructions are clear, unlike other inventors in this field.

When we look at his simplest "reactor" (Figure 2d), it is nothing but a point to plane corona discharge electrode pair

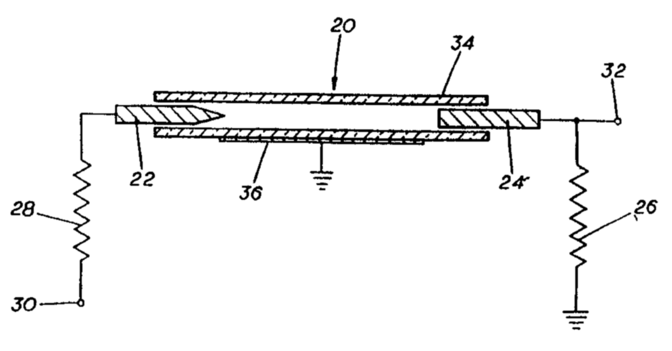


Figure 2d. Shoulders' point to plane corona discharge reactor. It is the appropriate design to study the properties of condensed plasmoids. Fusion takes place only in a hydrogen atmosphere.

known widely as a corona discharge test configuration. The only difference is in the method of supplying power. Usually the power supplies are stabilized DC sources. Shoulders used sharp pulses generated by fast thyratron tubes. The most extensive description of this general setup comes from Nikola Tesla for all kinds of high frequency, high voltage power supplies and electrode shapes. (See Part 1 and Part 2.)

The pin-plane geometry is the most basic geometry for high spatial electric field gradients. Even a DC power supply generates a pulsed corona at atmospheric pressure in the presence of hydrogen or water vapor (St. Elmo's fire), driving it with an interrupted inductivity. A Ruhmkorff coil is the usual power supply (Collie *et al.* used it in the 1910s), because it yields a very steep temporal gradient as well. This in turn generates a spin field vortex as discussed in Parts 1 and 2, which is an essential condition for condensed plasmoid formation.

This effect was rediscovered by G.A. Mesyats in Novosibirsk, Russia in 1966. He published a book on these "explosive" discharges with Yu.D. Koroljev in 1982, in Russian. This was an academic research. They noted the appearance of "self assembling," growing tips on cathodes. Only pulsed currents generated these tips. I have also observed these extremely sharp, self-grown tips on the Chernetsky cathodes made of molybdenum, but in yellow color (transmutation?).

Shoulders termed these catalytic quasi-particles as Electrum Validum (EV), or "heavy electrons." They are not the same as Widom and Larsen described them, because they meant coupled plasmons on the metal surface, while a polariton or polarization wave spread in the metal.

J.M. Zawodny also used this term in his patent ("Method for Producing Heavy Electrons," U.S. Patent 0255645; 2011). In order to avoid this mess in terminology, in this paper, we always use the term "condensed plasmoids" coined by Lutz Jaitner. Shoulders' last published patent is "Circuits Responsive to and Controlling Charged Particles" (U.S. Patent 5,148,461; 1992).

His work on quasi-particles should have been published in applied physics journals, but they never were. He wrote a book about the course of his research with the title *EV: A Tale of Discovery*.[10] In his patents and book he outlines the most apparent method for the formation:

> The principal requirement for generating an EV is to suddenly have a very high uncompensated electronic charge in a small volume space. This implies an emission process coupled to a fast switching process...In previously described types of EV generators, the switching process comes from the nonlinear action of gas ionization, and perhaps some electronic ram effects.[10]

He clearly distinguished between high vacuum field emission effects and gas discharge effects. For us only the latter is of value due to the necessity of hydrogen for LENR (Chapter 8, page 16). His "picopulsors" pulse the emitter on and off very rapidly.

This criterion was not met with Wada, and only partially and unintentionally, by chance, with Karabut, and met fully, although by chance, by Dufour.

Shoulders never used EVs in a hydrogen atmosphere even after mastering the method, thus he missed the most important catalytic applications (just as Edison missed the significance of vacuum diodes and triodes).

Shoulders further clarified the concept in a paper published in *Infinite Energy*.[11] He raises the question about the difference between a spark and an EV, writing, "It was found that there is none. A spark is simply the visible, ionized gas trail left by an EV, although in some sparks the EV is so weak that it is barely detectable in the trash surrounding it. Every spark made has an EV running out in front of it. In addition, the EV has electron feelers running ahead of it to tell it what to do."[11,p12]

In another paper published in *Infinite Energy*, Shoulders states some troubling ideas[12,p41]:

> One thing is clear in all instances, the normal repulsion laws for the like sign of electric charge between single particles do not hold in the new realm. The particles, or wavelets, are much more tightly bound than those in solids even though the number density is virtually the same, in the range of Avogadro's number. This high binding energy is demonstrably large when the ensemble is either suddenly disrupted or the group is caused to bore through ordinary solid matter.

Indeed, this high electron density, about 10^{12} electron/cluster, is way too much to hold together within the framework of textbook physics. Shoulders therefore rejects the established principles of electrostatics. This makes most scientists skeptical of him.

The problem with spark channel formation has been known for decades. Honest authors like Y.P. Raizer note: "...a well developed spark channel is preceded by a poorly understood stage at which the degree of ionization in the streamer increases quite rapidly..."[13] This unexpected, unexplained effect is ostensibly caused by condensed plasmoids.

A different path is followed in this paper: the electrodynamics is extended to include the rotational symmetry of charges. Indeed, this vortex-type movement generates the spin field, which counteracts the Coulomb repulsion in a quasi-stable manner. While a "pinch" effect is known in electrodynamics as a form of charge (current) constriction, it is a short time effect. It seems that a spin field, maybe torsion as well, constricts the electrons. Note that the rings consist of several smaller "pearls," the smallest units in a condensed plasmoid.

However, condensed plasmoids are quasi-stable compound particles with an enormous surface electric field intensity due to this high excess electron density. This makes them a catalytic agent of LENR fusion, because this is more than enough for Coulomb screening for hydrogen isotopes. (See Part 1 and Part 2.) This makes possible a nearly continuous catalytic fusion effect while these particles attract the positive ions of hydrogen or deuterium, so they can fuse on the surface of a condensed plasmoid.

The design and operation of the LENR reactors make possible this process in all inventions to be discussed here and in the forthcoming Part 5C. They form a condensed plasmoid with an electric current pulse and separate the condensed plasmoid "beads" to keep them in their active, catalytic state, in the "white EV" conditions.

It is the skill of the inventors to optimize this process. They want to efficiently create as many condensed plasmoid "pearls" as possible, and not just a useless steady plasma, like those in a glow discharge or a quasi-stable arc discharge.

Condensed plasmoids can be formed even under water with a DC power input, because underwater plasma formation is inherently unstable on the tips of a rough cathode surface. This is an intermittent and not very efficient, process.

The central issue of all of the inventions to be shown is the *economy* of the condensed plasmoid formation and maintenance. This makes the difference between a *discovery* and an *invention*. For an inventor the "sky is the limit" in the efficiency, while an applied physics researcher is satisfied with revealing the fine details of this chain of events.

There is no definitive study about what happens if a condensed plasmoid is created in mixed gases, like Papp's water vapor and mixed inert gas system. Or, what happens when condensed plasmoids are created in a certain gas, but the atmosphere is quickly changed to hydrogen?

Question Marks Around the Transients

The anomalies around transient water splitting have been with us for quite some time. There are two experimental papers that highlight the "spooky" nature of these problems.[14,15] These papers challenge the established rules, but unfortunately made no impact on mainstream science. The C.H. Dharmaraj and S.A. Kumar[14] paper describes remarkable test results of a water splitter.

The novelty of their device and method is based on the very sharp rise of cathode potential just as with Shoulders—typically within some nanoseconds. These short, needle-like voltage "bursts" yield a nearly tenfold improvement in efficiency—which is impossible in textbook physics, because it violates the conservation of energy. Obviously (if the test results are correct), LENR energy is the most plausible explanation. See Figure 3.

This avalanche diode-based pulse generator yields an unusually steep increment in voltage and current. This is due to a unique power supply driven by a field effect transistor (FET).

This FET is not an ordinary one, but hand picked as the fastest from among about 1000 pieces. The circuit is published in their paper.[14] The "secret" of these very fast semiconductors is unusual. During manufacturing, instead of a crystalline semiconductor, occasionally an amorphous one is manufactured, which is faster than the regular crystalline one. The effect was known to T.H. Moray in the 1920s in his "valves." It was forgotten, but rediscovered by S.R. Ovshinsky, who used it for the coating of CDs and DVDs, and thin solar cells. There are no available ultrafast FETs on the market, as there is no demand for them. The green economy (hydrogen economy) could profit enormously from this method.

In conventional DC electrochemistry, 120,000 KJ of electric energy is needed to make a kilogram of hydrogen, assuming a 60% splitting efficiency. In the case of conventional electrolysis, an 18 W input yields 0.58 ml/sec hydrogen, while nanosecond pulsed power requires only a 0.58 W input.

This is achieved with 200 nanosecond pulses, with a frequency of 100 MHz. The peak pulse voltage is not mentioned, and neither is the type of transformer core used in the pulsed power supply. The electrolysis cell is a coaxial cylinder, with a length of 210 mm. The cathode is 25 mm in diameter; the anode is 20 mm external diameter, made of stainless steel. There is no mention of the surface quality of either electrode. The liquid is a solution of NaOH, with a pH 12.58 at 4 grams/liter concentration. Readers are encouraged to check out these remarkable test results. This is not a textbook electrolysis, but the power supply specification is a technical challenge. It must be noted that these fast transients of high voltages are very hard to detect for two reasons:

1. The oscilloscope must have a high resolution up to 1 GHz.
2. Digital circuits suffer and are ruined under these transients.

Dharmaraj and Kumar thought to look for an explanation of their outstanding results.

Cavitation

There is another way to produce short pulses during electrolysis: fast bubble collapse induced by cavitation. This is the idea for Yull Brown's gas, and Ryushin Omasa's invention (U.S. Patent 7,459,071; 2008).

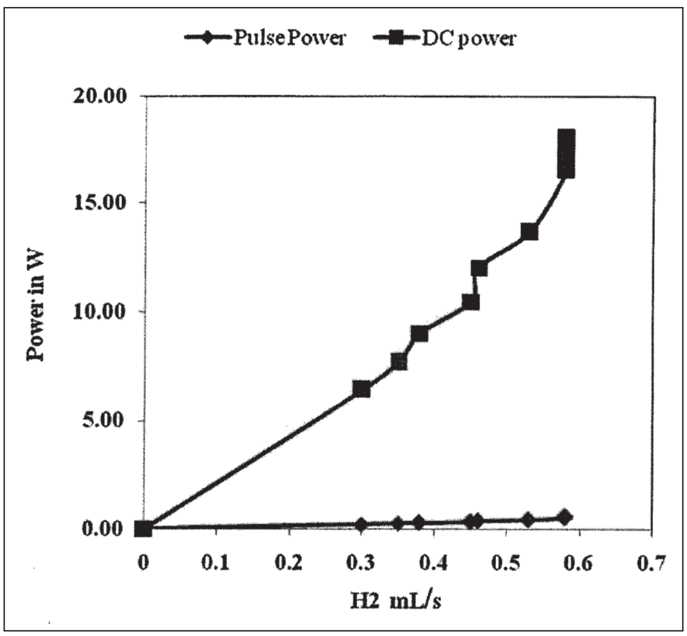


Figure 3. Hydrogen yield of the fast, pulsed, transient water splitter, in the experiments of Dharmaraj and Kumar.[14] Note the significant differences between the steady (upper curve) and the pulsed current methods (lower curve). In case of 10 W input for DC input, the yield is about 0.4 milliliter/sec. For pulsed current, less than 1 W input is required.

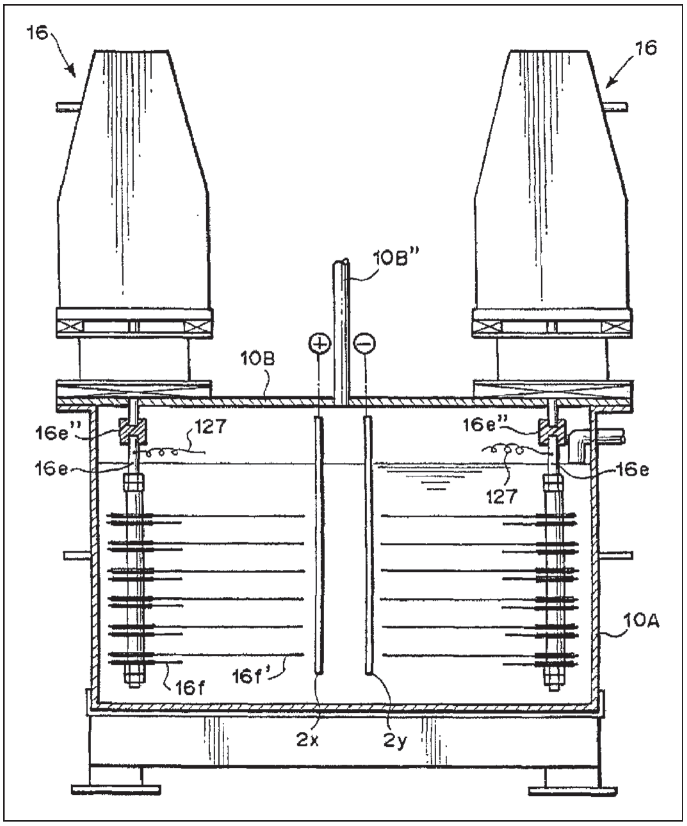


Figure 4. The cavitation-based electrolysis device of Omasa. The cathodes and anodes are on the oscillating plates; thus oxygen and hydrogen are mixed. On this setup the electrodes are separated; thus hydrogen and oxygen leave from different tubes (European Patent 1,460,149,A1; 2003).

The fast change in the electric field is achieved here with ultrasound frequency range cavitation, during DC electrolysis. Out of many possible reactor layouts, only one is shown in Figure 4. This design is not efficient because the cavitation inducing vibrating plates and the electrode plates are not the same. There will be many bubbles *without cavitation*. The acoustic intensity is not uniform along the electrode plates. They have their maximum only at the nodes, but the bubbling by electrolysis is uniform.

When oscillating plates are used to generate cavitation-inducing ultrasound range pressure oscillations, there will always be low intensity locations, where electrolytic bubble generation is of little use. This is the disadvantage in this design. Its strength is its relative simplicity and reliability. (See Part 5A on the details of transmutation and cavitation.)

Suhas Ralkas' piezoelectric ultrasound generation is more economic in this regard (shown later in Figure 5c).

Underwater Explosions

Yet another research reactor design utilized an underwater explosion by overheating a very thin titanium foil by a short transient. L.I. Urutskoev *et al.*[16] exploded a thin titanium foil in water, in a tightly closed vessel by discharging a capacitor bank via a spark gap. This spark made possible a very fast rise of voltage along the foil, while heating and thus exploding it at the same time. This is not a frequently repeatable test like the previous ones, yet it is interesting from a fundamental research view. (They found a number of transmutations.) They also noted that particles behaved like magnetic monopoles. (Tesla also mentioned it briefly with the high frequency brush discharges.) There was no attempt to explain the formation of these magnetic particles which are condensed plasmoids in our terminology. The titanium foil was selected because its vapor reacts with water, releasing energy. Both water and titanium have all the possible phases reacting with each other mutually. This is a hopeless theoretical situation, even without LENR.

B. Yu. Bogdanovich *et al.*[17] used another similar method when powerful spark was discharged through water droplets flowing through a thin tube. They noted a very long life time for shiny plasmoids, sometimes minutes or even two days. The spheroid toroid shape of the quasi-stable plasmoids were recorded on video.

The French research group of C. Daviau *et al.*[18] repeated Urutskoev's experiment, but replaced the thin titanium foil with a titanium wire, and exploded it during a 70 µsec period, by discharging 3-8 kJ capacitors, with peak currents of 30-40 kA. (These operation parameters are excessive, and can't be achieved in a repeated manner in an industrial device, as mentioned previously.)

Nevertheless they found tracks of quasi-particles, condensed plasmoids on X-ray films, with right and left-handedness. They claim they are magnetic monopoles, like those mentioned by F. Ehrenhaft and V.F. Mikhalov. (See Parts 1-2.)

Though the design and operation parameters are varied in the above explosive underwater sparking experiments, there are noteworthy common parameters:

1) Plasma is generated by the electrolysis or overheating of water, which involves hydrogen-rich plasma. It is strange, but no other hydrogen-rich plasmas were tested, like methane.
2) The hydrogen plasma generation/termination period is short, on the order of micro or nanoseconds.
3) The electric pulse generating the hydrogen containing plasma is a high power transient. It is usually above 5 KJ, evaporating a metal foil. Several transmutation reactions were recorded in the above papers.[16-18]

The above experiments never used palladium or heavy water, yet they yielded transmutations.

These conditions seem to be necessary for transmutations/excess energy generation by LENR.

Is it possible that the Pons-Fleischmann type light water electrolysis LENR experiments had also the above effects at least partially? Yes, if the overpotential exceeded far above 3-5 volts, as suggested by J.O'M. Bockris, and sudden voltage spikes were used (as in our modified Patterson type "floating bed" thin layer cathodes).

Plenty of backyard inventors use simple underwater arcing experiments that yield a noisy arc discharge in saturated and overheated plasma. Sometimes they report transmutations, and excess heat as well. However, this simple layout without resonances is just "hobby research" with no chance of commercial, highly efficient, or competitive applications.

Our purpose is just to review the most relevant set of "precursor" experiments, that is, the essential fundamental LENR tests.

Matsumoto's Test Results — and His Blunder

While several aspects of transient gas discharge related

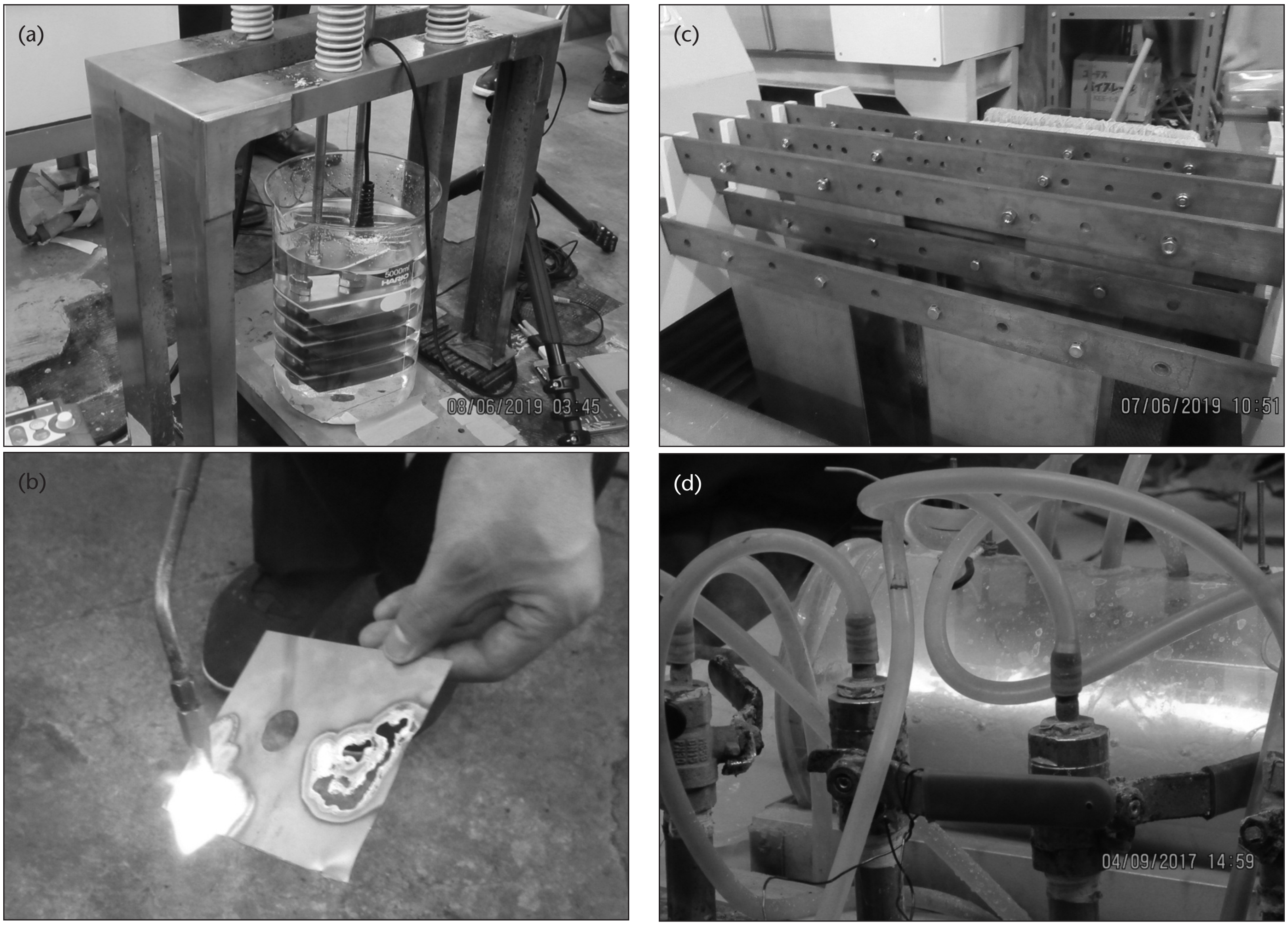


Figure 5. (a) A photo of an Omasa vibrating plate cavitation-induced LENR reactor. The vibrating plates are shown. (b) A 0.5 mm thick molybdenum plate evaporated immediately when the gas flame touched it. The flame temperature was slightly above 90°C. (c) The underwater electrolysis device of Suhas Ralkas also driven by cavitation. The treated cathode is heated, and is immersed into the oscillating plasma. (d) The device of Suhas Ralka, Mumbay. It is a combination of underwater sparking, electrolysis and cavitation by ultrasound.

observations were made after the Pons-Fleischmann announcement, only Takaaki Matsumoto made an LENR-related study based on condensed plasmoids. All of his observations were made by underwater sparking for large-diameter flat, thin Pd foils. (See Part 5A.) This is far from being the ideal method of spark generation, but above 50-60 V DC, the sparks intermittently form on the Pd foil cathode. They quickly erode the foil surface, so craters help the formation of underwater sparks. Matsumoto observed the traces of condensed plasmoids on X-ray- films, under the Pd cathode, at several parallel layers. He assumed the causal relationship between the observed excess heat and condensed plasmoids, in a qualitative manner.

The X-ray foils were placed under the flat cathodes. Somehow these condensed plasmoids left the reactor via the walls. However, he did not observe any holes in the walls of the reactor vessel. Is it a tunneling effect, or teleportation (Part 3), or unnoticed holes on the cathode? I met the same effect during the microwave-driven dust fusion experiments. While the plasma was always confined to a spherical glass, (connected to a long, thin quartz tube shown in Part 5A), condensed plasmoid-like traces were found on the inner wall of the electromagnetic cavity resonator made of aluminum. How did they get through the glass wall? Robert Greenyer had a sharp eye also, and made a systematic study with microscope, and published the results.

Like Shoulders, Matsumoto also noticed that condensed plasmoids somehow leave the cathode and make marked circular traces on dielectric X-ray films. He made some very wild speculations on the nature of the condensed plasmoids (like gravity decay), but his observations under an optical microscope help us to make some order in a large group of unusual observations.

Matsumoto corroborated Shoulders' fundamental test finding, that the plasmoids consist of several small (~1 μm) beads, maybe in a quantized order. He stated that the most usual size ring of plasmoid "pebbles" or "pearls" have a diameter of 22 μm, and they are made of 42 beads. The larger ones have about 60 μm diameter, and consist of 73 pebbles.[19]

The largest ring had a diameter of 364 μm, one-third of a mm! Russian scientists observed condensed plasmoids with diameters as large as 2 cm,[17] also in underwater sparking. (See Figures 5a-d.)

Matsumoto also observed star-shaped rings, ostensibly after an explosion. This may explain the two different half-lives of these objects, observed by Dufour. The shorter may be related to the 30 min half-life, when electrons are shed continuously. The 10h half-life may mark the end of stability, when the "bubble bursts." (See Figures 6a and 6b.)

One of the most puzzling objects is the "Itonic frost" (see Figures 9a-b[20]). In Figure 7 some of Matsumoto's photographs are reproduced and enhanced with graphics.

Indeed it looks like ice crystals, and probably these objects are made during the underwater cavitation experiments, discussed in Part 5A.

Some conclusions to be drawn: Academic "pure" research has not yet reached the interesting area. LENR researchers, mainly electrochemists and experimental nuclear physicists, did not have the necessary skills in plasma physics. They failed to pinpoint the transient corona discharge as the root cause of catalytic fusion. Further, the catalytic nature of plasmoids were missed, and in general the missing rotational symmetry was not acknowledged.

The Karabut group noted the importance of the surface quality in inducing LENR,[21] also the max. 10h long activity of charged particles after switching off the device, but they were unable to connect the dots. They never mentioned the results of Chernetsky, who came to the same conclusion using an oscillating hydrogen plasma, some years earlier. Dufour was unable to realize that sparks generated catalytic particles, so he abandoned this successful research line. He thought "any type of excitation" will trigger LENR.

In fact, this is not true, and it is a very hazy description. Mechanical, internal stress and high frequency lattice oscillations (Part 4) and quasi-particles, like condensed plasmoids (Parts 1-3) and rotating charges particles, are responsible for the catalytic actions.

Matsumoto had the lion's share of success to find the nature and circumstances of condensed plasmoids, along with Russian, U.S. and French researchers. Matsumoto published several papers in *Fusion Technology* on the physical nature of condensed plasmoids, culminating with his seminal paper "Cold Fusion Experiments with Ordinary Water and Thin Nickel Foil."[20] This paper shows several traces of interactions of condensed plasmoids with X-ray films where ring and conical traces are revealed, as well as ice crystal-like structures. (See Figures 7a and 7d.)

However, Matsumoto made some over-statements detrimental to LENR research, because they became the "casus belli," the cause of war.

He claimed that some ring-like structures were "black holes," while others were "white holes." A more plausible explanation is that they are carbon depositions (black) and lithium or beryllium depositions (white) due to transmutation. The photographs of these ring-shaped (charge) clusters are littered with small (1 micron-sized) black dots, the "pearls" of condensed plasmoids, as the likely catalytic agents. However, no attention is paid to the most likely "work horses" of catalytic LENR, the isolated beads, not attached to each other. Researchers never mention them. The very mention of "black and white holes," however, enraged the hot fusion community, which made a common stand against the LENR field. A strict ban fell on LENR papers with very rare exceptions. The exploratory freedom, even the freedom to err, simply disappeared. Very few research papers about LENR have been published in *Fusion Technology* since then; it seems a restrictive censorship was initiated against all LENR related papers. This ban has not been lifted yet.

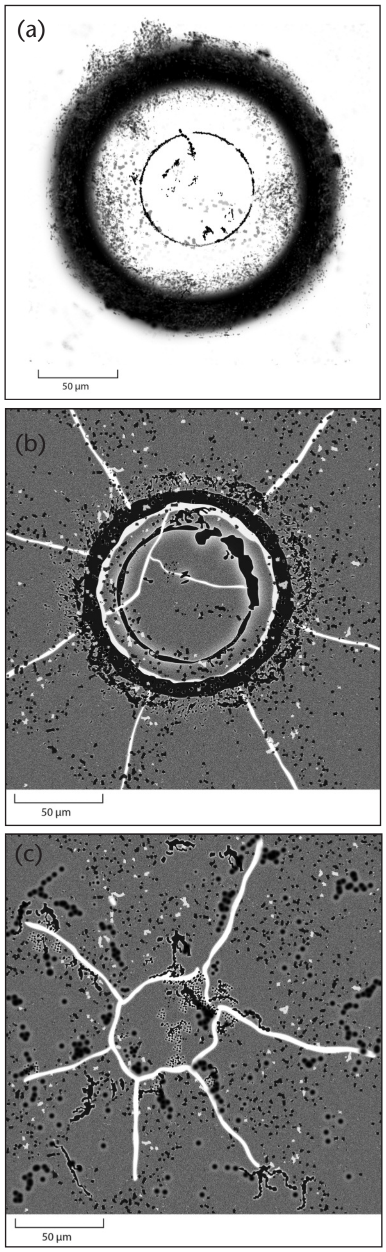


Figure 6. (a) A ring-shaped chain of condensed plasmoids exploded. (b-c): Star-shaped traces left on the X-ray film observed by Matsumoto. Note the central and mirror symmetry of the traces expected in an explosion.

In the forthcoming Part 5C of this paper we shall see inventions, but all of them are spark and hydrogen related, showing the definite connection between fusion and condensed plasmoids. Part 2 showed how catalysis works in practice. It makes condensed plasmoids, rotating, charged dust particles and rotating, charged ATP-ase enzymes in the inner cell membrane of the mitochondria.

Condensed Plasmoids — Their Shape and Features

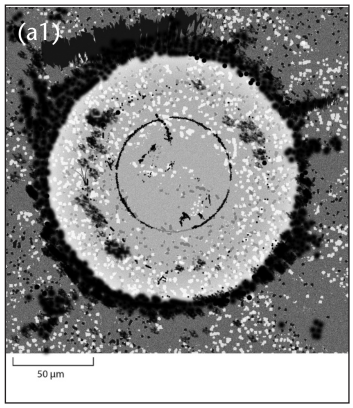
Readers may raise the painful question: why were condensed plasmoids not observed or discovered during their use in arc, spark and corona discharge experiments, at least as catalyzers? In fact, they were known, although indirectly. It is quite usual in science that one fails to recognize the novelty in what they already learned. A minor effect, like darkening a photographic plate near uranium salts, will escape the attention of 99 of 100 researchers. This probability is further reduced when several steps are involved, like measuring the energy balance. Glow or arc discharge academic studies never reached this area.

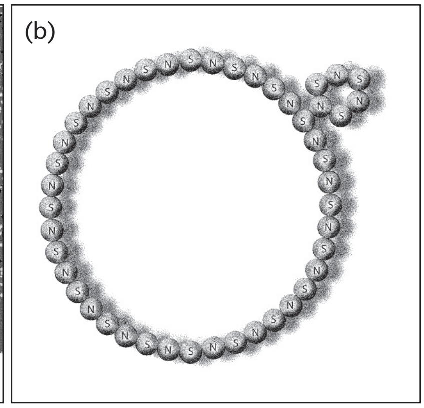
The occasional bizarre voltage current characteristic of wire and point corona discharge has been known for decades. Such a test result is shown in Figure 8a from a textbook of non-equilibrium plasmas.[22,p296] In fact, we expect a voltage-current curve shown in Figure 8b based on textbook physics, but observations show otherwise.

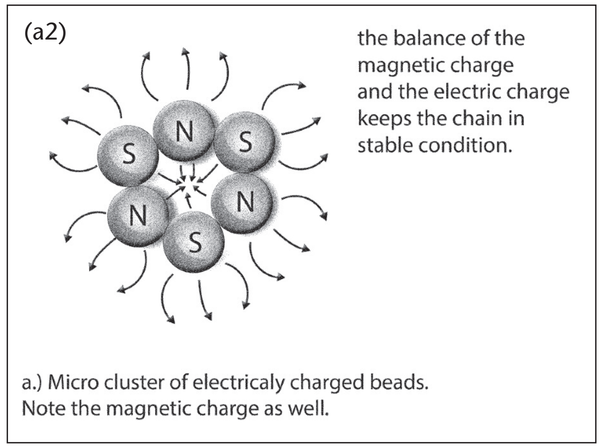
There are really odd features of the observed experimental current voltage characteristics:

1. There are periodic current peaks at zero voltage (where rot S(t) ~ $\partial E(t)/\partial t$ has maximum).
2. There is no current burst at maximum voltage (where rot S(r,t) = $\partial E(r.t)/\partial t = 0$).

Figure 7. Traces of condensed plasmoids on X-ray films observed by Matsumoto under a microscope. (a1) A large, ring-shaped chain of condensed plasmoids as observed on X-ray film. The outside is usually darker; inside there is a whitish ring. There may be transmuted carbon outside, and beryllium or lithium inside. (a2) The ring-shaped chain is self-assembled from ball-shaped condensed plasmoids with electric and magnetic charges, or spin field dipoles. (b) "Necklace" type condensed plasmoids. The beads attract each other, forming closed and open, two- and three-dimensional objects. (Drawing based on a photograph.) (c) Three-dimensional ball-shaped bead formation. They can also be an assembly of electric and magnetic charges, like in (a2). (d) The formation method of "beads" is similar to the "crown" when a water droplet falls into a pond. This is a typical self-organizing process. (e) Ice-like, condensed, tightly packed structures. Is it solid hydrogen? Or solid crystal-like condensed plasmoids?





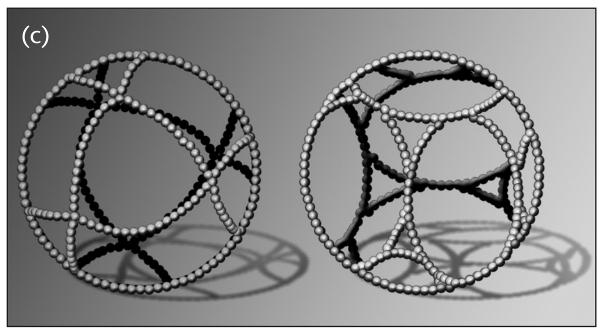


3. The maximum current peaks are seen only when the electric field change is maximum as a function of time.

This latter effect was described in Part 1, when the generation of spin fields was discussed, that is rot $S(t) \sim \partial E(t)/\partial t + \ldots$

That is, spin field generation and thus condensed plasmoid formation intensity peaks when $\partial E(t)/\partial t$ is the highest, yet the voltage is zero or small. (These needle-sharp current spikes are also found in old textbooks on arc discharge, where raw data is published.)

It is expected that after several discharge cycles, condensed plasmoids accumulate on the cathode and anode wires. They catalyze LENR and trigger discharge as well. It is strange that *there is no current at all on the negative slope*, when the electric field is decreasing. This temporal asymmetry is important, and it was disregarded in the textbook studies of transient non-equilibrium plasmas. The speculative answer to this asymmetry is that plasmoids are active, catalytic, "white" mode, shedding electrons, where $\partial E(t)/\partial t$ is positive. On the other hand, the condensed plasmoids are non-catalytic, dormant, "black" state, maybe absorbing electrons, when the electric field peaks and decreases. This behavior is unknown in plasma physics, where current is proportional, in a non-linear manner, to the external electric field for metal electrodes. This effect alone should have rung the alarm bell in plasma physics, like radioactivity and black-body radiation did in the 1880s. This sloppiness has cost an extreme loss in new, green technologies since 1914.



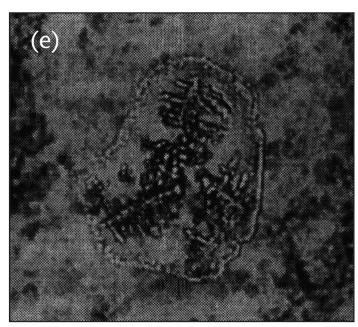
When engineers using arc discharge write monographs, they note the severe differences between theory and practice. Traces of condensed plasmoids are quite similar to those found as isolated cathode spots. Obviously, they have never been tested for possible transmutations. Low-current arc discharges may generate condensed plasmoids, because they are always "noisy," but they may destroy them as well due to their intense heat.[23,p155] (See also pages 137-139 of Reference 24 for cathode spot micrographs.)

The series of isolated voltage-current peaks are shown in the textbook *Electrical Breakdown of Gases* by Meek and Craggs.[24,p467,Figs12,17] They note that inductivity in the electric circuit helps this phenomenon.

Max F. Hoyaux's book *Arc Physics*[25] repeatedly remarks on the anomalies:

> It happens quite often that an arc gets extinguished following a rapid current surge...No satisfactory theory exists to our knowledge."[25,p23]

> The concept of work function...becomes somehow deeply modified, or even meaningless."[25,p179]



Hoyaux also noted that cathode spots move to the "wrong" angular velocity direction, cast-

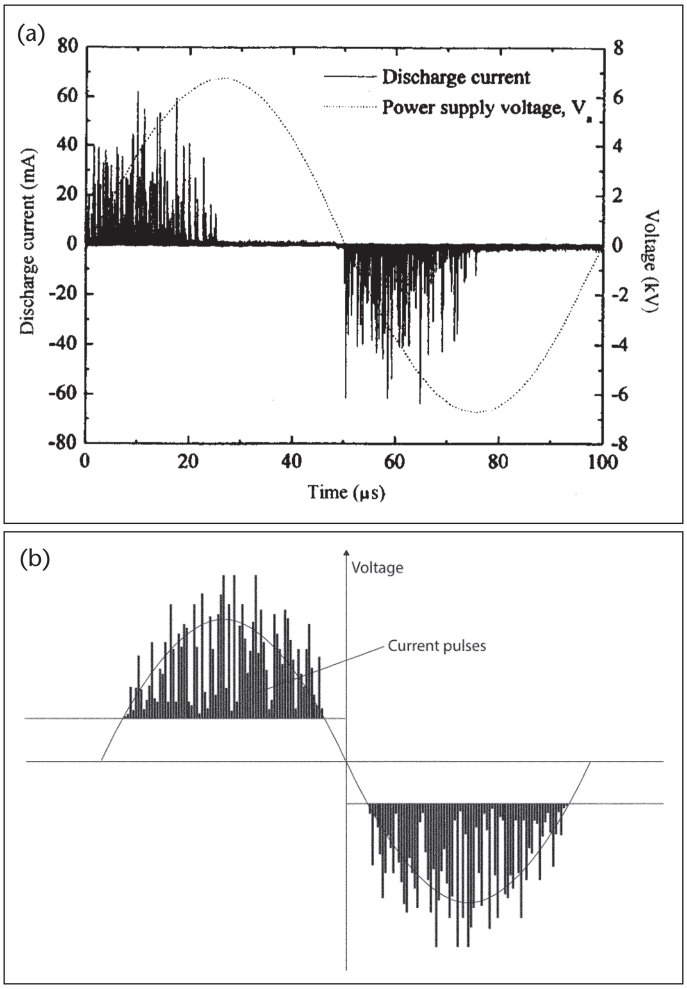


Figure 8. (a) Current of an actual wire corona discharge. Note that the current is the highest at zero voltage, and zero at maximum voltage. At zero voltage, the ∂E(t,r)/∂t gradient has maximum value, while it is zero when the voltage is maximum. (b) If textbook physics is correct, the current should peak at the maximum voltage, and cease under a threshold value.

ing doubt on the validity of the Lorentz force.[25,p186] This is a puzzling retrograde motion.

It means that if we do not read patiently the monographs of transient discharges, a number of problems are brushed aside. Needless to say, most of these observations were made in air or argon, the usual medium of arc welders. Deuterium (especially in transient electric circuits) has never been investigated. Correa tested transient arcs in many gases, except hydrogen (see Part 5C). So it is naïve to expect that all potentially valuable phenomena have already been investigated. Usually scientists see the patterns they were taught in schools. They do not always notice what should not exist. Actually, condensed plasmoids do exist in streamers among "debris," as Shoulders noted. Self-organizing, sudden glow-arc transitions, glow instabilities and field transients are all possible sources of plasmon polaritons on conical electrodes, and condensed plasmoids form on sharp electrodes.

The lack of curiosity reeks from the pages of gas discharge monographs. There is no mention of tests of:

1. Emission spectroscopy, or time of flight mass spectroscopy, as a means of finding transmutations.
2. No energy balance or calorimetry, tests.
3. No rotational, magneto-hydrodynamic, discharge experiments like Bostick. There are no cathodes made of strong permanent magnets.
4. No measurements of mechanical forces between electrodes (though this is difficult for high frequencies).

This hiatus stems from the ignorance of Curie principles: the reduction of symmetry causes a new effect. No wonder all inventions to be discussed in Part 5C stem from this vast unexplored area. One can see that the unexplored areas are far bigger, by orders of magnitudes, than the known ones, if the combination of the above points are considered.

"These researches were not forbidden as such. Just they are not in fashion." Semiconduction and radioactivity have not been fashionable areas for decades. However, it was allowed to correct these fields, even up to the 1930s. Then the intellectual hunger gradually vanished and crossed the zero line. Now we are in the negative, intellectually repulsive period. This is the reason why only backyard inventors driven by luck or curiosity had the opportunity to move ahead. They are listed in Table 1.

There is a fundamental difference between the usual Townsend (homogeneous avalanche) type ionization and non-equilibrium, inhomogeneous streamer discharge. While for the Townsend type breakdown the Debye radius (where positive and negative charges compensate each other) is small, the opposite is true for streamers. (See Figures 9a-d.)

There is a high electron density "head" followed by a slower positive ion trail. The field intensity can be higher between the anode and the electron head than the original potential (field) intensity. Thus a very fast moving, extreme field intensity, quasi-particle arises with a Coulomb shielding capability. (See Figures 9c and 9d.)

Some authors assume the negative head is a separate entity (based on nanosec resolution photographs), and others assume it is just a severe internal charge polarization. No one assumes that this quasi-particle, the condensed plasmoid, has a lifetime measured in minutes.

The take-home message is: streamer discharges are the known sources of high mass, high charge quasi-particles capable of Coulomb shielding. This kind of filamentary, non-thermal equilibrium, weakly ionized high-density plasma is found in all water or hydrogen-based excess energy inventions. They come in different forms, but streamers are always there in one way or another.

The Advantage of Transient Discharge

The formation mechanism of condensed plasmoids was outlined in Part 1 as a consequence of new fields due to rotation in electrodynamics. There are some related technical data worth knowing before we continue with underwater sparking and corona discharge, the "promised land" of LENR reactors.

The technical parameters of condensed plasmoid (and transmutation) related gas discharge research are worlds apart from the parameter range used in practical inventions. In the researches of Urutskoev, Bogdanovich and Daviau *et al.*, the peak currents are in the order of kilo Amperes, and the pulsed power is kilo Joules, and pulsed charges are in the order of Coulombs. Inventors are way below this parameter range by orders of magnitudes! These modest pulse parameters are apparently useful in engineering applications, and

Table 1. Comparison of excess energy generation methods of various inventions.

	Plasmon waves, Condensed plasmoid	Micro discharge	Plasma material	Cathode material	Cavity	Energy extracted	Status
Tesla, Nikola	yes	yes	?	SiC	?	electric	demo
Moray, T. Henry	yes	yes	Air+H_2O	PbS	yes	electric	demo
Papp, Joseph	yes	yes	H_2O + inert gas	Fe alloy	yes	mechanic	demo
Colman, Gillespie	yes	yes	H_2O?	ZnO	yes	electric	demo
Gray, Edwin	yes	yes	?	?	yes	electric	demo
Jekkel, Janos	yes	yes	H_2O	AgO	yes	oxygas	demo
Correa, P. & A.	yes	yes	Air+H_2O	AlO	yes	electric	demo
Chernetsky, Alex	yes	yes	H_2	Mo	yes	electric	demo
Hyde & Testatika	no	yes	Air+H_2O	?	no	electric	demo
Shoulders, Ken	yes	yes	Air	?	no	electric	demo
Godin & Roschin	no	yes	Air+H_2O	?	no	electric	demo
Horvath, Stephen	yes	yes	hydrogen	steel	yes	mechanic	demo

less dangerous to the environment.

Where are we in terms of parameters? It is worth comparing equilibrium (steady state glow) and non-equilibrium (transient) discharge parameters at first.

Table 2 shows equilibrium discharge compared to transient micro-discharge, preferably a corona discharge; the latter yields higher electron density.[26] Thus, more freely moving electrons are available for the formation in condensed plasmoids and plasmons. There is no data on cavitation plasma, but rise time/bubble collapse duration is in the same order of magnitude. Note that equilibrium and non-equilibrium discharges are different from each other in each aspect by orders of magnitudes. Thus their behavior is definitely different, which should have rung the alarm bell again.

There are some logical, but also some counter-intuitive properties of micro-discharges. Filamentary or micro-discharges occur in groups or "sets," not in a sequential time series, one by one.

For example, the frequency of sets depends on the voltage. For atmospheric air, and a 1 mm wide spark gap, the number of discharges in 10/msec depends on the voltage in the following manner:

Voltage across the gap (kV):

6 8 10 12 12 16

Number of simultaneous discharges/cm^2:

15 20 25 26.2 30 42

However, this near linear relation is valid only up to 4 mm.[28]

There is again a different behavior for small gaps, under 1 mm, where the frequency grows over small distances.

The diameter of the micro-discharges depends on the nature of the gas. It is 16 mm for N2, while for oxygen it is only 4.2 mm. (There is no data on hydrogen.)

The transferred charge is in the order of a nanoCoulomb (nC) for a single discharge. The polarity, discharge gap length and pressure are the major influencing factors. For example:

Gap (mm):

1 2 3 4 5 6

Charge transfer (nC):

0.1 0.3 0.6 1.2 1.6 2.8

The big "gaps" in our knowledge are: where and to what extent do surface plasmons/electron density waves aid LENR? It is the opinion of this author that plasmon waves *do participate* in thermal neutron formation (Widom-Larsen model), and maybe several neutrons form a "catalytic crystal," such as the model of John C. Fisher published in *IE* but forgotten by now.[27] Matsumoto[28] came up with a similar idea, the "Nattoh" model, but it is hard to comprehend and compare them. It is quite feasible that the neutrons, or deep-orbit proton-electron pairs, do not leave the reactor as they interact.

Is it possible to make di-neutrons or tri-neutrons? Or do neutrons form a stable catalytic particle only above 6? Is it possible that condensed plasmoids contain a number of neutrons, thus contributing to their stability? We may label them "coherent matter," but it is not enough for an answer. Matsumoto suggested the formations of quasi-neutrons in the "Nattoh" model.

What is the most favorable technical process for the for-

Table 2. Equilibrium discharge compared to transient micro-discharge.

	Equilibrium Discharge (glow)	Non-Equilibrium Discharge (spark)
Electron density	3x10^6 electrons/cm^3	10^{14} - 10^{15} electrons/cm^3
Rise time (typical)	order of milliseconds	1.3 nanosecond
Current density	1 - 10 A /cm^2	2000 A/cm^2 on a tip of a needle
Energy, peak	0.2 - 5eV/electron	1 - 10eV/electron

mation of *condensed* plasmoids? Surface plasmon waves during sparking are not condensed; they remain in their gaseous phase.

Cavitation also seems to be a good candidate for polyneutron formation, because the plasma density is very high after a bubble collapse. Proton electron pairs may form neutrons, and the plasma temperature is also high, exceeding Parkhomov's threshold.

Thus Brown's gas and Omasa gas (electrolysis under cavitation) can be viable methods to generate polyneutron formation. Brown's gas and Omasa gas—which may contain "frozen, closely packed hydrogen crystals," polyneutrons or condensed plasmoids—are most suitable for welding and transmutation, but can be an additive to carbohydrate fuels of cars as well. See Figure 7e. However, most economic inventions are related to abundant spark (micro-discharge) formations, soon to be discussed.

The Pulsed Plasma Inventions

Table 1 compares a dozen pulsed, hydrogen sparky micro-discharge plasma-based, excess energy production methods. This list is obviously incomplete, because only a small fraction of these inventions are patented, and thus published. Maybe 1%, or even half a percent, of the LENR inventions are accepted as patents, or research papers, and I have found only a fraction of them. There is news sometimes that water-driven engines have been invented in Brazil, Pakistan or the Philippines. Then they disappear from the limelight after a short local media splash. These are the "luck driven" inventions. However, most people prefer the safety of a regular salary instead of taking the risk of hitting the jackpot. This paper pinpoints where, why and how these devices work.

None of the inventors noted in Table 1 were aware that they had run into catalytic fusion of hydrogen/vapor. None were aware of the other inventors' technical achievements. *Practically all of them were serendipity-based inventions.* (This is due in part to brutal censorship.) Successful devices are typically the result of continuous R&D, when tens of thousands of researchers, designers and manufacturers work on them. It is rare that a single inventor develops a market-ready machine capable of mass production. Therefore we can't judge the inventions in Table 1 on the same merit as mobile phones, jet planes, TVs, etc. So getting to a demo device is the most one can expect from a lone inventor—as all LENR demo reactors in Table 1 were developed this way.

Nevertheless, there are important lessons to learn and share, as was promised in Part 1.

We shall talk about each of the individual inventions soon, but their *common patterns*, the subject of science as method, will be discussed first. Transient discharges and streamers come in a variety of forms and gas compositions. They are considered only a third-rate problem of little practical importance. The long and short streamers, and micro-discharges, have a common structure. Their most important feature is their unique structure, a characteristic small, fast-moving region with a negative space charge. Its structure is shown in Figure 9d. Region 1 is a cloud of

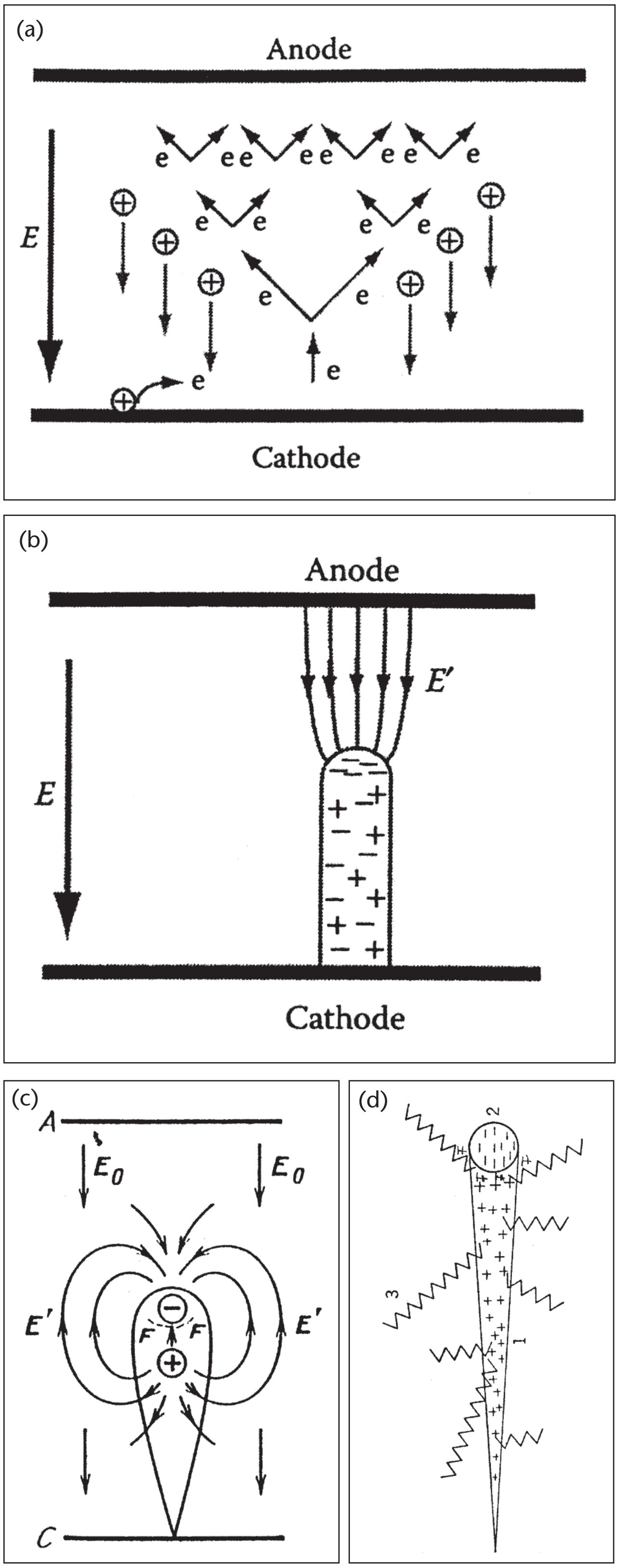


Figure 9. The spark discharge is always full of spatial and temporal non-equilibriums. There are different aspects emphasized by various authors. (a) Townsend-type avalanche ionization. The plasma is spread, and the Debye length is small. (b) A spark channel. Leading edge or "head" of a spark channel.[22] Note the concentration of charges. There are uncompensated local charges. The Debye length is large due to uneven charge distribution. (c) The E' electric field intensity is higher between the negative and positive charges than between the electrodes E_0.[13] Fusion (noted by F) may take place between the accumulated negative and positive charges. The condensed plasmoid is in the negative charge cloud, hydrogen ions (protons) are in the positively charged cloud. The spark channel acts as a field intensity amplifier. (d) Another drawing of the spark channel.[31] The condensed plasmoid is in the negatively charged cloud (2). The positive ion trail (1) follows the negative cloud. Released energy (3) triggers other ionization channels. Fusion may take place between the two charged regions, 1 and 2. For us the "leader" (2) is important.

positive ions. Region 2 is the negative space charge we call condensed plasmoids. Photons are marked with 3. It is quite plausible that the catalytic agent, or the dense negative space charge region, has already been in the monographs since the 1960s. This is an oversight, sloppiness, as usual in science. (The drawing was copied from the monograph of Essam Nasser.[29]) This negative region acts more like a muon or pion, it has a very high mass, and rotates, as discussed in Parts 1 and 2. Also, it may behave as a magnetic monopole noted in Daviau[18] and described by Tesla 120 years later.

Streamers are easy to generate. However, it requires considerable know-how to form them in an economic method. Their flow patterns are the Lichtenberg figures. They are called "feathers," especially for negative coronas, because they spread in high pressure plasma in a feather-shaped pattern.

Though they exist without a doubt, their nuclear catalytic capability has never been expected, thus it has never been investigated. There is no reliable mathematical model for streamers; because they are so erratic and unpredictable, they depend on many slight changes. (Even the transient arc discharge has no reliable mathematical model.)

Common Features — Micro-discharges

All devices producing electrical and mechanical energy (or oxygas) are commercially more exciting than heat producing reactors. All of them use the following effect: A small spark (preferably from a corona discharge) produces a condensed plasmoid (EVO, strange radiation), and it is attached to the cathode and the anode. Polarity of the cathode is unchanging—when we know about it at all. There are no alternating polarity electrodes among the inventions of Table 1 and probably for a good reason—as it lets hydrogen diffuse into and under the cathode surface. Only pulsed current is used, because only that forms condensed plasmoids, as discussed in Part 1.

During spark formations, unbalanced charge waves (called plasmons) are also formed on the cathode. When the cathodes are made of semiconductors, they may even form high frequency waves (GHz-THz range). This is the case when they have a section of negative V-I characteristics. (Gunn diode wave generation is a practical application.) Thus the charge wave (plasmon polariton) and condensed plasmoids are both present in these devices but *we don't know their share in the catalytic LENR process*. They are not mutually exclusive, but co-operative effects. The best general design criterion is: let's set free all possible energy generation effects simultaneously!

In some cases, external transient electric and magnetic fields boost the effect. Their task might be to drag the waves and condensed plasmoids along the electrode surfaces. Thus the catalysis is more efficient when they cover a larger area. The Parkhomov threshold may be exceeded temporarily at some spots, where the cathode is heated by a spark. (This statement is speculative, not yet backed by test results.)

The extraction/harvest of the fusion energy requires further efforts. Although it is based on textbook physics, there is a different solution for each invention. Here are some brief examples:

— The shock wave of an oxygas explosion is turned into mechanical energy in Papp's engine—just like in internal combustion devices. The mechanism is the same with the Omasa gas, and in Horvath's deuterium enriching machine (U.S. Patent 4,454,850; 1984). Papp's rival, Horvath, working in Australia, continued the development of his liquid water splitter system (U.S. Patent 4,107,008; 1976), discussed briefly in Part 5A. This is a system based on spark discharges.
— In the Jekkel oxygas reactor, the energy is released by catalytic fusion. The fusion energy splits superheated, high pressure H_2O molecules.

A huge wealth of important information is buried in the archives of patent offices. Nowadays they are digitized and available for free, especially U.S. patents. Nevertheless, a host of other nation's creativity is still not accessible (partly due to language barriers like Russian, Japanese, Chinese, Italian, German, Scandinavian, etc.). The other big problem is the lack of proper catalog search terms. There is no search term for LENR reactors, or free energy devices. Inventors hide them under the shaky terms of "energy conversion device" or "pulse converters"—meaningless expressions.

Finding valuable, but lost, inventions requires extreme patience, perseverance and keen eyes for the unexpected.

However, it is more likely that an important effect (along with an engineering application) ends up in a patent office than on the editorial desk of *Physics Review*, *Applied Physics Letters*, *IEEE Transactions* or any other journal.

In a tragic manner, patent offices have not published rejected applications for decades. Thus the reactors of Tesla and Moray are lost forever due to this fatal practice.

Science journals no longer allow any breakthrough results to be published—let it be physics or biology. A rare exemption was the early years of *Fusion Technology*, when George Miley was the editor. When he was replaced, all such publications were banned: instead the term "science" was added to the title. It looks as though LENR and "science" mutually exclude each other. Hence *Fusion Science & Technology* is a journal where useless concepts are published—untenable hot fusion models, unsolvable turbulent equations and failed constructions. It is a Ponzi scheme now.

I found only one historically important paper (by Collie *et al.* in 1914) where a breakthrough was published about transmutation due to high voltage transient sparking in hydrogen.

In a tragic manner, this work was forgotten due to the outbreak of World War I. No one knew about it when Pons and Fleischmann published their work in a quite different area of LENR (nearly a century later). Researchers never returned to the fertile area of spark discharge devices, assuming that only lattice-based quasi steady-state LENR exists.

Inventors repeatedly stumbled over into it, meeting with hostility from science as an institution. The third part (Part 5C) of this paper will return to their identical technical, physical features, however.

The general lack of thinking about nature in terms of symmetry is also a real death trap. The lack of rotation of electrodynamics (Parts 1-3), hyperspace (Part 3) and ether at short and long distances (Part 4) are a lethal brew, killing progress since the 1970s.

The early study of gas discharges led to the discovery of electrons and protons in the 1880s, the start of particle physics and the spectral lines (atomic physics). Semiconductor studies were considered a complete waste of effort at that time, despite their later use in crystal radios. In the same manner, corona discharge was dismissed as a promising area of any meaningful discoveries, as well as their more powerful cousins—high frequency spark and arc discharge, home of dusty plasmas, and thus transmutations. Actually, there was only one inventor, Nikola Tesla, who had all the proper technical skill for these experiments: air core resonant transformers, gas discharge tubes, Geissler tubes.

Nuclear physics followed a different path due to the accidental discovery of a blackened photo plate The dots were not connected between transient gas discharges and nuclear physics, or ether excitations. However, as the body of their observations grew, these areas became even more and more distant from each other, which is a deadly process.

The Triple Trap Repeatedly Stumbled Over

There must be a reason why science as an institution lost touch with LENR (and all practically useful effects). The stakes can't be higher, because life on our planet is doomed without unlimited clean energy sources.

Few researchers are able to think outside of their very tiny boxes. When controlled fusion is considered, mainstream physicists can't get rid of the H-bomb concept and process, and other nuclear concepts (first trap).

In that area, the usual time and distance scales (10^{-20} sec and 10^{-12} m) and the relatively slow and huge distances of metal lattices (10^{-10} sec and 10^{-8} m) seem completely unrelated, like a fruit fly and a whale.

Not even a hint of relation is considered between them. In the same manner, LENR researchers trained in electrochemistry seldom think outside of their box of bulk metal diffusion, and electrochemical lattice loading. The concepts of variable ether fluctuations, dusty plasma and quasi-particles as fusion catalysts are alien to them as well (second trap).

Disregarding catalysis, a fundamental concept in biology and chemistry is a death trap in fusion science and technology (third trap). It should be obvious by now for hot fusion researchers that sheer muscle (high temperature) is untenable due to the ever present plasma instabilities. However, it is disregarded in hot fusion reactor designs. A fundamentally flawed physical concept cannot work with any shrewd engineering design. The same applies to LENR reactors.

All successful LENR reactor designs were based on the combination of resonant plasmon polaritons and condensed plasmoids.

The "coldest" cold fusion, muon-catalyzed fusion, resurfaced from time to time. Leif Holmlid applied for a patent (SE539684C2), where a powerful short laser beam creates muons according to the inventor. Several of his papers quote experimental results.

A catalytic process is also the basis of Randell Mills' concept. However, his process is not a usual fusion, but a catalytic process based on "deep orbit" atoms where electrons get much closer to the nuclei, releasing energy as soft X-rays, or UV radiation. The problem is that no one has been able to repeat his test results. His publications are not suitable for repetition.

The Catalysis

Through the rest of this paper, and Part 5C, the catalytic process has a central role, as the fusion of hydrogen or deuterium/tritium is the essence of the process.

Catalysis, and enzyme activity, make life possible. It is far more fundamental than the fashionable DNA-related reproduction. The structure of enzymes, and their extreme sensitivity to their shape, is not explained by biophysics despite all efforts. No one ever created an enzyme in a test tube. Fission and fusion of large organic molecules are both possible with enzyme catalysis. They are "internal" processes so the reagents to be fused or split become part of another huge protein, the template, during the catalysis.

The same happens with muon-catalyzed fusion, when the muon replaces an orbiting electron, and becomes part of an atom with a deep orbit, which in turn reacts like a neutron. (See Part 4.)

This "quasi-neutron" has also the ability to overcome the Coulomb barrier, thus to participate in a fusion process.

This seems to be the essence of Holmlid's artificial muon generation as well.

Chemical catalysis, on the other hand, is an external catalysis, where a platinum surface or zeolite cavities do not become part of the new molecule. Only their surface potential is used to create a "potential tunnel" fusing two reagents, like hydrogen and oxygen at room temperature. They are not activated by the heat of a chain reaction, or combustion, but sequentially, at modest parameters. This is the essence of catalysis.

There is only indirect evidence that condensed plasmoids catalyze fusion of hydrogen isotopes, and maybe still much heavier ones, like one, two or three helium nuclei, up to carbon, and maybe neon. Anything above it is in doubt, waiting for further verification.

Starting with Tesla and Moray, inventors stumbled onto this chain of events and sweat the details out by trial and error. The evidence for catalytic fusion is indirect, empirical. Excess energy (fusions) was found with transient discharges. Correa and Chernetsky found them with arc discharges, Tesla and Moray found them with corona discharges (microdischarges, brush discharges and streamers).

Shoulders and Matsumoto were the first to recognize that there were traces of condensed plasmoids ingrained into X-ray films (Matsumoto) or thin insulating layers on metal templates (Shoulders), whenever transmutation happened. Still, a number of relevant questions remained open. We list them below with the tentative answers marked with Greek letters (guesses). What we don't know for sure is:

1. What is the "best" material composition of condensed plasmoids? Can they form from hydrogen isotopes alone, or is additional water vapor preferred, or a mixture of heavier gases? Can condensed plasmoids form from metal vapors?
α) Condensed plasmoids can be formed from any plasma mixture including metals. However, only a mixture rich in hydrogen isotopes is preferred for fusion. Note, there is no diagnostic tool yet to study the actual composition of an individual condensed plasmoid.

2. Does the catalysis happen inside or outside of them? It looks like both cases are possible, but this is a difficult question. (It won't be answered for quite some time!)
β) The catalytic capacity is due to their extreme density and electric, magnetic and spin field intensity. It appears on the surface, so a condensed plasmoid moving in hydrogen plasma will catalyze fusion, not fission.

3. What makes condensed plasmoids stable/unstable? (Are

they characterized by black/white states?)
γ) Pearl-shaped or spherical plasmoids are quasi-stable after their formation due to the self-constricting spin fields. They may be stable for a long time, even for months, when there is no external, pulsed electric or magnetic field. Just like nuclei, only quantum fluctuations or ether oscillations may tear them apart. If they are in a hydrogen plasma, and thus catalyze fusion, the locally released energy may break them apart quite soon. The former condition is the invisible, the dominant, or "black" mode; the latter is the active, or "white" mode. It is just like a plant seed: it is in its dark mode, or stealth, without wet soil, but it grows and is active in white mode with warm wet soil.

4. Do they catalyze in their stable state or only in the unstable ones?
δ) They catalyze only when they interact with ionized plasma in a pulsed external electric and/or magnetic field. Therefore repetitive pulsing fields, or acoustic waves, are more favorable than a single powerful pulse.

5. Is their size/mass limited? (What is the lowest and the highest mass?)
ε) All published works on condensed plasmoids were done with exposed films and optical microscopes. Their resolution is limited to the micron sizes. There is no other experimental method providing a better resolution. However, there is no known theoretical upper or lower limit on their size as yet. It is very probable that there is a theoretical lower threshold, minimum mass, during their formation, somewhere around thousands of nuclei in a "pearl." They are invisible to the optical microscope, just like viruses.

6. How do they move on different surfaces and how do they attach to materials with different dielectric, magnetic and chiral properties?
ω) They polarize the plasma and solid materials around them. Shoulders called them feminine, because they are attracted to mirrors due to charge influence, and polarization. There has not been any study on chiral or organic media so far, only on metals.

7. What types of materials do they move along?
κ) They prefer cracks to move on with an electrically insulating surface, according to Shoulders' patent.

8. What sort of external fields do they respond to and in what manner?
μ) External electric fields move them according to Shoulders' patents. They tend to stick together in plane and three-dimensional ball-like formations. Thus their magnetic and spin fields are diminished just like magnetic and electric domains in ferromagnetic and ferroelectric materials. External fields tear apart these structures, making them an active, "white" mode again. Moreover, a single "pearl" may shrink or elongate due to external fields, just like Maxwell's stress in ferromagnetic/ferroelectric materials.

9. How does catalysis take place? (Rephrase of Question 2.)
ϕ) Catalysis is due to the Coulomb shielding, magnetic shielding and spin field shielding. (See Parts 1-3.) The overabundance of electrons in condensed plasmoids compensate for the mutual electrostatic repulsive fields of ions. For heavy ions see Part 3.

10. Do condensed plasmoids and polariton waves help each other?
τ) Surface polaritons move the plasma around condensed plasmoids, intensifying their catalytic action.

11. What is the nature of the catalytic action?
ν) When a condensed plasmoid interacts with hydrogen plasma (a proton cloud), energy is released as thermal energy. Electrons, and maybe some neutrons, are emitted. Most energy is carried off by the emitted electrons due to the high mass of condensed plasmoids. This process makes possible the direct production of electric energy. When a condensed plasmoid meets a neutral hydrogen isotope, it may ionize it due to its "hot" temperature. Thus higher partial hydrogen pressures are more economic. The condensed plasmoids do behave as classical objects, and also as macroscopic quantum objects, as a sort of collective behavior—like ferromagnetism.

There exist only circumstantial evidences for any of the above answers, that is, more or less guesswork. Nevertheless, they may be closer to the truth than contemporary physicists know about the structure of nucleus.

It is the common feature of the patents listed in Table 1 that they make no sense at all based on textbook physics. According to textbook physics, sparking is definitely a dissipative process, and there is no way to gain energy from it. However, the micro-discharges and hydrogen gas is always there if it is noted. So an unknown process must appear!

This is the reason for the first four parts to have been devoted to extend the background physics.

There is a further common feature of the inventions: they do not produce heat, rather other energy forms: chemical (oxygas), mechanical (shock waves by burning oxygas) or electric energy, the most useful form of energy. (In Part 6, anti-gravity will be added to this list.)

In the rest of the reactors, when electric energy is extracted from the device, two types of mechanisms may appear:

1) Electrons are emitted from the cathode covered by condensed plasmoids heated by the fusion energy. They are captured by an anode with a high electric potential slowing them, and turn this kinetic energy into potential energy. (It is no small feat!)
2) Collective oscillations of the cathode surface charges release only one high energy electron. This effect was suggested as a multibody effect by A. C. Zuppero and T. J. Dolan. It has solid experimental backing found in chemistry.[30]

Before we discuss the row of micro-discharge and plasmon based inventions of Table 1, the important properties of condensed plasmoids will be finalized. As they are formed from micro-discharges (discussed in Parts 1 and 2, and earlier herein) their main shortage is that they never mention the possible generation of plasmons and condensed plasmoids, thus casting doubt about their reality. (See the textbook *Non-equilibrium Air Plasmas at Atmospheric Pressure*[26,pp23,42,47,289] and also *Physical Chemistry of the Barrier Discharge*.[31,pp25,27,29]) The scope of these investigations was never extended to hydrogen, and no transmutation traces were sought with emission spectroscopy, like Collie *et al.* in the 1910s.

The nature of condensed plasmoids was explored in the West by Shoulders and Matsumoto and Mesyats in Russia. Even they were unaware of each others' work but came roughly to the same conclusions in the 1980s and 1990s.

There is another misleading set of observations. Condensed plasmoids usually appear as "beads" in a chain, most frequently in a 1-200 μm diameter ring chain. It is assumed taciturnly that these rings are condensed plasmoids. It seems that the toroidal form described in Part 1 is further constricted into a string of beads during its formation. The micro-discharges have enough charge density and a steep rise time to form Helmholtz-type charge vortexes at first, then (probably due to torsion fields and spin fields) they are constricted further to a loose chain, as shown in Figure 7d. These objects leave a ring-shaped trace on dielectric films, as seen by Shoulders, Matsumoto, and later Savvatimova, Urutskoev, Lewis, Daviau, Priem, Racineux, etc. The circular chain shown in Figure 7a1 is formed when the pearls attract each other. The electric field of the spherical plasmoids repel each other, but the stronger magnetic fields keep them together in a flexible chain, shown in Figure 7a2. This chain can even be open!

The ring trace is not always circular, but sometimes made by smaller rings of a less regular shape. They are attached to each other. (See Figure 7b.) These objects may roll along cracks and grooves, probably due to external electric and magnetic fields.

Matsumoto assumed that these objects may assemble themselves into semi-spherical objects. A possible shape is shown in Figure 7c, as suggested by Matsumoto.

As these objects move/roll along dielectrics, it is clear that they have net electric charge of the same sign. The fact that their preferred form is a ring also points to it, due to their mutual repulsion.

However, there must be some mutual attraction as well, to hold the chain together, otherwise it would fly apart. This is ostensibly magnetic attraction, either as magnetic dipoles or monopoles suggested by Daviau and Kovács, discussed in Part 1.

Why is this of interest? They may be the much sought-after fusion catalysts for LENR, acting like a high mass, charged muon or pion. The Coulomb shielding and spin field shielding is created by these rotating quasi-particles of surprising stability. The detailed process of LENR catalysis is murky at best (discussed in the Introduction of Part 5A). It looks as though it is able to catalyze even ordinary hydrogen into deuterium, tritium or helium.

There is no direct straightforward observation of this catalysis (which is technically hopeless), but the indirect evidence is overwhelming, as seen from the inventions to be discussed. The catalysis of heavy nuclei is doubtful though—for that purpose dust fusion is the viable option.

It is highly probable that catalysis is the best when the "beads" are alone, far from each other. This may be the catalytic white mode, when the external fields are also changing. When they are stuck to each other into any large-sized (several μm) open or closed chain, they shield each others' fields. This hampers their catalytic capability. This is ostensibly the black mode. External electromagnetic fields and plasma, however, may tear them apart, thus reentering into the white mode.

The marks and the traces of the chains are visible even on metals and on dielectrics, preferably in polarized light at an angle around 45°.

Matsumoto noted and published photographs about the breakup of these chains. There are traces of 6- and 4-fold star-shaped paths of diverging pearls leaving a track on photosensitive films. (See Figures 6a-c.)

Shoulders published photographs of condensed plasmoids penetrating thin metal plates, while boring a hole through them, and transmuting their materials.[11]

There is still much to be learned in this area as discussed in the Introduction (see Part 5A). These "beads," or spherical condensed plasmoids, can't be stable forever with their 1 μm size. They are much bigger then atoms, or even protein molecules, yet they seem to obey both macroscopic and quantum mechanical behaviors. A pioneering effect was made by Lutz Jaitner, mentioned in Part 1. He assumed a self-constricted, self-winding superdense string caused their stability. The condensed plasmoids, however, seem rather like a string of individual spherical beads. Readers are encouraged to read Jaitner's review of condensed plasmoids.[32] In our view, the comprehensive collection of inventions pinpoints to a much lower parameter range of a condensed plasmoid formation. It seems that nanoCoulombs are enough to form them, though also in the micro- or pico-second time frame. The other different opinion is (in my own argument) that the formation of condensed plasmoids is beyond textbook physics. No theoretical model attempted to describe them in this form. However, the work of John Wallace on quantum mechanics seems to offer a plausible solution in the long term, by the extension of quantum mechanics to microscopic realm.

After the discussion of these common features listed in Table 1, the individual reactor solutions will be listed. The above-mentioned sequence of events is the most important conclusion of this study. Note that most of the know-how, and individual technical parameters, were lost by the death of the inventors. Now we will begin to look closer at the inventions noted in Table 1. (In this part, we shall discuss Tesla. Other inventors will be discussed in Part 5C, scheduled for Issue 158.)

1. Nikola Tesla

The catalytic fusion-related results are the least known area of Tesla's work. His achievements in AC motors and generators are widely known. The results of his longitudinal wave radio emitters and receivers are mostly forgotten, or ignored, but not denied. He was a century ahead of us: transmutation/electricity generation, and a LENR driven car (the Pierce Arrow demo in Buffalo in the 1930s). This is strictly denied, or ignored today.

However, readers are familiar with his streamer related, well-publicized work. His Colorado Springs Laboratory produced spectacular large streamers. He demonstrated several streamer-related experiments in his lecture tours. (See Figures 10a and 10b.)

For this reason, I doubt that the innovative energy company TESLA will ever reach the sophistication of Nikola Tesla, the innovative engineer. TESLA badly needs Tesla's results, because even the best battery can't match onboard electricity generation. Such a car may supply the electric energy to a home or to the grid when the electric motor is idle, not in use. Until then, we have TESLA without Tesla.

Very few technical details about his inventions were left in the public domain. However, what little we still have is enough to suspect, in my opinion, that he really did it.

Six of his discharge tubes out of more than a hundred are shown in Figure 11, preserved in very poor quality photographs in *Nikola Tesla on His Work with Alternating Currents and Their Application to Wireless Telegraphy, Telephony and Transmission of Power*.[33] All these discharge tubes were made prior to his longitudinal wave transmitters and receivers in 1890. About half of these photographs are so opaque that no minor details are preserved, just the layout. (I still recommend readers find a copy.)

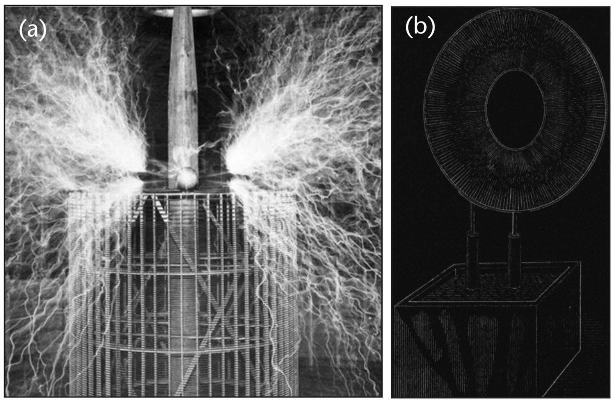


Figure 10. Tesla mastered the art of pulsed spark generation, small and large (not yet micro-discharges). (a) Streamers from a magnifying, resonant transformer in Colorado Springs, 1890s. (b) Streamers from a table top high frequency device from Tesla's London demonstration. He also observed that a permanent magnet rotated the streamers. He suspected the magnetic features of the streamer rays.

Note that Tesla's biographers miss most of his work done after about 1910, because the results are outside of the range of recent textbook physics. Monographs devoted to non-equilibrium plasma (corona, barrier discharge) omit his research altogether, despite the detailed description and figures, and photographs of corona discharges, especially at Colorado Springs. After reading all historical reviews on corona discharge, I found no reference at all to his copious amount of published work. Only minor, far less detailed works of contemporaries (Siemens) are mentioned. He was indeed erased from science history books due to his "heretical" views.

Needless to say, his work on transmutation-related electric energy generation is completely omitted, and ignored. His technical skills were superior to those of Collie *et al.*, who did publish reliable transmutations in hydrogen in the *Proceedings of the Royal Society*.

Nobel laureate physicists, such as Feynman, Thorne, Weinberg and Penrose, are completely ignorant of his experimental results, as mentioned in Part 4. Tesla is completely erased from contemporary physics due to his firm stand on the reality of ether, and transmutation.

So what follows is "crypto" engineering in the same sense as cryptozoology and cryptobotany is used. This involves learning engineering from fossils. His experimental work on high frequency, high voltage power supplies is described in the book Nikola Tesla Colorado Springs Notes 1899-1900. The extensive experimental work on high voltage, high frequency micro-discharges are detailed in his book *The Inventions, Researches and Writings of Nikola Tesla*, as a collection of demonstrations.[34] (See Part 1). He had hands-on experience with brush discharges with "single wire" polarization current experiments. He demonstrated it in London, Philadelphia and St. Louis in 1893, so the effects of condensed plasmoids were evident for him.

Only six tubes have been selected to explain how he might have accomplished the generation of excess electric energy. Obviously all such arguments are speculative, based solely on the author's own laboratory experience.

In Part 1, the carbon button lamp has been shown as a discharge tube with an irreducible simplicity, to produce a corona discharge of 50-100 kV around the spherical SiC cathode. The anode is at the ground potential, and thus a glass barrier discharge is used. Tesla noted that the cathode surface was "broken" after awhile. Therefore the initial breakdown voltage was lower and lower in the next experiments, and this "crater surface" feature was preserved.

There can be two possible reasons for the gradual decrease of breakdown voltage:

1. There were sharp edges and craters created on the cathode surface, thus a lower potential was enough to create the breakdown electric field.
2. The accumulation of condensed plasmoids on and beneath the cathode surface.

By investigating different cathode diameters, Figures 11a and 11b, the effect of current density was clear at a given pressure and gas. Thus the relations between the higher cur-

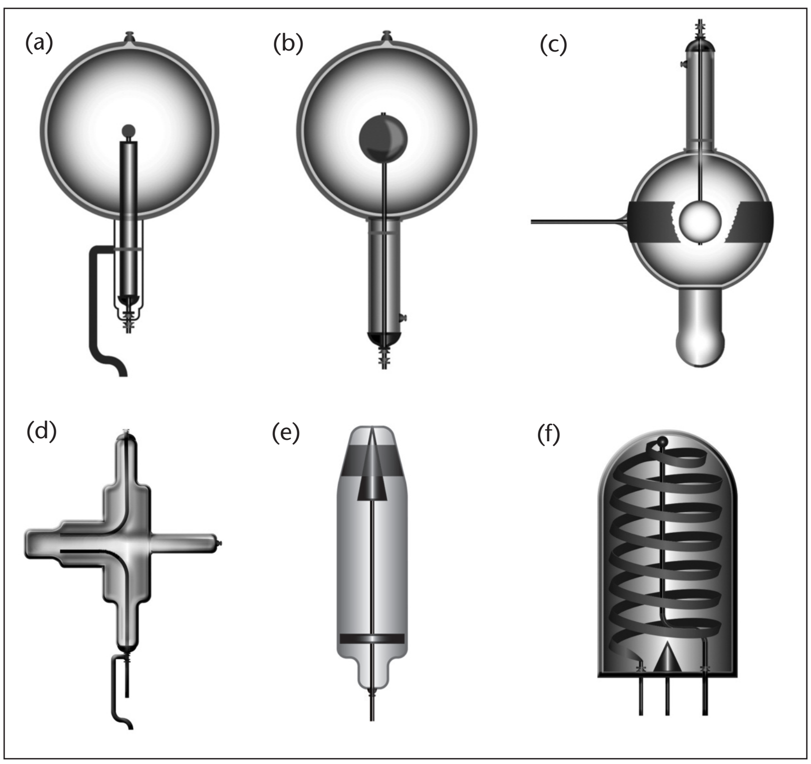


Figure 11. Six discharge tubes Tesla made before 1890. Each of them are suitable for micro-discharge generation. See text for details.

rent density, a rough surface, and a higher output (luminosity, and heat) might have been established. This is for a spherically symmetric discharge.

The next step might have been to reduce the symmetry of the electric field by adding a belt-like anode (Figure 11c).

It is not clear whether the belt electrode was inside the glass sphere (then a corona discharge is at ~50 kV), or outside of it (then barrier discharge is at about 100-200 kV). By adding a tangential, transient electric field component, the movement of condensed plasmoids was noted—in an asymmetric field.

Given the same input energy, the belt-shaped anode showed an improvement in the output. (The belt is broken in Figure 11c to show the spherical cathode under it.)

It was clear by now for Tesla that asymmetric electric fields are useful. Therefore he tested a number of geometric configurations. Only one of them is shown in Figure 11d, where the discharge commences somewhere between the L-shaped electrodes. Note: It is not necessarily at the shortest gap! Corona discharges, positive and negative ones, are asymmetric for DC, AC and pulsed glows. Corona discharges are fundamentally different from steady-state glow discharges, because the inductive terms (Part 1) allow for the formation of plasmoids.

Tesla must have noted the importance of cathode roughness and sharp edges during these studies. A conical cathode discharge tube, one of several similar tubes, is shown in Figure 11e. Thus he might have noticed that charge waves/condensed plasmoids may form, based on the lower power demand of these tubes. This effect was rediscovered over and over, for example by Papp and Shoulders, the Testatika, etc.

Finally, the benefits of rotary discharges appeared on the tubes shown in Figure 11f, again with a conical cathode. When the anode is a spiral-shaped ribbon, and the discharge itself rotates, there is a periodic corona or spark discharge with spin field generation.

Though the above-mentioned sequence of events is highly speculative, this seems to be logical. For example, the coil-shaped anode induces a rapid change in the magnetic field around the discharge in Figure 11f. Thus again the induction term of S(t) spin field appears (analogous to the previously discussed transient electric field). That is, $\mathrm{rot}\, S(t) \approx \partial E/\partial t + \partial B/\partial t$. With a spiral anode, both E(t) electric field and B(t) induction fields contribute to the appearance of a spin vortex field. In turn, this rotates condensed plasmoids, which catalyze LENR. It seems that condensed plasmoids have a negligible catalytic reaction rate without external, increasing electric and magnetic fields. There are externally wound solenoids around the discharge tube in most inventions in Table 1. This may be the reason that inventors suspected a benefit in trying them. In Figure 11f, it is indeed speculative to assume that Tesla found the beneficial excess catalytic fusion effect of this tube. (Readers are encouraged to build and test these tubes to verify or falsify the above hunches.) Nevertheless, the recurrence of the external solenoid seems to support the importance of rotary spin field induction. (See Part 1 for details.)

The scope of Tesla's experimental investigation, and the depth of insight gained by these early tubes, is breathtaking, considering the next 120 years of gas discharge research. Most of these later investigations were restricted to the narrow area of parallel or coaxial electrodes, DC or low frequency AC.

It is crystal clear that Tesla was way ahead about the comprehension of physical effects of nature not only of his contemporaries, but even of today's top notch "star" physicists, who openly frown at and detest laboratory research. While useful physics was of primary importance for Tesla, the opposite is true today. We do not know what happened with the Pierce Arrow company that wanted to mass produce the car driven with a fusion reactor. The tragedy of his contemporary, Henry Moray, a forgotten inventor today, gives us a clear idea.

Readers are encouraged to read detailed gas discharge monographs and journals. They will not find studies on highly asymmetric non-equilibrium transient discharges (especially if it is dusty plasma).

The scope of plasma research has never reached the careful study of cathode morphology and condensed plasmoids. Local transmutations were not investigated. This narrow-mindedness (strive for mathematical modeling at the expense of understanding nature) is quite visible with the negligence of Tesla's work, and worshiping Einstein, whose results are not related to any useful effect.

This study is a confrontation between the conservative and reactionary approach when discussing the results of a revolutionary: Tesla.

Contemporary science is reactionary, simply denying and banning important past results. This paper is about the conservationist view: let's try to conserve important insights of the past!

It is not known what happened with Tesla's research after 1890, when the photographs in Reference 34 were taken—part of a legal process against the foreclosure of the Wardenclyffe plant on Long Island, New York.

What were the plasma diagnostic tools available for Tesla and his contemporaries? Spark gaps for voltage measurements, and optical prisms for emission spectroscopy—to find transmutation, when a new element appears. (These were the tools for Collie in 1914, when they published their landmark results of transmutations in transient hydrogen plasma.)

Power output was measured by taking the change of resistance of a nearby hot wire. This can be calibrated accurately by a known power source.

Crude they are, but simple and useful. Note that nitrogen was the available inert gas in the 1890s. It was always diluted by water vapor, by diffusion through the simple borosilicate glass of those days. Today no one reads papers written even 50-60 years ago, at our peril. Those very early results of the 1890s by Tesla were full of insight, and originality. I leave it to the reader to find out whether Tesla made the Pierce Arrow with an onboard fusion reactor, but we shall see that it was certainly possible. Will TESLA ever be up to Tesla?

The TESLA company was able to think "outside of the box" of internal combustion engine technology. Is it also able to think "outside of the box" of textbook physics? I don't know the answer, but I am very skeptical about it.

[The remaining inventors and excess energy generation methods noted in Table 1 will be discussed in Part 5C, scheduled for Issue 157.]

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