Background on the DHT Energy Corp. Hydrogen Production Invention

Dr. David J. Nagel

20240110

Introduction. The patent currently being sought by DHT Energy Corp. is aimed at improving the electrical efficiency, and hence, lowering the costs of hydrogen production by electrolysis. This document provides additional information on the features and advances in the DHT invention. It is organized along the lines of the block diagram of the DHT invention, as shown in Figure 1.

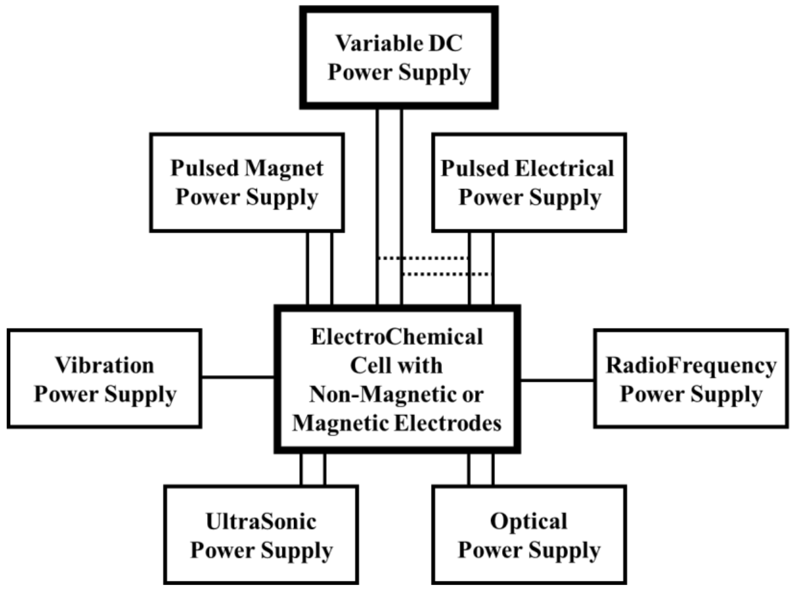

Figure 1. Block diagram of the DHT Energy system showing the components and connections for the basic electrolysis cell and various excitations.

Magnetic Electrodes. The invention contains two major types of advances in electrolyzer design. The first is the optional use of magnetic electrodes. It is not known yet if employment of such electrodes will produce construction and efficiency improvements that will offset the somewhat increased costs of making such electrodes. Magnetic electrodes offer the possibility of beneficially orienting the molecules in catalyst particles on their surfaces. They also offer a strong potential advantage in being able to hold magnetic catalysts in place during operation, and enabling easy replacement of them if and when they age to become less effective. The performance and economics of magnetic electrodes are being determined in a series of experiments by ICIQ in Tarragona, Spain, under a contract with DHT Energy Corp.

DC Variations. The second improvement in the DHT patent is the employment of various additional excitations to the cells in which electrolysis and hydrogen production occur. They fall into two categories. The first is creative use of the necessary Direct Current (DC) power that must be supplied to any electrochemical call to make it split water into hydrogen and oxygen. We envision of the use of variable DC excitations (voltages and currents) in order to improve the rate of hydrogen production, and reduce the amount of required input energy (and associated cost).

Additional Excitations. The other excitations that are claimed in the DHT patent application involve the applications of various types of excitation energies to the electrolysis cell. Each of them involves four components: (a) a power supply of some type, (b) an actuator or source to generate the kind of desired excitation, (c) means to controllably modulate the time history of the excitation ranging from steadily constant or oscillating to variable to pulsed intensities of any physically-realizable characteristics, and (d) some means of coupling the produced excitation into the electrolysis cell. The six types of excitations shown in the figure will be discussed in a clockwise sequence, stating with pulsed electrical stimulation.

- The first of the additional excitations, which is closely related to the basic electrochemical power supply, involves the application of electronic pulses in addition to the DC voltages and currents from the fundamental electrolysis power supply. The pulses can vary widely in their time history, from nearly constant waveforms with shallow modulation to fully modulated (ON/OFF) pulses. A Google search using the phrase "pulsed electrolysis of water" produces 3.0 million results. One of them is a Wikipedia article[1]. Another involves the use of both high and pulsed voltages[2]. Hence, it is clear that pulsed electrolysis has been widely explored, and has produced beneficial improvements in electrolytic hydrogen production. However, the synergism of pulsed electrolysis with the other excitation modalities remains to be explored. Again, the tests at ICIQ in Spain will address that potential.

- The second type of excitation in the DHT Energy patent involves the application of radio frequencies to the electrolysis cell, either as electrical signals or electromagnetic waves. Google search using the following phrase produced 2.4 million hits: "RF effects on electrolysis of water". One of them illustrates the efficacy of RF excitations for electrolysis[3]. That website states: "Water dissociation with RF (radio frequency) waves is a method of breaking down water molecules into hydrogen and oxygen gas using radio frequency energy. This process is similar to water electrolysis, but instead of using an electric current, it uses RF waves to excite the water molecules and cause them to split apart. This method is often used in industrial applications, as it can be more efficient and cost-effective than traditional electrolysis methods." A Ph.D. thesis from 2021 explored the benefits of RF excitation of water electrolysis[4]. It is entitled "Alkaline water electrolysis enhanced by radio frequency alternating magnetic field". That is, it is seen to involve two of the types of excitations considered in the DHT Energy invention. The synergy of such excitations, and the others in the invention will be explored by ICIQ in the coming months.

It is known that the application of specific RF frequencies can have large effects on electrolytic Low Energy Nuclear Reaction (LENR) experiments. Those experiments involve the production of deuterons from heavy water by electrolysis, and then subsequent nuclear reactions of the deuterons. One example of the impact of RF energy on a LENR experiment is given in Figure 2[5].

---

[1] https://en.wikipedia.org/wiki/Pulse_electrolysis
[2] https://www.mdpi.com/1424-8220/23/8/3820
[3] https://www.physicsforums.com/threads/water-electrolysis-and-water-dissociation-with-rf-waves.261317/
[4] https://theses.hal.science/tel-03628368/
[5] J. O'M. Bockris *et al*., "Triggering of Heat and Sub-Surface Changes in Pd-D System," Transactions of Fusion Technology, vol. 26, pp. 267-290 (1994)

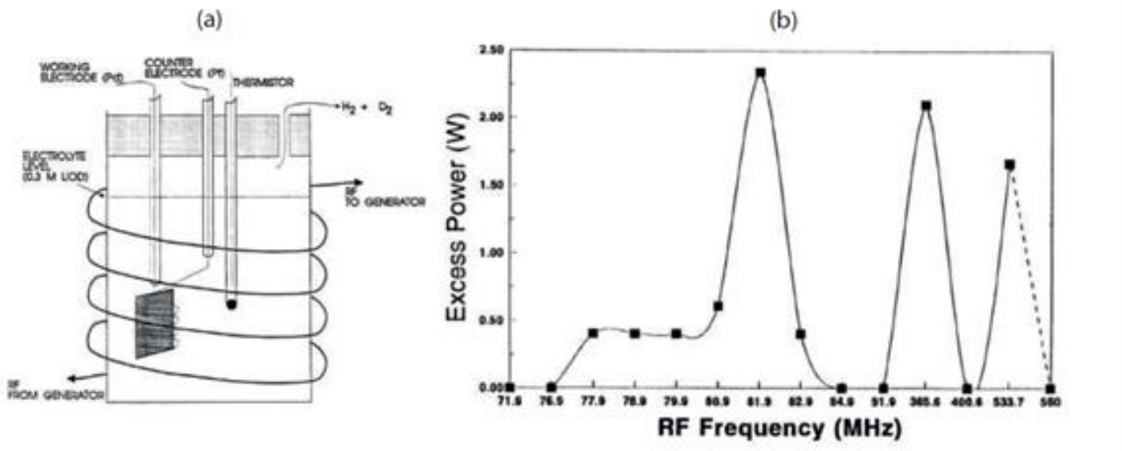

Figure 2. Left: The experimental setup in which a coil encircled the LENR electrochemical cell. Right: Variations in the excess power as the excitation frequency was tuned.

It shows on the left a schematic of the experimental electrochemical cell surrounded by a coil to introduce RF frequencies into the cell. The variations in the produced nuclear power are in the graph on the right. The RF excitation might influence either or both the electrolysis and nuclear reaction rates. The ICIQ experiments should help separate the two effects.

▪ The third kind of excitation in the DHT Energy invention is light in and near the visible region of the electromagnetic spectrum. That excitation has been widely explored for two reasons. For one, such light brings significant energy into the electrolysis cell, which beneficially promotes water splitting. Photons in the visible region of the spectrum carry from 2 to 2.75 electron volts (eV) each, that is, energies that are on the same scale as the energy needed to split water. Secondly, light energy is readily available from the sun, so the addition of optical radiation to electrochemical cells can be done without an additional power supply or source. This is the only one of the six excitations in the DHT Energy invention that does not require a power supply and source.

Because of these features, simultaneous optical excitation of water electrolysis cells has been widely studies. That field is termed "PhotoElectroChemistry" or PEC. A google search on the full term returned 0.5 million results. One of them is another Wikipedia article[6]. A website of the US. Department of Energy is devoted to PEC water splitting[7]. Many of the PEC studies involved the use of diverse catalysts. A recent article by Backranova and Nagel with 124 references reviewed the use of zinc oxide (ZnO) as a catalyst for PEC: "ZnO for Photoelectrochemical Hydrogen Generation"[8]. As with the other excitations in the DHT Energy invention, beneficial interactions between PEC and the other five techniques will be explored in the Spanish experiments.

▪ Ultrasonic excitations with frequencies greater than 20 kHz constitute the fourth type of excitation in the invention. Searching Google with the phrase "ultrasound and electrolysis" yielded 1.2 million results. One of them is a 2009 article with the title "Water electrolysis in the presence

---

[6] https://en.wikipedia.org/wiki/Photoelectrochemistry
[7] https://www.energy.gov/eere/fuelcells/hydrogen-production-photoelectrochemical-water-splitting
[8] https://www.mdpi.com/2571-8797/5/4/63

of an ultrasonic field"[9]. It already has over 150 citations, a favorable measure of activity in the field. Again, ICIQ is exploring the synergy of the use of ultrasonic excitation of electrolysis cells in tandem with each of the other excitations.

- The fifth type of excitation is conceptually related to the use of ultrasound. Both involve mechanical vibrations, but at different frequencies and for different purposes. The vibrations of interest in the DHT Energy invention are designed to shake bubbles off of electrode surfaces. While a bubble of hydrogen or oxygen grows on the surface of an electrode, it prevents part of the electrode from participating in electrolysis. That can reduce the effective electrode area and, with it, the electrolysis efficiency. The vibratory excitation is applied to shake bubbles from electrodes when they are smaller, leading to a larger average effective electrode area.

A Google search using the terms "water electrolysis with vibrations" gave 5.7 million results. One of them is an Australian report on the efficacy of vibrations on electrolysis efficiency. An article[10] on the paper stated "……the invention uses high-frequency vibrations to split water molecules by using electrolysis to release 14 times more hydrogen compared with standard techniques." The magnitude of that improvement is surprising. Nevertheless, the use of vibrations appears to be strongly favorable, and its synergism with the other excitations will be a major part of the experimental explorations at ICIQ.

- The sixth kind of excitation that is part of the DHT Energy invention involves the application of pulsed magnetic fields to the electrodes in the cells. They can be used with either non-magnetic or magnetic electrodes. Those fields can be made to originate from within or outside of the cell, depending on the construction of the system. Like the electrical pulses, the magnetic pulses can vary widely in their time history, from nearly constant waveforms with shallow modulation to fully modulated (ON/OFF) pulses. That is, the invention includes both essentially constant magnetic fields as well as strongly pulsed magnetic fields with diverse time histories.

A Google search with the phrase "electrolysis with magnetic fields" produced 4.8 million hits. Some of the results are directly applicable to part of the DHT Energy invention. Two examples are (a) a 2022 paper entitled "Studying the Effect of Electrode Material and Magnetic Field on Hydrogen Production Efficiency"[11], and (b) the 2007 paper "Water Electrolysis under a Magnetic Field"[12]. The second paper stated "The energy efficiency of water electrolysis was considerably improved under a high magnetic field. A large reduction in the cell voltage was achieved in a magnetic field, especially at a high current density." More reasons for interest in magnetic fields comes from another LENR study.

Chubb and Letts found that the rate of nuclear energy production depended on the application and orientation of steady (permanent magnet) fields to electrochemical cells[13]. Figure 3 gives their

[9] https://www.sciencedirect.com/science/article/abs/pii/S0013468609002254
[10] https://www.awa.asn.au/resources/latest-news/vibrations-turbo-charge-green-hydrogen-production
[11] https://www.mdpi.com/2312-7481/8/5/53
[12] https://iopscience.iop.org/article/10.1149/1.2742807
[13] S. R. Chubb and D. Letts, "Magnetic Field Triggering of Excess Power in Deuterated Palladium," Infinite Energy, Issue 95, pp. 40-54 (2011)

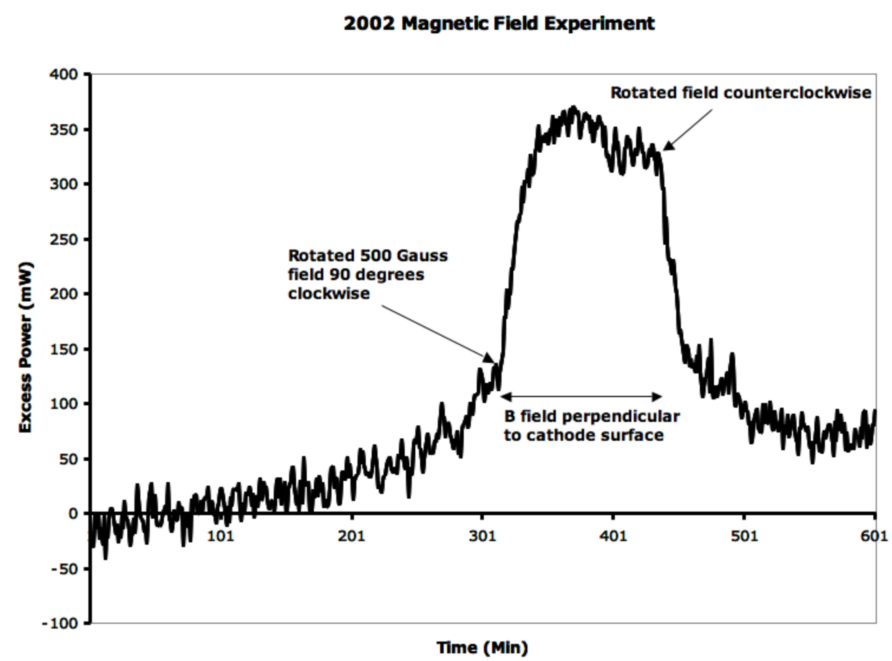

Figure 3. Dependence of the LENR power on the orientation of the magnetic field from a permanent magnet relative to the plane of a palladium cathode foil.

data. It is not known yet if the improvement with rotation of the magnetic field relative to the planar cathode surface was an electrolysis effect or a nuclear effect. However, the ICIQ experiments are expect to resolve that question.

Conclusion. The paragraphs above show that there are strong experimental reasons to consider the additional excitations shown in Figure 1. Each of them can produce beneficial effects of experiments involving electrolytic splitting of water to produce hydrogen. It remains to be determined in the coming year how the separate excitations reinforce each other, and the quantitative payoff in terms of hydrogen efficiency increase and associated cost reduction.

We can liken each of the excitations considered above to a section of an orchestra. By themselves, each section can make pleasing music. However, in combinations, the music is more varied and richer. DHT Energy will determine and commercialize whichever of the combinations for hydrogen production is most melodious, that is, most profitable.