Pulse-Controlled LENR - The Technology of Magnetic Miles LLC

An Interim Report

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Abstract

LENR (low energy nuclear reaction) is the fusion of two or more atomic nuclei at temperatures and pressures significantly below that needed to achieve hot fusion. The table below summarizes the expected behavior of any LENR apparatus that utilizes an electrical discharge in water, air, or other environment to initiate the reaction. The experimental results obtained for the Magnetic Miles apparatus are listed for comparison.

Anomalous Behavior	**Expected LENR Behavior**	**Magnetic Miles Apparatus**
Excess heat	Up to 300% of applied energy	250% of applied energy
Excess electrical energy	Speculative	30% of applied energy
Production of excess hydrogen	Up to eight times expected amounts	Unknown
Production of neutrons or γ rays	Anecdotal–E-Cat up to 300 keV x-rays Laboratory experiments at 3 keV bursts	High intensity γ bursts detected at 60 times background levels
Transmutation of electrode elements	One or two atomic number higher or lower	Unknown

Although more study is needed for final confirmation, it would appear that the excess electrical energy produced in the apparatus is a result of thermionic emission from the cathode, and the excess heat is a result of a low energy nuclear reaction.

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I. LENR Science and Technology - A Quick Review

LENR (low energy nuclear reaction) is the transmutation of one element into another using low energy impacting particles. Besides energy production, its use has been proposed for the transmutation of radioactive waste into non-threatening materials [Vasperman, 2004].

To put LENR into historical perspective, consider first, the hot nuclear fusion process. In its simplest form, hot fusion is a deuterium-deuterium fusion yielding helium three plus a neutron. The hydrogen bomb and the fusion reaction in the stars including our own sun are examples of uncontrolled and controlled fusion reactions. Controlled fusion requires the product of the plasma density, the temperature and the time be greater than 3×10^{21} KeV sec/m^3. This is known as the Lawson criteria which has yet to be achieved in any significant manner in the laboratory, although multiple billions of dollars have been spent over the past fifty years or more to do so.

In the early 1970's, plasma physics focused on the pinch effect as one of the mechanisms proposed for achieving a controlled hot fusion reaction. Basically it consisted of running a high current along a plasma column with the result being a self-generated magnetic field that compressed the plasma down to a very narrow filament. It was dense and hot; if it could only last a little while. It turned out to be a very unstable state lasting just micro-seconds even with external stabilizing magnetic fields applied. The toroidal shape came along about 25 years later with somewhat greater success. The tokomak device is a result of this early work and is one of the possibilities for success for this technology. Commercialization however is not eminent.

A. Non-Pulsed LENR

The first team to achieve a low energy nuclear reaction is often cited as Ponce and Fleishman [Pons, 1989] in 1989. But in reality the transmutation of matter, goes back many centuries to the time of the Alchemists (of which Isaac Newton was one) and the "philosophers stone". This piece of rock supposedly transformed a base metal such as mercury, into a precious metal such as gold.

One of the twentieth century's earliest tudents of LENR was Philo T. Farnsworth who developed the famed "Fusor" device [Vasilatos, 1997]. Having developed the cathode ray tube for television, Farnsworth used the concept to create a bench scale linear accelerator for accelerating and impacting particles on a target. This technology is still being explored as a confinement technique for hot fusion.

In 1989, Ponce and Fleishman, [Pons, 1989] working with deuterium in heavy water and palladium electrodes in an electrolytic cell, achieved more energy output in the form of heat than what was put into the cell. It wasn't a chemical reaction because the energy densities were much too high. They released news of the discovery at a press conference in March of 1989 at the University of Utah in Salt Lake City, coinciding with the release of their paper in the prestigious Journal of Electrochemistry. Pons and Fleishmann concluded that they had discovered a new form of nuclear reaction and coined the term “Cold Fusion”. There was an immediate uproar, with over 800 replications being attempted at various university and other organizations worldwide. Replication was a disaster with researchers claiming everything from nil results to destructive explosions. In the end it was concluded that the experiment itself was anomalous and not repeatable.

The proposed reaction was that heavy water was separated into oxygen and heavy hydrogen (deuterium) by electrolysis, the latter of which was then fused into a helium in a palladium lattice. Over the past twenty-five years many mechanisms have been proposed for this reaction without any all-encompassing success. Pons and Fleishmann left the US in disgrace and moved to southern France to further their research (funded by Japan). Research continued however, mostly in corporate Japan, with publications presented at mini-conferences and web-published or published in small esoteric journals with limited audiences. Cold Fusion has over the years has become known as LENR which usually stands for low energy nuclear reactions, but can mean lattice enhanced nuclear reactions depending on the situation.

Since 1989 there have been more that 1500 demonstrations of LENR reactions. They fit for the most part into the categories listed in the table below. This list could certainly be extended to include the more exotic forms of LENR such as acoustic resonance, laser resonance, etc. but for the purposes of this review, this is not necessary. There is overlap in some of the ad-hoc categories in this table. For example, the electrolytic cell may have micro-discharges of an electrical nature occurring at charge concentration sites on the nickel or palladium electrodes creating localized plasma conditions. Again, such distinctions are not relevant at this level of review. These devices have demonstrated excess thermal energy and excess hydrogen generation over conventional predictions. The anomalous generation of electricity is getting some discussion [Rossi, 2016], [Karabut, 2004] but definitive results are limited.

Type of Reaction Cell	**Reaction Components**	**Energy Output**	**Scalability**
Liquid-Electrolytic	Deuterium-metal	Hot Water	unknown
Liquid-Electrolytic	Hydrogen-metal	Hot Water	unknown
Solid / gaseous (E-CAT)	Nickel-Lithium-Hydrogen	Dry heat	Utility/Local
Plasma-aqueous	Electric discharge	Hot Water/ Steam	Utility/Local

A limited examination of the various cell types suggest that the plasma and solid types of reactions offer the best approach for commercialization based on scalability to useable energy levels. It is not known if the anomalous production of hydrogen associated with the electrolytic and electric discharge processes, scales to industrial levels. Its overall use however, other than as a local source of hot water is unknown. The solid-gaseous reactor, typified by the E-CAT device [Fogarti, 2010], has the material initially in solid form, but with the application of heat, becomes a mixture of solid, liquid, and gas. Currentrly, heat is the only energy output from this type of device, but unsubstantiated claims [Sharma, 2016] are made suggesting that there is significant electrical output. This device is targeted to be a direct replacement for fossil fuel sources of energy where heat is used to drive steam turbines, etc., a utility level of application. It could also be coupled to a thermo-photovoltaic device for electrical generation at the local level. The electric discharge process, though not necessarily aqueous, has heat and/or steam as an output. For the aqueous device, this limits its application to utility installations where steam driven turbines, etc. are the major energy conversion devices. It may be possible to couple this class of device to thermo-photovoltaic convertors for use at the local level, but temperatures for this to be feasible, have yet to be demonstrated. Of the types of LENR listed in the above table, only the last two will be discussed from this point on. The dry gas reaction of the E-Cat device, is in the process of commercialization. The technology of Magnetic Miles LLC fits into the last category of the table above, and is at the demonstration or feasibility stage. The other processes listed above have been reviewed extensively elsewhere [Pickens, 2016].

Little attention has been given to the LENR process by mainstream academia. Most published work is generated by corporate or military scientists and backyard enthusiasts where reputations are perhaps a little harder to tarnish. According to Wikipedia, cold fusion remains "a hypothetical type of nuclear reaction that would occur at, or near, room temperature, ... There is currently no accepted theoretical model which would allow cold fusion to occur" … In 2014, the DOE introduced a funding program for demonstrations of economically disruptive energy technologies, with LENR a distinct category for funding. University activity is slowly picking up.

Nickel, Lithium, Hydrogen in a Low-temperature Plasma or Gas

Efforts are underway to commercialize the dry/solid LENR process as a stand-alone power generation device - the E-Cat device [Rossi, 2015]. The technology is based on the transmutation of one nickel isotope to another with the resulting excess energy being released as heat in excess by what could be expected from chemistry. Recently Rossi sold/licensed the technology to a North Carolina company, and together with an Italian company and some leading US universities are refining and testing the device on the path to commercialization. Also recently, a team of Norwegian scientists have inspected a one megawatt power plant based on Rossi's technology and confirmed that it is working as claimed [Norway, 2015].

The E-Cat device is a utility level, heat generator that if successful will be a "bolt-in" replacement for fossil fuel and nuclear heat sources in use today. A one megawatt generator, for example, is claimed to have the following characteristics

- Fuel Cost $1/MWhr (0.11 cent/kWhr)
- Recharge frequency: twice per year
- Estimated lifespan: 30 years
- Energy output comparison (100 000 x oil)
- Estimated energy reserves (10 billion years)

This makes the device competitive with existing technology, besides being clean, and green. The waste product is a non-radioactive isotope of the fuel which can be used in applications where the fuel is currently being used. The reactor consists of a series of ceramic tubes, each containing a fixed fuel charge. The fuel, a Nickel-Hydrogen-Lithium powder is gradually heated to 1350 ^{o}C in small increments. When the reaction is running, the output heat from the reactor is significantly greater than the input energy with a coefficient of performance of about than 3.6. The device puts out more power per kilogram than all conventional sources, including standard fission type nuclear reactors.

The fuel for the E-Cat device is a dry powder mixture of nickel, aluminum-lithium-hydride plus some additives. The nickel powder has an average particle size of a few microns and represents about 90% of the fuel's weight. It is not known if the particles have been treated to change the surface structure. When the power is turned on in the reactor, the fuel begins to heat. At about 150 ^{o}C the Li Al H_4 begins to melt and release hydrogen. By 400 ^{o}C, the hydrogen has totally been released leaving a lithium-aluminum alloy. At about 1350 ^{o}C, the lithium boils out of the alloy leaving aluminum liquid and a lithium gas in a hydrogen atmosphere. Atomic hydrogen is present but only in small quantities at this temperature (less than 1%). The nickel remains solid. After several hours of being held at this temperature, ash analysis provides the following data [Levi, 2013a], [Gulstrom, 2014], [Levi, 2013b]:

Isotope	**Fuel (%)**	**Ash(%)**
Li^6	8.6	92.1
Li^7	91.4	7.9
Ni^{58}	67	.8
Ni^{60}	26.3	.5
Ni^{61}	1.9	0
Ni^{62}	3.9	98.7
Ni^{64}	1	0

The rather large amount of ^{7}Li present in the fuel has been replaced by ^{6}Li in the ash. Similarly, the large amounts of ^{58}Ni and ^{60}Ni in the fuel have been largely replaced by ^{62}Ni. This indicates very strongly that some form of nuclear reaction has taken place. There has been no analysis to the author's knowledge of the usual engineering properties of the ash from this process. It is not known whether this represents an environmental concern or not, although there is no indication that it should be. There has been no discussion of residual radioactivity in the process ash.

Recent studies [Bettini, 2011], [Focardi, 2010] suggested the following reaction for this nickel nuclear "upgrading" process;

$$Ni^a + p \rightarrow Cu^{a+1} + MeV \rightarrow Ni^{a+1} + e^+ + \nu + MeV$$

The transmutation from the lower atomic weight isotopes to higher atomic weight isotopes was predicted to occur through a transmutation involving copper. However, it [Cook, 2015] has suggested that one should discard this reaction scheme from the list of possibilities since experimental evidence does not support the presence of copper as expected.

If a source of neutrons is available, alternate reaction sequences for changing the isotope structure of nickel have been suggested [Lindstrom, 2016a], [Lundin, 2015], of which one is

$${}^{a}Ni + n \rightarrow {}^{a+1}Ni + \gamma$$

This is a well-known nuclear reaction [Wasson, 1965], [Ishaw, 1977], [Raman, 2004] and has been studied for several decades. The above nickel reaction is known for its γ bursts in the 6 – 9 MeV energy range [Koshio, 1998] and is used for calibration of detectors used in the nuclear industry.

A source of neutrons is available from another well understood nuclear reaction, the reduction of ^{7}Li to ^{6}Li through the resonant absorption of a proton, with subsequent release of a thermal neutron [Lefevre, 1969] and is given by

$${}^{7}Li + p + 2.5\ MeV \rightarrow\ {}^{7}Be + n$$

$${}^{7}Be + e \rightarrow\ {}^{6}Li + p + .86MeV$$

In this scenario, ${}^{7}Li$ is impacted by an energetic proton becoming ${}^{7}Be$ plus a neutron. The beryllium isotope is unstable and decays with a half-life of 53.7 days releasing the captured proton. The drawback to this reaction scenario is the availability of energetic (2.5 MeV) protons. As mentioned above, concentrations of monatomic hydrogen are low even at the maximum operating temperatures for the E-Cat device. This is well below the 2.5 MeV energy level required for this reaction to proceed.

This established lithium reaction is in some ways simpler than the nickel reaction through the copper intermediary described above. Confirmation requires looking for the beryllium reaction product in the ash from the reaction, which has not been done to the author's knowledge.

From a standard physics standpoint, there seems to be no starting point for the above reactions. The problem is that as a proton approaches the nucleus of another atom such as lithium, a strong electrostatic repulsion occurs. Unless the proton has sufficient energy, it can't get close enough for the short range nuclear forces to allow the proton to penetrate into the nucleus. A theoretical discussion of this is beyond the scope of this document, except to say that competing theories [Lundin, 2015], [Evans, 2013] offer mechanisms for the production of energetic protons.

Rossi's first E-Cat patent was based on the nickel reaction in a continuous flow heated reaction vessel [Rossi, 2009]. His most recent patent is for a fixed charge reaction vessel [Rossi, 2015]. Electrical discharges are not discussed. However, in a recent paper on LENR in an aqueous electrical discharge, it was speculated that perhaps the Rossi device may have incorporated an electrical discharge in its construction, presumably to act as the source of and driver for energetic protons required by the lithium reaction [Sharma, 2016].

Transmutation in Electrical Discharges

As discussed in a prior publication, [Evans, 2013], much work has been done on the transmutation of the elements using an electrical discharge. When a carbon - carbon pair of electrodes for example, has an electrical arc struck between them in either in a gaseous or water environment, anomalous production of elements, predominantly iron and calcium is reported. In 2012, Kozima and Tada [Kozima, 2012] summarized the work of Sundaresan and Bockris [Sundaresan, 1994] and reported the transmutation of carbon and oxygen to iron in an electric discharge. The discharge was performed both in air and under water with the production of iron being two orders of magnitudes higher than the trace amounts of iron in the electrodes. Spectroscopic evidence [Hanawa, 2000] also indicated the presence of Mg, Pd, Ca, Al, Zn, and Cu.

Sharma [Sharma, 2016] et. al. reported a net energy surplus using a carbon-carbon arc in an aqueous environment.

Cirillo [Cirillo, 2013], [Cirillo, 2012a], [Cirillo, 012b], [Cirillo, 2012c], [Cirillo, 2008], [Cirillo, 2004] claimed low energy nuclear reactions in an aqueous electrical discharge between tungsten and iron electrodes with production of rhenium, osmium, gold, hafnium, thulium, erbium, and ytterbium on a tungsten cathode that were not present prior to the discharge process.

The following types of anomalous results have been reported for the electrical discharge LENR.

- Production of excess heat
- Production of excess electrical energy
- Production of excess hydrogen
- Production of neutrons, protons, γ rays, and/or other nuclear particles
- Transmutation of the elements forming the electrodes

All of these are not necessarily present at the same time. It has not been conclusively demonstrated that excess hydrogen production and excess electrical energy are part of the LENR process. In fact, thermionic emission has been suggested as the source of excess electrical energy [Cirillo, 2004], [Purratio, 2007], and may also be the energy source for anomalous hydrogen production when it occurs [author's comment]. Thermionic emission, the release of electrons from a hot cathode (basis of operation for the vacuum tube of prior eras), has been suggested as being detrimental to the initiation and maintenance of a low energy nuclear reaction [Purratio, 2007], [Cirillio, 2004], [Rossi, 2016], but there is no experimental evidence available to substantiate this claim.

The following table lists of a few of the experimental results from several sources that illustrate the variety of materials used and the type of LENR phenomena observed in electrical discharges.

Author	Anomalous Behavior	Electrodes	Environment	Author's Comments
Oshawa	Transmutation	Carbon	Aqueous	Unreliable
Sandaresan	Transmutation	Carbon	Aqueous	Unknown
Sharma	Transmutation, excess energy	Carbon	Aqueous	Work needs refinement
Cirillo	Transmutation, neutron flux	W / Pt	Aqueous	Over unity claims withdrawn
Widom	Neutron flux	W / Pt	Aqueous	Valid
Biberian	Excess energy	W	Aqueous	Valid
Mizuno	Excess energy, neutron flux	Ti, Ni, TaNi, Pt	Aqueous	Valid
Brockris	Transmutation	Carbon	Aqueous	Valid
Correa	Excess energy	Various	Rarified gas	Unknown

In a series of papers beginning in 2004, Dominico Cirillo demonstrated the transmutation of metals in a water based electrically driven plasma. In his earliest work, Cirillo [Cirillo 2004], used a DC voltage source (up to 340 VDC at 8 amps.), a potassium carbonate solution of 0.2 M concentration for the electrolyte, heated to 70 ^{o}C, and tungsten electrodes. Surface melting of the electrodes was observed (SEM) after 4000 seconds of operation. Cirillo claimed thermally generated currents as large as 500 amperes were produced with accompanying cathodic temperatures of 3400 ^{o}C. Based on heat energy calculations, they speculated that a coefficient of performance of 1.2 to 1.4 had been achieved. Transmutation of the tungsten to rhenium, osmium, hafnium, thulium, erbium and ytterbium was observed using SEM surface analysis. They also observed radio frequency emissions in the kHz to the hundreds of MHz range. By 2008 [Cirillo 2008], Cirillo retracted the over-unity claims, realizing that electromagnetic interference caused the measurements to be unreliable. By 2012 [Cirillo, 2012 a and b] a substantial neutron flux from the discharge had been measured using non-electrical measuring techniques. This has been rejected by others [Faccini, 2013] but experimentally reaffirmed [Widom, 2013], [Sharma, 2016]. The latter claims a coefficient of performance as high as 800%. Further confirmation of over unity effects has been offered recently [Biberia, 2015] where concentration on heat measurements rather than other phenomena is indicated.

B. Pulsed LENR

Little work has been published on power sources for LENR that are pulsed or otherwise varied, in some controlled manner. Most discharge processes experience pulsed electric fields, but these are essentially uncontrolled result of the discharge itself. A few research groups have explored this approach however – the Correa's with patents granted in the mid 1990's, the Brillouin Energy Corp., currently doing R&D in the field and a third entity [Purratio, 2006, 2007, 2016] that has a plasma jet device in some vague state of development.

Paul and Alexandra Correa [Correa, 1994, [Correa, 1995], [Correa, 1996] secured a series of patents for a process they named "Pulsed Abnormal Glow Discharge" or PAGD, in which they claimed unusual electrical phenomena that didn't seem to obey standard physical laws. Their patents center around a low pressure discharge tube, where the discharge is maintained in a so called cold state (unheated cathode) with electrical breakdown prevented by the application of an external electric field. Negative resistance and over-unity effects are claimed. Low energy nuclear reactions are not a focus point of their research.

Brillouin energy's process consists of forcing hydrogen into a nickel lattice through the use of their proprietary "Q Pulse" generator. Claims are that their nickel lattice is a highly engineered product. The Brillouin device is not a discharge device, but works primarily [Brillouin, 2015] in an electrolytic cell mode, along the lines of the original Pons an Fleishmann design. Hydrogen nuclei experience compression in nickel lattice using phonon vibrations in the fusion process.

Richard Reichmann and Karl-Ludwig Barth with Purratio Ag [Purratio, 2006], [Purratio, 2007], developed a plasma torch using a regular capacitive discharge in a hydrogen or water atmosphere. Over unity heat production was claimed. The authors design allowed for the simultaneous application of a DC current and a short duration pulsed current (~ 1µ sec., 60 Amps) to initiate a fusion event, claiming that the that electron flow from the cathode, which was thermionic in origin, needed to be minimized. This maximizes the opportunity for hydrogen nuclei, lithium nuclei, etc., to impact the cathode which is one of Group II X or Group IV A metals on the periodic table. These metals include Pd, Fe, Co, Ni, and a plethora of more exotic varieties. The cathode was either a pure metal or a coating on a metal grid. The company is still in existence, and has an LENR technology they have called SolFire that is in some rather vaguely defined state of development [Purratio, 2016].

III. LENR and the Magnetic Miles Device

A. Characteristics of the Device

The field of LENR is not an accepted science and is full of exaggerated and some genuinely false claims. The statement "extraordinary claims require extraordinary evidence" seems to have not been applied to most of the research. Even the established Rossi device is still under serious question as to its validity. In this section, the technologies of Magnetic Miles LLC. will be discussed as they apply to the LENR industry. The groundwork for extraordinary evidence will be presented to substantiate any claims that may be offered.

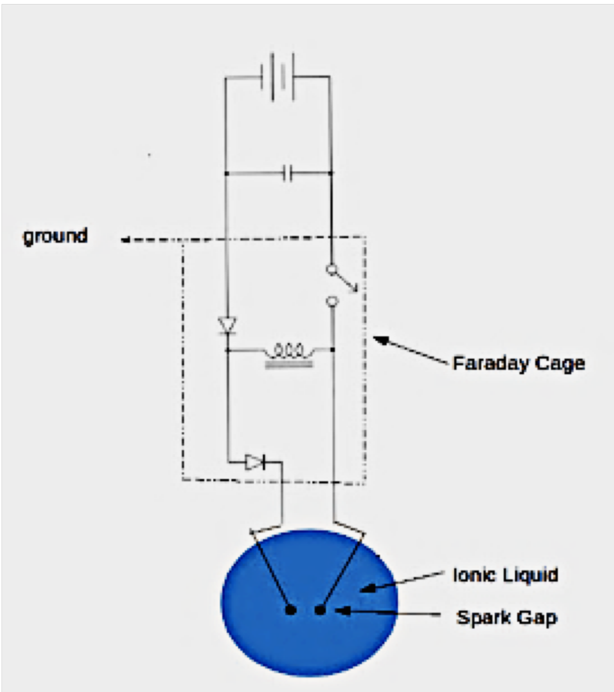

Figure 1

I will not go into the history of Magnetic Miles LLC since this and pertinent patent information is available on their web site [Magnetic Miles, 2016]. In its simplest form, the Magnetic Miles apparatus can be reduced to that shown in *Figure_1*. This has been amply discussed [Lindstrom, 2016b] and will only be summarized here. A rechargeable battery bank keeps a capacitor bank charged. This is repeatedly switched off and on and fed to an inductor at pulse rates in the kHz range. The inductor is in parallel with a discharge apparatus. The diode array allows the inductive collapse to pass only through the spark discharge.

Anomalous behavior in the Magnetic Miles technology has been reproducibly demonstrated in the following areas:

Anomalous Behavior	**Expected LENR Behavior**	**Magnetic Miles Apparatus**
Production of excess heat	Up to 300% of applied energy demonstrated	250% of applied energy as heat
Production of excess electrical energy	Speculative	30% in excess of applied energy available as electrical energy.
Production of excess hydrogen	Up to eight times expected amounts	Unknown
Production of neutrons or γ rays	Anecdotal–E-Cat up to 300 keV x-rays. Laboratory experiments at 3 keV bursts	High intensity γ bursts detected at 60 times background levels
Transmutation of the electrode elements	One or two atomic number higher or lower	Unknown

These results are in alignment with the expected behavior of LENR as described earlier. The bulk of the measurement data available has come from electronic monitoring devices, sampling each variable at a rate of 800,000 per second Intense electromagnetic fields exist in and around the electrical apparatus makes the signals from such devices inherently noisy. Confirmation of the measurements by non-electrical means is underway but at the time of the writing of this document, is not available.

The apparatus is characterized by a rise and fall in electrical energy levels in alignment with conventional thinking. What is unexpected are the huge power surges in the apparatus which occur in somewhat regular fashion. These surges have been termed "events" that may be associated with the anomalous, possibly LENR behavior observed in the apparatus.

Events

The voltage relative to ground and current measured at the cathode, illustrated in *Figures 2a* and *2b,* show the nature of the event. Similar patterns can be seen in battery potentials, anode current, etc.

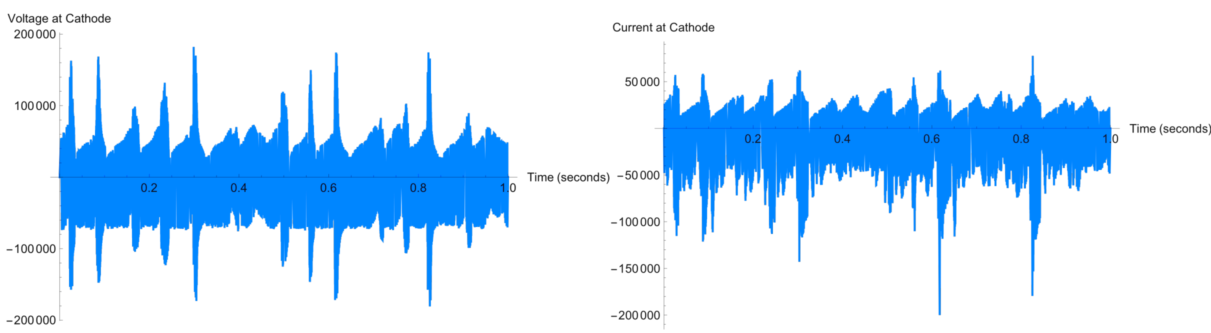

Figure 2a&b

Besides high frequency noise, these signals, exhibit a slow fluctuation in the 4-5 Hz. region that would be typical of a charging inductor (envelope of waveform). The cathode current follows this envelope, but then abruptly spikes, perhaps associated with the onset of an electric discharge phenomenon or perhaps some other "snap" or nonlinearity in the switching device.

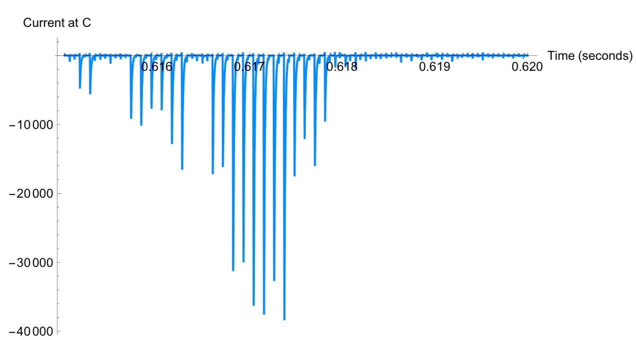

Figure 3

When the noisy background of the signal is removed, the event on a fairly fine timescale, the event becomes a series of unidirectional pulses, each pulse coinciding with the fall to zero of the driving signal as typified in *Figure_3.*

Excess Electrical Energy

One can think of the Magnetic Miles device as a three terminal device, where one terminal goes to the battery positive terminal, the second goes to the battery negative terminal, and the third connects the cathode to some unspecified current source I_g as illustrated in *Figure 4*. This current may be thermionic in origin [Cirillo, 2004]; at this point, its origin is uncertain, but this not needed for this discussion. From this drawing, one would expect that

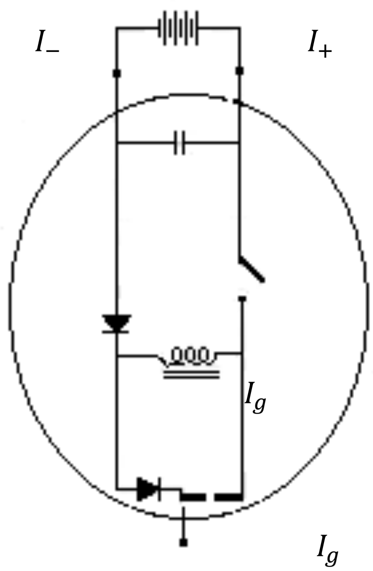

Figure 4

$$I_g = I_+ - I_-$$

where I_- is the current from the negative battery terminal and I_+ is the current returning to the positive battery terminal. For the purposes of energy considerations at the battery, what happens inside the box containing the circuitry is irrelevant.

The energy drawn from the battery stack is defined by the time integral of the battery voltage, $V_B = V^+ - V^-$ times the battery output current I_-, i.e.

$$\varepsilon_- = \int_0^\tau V_B * I_- * dt$$

From the experimental data supplied by Magnetic Miles, it is seen that more current flow is measured returning to the battery I_+ than was measured leaving the battery I_-. If this current I_g was gained at the cathode, through an as yet unspecified process, the total current at the cathode as given above would be $(I_- + I_g)$ and the electrical energy at the cathode is then

$$\varepsilon_+ = \int_0^\tau V_B * (I_- + I_g) * dt = \int_0^\tau V_B * I_+ * dt$$

This is the energy returned to the battery, i.e.

$$\varepsilon_+ = \int_0^\tau V_B * I_+ * dt$$

The electrical coefficient of performance defined as the energy returned to the battery divided by the energy drawn from the battery, is approximately given by

$$COP_E = \frac{\varepsilon_+}{\varepsilon_-}$$

The electrical energy gain relative to the battery drain is given by

$$Excess\ Electric\ Energy = \frac{\varepsilon_+ - \varepsilon_-}{\varepsilon_-} = COP_E - 1$$

Studies are underway to determine how the excess electrical energy is related to the energy contained in the event itself.

Production of Excess Heat

The heat generated in a low energy nuclear reaction is thought to be the result of slowing fast moving particles, often with a liquid such as water or with heavy water or graphite in the case of traditional nuclear fission reactions. Excess heat means that the heat energy delivered as heat is more than the energy that has gone into the system and has been demonstrated in the Magnetic Miles device. Temperatures in the electrolyte and in the atmosphere above the electrolyte were monitored along with the current and voltage at the power supply. Neglecting the heat loss due to conduction through the vessel wall, optical and acoustic radiation and gaseous escape, it is seen that significantly more heat is being produced than electrical energy needed to produce it.

The thermal coefficient of performance is defined as the heat energy acquired by the liquid electrolyte divided by the energy drawn from the power supply. The heat energy gained by the electrolyte from an initial temperature of T_0 to the time of observation is given by

$$Q_T = m * cp * (T - T_0)$$

where m is the mass of electrolyte being heated, and cp is its specific heat. The thermal coefficient of performance is given by

$$COP_T = \frac{Q_T}{\varepsilon_-}$$

Typical coefficients of performance for thermal energy and electrical energy are illustrated in *Figure 5*.

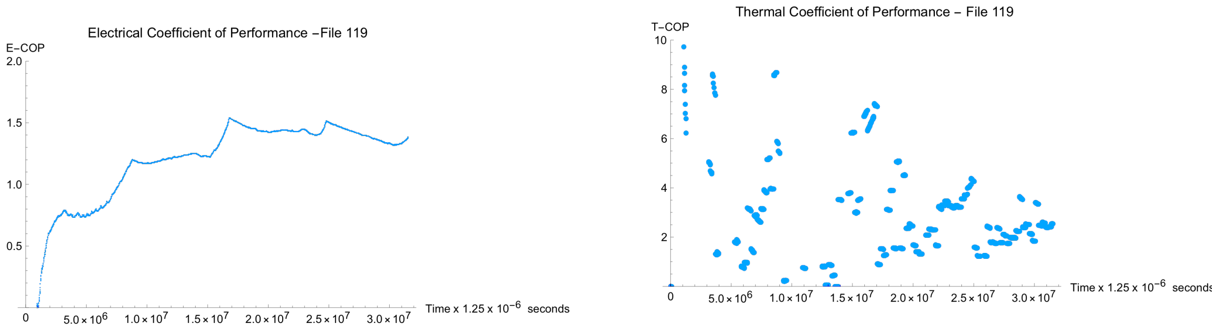

Figure 5a & b

Over a period of about 40 seconds, the excess electrical energy output from the device stabilizes to more than 30% of the energy drawn from the battery source (72 kw available vs. 53 kw drawn from the battery) and the thermal energy stabilizes to about 250% times the battery drain. This gives a total coefficient of performance of 290%. The total excess electrical plus thermal energy is about 2.9 times the energy drawn from the battery. The electrical noise present in the temperature measurements makes these values approximate, however convergence to a value is implied by the data.

Sometimes an experimental run does not develop an excess of energy. The reasons for this have not been fully determined, but starting temperatures for the electrolyte seem to affect the development of the electrical discharge, and this seems to affect energy levels. This has been reported elsewhere [Cirillo, 2004], [Mizuno, 1998]. Data is presented for a higher starting temperature (File 119) and a lower starting temperature (File 816) in the Appendix to the report. Consider first, the data presented for the higher starting temperature case. This state is reproducible, although because of the nature of chaos, results vary from test to test. The temperature data taken above the electrolyte is less noisy, for lack of a better term, than the temperature data taken within the electrolyte, possibly due to thermal shock waves in the electrolyte. It is assumed that the atmosphere above the discharge and the liquid are well mixed thermally, so that that temperatures taken above the electrolyte represent the liquid temperature. For the less chaotic File 816, in addition to a relatively noise free temperature profile, one sees that there is no energy gain. To within 5%, the energy gained as heat by the electrolyte is taken from the battery. This difference is easily accountable in the neglected energy loss issues such as dissociation energy required to dissociate the water into hydrogen and oxygen, heat losses, etc.

Production of Nuclear Reaction Products

A digital radiation detector placed near the discharge apparatus showed bursts in excess of sixty times the level of background radiation. This is either γ rays or x-rays since the other particles that the apparatus can detect would not escape the water barrier. Other authors have noted x ray production in LENR devices. [Rossi, 2016], [Karabut , 2004] The response time of the detection apparatus was too slow to correlate with any of the electrical events occurring in the discharge.

Are Conditions Right for LENR to Occur?

Of the five observed behaviors in LENR reactions, three have been experimentally confirmed to occur within the Magnetic Miles apparatus. This does not absolutely mean that an LENR event has occurred. If there is element transmutation on the electrodes, then LENR will have definitely occurred, and is likely responsible for the temperature rise. This analysis is in progress. Excess electrical energy is likely thermionic in origin (at the cathode). Whether or not this should be minimized or not remains to be determined.

B. **Commercial Advantages and Disadvantages of Magnetic Miles Technology**

Magnetic Miles technology offers several distinct advantages over the competing LENR processes; the biggest of these being process control. Process efficiency improvements are also significant. A total energy increase of 290% was achieved without any process or hardware optimization. It is unlikely that the best design was hap hazardously struck by accident. Improvements in efficiencies are expected when the process is understood better and such knowledge can be applied to the design of the apparatus.

Acceptance / Disruption

LENR is considered by some to be a severely disruptive technology [see DOE funding applications accepted in 2014]. The acceptance of LENR will change and/or displace many entrenched aspects of technology, most notably the fossil fuel and the conventional nuclear industries. If it is incorporated at the large scale or utility level of implementation, this disruption will be much smaller, especially if the LENR technologies can be developed to fit directly into the existing energy infrastructure. It is the opinion of this author, that the introduction of LENR technologies will, at least for the near term, be at the centralized power utility scale. Skilled operations and maintenance personnel will be required to keep generating plants running, something not immediately feasible for small, decentralized power generation facilities.

Mainstream science has yet to accept LENR as a real process. This makes it very difficult for this new technologies to get started, since decisions to invest would rely on the advice of mainstream science for validation of undertakings of this size.

Safety

LENR experiments are replete with runaway reactions that have resulted in laboratory and facility destruction. From the earliest work of Pons and Fleishmann, these reactions have been known to become un-controlled at seemingly unpredictable times, causing explosions that have leveled more than one laboratory. This alone would limit the use of the technologies to those installations that have the technical manpower skilled in dealing with such processes, certainly not small or local installations.

The reasons for this behavior are poorly understood, primarily because the reaction process itself is little understood. Safety generally reduces to process control, hardware design, and material selection. These require a level of understanding that is relatively mature. At present, the entire field of LENR has not reached a point of understanding comparable to the existing nuclear industry. It is only beginning to be accepted at the university level, and entry level products are only beginning to appear. This limitation is often true for technologies that are somewhat sophisticated. For example, lithium ion batteries contain a compound that explosively burns in the presence of water, yet little damage is reported from lithium battery failure in devices as commonplace as cell phones, tablets, etc. Such is expected for LENR technology and Magnetic Miles technology is particular, as it matures. At this point little else can be said about safety.

Reaction control

It could be said that reaction control is a safety issue. It is, but it is separated in this discussion because it is an important aspect of the technology from an implementation stand-point. There is extreme variability from test to test when duplication of LENR experiments is undertaken. Few reaction scenarios address controllability of the reaction, nor do they address the issues of shutting down an uncontrolled reaction. The science and engineering behind this is not understood in detail at this time. This understanding must be achieved before the technology can assume any role of significance.

The Magnetic Miles technology offers process control possibilities not possible in other forms of LENR apparatus. Control over the pulse rate driving the buildup of the magnetic field at the inductor offers a primary means of controlling the occurrence of discharge "event" which seems to be linked to LENR phenomena. The repetition rate for the "events" is dictated by circuit parameters, and is flexible in that the design and can be changed in-process if necessary. Feedback of energy from the spark chamber to the inductor is anticipated to offer control of the overall height and hence the energy contained in the energy burst. At this point, the link between the electrical energy burst and LENR activity is under investigation.

Utility Level Technology

As mentioned earlier, the scale of technology excludes small generating facilities at the single user (up to 100 kW) scale. This is primarily due to the level of sophistication of the apparatus which dictates trained technicians for its contemplated operation. Usage will likely be at the utility level (> 1 MW) limiting its use to large and small utility energy production facilities and situations where unavailability of alternate sources of energy makes this technology desirable. Final processes will likely be adapted to existing thermal generating stations and feed the energy grid in the normal manner.

Environmental Concerns

The impact on the environment by LENR technology has not been addressed in any rigorous manner. It is a nuclear process and may develop an image based on that of traditional nuclear industries, which to say the least is not good. This is a political barrier, one that is beyond the scope of this discussion, but does need to be understood and addressed.

Besides the above, the byproducts of LENR are poorly understood from a utilization standpoint. For example, for the technology behind the E-Cat reactor, the material properties of the "ash" from this reaction are not known. If one considers the nickel residue, it may be that the only material change will be a small density increase. Other properties including landfill disturbances, have not been addressed.

At present, the Magnetic Miles technology uses established and available materials and processes combined in a non-threatening manner. The results however are not traditional. At this point in time, it is not expected that any harmful waste (or any waste at all for that matter) will result as a result of the process. However, it is not known if the isotopes of the naturally occurring fuels will have the same mechanical properties as the natural forms. There are no concerns of radioactive waste as experienced by the present nuclear industry, nor is there likely to be environmental pollution concerns. Anticipated materials are all presently mined in an environmentally friendly manner with transportation logistics proven reliable and safe.

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Appendix Data Comparison

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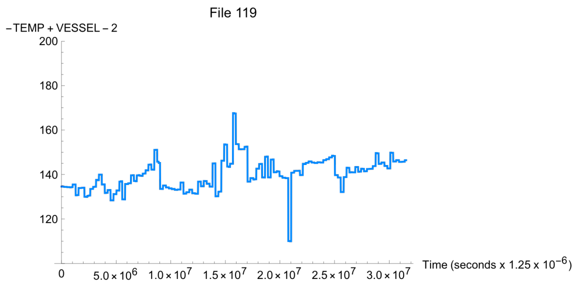
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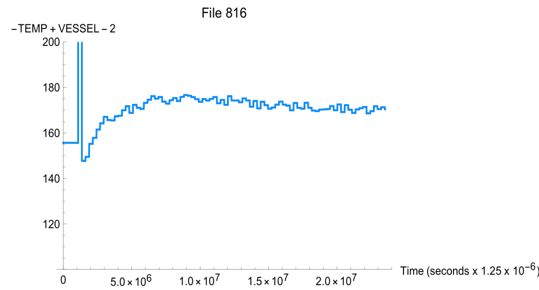
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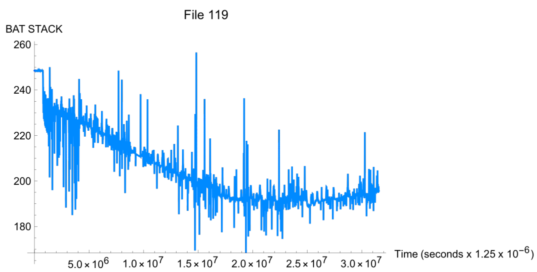
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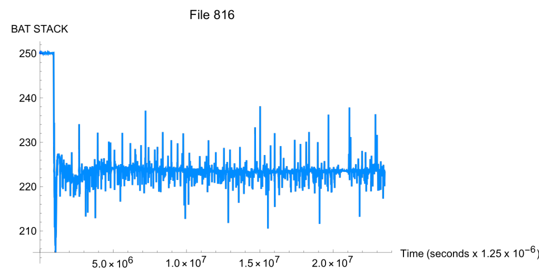
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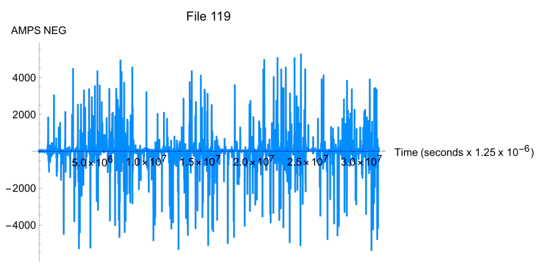
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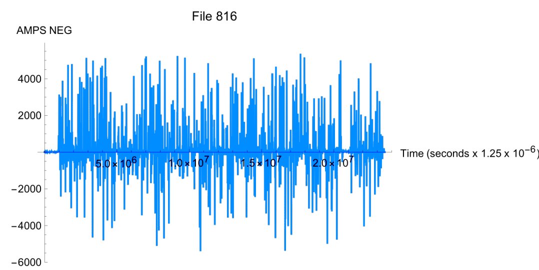
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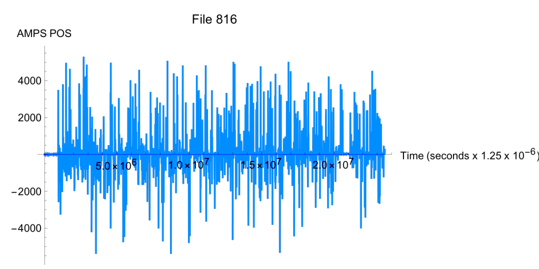
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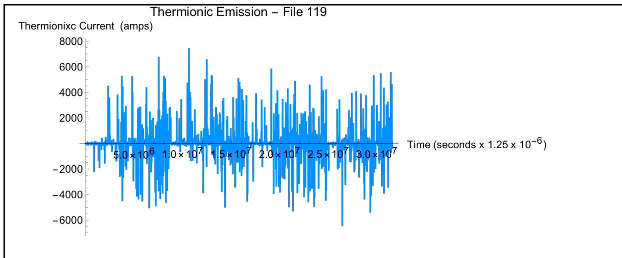

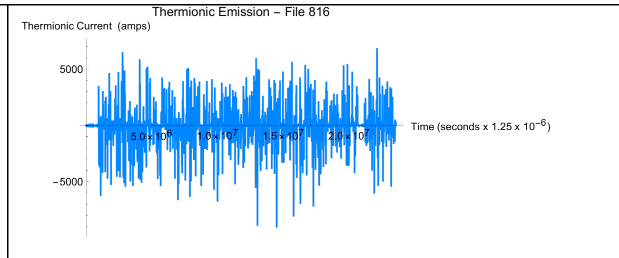

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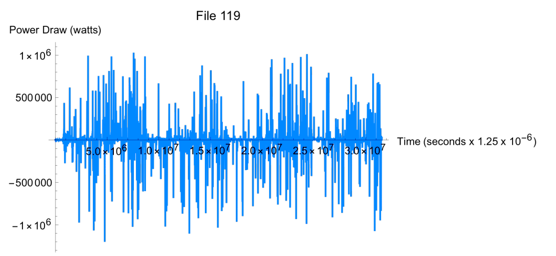

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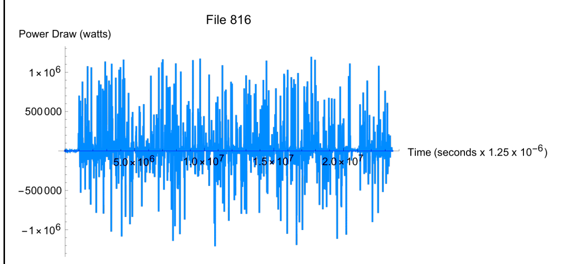

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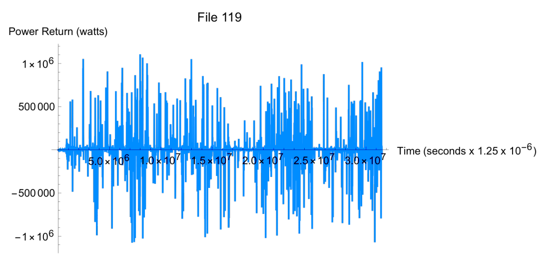

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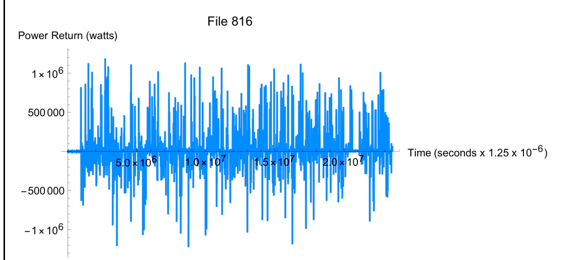

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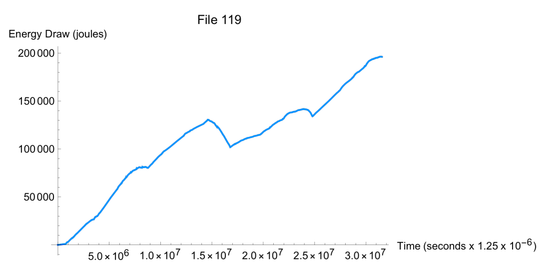

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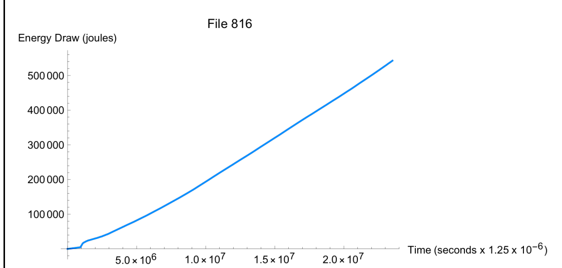

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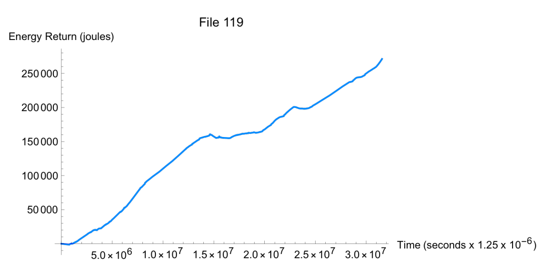

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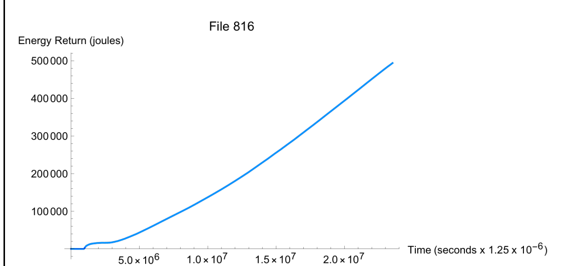

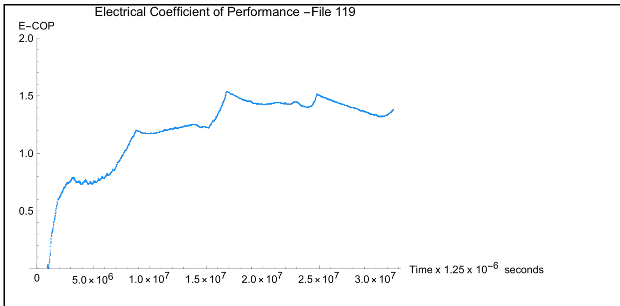

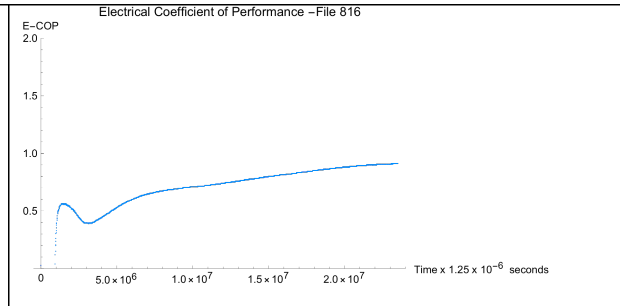

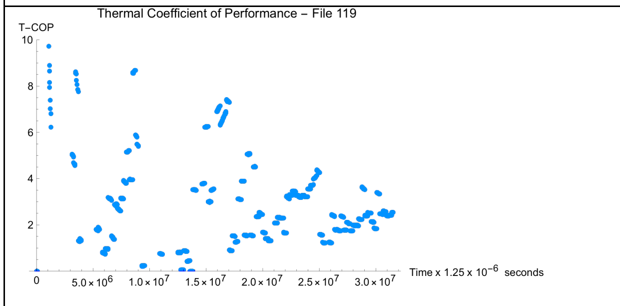

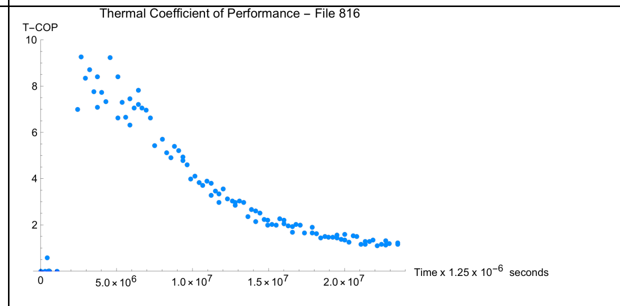

Start Temperature	156 F (68.9 ^{o}C)	135 F (57.2 ^{o}C)
Excess Electrical Energy (% battery draw)	30%	-9%
Thermal Energy Output(% battery draw)	250%	114%
Total Energy Gain (% battery draw)	290%	5%