Research Article

Water-free Replication of Pons–Fleischmann LENR

William H. McCarthy*

2156 Old Middlefield Way Mountain View CA 94043, USA

Abstract

Statistically significant heat is produced by a method similar to Pons and Fleischmann but not involving electrolysis or water. Instead of putting hydrogen into electrodes by operation for a few days, hydrogen solute is incorporated into electrode alloys by temperature and pressure, before the cell is assembled.

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1. Introduction, Rationale

The Low Energy Nuclear Reaction (LENR) system described here is fundamentally similar to the Pons and Fleischmann (P&F) [1] innovation as developed by many scientists over two decades. A more simple method was sought to avoid some of the complications of the electrolytic method, but to retain the fundamental metallurgy of P&F, notably the heavy saturation of the metal with hydrogen. Practical advantages could be had by loading the metal with hydrogen before trying to produce a nuclear reaction, rather than doing so by electrolysis during the operation of the cell. These include eliminating the need for recombining the electrolytic oxygen and hydrogen gasses, with the concomitant safety advantage of avoiding failure of a catalyst to do that. Also, if a dry system could be found, temperatures in the realm of commercial steam generation should be much more easy to obtain than with electrolysis.

Absent electrolysis, palladium would not be a good choice because the hydrogen saturation would not be retained at ambient pressure when the electric current was switched off. Many other metals, when rapidly cooled from high temperatures and pressures, retain small concentrations of hydrogen that are well above ambient saturation levels,. Iron, copper and nickel are a few examples. Among that set, copper is the easiest to process. LENR has often been observed in nickel, which has some (metallurgical) similarity to copper. For instance, copper and nickel form a complete set of binary solid solutions with no intermetallic compounds (monel, cupronickel, etc.) Typically, light hydrogen works with nickel, which has practical advantages over deuterium used in most of the palladium cathodes.

Substantial effort was expended in quenching encapsulated copper and some of its alloys from high temperature and hydrogen pressure. Since electrolytic cells have occasionally continued to produce LENR after switching off the

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*E-mail: santander@earthlink.net

electricity, it was thought that effect might be reproduced in this system by quickly installing the quenched copper or other alloys into a calorimeter. None of those tests produced anomalous heat and the experimental difficulties were formidable. Thinking about those results, it seemed that perhaps the Nuclear Active Environment (NAE) is not static as in the quenched copper case. That is, putting all the right materials together without any dynamic impulse to move charged particles, they may not encounter one another, no matter how unhappy they may be in the stress fields of the deformed metallic lattice. Where is the dynamism in P&F? Perhaps the hydrogen bubbles on the cathode surface locally obstruct electron flow out of the cathode to set up charge variations within the cathode just sufficient to get solute ions to move. Potentially, that could account for the infamous irreproducibility of the P&F effect. Those bubbles must change significantly depending on details of electrode geometry, suspended matter in the electrolyte, current density and other apparently minor variables.

Applying the scientific method (per the Conference title), a working hypothesis was conceived to assemble the above ideas and knowledge into a test program to clarify some of the uncertainties in LENR and to improve the generation of anomalous heat. It is expected that industrially significant products will eventually result. That working hypothesis includes the following elements:

(1) Near super-saturation of hydrogen into a metallic lattice is a necessary, but not sufficient, prerequisite to these reactions (either stable hydrogen isotope and a variety of metals can be used).
(2) The NAE is not static nor electromechanically uniform on a μmeter scale or smaller (variations of electric current in location and time along the surface of an electrode are important and may account somewhat for the
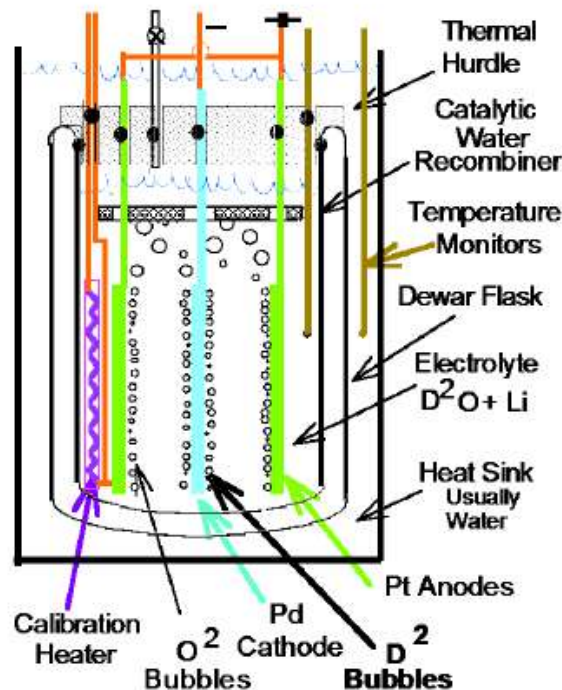

Figure 1. Pons and Fleischmann schematic arrangement.

lack of reproducibility typical of LENR.)

(3) Other light element solutes may be reactants (lithium and boron are of particular interest.)

Following that working hypothesis, cells were built, more like electronic capacitors than electrolytic cells, with copper alloy electrodes separated by a dielectric containing small electrically-conducting particles. Those particles inject electric current at discrete, separated, locations along the surfaces of the electrodes. That is the reverse of the electrolytic system where electrons depart the electrode, except where obstructed by a critically sized (dielectric) gas bubble. Fine graphite particles have been substituted for the hydrogen bubbles. The spacial separation of conduction is obvious in both cases. Also, some change over time (due to Brownian motion), functionally equivalent to bubble motion (due to gravity) might take place, provided that the graphite particles are small enough and their embedment is heavy and hot enough. In spite of pyrophoric considerations, metallic powders are expected to be studied in future.

Copper-based alloys and light hydrogen were chosen for practical reasons. Vacuum-pump oil and silicone grease have been used to suspend the graphite particles. Schematic diagrams, showing the features that are salient here, for a composite P&F electrolytic cell and for a typical dry, no electrolysis, cell are given in Figs. 1 and 2, respectively.

2. Experiments Described

2.1. The cell

In the present arrangement, shown in Fig. 2, the electric current is distributed over the electrode surface by an array of tiny graphite particles suspended in oil or grease. The electrodes are strips of copper alloy about 0.13 mm (0.005 inch) thick, 7 mm (0.28 inch) wide and 64 mm (2.5 inch) long. Hydrogenation of the electrodes is carried out in capsules pressurized to about 20 bar (300 psig) at 600–900°C. After 30 min or so, the capsule is water quenched. Dehydro-
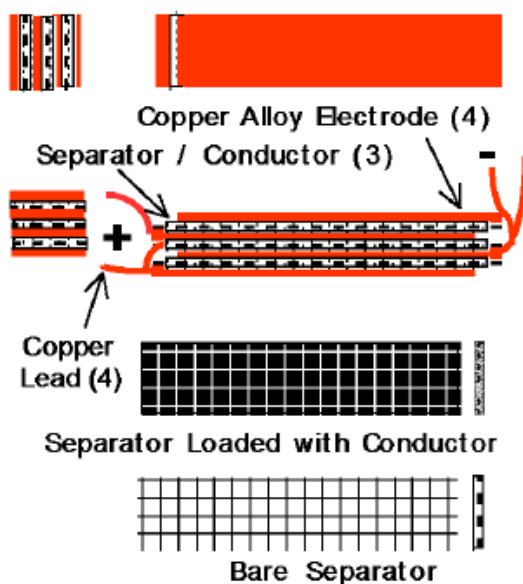

Figure 2. Schematic of the dry cell .

genation to prepare control electrodes is done by several vacuum (20 μm Hg) anneals at about 700°C alternated with argon pressurization (20 bar). Cells are prepared from alternating stacks of these electrodes separated by textile mesh saturated with a petroliferous suspension containing graphite particles. These cells are thus poor (low Q) capacitors of a few microfarads and 3–20 Ω.

2.2. Calorimetry

A typical seebeck calorimeter, as used here, is based on a thermopile consisting of a series string of eight to ten Type-E thermocouple junction pairs. For this spider structure, the warmer junctions are cemented at the edges and between two strips of polycarbonate that form the base of the specimen carrier. The alternate cold junctions are cemented to similar polycarbonate strips attached to the body of the calorimeter, which is maintained at ambient temperature. Thin copper channels are cemented to the carrier polycarbonate on both sides, to stiffen the assembly and disperse any temperature gradients. The specimen is clamped to one side of the carrier with small brass screws and nuts. Thin rubber pads are usually included to prevent short circuits, without seriously affecting the sensitivity of the calorimeter. A joule heater is attached to the opposite side of the carrier, in as symmetrical a fashion as its geometry and that of the specimen allows. That electrical resistance heater consists of nichrome wire wrapped around a strip of polycarbonate and covered with a thin layer of silicone adhesive.

The thermocouple wires have three functions in this arrangement: They mechanically support the specimen/heater carrier, they signal the voltage corresponding to the temperature difference between carrier and ambient to measure the thermal power deposited on the carrier and they provide most of the thermal hurdle that maintains that temperature difference. The sensitivity of the calorimeter can be adjusted by selecting the diameter and length of thermocouple wires.

A sketch of the power sensitive part of such a calorimeter is shown in Fig. 3. A complete assembly is diagrammed in Fig. 4.

2.3. Calorimeter

The spider is enclosed in a vacuum chamber as shown schematically in Fig. 4. That chamber has a clamshell design consisting principally of two copper half-cylinders, each brazed to steel quarter-spheres on the ends. The enclosure is mechanically pumped (about 20 μm Hg) to eliminate convection and greatly minimize gas-conduction heat transfer.

There is some radiation cooling of the spider assembly. At the power levels used here, however (less than 650 mW), radiation can account for no more than one-quarter of the heat passed from the spider to the enclosure shell. It was found in practice that that level of thermal radiation is insufficient to produce detectable nonlinearity in the test results.

2.4. Testing

Cells are activated by direct current provided by a lead-acid battery. Thus, power factor concerns are eliminated. Current is controlled by a single-transistor power supply of the author's design and construction. The same Hewlett Packard Model 3445A voltmeter is used for all current and voltage (hence power) data. Cheap DVMs are connected to aid in adjustment and error finding but such data are not included here. The HP 3445 instrument provides visual digital output with least count of one millivolt. The range of power levels used here is from about 50–600 mW. The corresponding HP3445 range is typically 0.8–5.0 V. A four-wire arrangement is used to connect the power supply to the specimen or joule heater. Current is supplied by one pair of the quad and voltage is measured with the other pair. Voltage drops in the leads are thereby not included in the results. Further, the HP 3445 voltmeter has very high input impedance.
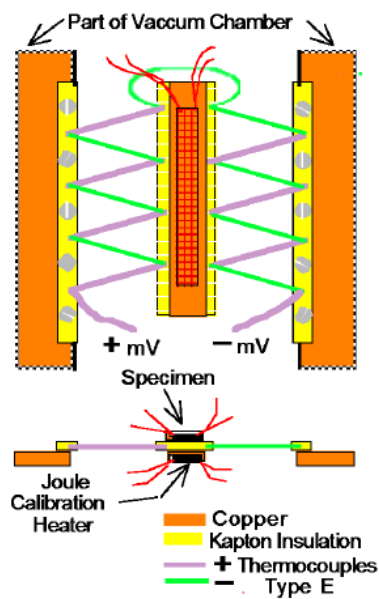
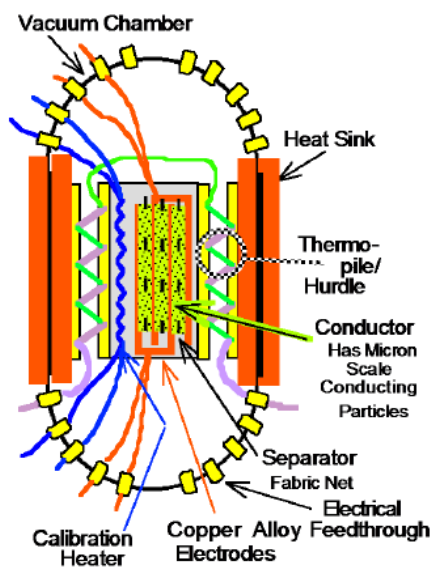**Figure 3.** Seebeck calorimetry spider (heat sensor).

Figure 4. Calorimeter assembly.

A device is available to reverse automatically the specimen polarity. It is based on an electromechanical relay and Type 555 integrated timing circuit. In practice, with a reversal period of roughly ten minutes, any power factor concern is insignificant.

Voltage is measured directly. Current is measured by the voltage drop across a standardized string of 10 W resistors. For any test run, the same resistor(s) are used for both specimen and calibration heater. Joule heaters are designed to be fairly close in resistance to specimens. The standardized resistors are selected to be in the same range. Thereby, only one range of the HP 3445 is normally used for joule and specimen readings (both current and voltage) over a moderate range of input power – often those raw measurements are mutually within a factor of about three. Comparability among all four voltage, current, joule and specimen measurements is thus assured.

Thermopile output (dependent variable) is assessed using a Leeds & Northrup Model K-2 potentiometer. That 1960s era manually balanced wheatstone bridge uses a calomel standard cell. It has a least count of 1 μV. At a typical calibration minimum input of about 50 mW, the thermopile produces about 1 mV.

The procedure is to power the cell or heater to some fairly arbitrary power level and wait perhaps an hour for thermal equilibrium, as shown by near constancy in the K-2 readings. Then typically three readings, separated by 5–10 min, are recorded. Input power is then adjusted, and/or input is switched between specimen (or polarity) and joule heater. To get some semblance of randomness, power levels are changed arbitrarily (not in up or down series, nor in order of power level). For efficiency, however, specimen and calibration will usually be switched at roughly the same power level. A set of the order of 50–100 equilibrium calibration and specimen data points is thus acquired over several days

Readings are taken while power is stabilizing and the cell is coming to equilibrium. Those data are useful to assess calorimeter performance and to estimate total anomalous energy produced during a run. Only equilibrium data are reported here, however. So far, only manual data recording on paper has been employed, without automated data acquisition. The raw data are entered onto an Excel spreadsheet to calculate powers, provide least-squares equations for calibration and specimen performance and to compile ancillary results.

Data analysis and graphic displays are relied upon to define the performance of specimens and calibration heater, rather than trying to compare individual data points. Thus, the considerable trouble required for operation at precisely the same set of input levels for both heater and specimen measurements is avoided.

3. Experiment Results

3.1. Rough description of the experiment array

About two score of test runs have been performed, so far, to explore the effects of electrode alloy, separator and conductor composition, processing and testing technique. Electrodes have been prepared from three copper based, intentionally alloyed, compositions plus two types of unalloyed copper. Commercial materials were used: the presence of tramp elements is assumed. Intentional solid solutes were lithium and boron at total concentrations of less than one weight percent. Those alloys were cast and rolled to thin sheet or foil by the author. He added nominally two weight percent lithium or boron master alloys to commercial copper to get the desired compositions. Those copper base master alloys are normally used for copper deoxidization. Electrode materials were hydrogenated, dehydrogenated or prepared without hydrogen adjustment. Some electrodes were made of cold rolled material.

Eleven compositions of conductor have been tried. Particle content in those suspensions ranged from 2 to 19 vol.%. Cells that produced anomalous heat had typical resistance (it changes during testing) of about 3–20 Ω. Less resistance made specimens uncontrollable by the simple power supplies used. Input power was about 50–600 mW. Maximum anomalous power was 35 mW. One early cell at 100 Ω resistance produced 5 mW excess, which was within the upper half of the three-sigma band. Adjustment to 12 Ω resulted in 15 mW excess, then above the band.

3.2. An active cell

Some results from an active cell are given in Fig. 5. One electrode was a copper, 0.75 wt.% boron alloy hydrogenated at 820°C and 20 bar (300 psig) for 45 min, water quenched in capsule. The other electrode derived from a commercial copper tube. The separator was a layer of medical gauze about 25 μm (0.001 inch) thick. To make the conductor, it was saturated with a suspension containing nominally 3 μm (120 μinch) graphite particles in mechanical vacuum pump oil. Specimen resistance was about nine ohms to start.

Figure 5 is a plot of thermopile output versus input power for that example. Three-sigma statistical limits for the joule calibration data are defined by the band between the solid green lines in Fig. 5. That band is 3.2 mW wide and 0.4 mV tall ($\pm 3\sigma$). The 18 calibration data points are shown as green circles (in essentially isopower subsets of three). The green dashed line is the least-squares fit of the joule calibration data. Red triangles and blue squares indicate data points for the low-Q capacitor specimen. Corresponding dashed lines are the least-squares fits, direct and reverse polarity, respectively.

Both specimen lines and all data points are above (in output) and to the left (less input for given output) than he upper three-sigma limit of the calibration data. Above about 250 mW, that separation is roughly another three-sigma amount. Therefore, the probability (assuming normal distribution and other standard statistical criteria) that the specimen and heater outputs are the same is less than 0.3%. It appears, however, that polarities are indistinguishable from one another.

Even though the low-Q capacitor results are substantially significant statistically, the magnitude of anomalous power (excess of output power over input) is small, as illustrated by Fig. 6. Anomalous power is plotted against input, with red and triangles for direct polarity and blue and squares for reverse. Symbols are data points and lines are corresponding least-squares fits, of course.

The excess power is moderately scattered over the range of 10–30 mW for the input range of 100–310 mW. Each of the three black dashed vectors define a given locus of relative anomalous power: 6, 9 and 12% of input power. All of the data fall within the 6–12% anomalous band. They tend to cluster around the 9% vector.

3.3. A control cell

A cell using commercial copper electrode materials subjected to dummy hydrogenation was prepared. Instead of high temperature pressurization with hydrogen, alternating vacuum and argon pressurization was used. The conductor was similar in dimensions but moderately different in composition versus the active cell of Subsection B. Resistance was about 10 Ω. Results in the form of a plot of input power versus thermopile output are shown in Fig. 7.

As in the active example, the joule calibration data are shown as green circles for the individual measurements (three per power level). The three-sigma band is defined by solid green lines. A dashed green line shows the least-squares fit. The three-sigma band is 11.2 mW wide by 0.2 mV tall.

Specimen data are shown by black triangles. Least-squares fit for the capacitor is the dashed black line. In this case, there was no anomalous power because the dashed lines are indistinguishable, each from the other. There was no point in considering polarity, because the electrodes are identical. This specimen behaved thermally exactly as did the joule heater.

4. Plausibility of Nuclear and Chemical Energy

The active specimen of Figs. 5 and 6 produced a modest 406 J of anomalous energy during the testing described above. That amount is not quite enough to run one Christmas-tree light for 1 min (7.5 W times 60 s = 450 J). It was determined by averaging the beginning and ending excess power of each measurement step by the time elapsed during that step. The resulting step energies were added together over the whole set of 71 measurement steps recorded during
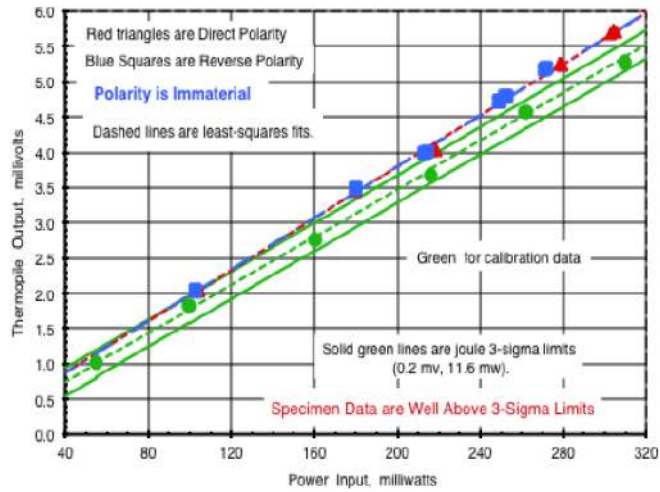
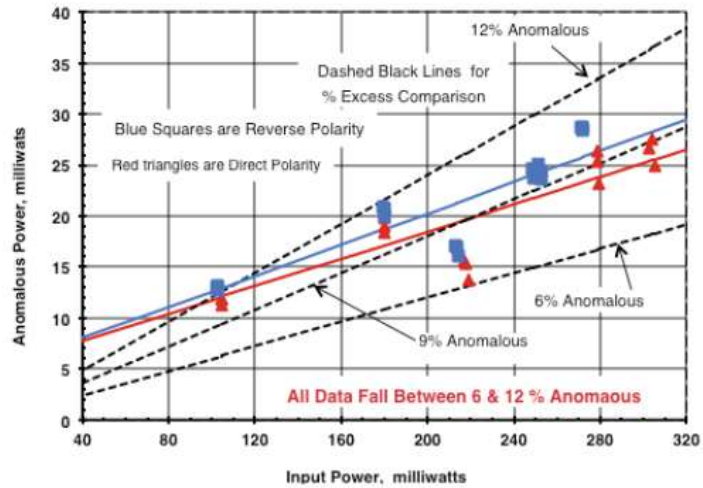**Figure 5.** Test and calibration: copper, boron and hydrogen.

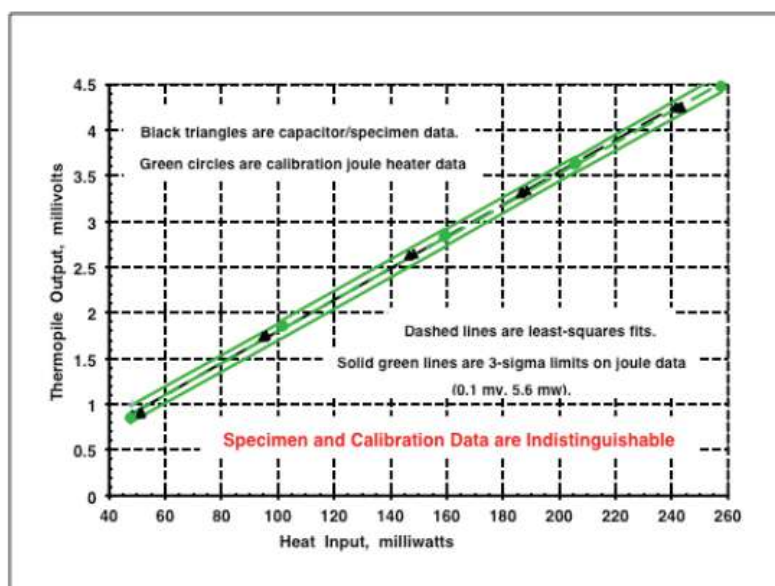**Figure 6.** Anomalous vs. input power.

Figure 7. Test and calibration of dehydrogenated copper (control).

activation of the specimen. Step-time was usually 5 min and the total time over all steps was 6.32 h (6.8% more than if all steps were precisely 5 min). Excess energy is the difference between total energy measured and the input energy. Total power here is the millivolt output of the thermopile, as measured by the K-2 potentiometer, converted to power using the equation obtained from activating the joule heater at various calibration power levels interspersed among the specimen measurement steps. Input is, of course, the product of voltage and current at each measurement step.

To assess whether the observed 406 J produced in the active specimen described here could be nuclear and/or chemical in nature, we can compare it to the energy that would result from the amounts of the various constituents of the specimen were they to undergo selected chemical or nuclear reactions, the energetics of which have been published. The calculations and published thermochemical and nuclear values used will be made available upon request. Also, readers are encouraged to apply their own chemical, physical and nuclear coefficients to the materials and dimensions reported here, to perform their own analysis of whether chemical, nuclear, or effects unknown to the author may be at work here. The specimen of Figs. 5 and 6 conforms well geometrically with the diagram of Fig. 2, which may be used to more fully understand the array of materials involved.

4.1. Chemistry

The specimen electrodes described above consist of four strips total of copper alloy 0.13 mm (0.005 inch) thick. Each is 0.76 mm (0.30 inch) wide by 6.53 mm (2.5 inch) long. Were they to be completely oxidized to Cu_2O, the (ambient) enthalpy change would be 7.7 times the 406 J produced in testing. Assuming that only 25 μm (0.001 inch) of copper on the six layers touching conductor were oxidized to Cu_2O, there would still be about four times more chemical energy evolved than produced here. With one exception, no change in appearance of any electrode has been observed following testing but the oxidation described above would be obvious. Also, there is no source of oxygen, or similar material, in the calorimeter because it is evacuated during testing. The one exception involved sulfur in the conductor,

erroneously thought to be in an inert form; after test, the black films on electrodes seemed typical of Cu_2S.

Consider oxidation of the separator/conductor. That is polyvinyl chloride (PVC, medical) gauze soaked with oil containing graphite particles, with sometimes a proprietary inert powder addition. To be conservative and avoid complexity, assume it made entirely of gasoline or similarly energetic alkane. The gauze was 25 μm (0.001 inch) thick and there were three layers of separator/conductor pressed against the electrodes. That volume of gasoline would yield about three times the 406 J produced, if completely burned to carbon dioxide and water. There was no oxygen available to do that and no such thing was observed.

Perhaps the oil of the conductor could polymerize, crack or react in some way with the PVC or graphite. It seems inconceivable that could be more energetic than the decomposition to elements (C and H_2)of an equal volume of alkane, say octane or dodecane, to produce their enthalpies of formation (250 and 352 kJ/mol, respectively). Accounting for their molecular weights and densities yields a volumetric enthalpy of 1.5 kJ/ml, for either alkane. The 406 J of anomalous heat works out to 700 times the alkane decomposition heat estimated in this way. Also, there was no evidence of any such reaction.

Suppose that only the hydrogen dissolved in the electrodes was oxidized to yield the excess energy observed. One published relationship between solubility of hydrogen in copper and temperature at ambient pressure is:

$$C = 0.102 \exp\left(-4,535/T\right),$$

where C is the hydrogen concentration in atomic percent and T is the temperature in K. Using that relationship and a square-root of pressure rule, one finds the hydrogen concentration in the present electrodes to be 0.00720 at.%, further assuming that concentration to be preserved following electrode processing at 820°C and 20 atm. Applying the mass of the electrodes and the enthalpy of formation of water results in the 406 J produced being about nineteen thousand times the heat possible from burning that dissolved hydrogen.

4.2. Nuclear reaction

Now consider the energy that might be produced by some nuclear reactions taking place in the 0.00720 at.% hydrogen dissolved in the electrodes as described in the previous subsection (about 9×10^{-8} hydrogen moles). Some potential nuclear reactions of light and heavy hydrogen with themselves and with lithium, beryllium, boron, nickel, copper or palladium are shown in Table 1.

Table 1 is based on simple arithmetic differences between the well known and published masses of the various reactant and product isotopes involved.

First, suppose boron 11 alloying-ingredient reacts with all of the light hydrogen in the electrodes to produce three helium 4 isotopes per boron 11 and 8.68 MeV, per Table I. That reaction would produce 185 times the 406 J measured, assuming the hydrogen content from processing the electrodes at 820°C and 20 atm. was retained. Should the retention correspond to only 600°C and 5 atm, the ratio of complete hydrogen burnup to energy produced would still be a factor of 33. If the reaction produced carbon and 15.95 MeV, per the table, it would be 340 times the 406 J with the nominal 820°C, 20 atm. processed electrodes or 60 times the observed output with degraded (600°C, 5 atm.) electrodes.

Second, consider that the light hydrogen reacted with the majority (69%) copper 63 content of the copper electrodes, producing zinc 64 and 7.7 MeV, per Table 1. That would be 164 times the observed anomalous power for nominal electrodes and 29 times for degraded ones.

Third, the very small heavy hydrogen content (0.0151 at.%) of the ordinary hydrogen mix used here could conceivably be responsible for the observed anomalous energy production. The maximum intrinsic output then would be 0.0036 MeV based on total hydrogen content (0.0151% abundance of D in H times the 23.8 MeV of the top line in Table 1). (The other two heavy hydrogen reactions listed produce only a fraction of the 23.8 MeV, and dangerous

Table 1. Potential nuclear reactions of light elements with hydrogen

Reactants		Products	Mass difference per reaction		Energy (kW-h/g) reacted	Value (US $ of energy/g)
			AMU	MeV		
$H^2 + H^2$	$\rightarrow$	He^4	0.02560	23.837	1,59,619	3192
$H^2 + H^2$	$\rightarrow$	$He^3 + H^1$	0.00433	4.032	26,825	537
$H^2 + H^2$	$\rightarrow$	$He^3 + n^1$	0.00351	3.268	21,745	435
$Li^6 + H^2$	$\rightarrow$	$2\ He^4$	0.02402	22.363	74,874	1497
$Li^7 + H^1$	$\rightarrow$	$2\ He^4$	0.01862	17.340	58,056	1161
$Be^9 + H^1$	$\rightarrow$	$Li^6 + He^4$	0.00228	2.125	5685	114
$Be^9 + H^2$	$\rightarrow$	$Li^7 + He^4$	0.00768	7.148	17,387	348
$B^{10} + H^2$	$\rightarrow$	$3\ He^4$	0.01923	17.905	39,965	799
$B^{11} + H^1$	$\rightarrow$	$3\ He^4$	0.00932	8.679	19,372	387
$B^{10} + H^2$	$\rightarrow$	C^{12}	0.02704	25.176	56,231	1125
$B^{11} + H^1$	$\rightarrow$	C^{12}	0.01713	15.950	35,624	712
$Ni^{62} + H^1$	$\rightarrow$	Cu^{63}	0.00657	6.120	2607	52
$Cu^{63} + H^1$	$\rightarrow$	Zn^{64}	0.00828	7.709	3232	65
$Pd^{106} + H^1$	$\rightarrow$	Ag^{107}	0.00621	5.787	1451	29
$Pd^{105} + H^2$	$\rightarrow$	Ag^{107}	0.01409	13.122	3290	66
Fission Comparison (U^{235})			0.21050	196	5589	112
$H_2 + O_2$	$\rightarrow$	H_2O	Nil (3E-9)	2.5 eV	3.7 E-3	7.5 E-5
$Coal + O_2$	$\rightarrow$	CO_2	Nil (1E-9)	1.1 eV	7.0 E-4	1.4 E-5

Value based on 0.10$ per electrical kWh delivered and 20% thermal to electric power conversion efficiency thermal to electric power.

radiation.) The 406 J observed here is, on this basis, a minimum of 13 times that which could result from complete burnup of the heavy hydrogen content of these electrodes.

In summary, it is apparent that the 820°C, 20 atm. processing of the electrodes discussed here could load them with sufficient light hydrogen to account for the 406 J of anomalous heat observed. Two reactions of light hydrogen with the boron alloying content and one with the copper were considered. Even if much of the hydrogen dissolved in the high temperature and pressure treatment is not retained (equivalent to only 600°C and 5 atm.) the remainder is still adequate. The heavy hydrogen content of the natural hydrogen used is, however, insufficient. If reacted chemically, the hydrogen in the electrodes is insufficient, by at least three orders of magnitude, to account for the anomalous energy observed. Chemical oxidation of the electrodes, or of the separator/conductor, might produce up to 10 times the anomalous energy shown if there could be any chemical reactant in the evacuated chamber that was used. Such a reaction would be obvious, but was not seen. Any chemical degradation of the separator/conductor, also unseen, would yield insufficient energy to account for these results. A chemical basis for these results is, therefore very unlikely but some, as yet undefined, nuclear reaction is probable. Table 1 lists a few, of many, possibilities. These low-Q capacitors need to be operated for months, at least, instead of the hours here, to produce sufficient nuclear reaction product necessary to elucidate what reaction(s) are responsible.

5. Conclusions

Pons–Fleischmann fundamentals are replicated, once again. This low-Q capacitor system, like several LENR methods, uses materials and processes foreign to electrolysis. Copper alloys containing light hydrogen replace deuterium-saturated palladium. Oil, containing tiny conducting particles, substitutes for lithium-bearing heavy water electrolyte. Tiny conductive solid particles replace the small deuterium bubbles deposited on P&F cathodes, for microscopic charge distribution across electrode surfaces.

The excess of output heat over input electrical energy is small (roughly 10% on good days) but statistically significant. It is barely possible that the small amount of anomalous energy shown here could have a chemical source. There are at least a few nuclear reactions, however, that do account for the energy observed, by margins of over 100 times. To uncover the reaction(s) responsible, it will be necessary to operate these cells for prolonged time and then to measure the reaction products.

No incubation period for anomalous heat was observed with low-Q capacitors. If excess heat appeared, it was there when the system stabilized (in less than an hour). This system seems consistent and reproducible but systematic repetition was not attempted. Exploring the large experiment space was desired rather than detailing it. Prospects for improvement are manifold. Development of commercial power generation appears to be feasible. In particular, the normal boiling temperature of water, as in electrolysis, is no limitation. The outlook for a supercritical steam source (say 400°C) is good.

Common, inexpensive materials and processes (e.g. Cu, light H, vacuum, thermocouples) are used instead of rare, expensive and exotic ones (Pd, D, mass-transfer calorimetry). Thus, LENR can now be advanced by a larger set of researchers and financial supporters than before. The resource limits and preliminary success of the present author attest to that fact.

There is much to be done.

References

[1] M. Fleischmann, S. Pons and M. Hawkins, *J. Electroanal.* **61** (1989) 301.