Final Consultant Report

From:

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To:

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Abstract

On December 21, 2011 I visited BLP and observed tests of and protocols for the CIHT cells. Three cells were prepared during my visit while I watched. The results generated by these cells were very consistent with those of similar cells, based on data provided to me by BLP, with electrical outputs from 10 to 2000 times the input energy. In addition, I viewed control cases that were run, and discussed with the engineers the data acquisition and sample preparation processes. After the visit, I conducted analyses of alternative possible energy routes for the observed energy release and shared these results with BLP. Based on my observation, I find no plausible alternative explanation for the observed energy release other than that of a novel electrochemical effect. Recommendations to further refine the results and exclude possible, but highly unlikely, energy sources are presented.

I. Overview

The agenda for the visit of December 21, 2012 included the following items:

1) Review with Dr. Mills the basics of his theory and potential applications.
2) Assemble typical CIHT cells and review the preparation process and results.
3) Participate in running control tests
4) Discuss and review data acquisition procedures with the technical staff.
5) Review plasma results and discuss experimental details with Dr. Lu.
6) Additional analysis performed after the visit.

Each of these items will be reviewed below.

1) Theoretical discussions

Dr. Mills spent a significant block of time reviewing the theory, with which I am somewhat familiar. Much of the theory arises from Mills' postulates on the dynamics of electrons, and in particular on the non-radiation of stable bound states. These postulates lead to a novel mathematical description of sub-atomic, atomic, and molecular systems which appears to replicate experimentally observed results, often with very simple closed form expressions. A critical difference between Mills' theory and those of other proposed unified theories is the scope and scale of the agreement between the analytical model and experimental results. This agreement includes (among many other things): bond and ionization energies, vibrational frequencies, spectroscopic constants, electron magnetic moment, Lamb shift, and nearly every measured property of the hydrogen atom and molecule. In addition, the theory predicts some critical parameters such as the masses of subatomic particles that are not predicted in the Standard Model based on the most widely used form of Quantum Mechanics.

Experimental evidence for the theory is quite diverse, and this also makes the Mills theory very unique. Data from anomalous line broadening in plasmas, spectroscopic measurements of lines and continuum features that match the theory's predictions for hydrino or dihydrino and do not correspond to any other known species, NMR shift data, excess heat generation, and many other results support the theory. These results are published in a large number of peer-reviewed publications, and the experiments involve state-of-the-art equipment and scientific personnel with Ph.D.s from leading institutions. Some results (e.g. the deep UV continuum and excess heat generation in chemical cells) have been independently replicated at other institutions.

2) Testing of CIHT cells

Blacklight Power has developed an electrochemical cell that they call the CIHT (Catalyst Induced Hydrino Transition) cell. The cells contain anode, cathode, and electrolyte, all of which are contained in an alumina crucible, and then sealed in a stainless steel or quartz vessel. The input to the cells is a mixture of argon and water vapor (regular water or heavy water), which is generated by passing the argon flow through a bubbler at room

temperature. The cell is provided with an input pulse of energy, which BLP suggests generates hydrogen gas from the water vapor. After the short hydrogen generation step, the circuit is reversed, and an output energy is measured. BLP suggests that this output is due to the hydrogen gas reacting with the H_2O-based catalyst having an energy level particular to the lithium hydroxide-lithium bromide electrolyte to induce a transition to a hydrino state – liberating energy in the process, and this energy shows up as electrical output since the output and hydrino reactions mutually depend on ion and electron flow. Cells are monitored with redundant state-of-the-art electronics designed especially for this type of testing.

Three cells were prepared during my visit, two with nickel anodes and one with a molybdenum anode.

Nickel anodes – cells 1318 and 1319

I observed the assembly of these cells, and the weighing of the anodes, LiOH, MgO and LiBr. Data provided by BLP and listed below are consistent with the numbers recorded in my notes to within +/- 0.1 grams on the electrolyte components and +/- .0001 grams on the anode. Electrode sizes are consistent with my observation, though I did not measure them explicitly.

122111XY1-1318 Flange closed, paste electrolyte Ni/LiOH-LiBr-MgO/NiO. (Validation cell for N. Glumac)
-Anode: Porous Ni C6NC (OD 1.5", 11cm2, 4.4382g, incl. wire), submersed into electrolyte.
-Cathode: Pre-oxidized porous Ni C6NC (1.5*1.5"), on top of electrolyte.
-Electrolyte: 15.0g LiOH + 75.0g LiBr + 30.0g MgO.
Temperature 450 C
Flow through Ar (Pre-humidified)

122111XY2-1319 Flange closed, paste electrolyte Ni/LiOH-LiBr-MgO/NiO. (Validation cell for N. Glumac)
-Anode: Porous Ni C6NC (OD 1.5", 11cm2, 4.9864g, incl. wire), submersed into electrolyte.
-Cathode: Pre-oxidized porous Ni C6NC (1.5*1.5"), on top of electrolyte.
-Electrolyte: 15.0g LiOH + 75.0g LiBr + 30.0g MgO.
Temperature 450 C
Flow through Ar (Pre-humidified)

Anodes were placed in the crucible, and electrolytes were placed on top of the anode and in the crucible. The assembly was then placed into a heater. The heaters appeared to be of the resistive type, controlled by Variacs. There was a readout temperature, which was typically around 530 °C. I did not see where the type Kthermocouple was placed, but I was told that readings of 530 °C corresponded to cell temperatures of 450 °C, based on some previous calibration. Such a difference is consistent with an external thermocouple which would measure a higher temperature than what is in the interior, though the temperature difference would be expected to decrease with time until a steady state difference is reached. Any residual temperature difference would be maintained by heat loss through the top of the cell.

After a time period of approximately one hour, the electrolyte was liquefied, and I verified that the electrolyte was liquefied visually. At that point, the cathode was inserted, and the cell closed and sealed. Both nickel anode cells were in stainless steel cells where the top was sealed with a conflat-type flange and a viton gasket. Lead wires were connected to rods on which alligator-style clips were attached. The rods were

passed through electric feedthrus in the top flange, and sealed with compression-type fittings with Teflon ferrules. The fittings were hand-tightened to seal the joint.

At this point, electrical connections were made, and the flow of argon was initiated through the water vapor generator. The Ar flow rate was set at 2 sccm. I was directed to the computer that was connected to the Arbin BT2000 unit. I saw the line appear on the readout for the cells we had prepared, and the program routine was engaged for cycling the cell according the parameters reported by BLP. I verified that these parameters were indeed the ones that I saw on the screen.

After this point, data were provided to me by BLP, and my report will comment on the data as provided to me.

Molybdenum anode – Cell 1320

This cell was prepared in a fashion similar to that of the nickel anodes, except that it was a quartz cell with a Teflon seal. In my opinion, the type of cell makes little difference in the analysis of the results, and this opinion is consistent with that of the BLP engineers that I worked with. There is an increased expense of working with transparent cells, as well as an increased possibility of damage. Having the ability to view inside the cell is advantageous, but only minimally. Similar data was also provided on Mo cells run in stainless steel cells that was generated as part of the validation programs for other scientists.

Note: Materials used in these tests were present at the BLP facility and used in my presence. I cannot verify (nor did I ask to verify) that the materials used were exactly as specified by BLP (e.g. that the anodes were nickel and molybdenum, that the chemicals used were what was specified on the bottle, etc.). However, there was no reason to doubt this identification, and samples were offered for testing. The molybdenum anode looked much like moly samples I have used in the past, and powder samples appeared to be of the appropriate form.

Output cell data

Data from the cells that was provided to me is appended as data sheets for each case, as well as a summary sheet. Based on the data that was provided to me, the two nickel cells that were initiated during my visit exhibited energy outputs far in excess of the input. At 17 days after initiation, one cell (1319) showed 9.9x output compared to the input, and cell 1318 showed 14.4x output. The final dataset that I saw was for 36 days of run time, at which point these cells continued to show strong net outputs (9.1x for 1318, and 12.4x for 1319). While there was a factor of up to 1.5 difference between the two cells at times (which is indicative of variability in the process) the output remains far above the input. It is important to recognize that the difference between input and output is orders of magnitude (as opposed to a fractional difference that has been reported in many alternative energy schemes), which makes this particular process exceptional.

The molybdenum anode cell showed a much greater energy input/output ratio of over 1800x, which was fairly steady over 18+ days, starting at around 2400x, dipping down a bit to 1600x, before asymptotically approaching 1900x. Output was still climbing at 18 days with a total output of nearly 1.8 W-h, suggesting that this cell was showing no signs of adverse aging effects. At 36 days (the final update), the output remained at 1890x input. The huge difference in output versus input here likely dwarfs any reasonable uncertainty estimates in energy input.

3. Control cells

I was presented data and information on several control cells that were run previously by BLP. In my opinion, the company has made an extensive effort to run a variety of controls to exclude other possible energy-related phenomena that might interfere with the results.

Test data presented before my visit were for essentially identical cells without the addition of water vapor, as well as a case where the anode was replaced with NiO and a case where the MgO was removed. In all these cases, the cell was continuously discharged. Results for these cases all appeared similar, with the cells producing minimal output for several hours and then going negative.

During my visit the control of dry argon flowed into the cell was repeated, and several additional controls were run with the intermittent discharge. These controls comprised a Ni anode cell having the LiOH-LiBr electrolyte with dry Ar, a Ni anode cell with KOH instead of LiOH, and a Ni anode cell with NaOH instead of LiOH. Subsequent to my visit, I was presented with additional controls and data on the effect of H_2O and electrolyte on the oxygen reduction rate. These, in my opinion, are more appropriate controls since they are subject to the same conditions as the output-producing cells. The results shown to me indicated that all the cells produced a small burst of power in the first few hours (presumably due to adsorbed water from cell preparation), followed by a sharp drop in output by the end of the first day. At this point, the cell output was less than the input. After two days, outputs of 0.02 W-h were observed, whereas data from the test cells typically had several times greater output by that time and were producing a net output (output > input). Additional supplementary data included the confirmation that the anode was not corroded as indicated by SEM, and analysis of the electrolyte by ICPMS and XRD showed that it was unchanged other than some dehydration, a process that consumes energy.

4. Data acquisition system

Considerable time during my visit was devoted to discussing the data acquisition system. While I was present, I observed a static voltage calibration where one volt was applied by the Arbin system, and the data acquisition system output and a Fluke meter output were monitored. The agreement was within about 1 mV.

I asked to see dynamic calibration data, and I was presented with some data during my visit and additional data after the visit.

In particular, I was shown the following:

- Tested against a dual square waveform generated by an Agilient 33220A 20 MHz Arbitrary Waveform Generator and compared to a Tektronix TDS 3054B 500 MHz 5 GS/s Oscilloscope:
    - Major waveform: 2 Hz cycle, 300 ms on pulse, 0.2 V p-p
    - Minor waveform: 166 Hz cycle, 600 μs on pulse, 40 mV p-p
    - Sample data obtained at 10 KS/s on both the DAS and oscilloscope and both the major and minor waveforms were clearly resolved
    - V*t areas matched to 0.6%

The waveforms that are analyzed for processing to determine energy input and output consist of two regions – a short input period that is much less than one second, and a longer output pulse. Both pulses must be accurately time-resolved, and the calibrations that were provided suggest that the system is capable of accurately resolving any transient process down to at least as short as a few hundred microseconds.

5. Plasma discussions with Dr. Lu

I am quite familiar with the plasma spectroscopy work of BLP, and I was interested in seeing the setup and the techniques used, as our lab conducts similar research. I spent approximately 1 hour with Dr. Lu, and I went over his setup and approaches and reviewed some results. I find the spectroscopy setup at BLP first-rate, and the equipment and procedures are all state-of-the-art. The results obtained by Dr. Lu are, in my opinion, likely to be highly reliable.

6. Post-visit Analysis

Subsequent to my visit, I looked into several issues related to the thermochemistry of these cells. A central theme of the BLP claim is that there is no conventional thermochemical explanation for the observed results. The primary claim is that the output energy cannot be explained by anode oxidation or electrolyte chemistry. I reviewed these claims and added some additional analysis. I identified two possible exothermic pathways that I had not seen mentioned in the BLP analysis, and I investigated the possibility of thermal dissociation of water to produce H_2 and O_2. I forwarded some preliminary analysis to BLP, and they provided detailed analysis that ruled out these possible pathways.

II. Conclusions and Recommendations

Based on my visit to BLP in December 2011, I saw no significant flaws in the approach used by BLP with regards to the CIHT cells. Experiments were performed carefully and in a repeatable fashion. Appropriate precautions to avoid experimental bias were taken.

Many different control runs were performed to assess possible sources and identify processes that contribute to the overall energy release. The equipment and setups are state-of-the-art, and the equipment used is operated within its appropriate range. Experiments are repeated regularly to assess test-to-test variation and verify results.

The energy produced is small, but not insignificant. About 2 mW of power are produced – similar to a very small battery. The total energy of 2 W-h is much smaller (at least 10x) than the energy required to heat the cell to operating temperature. As such, it is critical that accurate measurements of voltage and current be made here to insure that excess power is indeed being produced. In my opinion, BLP is making measurements of the appropriate level of accuracy to resolve the power output and conclude that it is far in excess of the input.

Scale-up, of course, is critical, and scaled-up results showing a true net energy output (i.e. electrical output out greater than input to cell plus input to heater) is obviously necessary for commercial success. However, the detailed and careful results presented to date clearly warrant scale-up and provide confidence that scale-up will be successful.

I provided several minor recommendations to BLP regarding possible improvements to their setups to improve characterization of the transient electrical pulses, improve sealing on the cells, and on generating more thoroughly instrumented cells that would enable more data to be collected from inside the cell during operation. None of these recommendations is critical nor are they likely to alter previous results and conclusions, but they would represent further incremental improvements in the setup, improve the precision of the measurements, and certainty of the analysis.