10 meter Electrolytic Cell Experiment

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BACKGROUND

The following was cobbled together from a hodge podge of posts and old photos. Hopefully I got the photos labeled right. The experiments here should be repeated with good equipment and on a more professional basis. Their main value lies in the fact the perspective seems to be a bit novel.

To investigate the rate of electric potential travel and conductivity changes vs. flow rate, I constructed a super-stretch 10 m cell to enable measurement of timing using my very unstable 1960's vintage war surplus oscilloscope.

The 10 m cell length is actually 10.31 m of 1/8" ID Tygon tubing. The length of the Pt exposed to the electrolyte is 6 cm, the NiCr wire 18 cm. The length of Pt wire exposed to moving electrolyte is 3 cm., the NiCr wire, 13 cm. The difference is due to the fact the wires are inserted into the flow using a 1/8" ID barbed T connector, where the electrolyte enters from a 90 degree angle and the wire goes straight through the T. The end seals are compression fittings made by cutting halfway though a rubber stopper and inserting the wire. This was fit into the large end of a threaded 1/4" pipe to hose fitting. A compression cap was made by drilling a 1/4" hole in an ordinary 1/4" pipe cap. A piece of 1/6" thick rubber spacer was cut to fit on the end of the stopper and a small hole was punched through the middle to accept the wire. The compression cap was fitted over the spacer with the wire extending through the middle and tightened down. All the seal parts were bought at Eagle Hardware.

The electrolyte used was 200 ml of 1 M Li2SO4. Fluid flow velocity was 9'5" in 60 s or 4.78 cm/s. Fluid flow rate was 23.9 ml in 60 s or 0.40 ml/s. Pressure oscillated between 21 and 22 mm Hg at the pump rotational frequency of 2 Hz. A drip degasser was included in the fluid circuit to ensure the current flow was one way. The steady state and flowing state battery voltage from the Pt-NiCr battery was .382 V. For this experiment flow was always from the NiCr electrode towards the Pt. electrode. The electrode leads were switched between the two sets of measurements.

The following V vs uA measurements were made:

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Table 1 – uA with – on NiCr and + on Pt

V,	Steady,	Flow,	Steady,	Flow
3,	7.9,	7.8,	7.8,	7.5
5,	18.3,	17.8,	18.2	17.7
7,	28.6,	28.0,	28.4,	28.0
11,	39.1,	49.9,	49.4,	49.6

Table 2 –uA with – on Pt and + on NiCr

V,	Steady,	Flow,	Steady,	Flow
3,	13.1,	12.6,	12.5,	12.4
5,	23.3,	22.9,	23.0	22.9
7,	33.3,	33.5,	32.7,	33.3
11,	53.6,	55.3,	51.9,	55.2

The measurements were made by starting with a steady flow at 3 V and moving up to 11 V, then turning on the pump and varying the voltage downward to 3 V, and the turning off the pump and varying the voltage upward. The significance of this is in the fact the changes in uA between steady and flowing involved no change of settings on the power supply, the current simply increased when the flow was turned on, i.e. 39.1->49.9, 49.4->49.6, 53.6->55.3, 51.9->55.2. The current increases took place over a period of about 10 seconds. I have no explanation for the very large increase of 39.1->49.9 uA at 11 V in the first set of data, but it is not an error in recording the data. It is possible (but not likely) some bubbles were very slowly cleaned off the electrodes, but the other data was taken in the same fashion and the 10 V change never occurred again.

To check propagation rate a 5 V 1 kHz A/C square wave, with the plus pulse slightly longer than the negative pulse, was applied in both flowing and steady state electrolytes. The results were indistinguishable. The output waveform matched the shape of the input, except the there was a typical RC response delay curve in both the rise and fall edges, indicating a significant capacitance. To check that the RC curve was not due to inductance, a copper wire was laid out on the floor next to the 10 m loop of Tygon and connected in the circuit in place of the fluid circuit. The output waveform exactly matched the square input waveform.

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The time constant of the RC response was about 40 us, i.e. the waveform reached 66 percent in two divisions or 4x10-5 seconds. This means the peak voltage is 99 percent reached in 2x10-4 s on a pulse width of 1/2000 th of a second, or 5x10-4 s. To check this the Tygon tubing was pinched with thumb and forefinger, thus increasing resistance, and the curve flattened out.

As a cross check a DMM was used to measure the capacitance. With the + lead connected to the Pt the capacitance was .094 nF or 9.4x10^-11 F. Reversing the leads the capacitance was measured at .084 nF, or 8.4x10-11 F. Using the first V vs uA table value of 17.8 uA at 5 V, we get a resistance of 280k, or 2.8x10^5 ohms. This yields a time constant Tc = (9.4E-11 F)*(2.8E5 Ohm) = 2.6E-5 s, or about 26 microseconds, which is not far from the 40 microsecond Tc approximated from the waveform.

This large time constant is an indication that the capacitance of the fluid will prevent better measurements of propagation rate of the electric pulse using this technique, even with a better oscilloscope, due to the long rise time caused by the fluid capacitance and resistance in a 10 m cell.

Earlier Michael J. Schaffer michael.schaffer@gat.com wrote:

"First, with regard to speed. What moves at the speed of light is the electromagnetic field. You apply a source of electrical energy to a system and electric and magnetic fields propagate throughout in accordance with the CHANGE in conditions, in this case connection of the source. Of course, the EM fields are modified by the environment, such as by wires, pure water, electrolyte, dielectric, magnetic materials, etc. The speed of an EM wave in water (from DC to microwave range of frequencies) is about 1/9 its speed in vacuum."

This experiment is completely in accord with 1/9 C as a propagation time, but can not confirm it, as at this speed the propagation time in the 10.31 m cell would be 3.44x10^-8 s, or .034 microseconds, which makes the 40 microsecond rise time look gigantic. However, the pulse leading edges matched the input waveform to a resolution of about 1 part in 100 or to 10 microseconds. This means the propagation speed can not be less than 100,000 m/s. This greatly exceeds the 1,500 m/s speed of

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sound in water.

EM waves in wires are propagated via electrons in metal conduction bands. Since the proton is 1836 times heavier than an electron, it seems like a propagation mechanism involving the proton would be limited to $C/1836 = 1.63 \times 10^5$ m/s, unfortunately very close to, but outside, the resolution of this experiment. It is necessary to repeat the experiment using a two channel digital oscilloscope.

Images of the oscilloscope traces from the super-stretch electrolytic cell EMF propagation speed experiments are shown Photos 1 - 3 below.
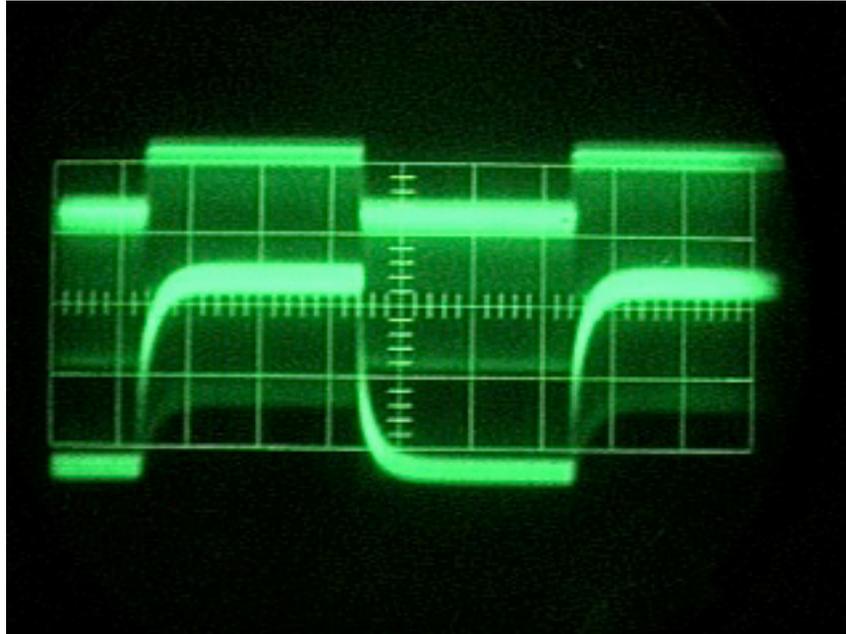

Photo 1 - V_in (top), V_out (bottom)

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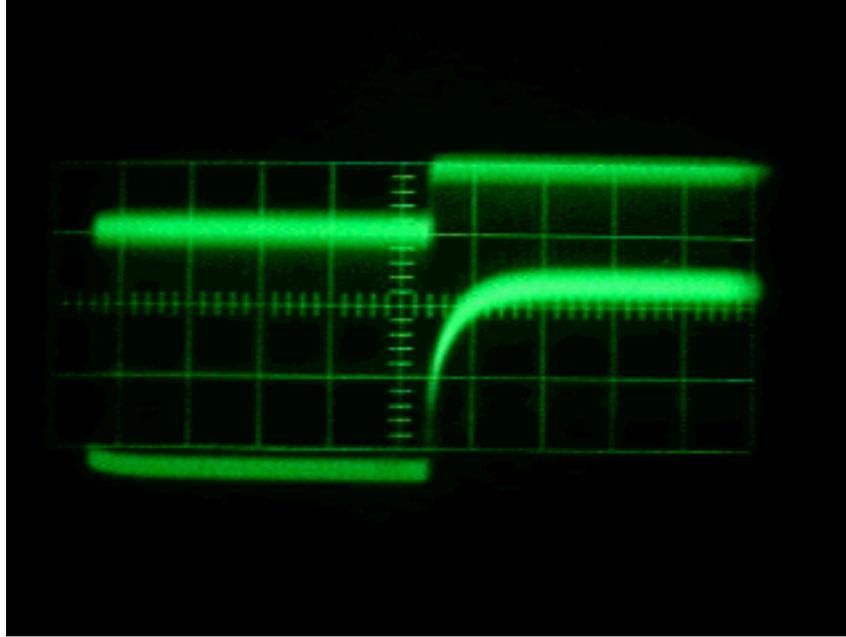
Photo 1a - V_in (top) V_out (bottom) - Exploded view
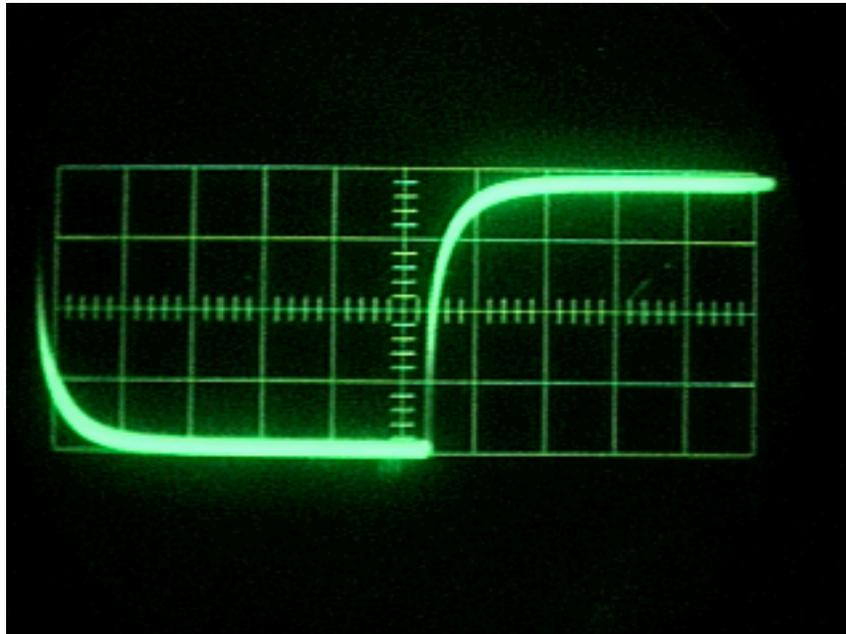

Photo 2a - V_out   - High Res.

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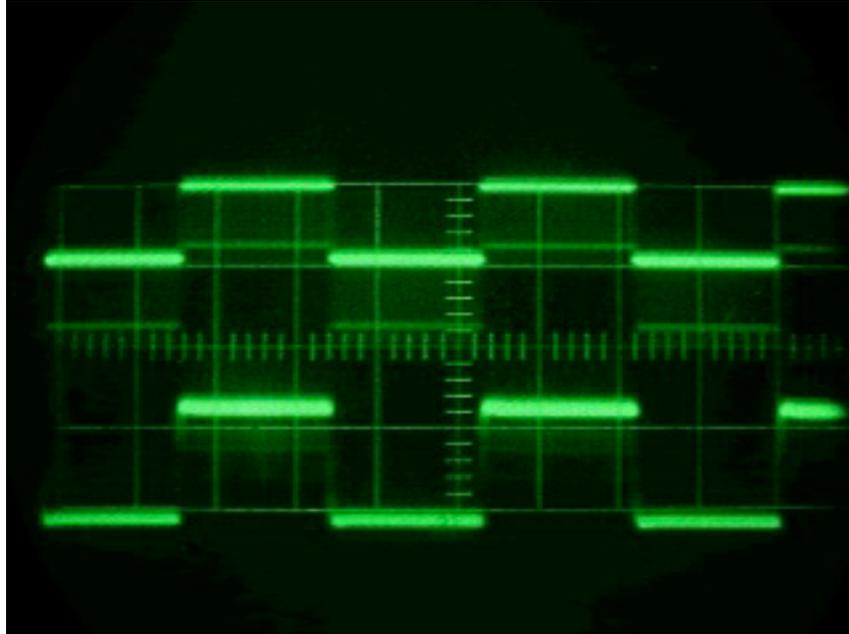
Photo 2 - V_in (top) vs I_out (bottom)
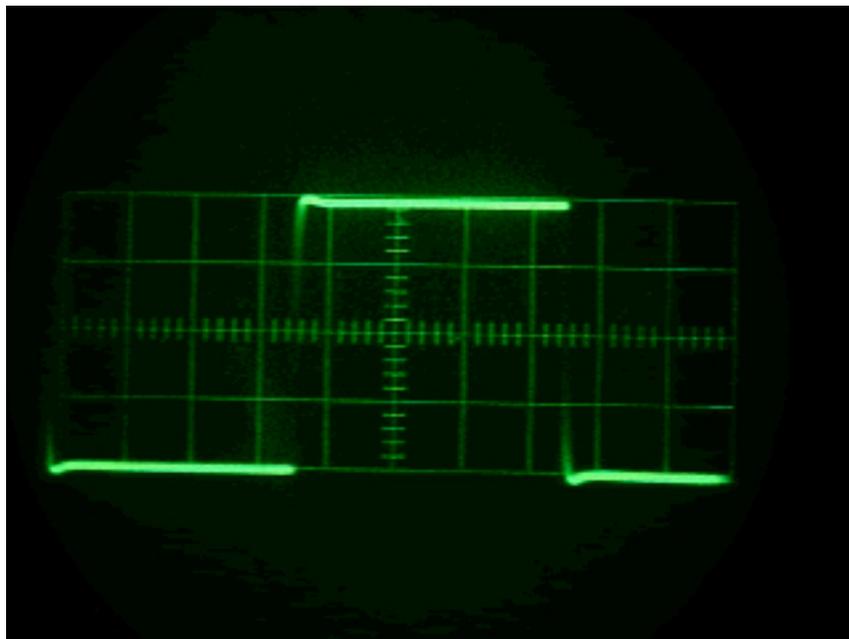
Photo 3 - Current vs time, higher resolution

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These images are provided so others can interpret the data directly. The images were taken today, by direct video with the Pt electrode as input and nichrome electrode as output. They are representative of the waveforms referenced in prior posts. Electrolyte flow was from the nichrome electrode toward the platinum electrode. Other cell conditions were as stated in the original post, and as restated below for convenience. Exactly the same waveforms occurred regardless of fluid direction or reversing the leads.

The input waveform appears at the top of the dual trace photos, and is 10 V peak to peak and 1 kHz. In the dual trace photos the two waveforms are presented simultaneously on the oscilloscope by chopping together the output of two preamplifiers. The quality of the single trace images is much improved because it was obtained by replacing the two-channel chopping pe-amp module in the scope with a single channel wide-band (well it was wide-band in the 60's) preamplifier module to get a better picture of rise time. The output waveform was obtained using a 100 MHz rated probe purchased yesterday, but that did not change the waveform from prior measurements using a lesser probe.   The output waveform is between 7.5 an 8 V, indicating a current draw is present corresponding to about a 1 megohm impedance from the scope and probe. Both probes were set to 1x.

Note that photo 2 shows no readily discernible time delay between leading edges of the input and output traces.

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Noting Photo 2, there is appx. 10 cm per $1x10^-3$ seconds. Each cm is therefore about 10^-4 s, and each 2 mm division about $2x10^-5$ s. The two waveforms match to at least .5 division, which is $1x10^-5$ s. The distance traveled is 10.31 m., so the minimum velocity must be $(10.31 m)/(1x10^-5 s) = 1x10^6$ m/s. My earlier estimate of 100,000 m/s was low because of the mental error of forgetting the cell was 10 m long. The corrected upper limit for propagation velocity is much faster than the suggested $1.63x10^5$ m/s upper limit for EMF propagation speed via the proton, so, by the arguments earlier posted regarding EMF propagation mechanisms, confirms that the only viable mechanism for propagating the EMF is via the electron.

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I included a 150.6 K ohm resistor between the cell output and ground. Thus the cell and the resistor would act like a voltage divider, plus the voltage measured at the resistor would determine the current through the resistor.

Using a 10 V supply we get a current of 44.3 uA and a resistance RCA = V/I = 10/44,3x10^-6 = 226 k ohms.

Because in the original tests the voltage dropped about 20 percent, it can be estimated that the scope itself has an impedance of roughly 904 k ohms. The combined impedance of the scope plus the 151 k ohm resistor is Re = R1*R2/(R1+R2) = 151*904/(151+904) = 129 k ohms. The combined circuit resistance is 192 k + 226 k = 418 k ohms. The voltage at the cell output to the resistor should be roughly (10 V)*(192 k)/(418 k) = 4.59 V. This voltage was measured at roughly 4.6 V by comparing the trace with the output of a 4.61 V series of 3 AA batteries. This means the peak current through the resistor is Zr = Zr/Rr = 4.6/150,600 = 30.5 uA. The peak current through the scope is 4.6/904,000 = 5 uA. The cell peak current was 35.5 uA.

The scope output showed almost exactly the same timing as before. However, the output peak flattened out a bit due to the better matched impedance, and there was a small overshoot to the leading edge. The overshoot had a duration of roughly 50 microseconds, and a voltage of less than .2 V.

The most startling result was that, when the fluid was flowing, the little overshoot oscillated (pulsed up and down like a human pulse rate) at a rate matching the pump pressure cycle as shown on the pressure gauge. Also, the leading edge looked animated, as if it were flowing, with little bright spots. The very strangest part of this is the exact same results were obtained by switching leads. It appeared that *any* flow rate increase would momentarily drop the cell resistance, increase the current, by a very small fraction (2 percent), *no matter which way the leads were connected.*

EM waves in conductors are carried by electrons, and the delay is a function of their mass. An EMF can only be carried by charge motion I=dQ/dT. True photon based propagation can occur in wave-guides or on the surface, but these will not propagate a DC EMF or current. A photon can not get very far inside a copper wire. It must

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displace a charged particle to propagate the EMF wave. It appears the EMF wave in a PPC (electrolytic cell) travels at over 1x10^6 m/s. Thus charge deficits are quickly equalized via electron motion. It appears, due to the Faradaic efficiency, though, that much of the current is carried via ions, but I think maybe this should be discussed a bit.

EXISTING DATA

The first test was done to get a picture of cell current vs time with a fixed supply of 10 V. This test was done with the Pt electrode positive, and the nichrome electrode negative. Electrolyte flow in all tests reported here were from the nichrome electrode toward the Pt electrode, regardless of the polarity used for any particular test. The I vs T data follows:

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Table 3 - I vs T Data


Time    Current in uA
0 s     47.1  (Electrolyte flow turned off)
15 s    46.5
30 s    46.1
45 s    45.9
60 s    45.7
75 s    45.7
90 s    45.6
105 s   45.5
2 m     45.4
2 m     45.8 (after tapping electrodes)
3 m     45.5 (Electrolyte flow turned on)
6 m     45.9
8 m     45.9
10 m    45.8
15 m    45.7
20 m    45.7
30 m    45.6
1 h     45.4
1.5 h   45.5
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The following uA measurements and calculations of average current for
flowing electrolyte conditions (Iavg) and corresponding V/I resistance k
ohms (Ravg), and the V/I resistance assuming a -0.4 V battery voltage
correction (Ravg at V-0.4), were made:

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Table 4 - uA with resistor still in place, - NiCr, + Pt

V  Steady  Flow   Steady  Flow   Iavg  Ravg   Ravg at V-0.4
3   4.2     4.2    4.2     4.2    4.2   714    619
5  10.0    10.0    9.9    10.1   10.1   495    455
7  15.9    16.0   16.0    16.0   16.0   437    413
9  22.0    22.1   22.0    22.1   22.1   407    389
10 25.0    25.1   24.9    25.1   25.1   398    382
11 27.9    28.1   27.9    28.1   28.1   391    377
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Table 5 - uA with resistor removed, - NiCr,  + Pt

V  Steady  Flow  Steady  Flow  Iavg  Ravg   Ravg at V-0.4
3   7.5     7.5   7.4     7.5   7.5   400    346
5  18.1    18.5  18.2    18.3  18.4   276    250
7  29.4    29.7  29.4    29.6  29.7   236    222
9  40.6    41.1  40.6    41.1  41.1   219    209
10 46.1    46.7  46.2    46.7  46.7   214    205
11 51.8    52.4  51.6    52.4  52.4   209    202




Table 6 - uA with resistor removed, - Pt,  + NiCr

V  Steady  Flow  Steady  Flow  Iavg  Ravg
3   16.7   14.1  14.0    13.9  14.0  214
5   26.2   25.2  24.9    24.9  25.1  201
7   36.2   36.7  35.9    35.9  36.5  191
9   47.1   48.0  45.8    47.9  48.0  187
10  52.5   53.8  51.3    53.7  53.8  186
11  58.1   59.8  56.7    59.4  59.6  185
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ADDITIONAL INFORMATION

Even though a current probe was not available, an effort was made to look
at current by running the cell output through a ferrite core before going
to ground. A 5 turn loop of wire was wrapped around the core and connected
to the oscilloscope ground and a 100 mHz rated probe. The resulting trace
was very low voltage but yielded some information about the current. First,
the trace consisted of spikes of unmeasurable width at a location on the
time scale corresponding to the square wave rising and falling edges. Even
though the spikes could not be resolved, it was very clear that there was a
complex waveform in the spike. This was clear because there were bright
spots in the waveform corresponding to what must be current peaks at
various times. A good scope should be able to break that spike out into a
kind of arrival time spectrum which might be related to electrolyte
composition.

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SUGGESTED METHODS OF IMPROVING THE EXPERIMENTAL TECHNIQUE
FOR FUTURE EXPERIMENTS

(1) Don't use metal parts in electrode seals. Some related corollaries to
Murphy's law: places that are supposed to be on the dry side of a seal
aren't. If they were dry yesterday, they won't be dry today.

(2) Based on the current vs time (at 10 V) curve above, the cell should be
allowed to stabilize at least one minute after changing cell voltage
before taking a current measurement. Failure to do so results in an up to
3 percent error.

(3) The electrolyte should be cleaned of impurities by filtering with a
carbon filter for and doing electrolysis

(4) The electrodes used in the experiment were fed through a T connector.
This means a portion of the electrode was in a stagnant location. This
could be improved by insulating the electrode up to the point where it is
immersed in flowing electrolyte. A possibility is to insert the electrode
through a fine hole in the tubing and seal it with goop or epoxy.

(5) Control the absolute pressure. This should not be dangerous because of
the very small amount of H_2 generated by the uA current of a 10 m cell.
This can be done by using a hermetically sealed drip chamber and applying
fluid pressure via maintaining water level in a piece of tubing branched
from the system via a T connector. The elevation of the water level can
be adjusted by moving the tube up or down so the pressure gauge at the pump
remains at a constant level.

(6) Use a high bandwidth digital scope with voltage and current probes.

DIRECT CONCLUSIONS FROM DATA

(1) The most significant conclusion is that charge differential can be
equalized in a 1 m Li_2SO_4 electrolytic cell at a velocity of more than 10^6

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m/s in a field gradient as small as 1 V/m, and this can happen in an electrolyte flowing at over 4 cm/s in either direction. This is determined by looking at the rise time of the square wave at output of cell vs input of cell.

(2) Cell current appears to be slightly improved by a flowing electrolyte.

(3) The unexpected 0.4 V drop in the output voltage square wave appears to be the well understood faradaic rectification effect.

ANALYSIS

It is reasonable to assume there are two very different electrolyte regimes in the electrolytic cell (a) The several micron thick electrode interface and (b) the solution. The electrode interface is an area of intense field gradients and electron transfer. It is significantly affected by electron tunneling. The electron flux is massive in *both directions*, but there is a net electron flux equal to the cell current. The interface has been a subject of much study and modeling. The nature and performance of the interface seems to be well known. The solution is a low field gradient regime where charge is assumed to be carried strictly by ions and charge transport, as well as all other matter transport is almost entirely by diffusion. This is because the field gradient is primarily at the interface, and not in the solution. An $H+$ deficit in the nearby vicinity of the cathode results in a concentration gradient approaching the cathode which results in diffusion. It is assumed that charge can be transported in the solution regime by species not directly involved in the primary reactions evolving H_2 and O_2, namely by $Li+$ and SO_4- radicals. Their role is to carry the current. Again this role is filled by diffusion.

Based the fact that charge can clearly move through the solution at 10^6 m/s, much faster than heavy nuclear ions can propagate a wave via a local field gradient change, there appears to be an inconsistency in the assumptions. I suggest the possibility that, to some degree, charge is transported through the solution regime via electrons. It is interesting that this could be true without changing any existing model for steady

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state electrolysis. This is because the electron charge transport would occur in the solution regime and terminate with great likelihood when the electron reaches the ion gradient at the boundary of the interface regime. The net effect of the electron transport could look like an actual ion transport. It is just that a charged species is replaced (in net effect) by an uncharged species at the end of the electron propagation chain, or vice versa. For example, given a starting condition of an Li atom at the anode and Li+ at the cathode, and electron exchange could occur of the form:

Li.............Li+ (initial condition, Li momentarily created by electronation)

Li+...e-..->...Li+ (electron transiting)

Li+............Li   (electron transit complete. Li then quickly gives up e-)

The net effect is equivalent to a charged species diffusing in one direction, and an uncharged species in the other. The electron propagation could be via holes or actual electrons. It is already suggested that the proton propagation rate is high and tunneling is being suggested as a possibility. Due to the electron's far greater ability to tunnel, it seems like electron tunneling in the solution regime should be considered a possibility.

SIGNIFICANCE TO COLD FUSION INVESTIGATIONS

(1) Due to the suggested electron conductance, there would be no change expected in the ratio of electrons through the cell to evolved H_2 (or O_2) because the suggested electron conduction would only affect the mechanics of charge transport in the solution regime.

(2) There should be no difference in the chemistry, other than recombination rate, of a cell with electrolyte flowing from cathode to anode (normal cell) or in a perpendicular way, between the two electrodes (orthogonal cell). The flowing electrolyte, according to the above data, increases the current flow, as would be expected, due to the fact that the

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rate of diffusion at the boundary of the interface is enhanced via the flowing electrolyte.

(3) The lack of difference in chemistry between the normal cell and orthogonal cell is extremely good for the development of CF, because the orthogonal cell can be easily scaled up to any required size, as per my prior posts. The one significant difference, that of recombination avoidance by the orthogonal cell, is beneficial. By placing a bubble barrier between the two electrodes, and maintaining separate electrolyte steams and degassers, the H2 and O2 can be separated for use in fuel cells, etc. The benefit of flowing electrolyte increasing the diffusion rate, and purging the bubbles, is still present.

(4) The rapid electron conduction rate is an indication that there is a very large domain of possibilities to explore in the high frequency range. Of special interest are nonlinear conditions at the interface where small (e.g. 120 mV) voltage change result in 10 times more current. Since the cell has a natural inductance and capacitance it may be possible to use the cell in this regime as a tank oscillator which can "hammer" the H+ ions into the lattice. The natural resonant frequency could be tuned by changing electrolyte concentrations and electrode geometries. An oscillating current electrode might be designed that would evolve O2 and adsorb or recombine nearly 100 percent of the hydrogen.

(5) Further investigation and analysis of the rate of charge equalization in the solution regime of an electrolytic cell seems warranted. It appears most investigations have been carried out using cells with electrodes, and thus electrode interfaces. This muddies the water with regard to transport in the fluid regime. Using electrodeless cells might assist in investigating electron charge transport, if existent. Charge differentials can be generated in tubing carrying electrolyte via induction, thus avoiding the need for electrodes altogether. Resulting currents can still be examined via current probes, which do not require electrodes. Such configurations might possibly be used to generate pressure peaks, i.e hammering pulses, in a sonoluminescence based fusion devices. It may be possible to generate such pulses in electrodeless MHD pulse generators. Understanding the mechanism of current propagation would be essential for

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engineering such devices.

SOME DISCUSSION

Electromagnetic fields can convey only oscillating fields, not a static charge. Only a particle can carry a charge. Even a purely static electrostatic field can only extend potentials according to the inverse square law. A static 10 V EMF at the tip of a .015" wire can barely be measured at 1 m, much less 10 m. You certainly can not do it with my equipment. If EM fields conveyed potential through conductors you could simply remove the water from the 10 m cell and still measure the same EMF. That will not work. The EMF can not be carried by photons, except *between* particles. The charge bearing particles receiving the impulse then must *move* to propagate a field strength change on to the neighboring (charge wise downstream) particles.

An EM pulse could induce voltages, at least a momentary field gradient, at 10 m distance, but it would require major energy, and would be clearly dynamic. The 1 kHz pulse comes up to equilibrium - it in effect is not a pulse. If you connected a 10 V battery instead of the square wave generator, it would come up to the same potential at the same speed and stay there indefinitely. An electromagnetic field is propagated in a sinusoidal form. For every potential swing there is an equal energy but opposite polarity swing due to the generated magnetic field collapse.   There would be some indication of back swing before the particle carried pulse arrived.

There is some evidence the potential can be carried forward by electrons in electrolytes. That evidence is the fact the Faradaic efficiency is not 100 percent. Some of the current must be in the form of electrons. It takes only a very small number of electrons to carry a potential forward. The number required to do so in a conductor that is open at the end strictly depends on the capacitance of the conductor, as determined strictly by it' surface area and geometry. Electrons must carry forward the potential in electrolytes in a manner similar to the way a lightning leader is formed. The heavy nuclear ions would respond eventually with motion.

Fast charge propagation via electrons is not surprising when you think about the size of the de Broglie wavelength of a thermal Electron. It is huge, much larger than the largest atom. And the mass is very small. Free electrons, and conduction band electrons, must be very very good at EMF propagation. Thinking aloud about this a bit, it is possible for electrons to propagate charge without leaving their orbitals.

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This is by simply deforming their atoms to create dipoles. The electron orbital moves relative to its nucleus, in a local field gradient, but the inertia of the nucleus prevents motion so the wave potential is propagated. Ions in the solution can then eventually respond (but in parallel) to the local gradients in a speed that approximates spontaneous inertial recovery of the atomic dipoles, i.e. due to the atomic dipole nuclei finally responding with motion. It seems like each atomic dipole nucleus would overshoot, resulting in a resonant decay mode frequency characteristic of the mass of the nucleus. Weird thought, EMP resonance instead of NMR. Forensics application there? Much slower effects, like H2O (naturally a dipole) molecular rotation could also complete the job of EMF propagation.

It is interesting that Storms in his "Critical Review of the "Cold Fusion Effect", page 42, item 10, states that RF frequencies, especially 82 MHz, is helpful. Maybe the electrolyte plays a role as a resonator/oscillator in this regard. If your get the right electrolyte mix, you get the right resonant frequency.

EPILOG - JANUARY 2006

There are really two issues explored here: (1) starting conduction fast and (2) sustaining current even though the electrolyte is flowing.

The "starting conduction fast" issue can be resolved by looking at the electrons shells as if they were a fully connected lattice. Only the lattice needs to move initially in order to subsequently get every nucleus accelerating *in parallel*. The wave front propagation does not depend on atom-to-atom nucleus momentum exchanges.

The "sustaining current against electrolyte flow" issue might be answered by noting that both positive and negative ions move with the flow. The species moving with the flow carries the current. The retarding of the other species also carries the current. The only condition that flow rate should affect conductivity would be the condition where there are no negative ions, and, due to dissociation, that does not arise.

It is noteworthy however, that electrons can tunnel through multiple water molecules. See:

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http://arxiv.org/pdf/cond-mat/0207016

http://www.dukenews.duke.edu/2005/11/watertunnel.html

At distance of up to a few angstroms tunneling rates don't change much:

http://www.physorg.com/news8476.html

http://www.eurekalert.org/pub_releases/2005-11/du-et112105.php

http://www.chemlin.de/news/nov05/proteins.htm

google: tunneling electrons water molecure