**Electrolyzer AC Power Design**

Horace Heffner September 2007 Draft #6

## OBJECTIVE

A frequent objective of electrolysis cell designs, and the objective here, is to overcome the DC bias required to push current through the interface layer between the electrolyte and the electrodes while driving the principle electrolysis current from an AC source. Figure 1 shows a method of adding an alternating electrolysis driving current on top of a DC bias in such a way the principle electrolysis current is driven by the AC source.

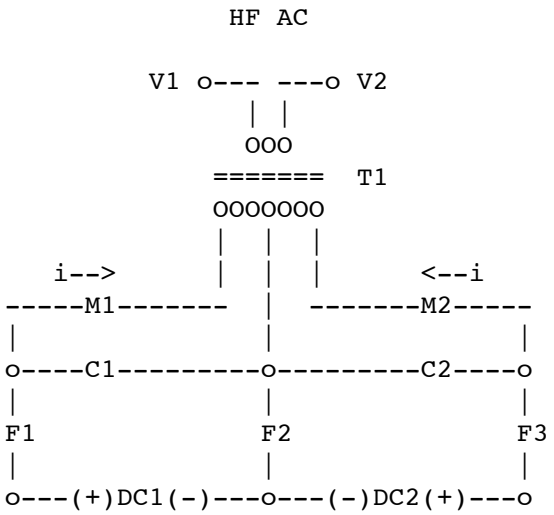


Figure 1 - Method of superimposing AC signal on DC electrolysis current

## CIRCUIT DESCRIPTION

The electrolytic cells in Figure 1 are designated M1 and M2. These cells can be implemented as series multi-plate cells, so that large voltages can be applied. DC power supplies DC1 and DC2 provide DC potential right at the critical voltage level, where cells M1 or M2 just begin to conduct current and thus perform electrolysis. DC1 and DC2 can contain protection diodes that prevent back current through them. Filters F1, F2 and F3 isolate the DC power supplies from the AC while allowing DC

to pass These can simply be large inductors. The center tapped transformer T1 provides current through M1 on one half phase, and M2 on the other half phase. The core of T1 is not biased on average by any DC current because any DC currents through the two secondary windings cancel magnetically. Capacitors C1 and C2 are provided to complete the AC circuit through the cells.

Note that the voltage applied in the secondaries of T1 are *incremental* to the voltage supplied by the DC power supplies. Note also that, except for electrolysis cell internal resistance, the active AC elements of the circuit are inductances or capacitances, providing as large a phase angle as possible.

The HF AC power supply is driven at the LC resonance frequency for the AC portion of the circuit. A tuning capacitor or inductor in either the M1 or M2 half of the circuit may be useful to match resonant frequencies for both sides of the circuit.

## THE HALF CIRCUIT

Figure 2 shows a half circuit version of Figure 1, which lacks the balance of the circuit in Figure 1, but which may be useful if the HF AC power supply can handle the current imbalance and an air core transformer is used for T1, or a transformer not operating near saturation and thus not adversely affected by DC current through the secondary.

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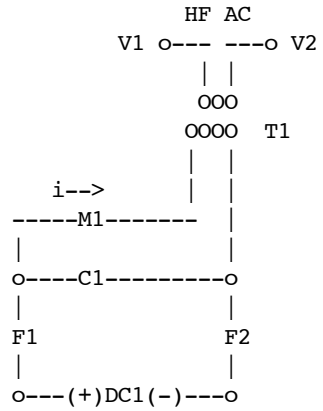


Figure 2 - Method of superimposing AC signal on DC electrolysis current - half circuit

Figure 3 shows the AC portion of the half circuit.

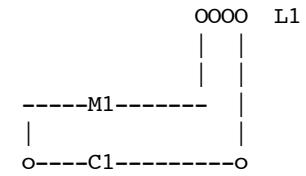


Figure 3 - AC portion of electrolysis half circuit

Part of the electrolysis efficiency provided by using superimposed AC is provided by the fact the electrolytic cell conducts by two parallel means: (1) ion current conduction and (2) AC capacitive conduction. DC can not use the capacitive conduction path through the cell. By using a superimposed AC current, the current to and through the electrolyte-electrode interface layer is increased for a given cell configuration by activating a second conduction pathway through the electrolyte. The reactance X of a capacitor, the equivalence to DC resistance, for capacitance C and frequency f is:

$$X = 1/(2 \pi f C)$$

When f is in Hz and C in farads then X is in ohms. Therefore, the higher the frequency and the greater the capacitance the more the AC current through the capacitive portion of the electrolyte at a given voltage.

It is notable that all AC current is not Faradaic, i.e. resulting in electrolysis. Though it passes through the electrolyte to the interface more easily, some AC current can pass through the two molecule thick interface without causing electrolysis. However, since a DC bias is provided, it is expected a high Faradaic ratio can be achieved.

## SOME SAMPLE CALCULATIONS

Water has a dielectric constant of about 50, which is large. If Cm is the capacitance of the cell M1, then the total capacitance Ct in the AC portion of the circuit is given by:

$$Ct = 1/((1/C1) + (1/Cm)) = (C1\ Cm)/(C1 + Cm)$$

For example, if C1 is made equal to Cm then Ct = 0.5 Cm.

The capacitance of a multi-plate electrolysis cell can be determined by looking at the area Ai and separation Si of each electrolyte gap. The capacitance Ci of gap i is then

$$Ci = 50\ (8.854\ F/m)\ Ai/Si$$

So, given plate size of 10 cm by 10 cm and plate separation of 0.1 cm we have:

$$Ci = 50\ (8.854 \times 10^{-12}\ F/m)\ (0.1\ m)^2 / (0.001\ m) = 4.427 \times 10^{-9}\ F$$

In the series of capacitances across an electrolytic cell gap, the double layer capacitance is insignificant because at about 0.2 F/m^2 it is 6 orders of magnitude larger than the electrolyte capacitance at $4.423 \times 10^{-7}$ F/m^2 at 0.1 cm plate separation. In other words:

$$Ci = 1/(\ (1/.002\ F) + (1/4.423 \times 10^{-9}\ F) + (1/0.002\ F))$$

= 4.42298x10^-9 F
= 4.423x10^-9 F

thus has no change due to consideration of the double layer capacitance.

The capacitance Cm of n electrolyte gaps in series is:

Cm = 1/((1/C1) + (1/C2) + ... + (1/Cn))

Given 12 equal sized gaps like the above for Ci we have:

Cm = 1/(12/Ci) = Ci/12 = 3.689x10^-10 F

Using C1 = Cm we have:

Ct = 0.5 Cm = 1.845x10^-10 F

Now to consider a toroidal air core transformer. Assume the conductor is made of tubing about 0.5 cm diameter. Small radius of the torus is 4 cm. Inner radius of torus is 15 cm. Major radius Mr is thus 19 cm. and outer radius is 23 cm. Total turns N = 45. Coil area A is about 50 cm^2. Coil conductor length is about 11.3 m. Inductance is approximated by:

L = u N^2 A (1/Mr) (1.26x10^-6 H)

L = (1) (45^2) (50) (1/(19)) (1.26x10^-6 H)

L = 6.71 mH

Resonant frequency f is

f = 1 / (2 Pi * (L C)^(1/2))

= 1 / (2 * 3.14159 * ((6.71x10^-3 H) * (1.845x10^-10 F))^(1/2))

= 1.43x10^5 Hz = 143 kHz

This frequency may be a bit high to be practical, and certainly requires good shielding. It appears a ferrite core transformer is most likely the best option. If the inductance is increased by a factor of 100 the frequency drops by a factor of 10, so for a 0.671 H transformer secondary:

f = 14.3 kHz

An alternative means to drop the frequency is to make the plates larger and use fewer in sequence.

## SOME OPERATING FREQUENCY TRADEOFFS

One good thing about using high frequencies is the filters Fi get cheaper and smaller. Choice of frequency may be important. Puharich , US Patent 4,394,230 (1983) used a rectified AM signal, and found resonances in pure water at 3,980 Hz, and octaves 7,960, 15,920, 31840, and 63,690 Hz. It is notable that running all those octave overtones gives a lazy (triangular half cycle) saw tooth wave. It has been conjectured that is why Stanley Meyer operated at around 16,000 Hz. Frequencies between 10 kHz and 200 kHz work well. However, if it is desired to carry a significant current through the electrolyte capacitively then a much higher frequency is required.

Even at 143 kHz, the electrolyte impedance is about 2.52 ohms/m^2, or about 252 ohms for just the 0.1 cm gap between the (0.1 m)^2 example plates. It takes about 14 MHz to drop the AC impedance to an ohm between them, and then it would take 100 V to get 1 A/cm^2 current. If the plate separation could be dropped to 0.001 cm, then the full 1 A/cm^2 could be conducted capacitively at 14 MHz at 1 V, or 10 MHz at 1.4 V.

It is now abundantly clear that the key remaining barrier to efficient AC powered electrolysis is obtaining a low AC impedance path through the electrolyte between plates.

If significant over unity behavior, that is to say significant free energy, can be generated using the electrolysis powering techniques described here, such as by cold fusion or other means, then it is economically viable to operate at 0.1 A/cm^2 and possibly even 0.01 A/cm^2, which puts plate separation back into a very viable

range.

## TYPE II FREE ENERGY

It is notable that, due to the AC being *incremental* to the underlying DC bias of about 0.8 V to 1.4 V, depending on operating temperature, this electrolyzer powering means appears to violate the laws of entropy, This Maxwell's demon extracts hydrogen and oxygen from solution through use of a low power hydronium electronation and hydroxyl de-electronation current, i.e. a current that drives electron tunneling across a biased electrode-electrolyte interface. Replacement hydronium and hydroxyls are separated thermally by ambient heat Boltzmann tail dissociation of H2O to maintain H3O+ and OH- concentrations in a temperature dependent equilibrium, and that is the source of an apparent thermodynamic law violation. Though this might be considered an apparent Type II Thermodynamic Law Violation, this is in fact not free energy because the cell temperature drops and thus reduces the dissociation rate. However, this method may be of great value in utilizing or converting to storable form the thermal energy available from solar and other means. No thermodynamic "cold side" is required, thus the method should work even better than sterling engines and the like in hot desert environments where solar power is easily obtained. A significant portion of electrolysis energy comes from heat in commercial high temperature high pressure electrolyzes.

## THE REDOX OPTION

It is of possible interest that very narrow gaps, including separation membranes, or solid electrolyte sheets, especially when using flow through plates to extract the products, are possible using redox reactions which do not generate gas products, and which can be used with existing fuel cell technology to generate power from the products. An example of this is the vanadium redox reaction used in commercially available flow cell batteries. See:

http://en.wikipedia.org/wiki/Vanadium_redox_battery
http://www.vrbpower.com/

## CLOSING THE ELECTROLYTE IMPEDANCE GAP

It is now exceedingly clear that the remaining barrier to obtaining efficient AC powered electrolysis is achieving a low impedance path in the electrolyte between plates. A useful method for achieving this is the use of a porous high dielectric constant material between the plates. An example of such a material is barium titanate, which, even at electrolysis temperatures, can have a dielectric constant of over 5000, two orders of magnitude greater than water. The size and quantity of pores in a barium titanate inter-plate electrolysis barrier can be controlled across a wide range by choice of distribution of granule shapes and sizes to be sintered together to make the barrier. Pore size and dielectric/electrolyte ratio choices involve balancing ion conductivity, AC impedance, and the gas separating ability of the high dielectric barrier. Even if a dielectric/electrolyte ratio as low as 0.5 is used, the AC impedance can be reduced by a factor of 50, and thus the feasible inter-plate gap size similarly reduced. The use of high dielectric constant inter-plate porous barrier brings the domain of high efficiency AC driven electrolysis into feasibility across a wide range of readily engineered options.

## FLOW-THROUGH PLATE DESIGN FOR AC DRIVEN ELECTROLYSIS

Figure 4 is a diagram of a partial cross section of central cell elements in a multi-plate AC drive cell. In Figure 4 assume the right side is the positive side, the left is the negative. Only the outermost (external) plates are connected to the power then. Figure 4 shows the equivalent of what would be two (internal) plates and a separating barrier in an ordinary multi-plate cell, but which are here in the form of assemblies which conduct the flow of electrolytes and products. Here, for brevity, oxygen will be considered the anode product and hydrogen the cathode product, but any appropriate product from the given electrodes may be used.

The first plate equivalent assembly includes a catalyst coating (1) on a porous conducting plate (2) internal to which is an electrolyte flow including evolved oxygen (3) drawn through the plate (2), adjacent to an internal gas separator plate (4), which is adjacent to an upward electrolyte flow including evolved hydrogen (5) evolved on coating (7) and drawn through the porous conducting plate (6), which has a catalyst coating (7) facing the electrolyte gap (8). All portions of this plate assembly are electrically connected conductors.

Adjacent to the electrolyte gap (8) is an assembly which is the equivalent to a plate separator or barrier, and which includes a porous high dielectric constant material (9) adhered to a porous conducting plate (10) adjacent to a downward flow of electrolyte (11) pumped into the cell through a manifold not shown. To the positive (right) side of the fluid flow (11) is another porous conducting plate (12) having adhered to it a porous high dielectric constant material (13) through which the electrolyte flow (17) occurs into the electrolyte gap (14). After the dielectric materials (9) and (13) are adhered to the separator assembly, it is anodized in order to electrically isolate all conducting surfaces from the electrolyte. The two conducting plates (10) and (12) are electrically connected, so the AC impedance between the separator assembly and adjacent plate assemblies is primarily due to the electrolyte in the gaps (8) and (14).

The second plate equivalent assembly includes elements 15-21 which correspond exactly in name and function to elements 1-7. The fluid flow inward (11) results in both hydrogen flow out (5) and oxygen flow outward (17).

The plate and barrier assemblies are sealed against the dielectric cell walls (22) in order to prevent conduction around the sides of the plates. The first plate assembly bottom (24) seals the bottom of the plate and makes electrical contact between the conductive elements. Similarly, conductive bottoms (27) and (29) of the barrier assembly and negative most (left) plate assembly seal their bottom sides and make electrical contact between conducting elements. Electrolyte fills all the internal and external gaps 8, 14, 23, 25, 26, 28 and 30, as well as saturates all the vertical plates except 4 and 12, which can be made of solid electrolytes, thus providing ionic paths throughout the electrolyzer while separating gas flows.

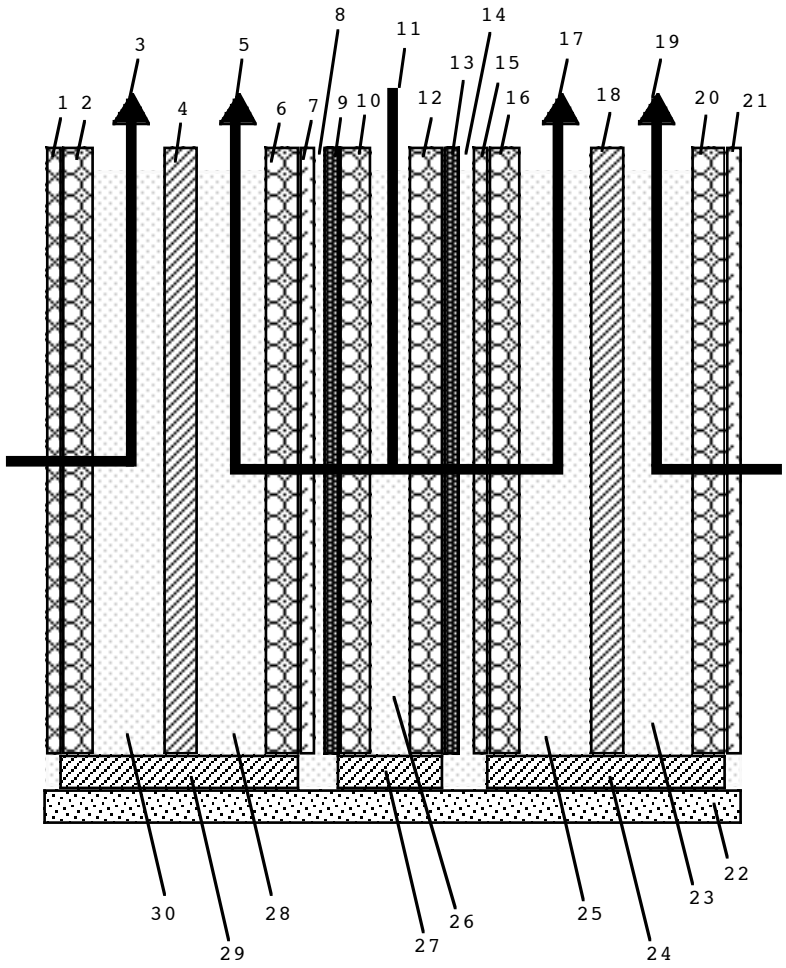


Figure 4 - Diagram of partial cross section of central electrolysis cell elements