PowerLabs Electric Water Atomization Research!

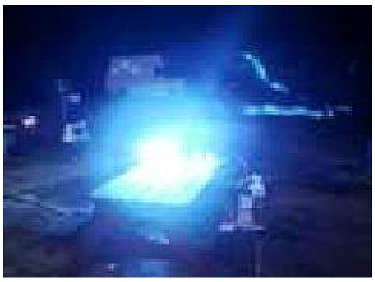
I.B. Extended Research Essay. By Sam Barros.

Water Atomization by High Magnitude Electrical Impulses: A study.

INTRODUCTION:

Run a current through water and its molecules will split up at the electrodes forming Hydrogen and Oxygen (**H20 => H_2 + O_2 requiring 854KJ/Mol**)[1]. The process is not 100% efficient, as it involves the movement of molecules and ions to and from the electrodes, causing them to bump into one another on their way and hence increasing overall enthalpy. In fact, a high enough current will heat a small water bath to the point of boiling during a very brief period of electrolysis.

However, this only happens because water in its natural form contains mineral salts which make it conductive. In its purest form (only obtainable through extensive de-gassing, purification and de-ionization), water is in fact a phenomenal dielectric, with a dielectric constant (K) of 80[2]2] and a voltage standoff in the order of several thousand volts per millimeter (this varies enormously with purity and somewhat with temperature). Because it behaves as a near-infinite resistance load for any source of EMF, ultrapure water, as is called the liquid having less than 10^12ohms/m resistance is used in some pulse forming network capacitors and for insulating some special high voltage high frequency lines and the like.



However, once the maximum voltage standoff for water is exceeded and the dielectric effect breaks down, something strange happens: The discharge stops being electrolytic (as molecules can no longer move to the electrodes at the rate dictated by the current) and the resistance plummets all at once, allowing massive currents to pass through it. When that occurs a bright flash of light is observed and some of the water in the sample is atomized (atomization here is used to describe a change from the liquid to the gaseous state that does not involve heating, such as in ultrasonic water atomisers) following a very loud report and a powerful shock wave traveling through the liquid.

What makes this effect all the more strange is the fact that if one takes into account the heat capacity of the water in the sample, and compares it with the energy delivered, it becomes clear that the liquid temperature could not have risen by more than a few degrees centigrade, let alone the several thousand degrees required to obtain the pressures necessary for the kind of explosion observed. Over the years, several scientists and researchers have attempted to explain the phenomena, using everything from cold fusion to electrolysis and subsequent water reformation. Most of these theories are obviously flawed and were quickly refuted by mathematical proofs, whilst others are still being contemplated as potential (partial?) explanations for what is happening, and may need experimental evidence to be disproved. *The objective of this study is to evaluate the all the distinct phases the water goes through when its atomized and using that come up with a theory explaining what causes this atomization.*

The importance of such an study lies in the fact that despite the lack of knowledge as to what causes it, the atomization effect is beginning to find more and more usage in such tasks such as rock fracturing for mining (where the shock produced by the discharge can pulverize the rock into fragments appropriate for recollection, but yet will not blow them all over the place or ignite them as a conventional explosive charge would, since with electrical discharges the expansion is very small), metal forming, and deep sea pulse echo sounding (tasks that were also done by conventional explosive charges before, but that now can be done safely and at lower costs by utilizing electrical discharges). The same effect is also being researched as a means of reducing urban waste, sterilizing liquid samples, and others. *With a deeper understanding of the processes involved, we should be able to find new ways of utilizing this technology, and optimize it for what it is already being used for.*

HYPOTHESIS:

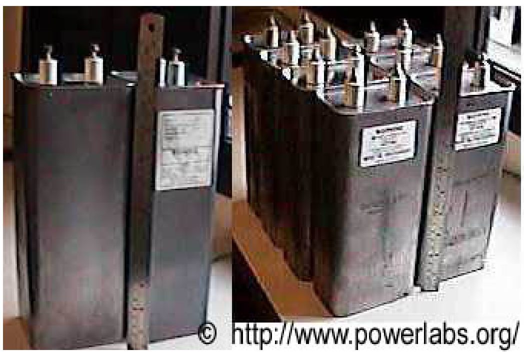
I believe there are two mechanisms related to the atomization of water, and that their combined effect leads to the sample being atomized without the need to actually bring the sample to its boiling point. The first mechanism is what happens when the voltage is applied to the sample: Being a polar molecule, H_2O should align itself with the electrostatic field set up. Once this field exceeds a certain threshold the molecule should become so stretched that its bonds would break, causing the rapid expansion that produces the shock wave. However, just as soon as the bond is broken, the water molecules that fly apart should recombine into water, as well as some H_2 and O_2, having a very small net volume change, mainly accountable for the small hydrogen and oxygen gas production.

The mechanism is decurrent from the first one and explains why despite the very small rise in temperature, a significant volume of water is changed into gas: It is known that when water is atomized by electrical discharges a shockwave is produced that travels through the solution. Shock waves are known to shatter things, and in this case I believe that the shock wave produced is literally vibrating the molecules apart, in a fashion very similar to the way ultrasonic "cold steam" generators (such as those used in inhalers) work. Hence, the atomization seen here is not a reduction of the sample into its simplest fractions (atoms), but rather the breakdown of the inter molecular bonds in the water, causing its molecules to separate and form into a vapor, but without heating it. The term "atomization" will be used in this essay to refer to that liquid/vapor transition without actual heating of the sample to its vaporization point.

MATERIALS:

The following equipment was used for this research:

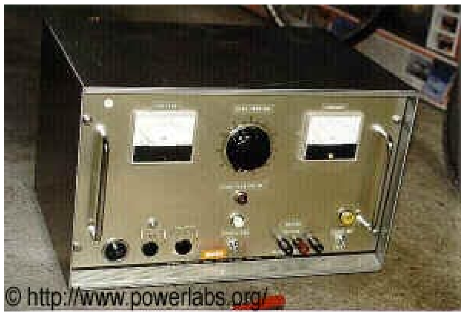
The electrical pulses were provided by banks of high voltage capacitors. The capacitance and voltage in the banks was varied so as to provide different current, voltage, and energy magnitudes so that their individual effects could be observed and their effect on the results observed. The banks will be made up of the following capacitors:



7 AEROVOX Energy Discharge Capacitors, rated at 5200V, 23uF (311J) each. ESL is 150nH. Peak current 5000A repetitive (12.5kA non-repetitive)

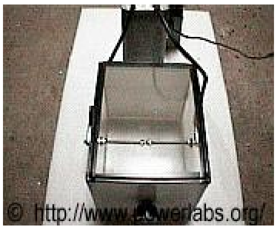
2 MAXWELL Pulse Discharge Capacitors, rated at 7.5kV, 36uF (1kJ) each. ESL is 100nH Peak current 25Kiloamperes (60kA non repetitive).

These were charged by a variable LASER power supply which allowed precise monitoring of charge voltage (and hence energy) and current. (accurate to 3V).



Temperatures were measured using a "K" type thermocouple probe with 1C resolution, -20 / 1000C range and 1.0% accuracy at the utilized range.
Pressures were read from a Norgreen 0 - 60PSI (0-4bar) pressure gauge with 2PSI resolution and 1% accuracy at the utilized range.

The discharges were switched by a homebuilt pneumatically actuated switch, consisting of two 10cm diameter spherical electrodes, one stationary and the other propelled by a 450Newtons piston. Switch closing time is calculated to be 80uS at 7.5kV).

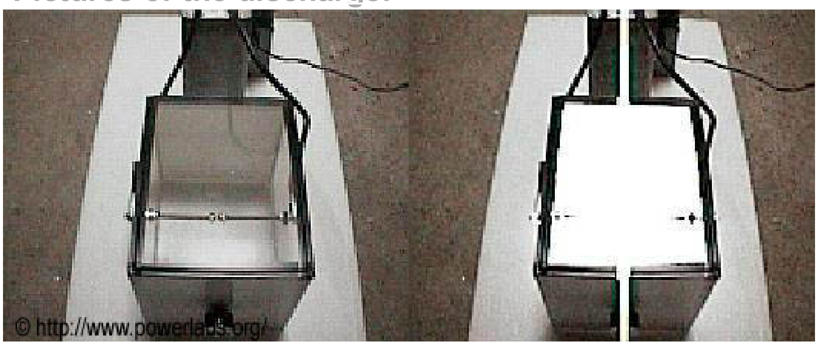


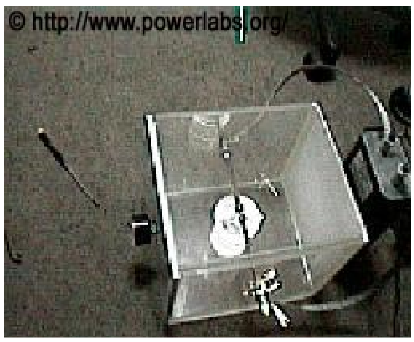
All experiments were conducted inside a Homebuilt gas tight bomb calorimeter with 8mm steel electrodes, mounted in such a fashion that their distance could be varied and measured within 0,01mm. The calorimeter was built out of 1cm thick impact reinforced acrylic sheeting, and has a volume of 12.5m^3 (20 X 20 X 30cm).

PROCEDURES:

First the system was calibrated by discharging a 36uF MAXWELL capacitor charged to 7500V (hence storing 1013J) through a 100Ohms wire wound resistor inside the calorimeter filled with one litre of water. The 75A discharge (I = V/R where V = 7500V and R= 100Ohms) had a peak power of 562500Watts and was utilized to simulate the fast temperature rise encountered during water atomization. 10 discharges were run in 20 seconds (hence an average power of 506.5W RMS ((1013X10)/20), and a total energy delivered to the load of 10130Joules). Given the heat capacity of water to be 4180J/kg/C at the 20 - 40C range, one would expect a temperature rise of 2.4C. A temperature rise of 2C was observed, which was in agreement with what was expected.
The calorimeter was than re-filled with 2 litres (+- 5ml) of deionised water (resistance = 3X 10^-9ohms/m), and the electrode spacing was initially set for 10mm. Several discharges were attempted, all of them being electrolytic (slow drain of charge, no shockwave or flash observed) and the electrode spacing was closed until an explosion occurred during the discharge. This distance was found to be 5,3mm (mean field strength = 1,415 million volts/meter), though this value is of little significance as it is a function of the water purity more than anything. Had pure water been used, a spacing of little more than 1mm would have been necessary.

Pictures of the discharge:





The thermocouple was than placed on a corner of the box, without contact to any of its walls (so as to prevent heat transfer), and several discharges were pulsed into the water, still using the Maxwell 7.5kV 36uF pulse capacitor. Though the capacitor is rated for a peak amperage of 60Kiloamperes, during the 3rd discharge it suffered internal damage, evidenced by excessive bulging to the case. A careful autopsy of the dielectric revealed no punch throughs: It appears as though the discharge exceeded the maximum amperage of the capacitor by so much that it caused its plates to repel each other and disconnect the internal leads.

The capacitor was than substituted and two more pulses were performed. During the second pulse, the contacts on the JENNINGS 25kV 100A RMS vacuum switch which was being used to switch the discharge were fully vaporized, and the switch was rendered useless. It became apparent that the discharge essentially represented a short to the system, and was allowing the peak currents to rise far beyond the individual component ratings. A pneumatically actuated switch was than built with the purpose of switching the discharge. The switch allows some arcing prior to its contacts closing fully, despite its 25m/s closing speed (which at 7.5kV gives a closing time of approximately 80uS). This should cause it to dissipate some power during the discharge, though that power cannot be quantified due to the many variables involved in the dynamic arc resistance.

It also became apparent that the large dimensions of the box (originally conceived so as to allow the gases produced plenty of room for expansion and hence minimize the risk of a enclosure rupture) would require very large energies due to the large volume of water used.

Risking a total enclosure failure, the capacitor bank was than set as six 5200V, 23uF AEROVOX Energy Discharge Capacitors with an ESL of 150nH. And a peak current of 5000A repetitive. The bank was set up as two serial rows of 3 parallel capacitors, giving an overall capacitance of 34.4uF (23x3 /2), an ESL of 100uF (150/3 X2), and a peak current rating of 37500A non repetitive (12500X3). The maximum energy stored in the bank (1/2CV^2) was 1860Joules (the internal transformer tap on the variable laser power supply was changed so as to allow charging up to 10400V).

10 maximum energy pulses were than run through the sample during a 20 second interval, amounting to a total energy delivered of 18600Kilojoules (1860 X 10, disregarding losses). The manometer was observed to jump during these discharges, but this has been attributed to the shock of the discharge itself, and not to any pressure rise, since after the 10 pulses the pressure inside the sealed box remained at 1ATM. A temperature rise of 2 degrees was again observed, which is in agreement with the amount of energy that was delivered to the sample (18600/(4180X2)=2,2C.

RESULTS AND INTERPRETATION:

After several discharges the pressure inside the box remained at 1ATM. If the water was being vaporized by the discharge a phase change expansion would be expected and hence some pressure increase should be observed. Similarly, if the water was being split up into hydrogen and oxygen by electrolysis, an even higher pressure increase should be observed. More importantly, there was no "fogging" inside the box, further refuting any steam condensation claims, and the temperature change was consistent with my theory that the water is not being vaporized. If only a small amount of Hydrogen and Oxygen was being produced, it could diffuse into the liquid and remain there in gaseous phase. In fact, analyzing the light emitted by a silent arc inside the atmosphere of the box with a chromatograph after 20 discharges showed the characteristic red line of hydrogen, as well as all usual signature produced by nitrogen and oxygen in air.

But how can a shock wave be produced when the net pressure change is zero? Conventionally, shock waves are produced by explosives, such as nitroglycerine, which upon being struck or heated above 280C, decomposes to give 10 000 times its original volume in gas. This tremendous expansion gives rise to a shock wave traveling at 4500 M/sec[3]. The shock wave can be thought off as a sound wave, or, more accurately, as a *pulse* traveling through a medium of some sort. In an explosive this pulse is provided by the initial expansion, which pushed air molecules outwards at a very fast rate. Because gases are produced, a net pressure increase is observed. In the water atomization experiment, the shock wave implies that there must be an initial pulse, or expansion, but the zero pressure increase tells us that this change is non permanent and very quick. We can therefore rule out vaporization, and electrolysis, as both would result in a permanent pressure change.

The only other way I can see for a momentaneous pressure rise to occur is if the water molecules were separated during the discharge. Assuming they are being separated, we can formulate a good hypothesis for the mechanism that allows that to happen. We already know that the water molecule, H_2O, is polar, since the oxygen atom has 4 unpaired electrons, only 2 of which are ionically bonded to the oxygen.

Conclusion:

The results obtained so far are inconclusive due to the small changes in pressure and temperature of the sample. By using a smaller sample of water, and increasing the energy delivered to it by discharging the capacitor through it more times, in a shorter period of time, will allow results to be obtained to higher accuracies. Because of that, the calorimeter is now being resized.

Bibliography:
[1] CRC Handbook of Chemistry and Physics 80th Edition (1999 - 2000), CRC Press, David R. Lide Editor in Chief.

[2] Hutte IV A Starkstromtechnik, 28. Auflage

[3] "Explosives," Microsoftï¿½ Encartaï¿½ Online Encyclopedia 2000
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Questions? Comments? Suggestions? Don't hesitate to e-mail me!

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