On the possibility of hydroelectric fusion: The evidence from the CES steam generator

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Abstract – The steam generator that has been developed by Cavitation Energy Systems generates steam whose energy is approximately five time greater than the electrical energy used to generate the steam. This paper proposes that the additional energy comes from the fusion of a minute fraction of the nuclei of hydrogen atoms in the water molecules. The energy for the initial fusion event comes from the accelerating of protons through the large potential differences that occur on the inside of the cavitation bubbles that are critical to the operation of the steam generator. Subsequent fusion events occur as a result of the energy from the initial events being carried to other protons through virtual neutrino exchange. Virtual neutrino exchange is also responsible for the mechanism by which the energy liberated heats the water in the steam generator and accelerates the water in electrospray systems. The acceleration of both protons and electrons create conditions for fusion that involves electron capture thus suppressing the release of gamma radiation that would otherwise come from the annihilation of positrons by electrons.

1. INTRODUCTION

There is a long history of systems where it was claimed that more energy is generated from the system than is used to drive the system. In all cases the claimed results remain contentious. There are frequently problems with reproducibility and the power gains were frequently marginal. Such systems come in a number of different flavours and one is systems that involve a combination of water and high voltages. Examples include a series of experiments involving passing electric arcs through water (e.g. Hathaway, Graneau et al. 1998) and more recently a system involving electrospray (Graneau, Verdoold et al. 2011).

The hypotheses presented to explain the origin of the additional energy in these water based systems has some similarities to a heat pump. It was argued that the specific way in which the bonds within water molecules are broken within these systems as a result of dielectric breakdown liberates latent energy that is then reabsorbed from ambient heat energy as the water returns to its initial state. There are problems with this hypothesis (Hathaway 2012) in that it appears to run counter to the laws of thermodynamics.

In the period from 2011 to 2017, Cavitation Energy Systems (CES) has been developing a steam generator and recent measurements suggest that the energy in the steam is five times greater than the electrical energy required for the pumps and heaters used to generate the steam.

It is possible to show that from evidence that is independent of the specific measurements made by C.E.S. that the energy levels are consistent with what has been claimed. This indicates that the CES system does not suffer from the problems of reproducibility and marginal power gains experienced by previous systems.

It is therefore necessary to consider how these energy levels are being achieved.

In the literature provide by CES this is explained in terms of formation and recombination of oxy-hydrogen. As an explanation this still does not fit well with the laws of thermodynamics.

While it is not possible to rule out mechanisms that would require slight reworkings of the laws of thermodynamics, this paper explores how the evidence from the steam generator and also from the electrospray experiments may provide an alternative explanation for the apparent 'energy gain'. This hypothesis is consistent with the known laws of physics, although they are applied in a novel way that will require experimental and theoretical validation.

Almost 30 years ago, Fleischmann and Pons (1989) claimed a 'lab bench' system where there was an apparent energy gain as a result of the fusion of deuterium. This proved to be extremely contentious and while many understand the results to have been discredited, there has always been a proportion of scientists who felt this possibility should be pursued. In recent years such research has become known as 'Low Energy Nuclear Reactions' (LENR) because a number of alternative ways in which energy might be liberated through nuclear interactions have been identified as well as the nuclear fusion.

Nevertheless the clear experimental results and associated scientific model has proved elusive.

By bringing together the design of the CES steam generator with the experimental evidence from the electrospray experiment this paper proposes that the 'energy gain' seen in the CES steam generator is as a result of a variant of LENR that had not previously been considered. While LENR research now considers many different possible interactions that could liberate energy, the model presented here is based on the most basic of nuclear reactions, the fusion of two protons to form a deuteron; the starting point for the fusion chain within stars.

The idea that the energy is liberated through proton-proton fusion initially comes from the simplicity of the CES steam generator, where the only raw material available is water. Of the two elements in water, hydrogen is the most promising contender for an LENR reaction that is capable of releasing significant quantities of energy.

Water on earth contains two isotopes of hydrogen that might be associated with any fusion interactions. The main isotope is protium, where the nucleus consists of a single proton. The other isotope is deuterium, where the nucleus consists of a proton and a neutron. This isotope is found in 0.003% of natural water.

There are therefore two possible ways that fusion could occur. The first would be that it involves the fusion of deuterium into helium where the deuterium comes from the small proportion deuterium containing heavy water found within ordinary water. The second is that it involves the fusion of protons to produce deuterons. Proton fusion is more difficult for reasons that will be considered later, which is why 'table top' fusion systems such as the Farnsworth Fusor (Edwin 2007) use deuterium. However, the CES steam generator does not produce steam using deuterium enriched water so if fusion is occurring then it is the more difficult proton fusion that would appear to be the more plausible possibility.

This raises the challenge of identifying the mechanisms at work in the steam generator that would allow such fusion to take place when such fusion is normally extremely unlikely.

There are four things that need to happen for proton fusion to be able to provide a significant source of energy in the CES steam generators:

1. Some protons need to acquire sufficient energy to overcome the coulomb barrier such that they come sufficiently close to another proton such that they can form a diproton.
2. The proton needs to decay into a neutron (together with a positron and a neutrino) such that the diproton becomes a deuteron, the isotope of hydrogen with an additional neutron. By doing so energy is released and this would be the source of the apparent energy gain.
3. The energy released from the creation of the deuteron must be transferred to the water to become available as heat.
4. The numbers of fusion events that are needed to produce the energy gain that is seen would appear to require an avalanche process such that for a reasonable period of time each fusion event produces more than one proton with sufficient energy to initiate a secondary fusion event.

This document describes how the CES steam generator may have, to a large extent inadvertently, provided the conditions for all four stages of such a fusion process to occur.

Appendix one goes through the details of the power calculations, and shows in two different ways that the steam generator produces approximately 600J of energy gain per pulse of water. If it is assumed that there are a million cavitation bubbles per pules then there would need to be of the order of 3×10^9 fusion events per cavitation bubble to produce this amount of energy.

2. Accelerating protons

Nucleons such as protons and neutrons are bound together within the nucleus using a residual component of the strong nuclear force. This force acts over very short distances, and for two protons to get close enough for this attractive force to become significant they must overcome the coulomb barrier, the force that normally keeps positively charged protons apart. This requires energy, and in stars this comes from the kinetic energy of the protons which are moving very fast because of the high temperatures at the core of the star. The minimum energy required for an individual proton to overcome the coulomb barrier (with a little help from quantum tunnelling) is of the order of 5keV.

The use of high temperature plasmas is also the approach taken to provide the positively charged particles with sufficient energy to overcome the coulomb barrier in experimental power generation systems based on fusion such as is used in the Joint European Torus (JET).

There is however another way to give the particles sufficient energy for fusion and that is to accelerate the protons through a potential difference of 5kV, such that they will have a kinetic energy of 5keV. This is the approach used with the deuterium plasma in the Farnsworth Fusor (Edwin 2007)(Figure 1). However, the Fusor is incapable of being used to generate power from the fusion in that most of the deuterons hit the cathode and very few hit each other, making the process fundamentally very inefficient.

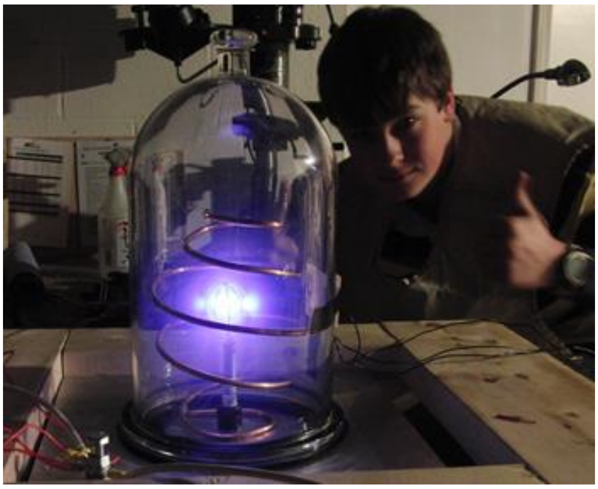

Figure 1 A Farnsworth Fusor

While the Farnsworth Fusor is unable to generate useful energy through fusion, there are at least three other situations where the evidence is beginning to suggest that fusion is taking, or has taken, place as a result of protons or deuterons being accelerated through a potential difference of >5kV, initiating what could be called hydroelectric fusion. Each of these on their own does not provide particularly compelling evidence, but together a pattern of evidence begins to emerge which is difficult to ignore.

The first case of hydroelectric fusion relates to the forked leader of a lightning strike; the initial almost invisible downward strike that creates the conductive channel through which large currents can flow. It is the forked leader that creates the zigs and zags that are characteristic of the lightning path. When this happens a significant neutron flux (Shah, Razdan et al. 1985, Bratolyubova-Tsulukidze, Grachev et al. 2004, Martin and Alves 2010, Gurevich, Antonova et al. 2012), positron flux (Briggs, Connaughton et al. 2011, Fishman 2011) and gamma radiation (Dwyer, Rassoul et al. 2005, Kong, Qie et al. 2008, Biagi, Uman et al. 2010) is generated.

The gamma radiation has been shown to be specifically associated with the changes of direction of the forked leader. The conventional explanation for the source of this radiation Bremsstrahlung, but there are dissenters (Chilingarian, Daryan et al. 2010, Gurevich, Antonova et al. 2012) who do not believe that this model is adequate to explain what is observed. The papers containing statements such as “This flux value (of neutrons) constitutes a serious difficulty for the photonuclear model of neutron generation in thunderstorm”.

I have been working for some years on an alternative model for what might be happening, the starting point being the acceleration of protons between the developing forked leader and nearby water droplets, where there will be a considerable potential difference between the two. This model appears to overcome some of the difficulties the Bremsstrahlung model has in explaining the neutron, positron and gamma radiation associated with thunderstorms.

The second case of hydroelectric fusion is the occasional reports of experiments involving water and high voltages which explode unexpectedly, producing significant quantities of energy. The difficulty with such events is that, by their nature, they do not tend to be formally reported. However, I have been indirectly associated with one of these events. A small group of us investigated the evidence, such as it was, and came to the conclusion that it was difficult to see how the more obvious explanations could give rise to the damage that occurred. In this case the origin of the explosion would appear to be when an instability occurs such that two water surfaces with a potential difference of at least 10kV immediately adjacent to each other. Again, such a scenario would allow for the acceleration of protons between the surfaces such that they have enough energy to initiate fusion.

The third example of such potential fusion are some of the experiments performed by Peter and Neal Graneau where an electric arc is generated within a small volume of water (e.g. Hathaway, Graneau et al. 1998). There are some issues associated with the assumptions made in the analyses in later papers, but the evidence from the early papers that there is an energy gain is particularly compelling. Again, the electric arc would appear to provide the conditions for adjacent water surfaces of very different potentials to be created such that protons can then be accelerated between the two.

In each case I believe it is possible to show that fusion occurred because protons are liberated from a water surface, accelerated across a potential difference of greater than 5kV and then collide with stationary protons such that fusion occurs.

Most recently there has been an investigation into apparent 'excess energy liberation' associated with electrospray systems (Graneau, Verdoold et al. 2011). While this is another system that involves a combination of water and high voltages, it is less immediately obvious how protons could have been accelerated through a potential difference of greater than 5kV in order to initiate the fusion that could give rise to the excess energy that was seen. We will return to this experiment later on to show where and how protons are accelerated.

Given that cavitation is at the heart of the CES steam generator it is perhaps significant that there has long been anecdotal reports of ‘excess’ energy being generated in systems that involve cavitation such and yet there is no obvious potential difference of greater than 5kV within these systems that would appear able to accelerate protons. However, if you look closely, it is possible to find such potential differences, which is what we turn to next.

3. Potential differences within cavitation bubbles

There has been a considerable amount of research over the years into cavitation bubbles. This has concentrated primarily on the high temperatures and pressures that occur within these bubbles as they collapse. This has prompted some groups to investigate whether these temperatures and pressures could be harnessed to initiate fusion, so far without obvious success.

However, it has long been known that during the process of cavitation bubble appearance and collapse some very significant potential gradients occur in the water immediately adjacent to the bubble as a result of the very significant transient pressure gradients that occur. This was explored in some detail by Lepoint, De Pauw et al. (1997) where they were looking for potential 'electrohydrodynamic' explanations for sono-luminescence.

The origins of such potential gradients can be seen by thinking about the movements of the electrons and protons when a shock wave travels through the water. The shock wave is propagated by means of the interactions between the electron orbitals of adjacent molecules, and the positive nuclei will then move in response to the movement of the electrons. The inertia of the nuclei will mean that there will be a slight lag in the movement of the nuclei. As a result the negatively charged electrons move in advance of the positively charged nuclei, and this transient differential shift in the positive and negative charges gives rise to a significant potential gradient.

It has been shown that the voltage gradients (Lepoint, De Pauw et al. 1997) could easily exceed the 10^8 V/m required for the breakdown of water and that formed the basis for a number of the potential explanations they listed for sono-luminescence. However, none of their hypotheses provide an explanation for any energy gain but instead just explain how the available energy could become highly concentrated during the process of bubble collapse creating high temperatures that could then generate the bursts of light that are seen.

The analysis that they present is consistent with there being potential differences of greater than 10kV occurring between different positions on the boundary of a bubble as it collapses. As a result, there are voltage differences within cavitation bubbles as they collapse that are sufficient to accelerate protons such that they have the energy required to initiate fusion. The only difference between this and other hydroelectric fusions processes is that the potential difference is generated internally within the system rather than supplied externally.

When considering the details of how a cavitation bubble grows and collapses, the simplistic assumption would be that it remains perfectly spherical and radially symmetric. As such the potential gradients and differences would be radial and the surface of the bubble would all be at the same potential.

However it has long been recognised that any non-uniformity in the bubble's environment causes the bubble to collapse in a very asymmetric way. The non-uniformities can include the presence of a nearby surface or obstacle, or a pressure gradient or shock wave. It is these asymmetries that cause significant potential differences between surfaces within the bubble (Lepoint, De Pauw et al. 1997).The asymmetry results in a 'jet' of water that emerges from one side of the

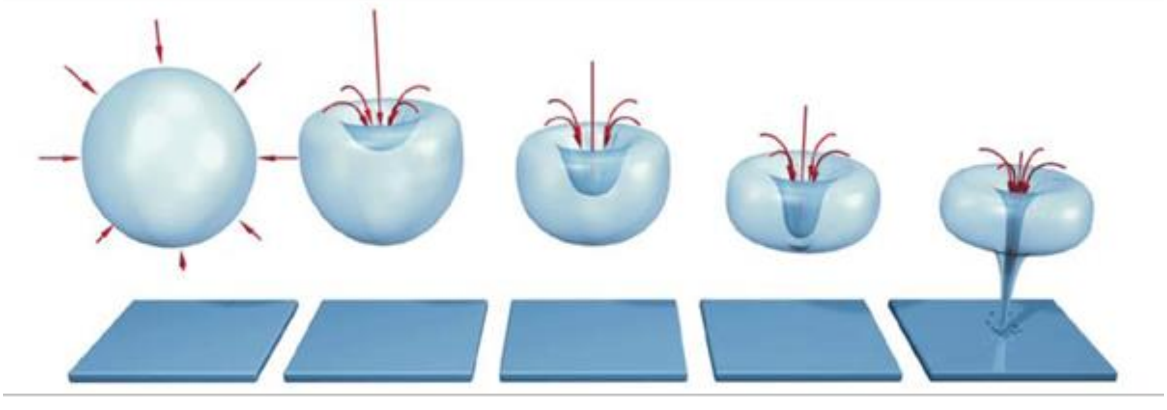

Figure 2 Micro-jet creation through collapsing cavitation bubbles (http://eswt.net/cavitation)

bubble and travels at great speed across the bubble (Figure 2). In this case the non-uniformity is often caused by the presence of a nearby surface, and the water associated with the jet will then travel at great speed towards the surface.

LePoint looks at the potentials associated with these jets and it is in these regions that the significant potential differences are most likely to occur, such as at the end of the micro jet should water droplets break from the jet (Figure 3).

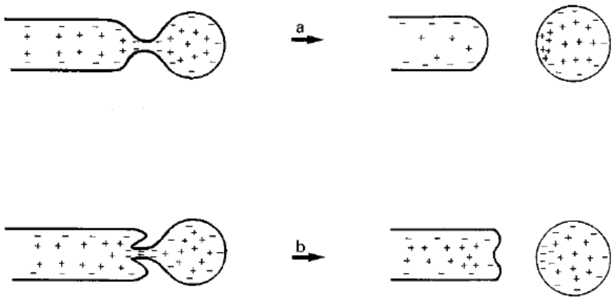

Figure 3 Build-up of large charge differences as a water droplet breaks away from the jet within a cavitation bubble (Lepoint, De Pauw et al. 1997)

Once such potential differences have emerged between different places on the surface of the cavitation bubble it is possible for protons to be accelerated between them and potentially initiate fusion.

Cavitation lies at the heart of the CES steam generator, so this understanding of the processes that take place association with cavitation provides a mechanism for giving protons sufficient energy to initiate fusion. However, for fusion to occur the protons must then decay to a neutron the action of the weak force.

4. Converting protons to neutrons

Giving the protons enough energy to overcome the voltage barrier that keeps two positively charged protons apart is only part of the problem. For fusion to occur the proton must decay into a neutron. If this does not happen then the two protons will fly apart again. Such a conversion is sufficiently unlikely that a proton will spend an average of a billion years hitting other protons within the sun before it finally converts to a neutron and remains stuck to another proton.

An explanation is therefore needed as to why the CES steam generator might have provided the conditions that would make the conversion much more likely.

The answer may lie in looking anew at the details of how two protons fuse together, as happens in the first stage of the chain of fusion reactions that take place in stars.

The decay of a proton into a neutron happens as a result of a weak force interaction and the proton is converted into a neutron, positron and neutrino. The neutron is then able to remain permanently bound to the proton, forming a deuteron. Usually, the positron will quickly encounter an electron and the two combine releasing two gamma ray photons (Figure 4).

The rest mass energy of the deuteron and neutrino is less than the two protons and the electron that are the

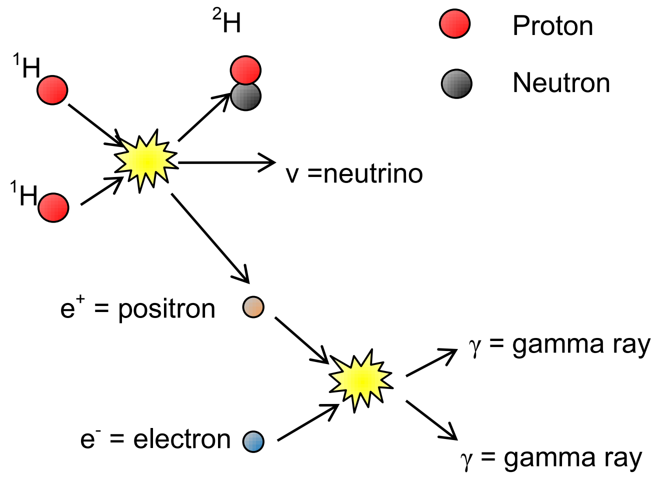

Figure 4 sequence of events associated with proton-proton fusion; the start of the fusion cascade that takes place within stars.

inputs to this fusion process, and the excess energy is released in the form of the two gamma ray photons and the kinetic energy of the neutrino.

The neutrino is normally then ignored. This is because when fusion occurs in hot plasma, such as is the case in stars or in fusion reactors, the neutrino will travel away from the fusion event and not interact in any significant way with any other matter. It will pass straight from the centre to the outside of the sun in a couple of seconds and then onwards, passing straight through objects such as the earth that they may encounter

5. Real and Virtual neutrinos

Many particles can exist in two different forms: real and virtual. Perhaps the most commonplace example of this is the photon.

Real photons provide a way for a particle or system to release energy in order to bring itself closer to equilibrium with its surroundings. A hot object such as the sun or a light bulb radiates electromagnetic energy which consists of photons that carry away the heat energy. Some chemical reactions release some of their excess energy as visible light photons. Radio transmitters convert electrical energy into photons of electromagnetic energy which radiate the energy away.

In all cases they travel onwards with no association with their ultimate destination.

Virtual photons represent a joint agreement for two particles to exchange a photon and are a means of carrying force. One particle releases the photon which the other accepts. This is what happens when there is an electromagnetic interaction such as an electrostatic attraction between oppositely charged particles or when there is a magnetic attraction or repulsion. This can only take place within the bounds of uncertainty that is set by the limits of the Heisenberg uncertainty relationship. In the case of massless photons this means that there is no limit to the range of such interactions. If you were able to sit astride a photon as it travelled from one place to another the journey would appear to be instantaneous, which potentially puts any two points in the universe within the bounds of the Heisenberg uncertainty relationship. This means that electrostatic and magnetic interactions, associated with virtual photons, are limitless in their range.

Electrons are normally 'real', but there are some situations, such as electron tunnelling when their behaviour has to be understood in terms of virtual particles.

Gluons, which are the force carrying particle between quarks in the nucleus only ever exist as virtual particles. They are heavy, so their range, set by the uncertainty relationship is very small, just within the confines of the nucleus.

The neutrinos that are produced during fusion reactions in stars or in fusion reactors are real neutrinos. They travel away from the fusion reaction outward into the universe. As well as star originated neutrinos, a large number of neutrinos were generated within the first second of the big bang and they continue to travel through the universe (Dolgov 2002). As with the cosmic background radiation, the energy of these neutrinos is now much lower than it was when they were originally produced.

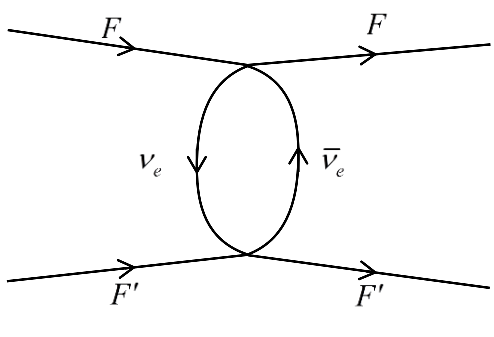

Figure 5 Interaction between two fermions as a result of an exchange of a virtual neutrino/anti-neutrino pair

There are also virtual neutrinos.

In the same way as quarks exchange virtual gluons, it has been shown that all particles are engaged in a continuous process of exchanging neutrinos

This can be thought of as a continuous process of fermions such as electrons, protons and neutrons generating neutrinos which traverse to a second fermion at the same time as the second fermion generates an anti-neutrino and sends it back to the first. The effect of the two largely cancels out so there is no change to the nature of the particles themselves (Figure 5) (Hsu and Sikivie 1994, Lusignoli and Petrarca 2011).

The potential energy of two particles that arises from this force such is that it gives rise to a repulsive force between the particles. It is proportional to r^{-5} where r is the distance between the particles, which means that the effect drops off very quickly. Compare for example with the electrostatic or gravitational potential which are both r^{-1} potentials. It is for this reason that it is usually assumed the effects are negligible, and unable to be measured with existing measurement techniques. The only times when such exchanges have previously thought may become significant is in extreme situations such as neutron stars (Woodahl, Parry et al. 1997).

There is a second interaction that occurs in the presence of a background neutrino flux, such as the neutrino flux from the sun or the residue background neutrino flux from the big bang (Ferrer, Grifols et al. 1999).

When the spins of the particles are ignored this causes an attractive force between particles when they are further apart than a distance T^{-1} where T is the temperature[1].

The force is also proportional to r^{-5}, which means that it too is thought to be too small to be measured using existing measurement techniques. For distances below T^{-1} the repulsive neutrino exchange force dominates.

When spin is taken into account the force changes to being one which is attractive when the spins are aligned and repulsive when they are anti-parallel. This is not considered in any great detail because:

> "*Since these forces will be even more difficult to detect than the spin-independent ones, for they do not add up coherently in bulk matter, we do not bother here to display the explicit form for the different limits*." (Ferrer, Grifols et al. 1999)

[1] I think this is the inverse of the de Broglie wavelength

Perhaps they were wrong to make this assumption in that there may be some very specific situations where the forces do add up coherently.

The neutrino based interaction would mean that two fermions separated by a distance of T^{-1} whose spins are aligned would be in a slightly lower energy state than if they were in some other alignment state. In principle this increases the likelihood that their spins would become aligned. There are two reasons why this will not normally happen. First the energy differences are likely to be extremely small so it would be likely that they would be swamped by thermal effects. And second, the lower energy state is only for interactions between fermions that are separated by a reasonable distance, so could only happen if there was something about the molecular environment that enabled a large number of fermions within a significant volume to adopt an aligned spin state.

The analysis in Ferrer, Grifols et al. (1999) was done based on the background neutrino flux from the big bang where T^{-1} is of the order of 1mm. The temperature of the solar neutrino flux is much higher, so that T^{-1} would be much smaller and it would be expected that the force would be attractive at much shorter distances, although it may well be the case that it is still a distance of many molecules. This means that the interactions are not nearest neighbour interactions so would not have an effect on the local mobility or structure of the fermions, but it might be expected to have an effect on the macroscopic characteristics of the material.

6. Neutrinos and EZ water

It has long been known that water exhibits unusual characteristics over a distance of hundreds of micrometers at its interface with certain solids or gases such as air (Henniker 1949). This is distinct from the salvation layer around charged molecules that has only been shown to extend for a small number of layers of water molecules (Burling, Weis et al. 1996). There have been a number of more recent studies of the more extended water layer most notably by Ling (Ling 1984, Ling 1988) and Pollack (Zheng, Chin et al. 2006).

While many aspects of this effect have been investigated, perhaps the clearest demonstration of the effect is when microspheres that are suspended in water are seen to move away from certain surfaces. This exclusion region emerges over a period of minutes creating a region that is devoid of microspheres that can be 200µm or more in thickness. This has been designated the EZ water state (Figure 6) (Zheng, Chin et al. 2006).

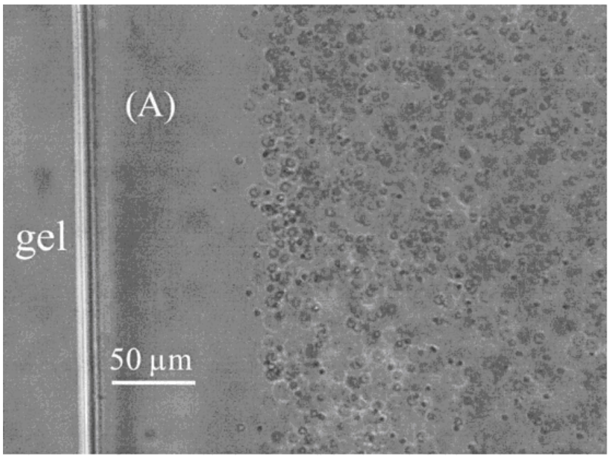

Figure 6 Example of microspheres being excluded from a region close to a PVA gel.

This region has been studied extensively, and many different characteristics of this region have been identified, however there is no agreement as to the mechanism that lies behind the effects that have been observed.

The mechanism would appear to require a long range ordering of some aspect of the water molecules that is not directly associated with the direct intermolecular interaction. The timescales of minutes to hours for these effects to appear also hint that the mechanism is likely to be associated with an interaction between the nuclei of the water molecules. This is because their relative isolation from thermal interactions allows them for the creation of relatively persistent states.

There is an intriguing convergence between the general characteristics of the intermolecular force generated by virtual neutrino exchange and the general characteristics of water in the EZ state. Given that is has not proved possible to explain the characteristics of EZ water using more conventional models, I have recently begun to look at whether neutrino interactions might provide the sought after explanation for the EZ water state.

This could be some combination of virtual neutrino exchange and interaction with the solar neutrino flux. This possibility has not specifically been considered before in that Ferrer, Grifols et al. (1999) considers interactions with the cosmic background flux instead. This means that some of the assumptions, such as the value of the neutrino chemical potential, that may be inappropriate in the case of the interactions between the solar neutrino flux and water. The assumptions mean that the final equations are not proportional to the magnitude of the flux in that it assumes a population of neutrinos that are in thermal equilibrium, such that the flux is linked to the temperature. This will not be the case for the solar flux. I therefore think that there might be a real example of a neutrino based interaction that was previously thought to be of no significance.

Assuming this link between EZ water and neutrinos we can begin to see if some of the other characteristics of EZ water might be consistent with the neutrino based attraction model.

First, it is a common (but not universal) feature of EZ water experiments that a weak magnetic field is necessary for the effect to be observed. For a macroscopic spin alignment to occur there needs to be something that will break the symmetry of the random orientation of the spins and set a specific direction that the spins will tend to align. Such a role could be achieved by a weak magnetic field. The experimental results indicate that best results are usually obtained with a weak field suggesting that there needs to be subtle interplay between the two effects which may not occur in the presence of a strong magnetic field.

Second, the evidence suggests that there needs to be some additional constraint on the mobility of the water in order that the macroscopic neutrino based spin alignment can occur. Ways that this appears to be able to be achieved includes the presence of a charged surface to which a layer of water molecules will bind, or indeed an air/water surface.

7. Neutrinos water and the weak nuclear force

Neutrino interactions could help us understand some real world water based interactions that were otherwise very difficult to explain. It may also be possible that such neutrino interactions might be relevant to the understanding of the physics behind the CES steam generator.

We return to the conversion of a proton to a neutron, a positron and a neutrino (Figure 8).

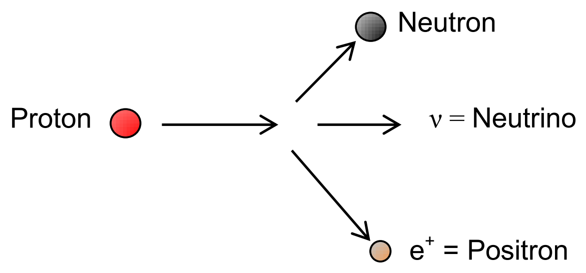

Figure 8 Decay of a proton to a Neutron, neutrino and positron as a result of weak force interactions

For fusion to occur there has to be a solution to the equations for conservation of energy, momentum, spin etc between the system at the start and the system at the end. It is the difficulty, and therefore the unlikelihood, of coming up with a solution that means it normally happens so infrequently.

The presence of the sea of neutrino exchanges that is taking place within the water may create additional potential options for the solutions to the equation that are not normally available. This would increase the probability that the necessary proton to neutron conversion can occur. In this scenario, instead of the neutrino being a real neutrino that is ejected and plays no further part in the process, the neutrino is a virtual neutrino that travels to a nearby proton or electron if conditions are suitable. As with other virtual interactions, the neutrino acts as a force/energy carrying particle, transferring energy from one particle to another.

Through the momentum of the virtual neutrino, the recipient particle then finds itself the recipient of hundreds of keV of energy that arose from the fusion event. One of the options that is then available is to pass a proportion of this energy onwards to another particle through a second virtual neutrino. This will

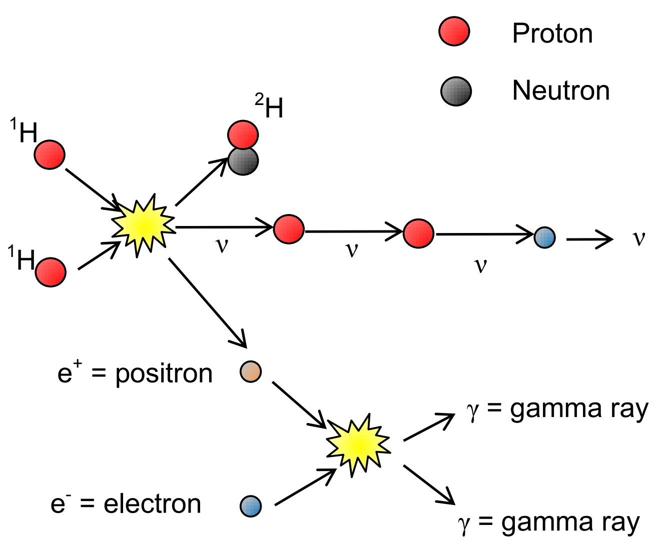

Figure 7 Proton-proton reaction with virtual neutrino exchange chain passing through two protons and an electron

continue until such time as a particle responds through the release of a real neutrino, thus terminating the neutrino exchange chain.

The proton-proton reaction is shown in Figure 7.

As a result the energy released as a result of the proton fusion is distributed through a cascade of neutrino exchanges where the energy of the final outgoing real neutrino is less than the incoming neutrino energy. By doing this, the energy liberated by the initial fusion will be spread over a large number of particles.

In some cases, this may result in the protons acquiring sufficient kinetic energy that they escape from their water molecule and head off at speed through the water where they can and initiate further fusion reactions.

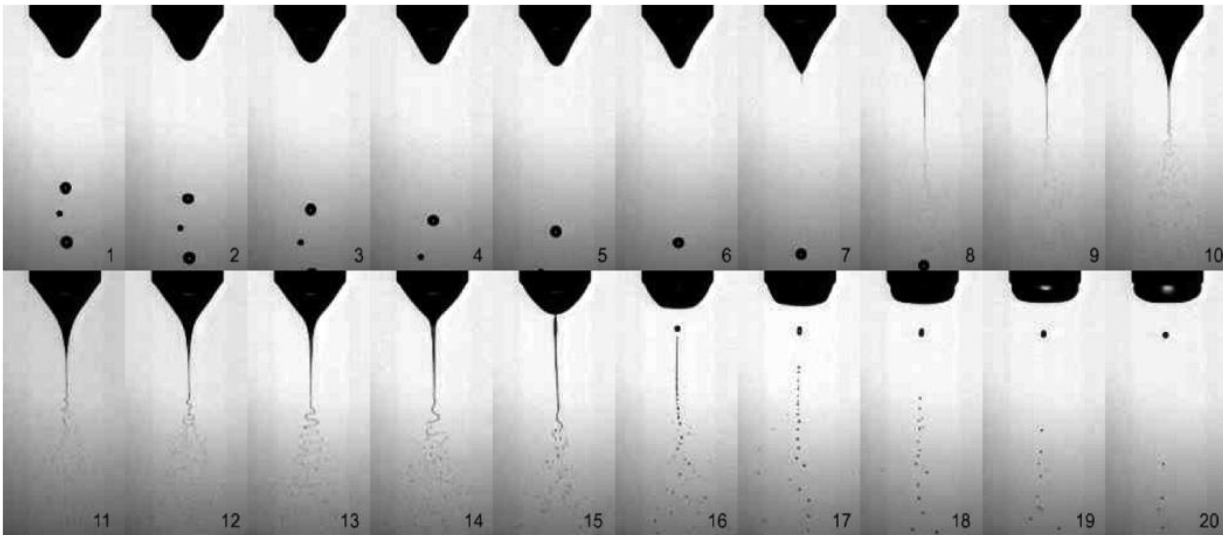

Figure 9 Still images from one pulse of electrospray when run in intermittent mode(Agostinho, Fuchs et al. 2011). The 'explosive' start to the pulse can be seen in frame 8.

Note that when this occurs it is still the case that the protons are drawn from the same body of EZ water so there will be a net alignment of spins which increases the likelihood of fusion occurring.

In other cases the energy may be thermalized, passing from the proton through to the associated water itself and the increase in the kinetic energy of all of the water molecules where this happens increases the temperature of the water.

Supporting evidence for this may come from the recent investigation into the excess energy apparently found in electrospray systems.

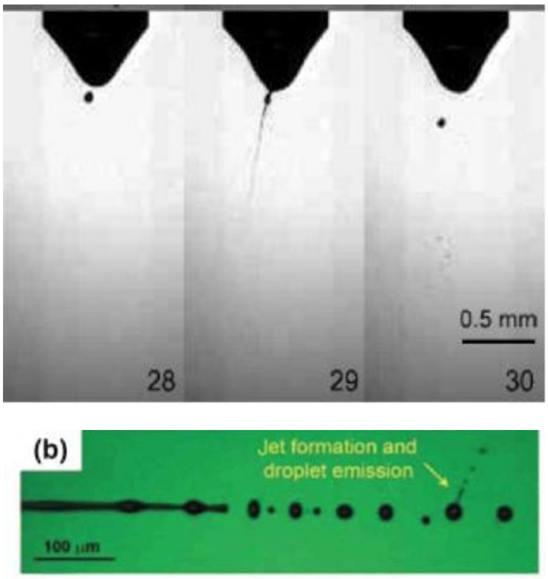

Figure 10 Secondary jet formation a) from a negatively charged droplet returning to the positively charged Taylor cone (Agostinho, Fuchs et al. 2011) b) from an individual electrospray droplet (Meyer, Gabelica et al. 2013)

8. Neutrino based momentum transfer in electrospray experiments

The characteristics of electrospray are well known. A suitable liquid, such as water, is fed slowly through a capillary tube which is at a voltage of greater than about 5kV compared to an adjacent conducting plate. The voltage gradient draws the water towards the plate during which time it breaks into very fine droplets. There has been a recent investigation which found that the kinetic energy of the water droplets shortly after the end of the jet segment of the electrospray exceeded that of the energy input into the system (Graneau, Verdoold et al. 2011). The explanation proposed in the paper where the results were published involved bond breaking and restoration, but it was not fully clear how this could result in the additional kinetic energy that was seen associated with the droplets as they left the electrospray jet

Electrospray systems can be run in a variety of different modes (Cloupeau and Prunet-Foch 1994). In the normal mode the droplets are sprayed continuously. The Graneau et al investigation was just with water, which is very difficult to run in continuous mode, the jet running instead in an 'intermittent' mode which consists of a continuous cycle of bursts of electrospray with short gaps in between.

Videos of electrospray, particularly when used in the intermittent mode, show that each pulse starts relatively explosively (Figure 9).

Interestingly such explosive jet formation can be seen at other times during electrospray (Figure 10)

The conventional explanation for jet and droplet formation such as shown in Figure 10b is Raleigh instability (Hunter and Ray 2009), where evaporation from a charged droplet reduces its size to the point where it is no longer stable as a result of the charge it holds and breaks into smaller droplets. However, examples such as Figure 10b do not sit well with this explanation in that there has been insufficient time for significant droplet evaporation. Furthermore the pictures show a highly directional acceleration of a very small volume of water from the droplet in a way that is not consistent with the Raleigh instability model.

The hydroelectric fusion process suggests an alternative explanation. When the water droplet passes close to another small water droplet of a very different potential one or more protons are accelerated between the two such that it acquires sufficient kinetic energy to initiate fusion. The energetic neutrino exchange would then generate additional high energy protons for further fusion events.

However the details of the reaction shown in Figure 7 may provide an explanation for the explosive, very directional ejection of water shown in Figure 9 and Figure 10. In Figure 7 the arrows do not represent the actual direction that the various particles will take, which will be determined by conservation of energy and momentum. An attempt to show what might happen is shown in Figure 11

In the diagram the kinetic energy of the virtual neutrino is shown being transferred to an electron (d) and a proton (e). The available neutrino energy could be distributed amongst many more protons and electrons in this way. The simplest possibility is that a certain proportion of the kinetic energy is left behind at each interaction between a virtual neutrino and a proton or an electron. The early particles in such a chain would receive a lot of kinetic energy, later particles much less. This could have the effect of dividing the interactions into two broad categories:

The first category would be protons and electrons that acquire sufficient kinetic energy to rip them from the water molecule that they were in. Some of the protons would have sufficient energy that they would be able to initiate a second fusion event if they interact with

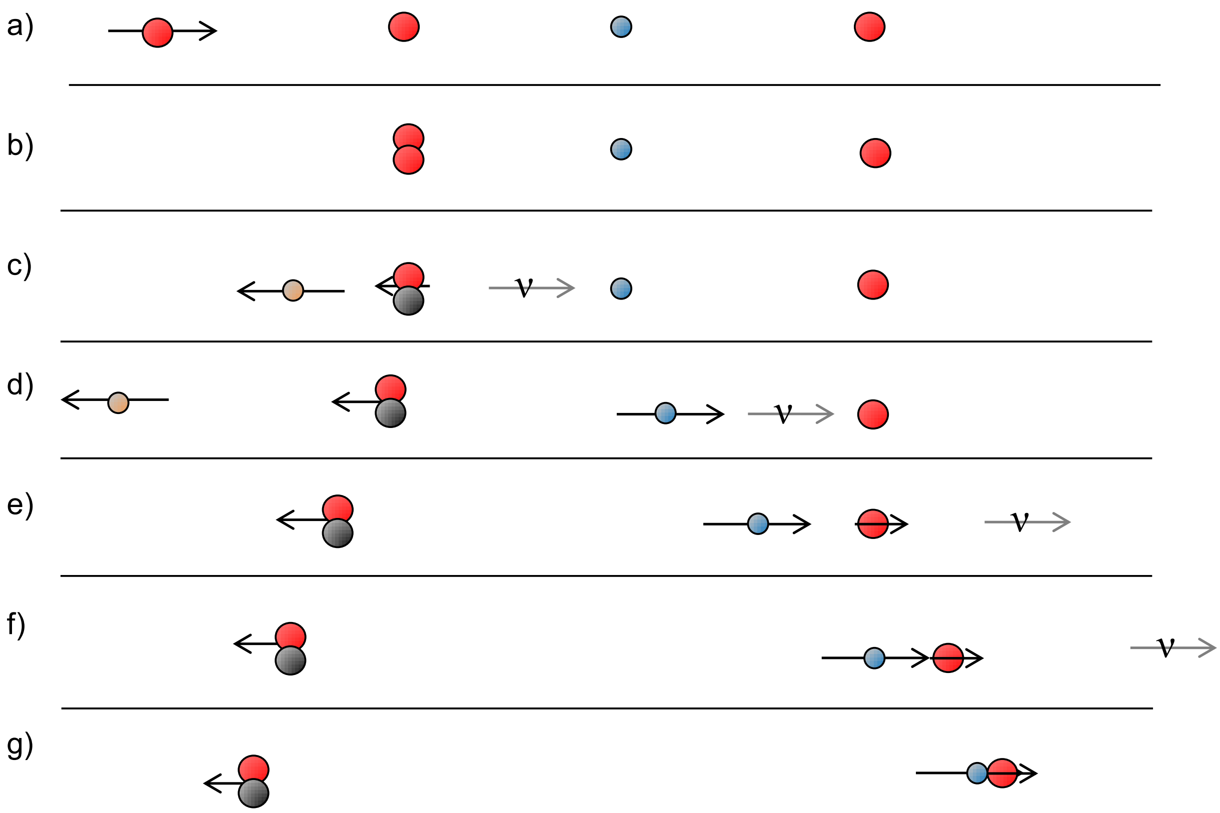

Figure 11 a) incoming proton; kinetic energy from being accelerated through 5kV+ b) Transient diproton c) proton decays to neutron emitting electron and virtual neutrino. Conservation of momentum causes neutrino and deuteron to go in opposite directions. d) Neutrino absorbed and reemitted by electron, leaving some residual kinetic energy which accelerates electron e) Similar transfer of energy to proton f)& g) electron and proton now both travelling along the same trajectory.

another proton in another water molecule.

In the second category the protons and electrons would remain associated with the water molecule and the kinetic energy would be transferred from the proton to the whole water molecule. At the same time, the deuteron formed by the original fusion, together with its associated water molecule would be moving in the opposite direction as a result of momentum conservation. The net result of this is that there is a repulsive force pushing the water molecules involved in the fusion chain away from each other, with the force acting along the line of the original incoming proton. Subsequent fusion events would reinforce this repulsive effect, and continue to act along the same axis.

This now begins to provide a possible explanation for the explosive events that propel a small volume of water at a significant velocity away from the Taylor cone, or other water droplets as shown in Figure 9 and Figure 10. The fusion reactions create a repulsive force acting along a specific axis that will push water away at a significant velocity, and as the water moves away it breaks up into the small droplets that are seen.

It would seem possible that one of these explosive repulsive events would be associated with the initiation of each of the pulses when in intermittent mode. However, the experimental evidence is that all of the water droplets during such a pulse have an energy that exceeds what would be expected given the input energy and not just the initial droplets. This would suggest that neutrino assisted fusion continues within the jet portion of the electrospray for some time after the fusion was initiated. The higher energy protons created by this process would provide the means for the process to continue. The kinetic energy of the lower energy protons would be transferred to the associated water molecule, providing the repulsive force along the jet. It is this force that results in the water droplets leaving the end of the jet with a greater velocity than would otherwise be expected based on a simple energy balance.

The additional kinetic energy measured of about half a milliwatt would require approximately 10^{10} fusion events per second within the electrospray jet, such that the proportion of protons that become associated with a fusion event is approximately 1 in 10^{10}.

The neutrino interaction would only take place between protons in the water molecules which are found in the very thin jet and this will ensure that the repulsive force that accelerates the water droplets also acts along the axis of the jet.

9. The role of neutrinos in creating efficient fusion

There are other potentially significant implications of a fusion model that involves virtual neutrinos.

The first relates to the likelihood of fusion taking place, in that normally the likelihood of proton-proton fusions is extremely small. In order to calculate the probability of a nuclear interaction, it is necessary to integrate over all the possible pathways that the interaction could take place. Each additional pathway increases the likelihood, the cross section, of the interaction. There will be a vast number of alternative pathways for the virtual neutrino cascade to take place, each involving a different combination of protons and electrons. The existence of each one of these will have the effect of increasing the likelihood of the original proton fusion event taking place.

This does however raise the question of why such virtual neutrino interactions are not taking place within stars such as the sun. We are currently able to model the nuclear processes in stars very accurately and these models do not involve virtual neutrinos.

There is one significant difference between the centre of stars and the CES steam generator and that is the temperature. The temperature at the centre of stars such as the sun is approx. 15,000,000 K, such that the protons in the plasma are travelling with a mean velocity of 600km/sec. In the steam generator the protons are travelling at a thousandth of this velocity, and it is this difference that might explain why virtual neutrinos might play a role in the fusion seen in the steam generator, but not in the fusion seen within stars.

Another possibility, that has also previously been considered in the case of neutron stars (Woodahl, Parry et al. 1997), is that the presence of a significant density of real neutrinos, as will be the case in the core of a star, will suppress virtual neutrino exchange.

10. The role of neutrinos in suppressing gamma radiation

One of the puzzling aspects of LENR is the apparent absence of gamma radiation. This is also relevant to the fusion hypothesis for electrospray in that electrospray is a sufficiently common process that if ionizing radiation was being generated by the combining of positrons and electrons would probably have been detected by now.

The model proposed would enable kinetic energy to be transferred to protons, neutrons and electrons, which would end up travelling along a common axis. Protons and electrons that have been ripped from their water molecules at a significant velocity could then become associated as a result of electrostatic interaction, but they are at too high an effective temperature for them to form a stable hydrogen atom.

The normal process of proton-proton fusion results in the generation of a positron (Figure 4). However the presence of the associated electron means that an alternative option is available, namely that of electron

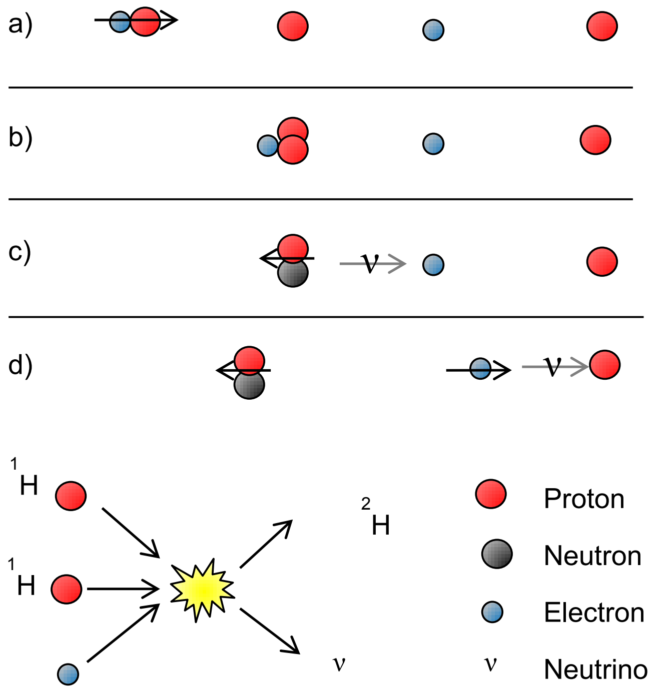

Figure 12 The arrival of a proton and an electron initiating fusion that incorporates electron capture rather than positron emission and this removing the step where a positron and an electron combine and produce two gamma ray photons.

capture. This removes the need for a positron to be generated in order to balance the equations and would result in a larger amount of kinetic energy being transferred to the neutrino ().

The virtual neutrinos would also be able to pass kinetic energy on to neutrons. However, the only significant source of neutrons within the water is the nucleus of the oxygen atom and virtual neutrino would have to supply the energy required to release the neutron from the oxygen nucleus, which is energetically unfavourable and so unlikely.

11. Cavitation and shock waves

Now that we have a picture of how cavitation bubbles can create the conditions where fusion can take place, we need to look in a little more detail as to how the CES steam generator does this in a particularly efficient manner.

There have been a number of previous attempts to use cavitation based systems to generate energy, and experimental results have indicated that there were small amounts of energy gain. As well as the underlying mechanism behind this energy gain not being understood, they have all suffered from three distinct and apparently insurmountable problems. This has been one of the reasons why it has been difficult to get wider interest in investigating and developing cavitation systems. There are two key and innovative aspect of the CES steam generator that appears to resolve all three of these problems.

The first of the problems is that in previous systems the cavitation occurred within water in the liquid state at standard pressure. This limited the temperature of the process to below 100C, the boiling point of water, and as such only appeared to be of use for heating up water. For the system to be used to provide work energy, such as could be used for generating electricity, would require the energy to be generated at a much higher temperature so that it could, for example, create steam to power a turbine.

The second problem was that the coefficient of performance, the ratio of the input to the output energy tended to be low. This meant that, as a water heater, these systems were not able to out-perform a heat engine based water heating system, making it unclear where there might be any practical application.

The third problem is that in the systems that had been investigated for generating significant quantities of cavitation the cavitation occurred immediately adjacent to surfaces. Most standard engineering materials proved unable to withstand the energy generated by the cavitation and would become damaged in a short space of time.

The first of the innovations within the CES steam generator is in some senses not an innovation in that it is a standard technique in a different context. Cavitation bubbles occur when there is a sudden drop in the water pressure as might be found on the surfaces of impellor blades that are operated outside of their intended operating range (Sreedhar, Albert et al. 2017). Another way of inducing cavitation is to put the liquid under pressure and then suddenly release the pressure, which results in cavitation bubbles forming throughout the bulk of the liquid. This is a standard technique in diesel injectors for dispersing diesel fuel more efficiently (Westlye, Battistoni et al. 2016).

However, when this was done previously with water this was not shown to produce much if any energy gain as the bubbles collapse.

The second innovative aspect of the CES steam generator is that the water that has just emerged from the injector and is full of cavitation bubbles hits a surface that is about 1cm away from the injector.

When the water hits the surface at about 500 m/s a shock wave will be generated that will travel back through the water at the speed of sound in water that is filled with cavitation bubbles. This will be slightly less than the speed of sound in water but will still be of the order of 1500 m/s

It has been shown that such a shock wave will have two effects. Firstly it will trigger the collapse of the cavitation bubble, and it will do it in a way that the re-entrant jet will point in the same direction as the direction of travel of the shock wave (Ohl, Klaseboer et al. 2015)(Figure 13,Figure 14). The effect of this on a volume of water that is saturated with cavitation bubbles resolves all three of the problems suffered by previous cavitation systems.

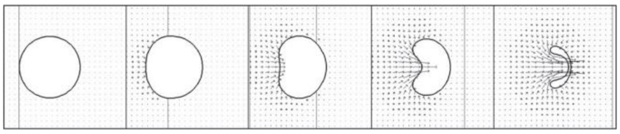

Figure 13 Simulation result of the interaction of a pressure pulse of 0.528 GPa with a bubble of radius 1.0 mm (Ohl, Klaseboer et al. 2015).

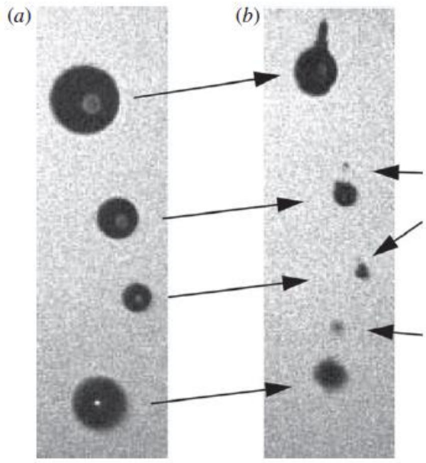

Figure 14 Four bubbles 0.3 ms before the arrival of the shock wave (a), and 1.5 ms after the shock wave has travelled from the bottom of the frame (b). The frame width is 250 μm. The left to right arrows depict the centre of translation and the other arrows show the remaining bubbles after the jet penetration. Note that each bubble has moved upwards. The top bubble still clearly exhibits the entry of a jet in the upwards direction. The three other bubbles show remnants of these jets in the form of even smaller bubbles. These have probably split off from the main bubble (Ohl, Klaseboer et al. 2015).

The second effect of the shock wave is that it will synchronise the collapse of all of the bubbles throughout the volume of injected water. Each bubble is then independently able to generate energy that heats up the water that is local to the cavitation. Sufficient energy is then generated to turn the water into high temperature steam which is potentially available for performing work such as generating electricity, thus overcoming the first of the problems suffered by conventional cavitation systems.

The technique of using pressurisation to fill a volume of water with cavitation bubbles, and then using a shock wave to generate energy from the majority of the bubbles, is also able to achieve a level of efficiency that is significantly greater than previous cavitation systems, and is certainly above that of conventional heat pumps. As such this then resolves the second problem associated with cavitation systems.

The third problem, which is the damage caused by cavitation bubbles, is resolved because the shock wave causes the re-entrant jet, and therefore the energy that is generated, to be directed away from the surface, which considerably reduces the damage suffered by the surface. The surface still has to be tough enough to withstand the forces associated with repetitive pulses of water a jet of water.

12. Conclusions

I think it is now possible to see how the formation of EZ water and the presence of a high accelerating voltage appear to be the two key ingredients for the generation of excess energy in a number of different systems which appear at first sight to be radically different from each other.

The CES steam generator would appear to combine the ingredients in an exquisite and inspired way that overcomes some of the limitations of some of the alternative systems that have been investigated.

For example, the conditions within the Graneau electric arc systems are very chaotic such that only a small proportion of the energy goes into arranging the water into the correct conditions for fusion to occur. It is almost certainly the case that a considerable amount of energy that simply goes into heating the water in a 'conventional way' through the formation of an electric arc, such that the additional energy from fusion, once the calculations are done correctly, is relatively small. A further disadvantage of the Graneau systems is that it is essentially a one-shot system that has to be precharged. The Graneaus recognised that the most effective solution ultimately should be based on continuous low, possibly based on the use of a turbine, and it is difficult, although not impossible, to convert the electric arc into an efficient continuous flow system.

The CES steam generator appears to be considerably more efficient than the electric arc system, in that the input energy is more efficiently directed towards creating the conditions required for fusion, and less of the input energy goes directly to heat energy.

There is evidence that 'conventional' cavitation systems such as occurs in pumps when there are large pressure drops adjacent to surfaces can also generate small amounts of energy gain. However, these suffer from a couple of significant problems. The first is that the heat from the cavitation bubbles was used to heat up the water, but the heat release was always small in comparison with the volume of water used so that the water temperature never exceeded 100C. As it approached 100C the conditions for cavitation disappeared. As a heat source this is potentially useful, but it is unclear how such systems could generate the high grade, high temperature heat is needed for applications such as power generation which has to be the ultimate goal.

A second limitation of such cavitation systems was that the cavitation occurs immediately adjacent to a surface. A considerable proportion of the energy then went into damaging the surface, considerably limiting the lifetime of the system.

The CES steam generator would appear to resolve both of these problems.

In the case of the water temperature CES has optimised the size of the water charge such that the available energy is able to completely vaporise the water, ultimately generating steam at 115C. The implication is that the water was probably converted to steam at a much higher temperature than this, and it is likely that further optimising the system is a matter of engineering. What we have at present is the equivalent of the Wright brothers first plane. The transition to the Jumbo jet was in some respects just a matter of engineering.

In the case of the location of the cavitation, inducing the cavitation through the use of a sudden pressure drop as the water leaves the injector successfully moves the cavitation away from a surface so avoiding the problem of surface damage.

However there is a problem with doing this, and again the CES may have found a neat solution to the problem.

The appearance of large potential differences within the cavitation bubble occurs as a result of asymmetric bubble collapse, which in turn results from asymmetries in the environment of the bubble. In previous cavitation systems that happens because of the presence of a surface, the problem then being the damage to the surface. My suspicion is that there is not adequate asymmetry within the water as it emerges from the injector for the internal jets and potential differences to occur.

The CES steam generator involves firing the jet of water at a surface, which is already recognised as being a key component of the design.

As the water hits the surface it will send a shock wave through the system which means that the bubbles throughout the volume of water will experience a dramatic, asymmetric and coordinated change in the local pressure which will have a significant effect on the way each bubble collapses, and possibly on the coordination of the collapse of the bubbles. Simulating and analysing this will probably be an absolute nightmare, but it is possible that this creates the conditions for a fusion front to travel through the water charge in a way that ensures the most efficient fusion process.

October 21st 2017

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Appendix 1: Calculations of power generation

CES have produced figures showing the energy usage required to produce 10.89lbs of steam over a period of an hour.

Water pump (kWh)	0.39
Hydraulic pump (kWh)	0.19
Heaters (kWh)	0.21
	0.79

Which equates to a total energy of 2844 kJ

From steam/water tables, the enthalpy of the water at the start and finish can be found

Enthalpy at finish	10MPa – 200C (kJ/kg)	2875
Enthalpy at start	1 atm – 20C (kJ/kg)	84
Increase		2791

10.89lbs equals 4.9kg, so the net energy increase is 13678 kJ, giving a coefficient of performance of 4.8 and total 'additional' energy generated of 10.1MJ.

Alternative power calculations

There is an alternative way of looking at the energy balance that is not dependent on the details of the power measurements.

Within the diesel injector the available energy comes solely from the additional enthalpy of the water being at a very high pressure and also having been preheated to 80C, an increase of 362 kJ/kg over that of water at room temperature and pressure. However at the output the water is fully converted to steam, and the pressure relief valve that allows the steam to emerge operates at 1500psi or 10MPa, implying that the steam must be at a minimum temperature of 310C. Assuming a temperature of 400C this represents an increase in enthalpy of 3013 kJ/kg over water at rtp, giving a coefficient of performance of 8.3. This is very similar to the figure calculated based on power measurements.

1 atm – 20C (kJ/kg)	84
140MPa – 80C (kJ/kg)	446
Increase	362

1 atm – 20C (kJ/kg)	84
10MPa – 400C (kJ/kg)	3097
Increase	3013

These calculations demonstrate that the most important factor in terms of showing that a significant power gain has been achieved is that all, or at least a significant proportion of the water is turned to steam. That this is so can be verified to a large extent by looking closely at stills from the video that has been published of the operation of the steam generator (Figure 15)

Fusion events per cavitation bubble

The system was operated at 5 pulses per second, so this is approximately 600J of energy per pulse.

If it is assumed that there are 10^6 cavitation bubbles per injected pulse of water this equates to 6×10^{-4}J of energy per cavitation bubble.

If it is assumed that the energy is derived from proton-proton fusion then the fusion of two protons yields a total of 1.44MeV, which is the energy from the original fusion event and the subsequent annulation of the positron when it combines with an electron. This is an energy of 2×10^{-13}J, suggesting that there are of the order of 3×10^9 fusion events per cavitation bubble.

a)

c)

b)

Figure 15 Stills from video of CES steam generator. A) shows the appearance before steam has emerged. B) shows the situation as the steam emerges. The steam in fully vapour and as such is invisible, but its presence is clear from the refraction of light from objects behind the steam. c) The steam cools and the water vapour condenses out into visible droplets.