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

The evidence from CES indicates that the steam generator achieves an energy gain of about a factor of five. The output energy is measured in terms of the enthalpy of the steam at a temperature of 115C so represents a relatively conservative estimate of the energy gain. The nature of the system and the form of the output energy makes it impossible to explain such an energy gain based on simple thermodynamics and molecular interactions, such as the explanations involving dielectric breakdown. In this situation it may be necessary to quote Sherlock Holmes: "Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth". One of the improbable things that remain is the possibility that fusion is the source of the energy gain. But is this feasible? Is this the truth?

Given that the only raw material in the CES steam generator is water, there are 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 0.003% of heavy water found within ‘ordinary’ water. The second is that it involves the fusion of protons to produce deuterons which would then increase the proportion of heavy water. Proton fusion is more difficult for reasons that we will come on to, which is why ‘table top’ fusion systems such as the Farnsworth Fusor (Edwin 2007) use deuterium. However, CES do 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 credible possibility.

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 the energy that could 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.

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 force to become significant they must somehow 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.

Such high temperature plasmas as are found in stars 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 to overcome the coulomb barrier, 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). 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 very inefficient.

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 I have dubbed 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 amount of neutron (Shah, Razdan et al. 1985, Bratolyubova-Tsulukidze, Grachev et al. 2004, Martin and Alves 2010, Gurevich, Antonova et al. 2012), positron (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 I and others (Chilingarian, Daryan et al. 2010, Gurevich, Antonova et al. 2012) do not believe that this model is adequate to explain what is observed, these 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 where experiments involving water and high voltages 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 and a small group investigated the evidence such as it was and came to the conclusion that it was difficult to see how the more obvious explanations, such as the discharge of the smoothing capacitor that was associated with the experiment could give rise to the damage that occurred. In this case the origin of the explosion would appear to be when an instability occurs that results in 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 a slight 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.

Potential differences within cavitation bubbles

It has long been known that during the process of cavitation bubble appearance and collapse some very significant potential gradients will 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 can also be used to show that potential differences of greater than 10kV can occur between different positions on the boundary of a bubble as it collapses. This means that 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 it the potential difference is generated internally 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 bubble and travels at great speed across the bubble (Figure 1). 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.

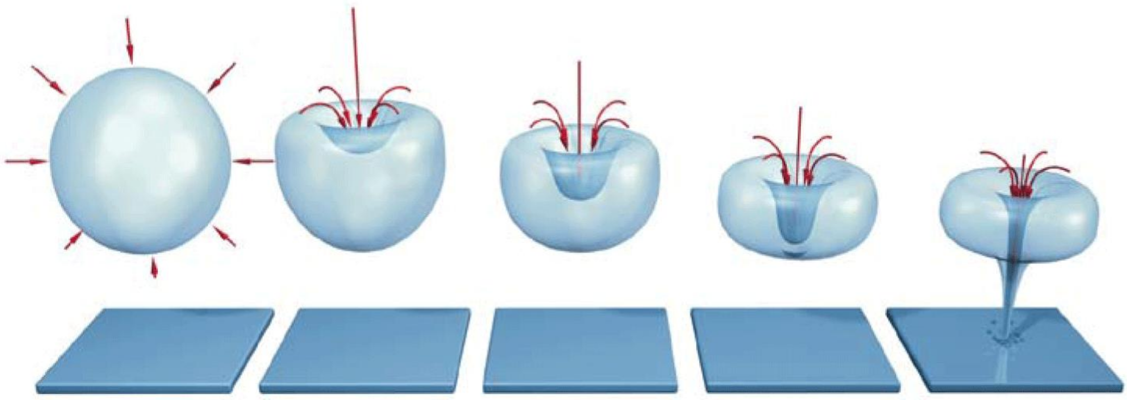


Figure 1 Micro-jet creation through collapsing cavitation bubbles (http://eswt.net/cavitation)

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 2).

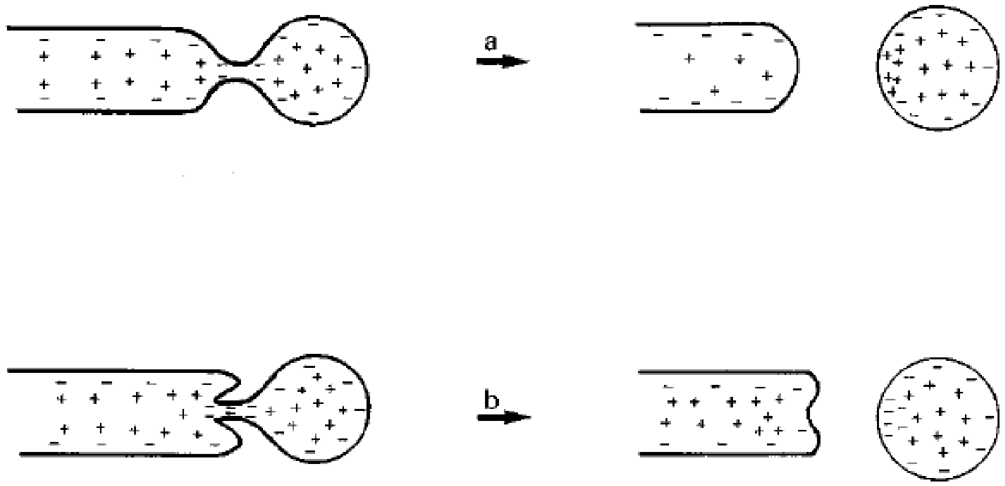


Figure 2 Build-up of large charge differences as a water droplet breaks away from the jet within a cavitation bubble (Lepoint, De Pauw et al. 1997)

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.

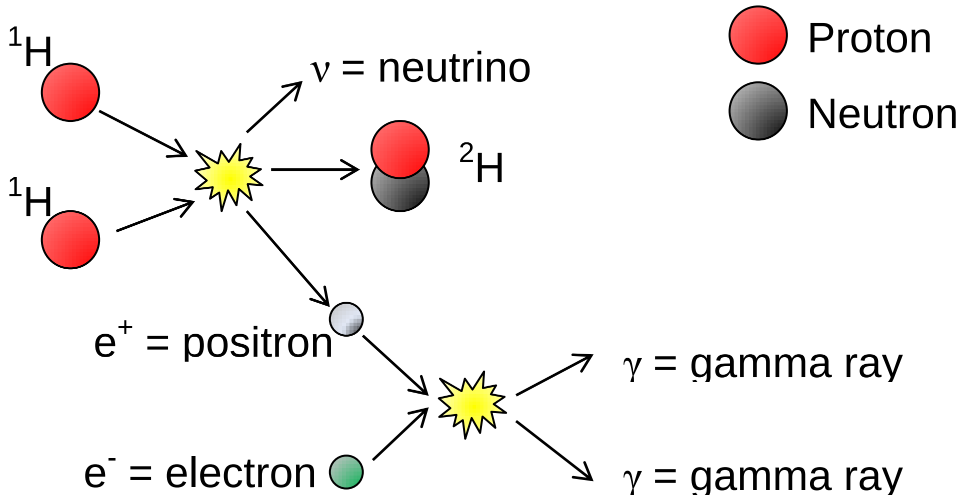
Cavitation lies at the heart of the CES steam generator, so this understanding of the processes that take place that are associated with cavitation provides a mechanism for giving protons sufficient energy to initiate fusion. However, for fusion to occur the protons must then decay to a neutron the action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

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 simply 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.

We therefore need an explanation 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 the sun



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.

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

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 are emitted as a way of something releasing 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.

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 3) (Hsu and Sikivie 1994, Lusignoli and Petrarca 2011).

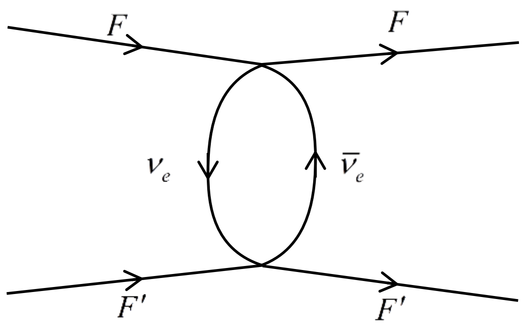


Figure 3 Interaction between two fermions as a result of an exchange of a virtual neutrino/anti-neutrino pair

The potential energy of two particles that arises from this force is:

$$V(r) = \frac{G_F^2 g_V g_V'}{4\pi^3 r^5}$$

Where g_V and g_V' are functions of the neutrino flavour and are of the order of unity and G_F is the Fermi constant. This gives rise to a small repulsive force between the particles.

The r^{-5} term 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).

In the simple spin-independent case the result is that for particles that are further apart than a distance T^{-1} where T is the temperature[1] then the potential is approximately

$$V_T(r) = -\frac{G_F^2 g_V g_V'}{2\pi^3 r^5}$$

The negative sign is critical in that this shows that the force is attractive (but still very small). For distances below T^{-1} the repulsive neutrino exchange force dominates.

When spin is taken into account the potential is given by:

$$V^{\text{spin}}(r) = \frac{G_F^2 g_V g_V'}{2\pi^3 r^5}\left[5\frac{(\boldsymbol{S}\cdot\boldsymbol{r})(\boldsymbol{S}'\cdot\boldsymbol{r})}{r^2} - 3(\boldsymbol{S}\cdot\boldsymbol{S}')\right]$$

In this case the $-3(\boldsymbol{S}\cdot\boldsymbol{S}')$ term is of interest in that this shows that the potential gives rise to an attractive force when the spins are aligned and a repulsive force 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)

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

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

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

the local mobility or structure of the fermions, but it might be expected to have an effect on the macroscopic characteristics of the material.

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 4) (Zheng, Chin et al. 2006).

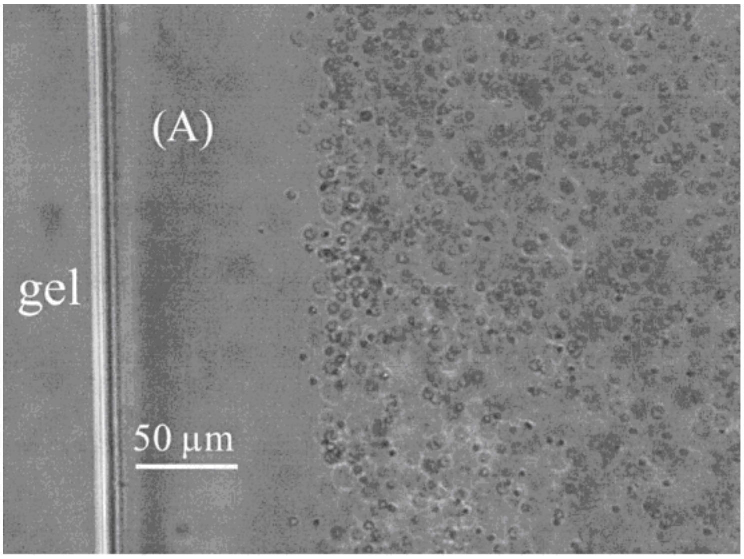


Figure 4 Example of microspheres being excluded from a region close to a PVA gel.

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 also hint that the mechanism is likely to be associated with an interaction between the nuclei of the water molecules.

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. There is also some evidence that putting water under high pressure can achieve the same effect but this is then effective through a large volume of water rather than just at a surface. It is then perhaps significant that the water used in the CES steam generator is pre-pressurised.

Neutrinos water and the weak nuclear force

Given that I had already started to see how neutrino interactions could help us understand some real world water based interactions that were otherwise very difficult to explain, it should not be a surprise that I began to wonder whether such 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 5).

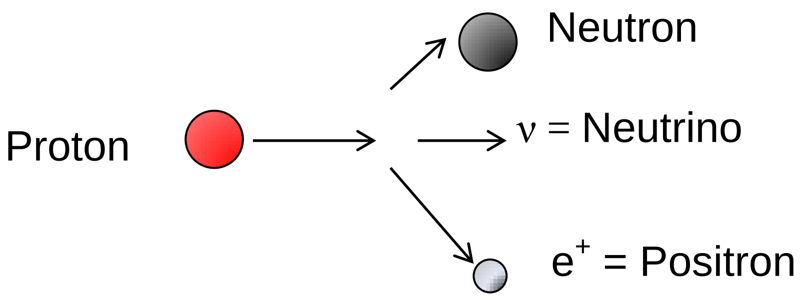


Figure 5 Decay of a proton to a Neutron, neutrino and positron as a result of weak force interactions

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 happens so infrequently and usually does not.

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 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 now looks something like

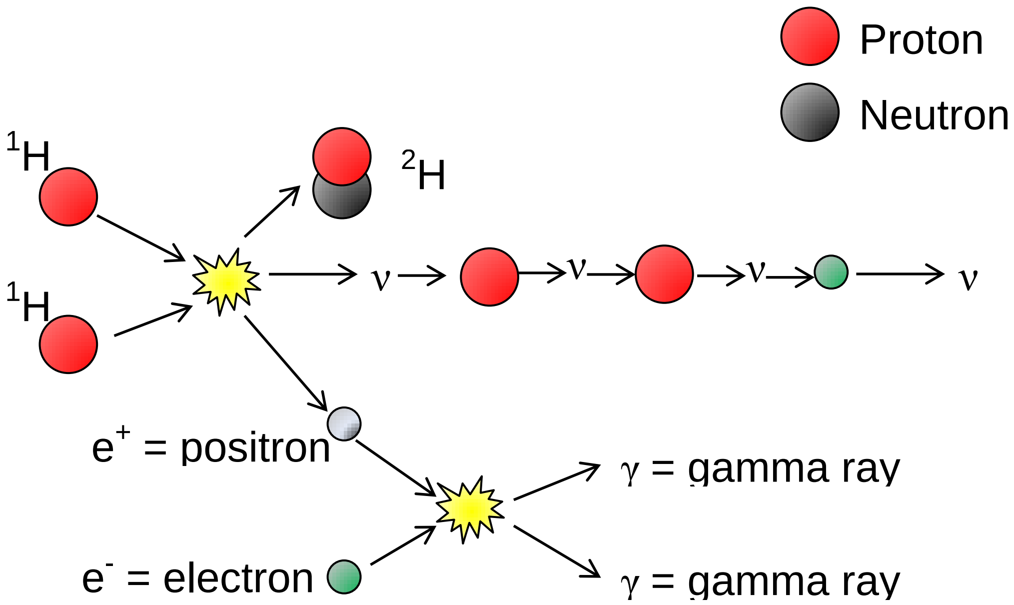


Figure 6 Proton-proton reaction with virtual neutron exchange chain

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 head off at speed through the water and initiate further fusion reactions. 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.

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.

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 7).

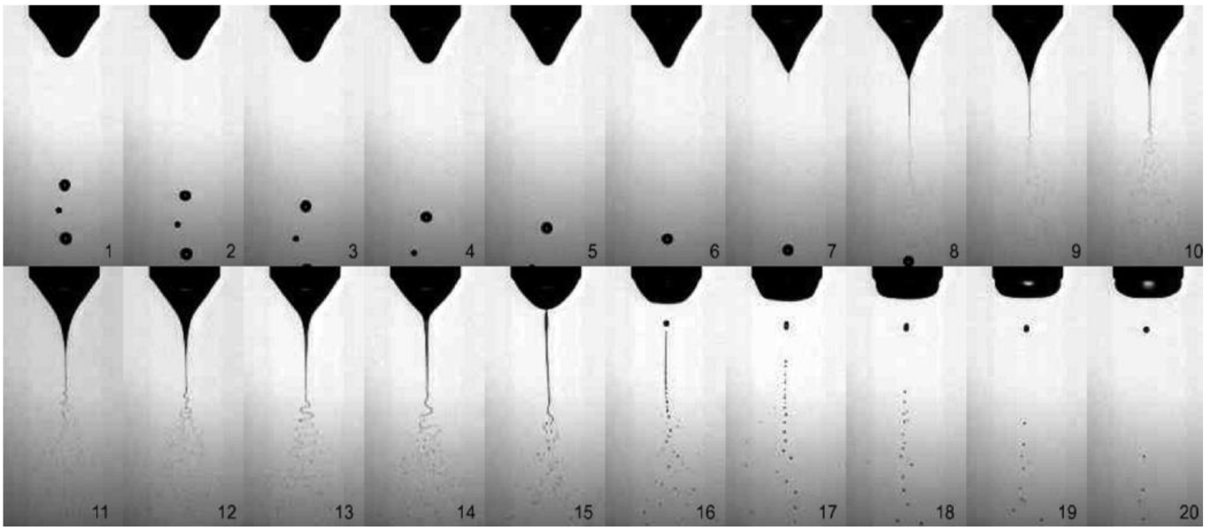


Figure 7 Still images from one pulse of electrospray when run in intermittent mode(Agostinho, Fuchs et al. 2011). The 'explosive' start to the pulse can be seen in frame 8.

Interestingly such explosive jet formation can be seen at other times during electrospray (Figure 8)

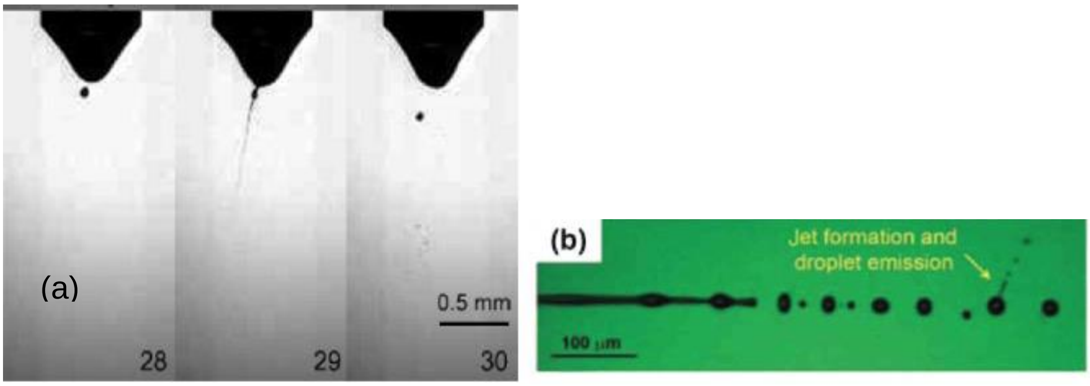


Figure 8 Secondary jet formation a) from a negatively charged droplet returning to the positively charged Taylor cone (Agostinho, Fuchs et al. 2011) b) from an electrospray droplet (Meyer, Gabelica et al. 2013)

The conventional explanation for jet and droplet formation such as shown in Figure 8b 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 8b do not sit well with this explanation in that there has been insufficient time for significant droplet evaporation and there is evidence of 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 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 6 may provide an explanation for the explosive, very directional ejection of water shown in Figure 7 and Figure 8. In Figure 6 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 9

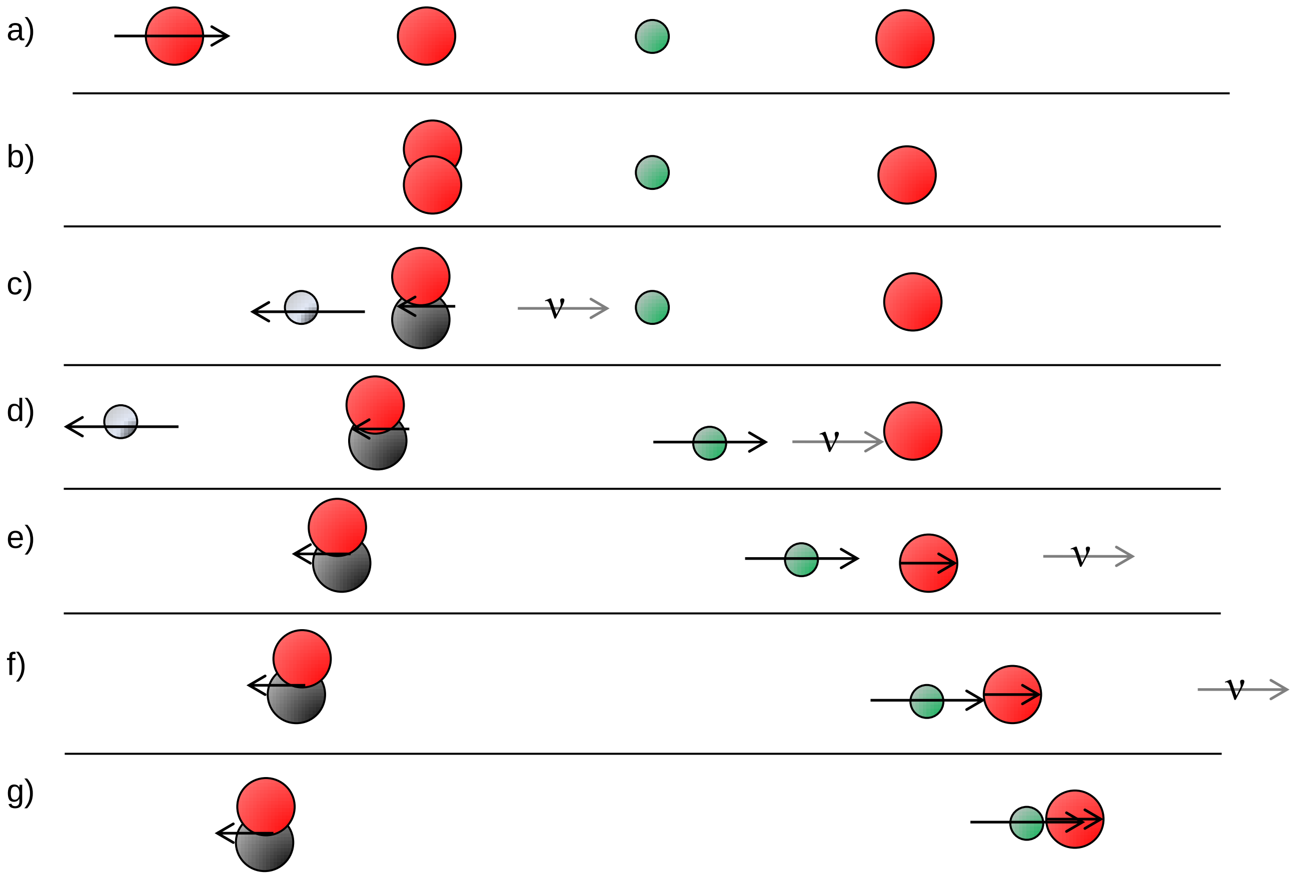


Figure 9 a) incoming proton; kinetic energy from being accelerated through 5kV+ b) Transient diproton c) proton decays to neutron emitting electron and virtual neutrino. Conservation of momentum causes neutrino and deuteron to go in opposite directions. d) Neutrino absorbed and reemitted by electron, 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.

In the diagram the kinetic energy of the virtual neutrino is shown being transferred to an electron and a proton. The available neutrino energy could be distributed amongst many 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 the virtual neutrinos and the protons and electrons. The early particles 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 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 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 7 and Figure 8. There is a repulsive force acting along a specific axis that will push water away at a significant velocity, and as the water moves away it would break up into the small droplets that are seen.

One of these explosive repulsive events is 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. The higher energy protons would provide the means for the process to continue, and the kinetic energy of the lower energy protons would be transferred to the associated water molecule, providing the repulsive force along the jet 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.

If this analysis is correct then it would have very interesting consequences. In acting to accelerate the water droplets in one direction, along the axis of the jet, the energy that has been released from fusion is being converted directly into work energy without an intervening heat energy stage. Such an option has not been available previously when extracting energy from fossil fuels or nuclear processes, although is inherent to using renewable energy such as wind and wave power.

However, the power generated by the electrospray system does not appear to provide a particularly useful power source.

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 in 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 means 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.

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 that I have 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 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.

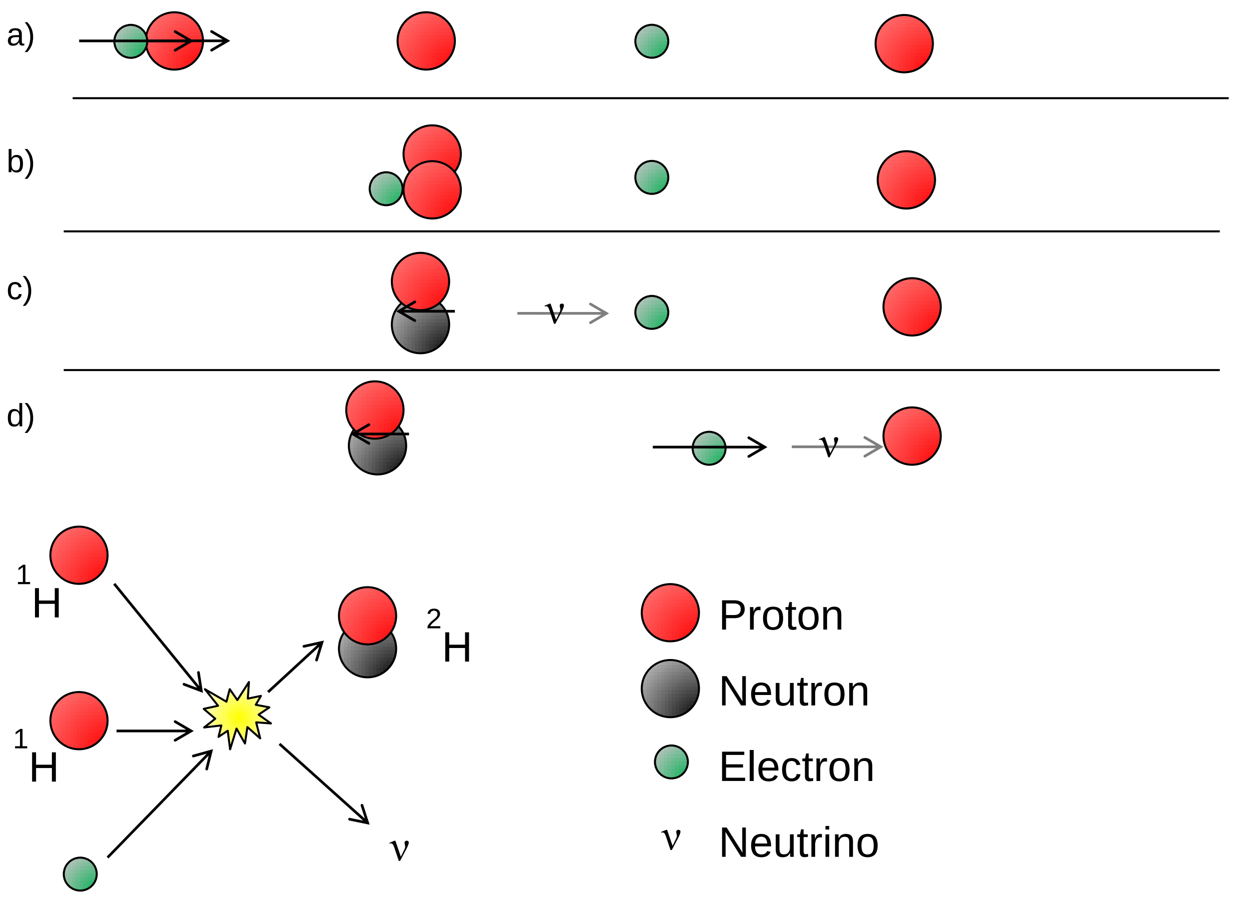


Figure 10 The arrival of a proton and an electron initiating fusion that incorporates electron capture rather than positron emission and this removing the step where a positron and an electron combine and produce two gamma ray photons.

When a proton forms a deuteron, I previously showed how this would result in the generation of a positron. However the presence of an available electron means that an alternative option is available, namely that of electron capture. This removes the need for a positron and would result in a larger amount of kinetic energy being transferred to the neutrino (Figure 10).

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.

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 operation 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 11,Figure 12). 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.

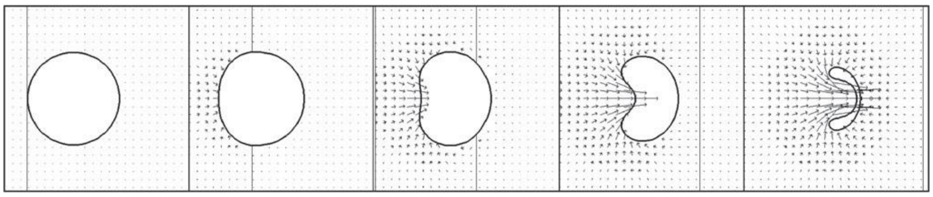


Figure 11 Simulation result of the interaction of a pressure pulse of 0.528 GPa with a bubble of radius 1.0 mm (Ohl, Klaseboer et al. 2015).

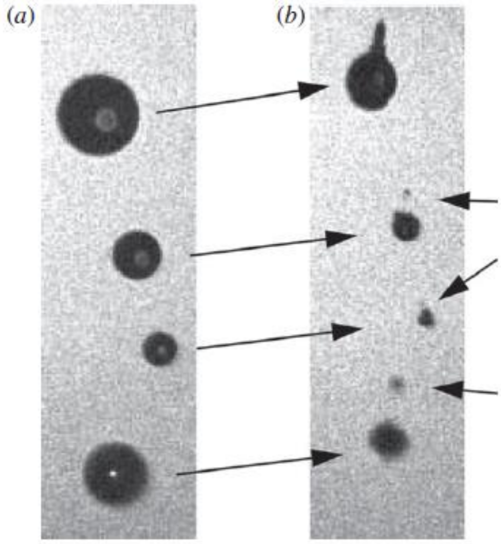


Figure 12 Four bubbles 0.3 ms before the arrival of the shock wave (a), and 1.5 ms after the shock wave has travelled from the bottom of the frame (b). The frame width is 250 μm. The left to right arrows depict the centre of translation and the other arrows show the remaining bubbles after the jet penetration. 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.

Conclusions

I think it is now possible to see how 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 is a very neat way of moving 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 may turn out to be a key component of the design, but not for the reasons that they have proposed.

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.

Nigel Dyer

8th September 2017

Agostinho, L., E. Fuchs, S. Metz, C. Yurteri and J. Marijnissen (2011). "Reverse movement and coalescence of water microdroplets in electrohydrodynamic atomization." Physical Review E **84**(2): 026317.

Biagi, C. J., M. A. Uman, J. D. Hill, D. M. Jordan, V. A. Rakov and J. Dwyer (2010). "Observations of stepping mechanisms in a rocket-and-wire triggered lightning flash." J. Geophys. Res. **115**(D23): D23215.

Bratolyubova-Tsulukidze, L. S., E. A. Grachev, O. R. Grigoryan, V. E. Kunitsyn, B. M. Kuzhevskij, D. S. Lysakov, O. Y. Nechaev and M. E. Usanova (2004). "Thunderstorms as the probable reason of high background neutron fluxes at L<1.2." Advances in Space Research **34**(8): 1815-1818.

Briggs, M. S., V. Connaughton, C. Wilson-Hodge, R. D. Preece, G. J. Fishman, R. M. Kippen, P. N. Bhat, W. S. Paciesas, V. L. Chaplin, C. A. Meegan, A. von Kienlin, J. Greiner, J. R. Dwyer and D. M. Smith (2011). "Electron-positron beams from terrestrial lightning observed with Fermi GBM." Geophys. Res. Lett. **38**(2): L02808.

Burling, F. T., W. I. Weis, K. M. Flaherty and A. T. Brunger (1996). "Direct observation of protein solvation and discrete disorder with experimental crystallographic phases." Science **271**(5245): 72-77.

Chilingarian, A., A. Daryan, K. Arakelyan, A. Hovhannisyan, B. Mailyan, L. Melkumyan, G. Hovsepyan, S. Chilingaryan, A. Reymers and L. Vanyan (2010). "Ground-based observations of thunderstorm-correlated fluxes of high-energy electrons, gamma rays, and neutrons." Physical Review D **82**(4): 043009.

Cloupeau, M. and B. Prunet-Foch (1994). "Electrohydrodynamic spraying functioning modes: a critical review." Journal of Aerosol Science **25**(6): 1021-1036.

Dolgov, A. D. (2002). "Neutrinos in cosmology." Physics Reports **370**(4): 333-535.

Dwyer, J. R., H. K. Rassoul, M. Al-Dayeh, L. Caraway, A. Chrest, B. Wright, E. Kozak, J. Jerauld, M. A. Uman, V. A. Rakov, D. M. Jordan and K. J. Rambo (2005). "X-ray bursts associated with leader steps in cloud-to-ground lightning." Geophys. Res. Lett. **32**(1): L01803.

Edwin, C. (2007). "The secret world of amateur fusion." Physics World **20**(3): 10.

Ferrer, F., J. A. Grifols and M. Nowakowski (1999). "Long range forces induced by neutrinos at finite temperature." Physics Letters B **446**(2): 111-116.

Fishman, G. J. (2011). "Positrons observed to originate from thunderstorms." Eos Trans. AGU **92**(22).

Graneau, N., S. Verdoold, G. Oudakker, C. Yurteri and J. Marijnissen (2011). "Renewable energy liberation by nonthermal intermolecular bond dissociation in water and ethanol." Journal of Applied Physics **109**(3): 034908.

Gurevich, A. V., V. P. Antonova, A. P. Chubenko, A. N. Karashtin, G. G. Mitko, M. O. Ptitsyn, V. A. Ryabov, A. L. Shepetov, Y. V. Shlyugaev, L. I. Vildanova and K. P. Zybin (2012). "Strong Flux of Low-Energy Neutrons Produced by Thunderstorms." Physical Review Letters **108**(12): 125001.

Hathaway, G., P. Graneau and N. Graneau (1998). "Solar-energy liberation from water by electric arcs." Journal of Plasma Physics **60**(4): 775-786.

Henniker, J. C. (1949). "The Depth of the Surface Zone of a Liquid." Reviews of Modern Physics **21**(2): 322-341

Hsu, S. D. H. and P. Sikivie (1994). "Long-range forces from two-neutrino exchange reexamined." Physical Review D **49**(9): 4951-4953.
Hunter, H. C. and A. K. Ray (2009). "On progeny droplets emitted during Coulombic fission of charged microdrops." Physical Chemistry Chemical Physics **11**(29): 6156-6165.
Kong, X., X. Qie and Y. Zhao (2008). "Characteristics of downward leader in a positive cloud-to-ground lightning flash observed by high-speed video camera and electric field changes." Geophys. Res. Lett. **35**(5): L05816.
Lepoint, T., D. De Pauw, F. Lepoint-Mullie, M. Goldman and A. Goldman (1997). "Sonoluminescence: An alternative “electrohydrodynamic” hypothesis." The Journal of the Acoustical Society of America **101**(4): 2012-2030.
Ling, G. N. (1984). In Search of the Physical Basis of Life Springer.
Ling, G. N. (1988). "Solute exclusion by polymer and protein-dominated water: correlation with results of nuclear magnetic resonance (NMR) and calorimetric studies and their significance for the understanding of the physical state of water in living cells." Scanning Microsc **2**(2): 871-884.
Lusignoli, M. and S. Petrarca (2011). "Remarks on the forces generated by two-neutrino exchange." The European Physical Journal C **71**(3): 1568.
Martin, I. M. and M. A. Alves (2010). "Observation of a possible neutron burst associated with a lightning discharge?" J. Geophys. Res. **115**: A00E11.
Meyer, T., V. Gabelica, H. Grubmüller and M. Orozco (2013). "Proteins in the gas phase." Wiley Interdisciplinary Reviews: Computational Molecular Science **3**(4): 408-425.
Ohl, S.-W., E. Klaseboer and B. C. Khoo (2015). "Bubbles with shock waves and ultrasound: a review." Interface focus **5**(5): 20150019.
Shah, G. N., H. Razdan, C. L. Bhat and Q. M. Ali (1985). "Neutron generation in lightning bolts." Nature **313**(6005): 773-775.
Sreedhar, B., S. Albert and A. Pandit (2017). "Cavitation damage: Theory and measurements–A review." Wear **372**: 177-196.
Westlye, F. R., M. Battistoni, S. A. Skeen, J. Manin, L. M. Pickett and A. Ivarsson (2016). Penetration and combustion characterization of cavitating and non-cavitating fuel injectors under diesel engine conditions, SAE Technical Paper.
Woodahl, B., M. Parry, S.-J. Tu and E. Fischbach (1997). "Neutrino trapping and neutrino mass bounds." arXiv preprint hep-ph/9709334.
Zheng, J. M., W. C. Chin, E. Khijniak, E. Khijniak, Jr. and G. H. Pollack (2006). "Surfaces and interfacial water: evidence that hydrophilic surfaces have long-range impact." Adv Colloid Interface Sci **127**(1): 19-27.

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 13)

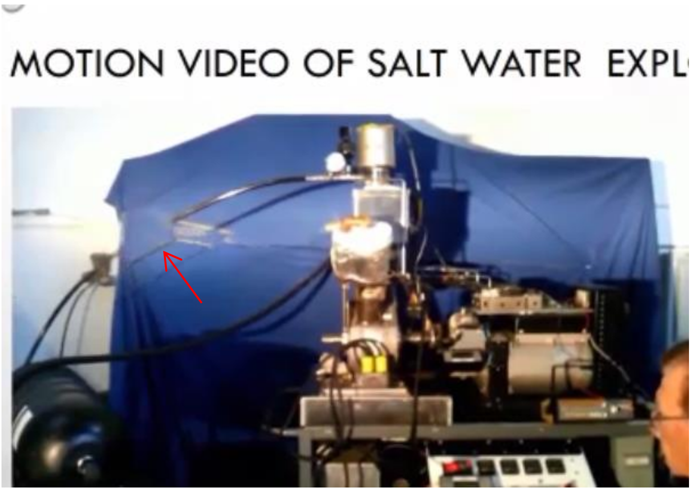
Fusion events per cavitation bubble

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)



b)

c)

Figure 13 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.