Efficient Liberation of Stored Intermolecular Bond Energy from Liquids– A Novel Renewable Energy Resource

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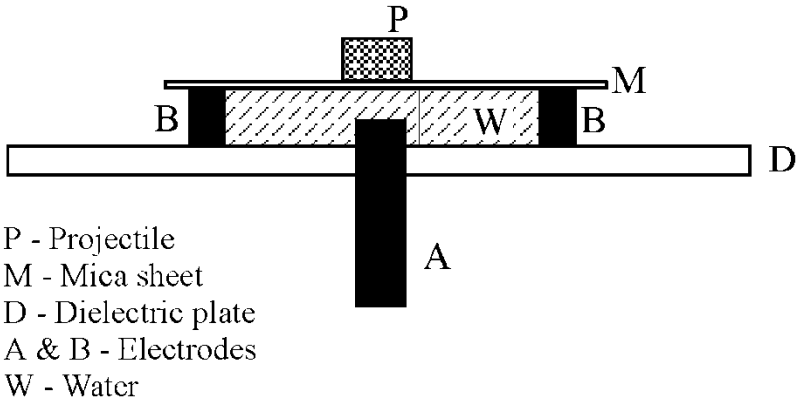
Early Discoveries at MIT

- Surprising results during an experiment on a novel electromagnetic boat propulsion system
- Experiments designed to investigate the cause of thunder revealed an non-thermal and not purely electromagnetic mechanism
- Early quantitative results from “saltwater cup” experiments inspired by Frungel (1947)
- “Gun” demonstration proved the technological potential of these discoveries

Anomalous Force in Water Cup Experiments

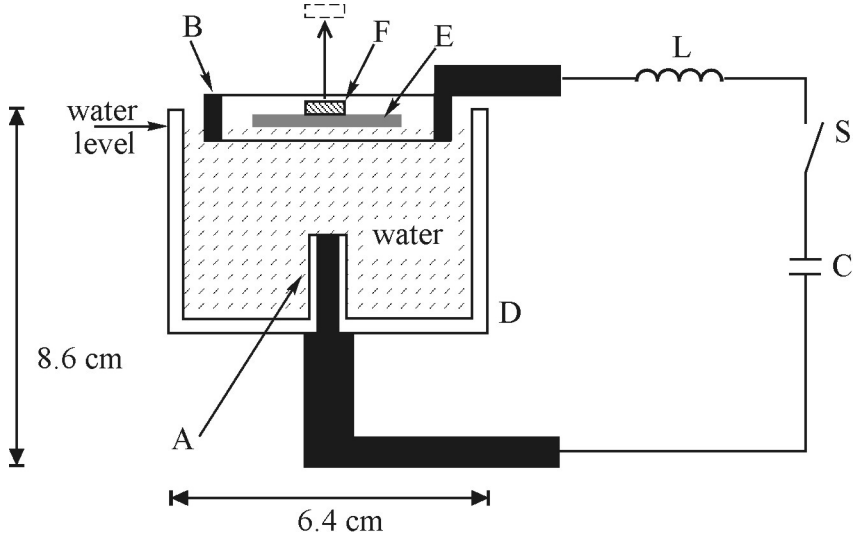
General form of Electrodynamic force law (e.g. Railgun 5<*k*<10)

$$F\Delta t = k\frac{\mu_0}{4\pi}\int i^2\,dt = \Delta mv$$



Frungel (1947)

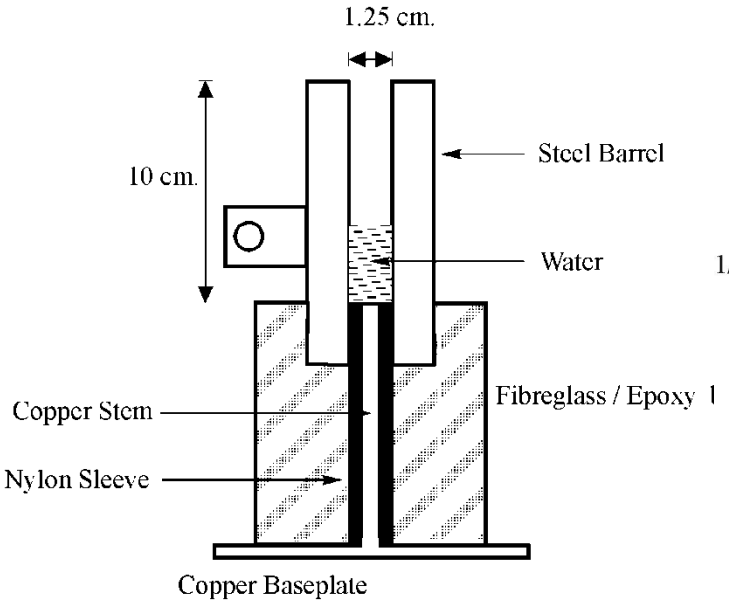
Tap water, (5 J discharge)
k ~ 190

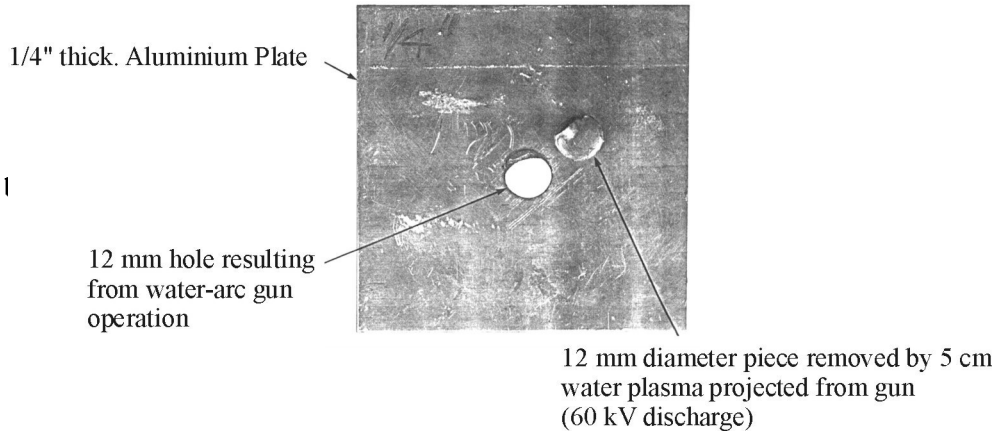


Graneau & Graneau (1985)

Salt water, (14 J discharge)
k ~ 6,000

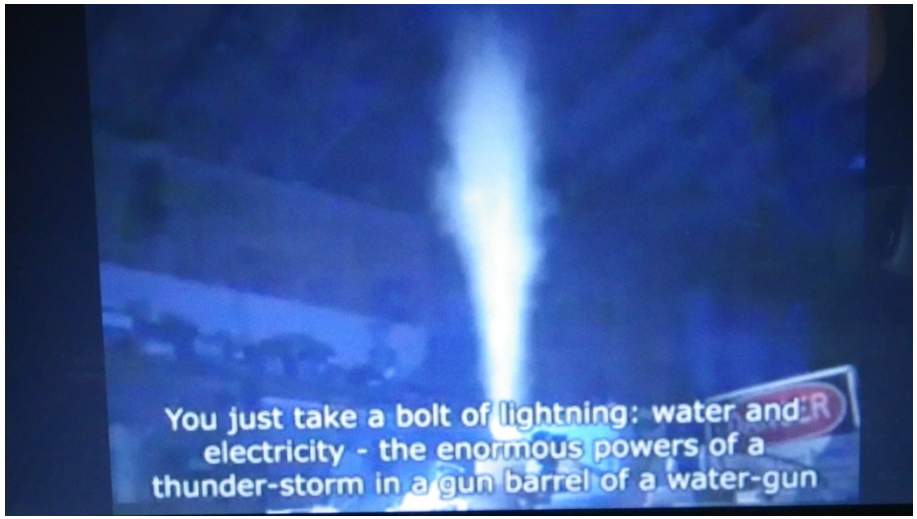
Scaling up the anomalous force





Large Force – Poor Efficiency
Gun breach easily damaged

Video footage from “Equinox”, C4 UK



Stills from video taken by “Equinox” in the laboratory of Richard Hull, Richmond, VA, USA

The Conundrum

- Electrodynamic, Electrostatic and Thermal forces appeared to be incapable of predicting the magnitude of the observed forces

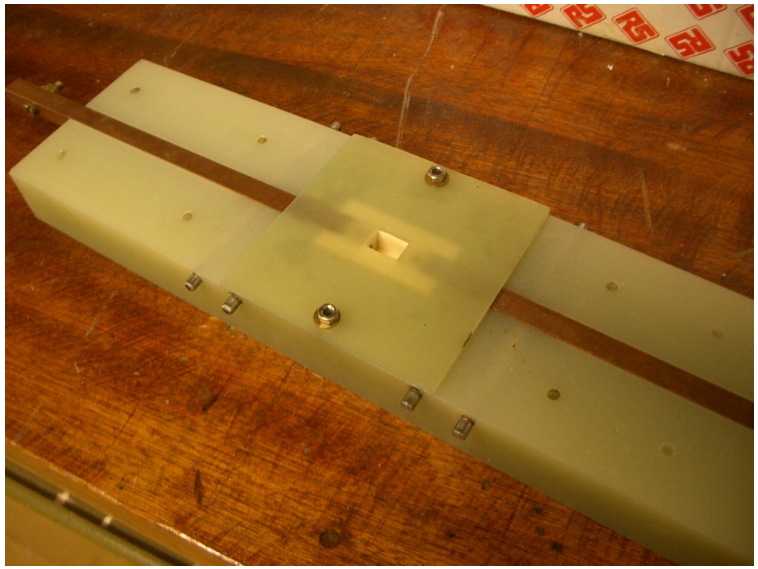
- Therefore, a hitherto unknown force seemed to be responsible for these results

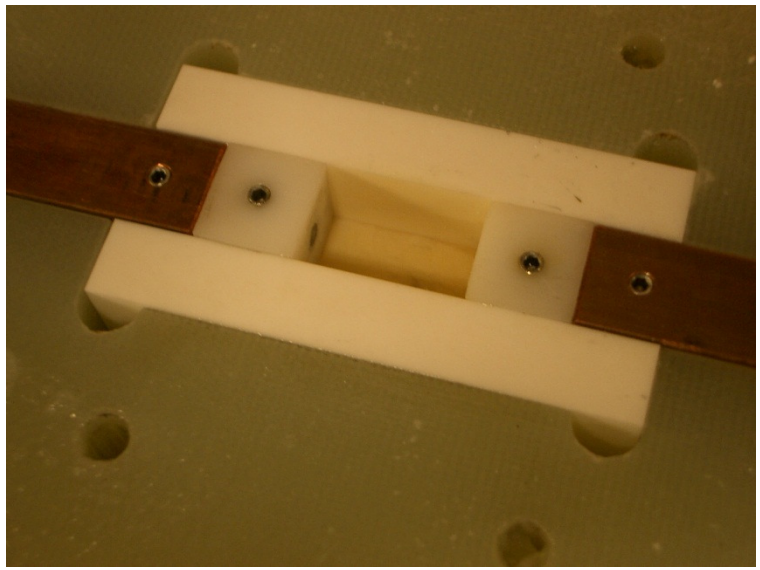
- Where there is a new force, there must be an unexpected source of stored energy.

- Can this new energy source be quantified, be consistent with existing theory and most importantly, harnessed?

The quest for measuring efficiency

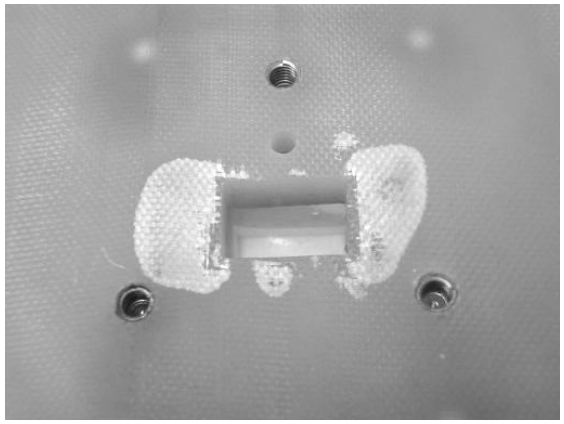
- Development of the Cartridge Accelerator
- Development of kinetic energy diagnostics



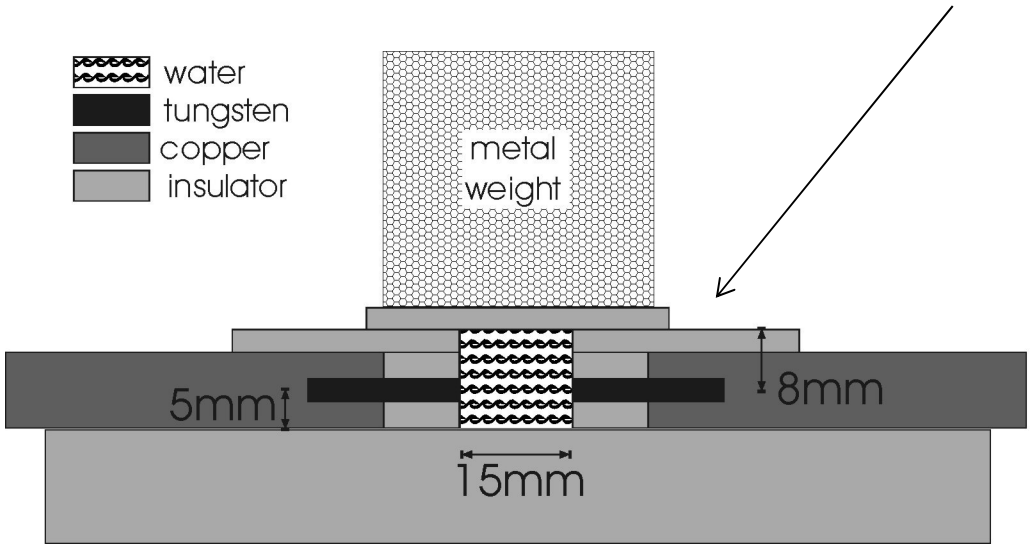


Oxford Cartridge Accelerator – 1.5 cm^3 water cavity, one open face

Typical Cartridge Experiments



Delamination of upper surface of cartridge due to high energy water escaping



C = 0.65 μF
L = 70 μH
V_0 = 30 kV
E_0 = 300 J
Projectile mass = 0.65 kg
Water : 1.8 cm^3, 1.8 gm
Projectile height gain ~ 30 cm

Typical Cartridge Results

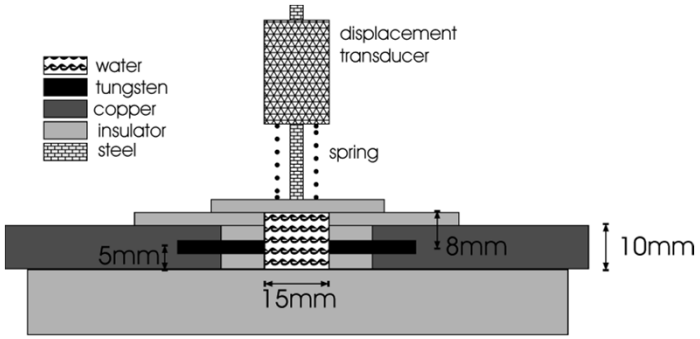
$$v_{water} = mom/m_{water} \quad ; \quad E_{Gain} = \left(\tfrac{1}{2} m_{water} v_{water}^2\right)/E_0 = \frac{mom^2}{2 m_{water} E_0} \quad ; \quad m_{water} \le 1.8\text{gm}$$

V_0 (kV)	E_0 (J)	h (cm)	cycles	mom (kg m/s)	mgh (J)	mom eff	mgh/E_0 %	E_{GAIN}
15.0	73.1	5.0	1.5	0.643	0.319	0.00880	0.436	1.57
15.0	73.1	4.5	1.0	0.610	0.287	0.00835	0.392	1.42
17.5	99.5	8.0	1.5	0.814	0.510	0.00818	0.512	1.85
17.5	99.5	7.5	1.5	0.788	0.478	0.00792	0.480	1.73
17.5	99.5	13.5	1.0	1.057	0.860	0.01062	0.864	3.12
20.0	130.0	11.0	2.0	0.954	0.701	0.00734	0.539	1.95
20.0	130.0	10.0	2.0	0.910	0.637	0.00700	0.490	1.77
20.0	130.0	16.0	1.5	1.151	1.019	0.00885	0.784	2.83
22.5	164.5	16.0	2.5	1.151	1.019	0.00700	0.619	2.24
22.5	164.5	14.5	2.5	1.096	0.924	0.00666	0.561	2.03
22.5	164.5	14.0	2.0	1.077	0.892	0.00654	0.542	1.96
25.0	203.1	23.0	2.0	1.380	1.465	0.00679	0.721	2.60
25.0	203.1	21.0	3.0	1.319	1.338	0.00649	0.659	2.38
25.0	203.1	19.0	2.5	1.254	1.210	0.00618	0.596	2.15
27.5	245.8	26.0	1.5	1.467	1.656	0.00597	0.674	2.43
27.5	245.8	23.5	3.5	1.395	1.497	0.00568	0.609	2.20
30.0	292.5	28.0	3.5	1.523	1.784	0.00521	0.610	2.20
30.0	292.5	29.0	4.0	1.550	1.847	0.00530	0.632	2.28

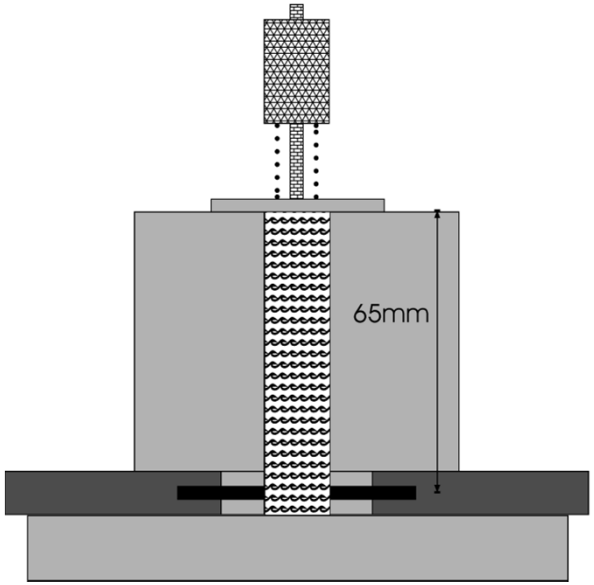
Interpretation of Cartridge Results

- 2 Ambiguities
  - The elasticity of the water / projectile impact
    - Damage to upper surface of cartridge reveals water escaping sideways with high force
    - Water has very low shear strength and is usually observed to slide along surfaces after impact (see kitchen sinks)
  - Single momentum pulse or multiple reflections
    - Harder to resolve with the current experiment.
    - Answering this question led to the design of the Cartridge / Chimney experiments

Cartridge / Chimney Experiments



Cartridge with low chimney

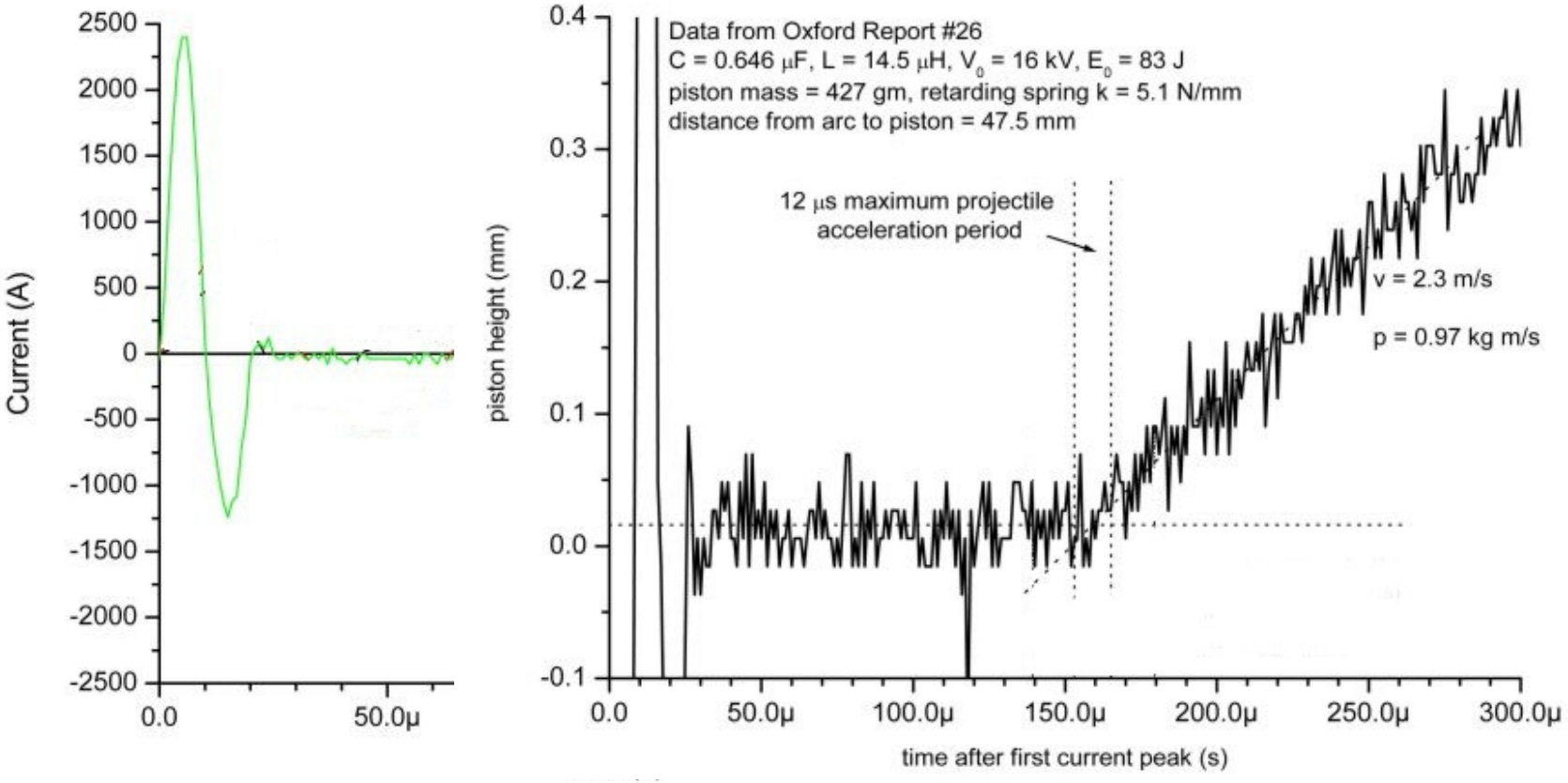


Cartridge with high chimney

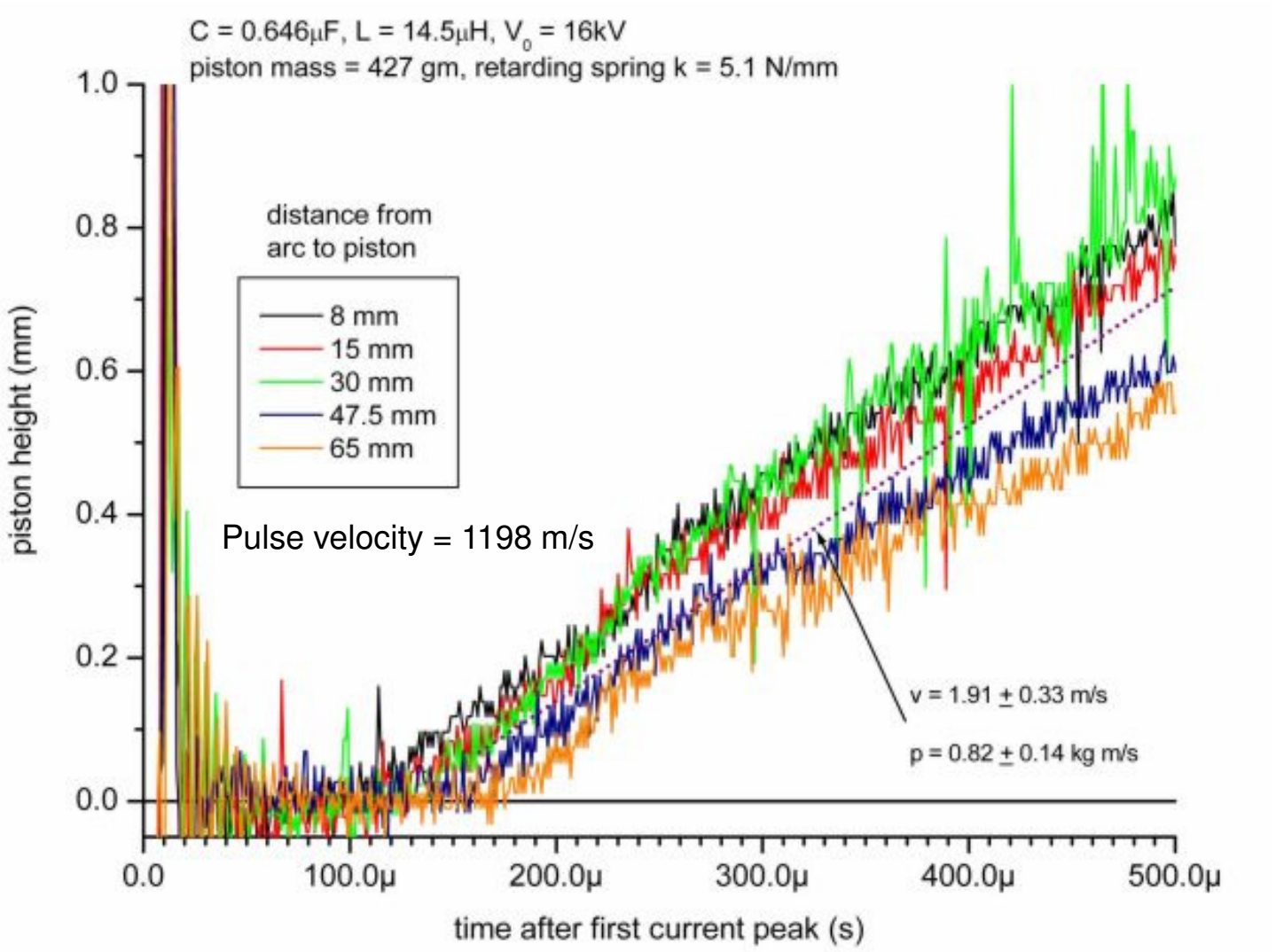
Typical Current and Piston Data

When piston gains 0.97 kg m/s in 12 μs, this implies a pressure of 5.4 kbar

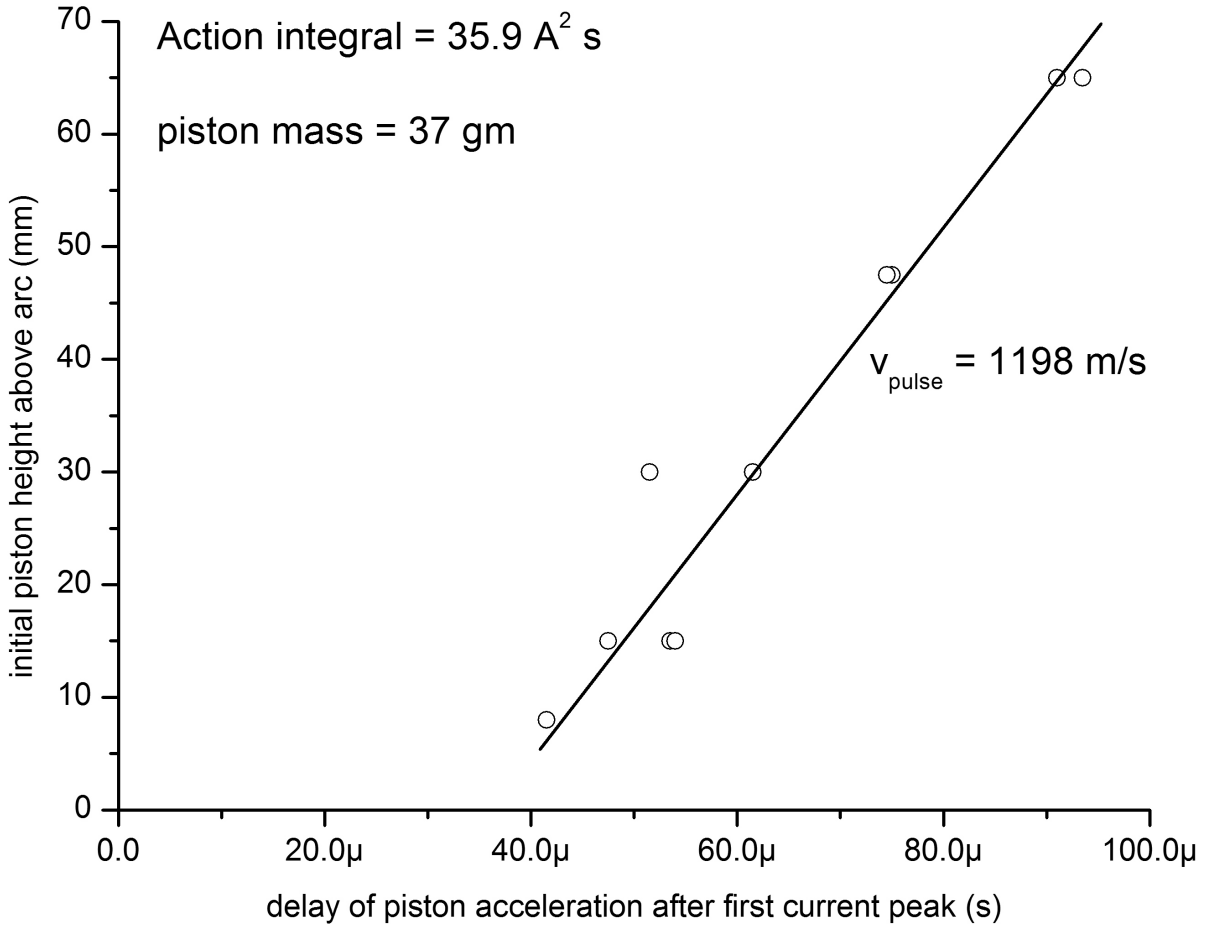
The stored energy is only 83 J. nb the energy stored in a match ~ 1kJ



Effect of chimney height on piston motion



Velocity of momentum pulse



Deducing the Water Energy Gain

Piston mass = 0.427 kg, initial velocity = 1.91 ± 0.33 m/s

Therefore piston momentum = 0.82 ± 0.14 kg m/s

Therefore water momentum pulse : $0.41 \leq p_w \leq 0.82$ kg m/s

(the range varies between totally elastic to totally inelastic water / piston collision)

Velocity of momentum pulse = 1198 m/s

Therefore Mass of water momentum pulse : $0.34 \leq m_w \leq 0.68$ gm

Therefore kinetic energy of water momentum pulse : $244 \leq Ew \leq 488$ J

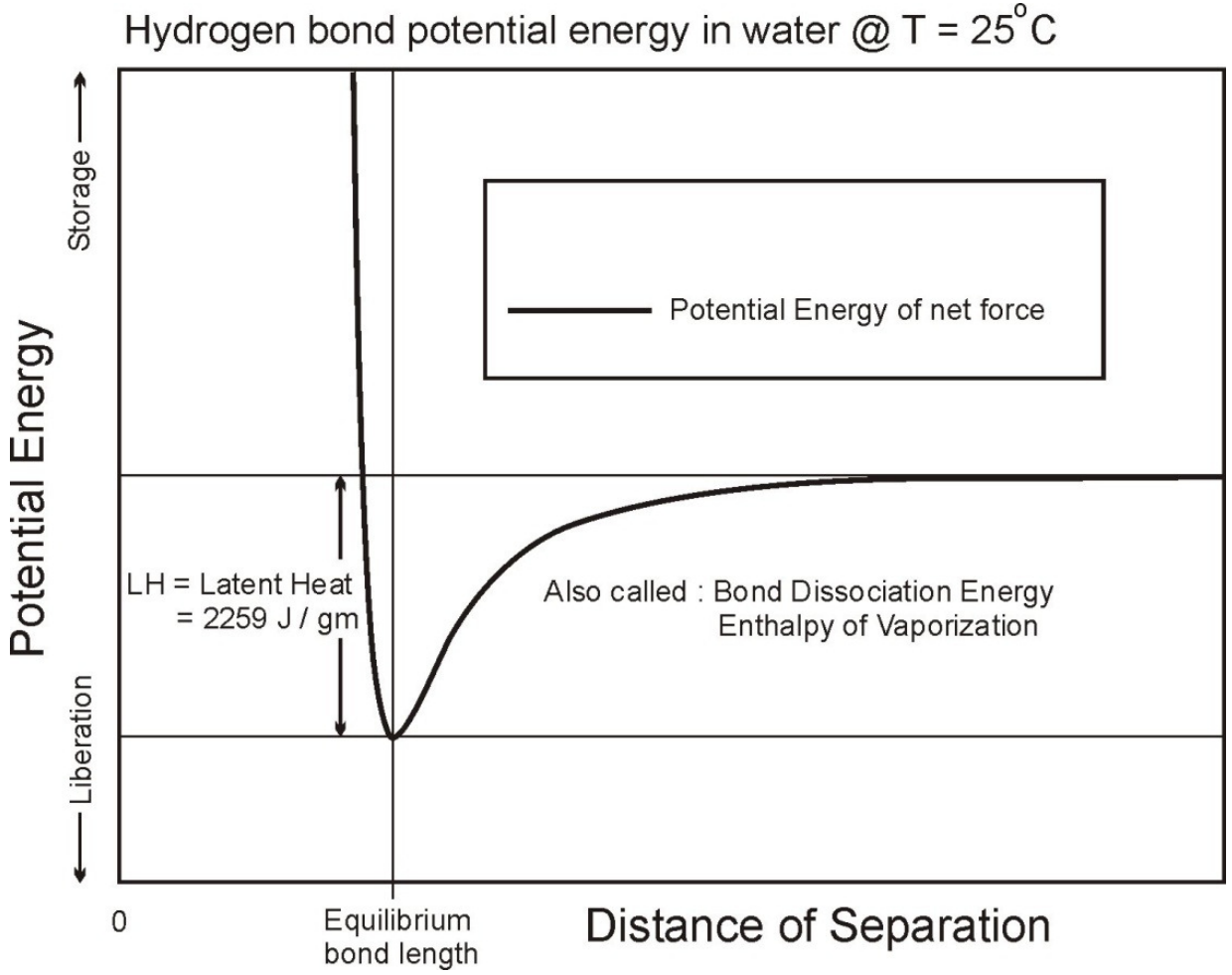
Initially stored electrical energy = 82.7 J

Therefore Energy Gain : $3.0 \pm 0.5 \leq E_{Gain} \leq 5.9 \pm 1$ (250% - 600%)

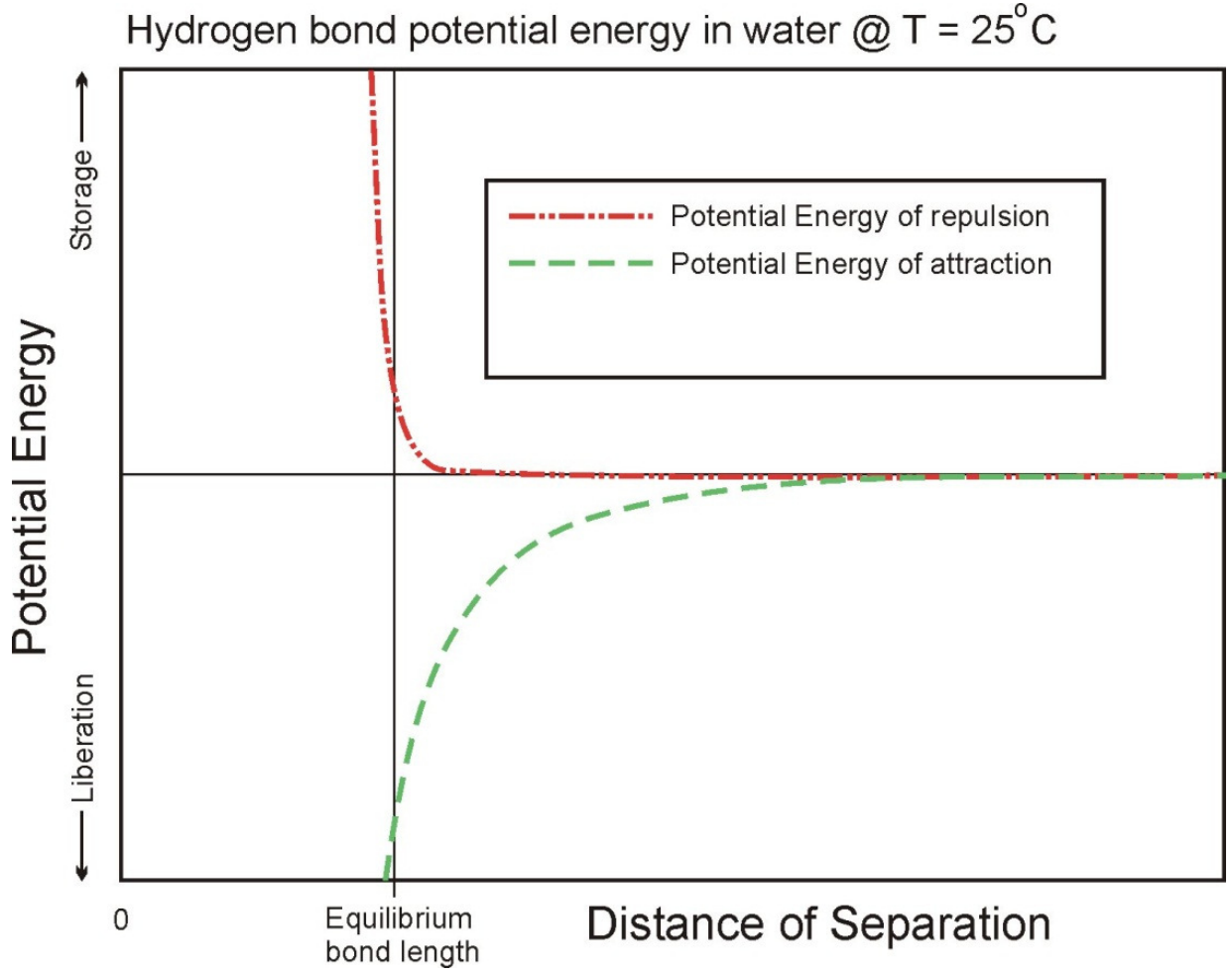
What is the source of the stored energy ?

- The visible output of the water arc explosions is in the form of droplets
- Experiments in enclosures indicated that all of the droplets naturally reconstituted back into the same volume of water
- Therefore none of the water was broken up into hydrogen or oxygen.
- The source of the stored energy is therefore suspected to be the ruptured intermolecular hydrogen bonds which hold the liquid together.

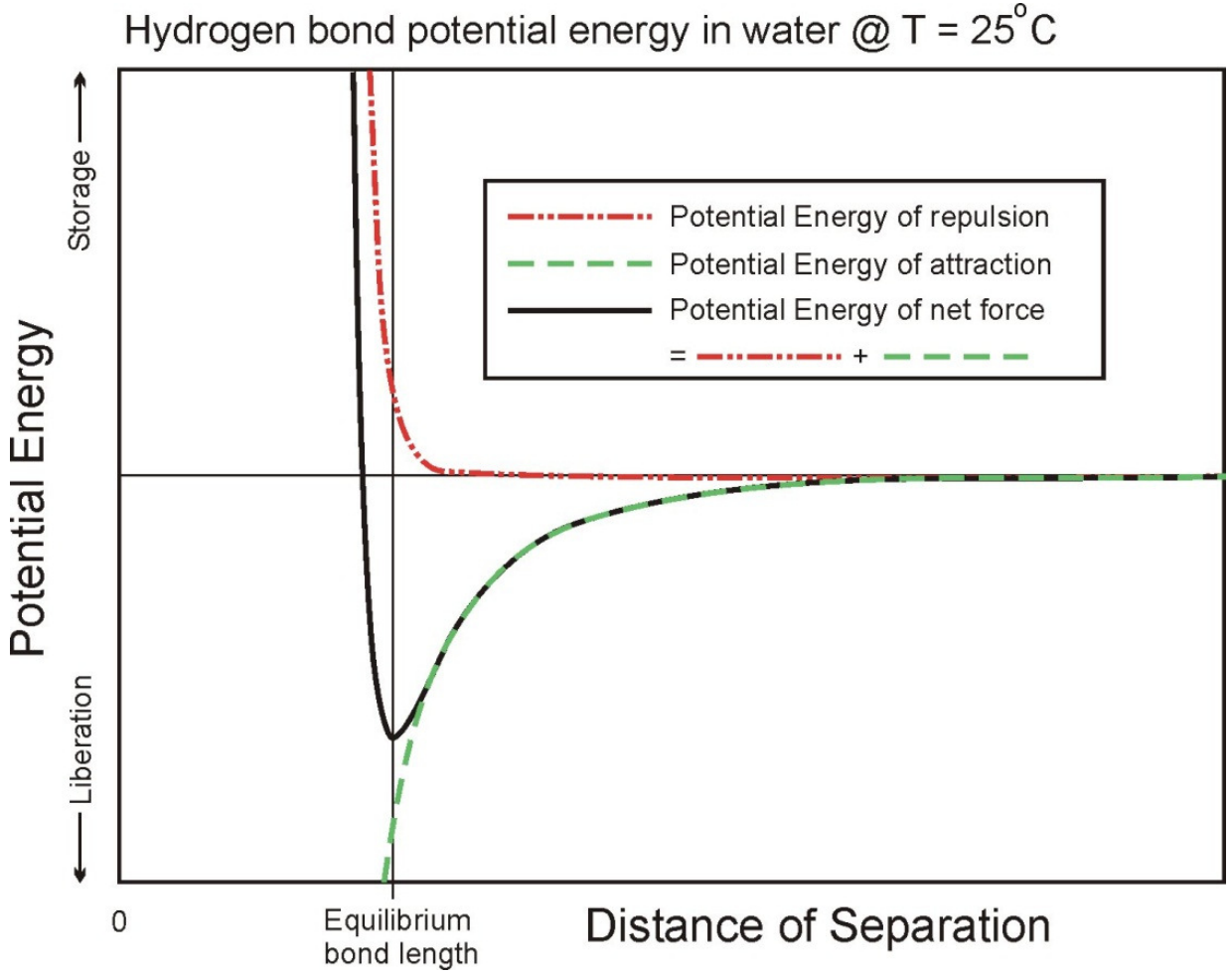
Normal representation of bonding energy



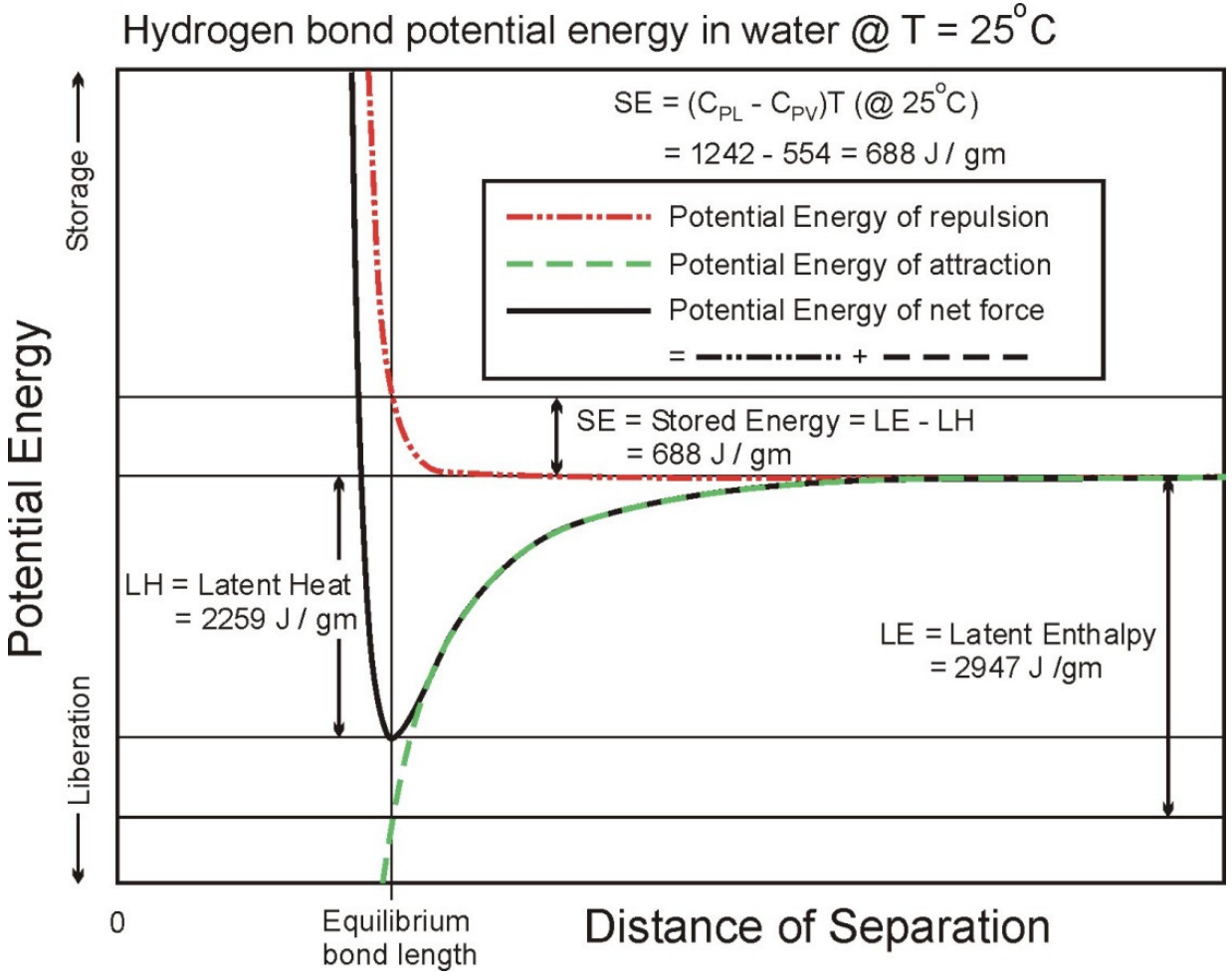
Potentials of repulsion and attraction in a bond



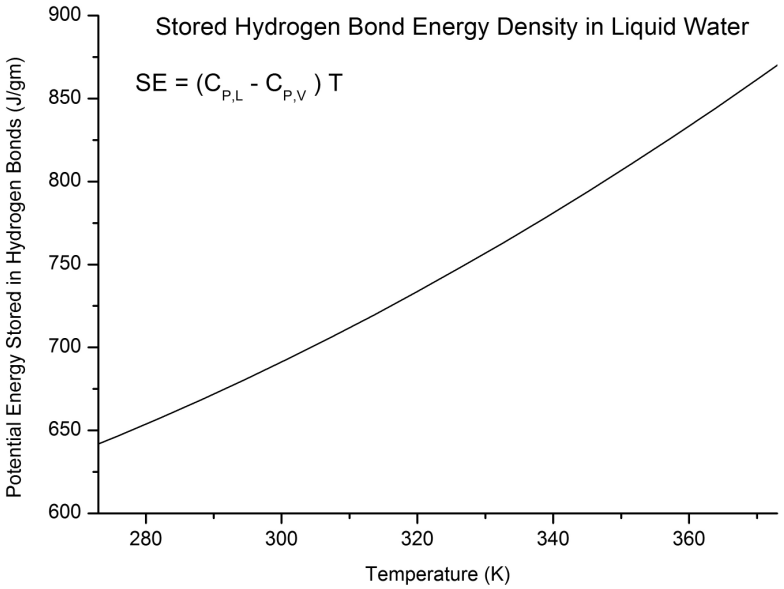
Combination of attractive and repulsive potentials

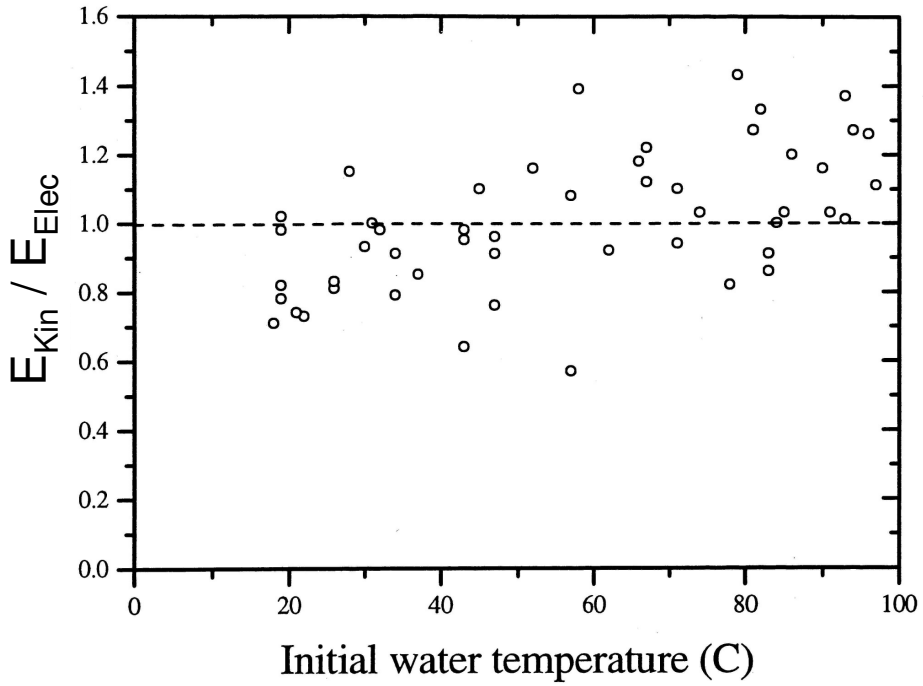


Energy Levels in a Hydrogen Bond



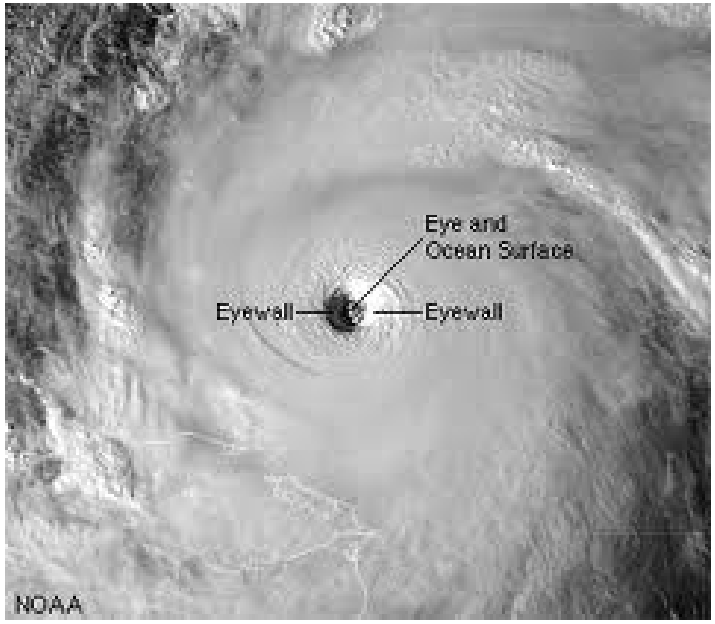
Effect of Temperature on Energy



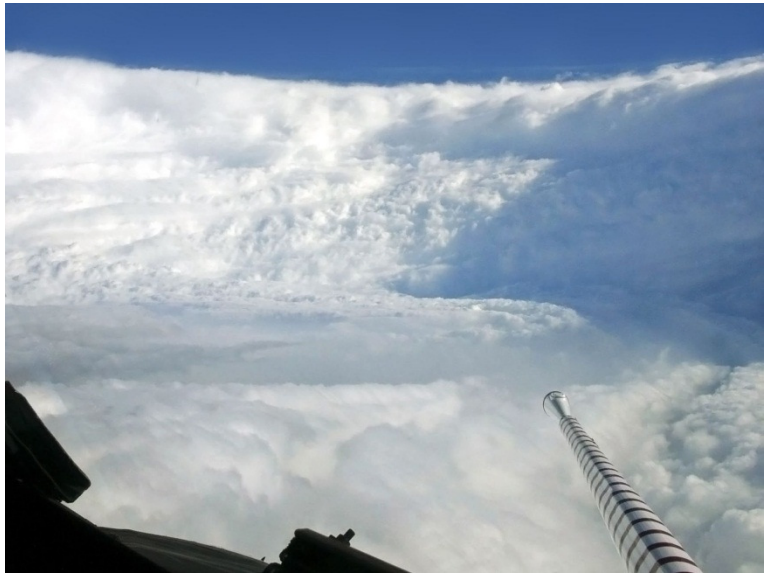


Water arc experiment with heated copper chimney

Does Liberated Bond Energy Gain Occur in Nature ?



Normal storms become hurricanes when over warmer water – where the stored bond energy density is greater

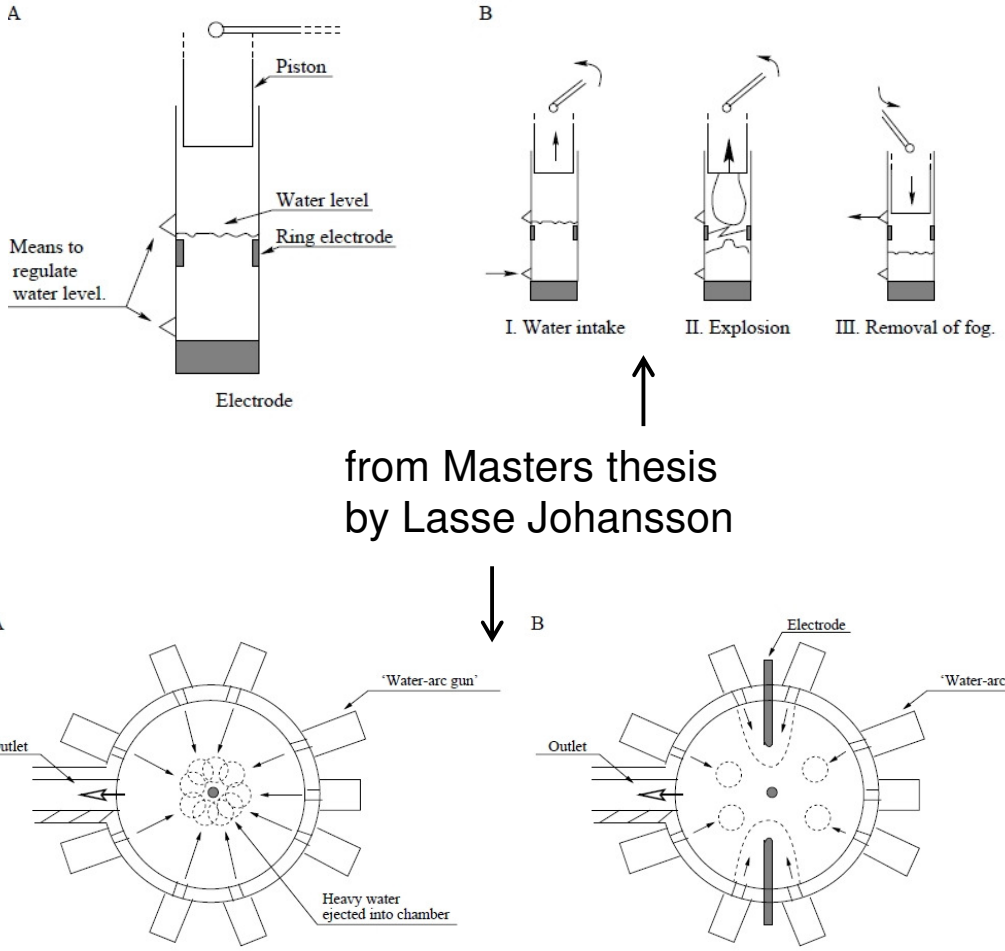


Very high winds at the wall / sea interface rip up the water into a foam of droplets with directed forces. The resulting liberation of the stored bond energy is the most likely explanation of hurricane self-intensification. – Over cooler water or land, the hurricane weakens

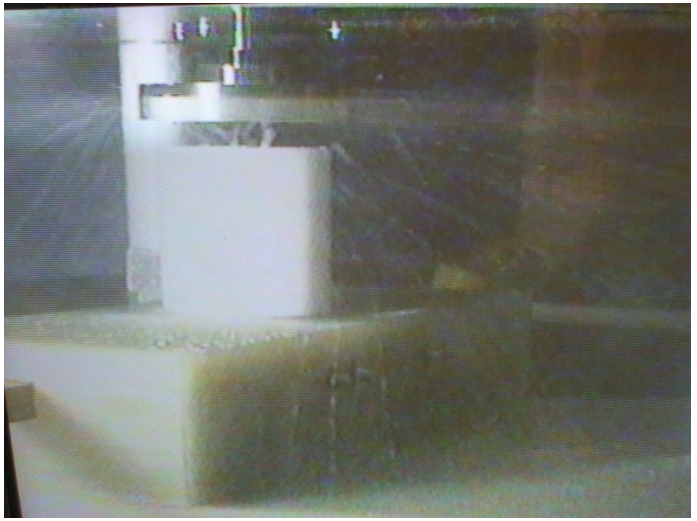
Energy Gain Proved !! … however

- The cartridge / chimney experiments demonstrated two very important points.
  - The pulse of kinetic energy and momentum travels from the arc to the projectile with a measurable velocity where it deposits its momentum by a single inelastic collision
  - The kinetic energy in the water is up to 600% greater than the electrical energy initially stored in the capacitor bank
- However …
  - The rapid generation of this kinetic energy in a confined cavity is very destructive, and to date no insulators have been found which can sustain this force for several shots or for future scaling up
  - Transfer of energy from a light water mass to a heavy piston is very inefficient

Early Generator Concepts



from Masters thesis
by Lasse Johansson



Water arc explosion driven into "spider" turbine

Figure 5.5: Plasma fusion chambers. (A) Impact fusion, (B) Impact fusion and arc-discharge fusion.

The Search for a New Approach

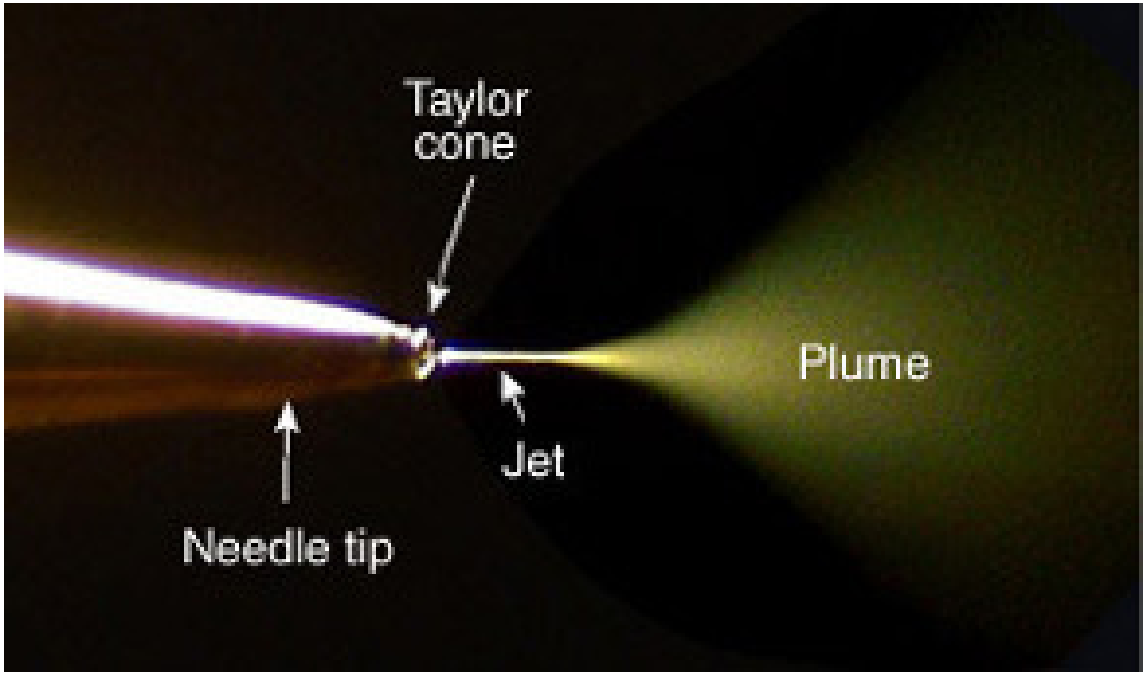
- Seeking another method of breaking intermolecular bonds in liquids in a continuous rather than pulsed manner.

- The bond breaking must be non-thermal

- The energy of the droplets must be easily measurable

- The electrospray technique was suggested by colleagues at WETSUS and TU Delft as a possibility

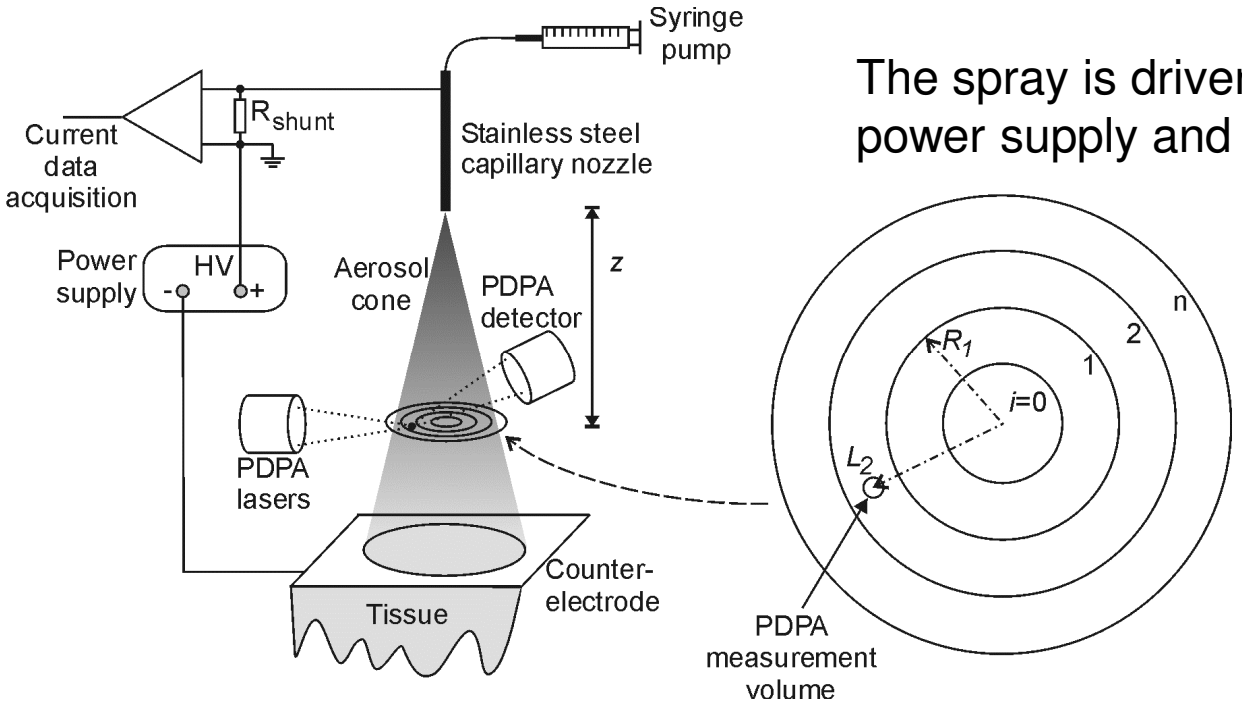
Electrospray Concept



- The Electrospray aerosol generator is used in many industrial processes from spraying inks to pharmaceutical manufacture

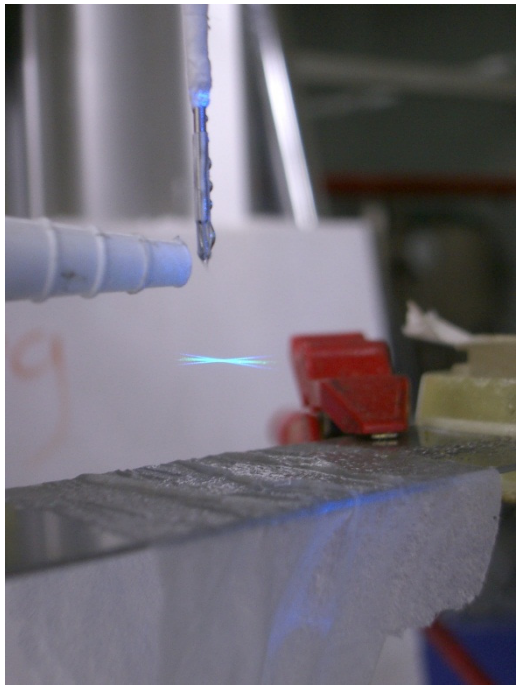
- While much of the underlying physics such as jet stability and droplet size and distribution have been well studied, the energy balance had never been measured

Electrospray Experiment



The spray is driven by a HV low current power supply and a syringe pump

The spray is diagnosed using a PDPA (Phase Doppler Particle Analyzer) measuring droplet diameter and velocity in the vertical and a horizontal direction



Energy Balance in the Electrospray

Energy Inputs

P_{Elec} – Electrical power produced by HV power supply

P_{Pump} – Kinetic power produced by syringe pump

P_{Grav} – Power introduced into aerosol by gravity

$P_{Surf,I}$ – The surface tension energy introduced per second into jet prior to formation of droplets

Energy Outputs

P_{Kin} – The kinetic energy flow per second in the aerosol

P_{Surf} – Total surface tension energy of droplets passing through a plane per second

P_{Drag} – Power lost to heating the background gas due to friction heating

P_{Ion} – Power lost due to gas ionization near the nozzle tip

$$\eta_{\min,Z} = \frac{P_{Kin} + P_{Surf}}{P_{Elec} + P_{Pump} + P_{Grav} + P_{Surf,I}}$$

PDPA Aerosol measurements

If the liquid flow rate, *f*
bulk density ,ρ ,
surface tension constant, σ,
nozzle inner diameter, *n*,
and height below nozzle, z,
are known, then the following
power flows can be
determined
at each measurement location

P_{Kin} (ρ,*f*,*d*,v_h,v_v)

P_{Surf} (σ,*f*,*d*)

P_{Pump} (ρ,*f*,*n*)

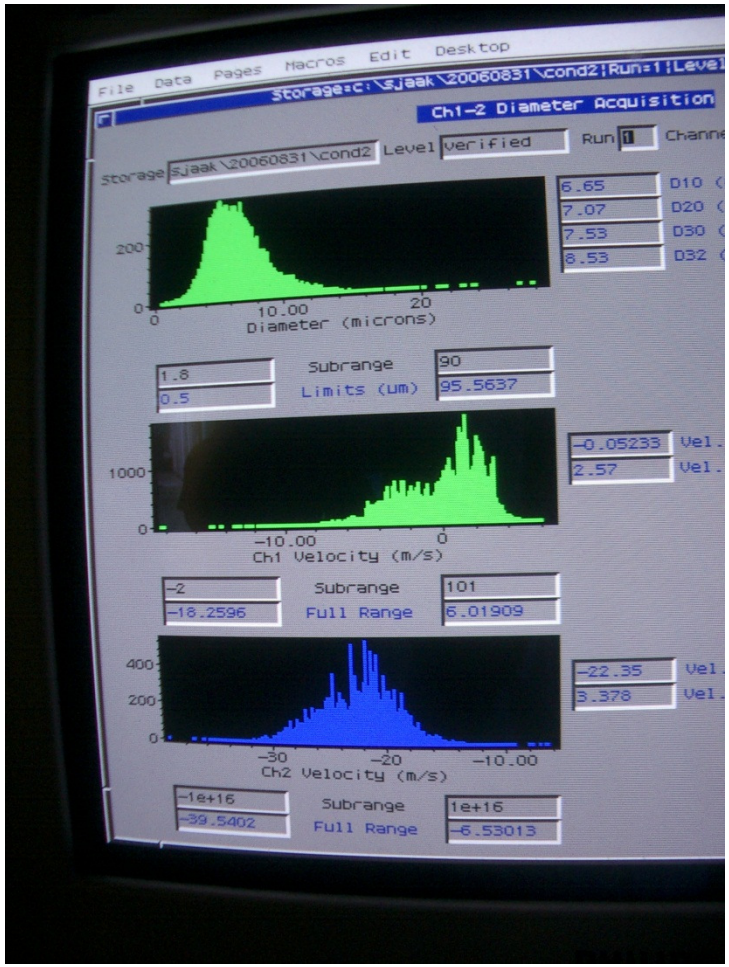
P_{Grav} (ρ,*f*,*z*)

$P_{Surf,I}$ (*f*,σ,*n*)

Droplet diameter, *d*

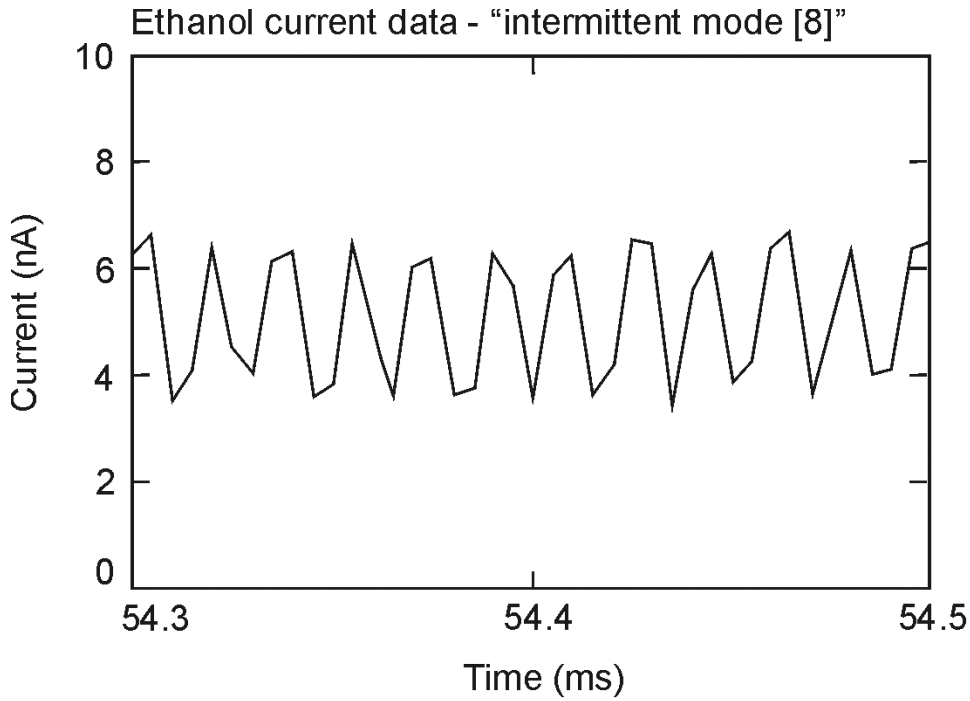
Horizontal velocity, v_h

Vertical velocity, v_v



Electrospray Electrical Power Measurement

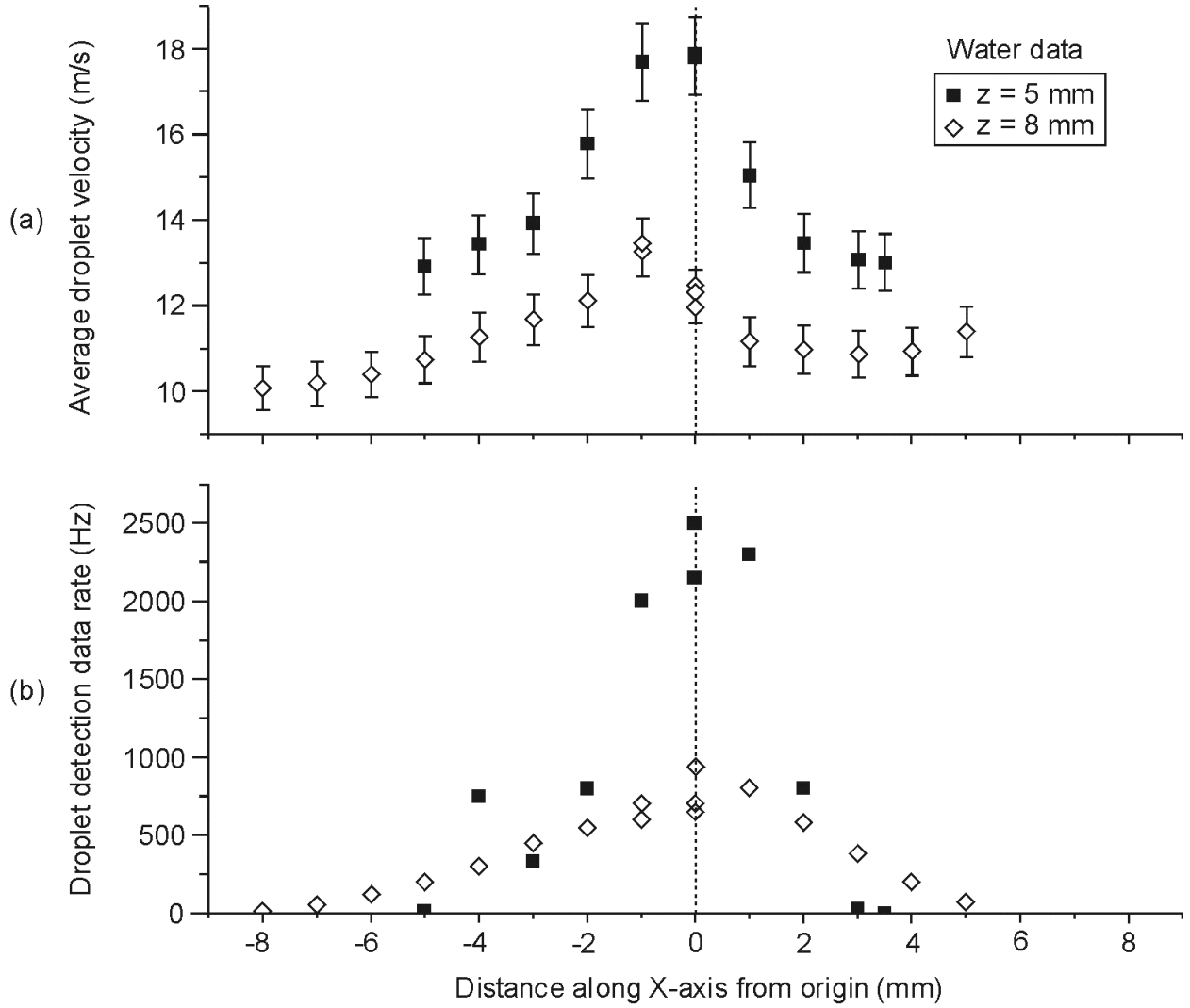
$$P_{Elec} = I_{av} V$$



The experiment was specifically set-up to be driven in the lowest current mode, usually referred to as the “intermittent mode”.

Most electrospray techniques involve the higher current “cone-jet mode” which produces smaller and more uniform droplets

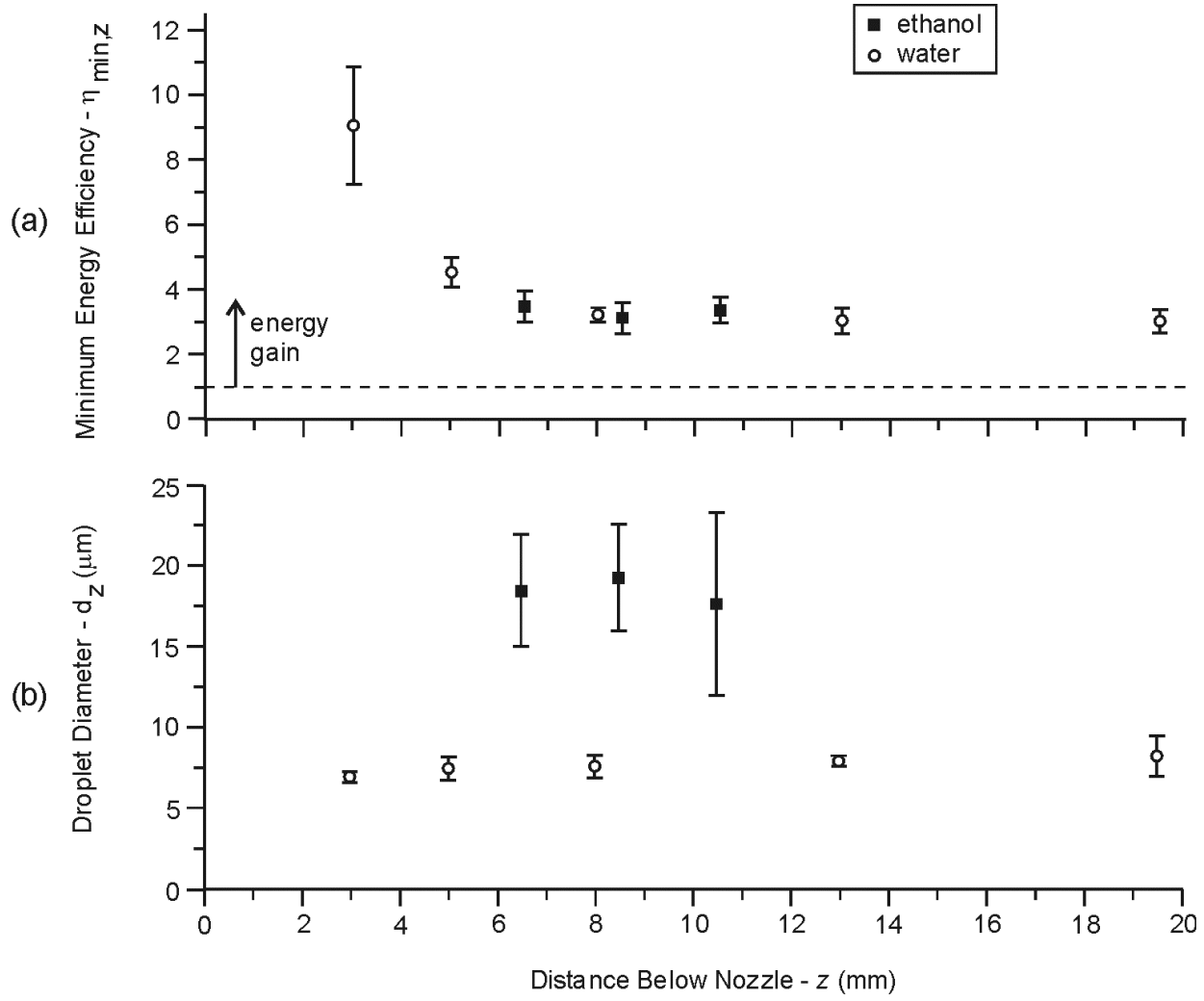
Water droplet velocity and detection rate



Electrospray Result Summary

Liquid	z(mm)	$d_z(\mu m)$	P_{ELEC}(μW)	$P_{SURF,I}$(μW)	P_{PUMP}(μW)	$P_{GRAV,z}$(μW)	$P_{KIN,z}$(μW)	$P_{SURF,z}$(μW)	$\eta_{min,z}$	$\Delta\eta/\eta$
ethanol	6.5	18.3	33.9	0.098	1.73×10^{-7}	0.056	109	6.82	3.41	0.14
ethanol	8.5	19.1	33.4	0.098	1.73×10^{-7}	0.073	95.8	6.65	3.05	0.16
ethanol	10.5	17.5	33.9	0.098	1.73×10^{-7}	0.090	106	6.73	3.30	0.12
water	3.0	6.87	139	1.25	1.15×10^{-5}	0.122	1051	214	9.04	0.20
water	5.0	7.37	163	1.25	1.15×10^{-5}	0.203	562	177	4.48	0.10
water	8.0	7.51	146	1.25	1.15×10^{-5}	0.327	282	184	3.15	0.07
water	13.0	7.83	148	1.25	1.15×10^{-5}	0.529	267	177	2.97	0.13
water	19.5	8.13	166	1.25	1.15×10^{-5}	0.795	314	184	2.96	0.12

Energy Efficiency and Droplet Diameter



Energy Conservation

1. Experiments: Demonstration that under certain conditions, the Non-Thermal Rupturing of intermolecular bonds (NTR) in liquids and creation of droplets can be exo-energetic.

2. In all the experiments described here, the NTR droplets rapidly coagulate back into bulk liquid form. This is the mechanism that makes intermolecular liquid bonds a renewable energy source
   – By the principle of energy conservation therefore this (post NTR) coagulation must be endo-energetic and therefore endo-thermic

3. The tricky point: Conventionally coagulation and condensation are found to be exo-thermic. However the NTR of intermolecular bonds can leave the outer electron structures in unusually low energy configurations. In the experiments described here, coagulation must require more thermal energy input to reconfigure the electron structure than the normal thermal energy that is released when a bond is formed. This mechanism is at least consistent with net endo-thermic bond formation.

The benefits of a proposed electricity generator

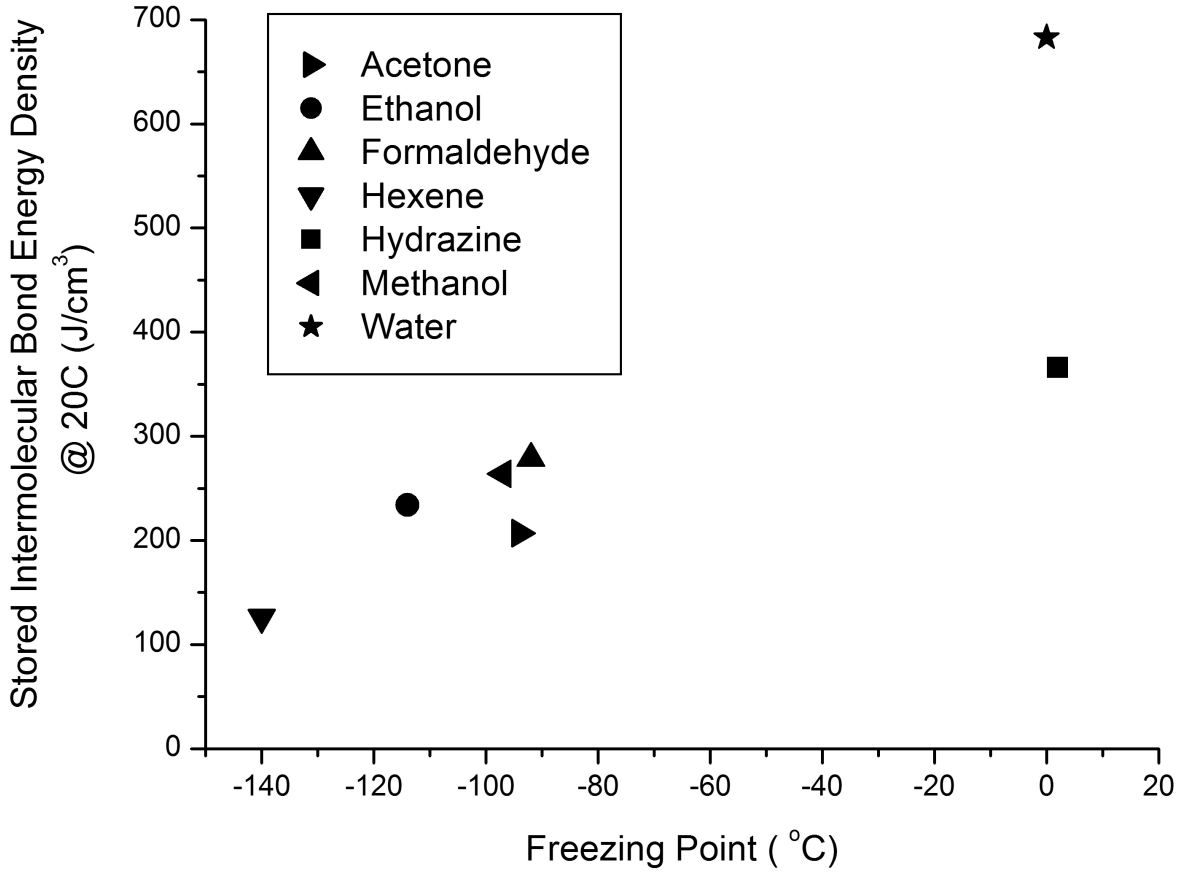
The effect of only targeting the energy in the intermolecular bonds has three extremely beneficial consequences;

- no molecules are broken and thus no new molecular species are formed and therefore ***no exhaust products are created***
- the molecules and droplets resulting from the bond breaking and energy liberating process rapidly re form back into bulk liquid as long as they are exposed to thermal energy from the environment, therefore ***no continuous external fuel supply is required***
- the electricity generated will be precisely equal to the thermal energy drawn from the environment, leading to ***zero net global warming or cooling***

Power can be produced 24 hours a day.

Power output could be 50-100 times as great as solar panels per unit area

Stored Intermolecular Bond Energy of 7 liquids



Water clearly has the highest stored bond energy density, but other liquids may be more practical for electricity generators as they remain liquid at lower temperatures

Thermodynamics of the proposed generator

- 2^{nd} law (Kelvin-Planck format); $K_{therm} = M+H$ ($H>0$)
- The corollary (often erroneously considered to represent the 2^{nd} law) that a work producer or generator requires two thermal reservoirs which define the maximum efficiency, ***only*** applies to "Heat Engines"
- Heat Engines are defined as devices that require heat to generate work and therefore have to deliver this heat to a cold reservoir in order to run continuously.
- The electrospray generator uses electrostatic force and liquid chemistry to generate work and is therefore NOT a heat engine. Therefore running from a single heat source is consistent with the 2^{nd} law
- Molecular motors in biological cells are known to produce mechanical work deriving energy from a single thermal heat bath.
- So what works for "life" should be applicable to other technology

Thermodynamics of the proposed generator Entropy

- 2nd law (Clausius Statement) $\Delta S > 0$: entropy, S, always increases.
- Another inaccurate corollary of the 2nd law is that heat, measured as temperature, is the lowest grade of energy (highest entropy) and is therefore unable to generate work without a thermal gradient.
- Entropy is related to the number of independent particles in a system. When thermodynamics was being developed, separated atoms or gas molecules represented the greatest possible number of particles in a state which could be easily measured (temperature), hence the now inaccurate corollary above.

Entropy - continued

- For every molecule or atom, there are many sub-atomic particles (mainly electrons) which change their motions (states) during bonding, un-bonding, charge capture and ionization. Therefore, these energetic transitions generate higher entropy when exchanging measurable heat with the environment.
- Example: heat is naturally absorbed by atoms in the process of ionization, so this transfer must represent an entropy increase
- In the proposed electricity generator, the gradient that drives the work output is from "higher grade, lower entropy" heat to "lower grade, higher entropy" electron structure. This transfer allows the post electrospray droplets to recover their higher energy configurations and coalesce into normal water for further use

Summary

- A long study of arcs in water led to the proof that stored energy in bulk water could be liberated as directed kinetic energy
- It was hypothesized that the liberation of this stored energy was caused by non-thermal hydrogen bond rupture.
- The hypothesis was tested by examining non-thermal rupture of hydrogen bonds by electrostatic force in an electrospray experiment.
- The hypothesis was confirmed and energy gains of 900% were discovered.
- A possible renewable energy electricity generator has been proposed and is consistent with the precise forms of the 2^{nd} law of thermodynamics
- Further research and sponsorship is now required to develop an electrical power generator which will work in all climates 24 hours per day. It will produce no exhaust, consume no fuels and lead to no net global cooling or warming. It may produce up to 1 kW/m^2. It only relies on the thermal heat bath which naturally surrounds the earth