
Electrokinetic Propulsion: The Ionic Wind Argument

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Purpose:

The purpose of this paper is to explore the possibility that Electrokinetic Propulsion is just another manifestation of the Ionic Wind Effect. Three different cases were explored; the first being normal atmospheric operation, in which the surrounding atmosphere was ionized. The second case used atmospheric ions present within a vacuum. The last case used the actual dielectric media as the ions.

Background:

Electrokinetic Propulsion is an effect that produces thrust when an electrical potential is placed across a capacitor. The reason that this force is of such importance is that there seems to be no apparent reaction force associated with it.

From a more technical standpoint, the amount of thrust generated by this effect depends on the amount of voltage applied across the capacitor, the surface area of the electrodes, distance between electrodes, material between electrodes, and the geometry of the electrodes. All of these factors, except the applied voltage, create a non-linear electric field gradient, which is believed to be an underlying principle that describes this effect. It is also believed that what is being observed might be a coupling between electricity and gravity, similar to that between electricity and magnetism. This thrust cannot be presently explained by any previous theories such as electrostatic forces, ion wind effects or corona discharges, thus further research is needed to provide an adequate explanation of what is observed.

Ionic Wind, on the other hand, is the effect observed when ions are accelerated by an electrical field and therefore, produces a thrust. This effect operates first by striping [sic] of electrons from surrounding atoms due to a large positive charge. The electrons are attracted to the positive electrode, but the remaining ions are thus left positively charged and are accelerated toward the negative ion. This acceleration between both the electrons and their respective ions results in a net force in the direction of the positive electrode.

The capacitor design that is used most is shown in Figure 1 below.

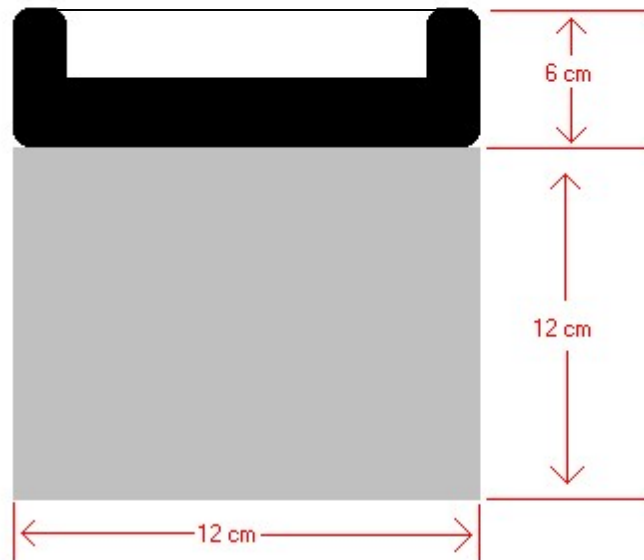


Figure 1: Superman Capacitor Leaf Design

This design entails the use of a 32 gauge copper wire as the fore electrode at the leading edge of the capacitor leaf. The aft electrode is constructed out of aluminum foil, and is **separated by a 1/32" thick bakelite dielectric of the shape** described above. The fore electrode is positively charged, while the aft electrode is connected to ground. During normal operations, 30-40 kV are placed across the capacitor, and a force is observed in the direction of the fore electrode.

This study used 30 kV as the investigated voltage in which the ionic wind is supposed to occur. When the device operates at said voltage, a Force of 2.38 mN is observed. This device also acts as a base line, for devices that are more powerful have been created and proven.

An ion collector was created out of aluminum shim, and was worked into a semi-circle of about a 50 cm diameter. It was then covered by aluminum foil on the top, and placed on another piece of aluminum shim. This collector was then placed on a wooden platform to insulate it from a ground, and then hooked up to a multi-meter. The multi-meter would then display the current created from the impingement of the ions leaving the device. The multi-meter was capable of measuring currents in microampere range. The collector was then placed directly behind the device, in front of the device, and the device was placed partially within the collector to record different perspectives of the ion collection.

Preliminary Calculations:

Bakelite: $C_6H_5OH + HCOH = CHO^+ + C_5H_5^+ + \text{Other unionized molecules}$

Air: $N_2 = N_2^+$ 78%

$O_2 = O_2^+$ 21%

	\bar{M}	(g/molecule)
N:	14.0067	$2.326e-23$
O:	15.9994	$2.657e-23$
CHO	29.0183	$4.819e-23$
C_5H_5	65.0945	$1.08e-22$

Velocities: $1/2mv^2 = Vq$

$$N_2 : v = \sqrt{\frac{2 * 30kV * e}{2 * 2.326e-26kg}} \quad v = 4.55e5 \text{ m/s}$$

$$O_2 : v = \sqrt{\frac{2 * 30kV * e}{2 * 2.657e-26kg}} \quad v = 4.25e5 \text{ m/s}$$

$$N_2 : v = \sqrt{\frac{2 * 30kV * e}{2 * 4.819e-26kg}} \quad v = 4.47e5 \text{ m/s}$$

$$N_2 : v = \sqrt{\frac{2 * 30kV * e}{2 * 1.08e-25kg}} \quad v = 2.98e5 \text{ m/s}$$

where:

m =the molecular mass

v =the final accelerated velocity

V =the applied voltage

q =the charge of the ion

Case 1: Ionization from Atmospheric Operation (N₂ & O₂)

In this case, it was assumed that the device would operate at normal sea level atmospheric pressure, and that only the atmosphere would ionize and participate in the ionic wind effect. Also that there are absolutely no collisions between ions, this gives ionic wind the benefit of the doubt, since the mean free path at standard atmospheric pressure is 6.5e-8 m. The following calculations calculate the current expected from the ionic wind at a nominal thrust of 1 mN and a potential of 30 kV.

$$T = \dot{m}_n v_n + \dot{m}_o v_o$$

(Thrust created by acceleration N₂ and O₂ ions)

$$\dot{m}_n = \Gamma \cdot 0.001 (\bar{M}_n)$$

(Γ is an arbitrary constant in mol/s)

$$T = \Gamma \cdot 0.001 (\bar{M}_n v_n + \bar{M}_o v_o)$$

$$\Gamma = \frac{T}{0.001 \bar{M}_n v_n + \bar{M}_o v_o}$$

$$\Gamma = \frac{1.25 \times 10^{-4}}{0.001 \bar{M}_n v_n + \bar{M}_o v_o}$$

(Atmospheric Composition)

$$T = \Gamma \cdot 0.001 (.78 \bar{M}_n v_n + .21 \bar{M}_o v_o)$$

$$T = \Gamma \cdot 0.001 \bar{M}_n (.78 * 14.0067 * 2 * 4.55e5 + .21 * 15.9994 * 2 * 4.25e5)$$

$$T = \Gamma \cdot 1.25e4 \bar{M}_n$$

(Where \bar{M}_n is the atmospheric ionization constant)

For a 1 mN thrust :

$$\bar{M}_n = 7.81e-8 \text{ (mol/s)}$$

$$N : 6.09e-8 \text{ mol/s}$$

$$O : 1.64e-8 \text{ mol/s}$$

$$\bar{M}_n = 7.73e-8 \text{ mol/s} \quad \bar{M}_o = 4.66e16 \text{ ions/s}$$

$$I = 7.47 \text{ mA}$$

Case 2: Outgassing of the Ions off the Dielectric

In Case 2, it was assumed that only ions created from the dielectric were being accelerated to create a thrust. The ambient pressure around the device was $1e-5$ torr. This would allow the bakelite to outgas and therefore would create free-floating bakelite molecules. It was also assumed that the molecules would not collide when accelerated, and that the bakelite would decompose in equal molar ratios.

$$T = \dot{m} v = 0.001(\overline{M}_1 v_1 + \overline{M}_2 v_2)$$

(Molecules 1 and 2 are CHO^+ and C_5H_5^+ molecules respectively)

$$T = 0.001(3.24e7)$$

$$T = 3.24e4 \text{ N}$$

for $T = 1 \text{ mN}$

$$\Gamma = 3.09e-8 \text{ mol/s}$$

$$\text{CHO} : 3.09e-8 \text{ mol/s}$$

$$\text{C}_5\text{H}_5 : 3.09e-8 \text{ mol/s}$$

$$6.17e-8 \text{ mol/s} = 3.717e16 \text{ ion/s}$$

$$I = 5.96 \text{ mA}$$

Case 3: Ionic Wind in Vacuum

In case 3 it was assumed that at a pressure of $1e-5$ torr, the entire atmosphere within a bell jar (Volume= $.037m^3$) was accelerated in the same second by the device, and also negating interparticle collisions.

$$P = 1e-5 \text{ torr} : 1.333e-3 \text{ Pa}$$

$$n = \frac{PV}{RT} = \frac{1.333e-3 \text{ Pa} * .037m^3}{8314 \text{ J/mol K} * 294.26K} = 2.02e-11 \text{ mol of Air}$$

$$N : 3.15e-11 \text{ mol} * 4.41e-10 \text{ g}$$

$$O : 8.48e-12 \text{ mol} * 1.36e-10 \text{ g}$$

$$T = m \cdot v = (4.41e-11 \text{ kg} / \text{s} * 6.429e5 \text{ m/s}) + (1.36e-11 \text{ kg} / \text{s} * 6.01e5 \text{ m/s})$$

$$T = 3.65e-7 \text{ N}$$

$$T = 3.65e-4 \text{ mN}$$

Observations/Conclusions:

When operating in atmosphere and at 30 kV two observations were made. The first reading was taken from the back electrode, with the aft electrode within the collector. The second measurement was taken from the fore electrode. From the first reading, it was observed that the current was 1.7 μA , whereas the fore electrode had a reading of .7 mA. The reasoning behind a larger current coming from the fore electrode is that the electric field is actually stripping electrons off the collector, instead of from the ions. Also the expected theoretical result in vacuum is off by a factor of more than a thousand (being a thrust of 3.65×10^{-4} mN expected, whereas a force of at least .31mN was observed at a lower voltage of 17kV). These were the only observations recorded, since it was deemed unnecessary to try to take readings within a vacuum since the observed and experimental currents are off by orders of magnitude and not enough to produce any meaningful effect during Electrokinetic Propulsion experiments.