Spring 5-12-2015

Theoretical and Experimental Study of the Biefeld Brown Effect

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Honors Thesis
Submitted in Partial Fulfillment
of the
Requirements of HON 420
Spring 2015

By
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Abstract

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By applying high voltage to an asymmetric capacitor, a thrust is created in the direction from the cathode to anode electrodes of the capacitor. Because of the high voltages, the anode ionizes the dielectric medium (air) and creates an "ion wind" by repelling the positively charged ions toward the cathode. This thrust is a result of the law of conservation of momentum. The application to this thrust has been observed in popular media as a levitating device (craft) but its full applications are still unknown and limited to lightweight crafts. In order to uncover its potential applications, this Honors Thesis built 47 lightweight crafts and tested them with an Ion Power Supply (GR8) that ranged its voltage from 20 kV to 30 kV. From the 47 crafts, the Quadrangle, Q2, which is a 30 x 30 cm^2 square shaped craft, was the ideal craft. A variable payload measured to observe the relationship between the current supplied by the Power Supply and the weight of the craft.

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Introduction:

In 1922, Thomas Townsend Brown observed a force when a high voltage (30 kV-50 kV) was applied to a Coolidge X-Ray tube, which is a vacuum tube possessing two asymmetric capacitors (electrodes). This discovery was the result of his precocious interest as child in electronics that were lavishly funded by his parents. Dr. Brown observed the physical properties of the Coolidge X-Ray tube meticulously. It was found that the effect increased as the electrodes asymmetry increased. As one end of the electrode was smaller than the other, the device experienced a net force toward the smaller electrode regardless of the polarity of the applied voltage. After his discovery, Brown elaborated on the phenomenon during his undergraduate studies at Denison University in Granville, Ohio, working under his advisor, Dr. Paul Alfred Biefeld. He later coined this phenomenon as the Biefeld-Brown Effect. It should be noted that the validity of Brown's work with Dr. Biefeld is still uncertain as Dr. Biefeld recalled only once talking with Dr. Brown. It would be interesting to do a historical research of Brown's life and his work with Dr. Biefeld.

With the historical discrepancies, theoretical principles remained inconclusive as they diverged from one another. The theory proposed by Brown was that the thrust was produced as a result of high voltages creating anti-gravity. Brown spent the rest of his life with the belief of wanting to unify gravity and electromagnetism.

With the years of speculation, the Biefeld-Brown Effect has been studied by NASA, US Air Force, US Army Research Laboratory (ARL), and researchers in order to unveil the true principles behind its propulsive effect. The main benefit of utilizing the effect generated by the asymmetric capacitor is thrust generated without moving parts, only an electrical source.

Theory:

In regards to the physical principles that lie behind the Biefeld-Brown Effect, Bahder & Fazi (2003), Canning, Melcher and Winet (2004), Ma, Lu & Ye (2013), Ianconescu, Sohar & Mudrik (2011), Matsoukas & Ahmed (2012) and Einat & Kalderon (2014) agree that there is a greater force experienced towards the smaller positive electrode than from the larger negative electrode when a high voltage is applied to an asymmetric capacitor, regardless of polarity (Einat and Kalderon, 2014). Bahder & Fazi (2003), Ianconescu, Sohar & Mudrik (2011), and Ma, Lu & Ye (2013), describe the cause as from the ionization of gas, in this case, air.

The first proposed theory to achieve propulsion from an asymmetric capacitor was due to an ionic wind. By applying a high voltage in between the electrodes, ions are accelerated from one end of the electrode to the other. Current either leaked (Canning, Melcher and Winet, 2004) from one electrode or charged the ions of the dielectric (Bahder, 2003; Ianconescu, 2011; Ma, 2013) and underwent multiple collisions with air

(Bahder, 2003; Canning, 2004; Ianconescu, 2011; Ma, 2013); these collisions transfer momentum, and therefore the propulsive effect is due to conservation of momentum, as for Newton's Third Law. Within the given literature, researchers have agreed that the ion wind is the one responsible for the propulsion (Canning, 2004; Ianconescu, 2011). However, Bahder & Fazi (2003) and Ma, Lu & Ye (2013) agree with this statement to a degree. Bahder & Fazi (2003) calculated the lower and upper limit of the forces that will be used to propel a certain mass with the ejected ions, in this case Copper ions and electrons; the masses resulted to be five to three orders of magnitude smaller than the mass of the craft.

The second proposed theory is due to ionic drift (Ma, Lu and Ye, 2013), where it provided with the correct calculated magnitude of values (Canning, Melcher and Winet, 2004). It is of interest in this research to calculate the correct values in order to prove which theory is valid in order to explain the Biefeld-Brown effect. Hence, further investigation is required (Bahder, 2003; Canning, 2004; Ianconescu, 2011; Ma, 2013).

By knowing the origin of the force, ways to maximize the effect (Einat and Kalderon, 2014) could be found. As the propulsion is created without the movement of any mechanical parts (Matsoukas and Ahmed, 2012), converting electricity directly into mechanical force, it is crucial to understand the effects created by different mediums, such as air or vacuum (Bahder, 2003; Canning, 2004; Ianconescu, 2011; Ma, 2013) and to build a device (Matsoukas; 2012, Einat; 2014) that would efficiently propel.

Modern conventional designs of the craft are triangular shaped ones, which consist of copper wire acting as the anode and the aluminum foil acting as the cathode. In order to achieve maximum propulsion, Matsoukas and Ahmed (2012), Bahder and Fazi (2003), and Einat and Kalderon (2014) experimented with different designs of the craft that would elaborate more on the conventional design. Researchers experimented with longer and shorter sizes of the cathode electrode (Matsoukas, 2012; Einat, 2014) and a circular shaped anode electrode (Matsoukas and Ahmed, 2012). They also tested by increasing the number of electrodes attached to the device as well as different types (Einat and Kalderon, 2014). Bahder and Fazi (2003) experimented with a square and flat asymmetric capacitors. In contrast, Canning, Melcher and Winet (2004) experimented with an Asymmetric Capacitor Thruster, which consist of a rotating device at its axis where the asymmetric capacitors are located at the ends of the lever arms.

Purpose:

In order to test the effects of the Biefeld-Brown effect, an Ion-Driver (GR8) and craft were used for testing. The GR8 supplies the high voltage, ranging from 20 and 30 kV, and the different designs of craft were tested in order to find the model that provides the best lift. Once the ideal model was found, a variable payload was attached to the model to make measurements. However, because of the high voltage, equipment such as voltmeter and oscilloscope were unavoidable of making direct measurements. As an alternative solution, current supplied by the Power Supply to the GR8 was measured with the change of weight data was collected.

As a multitude sets of experiments has already been performed to test the Biefeld-Brown Effect in different environments such as in vacuum, polarized mediums of gases such as argon and nitrogen, and gas pressures, this thesis specifically investigates the interaction between air at a standard pressure and the asymmetric capacitor. The craft was made as light weighted as possible in order to achieve maximum propulsion and achieve NASA Centennial Challenge of 70 Kg mass afloat at a height of 1000 m. Hence, a theoretical and experimental framework of the Biefeld-Brown Effect must be known in order to replicate the effects for larger scale materials as well as to discover other potential application.

Materials:

1. Aluminum Foil
2. Balsa Wood
3. Bass Wood
4. Compass
5. Cooper Wire
6. Cutting Mat (optional)
7. Digital Weighing Scale
8. Ion-Driver GR8 model
9. Power Supply
10. Ruler
11. Scotch Tape
12. Solder
13. Soldering Iron
14. Soldering Paste
15. Stainless Steel Wire
16. Super Glue
17. Tether
18. Wire Stripper
19. Wood Cutting Knife

Methods:

Construction requires some electronics experience when building the Power Supply. Steady hands as well as patience are needed to build the craft. It is not required to take any electronics courses such as Digital Electronics and Microprocessor Control Systems as the author has done to deal with the electronics. It is better off to start working on the electronics by following the amazing1.cim manual of the Ion Power Supply GR8 and external sources such as youtube.com. Any other inquiries in regards to the electronic components of the Ion Power Supply GR8 can be directed to amazing1.com.

Construction of the Ion Power Supply GR8 (20 – 30 kV)

1. Follow amazing1.com instructions manual to build the Ion Power Supply GR8.
2. Lay out and identify all parts and pieces of the GR8.
3. Solder each part and piece to the PCB board using a Soldering Iron. It is advisable to start from the bottom right to the top left and unnecessary to use the optional parts and pieces for the GR8.
4. It is imperative to build the heat sink. In difference to the soldering method on the PCB board, it requires the technique called the Smooth Globular Soldering Joints. The technique is applied on all high-voltage points when constructing the Cockcroft Walton Voltage Multiplier. The Smooth Globular Soldering Joints can

be done by melting the solder and allowing blobs to be formed. When the blobs are big enough, direct it to the joints of high voltage.

5. After the completion of the soldering the pieces and parts, minimal adjustments are needed to complete the Ion Power Supply by following the manual.
6. Once it is completed, check if the electronic components follow the schematic diagram. Beware with the connection of the Ion Power Supply connection to the 12V Power Supply.
7. Once the GR8 is built, build the Craft.

Construction of the Craft

1. The craft is built out of light weighted materials. It consists of a chassis, collector, and wire.
2. As a start, the traditional triangle craft is built.
3. There are many ways to build a craft. For the sake of conciseness, the methods will focus only on the building of the traditional craft, which is that of a triangular shape.
4. In order to get the most lift out of the craft, the chassis is made out of balsa wood, which can be obtained at a local hobby store. A 1/16 X 1/16 X 36 inch balsa wood is preferred to do the least cutting.
5. In order to achieve the triangular shape, a single 1/16 X 1/16 X 36 inch balsa wood was cut to yield three strands of 20 cm of balsa wood. Three more stands of 11 cm of balsa wood were cut.

6. The 11 cm and 20 cm strands of balsa wood are used for the vertical and horizontal sides of the chassis, respectively.
7. The 11 cm were marked from 4 centimeters from its end so that the 20 cm pieces of balsa wood could be glued together. Caution must be used due to the fragility of the balsa wood.
8. With the chassis built, two asymmetric electrodes must be attached. The larger electrode is obtained from the collector and the smaller one obtained from the wire.
9. The collector is made out of aluminum foil. Aluminum is used since it most lightweight material out of all metals. It is recommended to get the cheapest aluminium foilas it tends to be lighter than the ones that are labeled as heavy duty.
10. By taking into account the chassis of the already made triangular craft, cut a length of 62 cm and 6 cm of width from the aluminum foil. Make a mark of 4 cm of the width of the aluminum foil as it will serve to pinpoint the place where it will be attached with the horizontal frame of the chassis.
11. Use super glue to attach the strip of aluminum foil and fold the 2 cm left over foil and glue the aluminum foil together.
12. In order to get the smaller electrode, a thin wire is used. It is recommended to use stainless steel wire instead of cooper wire. The reason of this choice of wire was due to the fact that the tensile strength of steel is greater than that of cooper. This choice allows the wire to be the thinnest without breaking while the high voltages are applied.

13. One can obtain thin stainless steel wire out of scrap electronic wires and cables. When they are stripped out, there usually multiple bare wires branded and twisted together. Having insulated wires prevents the ionization of air and emission to occur.
14. Cut about 60 cm of wire and attach it 3 cm at the vertical frame above the horizontal frame of the chassis.
15. It should be sufficient to wrap the wire once at each corner of the vertical frame of the traditional triangular craft.
16. Ensure that the wires are tight from one end to the other. Having loose wires allows for the wire to fluctuate preventing stability in the lift.

Testing of the Craft

1. Have an insulating surface below the ion craft. It works best if the material is made out of plastic.
2. Connect the collector to the ground portion and the stainless steel wire to the power cable of the Ion Power Supply. The collector will act as the cathode end and the wire will act as the anode. The terms of cathode and anode are described in terms of capacitor nomenclature.
3. Attached three tethers to each corner of the traditional triangular craft with scotch tape or aluminum tape.
4. Connect the Ion Power Supply to the Power Supply.
5. Turn on and adjust 12 V and 3 amps to the Power Supply.

6. Turn on the Ion Power Supply and vary the potentiometer as to achieve the maximum lift.
7. Arcing may result from the Ion Power Supply or from the craft. In order to prevent it, make sure that the gap of heat sink of the Ion Power Supply is larger and there are no sharp edges at the craft.

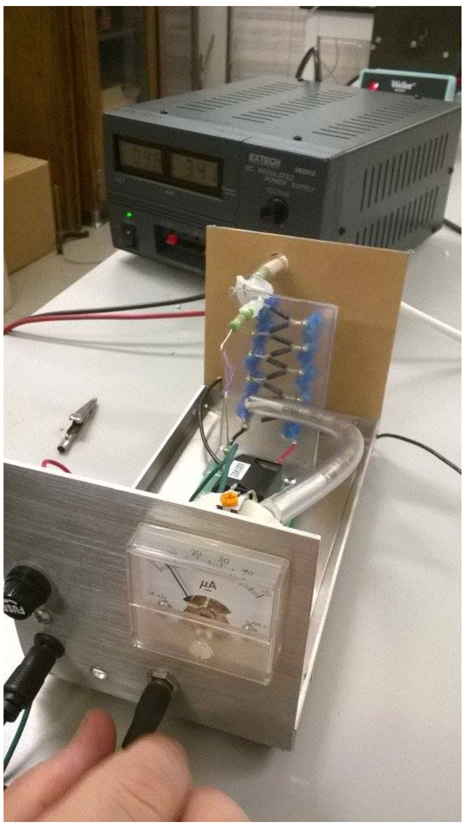


Figure I. Arcing on the GR8

Figure II. Arcing on the Craft

8. After finding the ideal craft attach a variable payload increase the mass of the payload by approximately 0.1 g each trial.
9. A Current vs. Weight plot was done. Current is read from the Power Supply.

Results:

By varying the parameters of the traditional triangular craft, various designs were constructed. The designs of the craft started with a traditional triangular craft and were altered for the purpose of finding the ideal craft. With the attempt of testing all built crafts, only a fraction was tested due to the fragility of the balsa wood that broke the craft easily. From the broken crafts, a general trend is observed where the craft is the most vulnerable when the wire is being looped around and stretched across the vertical frames of the chassis. If a quick remedy is needed, super glue can be applied. However, if super glue is being applied at the vertical frames of the chassis, there might be a chance that it won't hold it due to the tension of the wires. Additionally, too much super glue can also change the center of mass of the craft, where there is more weight than at the other ends. This can result in a destabilization in its flight. Next page has a table showing the parameters and lift of the 27 well-built crafts. Table 1. Craft Measurements.

Craft	Chassis Side (cm)	Chassis Height (cm)	Length of the Aluminum Foil (cm)	Width of the Aluminum Foil (cm) Total Width 5 cm	Distance in between the horizontal frame and wire (cm)	Weight (grams)	Lift	Comment
P1	10	5	31	1.2	2.5	1.3	No	• Insulated Copper Wire • Too small
P2	30	16.5	90.5	3.5	3	4.8	No	• Insulated Copper Wire • Heavy Duty Aluminum Foil • Too big
P3	10	5	31	1.2	2.5	1.3	Yes	• First Lift! • Changed the wire from Insulated Copper to Stainless Steel Wire
P4	18	8	56	3	3	2.6	Yes	• Heavy Duty Aluminum Foil • Too much super glue • Usage of Aluminum tape making

								the device heavier
T1	20	10	60.5	4	1	1.9	No	• Arcing on the Craft
T1.5	20	10	60.5	4	1.5	1.8	Yes	
T2	20	10	60.5	4	2	1.7	Yes	
T2.5	20	10	60.5	4	2.5	1.8	Yes	
T3	20	10	60.5	4	3	1.8	Yes	• Best Lift
T3.5	20	10	60.5	4	3.5	1.8	Yes	
T4	20	10	60.5	4	4	1.8	Yes	
T4.5	20	10	60.5	4	4.5	1.8	Yes	
T5	20	10	60.5	4	5	1.9	Yes	
T6	20	20	60.5	4	6	2.2	No	• Arcing on the Ion Power Supply
T7	20	20	60.5	4	7	2.2	No	• Arcing on the Ion Power Supply
T8	20	20	60.5	4	8	2.1	No	• Arcing on the Ion Power Supply
Horizontal T3	20	10	60.5	4	3	1.7	Yes	
Quadrilateral Emerging T2 and T2.5	20	10	60.5	4	4	4.5	No	• Arcing in between the Cathode Electrode
Quadrilateral Emerging T4s	20	10	60.5	4	4	4.5	No	• Too heavy • Arcing on the Ion Power

								Supply
Big Butt	20	13.5	60.5	7	4	2.9	Yes	
Quadrangle Q1	20	10	80.5	4	3	2.7	Yes	
Quadrangle Q2	30	10	120.5	4	3	3.4	Yes	• Best Lift • Stable
TD1	20 15	10 5	60.5 45.5	4 4	4 0	3.3	Yes	• The inner side did not have a wire. • There is a 3 3cm pieces of balsa wood joining the craft
TD2	20 15	10 10	60.5 45.5	4 4	3 3	3.6	Yes	• One of the corners of the outer side of the craft broke
TT	20 15 10	10 10 10	60.5 45.5 30.5	4 4 4	3 3 3	6.5	No	• There was too much arcing in between the aluminum collectors • Additional Three 6 cm balsa wood joints
Hexagon	15	10	90.5	4	3	5.2	Yes	

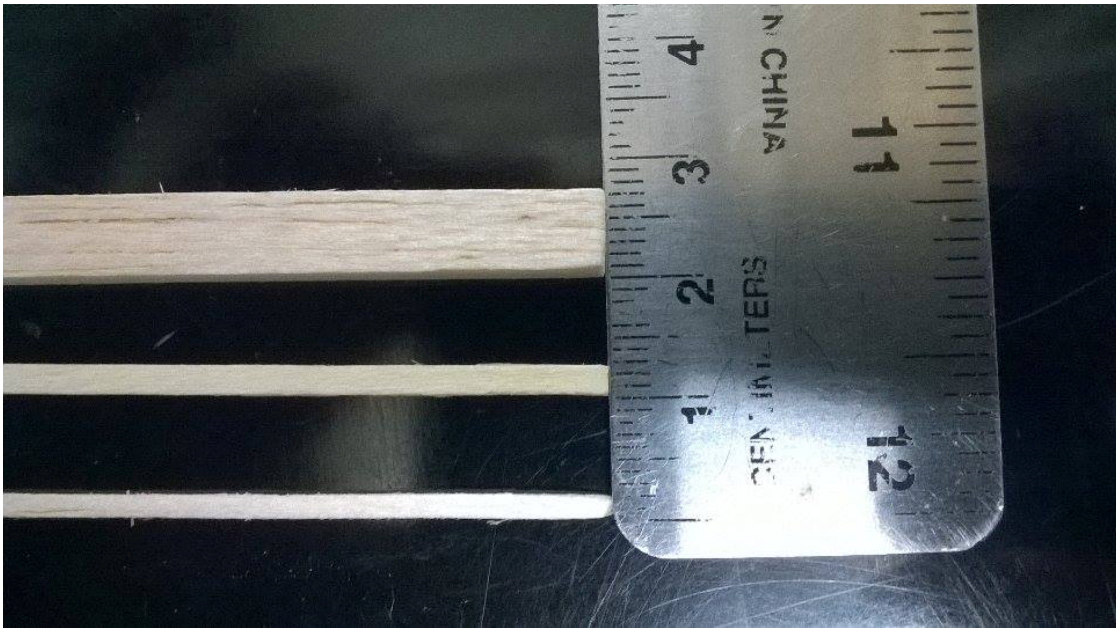


Figure III – The middle one is basswood that weighs greater than the balsa wood. It was first attempted to use the thick balsa wood at the top but it ended up being heavy as well. The bottom balsa wood strip was used.

Figure IV - The cooper wire in this craft was too thick. After the changes, the Copper Wire was insulated; this insulation prevented the ionization of air. It was later found that the stainless steel wire worked the best due to its tensile strength when dealing with thin wires.

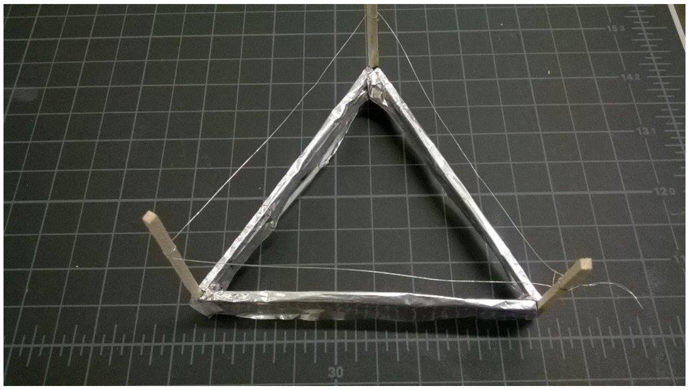


Figure V - Triangular Craft: With the changes implemented, the triangular Craft was able to take off the plastic launch pad.

Figure VI - The lift was not as efficient. The longer width of the aluminum did not help with the lift.

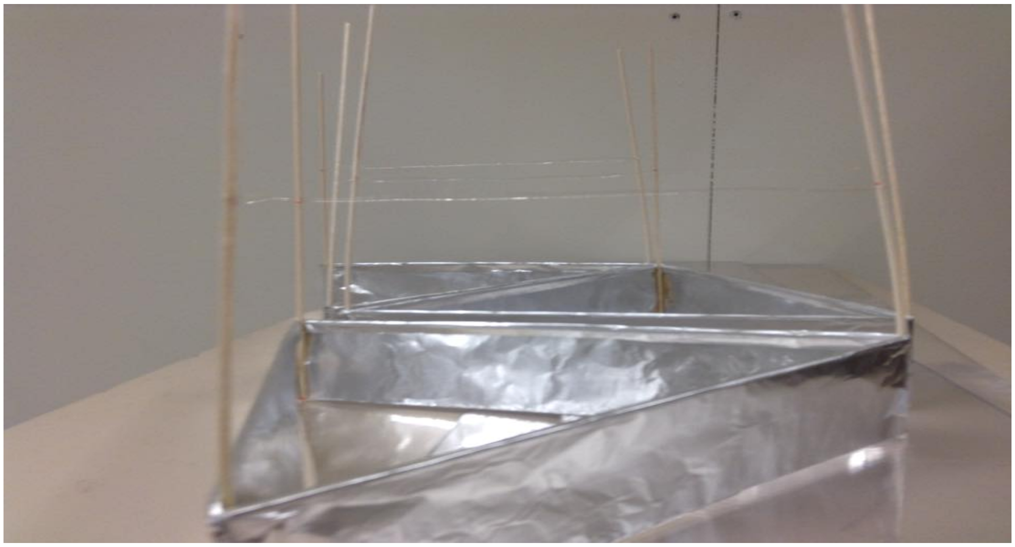


Figure VII - Increased length of the wire above the horizontal frame. The distance in between the electrodes for the triangular crafts are increased. From front to back, the gap was 4.0 cm, 4.5 cm, and 5.0 cm. It was observed that the lift began to be less efficient as the gap increased. At 5.0 cm, arcing was present at the Ion Power Supply. Further experimentation above 5.0 cm had to be discontinued as it posed a danger in damaging the electronic components of the Ion Power Supply.

Figure VIII - Double Triangular Craft: The lift was not as efficient

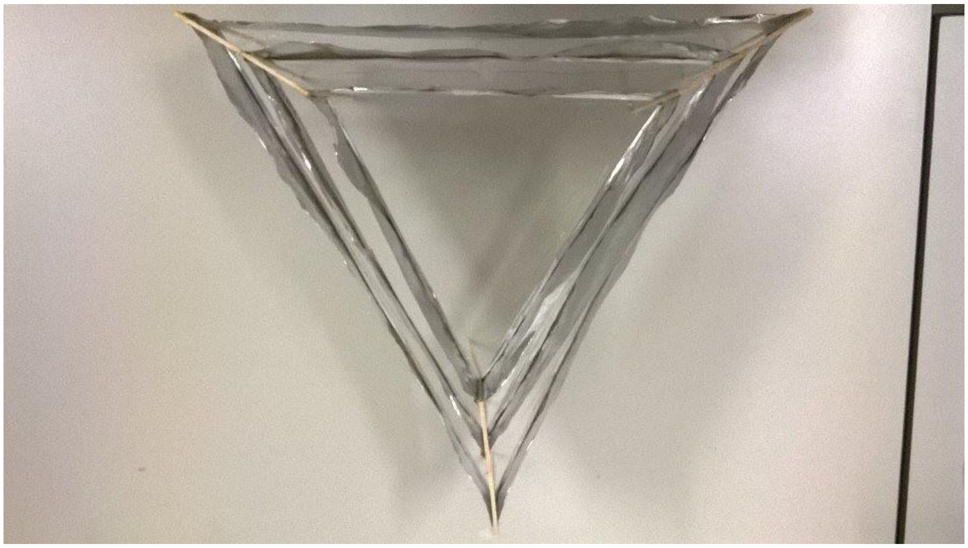


Figure IX - Triple Triangular Craft: Weight increased and more arcing present. The arcing was specially observed in between the cathodes.

Figure X - Ion wind: one can feel and smell the ion wind.

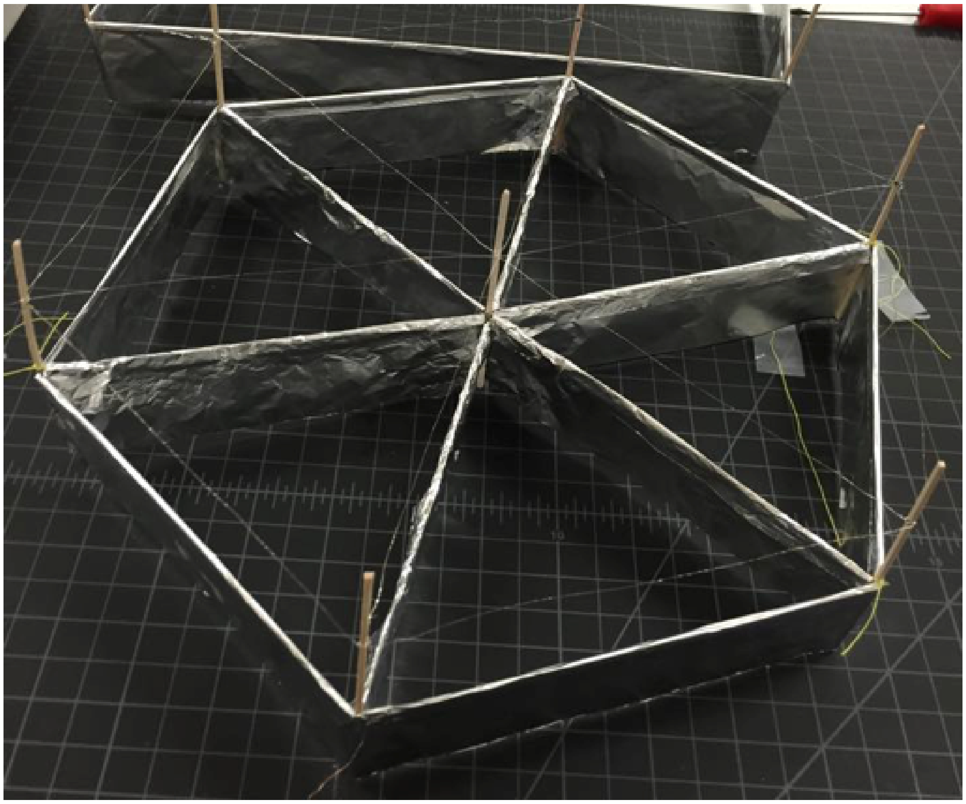


Figure XI - The lift was not efficient as thought to be. It is thought that the connections for the collector were not efficient.

Figure XII - In this picture there are 47 crafts. They are all located at the research room at the Department of Physics and Astronomy at Eastern Kentucky University.

Mass of the Craft (Kilograms)	Weight of the Craft (Newtons)	Current (Amps)
0.0049	0.0481	1.84
0.005	0.049	1.94
0.0052	0.051	1.96
0.0053	0.052	2.02
0.0054	0.053	2.14
0.0055	0.0534	2.23
0.0057	0.0559	2.2
0.0058	0.0569	2.33
0.006	0.0589	2.52

Table 2. Mass and Weight of Quadrangle Q2 with a variable payload, and current supplied by the Power Supply.

Temperature: 97 F, Humidity: 94%, and Atmospheric Pressure: 26 in

From all of the 47 designs, the quadrangle had the best design. The max height was 33 cm relative to the propulsion platform and 6 grams.

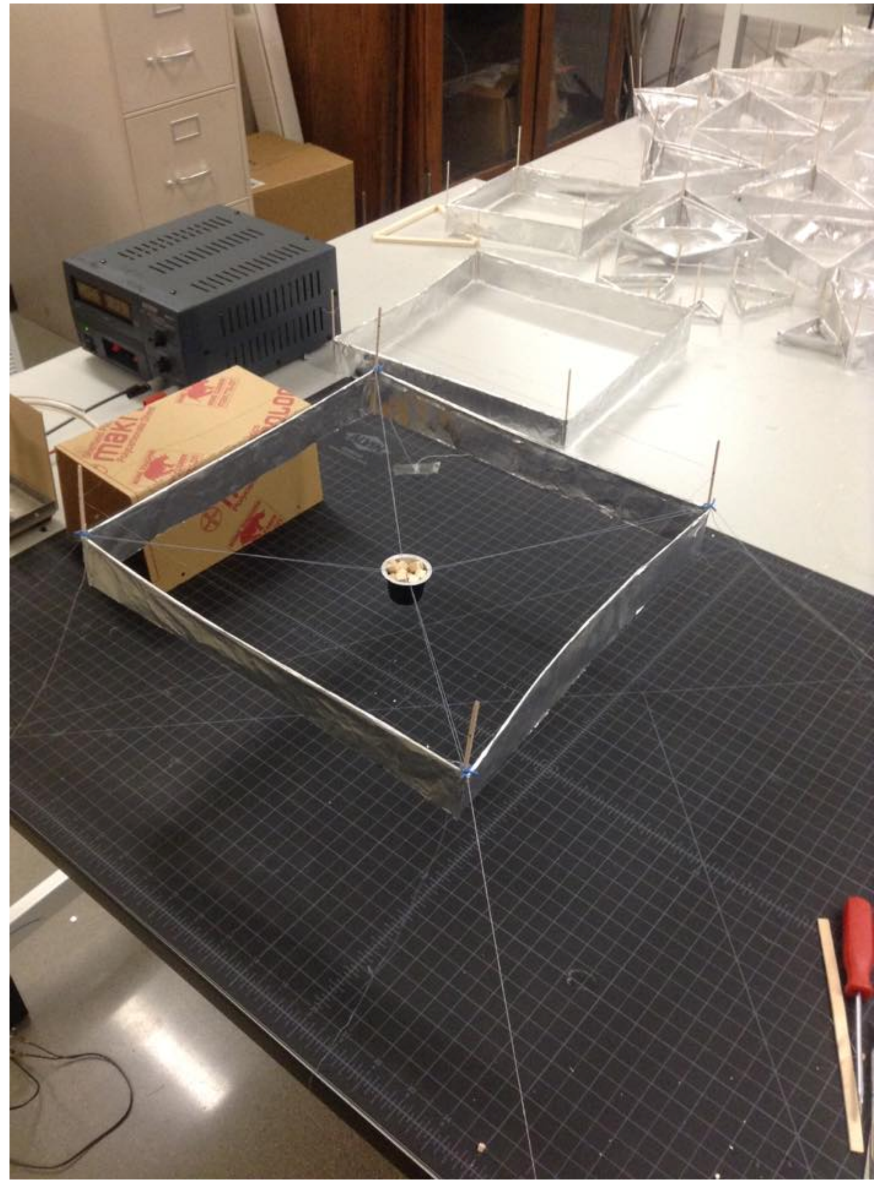
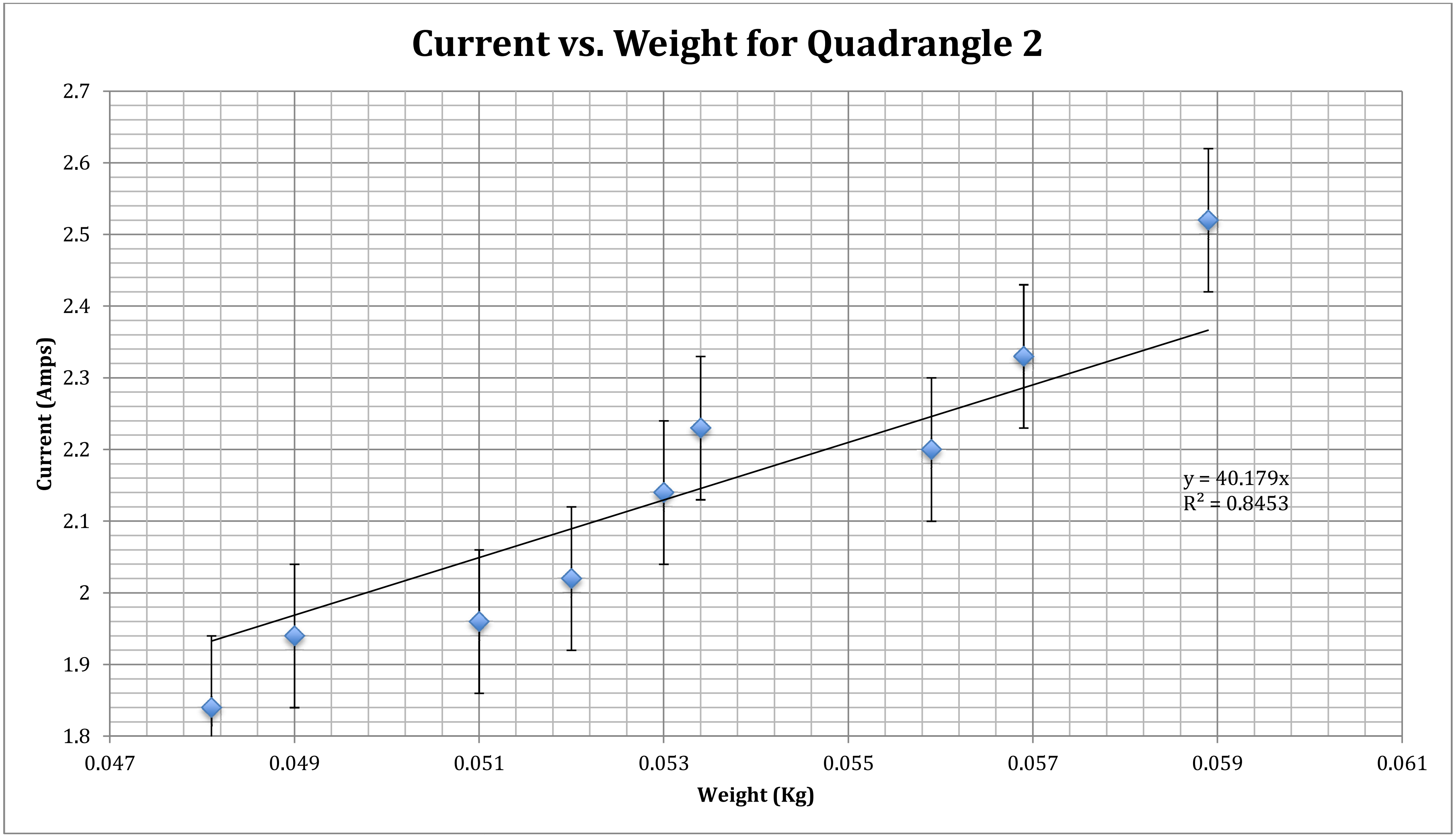


Figure XIII – Quadrangle 2 with variable payload


Current vs. Weight for Quadrangle 2
Current (Amps)
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
0.047
0.049
0.051
0.053
0.055
0.057
0.059
0.061
Weight (Kg)
y = 40.179x
R² = 0.8453

Using the Least-Square Fit Method and putting the y-intercept equal to zero, the best straight line is obtained

$$y = A + Bx$$

to fit these number N data points.

$$y = 40.179x + 0$$

Systematic errors are believed to be negligible. Without a manual that portrays the uncertainty in the digital meter, a reasonable assumption of the uncertainties of current read in the power supply for the current is 0.1 amps. Error bars are included to each data point to portray its uncertainty. From the plot, it can be seen that there is a linear relationship in between weight and current. As the weight of the Quadrangle Q2 craft increases, more of the current from the power supply is used to keep it afloat.

Discussion:

Although these measurements were limited, they provide with data that will serve for future experimentations of the Biefeld Brown Effect. Being unable to measure the exact voltage supplied to lift the craft was thought to be a disadvantage. On the contrary, by not being able to measure the voltage directly, other measurements of the Biefeld Brown Effect were emphasized, such as measuring the current that was used up in the Power Supply to maintain the craft with variable payload lifting at a fixed height. In comparison to other researches that have relied on measuring the voltage, the measurements done in this thesis provides with another facet of the Biefeld Brown Effect. This statement is not meant to make the measurement voltage trivial. It is imperative to get the needed equipment and measure them on the capabilities of the Ion-Driver GR8 as well as higher voltages than 30 kV.

Other facets that were taken into account were the dielectric medium in which the ionization occurred. In difference to other researches of the medium in which the Biefeld Brown Effect acted upon, this research focuses solely on air as the dielectric medium. It is important to note that the data collection occurred when humidity was 90%. The rate of ionization of air decreases due to the water molecules present. It is ideal to do such experiments are done in a dry environment. This spurs the question of how the rate of ionization and arcing results in different mediums.

A higher atmospheric pressure allows greater mass of air transported in between the electrodes. Greater mass of air travelling at low speeds allows a greater thrust. There was atmospheric pressure of 30.11 inches of mercury during experimentation, which is higher than standard conditions.

Conclusion:

From the parameterizations, it was found that the best craft in terms of lift and stability resulted to be the Quadrangle Q2. Because of the limitation posed in the measurements, another approach of collecting data was done. In difference to the conventional method of measuring voltage, the data was collected from the current used up by the Power Supply and variable payload attached to the Quadrangle. The Current vs. Weight of the Quadrangle plot shows a linear relationship. Although voltage was not measured directly, another aspect of the Biefeld Brown effect was looked closely in terms of the current supplied by the source. This is not to say that voltage measurements should be disregarded in future experimentation. As given from the results section, from all of the 47 designs, the Quadrangle Q2 had the best results. The max height of the Quadrangle Q2 was 33 cm relative to the propulsion platform and was done at a mass of 6 grams. By compare these results to the NASA Centennial Challenge of 70 Kg mass afloat at a height of 1000 m, there are still needed improvements in the design of the crafters and in the understanding of the Biefeld Brown Effect. Until then, its practical uses are still limited.

Acknowledgments

The author would like to thank Dr. Marco Ciocca from the Department of Physics and Astronomy at Eastern Kentucky University for his extensive collaboration in the completion of this thesis in terms of the experimentation of the craft with high voltages. With his guidance and insights, troubleshooting was done in matters of seconds rather than days. The author would also like to thank the Department of Physics and Astronomy and EKU Honors Program at Eastern Kentucky University for providing with the research space, equipment and materials for this thesis.

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