Investigation of an Energy Anomaly in Magnetic Circuits

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Abstract

In a report [1], Aspden describes an experiment in classical electromagnetism, whose outcome is new and distinct from predictions of standard physics. The experimental setup consists of a soft ferromagnetic circuit excited with a primary coil. The ferromagnetic circuit has an air gap. The claim of [1] is that the magnetic field energy stored in the air gap is more than the electrical energy input to the primary coil. The magnetic field of the gap is measured with a search coil. The author has carefully replicated the experiment described in [1], and no anomaly was found. In fact, the author found that the field energy measured in the gap depends strongly on the position of the search coil with respect to the pole face of the magnetic circuit. This is a pitfall that may give the appearance of a contradiction to standard classical electromagnetism. In reality, the premise of the gap energy calculation is no longer valid. In addition, field strengths higher than that used in [1] were explored, in hopes of replicating the anomaly, but no anomaly was found.

1.0 Introduction

Several provocative claims have been made into the existence of new physical effects which enable generation of "free" energy, i.e. a violation of the standard notion of energy conservation [1, 4]. The author has investigated one such claim made by Aspden [1].

In [1], three separate experiments are described. The first of the three experiments is the one investigated in this paper, and is detailed in [1] in the chapter entitled, "Mystery Energy Source: The Energy Balance Sheet." The other two experiments in [1] are not considered here. The experiment consists of a transformer with a primary coil, an air gap, and a search coil used to measure the magnetic field in the gap. The primary is excited with an AC voltage, and the peak energy entered into the transformer by the primary is calculated. In addition, the energy stored in the gap in the form of magnetic field energy is calculated. Aspden suggests that for sufficiently large gaps, the energy in the gap is in fact larger than that entered inductively by the primary. If true, this is a very provocative and significant finding, because it contradicts known classical electromagnetism.

Aspden's methods in reaching this excess energy conclusion appear sound, with one exception. He measures *changes* in the gap field energy due to *changes* in the input inductive energy, rather than absolute energy levels. He therefore has not in fact demonstrated excess energy per se, and his claims of absolute excess energy are not substantiated by his measurements.

The author has replicated Aspden's experiment, with one important difference; that is, the absolute input energy and absolute output gap energies were measured. No excess energy was found, even when magnetic field strengths higher than those used in [1] were employed.

This paper is organized as follows. Aspden's original experiment, as well as his results and findings, are detailed in sections 2, 3, and 4. The author's duplication of this experiment as well as results and findings are described in sections 5 and 6. Discussion and conclusions are presented in section 7.

2.0 Overview of Original Aspden Experiment

Figure 1 shows the experimental setup used in [1]. The setup resembles a transformer. A soft ferromagnetic transformer is excited by a primary coil. The transformer has an E-shaped core and a bridging yoke. Between the core and yoke is a gap, created by stacking paper cards of known thickness.

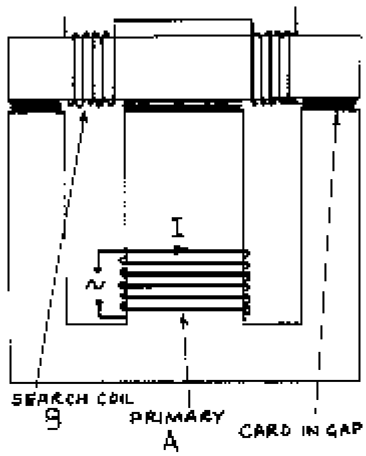

Figure 1. The original experimental setup used by Aspden in [1].

A search coil is employed near the gap, used to measure the magnetic field strength. The voltage on the search coil is the time derivative of the flux linked by the coil, and is therefore proportional to the magnetic field strength in the gap.

Broadly, Aspden's experiment consists of the following steps. First, excite the primary with a known AC voltage and current. Next, use this to calculate the peak energy entered into the transformer by the primary. Next, use the search coil to measure the magnetic field strength in the gap. Last, calculate the magnetic field energy stored in the gap knowing the magnetic field strength. The energy stored in the gap in the magnetic field is compared to the inductive energy entered into the transformer by the primary.

3.0 Overview of Findings of Original Aspden Experiment

According to known physics, the gap energy should be less than the inductive energy. However in [1] Aspden claims that in fact the gap energy exceeds the inductive energy, contradicting familiar notions of energy conservation [2,3]. If Aspden's finding is correct, then it is possible to build a perpetual motion machine. This machine would operate using the following cycle. First, with the primary un-energized, the gap is opened. This requires no energy. Second, the primary is energized by inputting electrical energy. Next, the gap is closed, extracting mechanical energy from the system. Next, the primary is de-energized. Lastly, with the primary off, the gap is re-opened. Because the energy stored in the gap is more than that input inductively into the primary, each cycle will produce more mechanical energy than it consumes electrical energy. This machine is suggested in [1].

4.0 Details of Original Aspden Experiment and Findings

The primary circuit is excited with an AC voltage at 50Hz frequency. The gap width is varied by using different number of paper cards to separate the bridging yolk from the remained of the magnetic circuit. As the gap is varied, the primary voltage is adjusted to keep the search coil voltage, hence the magnetic field strength, at a constant value of 0.2985 Tesla. Because the magnetic field strength is held constant, the energy density in the gap is constant, and the energy in the gap is therefore proportional to the number of cards in the gap.

The peak energy entered into the transformer by the primary is calculated as the product of V_1I_1/ω, where V_1 and I_1 are the primary coil voltage and current respectively. Quantity ω is the excitation frequency in radians, equal to $2*\pi*50$ radians/sec. The resistance of the primary is neglected.

Flux is linked by the primary coil, and part of the flux travels through the ferromagnetic path, and is therefore measured by the search coil. However, some of the flux breaks out of the ferromagnetic path before linking the search coil. Hence not all of the inductive energy input to the transformer will participate in the search coil and air gap. The primary peak flux V_1/ω must be derated to include only the flux linked by the search coil. Aspden arrives at a derated value of $V_1 = 47.1$ volts. This value of V_1 is assumed constant in his experiment. The exact method of arriving at this derated value is not clear to the author. In the author's own experiment, care is taken to account for the partial flux linkage, as described in section 5.

In Aspden's experiment, there are two variables remaining: the primary current I_1, and the gap width. Because primary voltage V_1 is constant, I_1 is proportional to the input inductive energy. The gap width is proportional to the energy stored in the gap. The energy stored in the gap is given by

$$E=2*A*g*B*B/(2*\mu_o). \qquad \text{("Gap Energy")} \qquad (1)$$

where A is the area of the pole face, g is the gap width, B is magnetic field strength measured by the search coil, and μ is permeability of free space, which is practically equal to the permeability of the cards. The extra factor of two is present because there are two gaps of equal width in the magnetic circuit.

A plot of primary current vs. gap width is therefore a plot of input inductive energy vs. output gap field energy. As pointed out by Aspden, a plot of these two should result in a straight line with unity slope. Any instance of the output energy exceeding the input energy is therefore evidence for violation the standard notion of energy conservation.

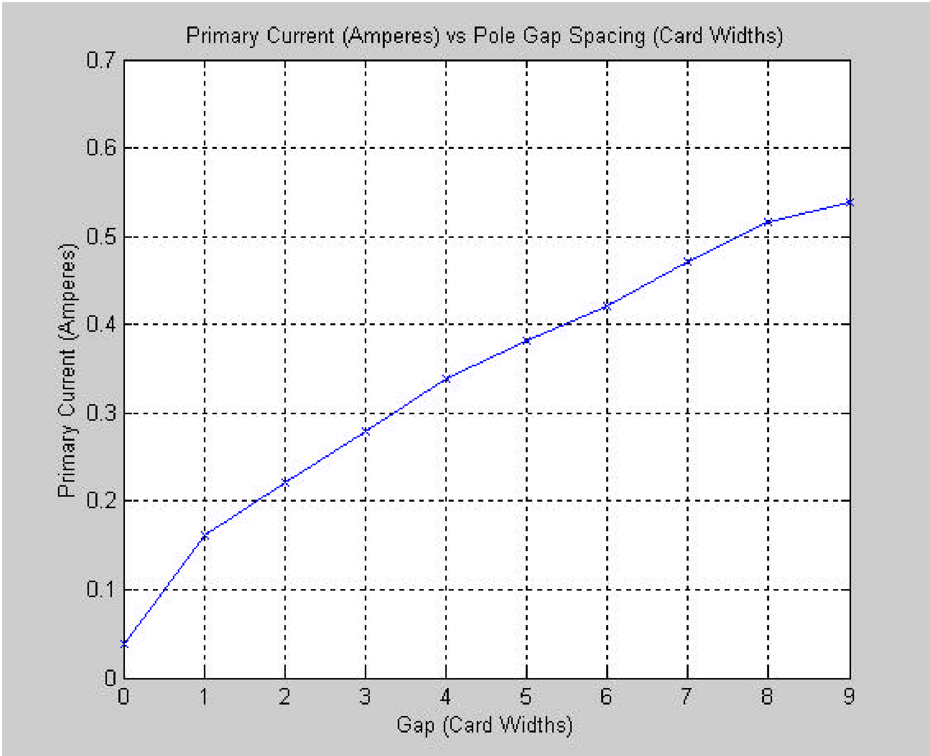

Figure 2. Aspden's data: plot of primary current vs. gap width. The primary current is proportional to input energy, and the gap width is proportional to output energy.

Figure 2 is a plot made by the author using Aspden's reported measurements [1]. The slope shows a slight negative curvature, implying that incremental changes in the input (inductive) energy cause larger incremental changes in the output (gap) energy. Aspden claims this plot is evidence for violation of the standard notion of electromagnetic energy conservation.

However, the negative curvature in the slope could be due to unaccounted-for factors such as decreases in loss mechanisms with increasing gap width. This is a major weakness in Aspden's conclusion that standard notions of energy conservation are violated. Moreover, the indications of negative curvature rely mainly on the two data points at gap=0 and gap=9 cards. If any other unaccounted-for factors influenced these two data points, these points should be disregarded. The curvature of the remaining data points does not appear to be strongly negative.

However, a more significant weakness in the conclusion is that Aspden has not demonstrated more gap energy than input energy, only larger *changes* in the gap energy for a given *change* in the input energy. The key issue to be demonstrated does not relate to the slope of Figure 2. The key issue rather relates to the *absolute* field energy in the gap being more than the *absolute* energy input inductively by the primary. It is difficult to determine the absolute levels of energy used in Aspden's experiment because the axes of Figure 2 do not have the units of energy; rather, the axes are merely proportional to energy. The experiment conducted by the author addressed this weakness by measuring absolute energy levels.

5.0 Overview of Author's Experiment

The purpose of the experiment performed by the author is to measure the absolute level of magnetic field energy in the gap, and compare this to the primary input inductive energy. That is, the validity of the following inequality is checked:

$$½*\Phi_1*I_1 > 2*A*g*B*B/(2*\mu_o) \qquad (2)$$

As before, I_1 is the primary input current, Φ_1 is the flux linked by the primary coil, B is the gap magnetic field strength, A is the pole face area, g is the gap width, and μ_o is the permeability of free space. Standard electromagnetism predicts that the inequality is true. However this inequality does not account for the fact that, of the flux linked by the primary, not all flux participates in the field energy of the gap. It can be shown that

$$½*\Phi_2*I_1*N_1/N_2 > 2*A*g*B*B/(2*\mu_o) \qquad (3)$$

is also true, where

$$\Phi_2=N_2*B*A$$

is the flux linked by the search coil. The validity of Eq.(3) assumes that the area A of the pole face is substantially equal to the area occupied by Φ_2 in the pole gap, which will be true if the fringing fields are small. The fringing field will be small if the gap width is small compared to the pole size, and the search coil is located near the pole face. More will be said later on the topic of minimizing energy errors due to fringing fields.

The validity of Eq.(3) can be shown to be true using Ampere's law, where the integration path is within the magnetic circuit, and traverses the gap. Ampere's law states that the current linked by a closed path is equal to the line integral of the magnetic field along the path:

$$\begin{aligned} N_1*I_1 &= H_{core}*L_{core} + H*g*2 \\ &> H*g*2 \end{aligned}$$

where N_1 is the number of primary turns, H is the magnetic field in the gap, H_{core} is the magnetic field in the magnetic core, and L_{core} is the length of the core. Multiplying both sides by $½*\Phi_2$, we obtain

$$\begin{aligned} ½*\Phi_2*N_1*I_1 &> ½*\Phi_2*H*g*2 \\ &> 2*N_2*A*g*B*H/2 \end{aligned}$$

The B and H fields in the above equation are located in the gap, which is filled with paper cards. Because the permeability of paper is substantially equal to that of vacuum, we have, $B=\mu_o*H$, and

$$½*\Phi_2*I_1*N_1/N_2 > 2*A*g*B*B/(2*\mu_o) \tag{3}$$

Eq.(3) is the basic equation whose veracity is investigated by the author. The left side represents the portion of the primary inductive energy which is present in the search coil flux (referred to as input energy); the right side is the field energy associated with the gap (referred to as gap energy).

The experiment performed by the author is similar to Aspden's, in that it uses a magnetic circuit excited by a primary coil, and a search coil to measure the field in the pole gaps. In both the author's and Aspden's experiment, measurements are made of the input inductive energy and the output gap energy.

However, there are two significant differences between the author's and Aspden's experiment. The first difference is that the author measured and reported the absolute levels of input and output energy, leading to a conclusive answer to the question of the presence of excess gap energy. Aspden compared changes in output energy to changes in input energy. Second, the author excited the primary coil with a step voltage function, rather than an AC voltage. Consequently, the primary current and the gap magnetic field also responded in a step-wise fashion. The motivation for step excitation was to enable easy achievement of magnetic field strengths (>1 Tesla) higher than those reported in [1].

6.0 Details of Author's Experiment

Three quantities were sampled using a digital data collector (PicoScope ADC-11 at 100 Hz with 8 bits of resolution): (i) the primary voltage (V_1), (ii) the primary current (I_1), and (iii) the search coil voltage (V_2). Once the data was recorded, digital processing was performed to obtain the B-field, Eq.(4) and energies of Eqs.(1,5). The output gap energy Eq.(1) was obtained by first computing the magnetic field strength as the integral of the search coil voltage

$$B = \int V_2 dt / (N_2 A) . \tag{4}$$

where N_2 (either 20 or 50) is the number of turns in the search coil, and $A=17cm^2$ is the area of the pole face. Two different search coils were used. The first search coil was comprised of $N_2=20$ turns of AWG 36 copper wire. The second coil used $N_2=50$ turns of AWG 29 copper wire. More will be said on the choice of search coil below.

Knowing the magnetic field strength B, the gap energy, Eq.(1) was then computed. The input energy was obtained by via:

$$E_{in} = \frac{1}{2}\Phi_2 I_1 N_1 / N_2 \tag{5}$$

where N_1=333 is the number of turns on the primary, and N_2 is the number of turn on the search coil.

Figure 3 shows a diagram of the experiment. The primary was comprised of N_1=333 turns of AWG 10 copper wire, and has a resistance of approximately 0.6 Ohms.

The current in the primary coil was measured by measuring the voltage V_c across the current sensing resistor R_c. This resistor is made from mangaloy metal configured in a geometry with large surface area, to minimize current-heating induced changes in the resistance. The value of this resistor was measured as R_c=0.1 Ohm +/- 2%.

The source V_{in} is a DC regulated power supply (Shenzhen-Mastech HY3020E), with an adjustable voltage of 0-30V, and a current of 0-21A. To actuate the voltage V_{in}, the control knob of the DC supply was simply turned by hand from 0V to its maximum setting.

Figure 4 shows a typical waveform of the primary current and voltage vs. time. The supply could only produce 21A, and it reached its current limit of 21A before reaching its voltage limit of 30V. Therefore, as the primary current rose from 0 to 21A, the primary voltage rose from 0 to only 12V. The ratio of the final value of the primary voltage and current is the coil resistance, which from Figure 4 is R_{coil} = 12/21 Ohm = 0.57 Ohm.

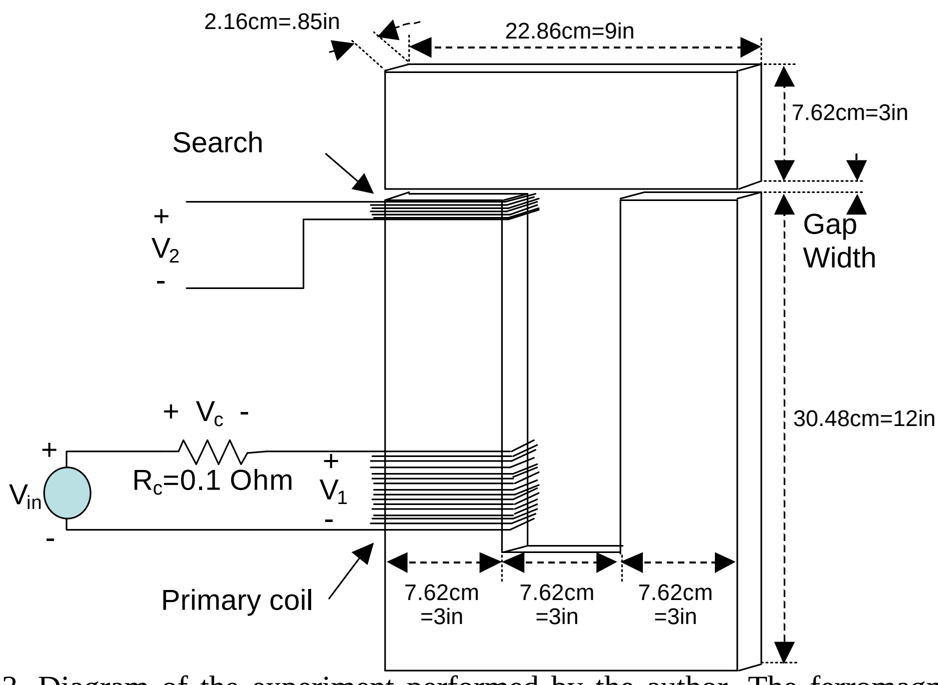

Figure 3. Diagram of the experiment performed by the author. The ferromagnetic core was comprised of 32 steel laminations.

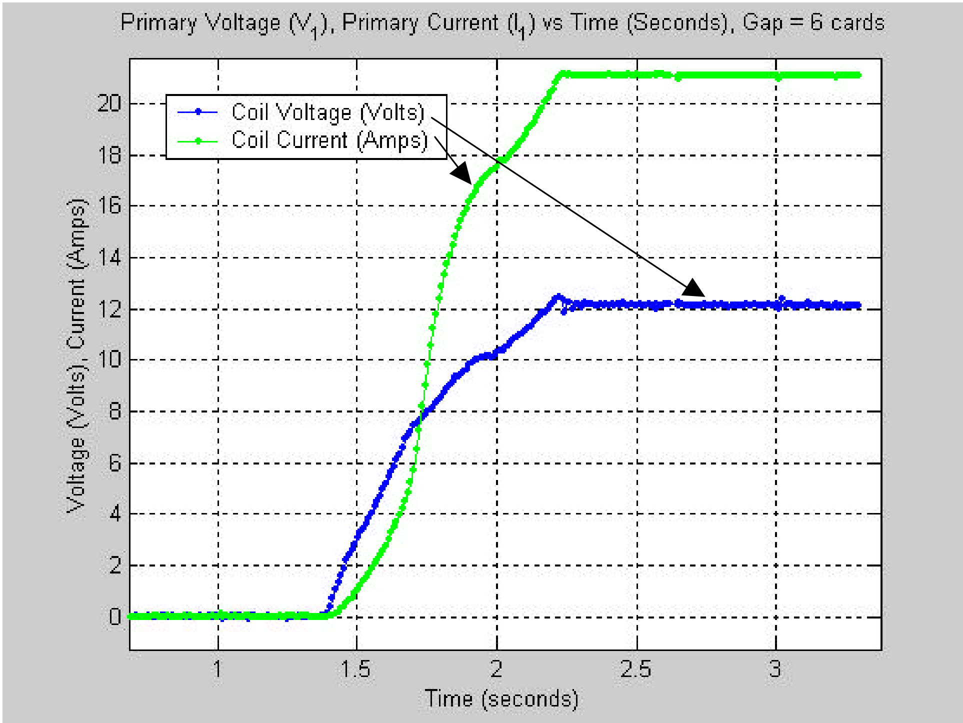

Figure 4. Plot of typical primary coil voltage and current vs. time. Each point corresponds to one sample. This experiment was made with a gap of 6 card widths, or 1.29mm.

Figure 5 shows a typical plot of V_2 vs time. Voltage V_2 has the shape of a pulse, because it is the time derivative of the flux, which in turn has an approximate step shape. This measurement was made with the search coil with N_2=20 turns of AWG 36.

Figure 6 shows the input and gap energies vs. time. Input energy is calculated using Eq.(5). The gap energy was calculated using Eq.(1) and Eq.(4).

Figure 7 plots the gap energy vs. the input energy. The experiment was performed for gap widths of 3, 6, 12 cards, which correspond to 0.6452, 1.2903, and 2.5806mm. A line of slope one is drawn on the plot. Points lying above this line are violations of Eq.(3), and points below the line satisfy Eq.(3). Since no data points are above this line, for all gap widths, no conflict with Eq.(3) is found. The measurements are in accord with standard electromagnetism. This plot summarizes the key experimental evidence of this report; it confirms Eq.(3), and contradicts Aspden's claim of excess energy.

This experimental results of Figures 5-7 were obtained with the N_2=20 turn search coil (using AWG 36 wire) shown in Figure 8. These measurements were repeated with a N_2=50 turn search coil (using AWG 29 wire) shown in Figure 9. The main difference between these two coils is that the N_2=50 turn coil was not wound as closely to the pole face as the N_2=20 turn coil. The 50 turn coil used a heavier gauge and occupied more space, making it harder to place near the pole face.

Because the search coil of Figure 9 was several mm from the pole face, it linked additional error producing fringing flux not linked by the search coil of Figure 8. The general pattern of fringing flux is well known: fringing flux exited the poles below the gap, bended away from the gap, before re-entering the opposite pole above the gap. Because the fringing flux occupied a larger area than the pole face area A, Eq.(1) is not valid. The area occupied by the flux was larger, while the magnetic field strength was proportionally lower. Since the energy in Eq.(1) is proportional to A*B*B, the net effect of the fringing is to reduce the energy below the level of Eq.(1).

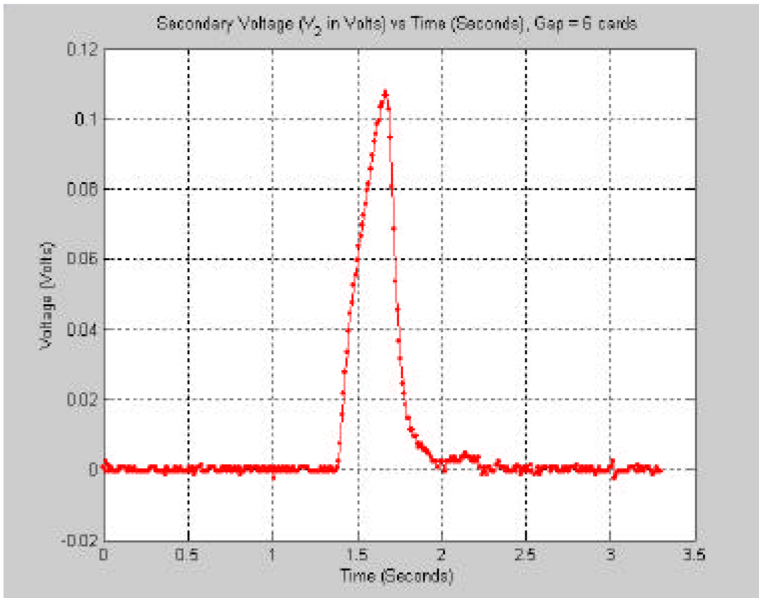

Figure 5. Plot of typical search coil voltage vs. time. Each point corresponds to one sample. Sample rate = 100Hz. This experiment was made with a gap of 6 card widths, or 1.29mm, using the 20 turn search coil.

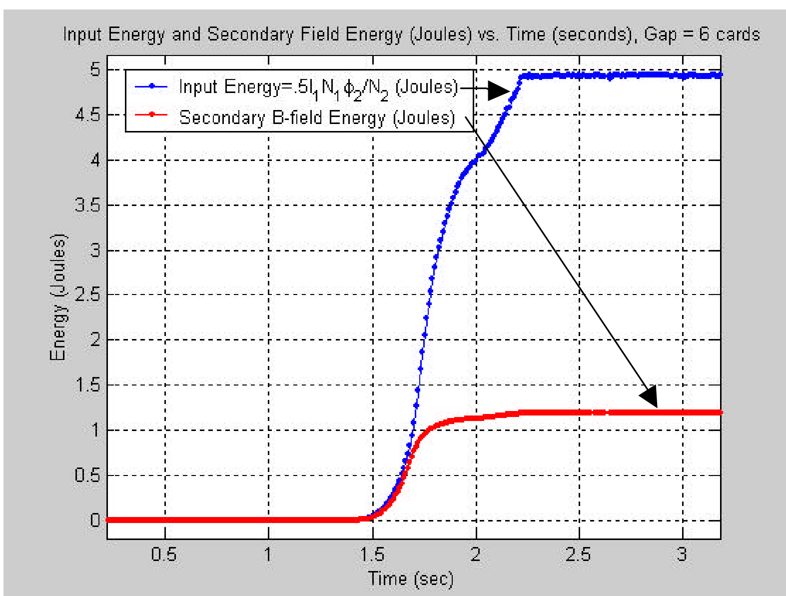

Figure 6. Plot of the input and gap field energy vs. time. Each point corresponds to one sample. Sample rate = 100Hz. Input primary energy is calculated using Eq.(5). Gap field energy was calculated using Eq.(4) and Eq.(1).

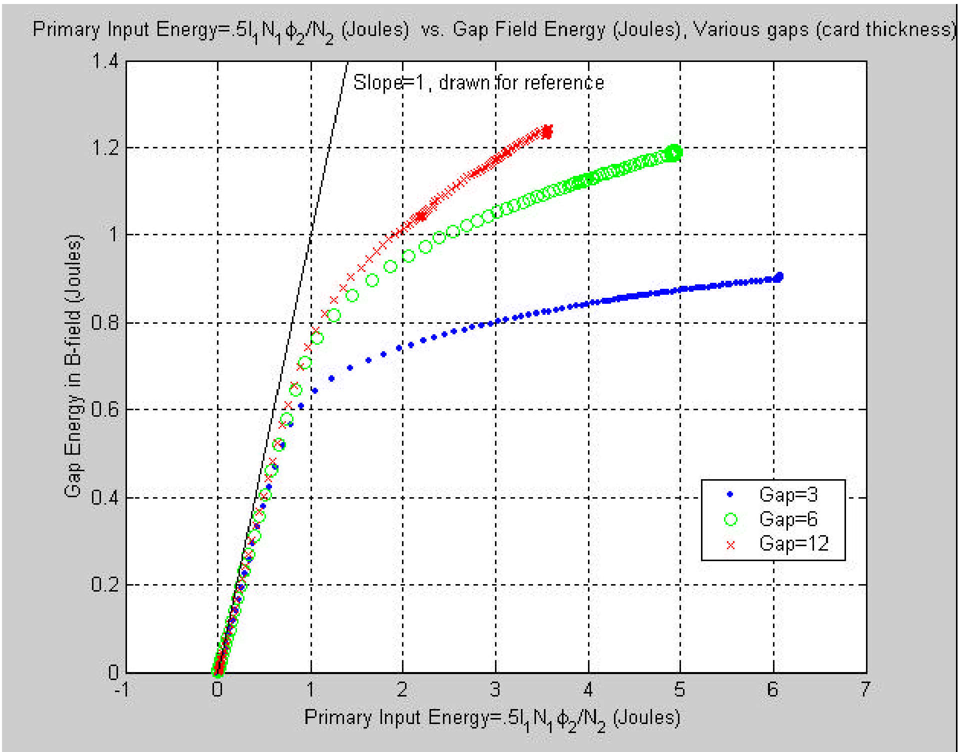

Figure 7. Plot of field energy in gap vs. input energy, for various gap widths. Search coil turns N_2=20. Each point is one time sample (sample rate=100Hz). Each card has a width of approximately 0.215mm. A line of slope one is added for reference. Any data points lying above this line are indications that the gap energy is more than the energy input in the primary. Since no points are found above this line, the validity of Eq.(3) is verified. No contradictions to standard electromagnetism are found.

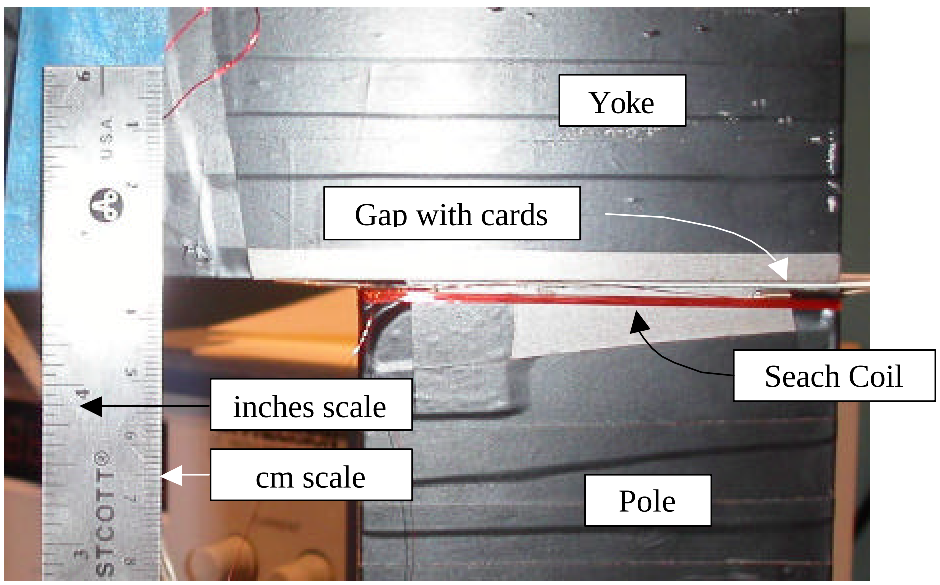

Figure 8. The N_2=20 turn search coil used to make measurements of Figures 4-7. Wire is AWG 36 Copper.

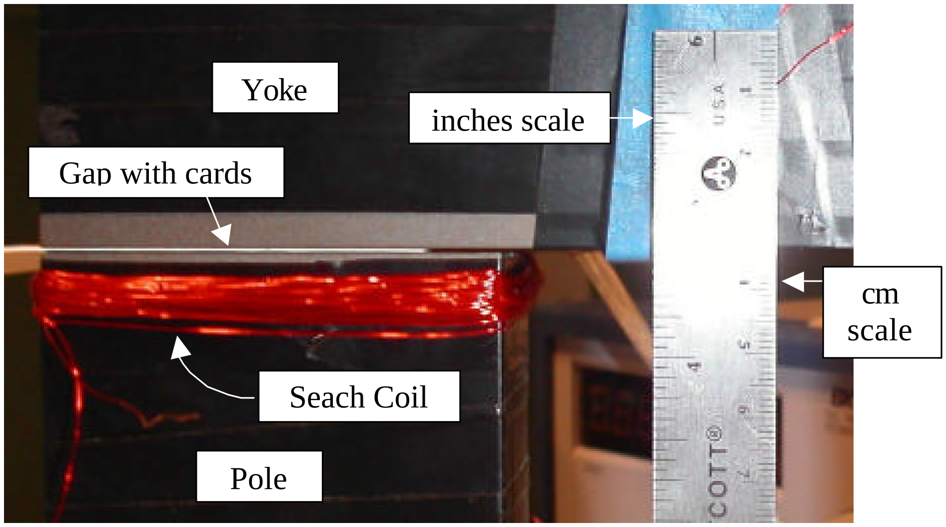

Figure 9. The N_2=50 turn search coil used to make measurements of Figure 10. Wire is AWG 29 Copper.

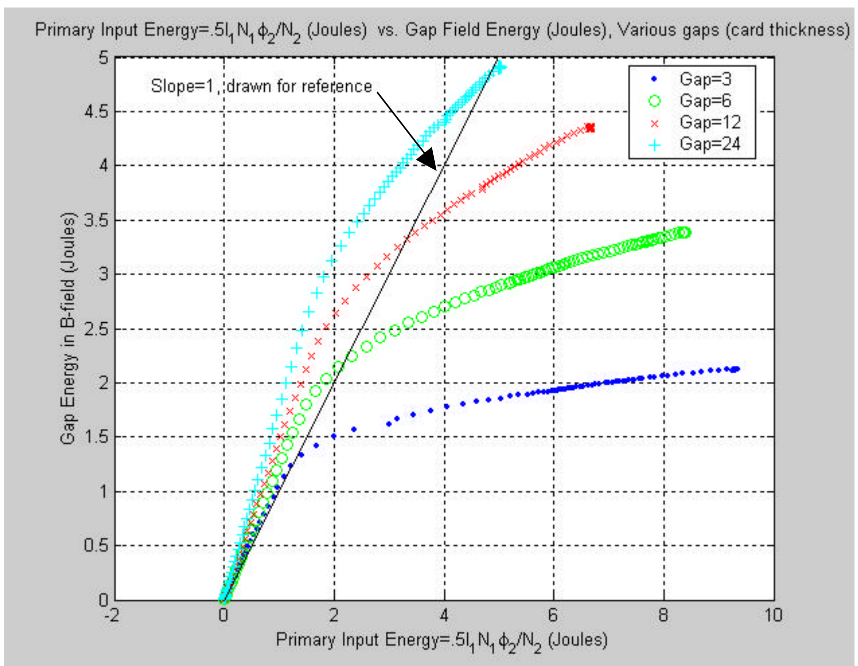

Figure 10. An invalid result. Plot of field energy in gap vs. input energy, for various gap widths. The plot was made using the erroneous assumption of minimal fringing flux, giving the erroneous result of more field than input energy. Search coil turns N_2=20. Each point is one time sample (sample rate=100Hz). Each card has a width of approximately 0.215mm. A line of slope one is added for reference.

Figure 10 shows a plot of the gap field energy vs. input inductive energy using the search coil shown in Figure 9, and using the erroneous assumption of negligible fringing flux. Because the search coil of Figure 9 was used, fringing was non-negligible, and the actual gap energy is less than that plotted in Figure 9. Figure 10 is an example of a misleading result which can be obtained when not exercising care in constructing the search coil which conforms to the assumption of constant area for the gap flux. The presence of fringing flux clearly makes these assumptions invalid.

In fact, the author used the search coil of Figure 9 first, and obtained the plot of Figure 10, before realizing that the presence of the fringing flux made Figure 10 invalid. He later constructed the search coil of Figure 8 and made the plot of Figure 7, which illuminated the key role of fringing flux, and the need to take care in constructing the search coil.

6.0 Conclusion

In [1], Aspden claimed violation of the standard notion of energy conservation in electromagnetic systems. His experiment on which this conclusion is based consists of a transformer with a primary coil, an air gap, and a search coil used to measure the magnetic field in the gap. The primary is excited with an AC voltage, and the peak energy entered into the transformer by the primary is calculated. In addition, the energy stored in the gap in the form of magnetic field energy is calculated. Aspden suggests that for sufficiently large gaps, the energy in the gap is in fact larger than that entered inductively by the primary.

Aspden's methods in reaching this excess energy conclusion appear sound, with one exception. He measures *changes* in the gap field energy due to *changes* in the input inductive energy, rather than absolute energy levels. He therefore has not in fact demonstrated excess energy per se, and his claims of absolute excess energy are not substantiated by his measurements.

The author has replicated Aspden's experiment, with one important difference; that is, the absolute input energy and output gap energies were measured. No excess energy was found, even when magnetic field strengths higher than those used in [1] were employed.

Furthermore, the author found that unless care is taken in winding the search coil to be near the pole face, non-negligible error-producing fringing flux gets linked by the search coil. This fringing flux undermines the constant-area assumptions underpinning Eq.(1), which can give the misleading appearance of energy conservation violation, as shown in Figure 10.

7.0 Acknowledgments

Special thanks to Dr. Ulrich Gerlach of The Ohio State University for derivation of Eq.(3).

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