

Comments regarding the report ‘Observation of abundant heat production from a reactor device and of isotopic changes in the fuel’ by Levi et al.

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Abstract

A recently published report that seems to imply cold fusion has received a lot of media attention. However, the presented data contains inconsistencies that prove that either the electrical measurements or the experimental set-up must have been different from what was reported. These inconsistencies are much larger than what could be attributed to measurement uncertainty, and can only be explained by a significant error in experimental procedure or set-up. Hence, the electrical data used in heat balance calculations cannot be trusted, and there is no reason to assume that any excess heat was produced in the “reactor”.

1 Introduction

The report [1] describes an experiment where a “reactor” connected to an electric circuit seemingly produced more heat than the amount of electric power it consumed. The authors claim to have observed “abundant heat production” and “isotopic changes in the fuel”. It is implied that a nuclear reaction (i.e. cold fusion) is taking place.

If the reactor actually produced energy as claimed, this would be wonderful news, not only to the people who have invested in the technology, but to everyone on the planet. It would solve all the world’s energy problems.

However, the report has not been well-received in the physics community. In a comment to Der Spiegel, Professor Karl Lackner, fusion researcher at the Max Planck Institute, said that he did not believe in the results, and that it looked like “Zaubertricks” (magic tricks).[3]

In this analysis I will focus on two things. First I will show, with mathematical certainty, that the reported electrical measurements are incompatible with the wiring diagram presented in the report, implying that either the actual currents or the actual circuit was different from what was reported. Secondly, I will analyze the possibility that the experimenters were deceived by a “magic trick”.

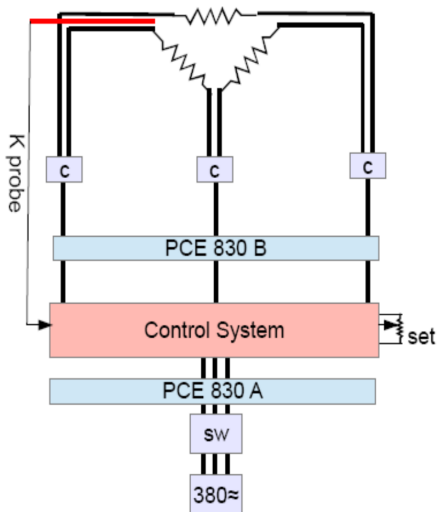


Figure 1: The circuit diagram from Figure 4 in the report [1].

2 Impossible results

The experimental set-up is described using the circuit diagram in Figure 4 of the report (reproduced here in Figure 1). It shows the “reactor” as containing three resistors in a Delta configuration.

Before the main experiment, a “dummy run”, without the “energy catalyzer” was performed in order to test the experimental technique. During this test, measurements were done not only of the three line currents, I_1 , at the location of the “PCE 830 B” instrument, but also of the phase currents, I_2 , going through the “reactor”. The results are described (page 14 in [1]) as follows:

Measurements performed during the dummy run with the PCE and ammeter clamps allowed us to measure an average current, for each of the three C_1 cables, of $I_1 = 19.7\text{A}$, and, for each C_2 cable, a current of $I_1/2 = I_2 = 9.85\text{ A}$.

These measurements were done in order to estimate heat losses in the cables, so by “average current” the authors clearly mean the root mean square (rms) current. (The word “average” is more commonly interpreted as “mean”, but elsewhere in the report it is stated that the mean current – or DC component – was zero.)

The result $I_2 = I_1/2$ is highly remarkable. Any basic textbook on three-phase systems will state the relationship between line and phase current in a balanced Delta-configuration as $I_2 = I_1/\sqrt{3}$. (See, for example, page 3-13 in reference [4].) Granted, most of those books assume a sinusoidal waveform and a resistive load, but it is relatively easy to show that for *any* type of waveform

and *any* type of load or source, the inequality $I_2 \geq I_1/\sqrt{3}$ holds. (A proof is given in appendix.) The relative difference between 2 and $\sqrt{3} \approx 1.73$ is much larger than the uncertainty of the measurements. The measured $I_2 = I_1/2$ is thus mathematically impossible!

So how can the report contain a measurement that is mathematically impossible to obtain? Since the measurements were done during the “dummy run”, the result cannot be attributed to an ability of the “energy catalyzer” to circumvent the laws of physics, but there are several other possibilities:

- The actual electrical circuit was different from that presented in the circuit diagram.
- The instrument used to measure the currents was faulty and gave a measurement error that was much larger than its supposed precision.
- The experimenter did not perform the measurements in a correct way.
- The data presented in the report is different from what was obtained during the experiment.

Regardless of which of these possibilities is true, the same thing that explains this anomaly would also explain the supposed “abundant heat production”.

I could end the analysis here, and conclude that the report does not give any credible evidence in support “heat production” (other than ordinary electric heating). But out of curiosity I will investigate the first of the possibilities in a bit more detail.

3 “Magic trick”

Let’s assume that the reason why the measured I_1/I_2 ratio is incompatible with a Delta-configuration, is that the experimental set-up did not contain one. Let’s further assume that whoever built the actual circuit did so with the explicit purpose of fooling the experimenters into thinking that the “reactor” produced excess heat.

One way of doing this would be to use two sets of star-connected resistors in the “reactor”, as in Figure 2. By feeding two out-of-phase currents through each cable, the instrument is fooled into reporting a lower amount of power than is actually transferred. (In Figure 1 it looks like the PCE instruments do a direct measurement of the current. This was not the case. The PCE 830 does an indirect measurement using current clamps.[2] If the cables contain multiple conductors it can only measure the sum of currents passing through each clamp.)

The set-up in figure 2 is sufficient to produce voltages that are 120 degrees out of phase, which is enough to explain a three-fold increase in power. With a slightly more advanced set-up, or clever pulsing of current, it would be possible to get currents that are 180 degrees out of phase, allowing an arbitrarily large ratio of actual to observed power.

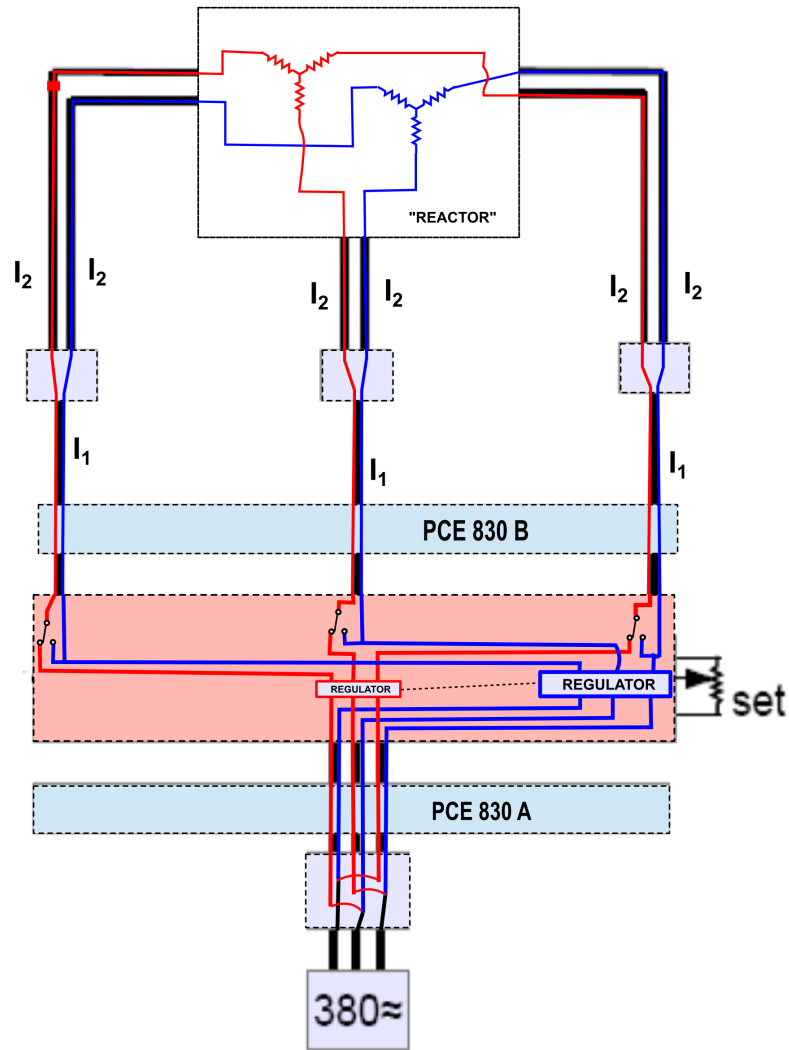


Figure 2: A possible “magic trick” set-up. When the red circuit is active, the instruments will measure the sum of two out-of-phase currents, and thus indicate less power than is actually transferred. The labels I_1 and I_2 are placed according how they are used in [1].

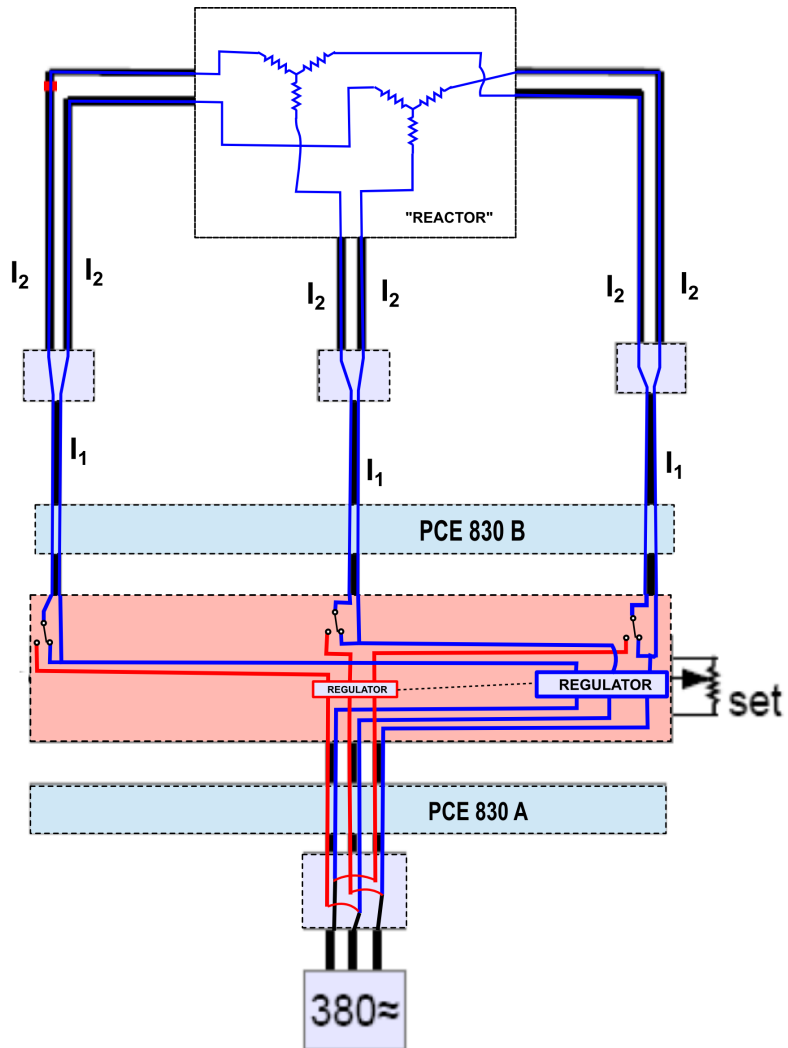


Figure 3: During the “dummy run”, the hidden circuit breakers are set so that the two star-connected resistor sets are in phase.

Figure 3 shows how this set-up would work during the “dummy run”. Because no excess heat production should be observed in this case, the two hidden circuits must be in phase. This can be accomplished using hidden circuit breakers that are set differently in the “dummy run” than in the “active run”. Because there are two star connections (instead of one Delta) in the reactor, we get $I_2 = I_1/2$ instead of $I_2 = I_1/\sqrt{3}$. This is exactly what was reported!

There are two more pieces of circumstantial evidence that support this hypothesis.

First there is the reported resistive loss in the cables during the “active” run. (These losses were not measured thermally. The I_1 and I_2 currents were obviously measured but not reported other than in this aggregate form.) If two resistors are connected in series, as the cables and the reactor are, then ratio of RI^2 heat generation is equal to the ratio of the resistance values, and stays the same even as the current changes (unless the resistance also changes). Assuming no change in resistivity, the heat losses in the cables should have increased from 6.7 W during the “dummy run” to approximately 11.25 W during day 1 of the “active run”. However, the reported value (Table 7 in [1]) is 37.77 W – more than three times as high!

If we calculate what would be measured on the “magic trick” circuit in Figure 2, assuming that all of the observed heat came from electric heating, then we arrive at 36.4 W. (The difference between 36.4 W and 37.77 W can be explained by uncertainty in the heat measurements on the “reactor”.) If the resistance in the reactor actually dropped by more than a factor three, as would be required to explain the data without the “magic trick” hypothesis, then it is strange that the report describes the voltage as being “increased” during start-up. The rms voltage would in fact have decreased.

Then there is the photo of a PCE 830 instrument showing the waveform of the current (Figure 5 in [1]). As pointed out in reference [5] this waveform is inverted. It appears that power is flowing from the load to the voltage source, rather than the other way around. This can of course be explained by an error in the experiment set-up – the current clamp was clamped on in the wrong direction. (That would also explain the “heat production”, as the power flow in this phase would be counted with the wrong sign.) But the inverted waveform can also be explained by the “magic trick” hypothesis. If the two currents in the clamp were 180 degrees out of phase, and the voltage was measured on the conductor that contained the smaller current, then the waveform would look exactly as it does in the photo.

4 Conclusions

The first conclusion is that the measurements that have been performed of the currents I_1 and I_2 during the “dummy” run cannot be reconciled with the presented circuit diagram. Therefore, none of the electrical measurements are credible, and there is no reason to assume that the observed heat production is due to anything other than electrical heating.

A further conclusion is that the reported measurements, including the supposed “heat production”, can easily be explained using the hypothesis that the experimenters were subjected to a “magic trick” where the actual electric circuit was different from the one they thought they were measuring on. In addition to resolving the impossible I_1/I_2 measurement, this would also explain two other anomalies in the report.

References

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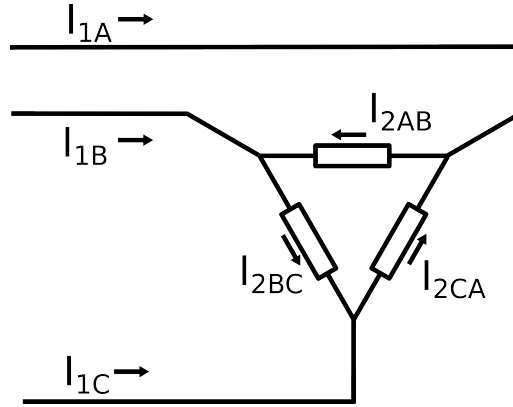


Figure 4: A Δ -connected three-phase load.

APPENDIX: Proof that the root-mean-square line current cannot be greater than $\sqrt{3}$ times the root-mean-square phase current in a balanced Delta-connected circuit.

I will now give a proof that, in a balanced Delta-connected three-phase system, the ratio of rms line current to rms phase current cannot be greater than $\sqrt{3}$.

Figure 4 shows a three-phase system with a Delta-connected load (or source – no assumptions are made on what goes on inside the boxes other than that there is no net accumulation of charge). The line currents are given by the vector

$$I_1 = \begin{bmatrix} I_{1A} \\ I_{1B} \\ I_{1C} \end{bmatrix}, \quad (1)$$

and the phase currents are given by the vector

$$I_2 = \begin{bmatrix} I_{2AB} \\ I_{2BC} \\ I_{2CA} \end{bmatrix}. \quad (2)$$

We can choose to interpret the above currents either as real-valued instantaneous currents at a given point in time, or as complex-valued phasors for a given frequency. The below reasoning works either way.

The relationship between I_1 and I_2 is dictated by Kirchhoff's first law:

$$I_1 = AI_2, \quad (3)$$

where

$$A = \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \quad (4)$$

Let $\|I_1\|$ denote the 2-norm, of I_1 :

$$\|I_1\| = \sqrt{|I_{1A}|^2 + |I_{1B}|^2 + |I_{1C}|^2} \quad (5)$$

and in the same way, let $\|I_2\|$ denote the 2-norm of I_2 .

The 2-norm of a vector is the the square root of the sum of the squares of the elements. It differs from the rms value (the square root of the mean of the squares) only by a constant factor equal to the square root of the number of elements. A ratio of rms values of equal-length vectors is therefore the same as the ratio of the 2-norms of those vectors.

The 2-norm of the matrix A is defined as:

$$\|A\| = \sup_{I_2 \neq 0} \frac{\|I_1\|}{\|I_2\|}. \quad (6)$$

In other words the 2-norm of A is defined as the highest possible ratio of $\|I_1\|$ to $\|I_2\|$. (This is also the absolute value of the largest eigenvalue of A .)

$\|A\|$ can be computed analytically, or using any number of software packages. With the definition of A in (4), we get

$$\|A\| = \sqrt{3} \quad (7)$$

This means that, for any nonzero set of currents,

$$\frac{\|I_1\|}{\|I_2\|} \leq \sqrt{3}. \quad (8)$$

Since this holds at any point in time (or frequency), it trivially also holds for the root-mean-square currents over time (or over frequencies, cf. Parseval's theorem). It is just a matter of changing the order of summation under the square root sign.

The relationship (8) applies whether the currents are balanced or not. In the special case where the system is balanced, i.e. the three root-mean-square line currents are identical, and the three root-mean-square phase currents are also identical, the ratio of the norms is of course equal to the element-wise ratios. So the inequality holds also for the element-wise ratios in this case.

Q.E.D.

Footnote

If anybody is interested in trying to contradict this proof, it would suffice to give a single counterexample. Such a counterexample could consist of a set of currents as functions of time ($I_{1A}(t), I_{1B}(t), I_{1C}(t), I_{2AB}(t), I_{2BC}(t), I_{2CA}(t)$) such that the rms values of the three first are identical, the rms values of the three last are identical, and the ratio of these sets of rms values is greater than $\sqrt{3}$. Alternatively, a counterexample could consist of a set of currents at a single point in time, such that $\frac{\|I_1\|}{\|I_2\|} > \sqrt{3}$. The only requirement is that Kirchhoff's

first law (equation (3)) is satisfied at each point in time. (It is not necessary to find e.g. a set of voltages and resistances that correspond to the currents.)

There is a spreadsheet available online at <http://goo.gl/aNgJ3e> which will compute the I_1 and rms currents given I_2 currents for different points in time. Anybody who wants to try to create a counterexample is free to download and use it.