H-G Branzell 2014-10-24

E-Cat: Independent Evaluation of Data from an Independent Report

About the E-Cat

Andrea Rossi, an Italian entrepreneur, is the man behind a series of different machines known under the generic name E-Cat which stands for Energy Catalyzer. The common feature of the various E-Cat models is that they allegedly produce heat from a new and still unknown process. The exact nature of this process is a secret even to the inventor, but the amount of energy produced is contended to be of such a magnitude that all sources like chemical reactions or electric batteries can be excluded. If this is true we must resort to nuclear reactions to explain the amount of energy produced. What is disclosed to the public is that the fuel of the E-Cat is a mixture of nickel powder and moderately compressed hydrogen enclosed in a small chamber. In order to start the reaction the temperature of the chamber and its contents are heated by means of an electric heater.

First independent third party investigation of the E-Cat

During the last few years several public demonstrations of E-Cats have been held by the inventor in order demonstrate and verify these claims. Since these demonstrations were not transparent enough to satisfy the public in general and the scientific community in particular, Andrea Rossi arranged for an investigation to be made by an independent third party.

The investigation was performed in March 2013 at the premises of EFA Srl in Italy. The report was published under the title “Indication of anomalous heat energy production in a reactor device containing hydrogen loaded nickel powder” [1].

Second third party investigation

In order to hopefully get rid of the word “indication” in the title of the first report preparations for a follow-up investigation were made by Andrea Rossi. The new test was carried out in March 2014 in the city of Lugano, Switzerland. In the beginning of October 2014 the ensuing report became available to the public with the title “Observation of abundant heat production from a reactor device and of isotopic changes in the fuel” [2].

Obviously the doubts inherent in the word “indication” have been overcome. The heading also implies unambiguous isotopic shifts. However intriguing this may sound we will not discuss this here. Instead we will focus on the electric power input to the E-Cat and see what that might lead to.

Setup of electric input power system

Figure 1 below is a simplified diagram for the setup. The electric power is supplied from a standard three phase outlet to the control electronics which is made up from a triac controller and a box with secret contents, See Figure 3 in the test report.

The active power and current delivered to the power wiring and the reactor are measured and logged on a computer via a PCE-830 power analyzer.

This instrument is capable of measuring true RMS voltages and currents covering 50 harmonics. It can also measure the active power delivered to a three phase system. Each of the three channels in the PCE-830 is equipped with a current clamp and a voltage probe, one for each phase that is driving the reactor.

There are two sets of wires. The first set called C1 has three wires of same type and length. Similarly, C2 is made up of six wires of same type and length.

Three heating resistors Rh1, Rh2, Rh3 with the same resistance are installed inside the reactor body.

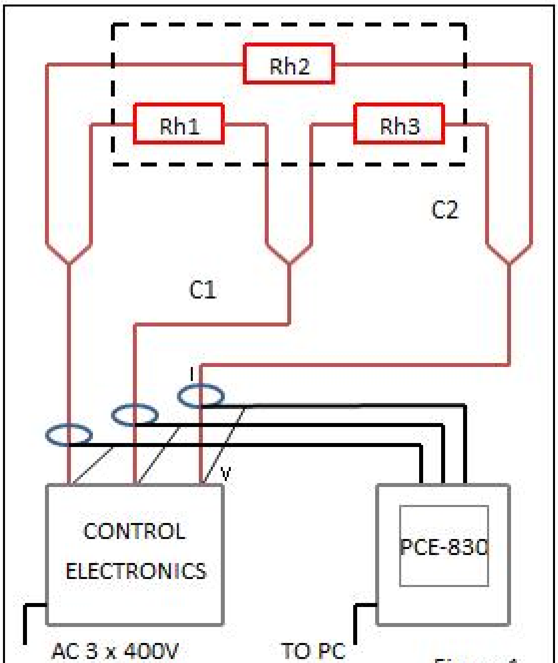


Figure 1

Dummy run

To verify the operation of the system the testing started with a short run without fuel in the reactor.

The currents in the three C1 wires are all equal and they are measured by the true RMS instrument PCE-830. The three heating resistors are also equal and therefore they will all be heated by equal currents, I_2. The authors of the report have assumed that I_2 is half of the current in the C1 wires. That turns out to be not true. Instead the full current I_1 is alternating between the two wires in the C2 wire pairs, so the voltage drop will be the same as for a single wire. For calculation of the resistance R_e in the wire system, see paragraph E1 in the spreadsheet and reference [3].

Knowing the resistances we use the current to calculate the heat losses in the cabling, see E3 where we use the corrected value for the resistance, R_{ec}.

The power delivered to the system is measured by PCE-830. The measured power can now be corrected by subtracting the wiring heat losses to get the power used to heat the reactor during the test without fuel, i.e. the dummy test, see E3.

In paragraph E4 we calculate the COP during the dummy run. It is found to be 0.93 which including error margins covers the expected value which is 1. We can say that the result is probably conservative; we are not exaggerating the gain. A byproduct is that we can calculate the equivalent resistance R_{he} in the reactor heating elements, see last line in the spreadsheet paragraph E3.

In paragraph E5 we use the wire heat losses ("Joule heating") from Table 7 in the report to calculate the corresponding currents I_1 from which we can calculate the electric power supplied to the reactor, see Table E2.

Finally, in E6 we calculate the COP in the same way as in the report, except that we replace the power as measured by PCE-830 with the one calculated by using the calculated currents and resistances.

To give an example, from the report:
COP = (TOT. + Rods)/(Consumpt. - Joule)

Data from Table 7, File No. 1
COP = (2128.32 + 307.98) / (815.86 –37.77) = 3.13

Then new calculation looks like this:
COP_{rev} = (2128.32 + 307.98) / 2503 = 0.97

Discussion

The calculations in the accompanying spreadsheet are made possible by the assumption that the reactor is a purely resistive load to the three phase power supply. This is most certainly true. To make a sizeable inductor you need a ferromagnetic core made from e.g. iron. Iron will not work though. Over the Curie temperature, 770°C, iron loses its magnetism and the temperature of the reactor was well over 1000°C. Cobalt has one of the highest Curie temperatures, 1131°C, but already during the low power part of the long term test the temperature was 1260°C.

A current - voltage phase shift could also be introduced by a large capacitor, a type of component that could not endure the high temperatures in the reactor, nor is the space for it available.

For the dummy test the COP was 0.93 and for the main test the calculated average COP for files number 1 – 6 is 0.99 and for file 6 to 16 it is 1.15. The step in COP coincides with an input power increase of 115 W which translates to 330 W in the revised calculation. The procedure for measuring the output power is very complicated and needs to be calibrated close to the actual temperature during the experiment. Therefore the from standard physics expected COP of 1 is probably within the margins of the measurement errors.

The proper way to do the dummy test would have been to run it with the same electric input power as the long term test. In this way the starting point for possible unconventional heat generation would have been firmly established.

The result from this alternative evaluation of data collected from the report is that the COP is close to 1, which is in stark contrast with the conclusion of the report that COP is around 3.5. Something is not right.

One possibility is that the PCE-830 measurements are wrong.

Against this speaks the fact that the dummy measurements gave the expected result which indicates that the power measurement was correct at that time, but we see most everyday instances of things that go wrong for one reason or other. More often than not errors are caused by human mistake. A possible mistake that would explain the discrepancy is that one of the current clamps was turned the wrong way during the long term test. The contribution from this clamp would then be subtracted from rather than added to the measured power.

A suggested explanation to the contradiction pointed at in this document is that the resistances in the reactor have very strong temperature dependence. Against this argument we can say that in the report it is explicitly stated that the resistors are made from Inconel wire, page 3, top:

“Three braided high-temperature grade Inconel cables exit from each of the two caps: *these are the resistors* wound in parallel non-overlapping coils inside the reactor.”

In Table E3 you can see that the resistivity of at least Inconel 625 has very small temperature dependence. It has a peak at around 500°C and starts to decline *very* slowly at higher temperatures.

This should establish that the resistance cannot be around three times lower for the second part of the test. Even if it were, it is unreasonable that the decrease in resistance would almost perfectly match the rate of generation of unconventional heat.

In the future

The contradictory result of the evaluation described here should be taken into consideration together with other aspects of the test, particularly the alleged isotopic shifts of the fuel powder. Extended evaluation of the collected data from the test may resolve the problems. After this the involved parties will have to decide whether a new test is warranted or not.

A third test should be done using exactly the same test equipment as the present test and the E-Cat must be of the same model. The discussion here indicates that the new crew should include at least one independent professional expert on electrical measurements.

Other expertise that is strongly recommended is that of an experienced physics experimentalist to build a strict test protocol and make sure that this is followed in every step. Needless to say the test protocol must include proper documentation of every step.

References

[1] Indication of anomalous heat energy production in a reactor device containing hydrogen loaded nickel powder
www.arxiv.org/abs/1305.3913

[2] Observation of abundant heat production from a reactor device and of isotopic changes in the fuel
www.elforsk.se/Global/Omv%C3%A4rld_system/filer/LuganoReportSubmit.pdf

[3] E-Cat: Independent Evaluation of Data from an Independent Report (This document)
http://lenr.fysik.org/eCat/COP=1_or_3.doc

[4] Supplement to reference [3] Rev. 1
http://lenr.fysik.org/eCat/COP=1_or_3.xls

[5] PDF document with [3] and [4]
http://lenr.fysik.org/eCat/COP=1_or_3.pdf

Alternate evaluation of COP in E-Cat test March 2014 Lugano

Supplement to http://lenr.fysik.org/eCat/COP=1_or_3.doc
H-G Branzell 2014-10-24

Notation

Data from report	***1,234***
Calculated here	1,234

E1. Wire resistances

(Pages 13 - 14 in report)

Resisitvity of copper ρ ***0,0175*** Ohm mm^2/m

R1, R2 = ρ*Length/Area

Table E1 Resistances as calculated in report

Cables	Items	Length m	Area mm^2	R_1, R_2 Ohm
C1	***3***	***3***	***12***	0,00438
C2	***6***	***2***	***12,45***	0,00281

E2. Wire heating in dummy run

I_1 = Current in C1 cables (3) ***19,7*** A

I_2 = Current in C2 cables (6) 9,85 A

$P = \Sigma R*I^2$

$P = 3*R_1*I_1^2 + 6*R_2*I_2^2 = (3*R_1 + 1.5*R_2)*I_1^2$

Equivalent resistance (not correct):

$R_e = 3*R_1 + 1.5*R_2 =$ 0,0173 Ohm

R_e is only used to deduce the currents in Table E2 from

the "Joule heat" in table 7, see below.

The true I_2 is the same as I_1, but alternating between wires.

Corrected $R_{ec} = 3*(R_1 + R_2)$ 0,0216 Ohm

E3. Electric power to dummy

Delivered by power supply P_d ***486*** W

Wire losses P_L 8,4 W

Net supplied $P_{in} = P_d - P_L$ 478 W

R_{he} See "Reactor heating" 0,7661 Ohm See Rev. 1

E4. Calculation of dummy COP

Heat from reactor + rods P_{out} **446** W

$COP_{dummy} = P_{out}/P_{in}$ 0,93

E5. Calculation of electric power fed to reactor

$P_{el} = 3/2*R_{he}*I_1^2$ See "Reactor heating" and Table E2. See Rev. 1

E6. Calculation of COP

Using TOT. and Rods from Table 7 we calculate:

$$COP_{rev} = (TOT. + Rods)/P_{el}$$

The result is presented in Table E2.

Please see also Table 7 for comparison.

Table 7 from page 22 in report

File No.	Consumpt. (W)	Radiation (W)	Convect. (W)	TOT. (W)	Rods (W)	Joule heat (W)	COP	Net Prod. (W)
1	816	1741	387	2128	308	37,8	3,13	1658
2	800	1733	386	2120	308	37,0	3,18	1665
3	791	1725	385	2110	308	36,5	3,20	1663
4	791	1729	385	2115	308	36,4	3,21	1668
5	786	1677	381	2058	308	36,1	3,16	1617
6	924	2382	428	2809	353	42,4	3,59	2281
7	922	2417	430	2846	353	42,2	3,64	2319
8	918	2407	429	2836	353	41,9	3,64	2313
9	918	2392	428	2820	353	41,8	3,62	2297
10	913	2348	426	2774	353	41,9	3,59	2255
11	905	2373	427	2800	353	41,5	3,65	2290
12	907	2398	429	2827	353	41,6	3,67	2314
13	910	2402	430	2832	353	41,6	3,67	2316
14	908	2395	429	2824	353	41,6	3,67	2310
15	905	2451	432	2883	353	41,5	3,75	2372
16	906	2455	431	2886	353	41,3	3,74	2374
					Average files 1 - 5		3,18	
					Average files 6-16		3,66	

Table E2

File No.	I_1 (A)	P_{el} (W)	COP_{rev}	COP/COP_{rev}
1	46,67	2503	0,97	3,22
2	46,18	2451	0,99	3,21
3	45,87	2418	1,00	3,20
4	45,82	2413	1,00	3,20
5	45,64	2394	0,99	3,20
6	49,46	2812	1,12	3,19
7	49,32	2795	1,14	3,18
8	49,15	2776	1,15	3,17
9	49,07	2767	1,15	3,16
10	49,17	2779	1,13	3,19
11	48,93	2751	1,15	3,19
12	48,98	2757	1,15	3,18
13	48,99	2758	1,15	3,18
14	48,95	2753	1,15	3,18
15	48,90	2747	1,18	3,18
16	48,77	2734	1,18	3,16
Average files 1 - 5			0,99	3,20
Average files 6 - 16			1,15	3,18

Table E3

Temperature		micro ohm-cm
°C	°F	
21	70	128.9
38	100	129.6
93	200	131.9
204	400	133.9
316	600	134.9
427	800	135.9
538	1000	137.9
649	1200	137.9
760	1400	136.9
871	1600	135.9
982	1800	134.9

Electrical Resistivity of Inconel 625

http://www.azom.com/article.aspx?ArticleID=4461

(Actually used Inconel type is not known.)

WIRING DIAGRAM

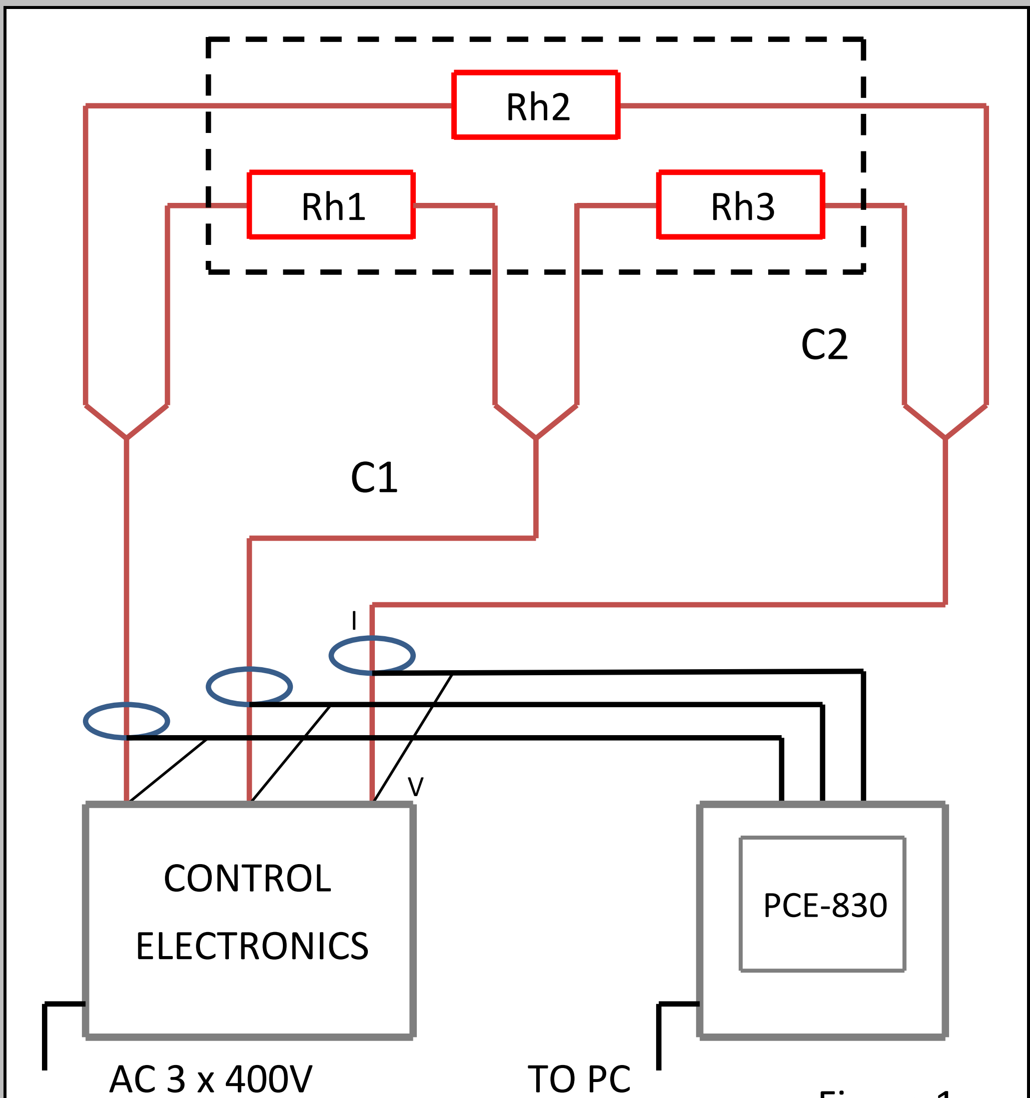


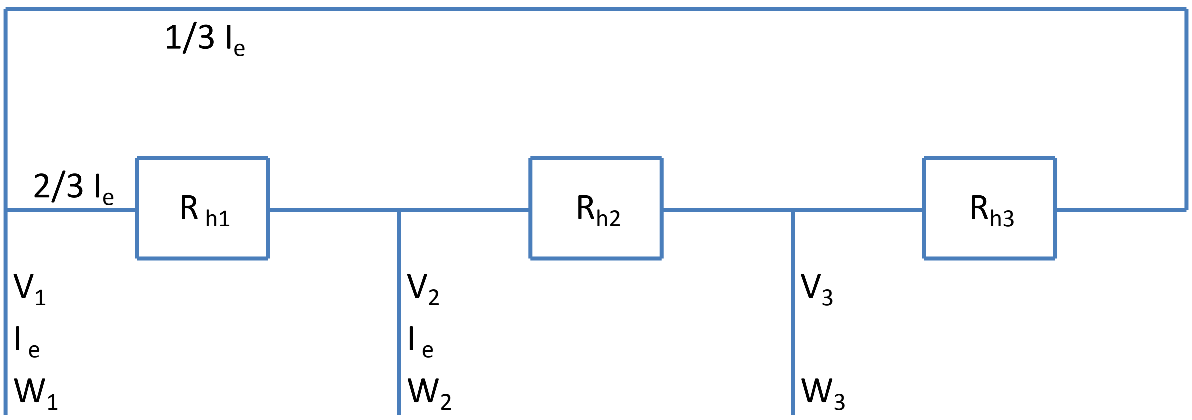
Figure 1

How it really works ...

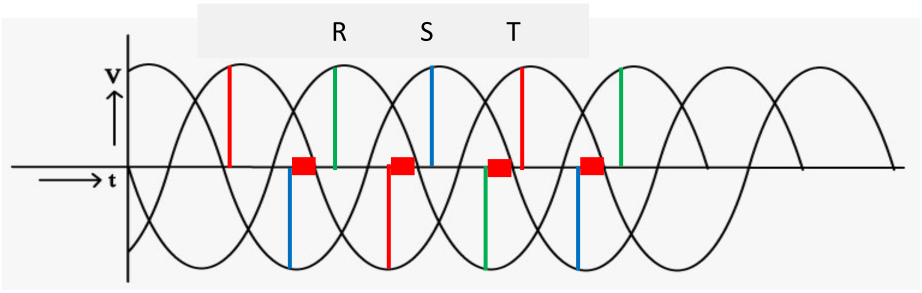
REACTOR HEATING

Due to its high temperature the reactor cannot contain any inductive or capacitive components.

Figure 2



Figue 3, Phase activity



Coloured vertical line: Ignition, next zero V crossing: Turns off
Red rectangles: Two phases on

The three resistors all have the same value, R_h.
Only two phases are active at the same time, see Figure 2.

In Figure 2 V_1 and V_2 are active, V_3 floating.
Equivalent resistance:
$R_{he} = 1/(1/R_h+1/(2*R_h)) = 2/3*R_h$ (See Revision 1)

The measured RMS current I_1, is the same in all three phases.

Look at one period of the AC power.

Rev. 1

The current is a function of time $i = i(t)$
Suppose V_1 and V_2 are active. We call this the first pulse.
The power delivered to R_e during the first pulse is
R_{h1}*Integral[$i(t)^2$dt].

The current is measured on wire W_2 and PCE-803 calculates the integral for the first pulse.

Next, V_2 and V_3 are active, this is the second pulse.
The same integral will be added once more to the integral that the instrument is calculating for wire W_2.
No more current will be flowing in W_2 during the AC period.
PCE-830 divides the time integral of i^2 by the period time, 1/(50 Hz) and takes the square root of the result to arrive at the effective current I_e.

But since current is only flowing through R_{h1} during the first pulse we will have to divide I_e by $2^{1/2}$ to get the effective current that is heating R_{h1}.
$I_e = I_1/2^{1/2}$

The measured thermal output from the three resistors in the reactor is P_{out}.

$P_{out} = 3*R_{he}*(I_1/2^{1/2})^2 = 3/2*R_{he}*I_1^2$
$R_{he} = 2/3*P_{out}/I_1^2$

Using data from the dummy test we get:
R_{he} = 0,7661 Ohm

Revision 1 2014-10-27

A detailed description of the calculation of I_e is added.
This shows that I_1 has to be divided by the square root of two to arrive at I_e, not 2 as was stated in previous release.

However, this error was cancelled in the formula for the power transferred to the E-Cat, so the final result that the COP during the long term test was close to 1 still stands.

The reason for the cancellation is that R_{he} is divided by 2 and I_e^2 is multiplied by 2 in the formula for P_{out} as compared to the erroneous expression.