

Final technical report on the Defkalion GT calorimetric protocol

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1 Abstract

I show that the experimental protocol used by Defkalion Green Technologies (DGT) is not reliable to demonstrate the production of large amounts of energy with the use of the reactor R5. Experimental tests carried out using the same measurement system used by DGT in public demonstrations show that the measurement of excess of thermal energy carried out following the experimental protocol of DGT is obtainable regardless of the use of H2 and of the high voltage excitation.

2 Introduction

In the fall of 2011, the company Defkalion Green Technologies (DGT), a Greek company based in Athens, officially declared to possess a new technology at the pre-industrial level based on the phenomenology called LENR able to produce thermal energy in the range of kilowatts. In November 2012 an Italian company based in Milan and named Mose srl signed an exclusive contract for the European industrial development of this technology. This contract provides for the complete transfer of the DGT technology to Defkalion Europe (DE), an Italian company (50% DGT and 50% Mose and composed exclusively of Italian members of Mose) with the intention to develop industrial applications using the DGT technology. In December 2012 DGT moved its headquarters to Vancouver in Canada and transferred its laboratories in the campus of the University of British Columbia (UBC).

As part of the mutual agreements, in January 2013 I went for two weeks in the DGT laboratories in Vancouver for acquiring the necessary know-how. I returned to Milan quite disappointed since I was not put in a position by the DGT engineers and scientists (namely John Hadjichristos (JH, CTO DGT) and Stavros Amaxas (SA, Chief Engineer)) to delve into the details of scientific and technological achievements of the technology.

With my return in Italy, as requested by DGT, DE started the setup of the laboratory in Milan as a faithful replica of the laboratory in Vancouver. In a short time DE prepared the laboratory fully in line with the expectations of DGT.

Only on June 17, 2013 SA came to Milan to start the first test of the DGT technology in the new laboratory in Milan. Very soon the demos for the European companies started, in line with the agreements reached between DE and DGT.

In the first week of July 2013 DGT asked DE to organize a live stream of a demo to broadcast to the ICCF18 conference scheduled in the United States from 21 to 27 July 2013 at the Missouri University, Columbia (MO). On July 23, 2013 the live streaming was broadcasted as scheduled from the DE laboratories in Milan.

This challenging request by DGT has led DE to accelerate the clarification of some important technical aspects of the calorimetry which until then had been denied by DGT. To this end, overriding a gentlemen's agreement, DE decided to undertake autonomous tests to identify any malfunctions of the calorimetry protocol. All these tests have been appropriately video-recorded and the results of these tests are described and detailed in the following paragraphs.

3 Anomalous behavior

I list below some anomalies related to the relationship between DGT and Mose :

- During the setup of the laboratory in Milan various improvements were introduced by the DE technicians and scientists concerning the calorimetry measurement. In particular a method independent of the flow rate measurement has been developed based on the heating of a large amount of water contained in a large tank and circulated through a pump in a closed circuit. This measure is independent of the measurement of the flow through the coil and it would remove any doubt about the heat measurement. DGT did not allow DE to

use such measurement in any of the tests of their technology. As a further improvement we added a second flowmeter upstream of the water system in order to verify the behavior of the main flowmeter during the measurement of the excess power but also in this case the added flowmeter was readily removed by the DGT technicians forbidding us to make any verification.

- In no case has DGT enabled DE engineers to attend the assembly phase of the active components in the reaction chamber of the reactor R5 (built by us according to the DGT diagrams) nor left the reactor R5 complete with all the necessary elements for running the experiment in the DE laboratories without their physical presence.

The total lack of cooperation from the part of DGT regarding both the technical information and crosschecks have made it necessary to carry out independent verification tests of the calorimetric measurements of excess power, especially to protect clients who were about to sign trade agreements and pay fees for the access to the DGT technology.

4 Experimental DGT protocol

In September 2012 DGT decided to release publicly its experimental results and to prepare to enter the industrial market. For this purpose DGT has defined an experimental protocolⁱ to demonstrate to potential clients and to the scientific community that the DGT technology is able to produce an excess of thermal power compared to the electrical input powerⁱⁱ.

It is therefore necessary to have a system for the calorimetric measurement of the thermal power produced and a system of measurement of the electrical power entering the system. The electrical input power is performed using a commercial power meter Carlo Gavazzi model EM21 and has been thoroughly verified by DE to be perfectly working and well performing. We will focus our attention on the calorimetric measurement in the next paragraphs.

5 Description of the DGT calorimetric system

The DGT experimental setup is based on a flow calorimetry, of which I give a brief description.

The hydraulic system, shown schematically in Figure 1, is an open circuit connected to the city water supply from which it picks up a quantity of water controlled by a precision Pneumax valve model 01/08/81/5. Downstream of the Pneumax valve is mounted a 20 µm sieve filter and a second filter in which the filter element has been removed. This component is used, according to DGT, to show that there are no air bubbles in the hydraulic system during the demo. Between the two filters an air vent valve is mounted, held closed during the tests. Downstream of the second filter an oval gear flowmeter is mounted, model Alpha Dynamic AM1 with digital output. Downstream of the flow meter is present a second valve FBP ¼ ". Downstream of the second valve is mounted a fitting fitted with a thermocouple for measuring the inlet temperature of the water in the reactor. The fitting is connected, via a flexible tube, to a coil welded to the surface of the central body of the reactor R5ⁱⁱⁱ. The coil consists of a copper tube, 1/4 " (inner diameter 7 mm) wound on two layers of nine coils each and able to remove very efficiently the heat coming from the reactor. The coil is connected through a flexible tube to a second connector equipped with a second thermocouple for measuring the outlet temperature of the water/steam. Both the hoses that connect the thermocouples to the coil are approximately one meter long. Downstream of the second thermocouple is mounted a ½" copper tube

having the shape of an inverted U about 5 m long as in Figure 1 and whose vertical parts are 1.5 m long. Finally, the terminal part of the copper pipe discharges the liquid water/steam in a water drain.

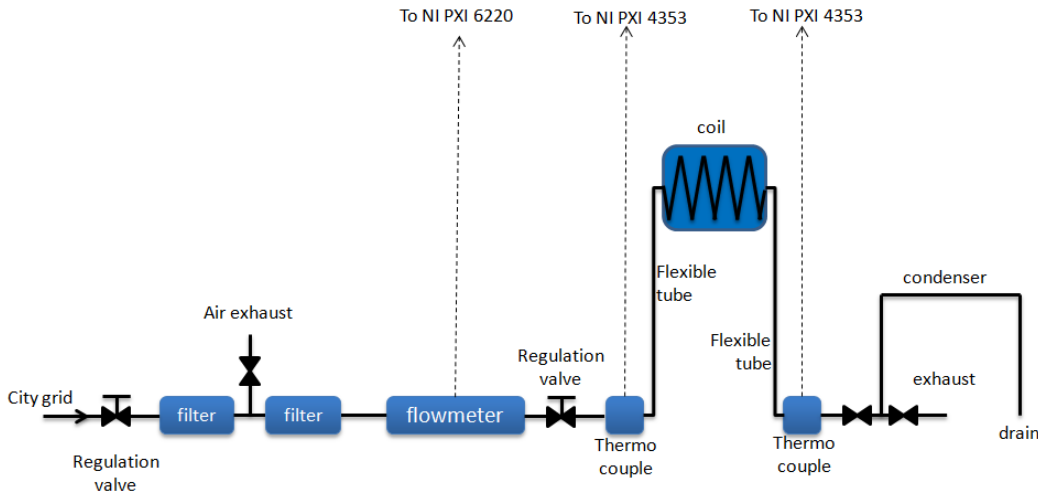


Figure 1 diagram of the hydraulic circuit in the DGT protocol

The counts of the flowmeter are acquired by a digital signal acquisition board National Instruments (NI) model PXI-6220 connected to a NI data logger model PXIe1073 and the signals of the thermocouples are acquired by a NI data acquisition card model TB4353 also connected to the NI data logger PXIe1073.

The acquisition is controlled by a Labview program, fully developed and tested by DE technicians in its entirety and independently of DGT. In particular, it was verified that the system provides a very good calorimetric measurement of the thermal power generated by the heaters, in the absence of the reaction, with a loss of less than 5 % of the electrical power supplied to the heaters in a configuration with no boiling of the water.

6 Calorimetric model

The measurement of the power produced in the experimental DGT protocol is based on a flow calorimetry. In flow calorimetry without liquid/vapor phase change thermal power is given by

$$P_{heat} = C_{p,H_2O_{liq}} (T_{out} - T_{in}) \phi \quad (6.1)$$

where $C_{p,H_2O_{liq}} = 4.18$ joule/cc is the heat capacity of liquid water, T_{in} and T_{out} are respectively the inlet and outlet temperatures of the water and ϕ is the flow of liquid water through the coil.

Since the cooling water reaches the boiling point during the experimental test the heat extracted from the reactor cannot be simply calculated from (6.1) but the latent heat associated with the liquid/vapor phase transition must be considered. Assuming that all the water entering the coil undergoes a phase transition we can say that the thermal power is given by

$$P_{heat} = \left[C_{p,H_2O_{liq}} (T_{out} - T_{in}) + L_{liq/vap} \right] \phi \quad (6.2)$$

where $L_{liq/vap} = 2260$ joule/gr. Since the temperature difference $T_{out} - T_{in} \approx 80$ °C we have $C_{p,H_2O_{liq}} (T_{out} - T_{in}) \ll L_{liq/vap}$ meaning that the contribution to evaporation is dominant compared to that of water heating. In the DGT Protocol the contribution of the vapor is not taken into account, leading to a significant underestimation of the power measured. Even assuming conservatively that 50 % of the water that passes through the coil does not reach the state of steam, part of the liquid being ejected from the coil before it can reach the state of vapor, the thermal power can be (under-)estimated approximately with the formula

$$P_{heat} = \left[C_{p,H_2O_{liq}} (T_{out} - T_{in}) + 0.5 \cdot L_{liq/vap} \right] \phi = k \phi \left(\text{lt} \cdot \text{min}^{-1} \right) \quad (6.3)$$

$$k = 24.4 \text{ kW} \cdot \text{lt}^{-1} \cdot \text{min}$$

where $\phi \left(\text{lt} \cdot \text{min}^{-1} \right)$ is the water flow rate, expressed in liters per minute. Then, using the typical value of flow measurement obtained by DGT during the demos of $\phi \left(\text{lt} \cdot \text{min}^{-1} \right) \approx 0.5 \div 0.7$ $\text{lt} \cdot \text{min}^{-1}$ we (under-)estimate a power of $P_{heat} \approx 12 \div 17$ kW.

7 Chaotic production of steam inside the coil

The inability to perform independent tests despite our strong request has led DE to suspect that there might be an incorrect use of the flowmeter. The experimental anomalies that resulted from the observation of the demos performed by the DGT technicians in fact revealed a strange behavior of the inlet temperature of the reactor, as can be seen in Figure 2 (data from the demo of June 27, 2013 for one of the potential clients). This observation led us to suspect that some of the water entering the coil around the reactor in some way was returning towards the inlet thermocouple thus increasing its temperature slightly.

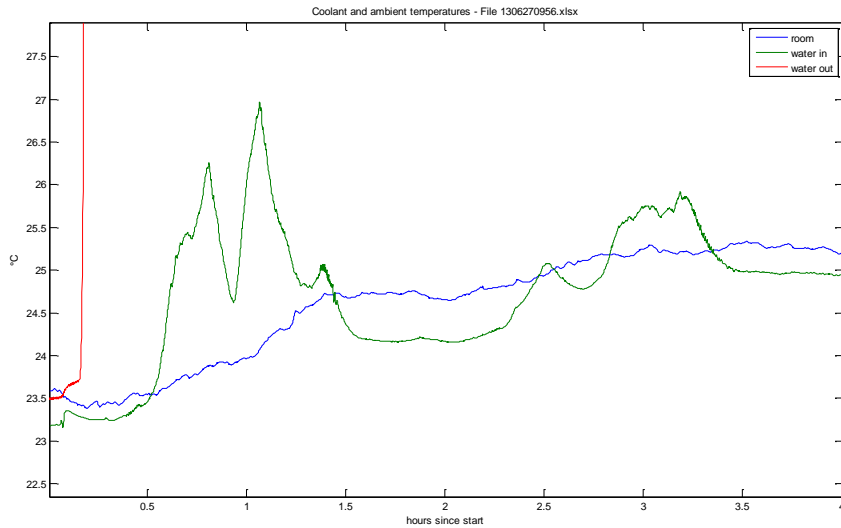


Figure 2 Abnormal increase in the inlet temperature (in°C) in the coil during the demo of June 27, 2013 (blue: room, green: water in, red: water out)

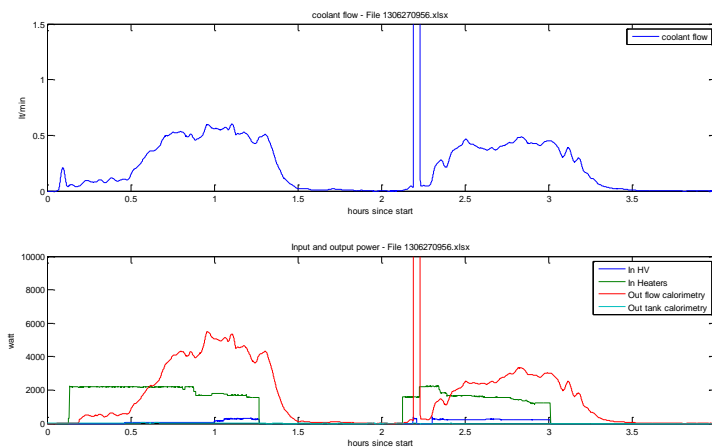


Figure 3 Flow rate (l/min, blue line), power input (watt, green line) and output (watt, red line) measured during a demonstration on 27 June 2013. Note the excess thermal power measured compared to the electrical power that would indicate that the demo has been successful. The test has been repeated two times over a period of about 4 hours (Tank calorimetry, indicated in the figure, has been actually disabled following a request from DGT, as explained in the text paragraph 3).

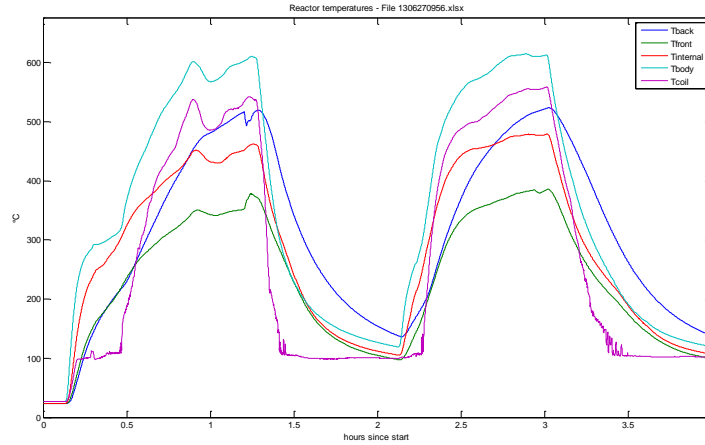


Figure 4 Evolution of temperatures during the demo of June 27, 2013

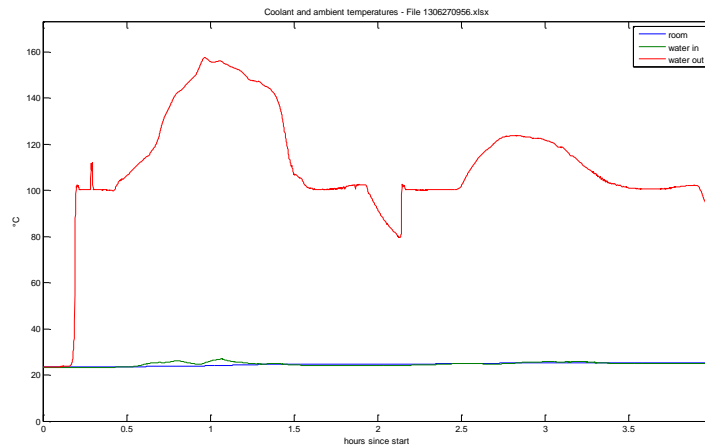


Figure 5 Overview of the temperature input, output and environment during the demo of June 27, 2013

Furthermore, the amount of steam produced at the exit of the hydraulic system used to remove the heat produced by the reactor was markedly lower than the amount of steam one may expect by a thermal power of 7 kW, as stated by DGT. We now estimate the output speed of the steam from the exhaust pipe assuming a production of thermal power of $\frac{dQ}{dt} = 7 \text{ kW}$. The number n of moles of steam produced per unit of time from such a power is given by

$$L \frac{dn}{dt} = \frac{dQ}{dt}, \quad (7.1)$$

where L is the molar latent heat of evaporation. Using the ideal gas law

$$n = \frac{pV}{RT} \quad (7.2)$$

we derive the volume of steam produced at atmospheric pressure $p_{atm} = 10^5 \text{ Pa}$ at a temperature of $T = 100^\circ \text{ C}$ as

$$\frac{dV}{dt} = \frac{dn}{dt} \frac{RT}{p_{atm}} \quad (7.3)$$

The output speed of the steam is given by $v = \frac{1}{\pi r^2} \frac{dV}{dt}$, where $r = 14$ mm is the inner radius of the outlet pipe. The speed can be rewritten as :

$$v = \frac{1}{\pi r^2} \frac{dV}{dt} = \frac{dn}{dt} \frac{1}{\pi r^2} \frac{RT}{p_{atm}} = \frac{dQ}{dt} \frac{1}{\pi r^2 L} \frac{RT}{p_{atm}} \quad (7.4)$$

Introducing the numerical values : $L = 40.58$ kJ/mol, $p = 10^5$ Pa, $r = 7$ mm, $R = 8.31$ J mol⁻¹ K⁻¹, $T = 373$ °K, we obtain the (underestimated) speed

$$v = \frac{7 \cdot 10^3 \cdot 8.31 \cdot 373}{\pi \cdot (7 \cdot 10^{-3})^2 \cdot 40.58 \cdot 10^3 \cdot 10^5} \text{ m/sec} = 34 \text{ m/sec} = 130 \text{ km/h} , \quad (7.5)$$

that, even considering the possible re-condensation of the steam, is very high compared to what you can also visually observe in the videos taken during the tests performed by the DGT technicians (see stream of 23 July 2013 ICCF18^{iv}). The situation gets even worse if we consider an estimate of the thermal output of 15-17 kW, as calculated in paragraph 6.

These observations have prompted DE to perform independent testing to verify the correct operation of the flowmeter during the test. To this end DE decided to check the operation of the flowmeter by performing a test using Ar in place of hydrogen and avoiding the use of the high voltage activation circuit. If the measure of the flow meter is correct, it should provide a measure of the thermal power lower than the electrical power sent to the heaters, in agreement with the principle of energy conservation.

The test was performed by replicating as closely as possible the thermal variations observed during the tests carried out by the DGT technicians (see for example Figure 4). The goal of the test was to verify the behavior of the flowmeter during the strong boiling of the water inside the coil that surrounds the reactor. We verified that, by suitably selecting the adjustment of the valves upstream and downstream of the flowmeter, the production of steam at low flow regime produces turbulence and induces a regurgitation of the inlet water able to temporarily reverse the direction of flow within the flowmeter itself.

Below is a description of the sequential processes that lead to an erroneous measurement of the flow of water passing through the cooling coil of the reactor:

- 1 - At very reduced flow the water remains in the coil for a time sufficient to reach the boiling inside the coil
- 2 - The volume increase resulting by the production of steam produces a pressure increase which tends to push the fluid upstream
- 3 - The compression of the water contained in the filters is of the order of 1 cc when the pressure exceeds 5 bar. In fact, the liquid water compressibility is $K = 2.2$ GPa. A change in pressure of one atmosphere thus involves a relative change of volume of liquid water of

$$\frac{\Delta V}{V} = -\frac{\Delta p}{K} = -\frac{10^5}{2.2 \cdot 10^9} = -4.5 \cdot 10^{-5} = -45 \text{ ppm} \quad (7.6)$$

If we assume an overpressure of 5 bar¹ on a volume of 4 liters (the volume contained in the filters upstream of the flow meter and the valve between the upstream and downstream), we obtain a change in volume of $\Delta V = -45 \cdot 10^{-6} \cdot 4000 \cdot 5 \approx -1 \text{ cc}$.

4 - The overpressure can build up for short periods of time because the outlet tube of the coil is connected to a vertical condensation column of about 1.5 m long (see setup, Figure 1) that contains liquid water as well as steam and then produces a barrier to vent the steam. The time required for the vaporization of the water is much shorter than the time needed to push the liquid water out of the condensation column. A barrier is generated by the inertia of the water inside the vertical condensation column allowing for impulsive buildup of the pressure.

5 – During the short period of time associated with the compression of the water inside the filters the gears of the flowmeter rotate in the direction opposite to the normal motion (negative rotation).

6 - Since the gears of the flowmeter make a full turn for each cc of fluid that passes through it (see datasheet), the flow meter sends pulse counts even when the gears rotate in the opposite direction (the valve downstream of the flowmeter is completely open, the valve upstream of the filters almost completely closed in this mode of operation)

7 - When the overpressure is sufficient to expel the liquid water from the condensation column downstream of the reactor the pressure is lowered again and the compression of the water inside of the filters cancels, again by rotating the gears of the flowmeter in a positive direction and generating another count of flow. Since the flowmeter is not able to distinguish the negative from the positive rotations, it will consider all counts as a positive flow. Such oscillation of the counting pulses of the flowmeter has been verified by a direct observation on the oscilloscope (see Figure 6 and Figure 7).

8 – Some of the liquid water contained in the condensation column returns into the coil in the liquid state or, alternatively, a small amount of fresh water enters the coil from the inlet hose.

9 - The water heated by the coil boils up, starting the process again. The ability of the DGT technicians in handling the valves has allowed them to make this process stable for the time required (a few hours) to demonstrate the appearance of thermal energy in excess of the electrical energy input².

10 - In this way, the flowmeter will produce a series of counts arising from the alternating clockwise and counterclockwise motion of the gears that do not correspond to a real flow of liquid water. One can get an erroneous measurement of flow as large as 1 lt/min (close to the flow rate measurement obtained by SA during demonstrations of the reaction) while having the upstream valve completely closed (thus corresponding to a null real flow) and this has been actually observed by us.

11 - When the alleged reaction has to be switched off, since it would not be sufficient to remove the power supply to the heaters to shut down the reaction because the heat stored in the metal of the reactor would continue to evaporate the water for at least another 10 minutes, the two valves (one upstream and one

¹ We were not able to make a direct measurement of the pressure fluctuations in the hydraulic circuit because we were not allowed by DGT to make any change in the hydraulic system

² In the tests carried out by DE, also the DE scientists, once they understood the oscillation mechanism, were able to obtain a measure of (overestimated) heat produced for a period of time of about one hour a few times greater than the electrical energy input, irrespective of the presence of the powder inside the reactor and of the type of gas used (H₂ or Ar).

downstream) are operated simultaneously so that the upstream valve is set entirely open and the downstream valve almost completely closed. By doing so the correct operation of the flowmeter is set back (because now the flowmeter is not subjected to any back stream) and the calorimetric measurements are again correct and show a thermal power lower than the electrical power input.

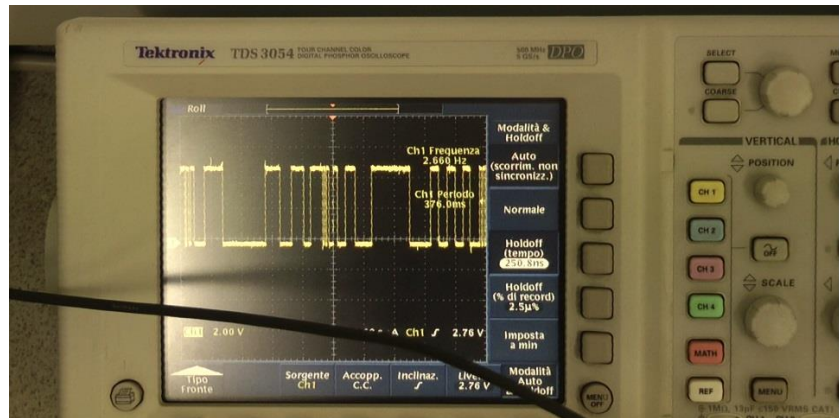


Figure 6 Trace of the digital output signal of the flowmeter during the regurgitation of the inlet water. Note the very irregular pulse in time



Figure 7 Trace of the digital output signal of the flowmeter during the phase previous to boiling of water in the coil. Note the regular pattern of the pulses in time

8 Experimental results

Figure 8 shows the plot of the thermal power measured using the standard DGT protocol in the verification test conducted by DE using Ar in place of H₂ and using the procedure that induces the pressure variations due to water boiling, as described in Paragraph 7. It is clearly noted that, while using Ar (considered by DGT an inert element for prompting the reaction and used as a reference gas to show that the reaction does not occur using Ar) in place of H₂ and without making use of the high voltage excitation circuit, we get a significant increase in the measured thermal power up to about 17 kW, well above that of the electrical power input of about 2.5 kW. This proves beyond any doubt that the test, as conceived by DGT, does not measure correctly the thermal power produced which in this case would have to be less than or at most equal to the electrical power input.



Figure 8 Screenshot of the test performed by DE using Ar and without using the HV excitation

Also the power of recondensation of the outlet steam from the exhaust pipe has been measured during the test. The steam output was bubbled into a container containing 5.1 liters of water and a temperature variation of the water contained in the container has been observed from 22° C to 31.6° C in a time of 180 seconds. The calculation of the thermal power required to achieve this change corresponds to 1 kW + - 10%. During this measurement the flow calorimeter indicated a power of 3 kW and an electrical input power of 1.5 kW. Taking into consideration the heat losses between the reactor and the exhaust pipes and the environment the measurement of 1 kW of thermal output at the exhaust pipe is compatible with the electrical power input of 1.5 kW but incompatible with the flow calorimetric measurement of 3 kW.

9 Discussion

After several tests performed by DE to validate the DGT calorimetry we must conclude that in the most benevolent case we are faced with a gross measurement error that has lasted nearly two years and has misled esteemed researchers who have personally witnessed demos of the DGT technology in Greece, in Canada and more recently in Italy.

DE has not been put in a position to carry out independent tests on the technology outside of a strict protocol defined by DGT and all the tests that DE has witnessed, even in its laboratories, have always been performed entirely by technicians from DGT (HJ and AS). During the periods when the DGT staff was not present at the DE site some component considered essential for obtaining the reaction was removed in order to prevent DE from making independent tests. Since this procedure is not consistent with established contractual agreements, DE had the need to perform independent testing taking the opportunity to have the complete and certainly working system in their laboratories during the days (and nights) just after the streaming of 23 July 2013, whose results are contained in this document.

Following the results obtained DE has formally requested technical clarifications to DGT to demonstrate that the results obtained by DE could be explained without questioning the existence of the declared phenomenology.

On the commercial side DE immediately stopped/froze all negotiations with both Italian and foreign companies to protect their clients.

10 Conclusions

Despite the importance of the findings, DE has decided to give DGT some time to provide unequivocal evidence that the DGT technology was immune to the criticisms raised by DE. However after several months and despite continuous and constant request to provide the relevant documentation and/or to repeat the experiment, no answer has been given so far. DE has now been put out of business. Consequently, I decided to make public the results obtained on the DGT technology stating that the experimental protocol proposed by DGT is not trustworthy.

Following the above results it can be concluded that the measurement setup in the DE laboratories in Milan, in the mode used by DGT technicians to perform DGT official demos to potential clients and during the streaming of the 07/23/2013 at ICCF18, does not correctly measure the heat output from the reactor R5 and the overestimation of the power produced is compatible with the non-functioning of the DGT technology itself.

The results described in this report, concerning only the methods used by DGT to measure the thermal power output, have nothing to do with LENR research and technology that remains a powerful and important research field that I believe is worthy of serious study and research and to which I am committed.

11 References

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- ⁱ http://iccf18.research.missouri.edu/files/day2/Protocol_and_test_results.pdf
 - ⁱⁱ http://coldfusionnow.org/wp-content/uploads/2013/04/2012-08-13-ICCF-17_Paper_DGTGx.pdf
 - ⁱⁱⁱ <http://www.scribd.com/doc/172213719/Heat-Energy-from-Hydrogen-Metal-Nuclear-Interactions>
 - ^{iv} <http://vimeo.com/album/2471728>