Three Part Series Outlining ECAT Operation by Analysis of Graphical Data

A significant quantity of test data was gathered during the October 6, 2011 demonstration of the Rossi ECAT device. The long lived release of energy in self sustaining mode after the initial ignition of the unit suggested that Rossi had demonstrated the future of world energy production. Many of the followers of this exciting technology wanted to delve deeper into the mysteries surrounding operation of Rossi's device and thus I began an extensive analysis. Mats Lewan of Ny teknik supplied an excellent collection of the important data within an Excel chart http://www.nyteknik.se/incoming/article3284968.ece/BINARY/Temp+data+Ecat_6_10_11+%28xls%29 that he published to their web site.

I found that a graph of the ECAT internal temperature T2 as a function of time in seconds starting at the beginning of water input flow initiation contained a wealth of information. I began my analysis just prior to the self sustaining mode for the part 1 section of this document for several reasons. First, I noticed that the temperature measured at T2 was fairly constant throughout the period which I had hoped indicated a form of steady state operation of the ECAT. Second, it was apparent that Rossi was going to lengths to carefully apply initiation energy to the reactor core by adjusting the duty cycle of the input power waveform. I suspected that he must use a similar drive function for his individual ECAT core module performance testing and I hoped to take advantage of his knowledge. Third, it was apparent that the output power of the ECAT would be near its maximum value and the signal to noise would be optimum around this time frame.

When the first part of my document was completed I determined that there was additional information showing up in the graph of T2 versus Time which I decided to analyze further. The part 2 section of the document contains information gleaned from the time domain changes in T2 as the ECAT began approaching operational status and eventually coasting toward final cool down. The ECAT must return to room temperature once the internally generated LENR energy production stops due to hydrogen venting or core cooling. It is apparent that the energy producing mechanism ceases to emit nuclear energy as the core temperature drops. I assume that the time domain performance of this process behaves in a manner similar to many natural systems exhibiting an exponential decay. The curve T2 versus Time adds support to this assumption.

Once I had completed part 2 of my analysis I decided to explain one of the strangest phenomenon displayed by the graph of T2 versus Time. This anomaly is revealed by the behavior of the temperature curve. As expected, the T2 reading has a gradual negative slope throughout most of the self sustaining mode until it begins to rise slowly toward a fairly constant plateau. This unusual behavior makes it appear that the ECAT is actually generating more output energy and thus power as time progresses which is counter to our expectations. It now appears that there is an excellent reason for this behavior and additional light is shed upon the ECAT performance during the October 6 testing. I concluded that this response must be due to the fact that a mix of vapor and water was exiting the ECAT output control valve. Extra pressure is required to force the combination through the check valve as the mix includes

additional water. Mr. Rossi claims that there is no control valve present within the output path, but some mechanism appears to perform this function. My part 3 section was the result of this new conclusion.

As I was examining the phenomenon I was inclined to make some interesting assumptions as to the quality of the vapor entering the heat exchanger. The two measurements that Mats Lewan obtained of output water flow contributed to the scarce data with which I had to operate. Fortunately, output water temperature readings were collected at the same time as the flow rate which allowed me to correlate the power indicated by cooling loop calculations with his data.

I now can determine that the thermocouple readings of the output cooling loop of the heat exchanger are very much in error during most of the October testing. All of the evidence strongly points in this direction and cannot be refuted. It would be wise for everyone to accept this conclusion and proceed to use other properly justified data to analyze the system and I am confident that the ECAT device will demonstrate excess energy production despite this clarification. The large system test conducted on October 28 adds additional support to this supposition. Also, it should be understood that the 107 ECATs contributing toward the 1 MW output each contain 3 core modules compared to the 1 core module used during the October 6 test. It is obvious that the October 6, 2011 test would have been far more impressive had the 3 cores been present and active.

I conclude my analysis of the ECAT test of October 6, 2011 with the publication of this three part series. There remains additional information disguised within the extensive T2 data that could still be revealed and it is hoped that some other researchers will complete this task.

This final compiled document contains corrections to mathematical calculations and wording modifications to improve readability. Also I have applied a hint of hindsight to the earlier parts as information improved.

Part 1

ECAT Measurements Confirm Excess Heat Production

I have been reviewing the data obtained during the September and October testing and can now confirm that there is adequate proof that the ECAT generates a large amount of excess energy. I would assume that the skeptics will read this report and realize that the proof has been before us for a long time, but is not easy to discern.

To follow my discussion you should start with an X-Y graph of the ECAT output thermocouple readings versus time. This thermocouple temperature data is referred to as T2 and was obtained during the October 6, 2011 Rossi demonstration. I am attaching a copy of the graph I used for my derivations to the end of this document for your reference.

My analysis is as follows:

Mr. Rossi conducted a carefully controlled ECAT power up procedure. The pattern of setting the input power to “5”, then “6”, all the way to “9” is intended to slowly allow the internal components to reach an ideal operational temperature. The reactor approaches equilibrium at approximately 13000 seconds into the test. Once this has been achieved, a series of on and off power pulses (“9”) is applied to the core. This series of pulses occur at a frequency that is high enough to be well filtered by the low pass nature of the internal ECAT heat flow mechanism. This filtering is evident by the smooth curve of T2 versus time that shows up beginning at 13000 seconds proceeding through about 15500 seconds. It is important to note that the T2 curve is slowly falling throughout this time duration. The average T2 reading is approximately 120.5 C and has a slight negative slope. I concluded that the final ECAT output power would also slowly decay in conjunction with this curve since that temperature drives the output check valve, etc.

What can we make of this curve of T2 versus time? It turns out that a lot of information is revealed. I did an analysis of the input power pulse waveform starting at 11400 seconds until 14881 seconds to get the average filtered component of the drive signal and obtained a net of 1252 watts. Then I realized that this power must cause the ECAT core module to reach its operational temperature. The core responds to the desired temperature and the LENR effect within starts to generate extra energy. The energy associated with the input power (1252 joules/second * time) adds to the LENR released energy of the core. These two energy sources supply extra energy to the water contained within the ECAT.

The ECAT water will either increases or decrease in temperature, depending upon the quantity of heat that is lost from the system. We know of at least three heat escape paths. The output leading to the heat exchanger is the desired path. Leakage water or vapor escaping from the case due to a damaged gasket takes away some energy of the system. Also heat leaving the case due to radiation or other means will reduce the net energy. We must prove that the sum of these loss factors is greater than 1252 watts in order to prove that LENR is active within the Rossi device.

There is one subtle point to explain. There is a very slight negative slope in T2 versus time throughout this region. I performed a quick calculation and found that the power lost within the water tank as a result of this slope is ((122-120.7) C x 4.188 joules/(C-grams) x 30000 grams)/1860 seconds = 88 joules/seconds or 88 watts (Data points:(13021,122 C)-(14881,120.7 C)). This calculation suggests that a very small increase in the drive power (+ delta) will allow the temperature of the water bath and thus the output power to remain constant. This is a very important discovery. The ECAT will continue to put out the same power for as long as this quantity of input power (1252 watts + delta) is applied. This may not be the ideal self-sustain mode that we all love, but it is significant.

Of course I was not content to leave out the additional knowledge revealed by this region of the T2 temperature reading versus time. There is more interesting evidence to glean. Notice the positive slope in T2 reading that begins at 16000 seconds. This slope is quite linear from 16000 seconds until the level “9” input power pulse ends at the beginning of the self-sustaining mode. An application of the identical formula as during the negative slope above shows the following: (4.5 C x 4.188 joules/C-grams x 30000 grams)/1760 seconds = 321.24 watts (Data points :(16001,119.3 C)-(17761, 123.8 C)). This calculation

suggests that Rossi can increase the output power by driving the core with an application of full input power “9” for a brief time.

We are fortunate to have additional information revealed by the T2 versus Time graph. The region following the peak in output power can enable us to determine the manner in which the unit responds to a no drive condition as when it is used for self-sustaining operation. Notice the slope after the peak at approximately 18000 seconds. The slope has a value that is clearly greater than the slowly falling region mentioned in my first calculation above. Application of an identical technique as in the previous samples yields (-5.1 C x 4.188 joules/(C-g) x 30000 grams)/1000 seconds = -640.76 watts (Data points :(19501,117.9 C)-(18501, 123 C)). This calculation suggests that the water is cooling relatively quickly and I suspect that this rate is indicative of the cooling rate that would be dominate if there were no LENR reaction present or if the heating element is attached to the heat sink and somewhat insulated from the core. Compare this slope to that which begins at around 30000 seconds after the hydrogen is eliminated and the water rate increased.

Further evidence of the LENR activity is revealed by the smoothly falling T2 within the region of 22000 seconds. About the only sensible explanation for this extended period of power output observed toward the end of the experiment is that the heat must be LENR related. It can be determined that the power generated by the LENR action within the ECAT is less than that resulting from the steady application of power observed in the first case I analyzed. I assume that this reduced power output is associated with the decision of Mr. Rossi to populate only one active core within the ECAT for this test. Three times the LENR generated power is expected when all three are installed.

Now, we can estimate the total output power of 3847 watts by the following technique. First, the power required to supply the output to the heat exchanger during the powered period is (4.2 C x 4.188 joules/C-gram x 178 grams/seconds = 3131 watts) (note 1). Second, it is estimated that 500 watts of power is needed to keep the ECAT case at its elevated temperature. And finally, the gasket has a leakage of 2 liters/hour which carries heat away from the device. This drains away (.55555 grams/second x 4.188 joules/gram-C x 92.8 C) 216 watts. Addition of all of the three components of the output power yields (3131 + 216 + 500 = 3847 watts).

The total output power of the ECAT is the sum of the input power and the LENR generated power. To determine the LENR contribution we subtract away the input power obtaining (3847 – 1252 = 2595 watts). Each core module should produce approximately the same output power so we multiply by 3 to obtain 7785 watts. Of course the input power must be added to this figure in order to arrive at the final total output power of (7785 + 1252 = 9037 watts). Using this figure and a little hindsight I can see that we will need 1000000 watts / 9037 watts/ECAT or 111 ECATs for the complete system. The actual number of ECATs connected together for the October 28, 2011 test was 107 which is reasonably close to this estimate.

An estimate of the COP for a complete ECAT device which has 3 active cores installed can be determined by dividing the anticipated output power by the input drive obtaining (9037 watts / 1252 watts = 7.2).

This number needs adjustment to include the wasted input power for controls, etc. These additional losses should not cause the final COP value to be below 6.

The proof of LENR for the October 6 test that we are seeking is revealed by noting that the output power of 3847 watts is obtained with one core driven by an input power of 1252 watts. This represents a COP of 3847/1252 = 3.07 in this configuration. A COP of greater than 1.0 proves the process is real.

I want to state another observation that was gleaned from the data and graph. A delay of 1526 seconds exits between application of a power pulse and its effect appearing as water temperature rise. It is not clear why there is such a significant delay within the device reaction, but the data supports this contention.

(1) This value is calculated by using the values measured at time 15:42 of output cooling loop thermocouples contained within Mats Lewan's report.

Part 2

ECAT Gold Mine-Data Review from October 6 Test

The data collected during the October ECAT testing is a virtual gold mine to explore. All you need is a sharp pick and a strong back to dig out the wealth. All of us would rather have mined the placer deposit that would have existed had Mr. Rossi placed the thermocouples in a better location and actually measured the input water flow rates, but it is necessary to use data at our disposal.

I have found additional important information left behind as clues contained within the temperature reading referred to as T2. It is necessary to review the graph of T2 versus Time that is attached to this document in order to follow the discussion below.

Please note that there are two very different time constants affecting the temperature curve from the time mark of 13000 through approximately 23000 on the X-axis. The first one I want to discuss is the slowly decaying exponential temperature droop occurring throughout the entire time region. This curve can be identified by taking the value at 13000 and proceeding to the right in time all the way to 23000. You must mentally subtract the bump in the curve occurring between 16000 and 21000 time stamps. The bump is a result of behavior associated with the second time constant which I will talk about later.

The LENR core energy release is responsible for the first time constant and is a result of the design of Rossi's device. Some form of thermal insulation is placed between the active cores and the heat sink inside the ECAT. Rossi should initially try using air for this insulation by adjusting the amount of core contacting the heat sink. This procedure would permit an engineered air gap and a better degree of control. The design would be easy to adjust since you can set the thermal resistance from the cores outward through the heat sink and ultimately to the water. The final thermal resistance from the core units to the water establishes the temperature at which the cores operate when delivering the desired output power.

The better your ability to engineer this thermal path, the longer the self sustaining mode can continue. The consequence of excessive thermal resistance is run away positive feedback and undesired core melting. A proper balance should be struck and the existing adjustment seems to be functioning well enough to satisfy Rossi's first customer.

Of course my entire hypothesis depends upon information supplied by Mr. Rossi to my requests on his web site. He stated that the energy was mostly if not all released in the form of radiation. This fact is critically important as it allows him to separate the heat generation mechanism from the energy generation component. This is a major factor since he now can heat the core with his electric heater and have minimal interference from the heat released by conversion of the radiant energy within the heat sink. Positive feedback is reduced and control is enhanced.

Soon I hope that Mr. Rossi will reveal the energy release function. I suspect that most of the energy will be in the form of high energy X-rays or low energy gammas that pass through the insulator. I have understood the reasons put forth that suggest that there cannot be any form of radiation to perform the job, but somehow it works. I suspect that a major point being overlooked.

I want to briefly discuss the second time constant I referred to and its implications. I propose that the electric heater is attached to the heat sink and somewhat insulated from the core modules. This conclusion can be drawn by analyzing the bump in the T2 curve that is maximized at around 18000 time stamp. This response stood out to me as unusual when I was attempting to calculate the COP of the ECAT from the collected data. This bump is obviously the result of thermal filtering of the final long power input pulse that occurs just prior to beginning the self sustaining mode. You should notice that it has entirely been dissipated within a short period of time compared to the long time constant associated with the core insulation.

It is evident that power inputted to the core heating element is subjected to direct heat sink cooling. Heat energy contained mainly within the heat sink is rapidly conducted into the water within the ECAT enclosure due to the low thermal resistance along this path. This observation offers additional proof for LENR activity since heat continues to be released according to the first, larger time constant in the self sustaining mode.

There is further evidence to support this supposition. The final curve beginning at 30000 time stamp proves this quite well. Note that the temperature of T2 falls like a proverbial rock beginning shortly after the hydrogen is released from the core region. There is a short period after the LENR activity has ceased and built in delays are satisfied. Within approximately 800 seconds, the decay begins at a rate similar to that seen due to the rapid time constant which establishes the conduction rate for heat stored within the heat sink. Review the falling edge of the pulse waveform around 19000 time stamp to see a similar decay rate. I detect important proof of LENR activity by pursuing this line of reasoning.

This analysis strongly suggests that placing the heating elements in close thermal contact with the core modules is an excellent idea. The heating element and the core as a unit should be removed from close thermal contact with the heat sink. If this is enacted, the ECAT COP will improve by a factor of 2 or more

(estimate) and the heat required to start the LENR function will similarly be reduced. This change will result in a major improvement in the device performance.

This part of the document is based upon observations obtained by reviewing the Excel file submitted by Mats Lewan and statements attributed to Mr. Rossi in his journal. I have mined the T2 data deeply and made inferences which might turn out to be incorrect, but the logic applied supports my conclusions.

Part 3

More gold in the Ecat data

The October test of the latest version of the ECAT generated a significant volume of data that I have mined extensively in my quest to understand the characteristics of the device. Most of the low hanging fruit has now been plucked and the task has become more difficult. There is, however one more observation that I wish to hypothesize upon.

I have been studying the last plateau of the curve defining the temperature within the ECAT (T2) as a function of time. You should review the high definition graph that is attached to the end of this document which will allow you to follow the discussion. Locate the beginning of the plateau at time stamp 25000 and follow it to the end of the test procedure at approximately 30000 seconds. This is the region under focus.

The portion of the curve that begins at 13000 seconds into the experiment demonstrates a long time constant that continues at least until 22000 seconds. After this time, the temperature curve begins to flatten off and stays flat until the beginning of the current region of interest. The rise of the curve following the flat region has been a thorn in the side of many of our members and seems to defy explanation. I now believe that a credible reason for this phenomenon is available.

First, you must realize that the ECAT core is operating in a stable mode. By this, I mean that its output power is following an approximately exponential decay as it slowly cools down during the self sustaining mode. The rate of cooling is indicated by the longer time constant that I referenced in part 2 above. At 13000 seconds, the temperature of the water bath is approximately 121 degrees C. By the time that the exponential decay becomes buried within the new rising effect at 22000 seconds, the T2 reading has decayed to 117.5 C. There seems to be insufficient data available to readily calculate the power associated with this temperature. But other indications act as our guide.

Second, I used the readings at time stamp 15420 to arrive at my estimate of the power capability of the ECAT. The reason for this choice for the calculation is complex and I will not explain it at this time. The high temperatures measured for this reading suggests that the output stream into the heat exchanger is totally vapor. Also remember that the output power of the ECAT is falling off exponentially with time and is more significant during the early measurement period.

Follow the curve T2 from 15420 forward until you just arrive at the beginning of the anomalous rise in temperature at time stamp 24000 seconds. I contend that this rise does not reflect an increase in output power from the core but is in fact an illusion. It is true that the energy contained within the

water bath has increased due to a higher temperature and pressure reading, but this does not prove that the power output of the core has increased. It is my hypothesis that the action of the ECAT output section causes the unusual observation according to the following mechanism.

Core output power drops steadily with time by the exponential curve described above. As LENR power drops, the power absorbed by the water follows as this is the only outlet for the energy. Less and less boiling results as the power slowly decays. Initially, a hurricane of vapor forces its way into the output port keeping most of the water out of its path. This very dry vapor causes any water contained within to flash instantly into steam as it exits the check valve. As time progresses, the hurricane becomes merely a bad storm and continues to lose strength. I suspect that the slowly rising edge starting at time mark 24000 and continuing to 25500 represents the transition region between virtually total vapor and a phase mix heavy in water. The pressure is climbing as the output valve passage becomes clogged with water. In the beginning this mix will all flash into steam upon exiting the valve, but eventually only water remains. If the power continues to decay for a long enough time, the output of the ECAT will consist of only water at a temperature elevated above 100 C. A small portion of this hot water will continue to flash into vapor upon exiting the check valve and will keep the water stream moving throughout the heat exchanger into the plumbing sink. As we approach this condition the input region of the heat exchanger will exhibit a pressure reading very nearly atmospheric.

By reviewing the T2 curve we can estimate the pressure at which the check valve begins to open and it is 1.64 bars (114 C). I used the reading at time mark 23000 to obtain this value. This particular time and temperature was chosen since it represents the minimum value reached while the output stream was mostly vapor.

The rapid drop in T2 which occurs at the very end of the test (32000 +) is not explained within this report. The abrupt nature of the effect suggests a valve closure, but it would be unusual for that to occur with the input water flow rate assumed. It is probably associated with intentional turn off of the test environment.

I suspect that the ECAT was ejecting a mix of vapor and water when Mats Lewan made his output flow rate measurements. The unknown quality of the vapor will confuse the power output estimate dramatically for his measurement at time stamp of 28619. Unfortunately the quality of the vapor output during this period is very difficult to determine accurately with the limited data available. I made an educated guess by assuming that the quality readings at both of his test times were such that approximately the same amount of vapor (.182 grams/second) was exiting. A quality value of .2 for the .91 grams/second measurement and .095 during the 1.92 grams/second measurement achieved this goal. Additional support for this estimate is found in the fact that the power delivered to the heat exchanger was in proportion to the ratio (1.55) measured by taking into account the thermocouple readings. This calculation neatly connects that anomalous data into the web. Time will tell whether or not these assumptions represent reality.

An attempt to accurately estimate the ECAT power output requires that we include the leakage water escaping from the device seals which is reported to be 2 liters/hour. The final estimated output power

is (.728 grams/second x 4.188 joules/gram-C x (116.6 C – 23.8 C) + .182 grams/second x 2260 joules/gram = 691.85 watts) for the normal path through the heat exchanger and (.55555 grams/second x 4.188 joules/gram-C x (116.6 C-23.8 C) = 215.9 watts) by escaping the enclosure. The total of these two power output sources is 691.85 watts + 215.9 watts = 907.75 watts.

The core device of the ECAT is also supplying heat to the outside surface of its container. It is reported that these surfaces are quite hot to the touch. Someone should calculate the power lost through this mechanism which can then be added to the core performance. An estimate of 500 watts for this effect is a good beginning until it can be calculated with precision. Adding these figures together yields a power of 1407.75 watts core output for this time stamp. Recall that I came up with an estimate of 3131 watts in part 1 at time 15420. This calculation did not include the other losses. The total core output power is 3131 watts + 500 watts + (.55555 grams/second x 4.188 joules/gram-C x 92.8 C) 216 watts = 3847 watts. The core output power appears to have drooped from an initial driven value of 3847 to a final value of 1407.75 during the test.

The above calculation may upset your confidence in the ECAT, but I see otherwise. The power output under driven conditions was pretty much as expected at approximately 3847 watts. This was the result of only one core module contributing to the output. When two additional cores are placed in close proximity to the current one, we can be assured that there will be interaction. The heat flow toward the heat sink from the core region will be several times as large as before. This will result in a temperature gradient that increases in the direction of the cores resulting in more output power. There is evidence that the combination of three cores results in improved power output consistency because of this positive feedback phenomenon. The large 1 MW system test demonstrates this by exhibiting nearly constant output when in the self sustaining mode.

Individual core test performance apparently does not translate directly into three core test performance unless the results are calibrated to take into account the two absent cores.

I have taken the opportunity to consider the assumed design parameters of the ECAT device and have factored in feedback that has been generously offered to me by my colleagues. My present inclination is to assume that the ECAT function probably relies upon heat generated within the core module itself as opposed to radiation escape. If this assumption is accurate, then Mr. Rossi has carefully adjusted the thermal impedance existing between the cores and the heat sink. This resistance is used as a form of thermal impedance matching. The cores operate at somewhat greater than 600 C while the heat sink is substantially lower in temperature. The varying thermal resistance paths would have to be responsible for the two dramatically different time constants seen and reported during my previous parts of this document. One interesting possibility suggests itself immediately. Positive feedback is often applied within the world of radio design to enhance the quality (Q) of resonant circuits. Perhaps the positive feedback generated by the careful trapping of heat within the ECAT core modules results in the observed response. If this is true, one would see the self sustaining mode become flatter as the core heats up until a critical temperature occurs at which point thermal run away would begin. This interesting mechanism will only occur if the power output of the core versus temperature is non linear.

It is hoped that the supporting data for this assumption is revealed by Mr. Rossi when he describes the physics behind his ECAT.

OVERALL CONCLUSION

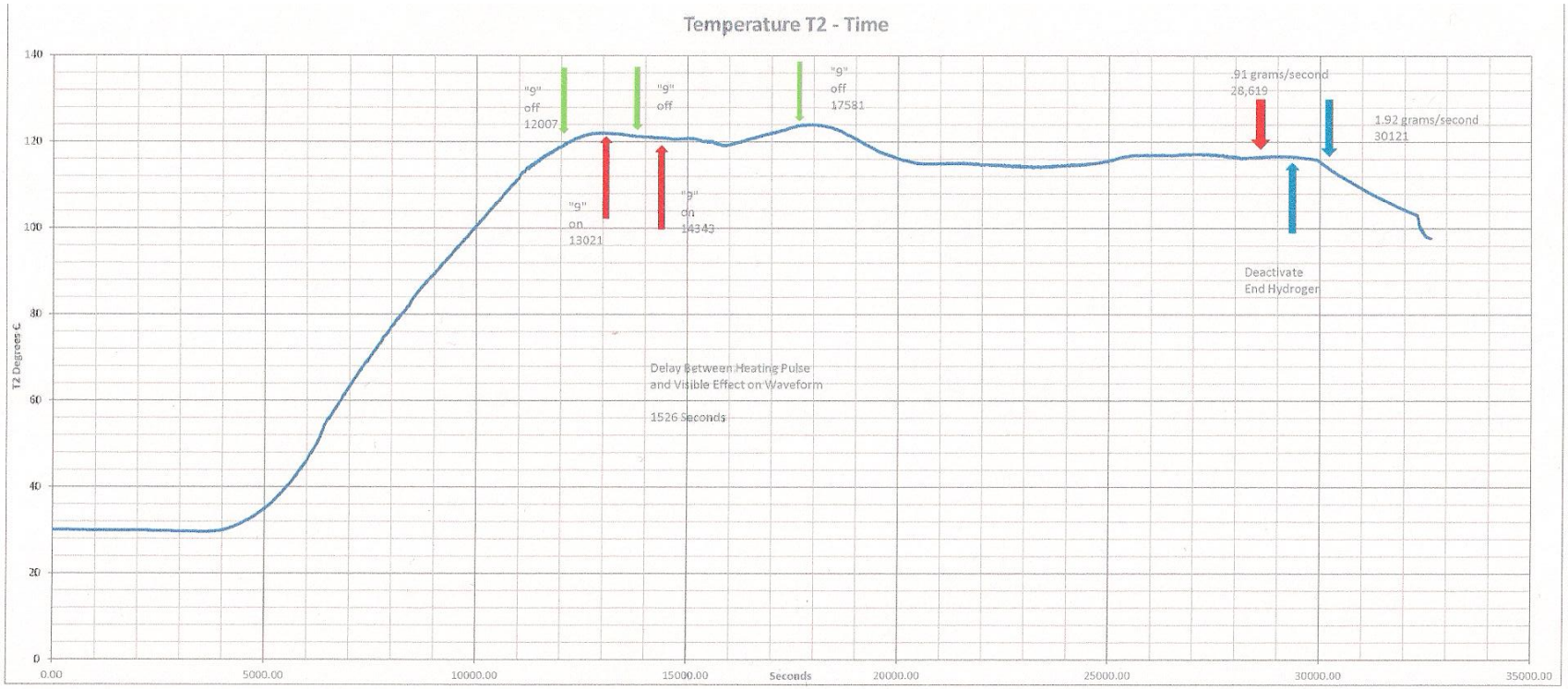
This constitutes the final document that I will submit regarding the performance of the ECAT device during the October 6, test. Uncovering the facts to the best of my abilities has constituted the solution to a complex puzzle with well hidden clues somewhat like solving a crime mystery. I hope that Sherlock Holmes would be proud of the results.

This endeavor has demonstrated that Mr. Rossi has achieved a marvelous goal. He deserves our gratitude for bringing forth the instrument that will make the world a far better, fairer, and safer environment for mankind. We will be freed from the bonds of the fossil fuel lords if the political obstacles can be overcome, which I have faith will happen.

I am saddened that 20 years was allowed to expire before this day because of the actions of a few well connected people of short vision. We can take comfort in the knowledge that many dedicated scientists and engineers have doggedly pursued the elusive effects of LENR reactions during this period with virtually nonexistent support from main line science funding sources. Their efforts are greatly appreciated.

In conclusion, LENR also known by many as “Cold Fusion” is real and proven. Any lingering doubts as to the validity of this statement will be removed in the very near future as more and more devices emerge. The first monumental demonstration by Mr. Rossi will be followed by many more as his Model-T device is upgraded and additional competitors spring forward. His dedicated effort will long be remembered.

David Roberson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