VERIFICATIONS OF FRANCESCO CELANI LENR DEMONSTRATIONS:

COORDINATION AND IDENTIFICATION OF BEST PRACTICES

Enhanced Documentation of Celani Demonstrations

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Executive Summary

Dr. Francesco Celani, a long-time researcher in the field of low energy nuclear reactions (LENR), has developed a method to produce anomalous effects in a nickel-hydrogen system. The nickel is alloyed with copper in a commercially available wire form with the name Constantan. An essential part of Celani's procedure is pre-treatment of the Constantan wire that involves partial oxidation at high-temperature to create layered structuring at the surface. Celani has reported anomalous effects attributed to LENR such as excess heat production and a reduction in the electrical resistance of the Constantan wire. These effects are achieved by exposing the wire to hydrogen gas under elevated temperatures inside of a custom-made reactor. The reactor is constructed with transparent glass tube, allowing it to also serve as a dissipative-type calorimeter after careful calibration. Temperatures of a few hundred degrees Celsius are reached by resistive heating of the Constantan wire or an inert nickel-chrome wire co-located with the Constantan wire inside the reactor.

After achieving apparent success with the experiment at his lab at INFN[1] in Frascati, Italy, Celani put on two demonstrations in August 2012 supported by National Instruments. The first demonstration was at NIWeek 2012 in Austin, TX, and the second was at ICCF-17[2] in Daejeon, South Korea. Subsequently, NI also supported Celani's effort to achieve self-sustaining LENR at his lab at INFN.

The results of these demonstrations and later experiments at INFN have been subjected to additional analysis and documentation in a manner consistent with that done by Celani for his paper presented at ICCF-17[3]. The work presented in this report is broken down into stages and

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[1] National Institute of Nuclear Physics

[2] 17th International Conference on Cold Fusion

[3] Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Proceedings of the 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 6 p.

outlined with referenced figures. Three datasets obtained from Celani's NI supported work are plotted and compared to data presented in Celani's original report.

In his experiments prior the August demonstrations, Celani observed excess heat and reduction in electrical resistance with two different treated Constantan wires. The excess power generated was about 5 W when the reactor was heated via the inert wire and increased to about 10 W when heated directly through the Constantan wire. Excess heat production by wire 1 began when the reactor temperature exceeded 125 °C, while wire 2 showed excess heat above 160 °C. Hydrogen loading of the Constantan wires was inferred from a reduction in the initial resistance to a ratio as low as 0.71. Excess power was also reported with deuterium as well as hydrogen gas.

Excess power production and reduction in Constantan wire resistance were also observed in the NIWeek 2012 and ICCF-17 demonstrations. Excess power of 18 W and a resistance ratio as low as 0.79 were measured at NIWeek 2012, while excess power of 9.5 W and a resistance ratio as low as 0.85 were measured at ICCF-17.[4]

In post-demonstration experiments at INFN, the reactor was thermally insulated in an attempt to achieve self-sustaining LENR. These attempts proved unsuccessful, as seen by characteristic cooling of the reactor after the removal of external power. However, in this experimentation the wire underwent hydrogen de-loading and reloading, as seen by a corresponding increase and decrease in resistance ratio, respectively.

Overall, the analysis of the two datasets from the August demonstrations has corroborated Celani's claims regarding the existence of excess heat and reduced electrical resistance. Although self-sustaining reactions were not achieved in the post-demonstration experiments, reloading of hydrogen in the Constantan wire was indicated by decrease in the resistance ratio. This additional analysis of the datasets has provided strong support for decisions made before, during and after the demonstrations for supporting Celani's research.

[4] After input power correction of +16% discovered in post-demonstration experiments at INFN

1 Introduction and Background

Cold fusion (CF) was announced in 1989 but was quickly rejected by mainstream science. Investigations into the phenomenon have continued, however, and it now appears that CF may yet prove to be real and, consequently, live up to its promise as a source of cheap and safe energy. In the early days of CF (LENR[5]) investigation, it was believed that expensive palladium and deuterium were required for successful experiments. However, some investigators[6] reported successful LENR experiments with much cheaper nickel and hydrogen[7]. Recent apparent LENR advances have focused on gas and metal setups rather than electrolytic cells of the type used in early experiments. One particularly promising approach involves the use of hydrogen with a nickel-copper alloy that has been specially treated with heating and partial oxidation. Oxidation of nickel-copper alloys has been investigated previously[8].

National Instruments (NI) has maintained an interest in the controversial LENR field since its beginnings in 1989. During 2012, NI provided support for two significant LENR demonstrations involving copper-nickel alloys and hydrogen. The demonstrations were put on by Dr. Francesco Celani[9], a researcher at Italy's National Institute of Nuclear Physics (INFN) at Frascati (see Appendix A for a biography of Celani). Celani's demonstrations took place during NIWeek 2012 in Austin, Texas (August 6-9, 2012), and at the 17th International Conference on Cold Fusion (ICCF-17) in Daejeon, South Korea (August 14-17, 2012).

[5] The term low energy nuclear reactions (LENR) is preferred over CF by many researchers in the field today. Others prefer the more restricted term anomalous heat effect (AHE), which does not include other phenomena such as radiation or transmutation.

[6] See, for example, Focardi S., Habel R., and Piantelli F., *Anomalous Heat Production in Ni-H Systems*, Nuovo Cimento, Vol. 107A, p. 163-167, (1994)

[7] Hydrogen consists of two isotopes – protium (with no neutrons in the nucleus) and deuterium (with one neutron). The convention of this paper follows routine practice in the LENR field of referring to protium as "hydrogen".

[8] See, for example, Pilling, Norman B, and Robert E Bedworth. *Oxidation of Copper-Nickel Alloys at High Temperatures*. Industrial and Engineering Chemistry, v 17, no 4, p. 372-376 (April 1925).

[9] Celani has worked in the LENR field for many years, starting within six days of the Fleischmann and Pons announcement on March 23, 1989. (Source: http://web.pdx.edu/~pdx00210/FTEssay/Essays/Celani.htm)

NI is interested in continuing to support Celani's research and in facilitating coordination of the research results of other investigators. In addition, NI would like to identify best practices for conducting research to achieve experimental success as well as effectively communicate such practices to interested researchers. An initiative is being undertaken with the Center for International Energy and Environmental Policy (CIEEP) at The University of Texas at Austin (UT) to achieve these objectives. This project, referred to as the NI-CIEEP Initiative, began with a Phase 1 report and proposed activities for Phase 2[10].

Since the August demonstrations, Celani has provided samples of his materials to other experimenters. A primary focus of the NI-CIEEP Initiative is to verify Celani's observations through documentation and examination of the work of these other investigators. To accomplish this objective, additional documentation of Celani's recent accomplishments is also being developed in this report. The purpose of this report is therefore to summarize Celani's work in three phases:

- Experimental work prior to the August demonstrations
- The demonstrations with NI support in Austin and Daejeon
- Continued NI support to Celani onsite at his INFN[11] laboratory in Frascati, Italy

In particular, the data collected in the two demonstrations is analyzed and interpreted in a manner similar to Celani's experimental work prior to the demonstration. This analysis, along with additional information collected from the other investigators, may then be used to inform planning for future experiments as described in Section 7. The information collection effort from other investigators is described in a companion document[12].

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[10] Grimshaw, Thomas W. Verifications of Francesco Celani LENR Demonstrations, Coordination and Identification of Best Practices – Phase 1 Report and Phase 2 Proposed Activities. Austin, TX, The University of Texas at Austin, Center for International Energy and Environmental Policy, unpublished report, 4 January 2013, 34 p.

[11] Istituto Nazionale di Fisica Nucleare. See Appendix B for a description of the Frascati facilities of INFN.

[12] Grimshaw, Thomas W. Verifications of Francesco Celani LENR Demonstrations – Target Entities and Experimental Results, The University of Texas at Austin, Center for International Energy and Environmental Policy, unpublished report, March 18, 2013, 12 p. (Initial Document to be Developed with Information Collection.)

Stefano Concezzi, NI Vice President, initiated and had overall responsibility for the NI-CIEEP Initiative, Lothar Wenzel of NI provided technical oversight and direction. Brian Glass provided technical expertise,with emphasis on data collection and analysis, and Tom Grimshaw of CIEEP was responsible for project organization , documentation, and report preparation.

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2 Overview of Experimental Design

The overall approach of Celani's experiments is to achieve the LENR effect through interactions of both hydrogen and deuterium gas with nickel (in this case alloyed with copper as Constantan[13]) in a heated tubular glass reactor that also serves as a calorimeter (Figure 1-1). The Constantan is in the form of thin wire stock. The occurrence of LENR phenomena is inferred from observed excess heat[14] and reduction in the electrical resistance of the Constantan wire[15]. The investigations also include procedures for treating the Constantan wires prior to use in order to make it "LENR-active".

The original LENR work by Fleischmann and Pons involved palladium and deuterium in electrolytic cells. Although research is still conducted with electrolytic cells, the main emphasis in the LENR field has shifted to gaseous and solid materials systems, primarily because of improved potential for practical energy production. Observation of LENR with nickel and hydrogen has resulted in further shift in focus because of the lower cost of these elements in comparison to palladium and deuterium. Although progress has been made in developing basic understanding of LENR phenomena, a complete and comprehensive theory remains elusive.

[13] Constantan is a copper-nickel alloy usually consisting of about 55% copper and 45% nickel. Its main feature is its constant electrical resistivity value over a wide range of temperatures. It is widely used in strain gauge applications and for making thermocouples. Constantan was developed by Edward Weston in about 1887 as his "Alloy No. 2". It was produced in Germany, where the name was changed to Constantan. Source: Wikipedia on "Constantan".

[14] "Excess heat" or "excess power" (referred to in this report as "anomalous power") is commonly used as a signature of LENR effects by investigators in the field. The "excess" signifies energy above what can be accounted for through chemical reactions. The term anomalous power refers to the rate of excess energy production (over time).

[15] Reduction of electrical resistance is inferred to indicate hydrogen "loading" in the metal lattice of the nickel. Such loading is a necessary condition for LENR to occur.

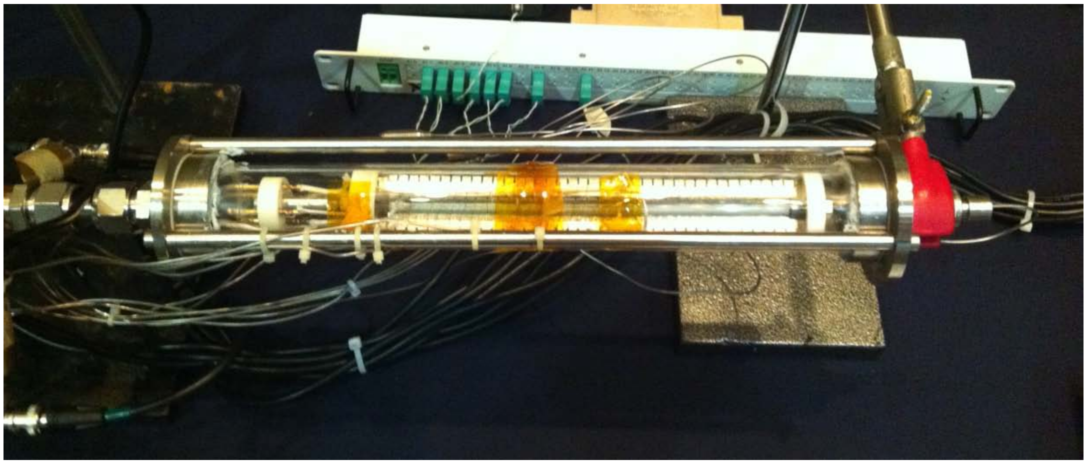

Figure 1-1: Francesco Celani's Reactor/Calorimeter. The reactor assembly is about 12 inches long. Photo by author at ICCF-17, August 14-17, 2012, Daejeon, South Korea

3 Experimental Work Prior to Demonstrations

The NI supported LENR work of Celani has its roots in recent experiments at his laboratory at INFN in Frascati, Italy. His work with Constantan and hydrogen was underway by June 2011, with a breakthrough in the Constantan preparation procedure occurring in January 2012. Experiments with the transparent dissipation-type reactor/calorimeter began in June 2012 and continued through July, when the apparatus was shipped to Austin, Texas for the first demonstration. The pre-demonstration experiments are documented in three publications by Celani and his colleagues:

- Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Preprint TuA1-3, Proceedings of the 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 4 p.
- Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Presentation at 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 56 p.
- Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Proceedings of the 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 6 p.

The third publication above is the most definitive description of the experiments[16] and is contained in Appendix C. This publication is reviewed in this report in a conventional

[16] An additional paper was published in March 2013 that includes detail on an earlier version of the reactor. (Celani, Francesco, et al. *Experimental Results on Sub-Micro Structured Cu-Ni Alloys under High Temperature Hydrogen/Deuterium Interaction*. Chemistry and Materials Research, vol 3, no 3 [March 2013], p 27-56.) For the purpose of this document, the third (ICCF-17) paper provides the information to guide future decisions for NI support.

organization format for experimental description – materials and equipment, procedure, results, interpretation, and recommendations. As noted above, this review provides the basis for analysis of subsequent demonstrations and experiments by Celani and NI.

3.1 Equipment and Materials

Celani's successful pre-demonstration experiments were performed with two treated Constantan wires, a custom made reactor/calorimeter, instrumentation, and LabVIEW software for data recording and analysis. These key components are described below.

3.1.1 Constantan Wires

The Constantan wires used by Celani are available commercially from a German company called Isabellenhutte and consist of 55% Cu, 44% Ni, and 1% Mn. Constantan was selected for experimental use not only because of previous observations of nickel-hydrogen reactions, but also because of desirable properties such as having a high diffusion coefficient of hydrogen, low cost, enhanced ability to disassociate hydrogen, and mechanical stability. Details of the Constantan wire material and its characteristics are provided in Appendix D-1. Treatment of the wire is necessary for experimental success and the preparation procedure is discussed in a later section.

3.1.2 Reactor/Calorimeter

A tubular reactor was built house the Constantan wire and function as a dissipation-type calorimeter, in which power output is measured based on the external reactor temperature and application of the Stefan-Boltzmann law. The reactor was designed to withstand both high pressure and vacuum at high temperatures. A transparent glass tube was chosen in order to allow observation of the wires and to ensure their proper working condition. The tube is made of borosilicate glass with a thickness of 3mm and inside diameter of 34 mm. The overall length is 30 cm, with two metal flanges sealing the glass tube while allowing passage for wires, gas, and sensors. The reactor contains two wires – an “active” Constantan wire and an “inert” NiCr wire[17] – wrapped in parallel in a helical manner with 22 turns around a mica insert, which offers thermal and electrical insulation for the wires. The wire (approximately 100 cm long) spans an active length of 10 cm along the center of the reactor.

3.1.3 Instrumentation

The reactor was equipped with several thermocouples to measure the temperature at various locations internal and external to the glass tube. A pressure transducer was also included for measuring the internal pressure of the reactor. A digital multimeter was used to measure voltage and current supplied to the wires, the latter being measured across a precision shunt resistor. These values were used to calculate wire resistance and input power. A NaI (Tl) scintillation detector was used to detect X-ray and gamma ray radiation for safety purposes. Custom software designed in LabVIEW was used to control the instrumentation, make measurements, and record data.

3.2 Procedure

Dr. Celani’s work involved two primary phases, beginning with preparation of the Constantan wires and followed by a series of tests with the reactor/calorimeter.

3.2.1 Constantan Wire Preparation

Preparation of the Constantan wires is an essential (and unique) feature of Celani’s experimental approach for achieving LENR phenomena. Because initial testing of untreated Constantan wire failed to produce any observable anomalous effects, Celani begin investigating ways to modify the material properties in order to make them more conducive to interacting with hydrogen. After finding that Constantan should not be exposed to temperatures above 600 ºC, Celani began to explore the effects of heating the material to high temperatures. After several months of experimentation, a process was devised that begins with Joule heating the bare wire in normal

[17] Also referred to as the “monitor” wire

atmosphere to burn off the plastic coating[18]. From there it underwent treatment involving high heating to partially oxidize the copper portion of the alloy[19]. The process resulted in a layered surface structure that increases the wire's diameter as well as the volume of active material at the surface. Celani believes that this so-called "skeleton" structure places a key role in producing LENR phenomena. The experiments reported in Celani's papers cited above used two treated wires, designated Wire #1 and Wire #2. These wires were described as having on the order of 700 layers, with each layer measuring 20-100 nm in thickness.[20] Details of the wire preparation procedure are provided in Appendix D2.

3.2.2 Reactor/Calorimeter Experiments

After the reactor/calorimeter and Constantan wire configuration was assembled and instrumented, a series of experiments was conducted to investigate anomalous behavior of the active wire, including hydrogen loading, changes in resistance, and excess power production. The primary aim of these investigations was to characterize these effects based on parameters such as:

- Internal reactor temperature
- Method of heating the Constantan wire
- Type, pressure, and concentration of gasses – argon, hydrogen, and deuterium
- Experimental step duration and repetition

Celani's experimental procedure can be presented as a series of stages as follows:

1. Determine Initial Resistances of Active and Inert Wires
2. Calibrate Reactor with Inert Gasses
3. Test 1 on Wire #1 (75 H_2/25 Ar, 48 W to Inert Wire)
4. Test 2 on Wire #1 (75 H_2/25 Ar, 48 W to Inert Wire)

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[18] As received from the German manufacturer Isabellenhutte

[19] As described in Pilling, Norman B, and Robert E Bedworth. *Oxidation of Copper-Nickel Alloys at High Temperatures*. Industrial and Engineering Chemistry, v 17, no 4, p. 372-376 (April 1925).

[20] It was later confirmed that the number of layers correspond to the number of heating/quenching cycles applied to the wire.

5. Test 3 on Wire #1 (75 H_2/25 Ar, 48 W to Active Wire)
6. Test 4 on Wire #1 (100 H_2, 48W to Active Wire)
7. One Week of Unspecified Testing
8. Hydrogen Unloading Cycles on Wire #1
9. Test 5 on Wire #1 (100 D_2, 48W to Active Wire)
10. Test 1 on Wire #2 (100 H_2, 48W to Inert Wire)
11. Hydrogen Unloading Cycle on Wire #2
12. Test 2 on Wire #2 (100 H_2, 48W to Inert Wire)

3.3 Observations and Interpretation

As noted above, Celani's observations are reviewed generally as they are presented in the final ICCF-17 paper[21] with minor changes in organization. The key figures in the paper have been expanded for improved interpretation and clear association with the corresponding observations in the text.

3.3.1 Stage 1. Determine Initial Resistances of Active and Inert Wires

The initial resistance (R_0) of Wires #1 and #2 were measured at room temperature after being installed in the reactor. Using a small test current of 4 mA, the resistance of Wire #2 was quoted to be 16.9684 Ohms, while the resistance of the inert (NiCr) wire was found to be 57.4394 Ohms.

3.3.2 Stage 2. Calibrate Reactor with Inert Gasses

Calibration of the reactor was performed by determining what Celani calls the "power exchange constant" of the reactor, which is denoted in equation 1 below by C and has the units of meters squared. This value acted as an effective surface area in the Stefan-Botzmann relation, which was used to calculate the reactor's total output power from the external glass wall and ambient temperatures.

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[21] Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Proceedings of the 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 6 p.

$$P_{Out} = C * 5.67 \times 10^{-8} [T_{Wall}^4 - T_{Ambient}^4]\, W \qquad (1)$$

To determine the power exchange constant, the reactor was filled inert gases[22] and electrical power was applied to the inert wire at 5, 15, 30, and 48W test levels. Depending on the gas pressure and composition, the internal glass wall temperature reached between 180 and 250 ºC. From the values measured for the external glass wall and ambient temperatures, the power output from Equation 1 could be equated to the electrical power supplied, giving a value for C. For cross reference, some tests were performed with power being applied to the active wire. The power exchange constant found by Celani was $C = 1/24.5 \approx 0.0408$. Detailed calibration data and procedures are not included in Celani's paper.

3.3.3 Stage 3. Test 1 on Wire #1 (75 H_2/25 Ar, 48 W to Inert Wire)

A mixture of hydrogen and argon (75/25 ratio) was introduced into the reactor at a pressure of 7 Bar. Electrical power of 48 W was then applied to the inert wire. Results of the test are shown in Figure 3-1. When the internal glass temperature reached approximately 125 ºC the resistance ratio of the active wire abruptly decreased to 0.92 in a period of 42 minutes (after an initial limited increase to 1.02). Over a period of 28 hours, R/R_0 had further decreased to 0.88, with the internal glass temperature at 180 ºC. Excess output power appeared to increase with some fluctuation along with the decrease in resistance ratio. Input power was stopped 28.6 hours after the initial decrease in R/R_0. In cooling to room temperature, the active wire's resistance ratio reduced to 0.80.

[22] Presumably helium, argon, and potentially mixtures of the two.

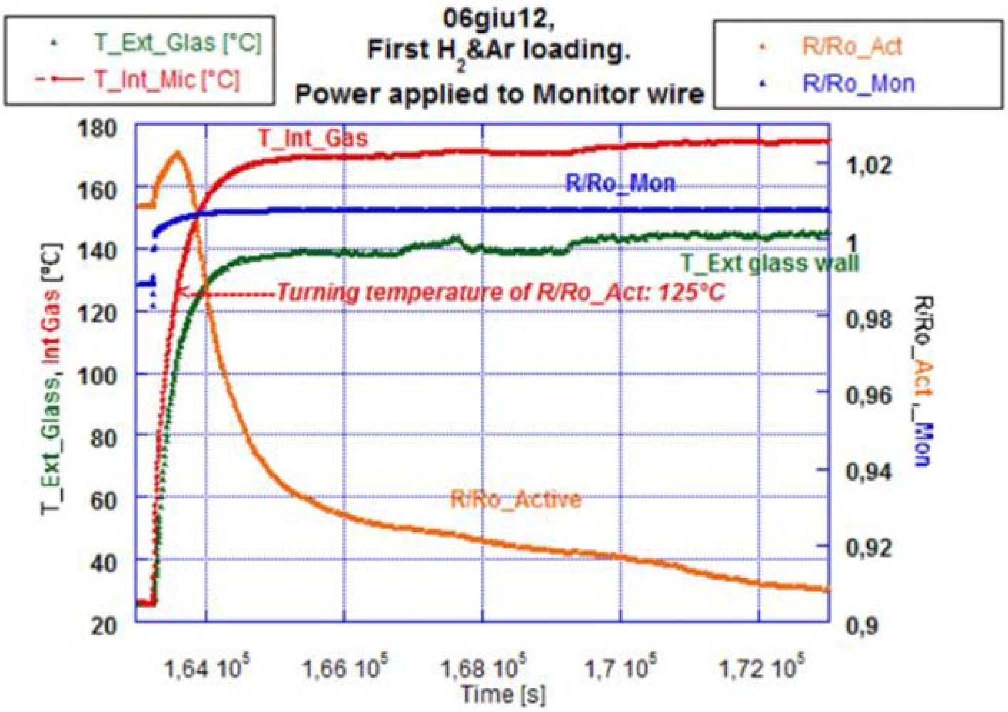

Figure 3-1: Active wire loading beginning at 125 ºC with 48 W to inert wire

3.3.4 Stage 4. Test 2 on Wire #1 (75 H_2/25 Ar, 48 W to Inert Wire)

After allowing the wires to cool to room temperature, 48 W was again applied to the inert wire. This is shown at approximately 270 ks in Figure 3-2. Shortly thereafter, R/R_0 of the active wire increased to the level observed just prior to discontinuing power. The resistance ratio then continued to decrease at a rate consistent with Test 1, reaching a value of 0.867 after 42 hours from reapplying power. Likewise, excess power was observed to increase over time to a value of approximately 8 W[23]. Celani reported that significant fluctuation in excess power (up to 6 W) correlated to small (<1%) variations in R/R_0. It was also assumed that the gradual increase in excess power corresponded to elapsed time rather than the small decline of R/R_0.

[23] From inspection of Figure 3-2

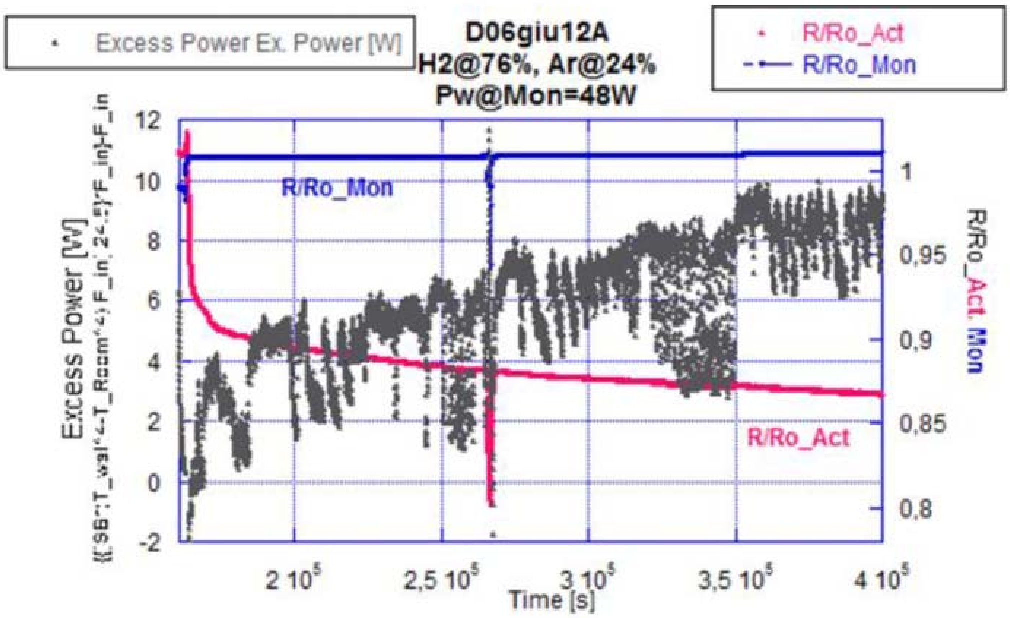

Figure 3-2: Continuity of anomalous power generation and lowered resistance ratio after reapplication of power (48W) to inert wire.

Although the average ambient temperature remained constant over the test stages, fluctuations between 23-27°C were said to introduce non-equilibrium conditions that aided in the production of anomalous heat. The observed trend of increasing power output over time remains valid on the basis that the initial room temperature did not change on average over the course of the testing.

Increasing power output over time with nickel-hydrogen systems has also been observed by the A. Takahashi and A. Kitamura group, among others, as reported at IX Pontignano Workshop[24] and ICCF-17. According to Takahashi and Kitamura, under their experimental conditions, constraints and materials, the anomalous power slowly increased from 0 to 3W in 2 weeks of experiments.

Anomalous power output appeared to stop when the reactor temperature dropped to 120°C, a temperature consistent with the value (125°C) at which the active wire resistance initially decreased. It is unclear at what point in the experimental procedure this was determined.

[24] IX International Workshop on Anomalies in Hydrogen-Metal Systems, April 2012, Pontignano, Italy

3.3.5 Stage 5. Test 3 on Wire #1 (75 H_2/25 Ar, 48 W to Active Wire)

After 84 hours from the application of hydrogen and argon, 48W was applied to the active (Constantan) wire, rather than the inert wire. The results are shown if Figure 3-3.

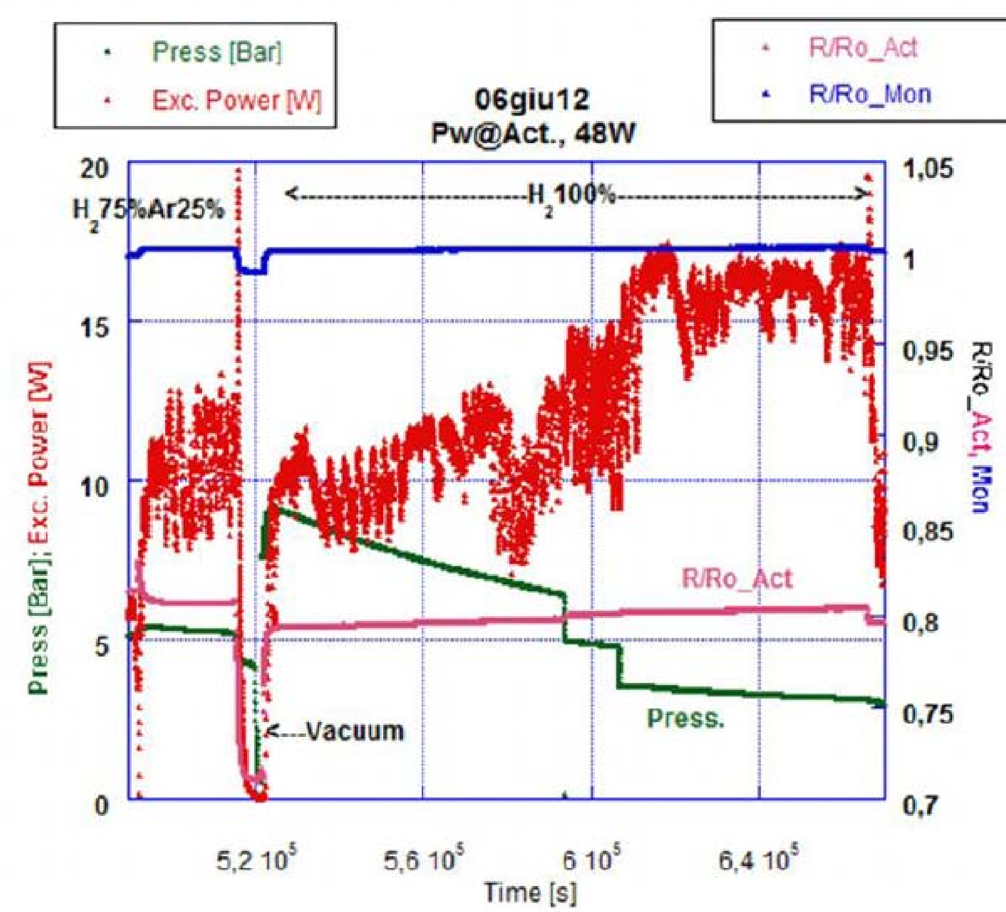

Figure 3-3: Increase in excess power generation with 100% H_2 and 48W applied to active wire.

Anomalous power increased to about 10 W and R/R_0, after initially increasing, stabilized at 0.808. The increase in anomalous power could be attributed to a higher local temperature of the active wire due to direct Joule heating. If this observation is correct, anomalous power has a positive correlation to wire temperature (above a threshold temperature)[25]. Similar effects were

[25] This observation became important after the demonstrations and led to further investigations in Celani's lab as described in Section 5 of this report.

found by Celani with an earlier wire in experiments ending May 2012. After 100 hours (515 ks in Figure 3.3), power was removed and the reactor was put under vacuum. At room temperature, R/R_0 had decreased to 0.71. Applying power to the active wire apparently improved hydrogen loading and anomalous power production.

3.3.6 Stage 6. Test 4 on Wire #1 (100 H_2, 48W to Active Wire)

After 113 hours (520 ks in Figure 3-3) the reactor was loaded with 100% hydrogen gas at 9 Bar. Anomalous power continued to increase to 16 W, but it cannot be said whether this was attributed to the effects of 100% hydrogen or increasing experimental duration.

3.3.7 Stage 7. One Week of Unspecified Testing

Unspecified testing was performed for one week. No procedure or observations were provided in the paper.

3.3.8 Stage 8. Hydrogen Unloading Cycles on Wire #1[26]

To ensure that the resistance decrease was a result of hydrogen loading into the lattice, rather than the reduction of surface oxides by hydrogen, the reactor was put under dynamic vacuum and elevated temperatures to de-load the active wire. After several hours under these conditions the resistance of the wire returned to the initial value with $R/R_0=1$, implying that the resistance change was not due to a permanent change in material properties, but rather an effect of hydrogen loading.

After recovering the original resistance of the active wire, it was again exposed to hydrogen gas and high temperature. Similar to the first exposure, R/R_0 was observed to decrease along with anomalous heat generation. De-loading of the wire for the second time resulted in an R/R_0 value of 0.93, not 1 as seen in the first test. It was suspected that this may be due to residual hydrogen still present in the wire lattice. It may also be attributed to a permanent change in the metallic properties of the wire.

[26] No data or figures were presented for this stage.

3.3.9 Stage 9. Test 5 on Wire #1 (100 D_2, 48W to Active Wire)

After the two tests of hydrogen de-loading with Wire #1, the reactor was filled with deuterium gas. Power was applied to the inert wire[27] to increase the temperature in the reactor. In this test R/R_0 showed little if any decrease, remaining constant around 0.94. From this observation it was implied that only a small amount of deuterium was absorbed.

During the heating period with reactor temperatures between 100 to 160 ºC, burst-like emissions of X-rays (and/ or gamma ray) were detected by the NaI (Tl) detector. Spectrum information was not measured, but the detector's range was 25 to 2000 keV. These emissions were clearly detectable and lasted for approximately 600 seconds.

During the first day of operation, negative excess energy was measured during two several hour periods, indicating an endothermic reaction was taking place. On the second day, however, the process became exothermic with excess power generation increasing on average to approximately 5 W over a period of 4 days[28]. The results are depicted in Figure 3-4.

[27] Although it is not explicitly reported, the power applied is assumed to be 48W.

[28] From inspection of Figure 3-4, peak excess power values were measured as high as 9 W.

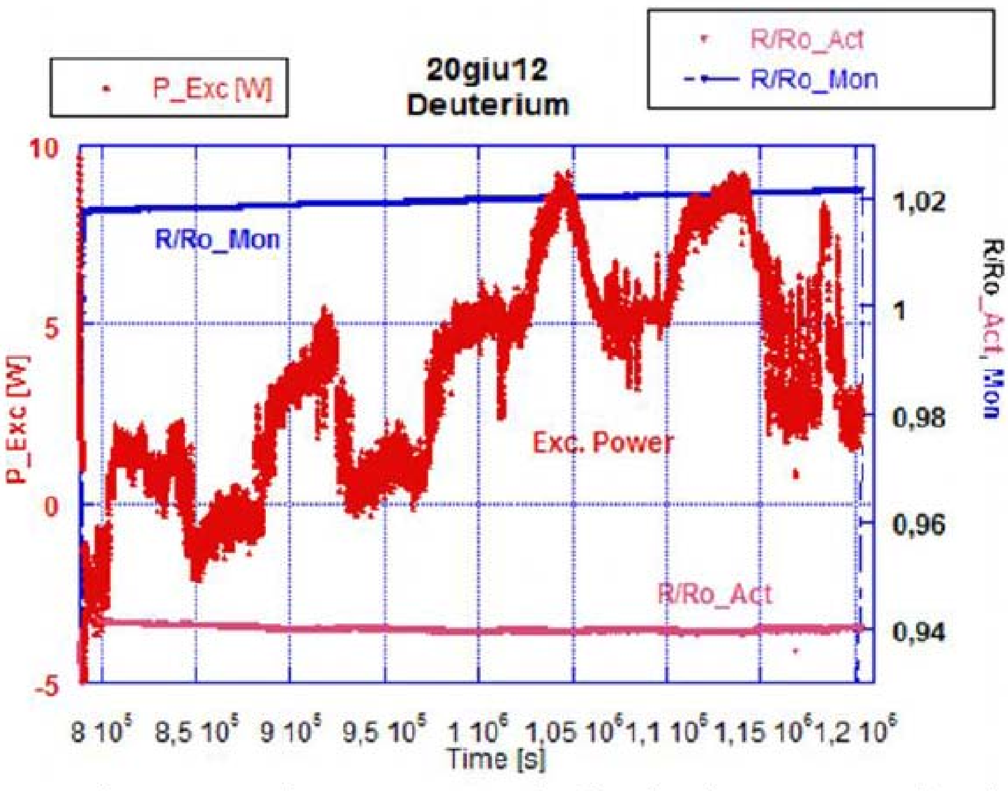

Figure 3-4: Excess power measured under D_2 gas. Initially excess power measurements were negative, climbing above 0 for several hours before again returning to negative values. After 24 hours, excess power remained positive.

After approximately 4 days of operation with deuterium, the reactor temperature abruptly increased and the wire broke. Although reactor pressure decreased due to gas leakage[29], this took place 22 hours prior to the wire breaking. SEM observations of the broken wire showed that a large piece of the wire became shaped like a ball, indicating the possibility of a fusion event. Further analysis was said to be in progress at the time of writing of the report.

3.3.10 Stage 10. Test 1 on Wire #2 (100 H_2, 48W to Inert Wire)

Experiments with Wire #2 began on July 10, 2012. Before beginning experimentation, three thermocouples were added at unspecified locations internal or external to the reactor. The

[29] Pressure and temperature data are not included for the deuterium test.

primary thermocouple used for power output calculations, originally located towards one end of the active wire external to the glass, was moved to the center of the active wire.

The initial testing on Wire #2 was performed with pure hydrogen and 48 W applied to the inert wire. The active wire was not able to withstand direct heating[30], potentially as a result of surface obstruction by contamination from the high-density polyethylene (HDPE) bag the wire was stored in. The loading temperature of Wire #2 was 160 ºC, as compared to the lower temperature of 125 ºC for Wire #1. Observations of resistance reduction and anomalous heat generation were qualitatively similar to those made with Wire #1, despite showing decreased performance. Figure 3-5 shows excess power generation of approximately 6 W with an active wire resistance ratio of around 0.80.[31]

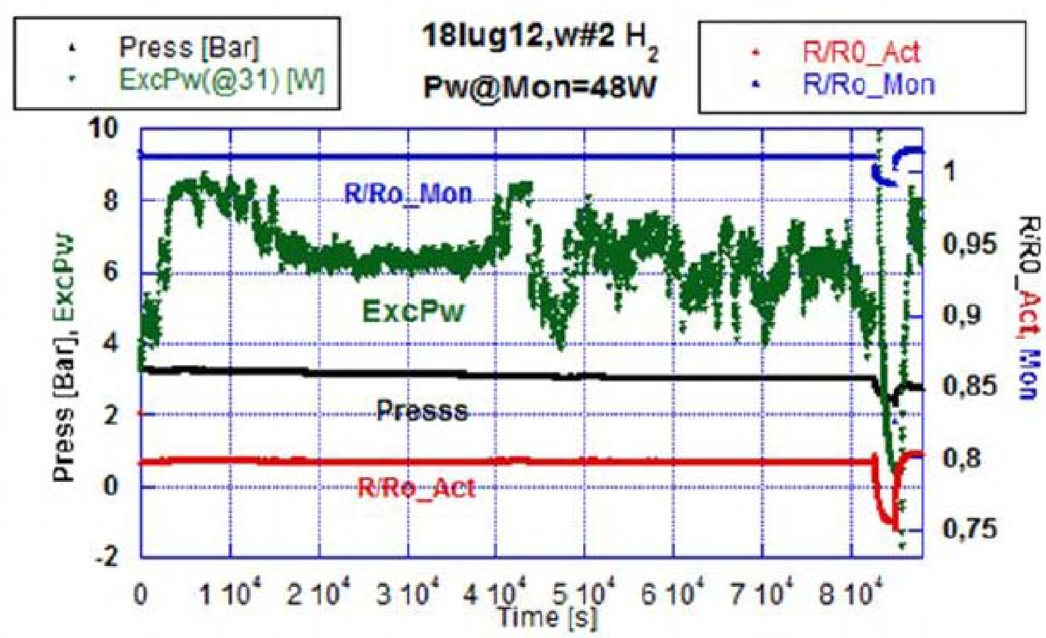

Figure 3-5: Excess power and resistance ratio measured with Wire #2 under 100% H_2.

[30] It is not stated as to what occurred on application of power to the active wire, or why it was concluded that it could not withstand direct Joule heating.

[31] From inspection of Figure 3-5, it appears that at room temperature R/R_0 reduced to 0.75.

3.3.11 Stage 11. Hydrogen Unloading Cycle on Wire #2

Thirteen days after the first tests with Wire #2, the reactor was put under dynamic vacuum and heated by the inert wire to an internal temperature of 220 ºC. After a 14 hour period, R/R_0 of the active wire recovered to approximately 0.9.

3.3.12 Stage 12. Test 2 on Wire #2 (100 H_2, 48W to Inert Wire)

After this period the reactor was pressurized with hydrogen for the second time with Wire #2. As shown in Figure 3-6, the test showed a vast improvement in the speed of loading, with R/R_0 decreasing to 0.85 in only 33 minutes. Likewise, measurable amounts of excess power were measured in less than 6 hours.[32]

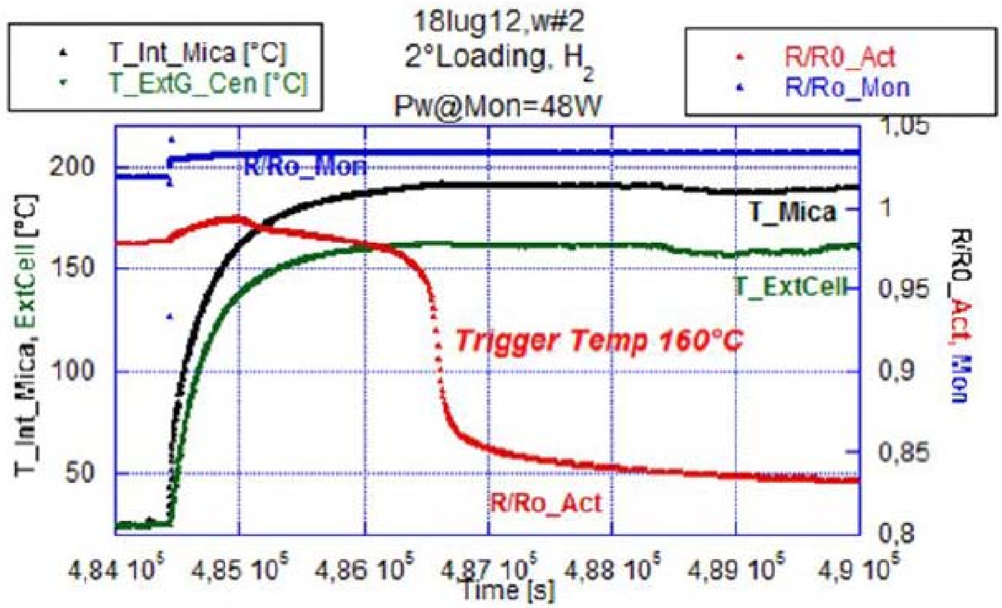

Figure 3-6: Shortened duration of Wire #2 resistance reduction during the second loading attempt.

Test 2 was discontinued on July 28 in order to package and ship the reactor to Austin, TX for the NIWeek 2012 public demonstration.

[32] Excess power was not presented for Test 2 with Wire #2.

3.3.13 Notes for the Austin Demonstration at NIWeek

Celani's ICCF-17 paper includes observations for the NIWeek 2012 demonstration. Despite the wire being shipped overseas and spending 8 days in regular atmosphere, Wire #2 retained an R/R_0 value of 0.81, nearly unchanged from the end of Test 2. During the 3 day demonstration with 48 W of applied power, maximum excess power was measured to be 21 W with direct heating, and 25 W with direct heating. It is noted that because the same power exchange constant was used for the NIWeek demonstration and experiments at INFN, excess power measurements may not be entirely accurate. Nevertheless, the trend of increasing excess power over time was reconfirmed.

3.4 Major Findings and Conclusions

The principal findings of the Celani et al experiments are summarized as follows:

- Reduction in resistance and excess heat production were observed with two different treated Constantan wires (Wire #1 and #2). This anomalous behavior was attributed to LENR.
- The amount of excess power generated by Wire #1 was about 5 W when the reactor was heated via the inert wire, and increased to 10 W when the reactor was heated directly via the active wire.
- Reduction in resistance in Wire #1 was onset when the reactor temperature rose above 125° C, whereas Wire #2 showed similar behavior above 160° C. Resistance ratios (R/R_0) of as low as 0.71 were achieved.
- Excess heat fluctuations appeared to be correlated with small changes in the resistance of the Constantan wire.
- Excess heat production appears to scale with increased reactor temperature, with increasing excess power generation occurring over the duration of the experimental run.
- The use of D_2 gas in place of H_2 resulted in excess heat production after an initial period of endothermic behavior. During the loading phase, tests with D_2 also resulted in bursts of X-ray and/or gamma-rays emissions.

- Celani's specific treatment of the wire enhanced, if not allowed for, anomalous behavior of the Constantan wire.
- With the "second generation" of wire preparation, a new/modified reactor, and new procedure, excess heat production could allow for reactor operation in the self-sustaining regime.

4 NI-Supported Demonstrations in August 2012

The encouraging results of Celani's experiments at INFN led to arrangements for a demonstration at NIWeek 2012 in Austin, Texas from August 6 to 9, 2012. A second demonstration then took place at the 17th International Conference on Cold Fusion (ICCF-17) in Daejeon, South Korea (August 20 to 24, 2012).

4.1 NIWeek Demonstration

The NIWeek demonstration was an opportunity to broadly communicate Celani's apparent LENR successes soon after the completion of his experiments in late July. NI provided support for both demonstrations, primarily in the form of:

- Two experienced engineers for setup and operation of the reactor/calorimeter
- A PXI experimental control and data acquisition platform and enhanced implementation of a LabVIEW control and measurement program
- Purchase of necessary supplies and ancillary equipment

Appendix E-1 contains a summary of equipment and supplies provided by NI.

4.1.1 Equipment and Materials

The experimental apparatus used in the demonstration was the same reactor/calorimeter described in Section 3.1, which Celani had brought from his lab at INFN along with other supporting equipment. Because Wire #1 broke in earlier experiments[33], only Wire #2 was used in the demonstration. Specific additions and enhancements made with the support of NI include the following:

- PXI Platform for experimental control and data acquisition, offering an improved form factor, simplified connection scheme, and enhanced synchronization capabilities.

[33] See Section 3.3.9

- Modular Instrumentation for the acquisition of measurement specific parameters without the need for auxiliary equipment and manual calibration.
- New LabVIEW control and measurement program with improved architecture and expanded functionality as compared to the previous implementation.

4.1.2 Procedure

Advance preparation began July 25, 2012 by NI staff and two other volunteer participants, Dennis Letts of Lettslab[34] and Scott Little of EarthTech[35], who provided support in the acquisition of connectors, gas, and other materials. NI System Engineer Chad Evans obtained components of the NI PXI system and NI Applications Engineer Brian Glass began development of a new LabVIEW control and measurement program.

Dr. Celani arrived in Austin, TX with his reactor/calorimeter on July 30, 2012, a week before the start of NIWeek. On August 1, the reactor/calorimeter apparatus was brought to Dennis Letts' laboratory, which is located near the NI campus in north Austin. For the next 5 days (up to 14 hours per day) Chad and Brian worked to interface the reactor/calorimeter with the PXI measurement system and complete the LabVIEW program. Assistance was also provided during that time by Dennis Letts and NI Applications Engineer Kyle Klufa.

The system was made completely operational August 5 at 10:09 pm. An initial test run was performed overnight until about 8:09 am, at which time the demonstration was transported to the Austin Convention Center for NIWeek 2012. Operation resumed at 10:57 am, in time for the conference opening mid-day on August 6. The demonstration was then run continuously until the morning of August 9 (9:49 am). A timeline of the NIWeek activities is included in Appendix E2.

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[34] Dennis Letts is an independent LENR researcher who has been conducting successful experiments in his "backyard" laboratory since the 1990s. He has provided experimental support to many scientists and engineers, and he has authored many papers on LENR observations, with emphasis on laser-induced reactions.

[35] Scott Little is an Experimentalist at EarthTech International, a privately funded Austin-based research organization exploring novel ideas in physics. Current interests include gravity, cosmology, and modifications of standard theories of electrodynamics, particularly as they may apply to space propulsion and new sources of energy. For more information, see http://www.earthtech.org.

The operating procedure for the NIWeek demonstration was similar to that of tests performed by Celani at INFN, with 100% hydrogen and the same power exchange constant ($C = 1/24.5$)[36] being used. Because of concerns that Wire #2 may break under application of direct power, heating was initially accomplished by applying 56.7W[37] to the inert wire. After about 48 hours, Celani removed power from the inert wire and applied 59.2W[38] to the active wire directly.

Two datasets were obtained during the NIWeek demonstration – the overnight test run (August 5, 10:09 pm to August 6, 8:09 am) and the demonstration run at the conference (August 6, 10:57 am to August 9, 9:49 am). Twenty-six parameters (shown in Table 4-1) were measured at 30 second intervals during the overnight test run and at 20 second intervals for the demonstration run. The demonstration run, referred to as “Run 6”, is most representative of Celani’s prior experiments, and is therefore what is analyzed in this report.

Date	Power Out
Time#	Act* Power In
T, Ext Glass Top Conn	Mon* Power In
T, Ext Glass Top Wires	Total Power In
T, External Ambient#	Total Power Ratio
T, External Glass Bottom Wires	Act Resistance
T, External Glass Center#	Mon Resistance
T, Internal Glass SS	Act Resistance Ratio#
T, Internal Cell Mica#	Mon Resistance Ratio#
T, Internal Glass	Pressure (Bar)#
Act* V (Voltage)	Pressure (Atm)
Mon** V (Voltage)	Excess Power*
Act I (Current)	
Mon I (Current)	

*Act = Active Wire
**Mon = Monitor Wire

Table 4-1. Parameters for data collection during the NIWeek Demonstration
(#Indicates Parameters Used in Plots for Analysis)

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[36] See Section 3.3.2

[37] Input power was measured to be 48W during the demonstration. 56.7W was the actual input power after a correction of +16%.

[38] Input power was measured to be 51W during the demonstration. 59.2W was the actual input power after a correction of +16%.

4.1.3 Observations and Interpretations

The NIWeek demonstration lasted a total of about 70 hours. The recorded data were subsequently plotted in a manner to facilitate easy comparison with Celani's results as described in Section 3. The data for seven parameters (indicated by "#" in Table 4-1) are plotted as a function of time of the experiment in two ways, referred to as "A" and "B". Both A and B include resistance ratios of the active and inert wires as well as reactor pressure. Plot A also includes temperature data, and Plot B includes excess power information. Plots A and B are shown in Figure 4-1A and 4-1B. The experimental results from Plots A and B are summarized as follows:

- Excess power was measured up to 18W[39], with an increasing trend over the duration of the demonstration.
- The R/R_0 values for the active wire (Wire #2) started at about 0.79 and increased slightly to 0.84. R/R_0 of the monitor wire increased slightly above 1 as expected with heating.
- The increase in excess power seen after 48 hours could be attributed to a 2.5W increase in input power, applying power to the active wire, or a combination of the two.
- Pressure decreased over the duration of the experiment from about 5 to 2 Bar.
- Fluctuations in external glass temperature (and consequently calculated output power) correspond to changes in the ambient temperature in the convention center.

[39] After input power correction of +16%.

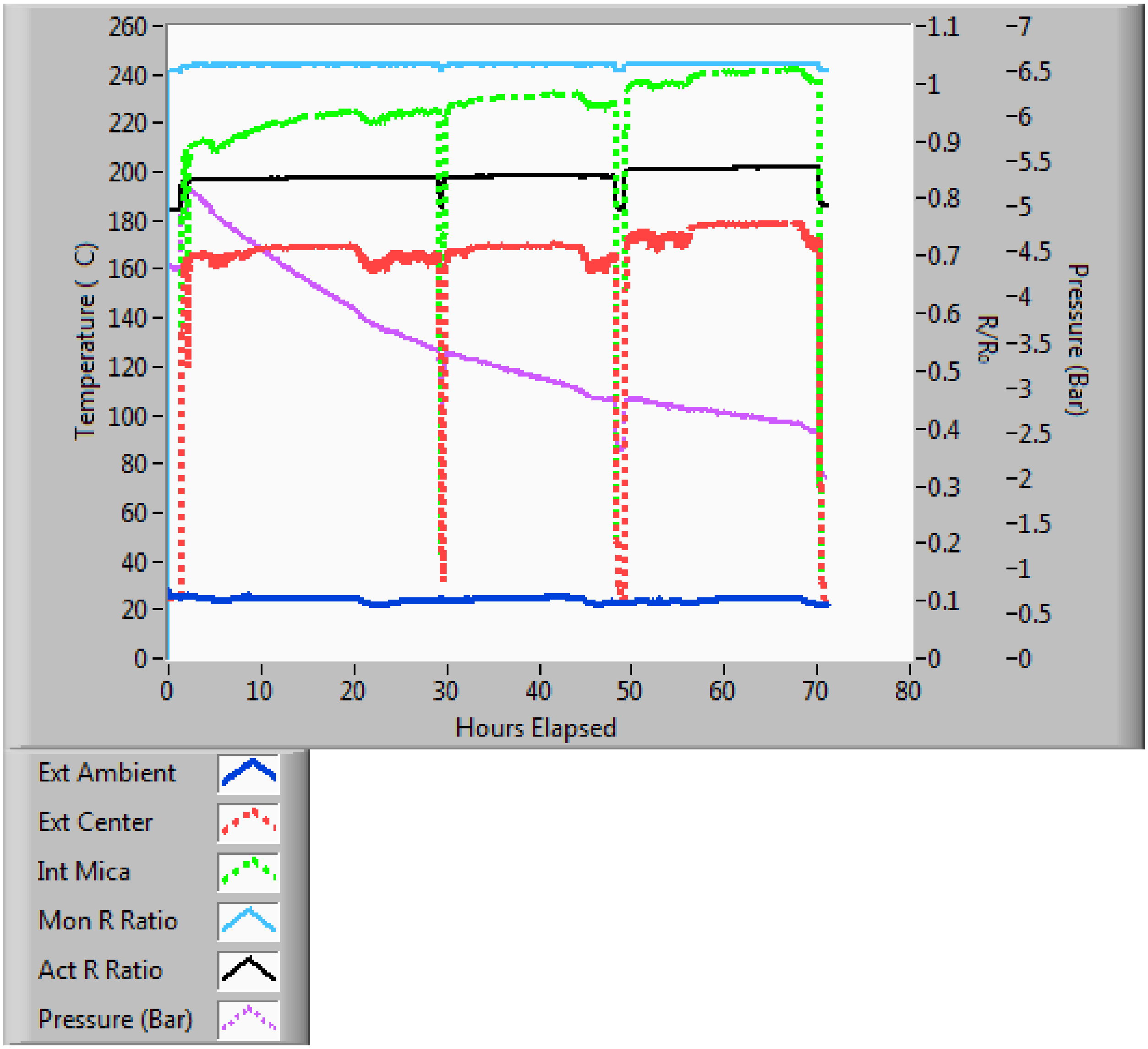

Figure 4-1A: Data Plots for NIWeek Demonstration:
Temperatures, Resistance Ratio, and Pressure ("Run 6")

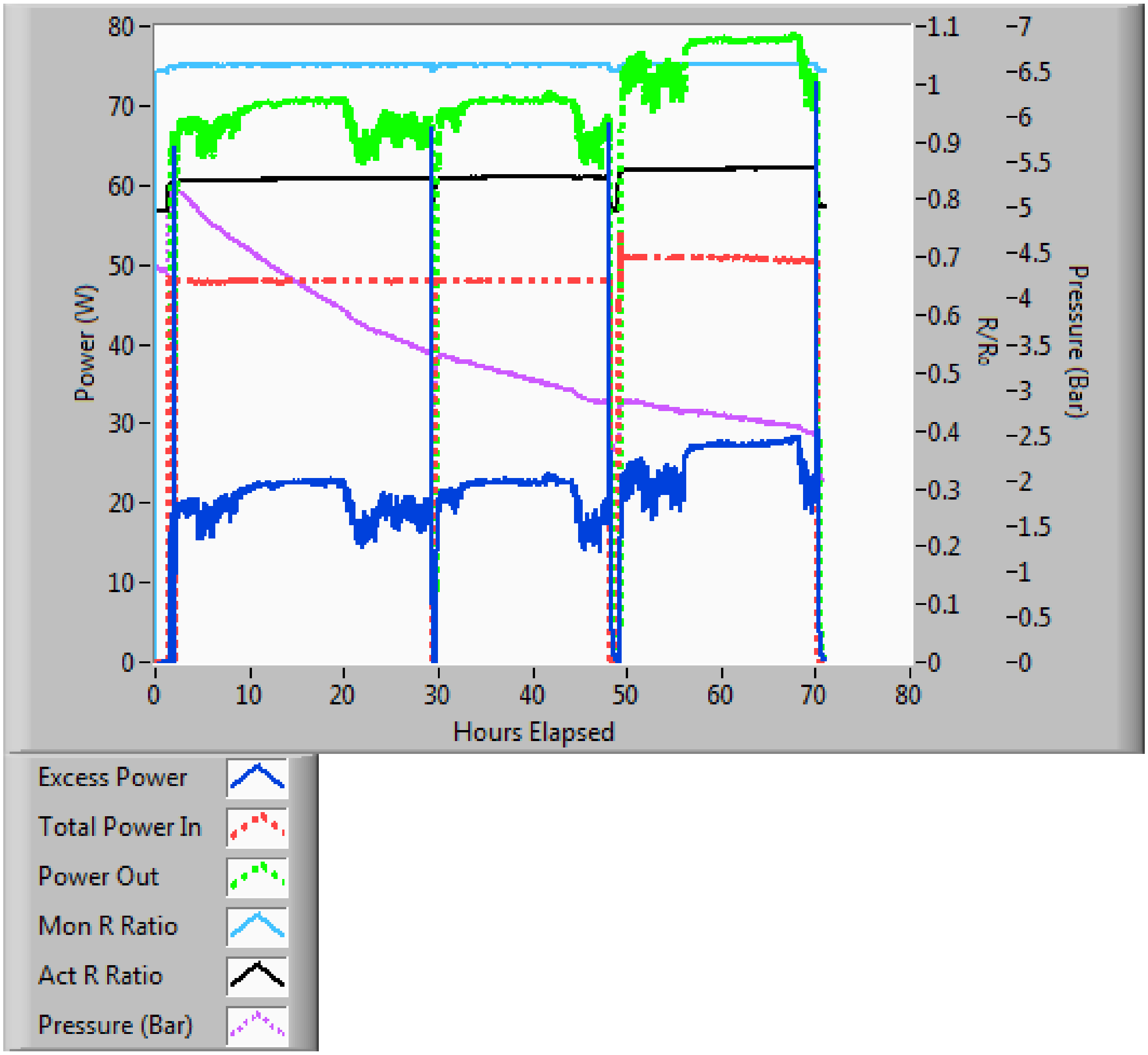

Figure 4-1B: Data Plots for NIWeek Demonstration:
Power In, Power Out, Excess Power, Resistance Ratio, and Pressure ("Run 6")

4.1.4 NIWeek Summary

The NIWeek demonstration was successful in building upon Celani's pre-demonstration work at INFN, despite the fact that it took place on a considerably compressed timeframe. Excess power production observed by Celani in his earlier experiments was not only reproduced, but was shown to be enhanced even after correction of input power in post analysis. R/R_0 was confirmed to be significantly lower than 1, showing the effects of hydrogen loading into the Constantan wire (Wire #2).

4.2 ICCF-17 Demonstration

The positive results from the NIWeek 2012 demonstration were determined to warrant further exhibition of the apparatus at ICCF-17 in Daejeon, Korea. The experimental apparatus and associated equipment were shipped by air freight from Austin, TX to the NI office in Seoul, Korea and then transported by ground transportation to Daejeon. The reactor/calorimeter was initially set up at KAIST[40] facilities and then moved to the Daejeon Conference Center, where ICCF-17 was held.

4.2.1 Equipment and Materials

The experimental apparatus and associated measurement and control systems were unchanged from the NIWeek demonstration.

4.2.2 Procedure

Prior to the start of ICCF-17, Brian Glass and Dr. Celani performed a calibration to ensure the validity of the power exchange constant C[41]. For a period of 45 minutes, 57.6W of power was applied to the active wire. During this time, the external glass temperature of the reactor rose, eventually arriving at a characteristic stable value. During this heating phase, Celani changed the value of C until the excess power was measured to be 0. If no excess power was yet being

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[40] Korea Advanced Institute of Science and Technology

[41] See Section 3.3.2

produced, this value of C would represent the correct power exchange constant of the reactor. It was found that the power exchange constant that produced 0 measured excess power was within 2% of the original value $C = 1/24.5$. For consistency with previous experiments, this original value was used during the demonstration run. A single run was performed at ICCF-17, which is analyzed below.

4.2.3 Observations and Interpretation

As in the NIWeek demonstration, seven parameters were displayed as a function of time in two plots – A and B (Figures 4-2A and 4-2B). The following observations may be made from these two plots:

- Excess power was measured up to 9.5W[42], with an increasing trend over the duration of the demonstration.
- The R/R_0 values for the active wire (Wire #2) started at about 0.79 and increased slightly to 0.86. R/R_0 of the monitor wire increased slightly above 1 as expected with heating.
- Pressure decreased over the duration of the experiment from about 7 to 2.5 Bar.
- Fluctuations in external glass temperature (and consequently calculated output power) correspond to changes in the ambient temperature in the convention center.

[42] After input power correction of +16%.

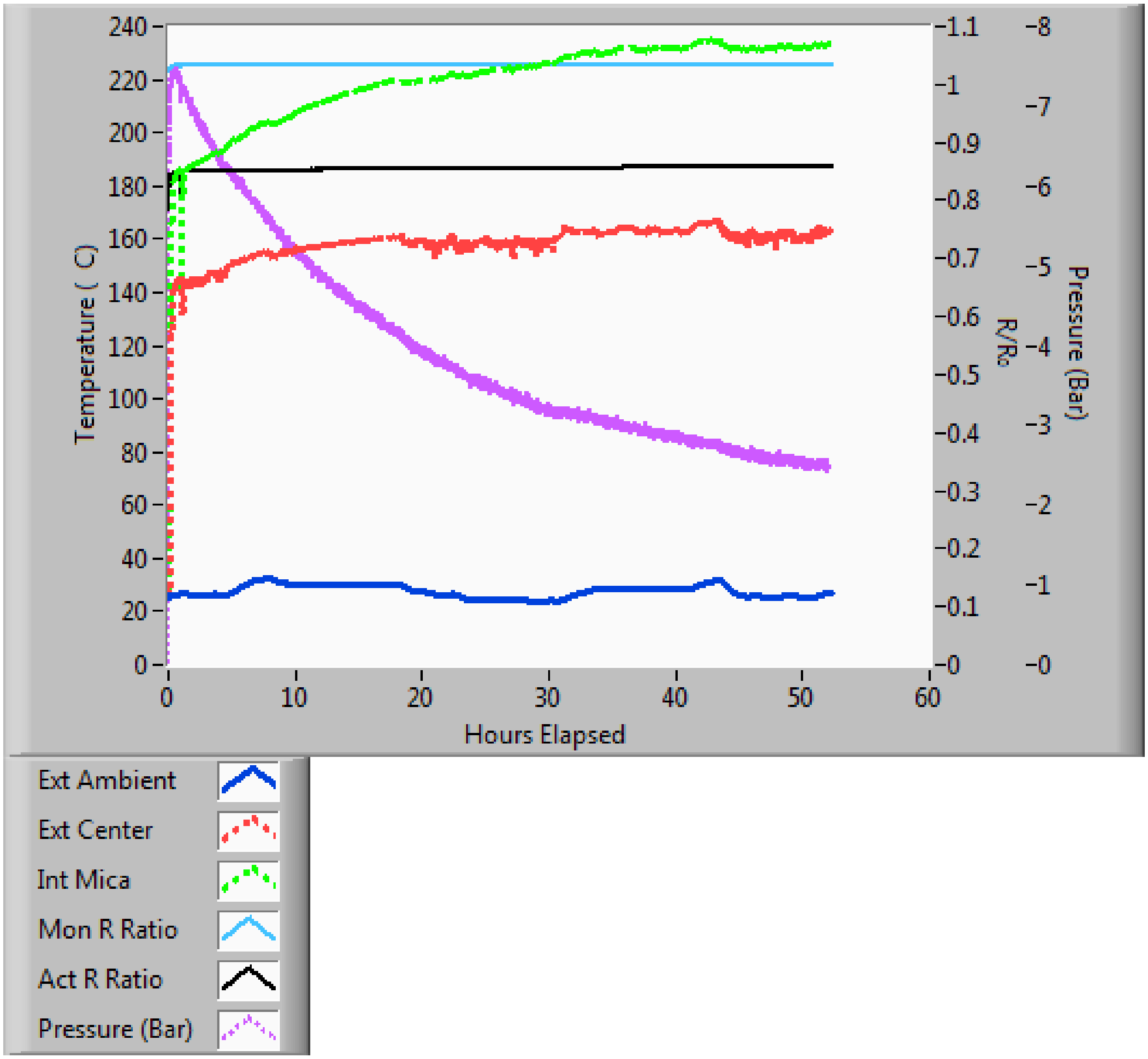

Figure 4-2A: Data Plots for ICCF-17 Demonstration:
Temperatures, Resistance Ratio, and Pressure (“Run”)

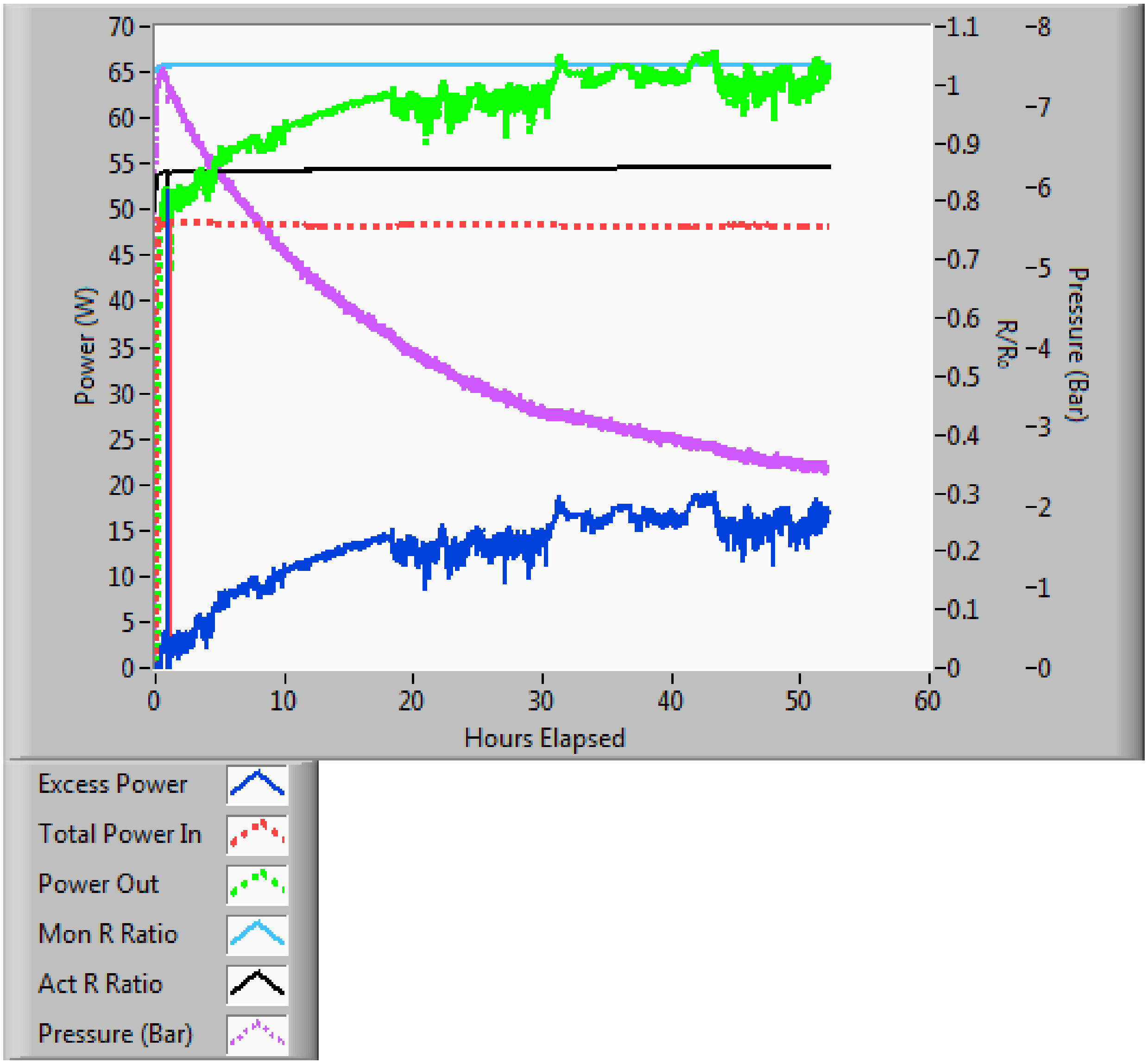

Figure 4-2B: Data Plots for ICCF-17 Demonstration:
Power In, Power Out, Excess Power, Resistance Ratio, and Pressure ("Run")

4.2.4 ICCF-17 Summary

The ICCF-17 demonstration benefitted from experience gained during the NIWeek demonstration. Overall, the results were similar to what was seen in the NIWeek demonstration, but with two notable differences: Excess power production was reduced from the NIWeek demonstration and effects of the ambient environment played a larger role in the fluctuation of measured parameters, as seen from the above plots.

4.3 Conclusions from the Two Demonstrations

The two demonstrations appeared to generally corroborate the findings from Celani's pre-demonstration experiments. Excess energy production was shown to be enhanced during the NI supported demonstrations for undetermined reasons. Celani speculated that the strong fluctuations in ambient air conditions may have contributed to the enhanced effect. Otherwise, differing conditions introduced by the new control and measurement system could also have changed the behavior of the system. Overall, sufficient evidence of LENR activity was observed to continue investigation, particularly into the possibility of creating a self-sustaining reaction.

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5 Post-Demonstration Experiments at INFN

Following the NIWeek and ICCF-17 demonstrations, NI continued to support Dr. Celani's work by providing assistance with further investigation into the possibility of operating the reactor in the self-sustaining regime. NI Applications Engineer Brian Glass provided on-site support at Celani's INFN laboratory in Frascati, Italy for this effort.

The primary objective of the initial INFN experiments was to discover if the reactor/calorimeter would operate as a self-sustaining system with proper thermal isolation from the outside environment. As noted, this was motivated by the large amount of excess power measured during the NIWeek 2012 and ICCF-17 demonstrations. During his presentation at ICCF-17 in August, Celani announced that he would attempt a self sustaining reaction over the next two weeks. It was thought that if the amount of excess power produced by the device exceeded the power that escaped to the outside environment, the device would continue to operate with no input of electrical power.

A secondary objective, which emerged after the first objective had been addressed, was to determine if the Constantan wire could be de-loaded and reloaded with hydrogen as shown previously once before. The INFN experiments were therefore performed in two stages corresponding to the abovementioned objectives.

5.1 Equipment and Materials

The reactor/calorimeter and associated equipment used in the demonstrations were also used in both stages of INFN experimentation. In an attempt to better thermally isolate the system from ambient air, Celani added several layers of reflective and insulating materials to the outside of the reactor. From the inner to outer surface the layers added were:

1. Reflective material
2. Thermal insulating material (0.07W/m*K)
3. Reflective material
4. Thermal insulating material (0.07W/m*K)

5. Reflective material
6. Black polyethylene (6 thin layers)

With the addition of thermal isolation, the total length of the reactor increased from 32cm (30 cm glass tube plus stainless steel flange) to 45 cm. The circumference was increased to approximately 30 cm. The reflective layers served the purpose of containing any radiation that would otherwise escape the borosilicate reactor walls, while the thermal insulating material acted to reduce the amount of dissipative heat lost to the outside air. The black polyethylene provided what was assumed to be a true black body source from which approximate calorimetric measurements could be made.

The addition of insulating materials to the reactor/calorimeter resulted in a modified power exchange constant C. Because the reactor was not recalibrated with these modifications, output power and excess power measurements from Stages 1 and 2 are invalid and therefore not included.

To perform rudimentary calorimetry, a temperature profile of the outer surface was measured[43] during some of the experiments. These data were later used for estimating the conductive and convective heat loss from the system.

5.2 Stage 1. Procedure: Self-Sustaining Reactions

Over the period of September 4 to 10, 2012 experiments were performed using the modified reactor with the goal of observing continued heat generation in the absence of applied power. The procedure consisted of supplying a constant input power to the active wire until the system reached thermal equilibrium. Power was then discontinued or stepped down and the internal temperature of the system was observed. If the reactor were to maintain a constant temperature after this period, a self-sustaining reaction would be achieved. Anomalous heat generation could also be implied if the system cooled more slowly than predicted by a traditional system going toward thermal equilibrium.

[43] Using an IR laser thermometer

5.3 Stage 1. Observations and Interpretation

Initially, hydrogen was supplied to the reactor to a pressure of approximately 3.5 Bar. Over the course of the next several days, power levels of approximately 17.4, 23.2, and 29W[44] were applied to the active wire. After discontinuing power for each test, the system characteristically cooled to equilibrium at room temperature with no indication of achieving a self-sustained reaction.

During the course of the testing, the pressure of the reactor steadily declined to about 2 Bar. For the weekend long test starting on September 7, the reactor was re-pressurized to 3.5 Bar. Upon return on September 10 after a weekend, the reactor pressure had again dropped to 2 Bar.

For each of the trials with varying power levels applied to the active wire, the system appeared to characteristically cool to room temperature with no indication of achieving a self-sustained reaction. An example of the results of the Stage 1 of the experiment is shown in Figure 5-1 (“INFN Run 9-5”).

[44] These values were the actual input power levels after a correction of +16%. Input power was measured to be 10, 15, and 25W during testing.

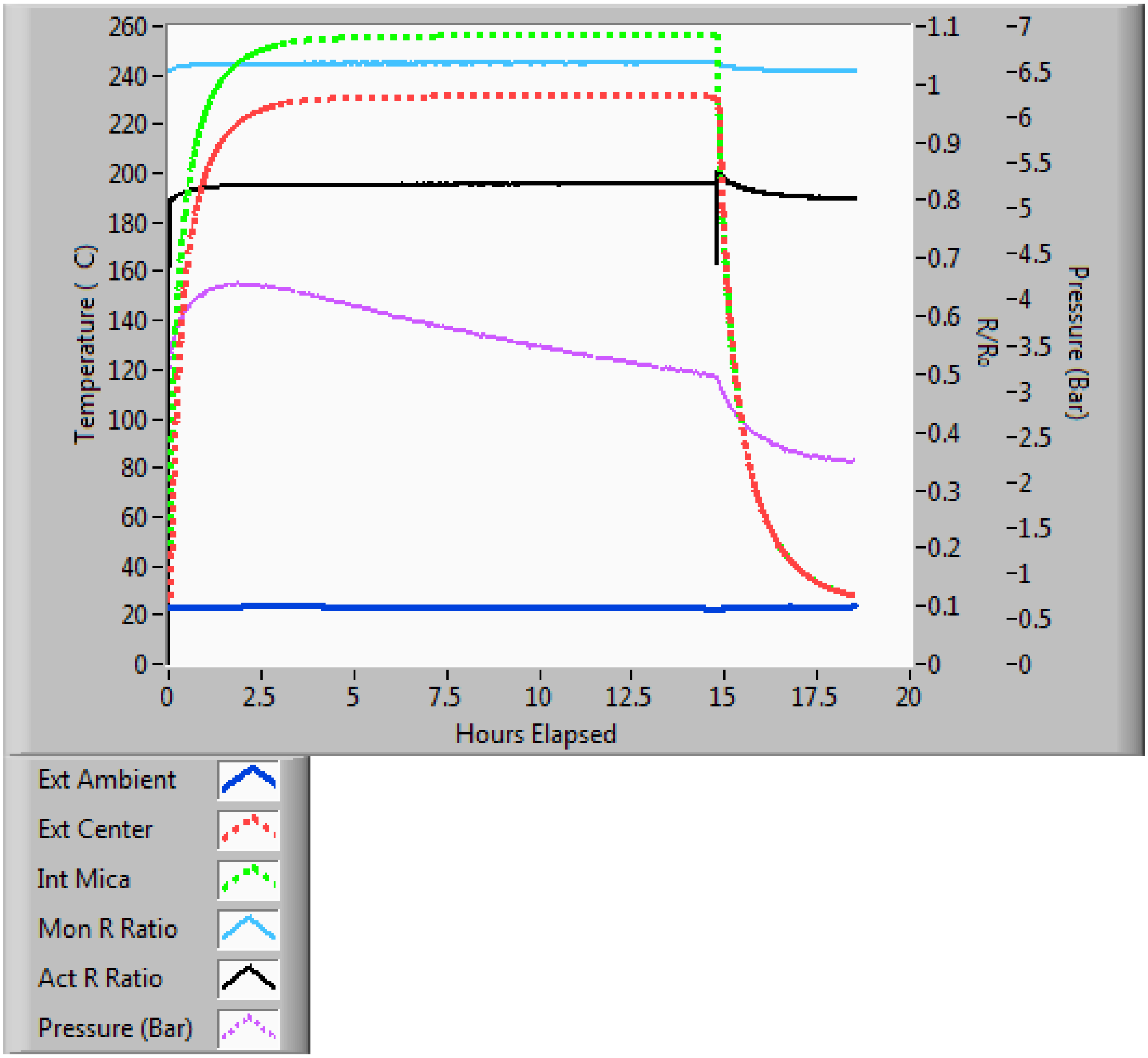

Figure 5-1: Data Plots for INFN Self-Sustaining Reaction Experiment:
Temperatures, Resistance Ratio, Pressure ("INFN Run 9-5")

5.4 Stage 2. Procedure: Impact of Hydrogen Loading on Electrical Resistance

Because the reactor showed no indication of a continued reaction in Stage 1, experiments were performed to determine if Wire #2 would undergo a third hydrogen loading cycle.[45] That is, if the wire's resistance would increase after removing hydrogen, then decrease again upon re-exposure at elevated temperatures.

To de-load the wire of hydrogen, power applied to the active wire was continued at 11.6W and the reactor was allowed to continue depressurizing. Just before reaching atmospheric pressure, the seals failed and the wire was exposed to outside air. After 24 hours, the power was stepped up to 17.4W for another 24 hour period, after which power was discontinued and the reactor cooled to room temperature.

In order to evacuate any remaining hydrogen, and to aid in the removal of contaminants from the wire surface, the reactor was subjected to dynamic vacuum with 11.6W of power applied to the active wire. After 16 hours under vacuum, power was discontinued and the reactor was allowed to cool to nearly room temperature. Hydrogen was then supplied to the reactor at 5 Bar, followed shortly thereafter by the application of 23.2W to the active wire.

5.5 Stage 2. Observations and Interpretation

With 11.6W of applied power, the resistance ratio of the active wire rose from 0.80 to 0.90. The onset of this dramatic increase was correlated with the reactor's rapid drop in pressure. At this point, the combination of current, high temperature, and exposure to outside air led hydrogen to evacuate the wire, thus causing the wire resistance to increase.

Increasing the applied power to 17.4W increased the wire temperature further, thereby setting off another period of rapid de-loading. This caused the wire resistance ratio to increase further to 0.94 as shown in Figure 5-2 ("INFN 9-7"). After 48 hours at room temperature, the resistance ratio was measured to be 0.96.

[45] Two loading cycles had been perform with Wire #2 prior to the NI supported demonstrations. See Section 3.

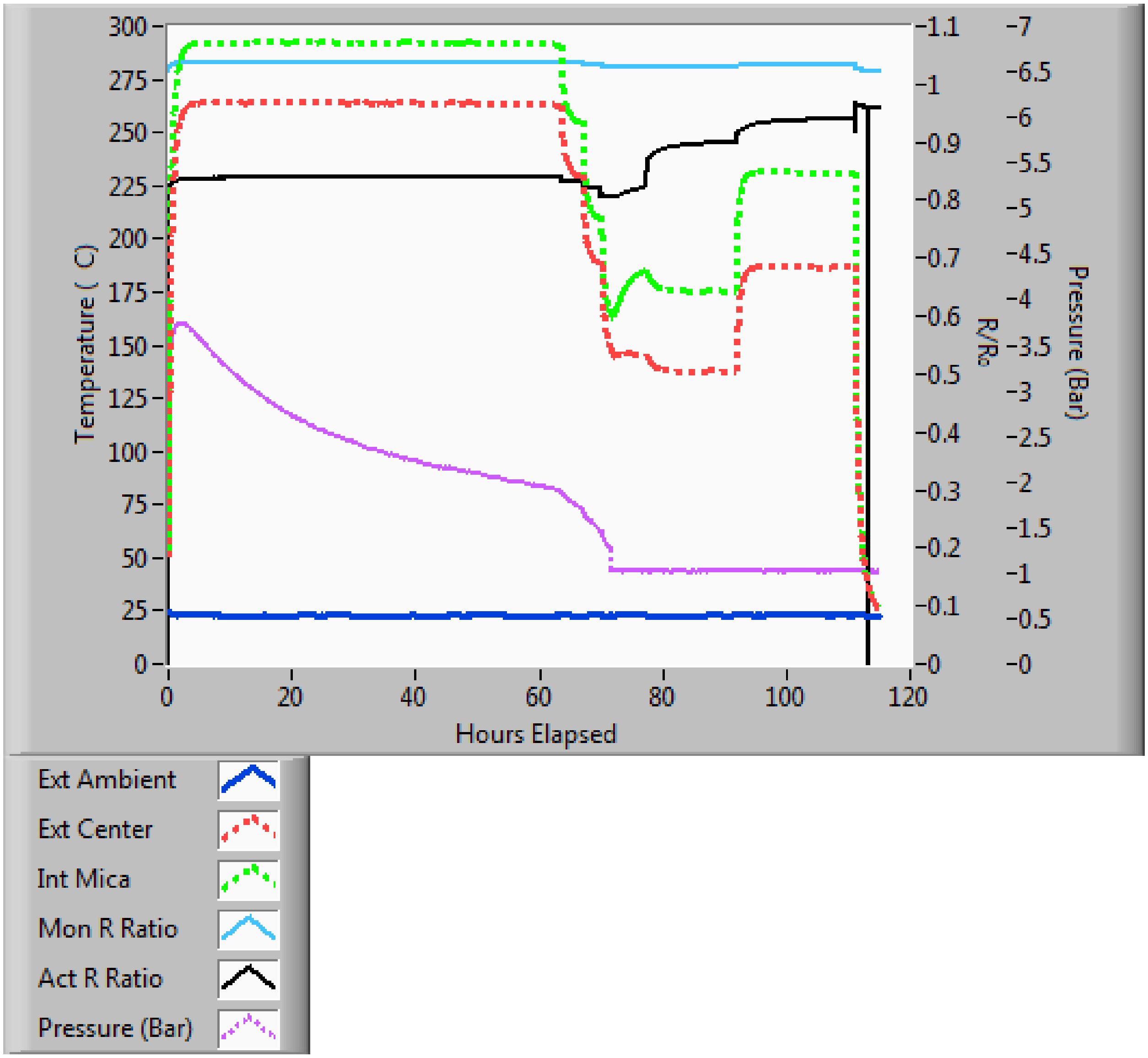

Figure 5-2: Data Plots for INFN Self-Sustaining Reaction Experiment:
Temperatures, Resistance Ratio, Pressure (“INFN Run 9-7”)

Under dynamic vacuum and elevated temperatures, the resistance ratio of Wire #2 reached 0.98 as most of the residual hydrogen was evacuated from the wire.

After pressurizing the reactor with hydrogen and applying power to the active wire, its resistance immediately began to decrease rapidly. After a few hours the resistance ratio had reached approximately 0.89 as seen in Figure 5-3 (“INFN 9-12, Run 2”), thus demonstrating that the wire had been successfully loaded with hydrogen.

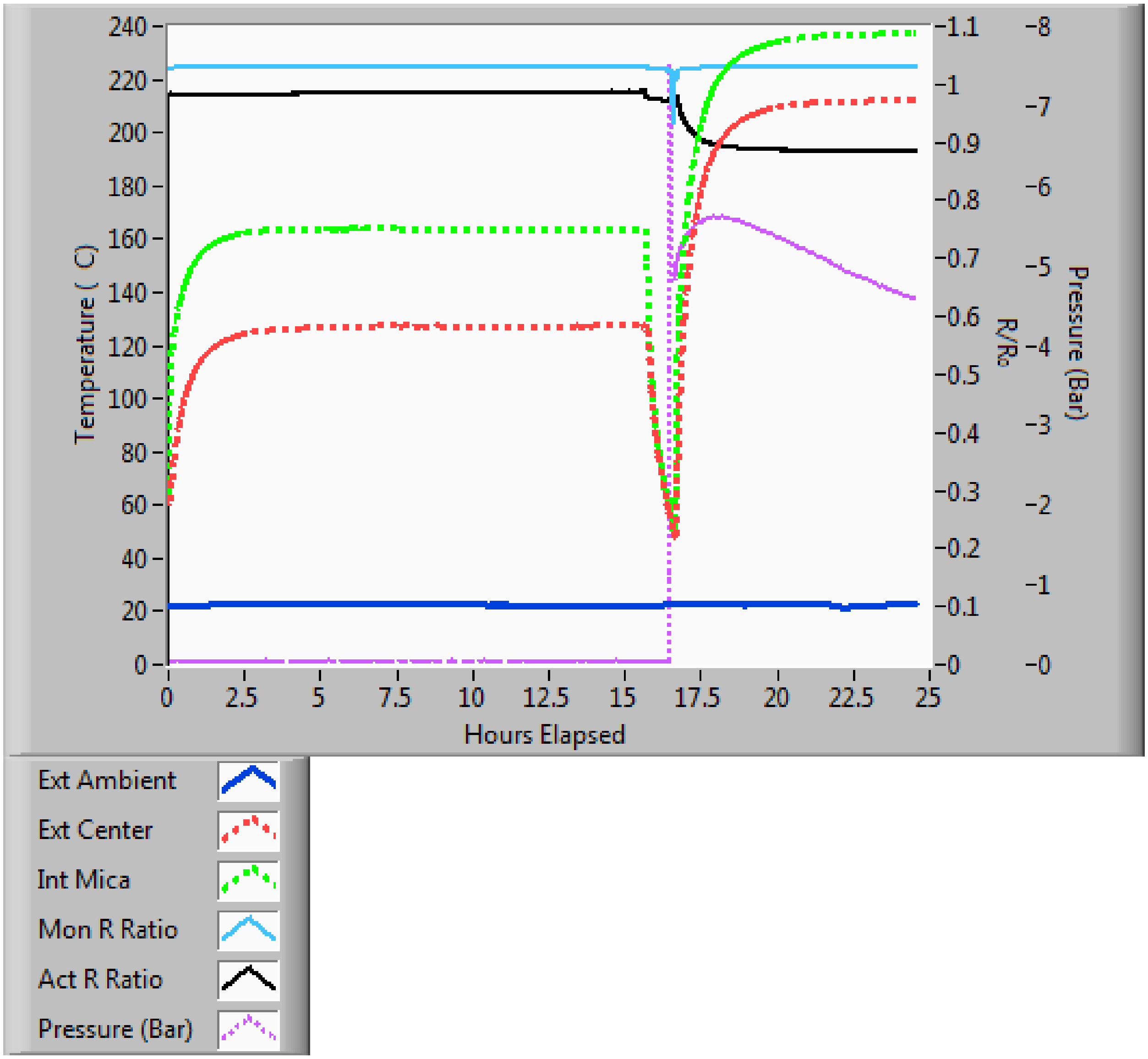

Figure 5-3: Data Plots for INFN Self-Sustaining Reaction Experiment: Temperatures, Resistance Ratio, Pressure ("INFN Run 9-12, Run 2")

5.6 Conclusions from Post-Demonstration Experiments

The attempts to produce a self-sustaining reaction during Stage 1 were unsuccessful, as evident by the lack of continued heat produced after discontinuing power to the active wire. This result could be attributed to the fact that any excess power produced by the system was quickly dissipated to the outside environment. To improve isolation and thus the chances of achieving a self-sustaining reaction, a material was obtained with an even lower thermal conductivity than that of air ($k < 0.024$). Experiments using this material were scheduled after Brian Glassdeparture.

Success was achieved in Stage 2 by reloading the Constantan wire for the third time. De-loading of the wire resulted in its resistance increasing to 98% of the initial value, while reloading decreased its resistance to 89 % of its original value. This lowered resistance was not as considerable as the first loading value of 79%, however it is not known whether higher heating or additional treatment would yield improved results.

In general, the post-demonstration results at INFN provided additional evidence that Celani's treated Constantan wires show anomalous effects when exposed to heat and hydrogen gas. This conclusion is further substantiated by the fact that these results were reproduced with the use of two independent measurement systems.[46]

An additional goal of the INFN experiments was to allow Celani and his colleagues to continue operation of the improved measurement system autonomously with limited technical support from NI. Training on the use and upkeep of the system was provided during the experiments, as well as system schematics and LabVIEW code documentation.

[46] It should be noted here, that in Phase 2 of the post-demonstration experiments, it was found that input power measured by the PXI system was lower than the value applied to the wire due. This was found to be due to an incorrect setting in the power supply and was later corrected. All power measurements quoted in this report have been corrected to display their actual values.

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6 Overall Summary and Conclusions

Dr. Francesco Celani claims to have produced LENR using specially treated Constantan (nickel-copper alloy) wires and hydrogen gas. The anomalous effects attributed to LENR are excess power production (excess heat) and a reduction in the electrical resistance of the wire.

These effects were replicated in two NI supported demonstrated at NIWeek 2012 in Austin, TX and at ICCF-17 in Daejeon, Korea. Additional NI-supported experiments at INFN after the demonstrations did not accomplish the primary objective of obtaining a self-sustained reaction. However, hydrogen loading of the wire was reconfirmed, as seen by corresponding changes in resistance.

The demonstrations of Celani's experiments described in this report, as well as the subsequent post-demonstration work at INFN, were well-advised at each stage of the sequence of activities based on the information available at the time.

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7 Guidance for Future Experimental Design

Based on the experimental reviews in this document, there was enough evidence for NI to conduct a survey of independent experiments attempting to verify Celani's findings. This document, along with the findings of other investigators, may be used to guide experimental planning for the future.

A step-wise approach appears to be an important premise for future experiments – Celani's experiments should first be replicated, with any reproduction efforts coming only from incremental changes of experimental variables.

Stefano Concezzi, NI Vice President of Scientific Research and Lead User Program, has obtained samples of the treated Constantan wires from Celani that may be used for future experiments.

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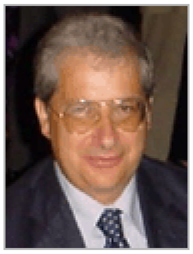
Appendix A. Francesco Celani Biographical Information



CV Francesco CELANI (CERN 22 March 2012)

*Francesco Celani, born in Rome-Italy (8 February 1951). Italian citizen.

* Married (Misa Nakamura, chemistry co-worker in LENR since 1994), 2 daughters.

* Degree in Experimental Physics from Physics department of University “La Sapienza”-Roma, on December 15, 1975 with marks 110/110. * Thesis (just after degree, published on NIM) at Frascati National Laboratories (LNF) of National Institute of Nuclear Physics (INFN) with argument applied cybernetics: electronic nuclear detectors used on nuclear accelerator (e+e- 3.1GeV Collider, ADONE).

* Staff member of INFN-LNF since July 1, 1976 (Researcher, experimental, in Physics).

* (1976-1983) Joined the NA1 experiment at CERN-SPS. I was involved, mainly, on the design of the first (in the world, at that time) ultra-compact, remotely controlled, High Voltage generators for both Multi Wires Proportional Chambers (MWPC) and Photo Multipliers (PM). The instruments was named FRAMM 77 System and largely used also in USA (FERMILAB) and France (Saclay). Developed an ultra-fast, variable repetition rate and power, pulser to calibrated, by short duration (few ns) light pulses the PM: discovered the so-called “rate effect” on PM. Because discovering of such unexpected effects that could produces fake signals in specific operating points of PM, the industries developed (since 1982) a new family of PM called “rate effect free”. Developed also some, fast, low-noise charge pre-amplifiers for silicon detectors used in the front-end of the SPS beam (350GeV).

* (1983-1987). After the experience with silicon detectors (sensitivity of about 1e-/3.6eV energy released), I decided to study innovative detectors having an equivalent sensitivity thousand times larger. So I started to study Superconducting Tunnel Junctions (Ni-Pb; T=4.2K), in collaboration with Salerno University, having an intrinsic energy gap of only few meV. Found some quite intriguing results using thick junctions on 1985. One of these were contaminated (by chance) from several other elements and showed behavior similar to superconductivity even at temperature as large as 77K (LN2). It was stated a multi-disciplinary Commission in order to clarify the origin of such signals. Unfortunately the results were rejected, a-priori, because in disagreement with the BCS model/theory (i.e. max temperature of superconductivity stated at 32K). One year later Bednorz and Muller (from IBM, Zurich), independently (and starting from

different points of view), found similar results in Cuprate Oxides mixed with rare-hearts and got Nobel Prize.

* (1985-1986). In parallel with superconducting studies, I joined a small group aimed to measure the neutron flux (expected very low) inside the Underground Gran Sasso Laboratory, at that time under construction. The experiment, although very adverse environments, was really successful and the final documents about the "nuclear qualification" of such Laboratory come also from our measurements of neutron flux (about 1000 times lower than sea level).

* (1987-1992). After the results of Muller, and just later of Chu (in USA), I started the developing of new procedures to improve the quality of High Temperature Superconductors, especially type YBCO. I get success and patented (January 1988) a new procedure based on Ozone annealing (instead of usual Oxygen) and synthesis by pyrolysis of citrates (instead of usual dry mixing of powders). Specifically, such last procedure produces materials at sub-micron dimensions that seem to be a key factor of their (excellent) performances. Later, because so called Cold Fusion studies, some of such materials were forced to absorb some amounts of both Hydrogen or Deuterium. Some of such sample showed a superconducting transition temperature as high as 101K, i.e. 10K larger than the 91 K of usual YBCO. The value of 101K is, still now, the largest reported for such materials.

*(1989-2012). Involved in the Cold Fusion studies, now re-named LENR (Low Energy Nuclear Reactions). I was involved, at the beginning, in the search of neutrons. We found some, at low intensity, inside the Gran Sasso Underground Laboratory, mainly during strong non-equilibrium transitions. The discovery of non-equilibrium was the key aspect of almost all my research in LENR. We studied both usual Pd-D2O electrolytic systems and (from 2003) gaseous environments. The last were based both on Pd-D2 gas system with thin and long wires (up to temperatures of 550°C) and $Ni\text{-}H_2$ (up to temperatures of 900°C). Studying electrolytic system I found even a new species of bacteria living in the heavy water. It was named Ralstonia detusculanense and his used even to recover/concentrate radioactive Co and Cs from spent nuclear fuel.

In some of previous experiments I found enough scientific evidences to convince me to work in such (controversial) field of research up to now.

Source: http://www.iccf17.org/popup/bio_5.htm

Appendix B. Frascati Research Center Overview

Francesco Celani's laboratory is at INFN facilities in Frascati, Italy. A description of the Frascati Research Center (also the home of ENEA) is shown below[47].

The Frascati Research Centre of ENEA is one of the major research centers – at the national and international levels – where R&D activities are focused on nuclear fusion, laser technologies and particle accelerators. The Centre's activities also include characterization and protection of the environment.

The Research Centre is located in Frascati, a little town in the province of Rome, along the State Road Tuscolana at 20 km from Rome. It spreads all over a surface of 150,000 square meters hosting 90 buildings endowed with plants, laboratories and offices.

The Centre accounts for 450 staff-employees and daily hosts 150 Italian and Foreign guests: fellows, bachelor students, visitors, and employees from various agencies, universities and other public and private institutions.

Frascati Research Centre. Aerial view

[47] Extracted from description of ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development). Source: http://old.enea.it/com/ingl/center/Frascati.pdf.

FRASCATI RESEARCH CENTRE AND ITS LOCATION AREA

The territory of Frascati, and that extending nearby Monteporzio, and part of South-East of Rome hosts other important research institutes a few kilometers far away from each other: INFN (National Institute of Nuclear Physics), ESA-ESRIN (ESA Centre for Earth Observation), INAF (National Institute for Astrophysics), CNR (National Research Council), Tor Vergata University, the Astronomical Observatory of Rome-Monteporzio.

The Frascati Centre carries on scientific, education and dissemination activities in strict collaboration with the above research institutes. In particular they co-organize seminars, guided visits, exhibitions and conferences within several scientific events such as *La Settimana della Cultura Scientifica e Tecnologica* (Science and Technology Week) sponsored by the Italian Ministry of Education, *ScienzaOrienta* (Science Orientation Exhibition) promoted by Tor Vergata University's Faculty of Mathematics, Physics and Natural Sciences, the *Researchers' Night* promoted by the EU, just to mention a few.

HISTORY

Frascati National Laboratories were set up in 1956-1957 under the technical and scientific direction of INFN (National Institute of Nuclear Physics) and with the funding and staff of CNRN (National Committee for Nuclear Research). The realization first of the Electro-synchrotron in 1959 and subsequently of ADA and ADONE – other elementary-particle accelerators – as well as the very-high-level scientific activities carried out in the sector of high-energy physics began to make the Laboratories very well-known worldwide. The studies on the basic and technological activities related to cryogenics, electronics, magnets, computing and plasma physics consolidated the excellence of the Laboratories within the international scientific community.

In 1960 CNRN changed its name into CNEN (National Committee for Nuclear Energy). In the Frascati premises and in collaboration with EURATOM, CNEN sets up the Laboratories for Ionized Gases. The design and building of the large toroidal-geometry FT (Frascati Tokamak) machine for magnetic-confinement thermonuclear fusion did coincide with the definitive separation between CNEN and INFN in 1975.

In 1982 CNEN was transformed into ENEA (National Committee for Research and Development on Nuclear Energy and Alternative Energy Sources). In 1991, ENEA acronym changed its meaning into the current Italian National Agency for New Technologies, Energy and the Environment. In the now Frascati Centre, the staff expertise and skills broadened to include superconductivity, molecular spectroscopy, lasers and innovative accelerators. For the first time in Italy a color centre laser (1979), an excimer laser (1980), and a free-electron laser (1985) were developed and set up; from 1985 on, high-power excimer lasers have been developed for scientific and application purposes. In 1988 the ABC laser facility was set in operation and in 1989, the advanced magnetic-confinement FTU (Frascati Tokamak Upgrade) machine was set up. In the same period the laser-assisted isotope enrichment technology was developed. The new know-how achieved in this field has been applied in several subsequent programs, such as, for instance, PNRA (the National Program of Research in Antarctica). Until the end of the 90s Frascati Research Centre was the coordinating nucleus of the environmental monitoring network shared by various ENEA's Research Centers.

ACTIVITIES

The activities regarding the following sectors:

- Nuclear Fusion
- Advanced Physical Technologies
- Characterization and Environmental Protection

NUCLEAR FUSION

Activities on nuclear fusion are concerning the study of fusion physics and development of appropriate technologies for the design and setting-up of fusion reactors.

As far as fusion physics is concerned, theoretical studies and experiments are carried out on magnetic confinement of ionized gases (plasmas) of thermonuclear interest by means of the Tokamak FTU (Frascati Tokamak Upgrade) machine. Such machine is designed to heat plasmas through high-power microwaves and its high magnetic fields allow for the confinements of high-density plasmas. Additional research is carried out on inertial confinement by means of ABC laser facility, operated by a neodymium laser capable of generating high-power pulses.

As to fusion-related technologies and engineering, the activities are focused on the design of new experimental machines and development of specific technologies targeted at setting up fusion reactors. Of particular interest are: research on special radiation- and high-temperature-resistant materials; the building of magnets operating at liquid nitrogen temperature and superconducting magnets; the development of fusion-reactor engineering; the studies on material irradiation, especially as to neutronic flux effect. Frascati Research Centre hosts one of the major Italian centers for superconductivity, the base technology for the building of large magnets of future fusion reactors.

Fusion activities are carried out within the European Fusion Program and the *EURATOM - ENEA Fusion Association*, where ENEA gives its considerable contribution to: the JET European Tokamak experiments; the international project to design and build the ITER experimental fusion reactor; R&D activities for DEMO fusion reactor; other international collaborations.

ADVANCED PHYSICAL TECHNOLOGIES

Activities in the field of optical and electro-optical technologies are focused on the development of sources, components and systems. As to laser sources, ENEA has achieved very important results by developing and building internationally-acknowledged laser facilities, such as: excimer lasers, color center lasers, Raman scattering lasers, free-electron lasers (FEL) with emission in the UV, visible, near and far (THz) infrared region. In addition to the above, a laser-plasma soft X-ray source has been developed.

With regard to components, the most interesting technologies developed are those targeted at building different kinds of metal optical components (spherical and aspherical mirrors, and diffraction reticules).

In the field of systems, the efforts are mainly focused on applications for: environmental protection (laser detection applied to air, water, soil and vegetation), material photochemistry and phototreatment, laser diagnostics of industrial processes, and metrology and non-perturbative diagnostics (Speckle interpherometry, fiber optic Bragg grating sensors FBG), which can also be applied to the conservation of cultural heritage.

Other research activities are related to low-temperature physics and cryogenic technologies, in which Frascati Centre can boast remarkable expertise in the development of hydrogen and deuterium technology within plasmas. As to electron and proton accelerators, R&D activities are targeted at developing industrial applications such as produce sterilization, medical applications like cancer therapy and radiochemistry, scientific applications such as the study of materials damage, etc.

All these technologies find their application in many sectors: environment, biomedicine, industry, telecommunications, microlithography, nanotechnology, photonics, aerospace sensoristics, and “security”.

CHARACTERISATION AND ENVIRONMENTAL PROTECTION

Activities are focused on atmospheric pollution from industrial and anthropogenic sources, and consist in planning, organizing and carrying out monitoring campaigns on atmospheric pollutants as well as characterization studies, with specific expertise in the field of environmental chemistry. To such purpose, several analytical techniques are used, such as high-performance liquid chromatography (HPLC), and graphite furnace atomic absorption spectrometry (GFAAS), just to mention a few.

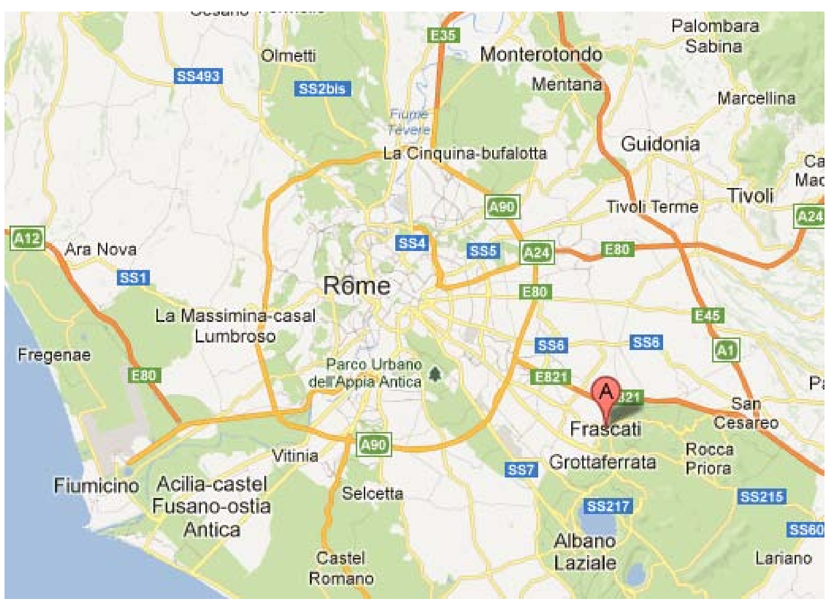
Particular attention is paid to: heavy metals, atmospheric deposition, persistent organic pollutants, atmospheric particulate and its characterization.

The results of these activities find several applications, among which mention must be made of ENEA’s activities in support to the Italian Ministry for the Environment, Land and Sea.

An additional field of intervention is the participation in research programs on natural catastrophes and their consequences on the Italian environment and cultural heritage.

Frascati Research Centre is endowed with an automatic meteorological station and a sensor for the detection of the acoustic pollution levels.

LOCATION



Appendix C. Celani's ICCF-17 Paper Describing Pre-Demonstration Experiments

A copy of Celani's ICCF-17 paper[48] appears in the following pages.

[48] Celani, Francesco, et al., Cu-Ni-Mn Alloy Wires, with Improved Submicrometric Surfaces, Used as LENR Device by New Transparent, Dissipation-type Calorimeter. Proceedings of the 17th International Conference on Cold Fusion (ICCF-17), Daejeon, South Korea, August 12-17, 6 p.

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Cu-Ni-Mn alloy wires, with improved sub-micrometric surfaces, used as LENR device by new transparent, dissipation-type, calorimeter

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***Abstract*-- Starting in February 2011, we studied the feasibility of new Nickel based alloys that are able to absorb proper amounts of Hydrogen (H_2) and/or Deuterium (D_2) and that have, in principle, some possibility to generate anomalous thermal effects at temperatures >100°C.**

The interest in Ni comes in part because there is the possibility to use also H_2 instead of expensive D_2. Moreover, cross-comparison of results using H_2 instead of D_2 can be made and could help the understanding of the phenomena involved (nuclear origin?) because use of such isotopes.

***Index Terms*-- Calorimeter, LENR, Nickel based alloys, sub-micrometric surfaces.**

I. AN OLD ALLOY USED FOR NEW PURPOSES

Because theoretical considerations, and thank also to some sentences reported in a paper (on catalysis) not related to LENR studies [1], we decided to explore the possibility to use the "large family" of CONSTANTANS alloys as starting material that could fit our purposes.

One of the merit factors was, according to use, the ability to dissociate H_2. One of the Constantans ($Ni_{37}Cu_{63}$), among the materials studied in the Ref. [1], has the highest value (i.e. 3.2eV; in comparison, pure Ni and Pd have respectively values of 1.74 and 0.42eV) of such dissociation. Moreover, even with large changes (factor of about 2) in the relative atomic amounts of Ni in respect to Cu (i.e. from 0.37 to 0.62), the dissociation values remain almost constant (from 3.16 to 2.86eV).

We focused on a commercial (low cost) material, called ISOTAN44, nominal atomic composition $Cu_{55}Ni_{44}Mn_1$, developed several years ago by Isabellenhutte Heusler, GmbH, KG-Germany.

The ISOTAN 44 was selected according to the following, overall, considerations, as pointed out by us since April 2012, Ref. [2].

A. Measurable diffusion coefficient of Hydrogen, in even the pure (not alloyed) elements, i.e. Cu and Ni, at high temperatures: Cu=10^{-6}cm^2/s at 200°C, 10^{-4}cm^2/s at 700°C; Ni= 10^{-7}cm^2/s at 200°C, 10^{-6}cm^2/s at 350°C. In comparison, the (good) values for Pd are: 10^{-5}cm^2/s at 200°C, 10^{-4}cm^2/s at 420°C; at 600°C were reported values as large as $8*10^{-3}$cm^2/s, but not reproducible. We think that the "flux" of H_2 or D_2, inside lattices is one of the is one of key factor to generate anomalous effects.

B. Lower cost, overall, even considering the procedure to "build" nano-structure at the surface, in respect to Pd, very expensive precious metal.

C. Very good mechanical properties in respect to aging effects due to cycles of both low->high->low temperatures and H_2 absorption-desorption: the sample of our ("*generation one*") long time lasting experiment was working for over 7 months; only after such long time of operations, we observed serious damages rising-up. Our results are, in some aspects, different from that obtained by A.W. Szafranski [Ref. 3]: he observed extreme brittleness in, as received, Cu-Ni alloy that was only cold rolled from 200µm to 20µm (the penetration depth of H into Ni is about 30µm) and then cycled between 77K and 300K under 1GPa pressure of H_2. We could think, only, that high temperatures and/or Mn (at 1%) addition have beneficial effects on reducing brittleness problems. Moreover, we never made experiments at 77K.

D. Extremely large values of (computed) catalytic power (ΔE) in respect to the dissociation of H_2, Ref. [1], as following:

$Ni_{0.3750}$-$Cu_{0.6250}$	==> +3.16eV
$Ni_{0.6250}$-$Cu_{0.3750}$	==> +2.86eV
$Ni_{0.8125}$-$Cu_{0.1875}$	==> +2.10eV
Ni	==> +1.74eV
$Ni_{0.1825}$-$Cu_{0.8175}$	==> +1.57eV
$Ag_{0.8125}$-$Pd_{0.1875}$	==> +0.57eV
$Ag_{0.625}$-$Pd_{0.375}$	==> +0.51eV
$Ag_{0.1875}$-$Pd_{0.8125}$	==> +0.51eV
Pd	==> +0.42eV
Cu	==> -1.11eV
Ag	==> -1.42eV

E. The possibility, at least in principle, to produce nano-micro structures (and obviously voids) both at the surface and deeper into the bulk, because selective oxidation of Cu in such alloy at high temperatures (650-1050°C). Both segregation of pure Ni among to CuOx and cooling rate are key aspects of the preparation to be studied in deeper details, although we spent a lot of time (and money) to investigate such key aspects.

Our studies, very exploratory, were devoted to finding simple and reliable/reproducible procedures to get these kinds of structures. Experiments with the selected material were operated for time as long as possible: "strength" and aging tests.

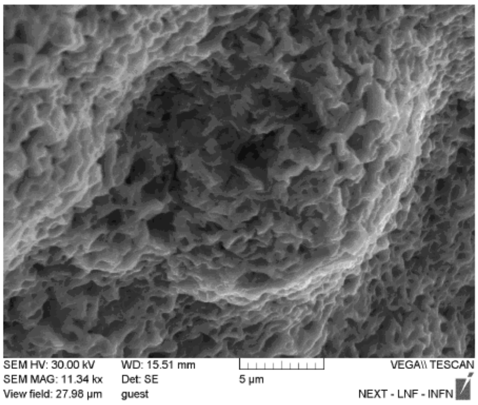
II. SAMPLES PREPARATION (PROCEDURES USED FOR THE EXPERIMENT UP TO MAY 2012, "*GENERATION ONE*"). SIMILAR COMPOSITION MATERIALS, TRUE NANOMETRIC, DEVELOPED INDEPENDENTLY IN JAPAN

In our exploratory preparations/tests we used "standardized" wires: ("nuked") Φ=200μm, l=105cm. Initial values of weight (e.g. 307.4mg), diameter (+-1μm) and resistance (e.g. 17.16 Ohm) were carefully measured.

We point out that, although very promising (expected) results with pure Constantan, in our explorative test (2-3 days of operations each, time span from February to June 2011) under H_2 atmosphere, we NEVER got any type of anomalies (like changing of resistance) on wires with applied temperatures as large as 900°C under the following status:

1. as obtained from the Company (we call them *ultra-virgin*);
2. with the surface cleaned-up from the enamel protection (enamel completely removed by burning up to 600°C in air) and stress released;
3. Acid etching of wire after burning at 600°C.

The wires, point 2), at the beginning, were just "cleaned-up" of the original "solderable" (type V) enamel insulating layer (as provided by Isabellenhutte) by Joule heating, in air, at current as large as 2000mA, time 5m.



SEM. Wire's surface after heat treatments at I=2500mA, 5m.

Figure 1. Wire surface after enhanced heat treatments, *generation one* experiments.

In such conditions the power dissipated was about 70W and the resistance ratio, in respect to the reference value (at 100mA of current injected) increased of only 1%, as expected for such kind of material (commercial name is Constantan, i.e. constant resistance). After first thermal treatment, the weight decreased of about 13mg, the resistance decreased from 17.16 to 17.02 Ohm.

We found that increasing both the current (up to 2500-3000mA) and the time at high power (5-1000s), decreasing the cooling speed (from 100s down to <1s) had dramatic effects on the growing of nano-microstructures and their dimensions (see Fig. 1, as example). The role of O_2, because free air treatment, is quite important. The wire temperature, in some tests, was even larger than 1000°C (rough evaluation by colour temperature; the melting points of pure Cu is 1083°C, of constantan about 1200°C in inert gas).

The quality of wire produced by this method was evaluated by SEM observations. According to us, as smaller were the particles at the surface and larger the total fraction in respect to the whole wire (i.e. the core), as better was the procedure of preparation.

The "best material" that we were able to produce, at the end of July 2011, using thermal treatments were put in our (high resolution) flow calorimeter.

As previously noted, such material was extensively studied, both in H_2 and D_2 atmosphere using a very accurate flow calorimeter (indetermination <2%). The total times of experiments were really long (over 10 months) and only at the end the damages were so heavy to prevent further reliable interpretation of the experimental results. They were discussed, very deeply, during the "X International Workshop on Anomalies…", on last April 2012 [Ref. 2].

We were very happy to know that also Akito Takahashi and Akira Kitamura (and Colleagues), respectively from Osaka and Kobe University (Japan), studied in secret (like us), an alloy of Ni-Cu (at true nanometric size, i.e. 5-20nm) dispersed in an inert matrix of ZrO_2. Such work was performed among collaboration with the Research Group of a Toyota Company (Technova). We got some information, by A. Takahashi and A. Kitamura, since January 2012, about promising results by a specific $(Ni_{85}\text{-}Cu_{15})_{35\%}\text{-}(ZrO_2)_{65\%}$ alloy [Ref. 4].

We recall that such material is a further development of the nanomaterial Pd_35%-ZrO_2_65% developed by Yoshiaki Arata (Osaka Univ., Japan) since 2005.

The "short information" about Ni-Cu-ZrO_2 came because I was invited to give a Review talk, on *Anomalous Effects in LENR Studies*, at the WSEC2012 Conference (World Sustainable Energy Conference 2012) organized by the ISEO (International Sustainable Energy Organization). The ISEO is an ONG linked to several not-politic Organizations (UNESCO, WHO, ILO,…) connected to United Nations at Geneva. Obviously, I requested that everybody involved in LENR studies, worldwide, communicate the most recent and interesting results to include in my Review. A similar talk, with even more technical/scientific details, was given even at CERN (Geneva) on March 22, 2012 in the framework of the (prestigious) CERN Colloquium. Under my specific request, it was added also a talk (by Y. Srivastava, Univ. Perugia, Italy) related to overview of theories in LENR.

The overall behaviours of Ni-Cu alloys although at different ratios of two main elements, in respect to H_2 and D_2 absorption, and the amount of anomalous heat detected, were, in several aspects, similar in the experiments performed both in Japan and Italy.

Such kind of evidence reinforced our intention to develop a better material (from the point of view of nano-dimensionality), keeping the starting Ni-Cu composition "constant". In other words, our efforts were devoted to improve the amount of active material at low dimensions (<100nm) and, at the same time, avoid the adverse effect of "leakage" of the smallest particle from the surface, e.g. under dynamic vacuum conditions.

III NEW TRANSPARENT, DISSIPATION-TYPE, "CALORIMETER"

By the end of May 2012 we were able to produce sub-micrometric materials, with nominal overall performances several times better than the best material produced at the end of July 2011, with enough good reproducibility about preparation procedures.

The new method, although started from the old one in some key aspects, was really revolutionary about the practical parameters of: mechanical stability (almost no leakage of the "best" material from the surface), fraction of material at small dimensions. Such last parameter increased from previous 1-2% (*generation one*) up to about 30% of the whole material (*generation two*).

Such big improvements were obtained because large economical (and man-power) help of an Italian Company that "believed" in our previous results. We were able to design, and build, specific electronics and mechanical set-up to produce such kind of sub-micrometric wires. Systematic (but very boring and expensive) experimental work was the key factor for the success.

Moreover, because one of our goals was to see, to the naked eye, if the wire was really stable about the leakage of "good" materials even after several cycles of low→high→low temperatures and H_2 loading (or even de-loading!), we build a new transparent reactor with borosilicate glass (Schott DURAN) of large (3mm) wall thickness to withstand enough large pressure drops (up to 8 bar), at internal wall temperatures up to 280°C.

For the calorimetric measurements, we adopted the simplified approach to measure the external glass wall temperature. Taking into consideration the temperature of interest, i.e. T_wall>140°C, the main channel of heat exchange to the environment is radiation of heat. In other words, it can be used the simple formula of Stefan-Boltzmann law:

$$P_{out} = 5.67 * 10^{-8}\left(T_{wall}^4 - T_{room}^4\right)\left[\frac{W}{m^2}\right] \quad (1)$$

In such formula the temperatures T are in K. Calibrations were made using our usual procedure to add an inert wire, very close to the "active" one, and make several measurements with inert gases. In the specific new set up, the wires were parallel, alternatively and helicoidally shaped, 22 turns. They were changed the input power, used different gases (He, Ar, Vacuum), fed the electric power alternatively to the inert and "active" wires.

Because in our real experimental set-up the geometrical dimension of the cell is constant (glass tube, external diameter 40mm, internal diameter 34mm, overall length of 280mm, central active length of 100mm), we can make a sort of simplified calibration curve just dividing the formula (1) by the input power. Obviously, we neglected the contribution to heat dissipations of free air convection (usual values are 5-25W*m^2*K, in "normal environments" are 12-15W). Finally, we just recall that in the temperature range of our interest (internal cell 250-350°C), the thick borosilicate glass behaves like a black-body for the wavelengths of interest (>2.5μm). Moreover, the effects of pressure variations *inside* the reactor chamber, with related temperatures variation due to different convection values (i.e. the internal temperature increases versus pressure decreasing), have values of temperature changing that can be neglected at the external wall, for the purposes of our experimentations. Anyway, specific test were performed, in He, varying the pressure between 6.5 and 2.5bar. Such tests were made at the beginning of the experiment (wire new, reactor glass wall "clean") and after some months (wire used, glass wall lightly "dirty").

IV RESULTS WITH THE NEW WIRES (*generation 2*).

At the end of May, 2012 two wires were produced, both with the same new procedures (*generation two*).

The first one was used few days later to the experiment, the second one was just put inside a HDPE envelop and kept closed at Room Temperature (RT). We called the experiments:

[a] *wire#1* (started 06 Jun, 2012);

[b] *wire#2* (started 10 July, 2012).

The main improvements in respect to previous procedure of fabrication, according to SEM observations, were the multilayered structures and total number of such layers, extremely large: of the order of 700. The thicknesses, of each multi-layers, were in the range of 20-100nm. The mechanical stability, against leakage of sub-micrometric materials, was largely improved.

The primary experimental procedures and results are listed as following:

1.) In order to use simple parameters easy to be managed by calculations, we adopted the usual term of R/Ro. Ro is the initial value of resistance at RT, i.e. 23.5°C (in that calibration), in free air atmosphere, inside the reactor. With our wires we measured, in situ (I-V methods), a value of resistance of 16.9684 Ohm and 57.4394 Ohm, respectively for sub-micro_Costantan and Ni-Cr (supposed inert) wires. The measuring currents were just 4mA, to avoid self-heating of the wires.

2.) First of all, were made calibrations by inert gases, with power of 5, 15, 30 and 48W applied to the inert wire. The maximum internal temperature of the chamber was of the order of 180-250°C, depending on the gas composition and its pressure. Some tests, as cross reference, were made also on active wire. Using the values of temperatures measured outside the glass cell (and ambient temperature) it was possible to evaluate the “power exchange constant” of the small reactor by (1).

3.) After adding a H_2/Ar mixture (75/25 ratio) at 7 bar of total pressure, and using as monitor parameter the resistance of both the active and inert wires, it was given power (48W) to the inert wire. It was found (Fig.2) that when the temperature inside the reactor was larger than 125°C, the resistance ratio of active wire, after a very limited increase (to 1.02), dropped to 0.92 in 2500s. Later on, in about 100000 sec, the R/Ro decreased to 0.88. We observed a correlated increase of the “anomalous excess heat” (although quite unstable) with the R/Ro decreasing. The temperature inside cell was about 180°C.

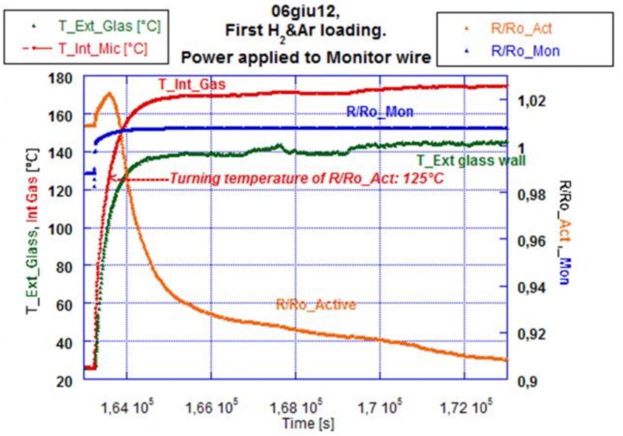


Figure 2. Details of first loading by H2-Ar mixture

4.) After 103000 sec from the beginning (Fig. 3), we stopped the power to the inert wire and allowed the reactor, and the wires, to cool to RT. The R/Ro value of active wire decreased to 0.80.

5.) Just after that, we give the same previous power to inert wire and after others 150000s from the interruption we measured an R/Ro value of 0.867. The anomalous excess power increased further (Fig. 3), in a way that, at a first observation, depends mainly on the time lasted and not to the R/Ro value (low decrease). The instability of excess power, if there weren’t other uncontrolled parameters to fake it, had values quite large and was correlated to the small oscillations (<1%) of R/Ro values.

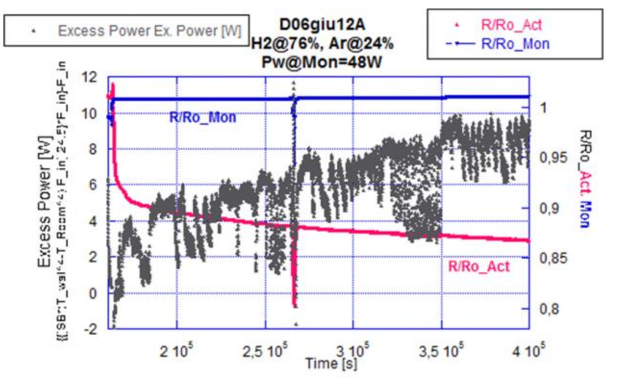


Figure 3. Behaviour of anomalous power generation, using indirect heating, i.e. power (48W) applied to Mon. wire.

6.) We observed that even the instabilities of room temperatures (usually 23-27°C) “helped”, in some aspects, the anomalous heat production, because, speculatively, introduced some non-equilibrium conditions. In other words, in order to avoid misinterpretations of the results, after proper long times, the values of room temperature were the same at the starting while the anomalous heat increased over time.

7.) Among others, the positive effect, of long time lasting under H_2 gas, was observed also by the A. Takahashi and A. Kitamura group (reported both at the X Pontignano Workshop and ICCF17). According to them, under their experimental conditions, constrains and materials, in 2 weeks of experiments the anomalous excess power slowly increased from 0 up to 3W.

8.) We observed that the minimum cell temperature to stop the anomalous heat is around 120°C, i.e. similar to the first “loading” temperature (i.e. 125°C).

9.) After 330000 sec from the first H_2/Ar intake, the power was given to active wire (Fig. 4).

10.) We observed a further increasing of anomalous power that, if there are no mistakes around, was about twice (i.e. absolute value of over 10W) of that detected when the power was applied to inert wire. The R/Ro value, after initial increasing, stabilized to 0.808.

11.) A possible explanation was that the local temperature of active wire, because Joule heating, was larger than that when the power was indirect. A very rough valuation of temperature is the range of 350-400°C, in respect to about 200°C with indirect heating.

12.) If the consideration at point 11) is correct, we can think that the reaction, apart some temperature threshold, has a *positive feedback* with increasing temperature. Similar effects were found by: our self (with the old wire, and experiment, up to May 2012); A. Takahashi and A. Kitamura group with Ni-Cu-ZrO_2 powders.

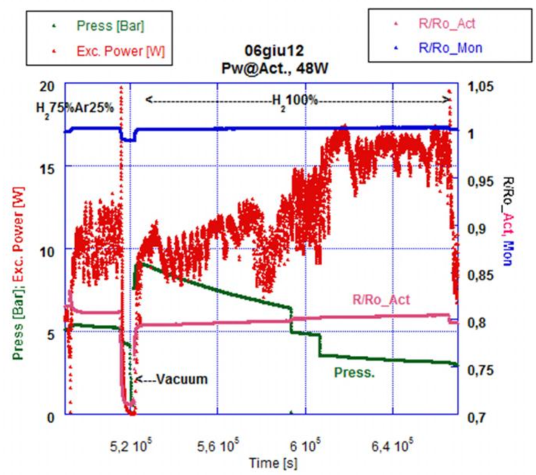


Figure 4. Experiment with power (48W) applied to Active wire. Up to time 518ks the gas mixture was H_2/Ar at 75/25 ratio. Later on, the power was reduced to zero and made vacuum: R/Ro was as low as 0.71. From time 522ks was added pure H_2: the excess power resumed the value before vacuum and, after controlled reduction of pressure, increased up to 16W.

13.) After 360000s from the H_2/Ar gas intake (Fig. 4), i.e. time 515ks, the power was switched off: the R/Ro, at

RT, dropped to 0.71. In other words, the direct heating (electro-migration phenomena and/or large temperatures) improved largely the loading, and then the anomalous power.

14.) After 410000s from first H_2/Ar intake, we made vacuum and added H_2 at 100% concentration.

15.) The results were similar to H_2/Ar gas and even better about anomalous heat production.

16.) We can't discriminate if the further improvements of performances were due to effects of pure H_2 or just time lasted under active gas (increased embrittlement).

17.) After another week of miscellaneous test, we decided to de-load the wire from H_2 absorbed, to be sure that the resistance reduction observed was due to a real absorption and not to a variation of resistance due to the reduction of oxides (by H_2) at the nano-particles surfaces.

18.) To get de-loading we put the cell under dynamic vacuum and increased the temperatures.

19.) After several hours, we get the original starting value of R/Ro at 1: the test was fully successful.

20.) We reloaded again the wire and get behaviour of R/Ro decreasing and anomalous heat not too different from the first cycle.

21.) Again we de-loaded the wire from H_2 to make experiments with D_2 gas (Fig. 5). This time the final value of R/Ro was 0.93, not 1 as expected. We supposed that some H_2 was stored some-where in the lattice.

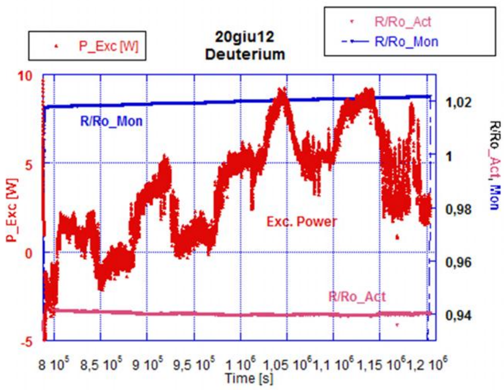


Figure 5. Experiments under D_2 gas. At the beginning, up to 1 day long, the reaction was ENDOTHERMIC; later crossed the zero line and began to be exothermic, as usual with H_2...

22.) After D_2 intake, we increased, as usual, the temperature by power to the inert wire. The absorption was really of small amount.

23.) We observed, for the first time in our experimentation with such kind of materials, some X (and/or gamma) emissions, coming-out from the reactor during the increasing of the temperature from about 100°C to 160°C. We used a NaI(Tl) detector, energy range 25-2000keV used as counter (safety purposes), not as spectrometer. Total time of such emission was about 600s and clearly detectable, burst like.

24.) About thermal anomalies, we observed, very surprising, that the response was endothermic, not exothermic. The second day the system crossed the zero line and later become clearly exothermic. Similar effects were reported also by A. Takahashi and A. Kitamura.

25.) After about 350000s from the beginning of D_2 intake the temperature abruptly increased and the wire was broken. We observed that the pressure decreased, because some problems to the reactor gas tight, but at times of 80000s before. The SEM observations showed fusion of a large piece of wire. The shape was like a ball. Further analyses are in progress.

26.) Starting from July 10, 2012, we used the second wire (#2), stored in the plastic bag.

27.) In the meanwhile, we improved the overall detection of external temperatures and added 3 other thermometers. The main thermometer was moved from the original position, little bit close to one end of the wire, to exactly at the centre of the area of glass tube were are located (in the inner) the wires.

28.) The results were qualitatively similar to the first wire, although at lower intensity. The starting temperature of loading, from the value of 125°C of the wire #1, increased to about 160°C. In particular, the wire was not able to withstand direct heating conditions. We think that the surface was partially obstructed from something (HDPE plastic?).

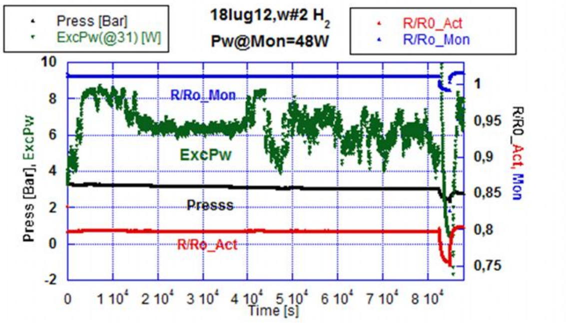


Figure 6. An example of anomalous heat on wire#2

29.) On July 23 we made de-loading and on July 24 we made loading again. The sequences were: a) dynamic vacuum conditions, 220°C internal reactor temperature, power at Ni-Cr, 50000s duration; b) H_2 filling.

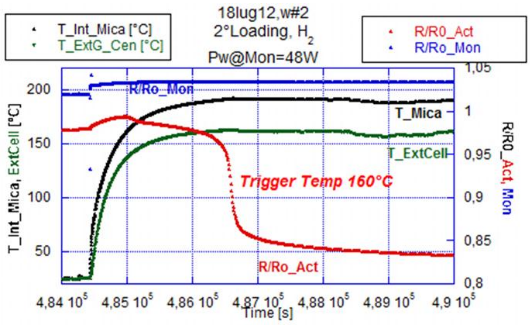


Figure 7. Behaviour of first re-loading of wire#2

30.) The results, Fig.7, seemed largely improved about: speed of loading (time of the drop of R/Ro from 1 to 0.85 of only 2000s), time necessary to get measurable anomalous heat (less than 6 hours).

31.) The experiment had been stopped on July 28 to package and "shipping" the reactor to USA (National Instruments Meeting at Austin-Texas) and later-on to Korea (ICCF17 Conference at Daejeon).

32.) The wire #2 “overcomes” the severe conditions of shipping and long time (8 days) without H_2, at free air conditions. When we resumed all the electrical connections, at Austin (USA), we realized that the R/Ro value of Active wire remained almost unchanged (about 0.81). At Austin, ALL the control and measuring electronics, and new specific software, were provided by National Instruments modules and Researchers.

Figure 8. Dr. Celani and his reactor at Austin (USA)

33.) The maximum excess power reached, after 3 days of operations (in public) at Convention center of Austin (Fig.8), NIWeek 2012, was about 21W with indirect heating and about 25W with direct heating of sub-micrometric Constantan wire. The input power, as usual, was 48W. They were the best values that we observed up to now. We remark that, because we used the “old” value of calibration obtained in Italy with different experimental geometric set-up, the absolute value of excess power has to be fully controlled. Anyway, the peculiar trend to increase the excess power versus elapsed time was reconfirmed.

V. CONCLUSIONS

It appears that the commercial Constantan alloy, with the surface deeply modified about geometry (i.e. skeleton type) and dimensionality of 20-100nm, multi-layers, is a good candidate for anomalous heat production due to:

a) intrinsic low cost of raw materials;
b) simple procedures (i.e. low-cost) of nano-structures growing, as recently developed by our group at INFN-LNF, Italy;
c) use of Hydrogen.

We observed that such materials have a behaviour of “positive feedback” of anomalous power in respect to temperature increasing.

The experiment showed to be reproducible as experienced both during the Austin (USA) NI Week and ICCF17 Conference (Korea). Several of the results found were similar to what detected by the Japan group (A. Takahashi, A. Kitamura) in collaboration with Technova (side of Toyota Company), using Ni-Cu alloy dispersed in Zirconia matrix. Anyway more and systematic work is necessary to elucidate the several open questions, first of all the stability over time of the anomalous heat generation, safety and a confirmation about reproducibility, not mentioning the “strange” behaviour using Deuterium gas.

Collaboration of the Community involved in LENR studies is welcomed and a series of attempts to replicate the experiment is currently performed by different organizations and laboratories worldwide.

The next step will be the use of quartz tube instead of borosilicate, at the moment in use. The quartz will allow to studies temperatures over 300°C; at the moment not allowed by borosilicate (1^{st} softening temperature of borosilicate glass is around 280°C).

If positive results will be reconfirmed with the wire made by new procedures (i.e. “second generation” of preparation), it could be possible to reach “regions” of operation were even the self-sustaining regime could be observed.

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- National Instruments, 11500 North Mopac Expressway, Austin, TX 78759, USA.
- Francesco Santandrea, ISCMNS, Latium1 Group, Via Cavour 26, 03013 Ferentino (Fr), Italy
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Appendix D. Pre-Demonstration Supplemental Information

Supplemental information for the pre-demonstration experiments involves Constantan wire characteristics, wire preparation, and overall timeline for the experiments.

Appendix D1. Constantan Wire Design and Characteristics

The properties of Celani's Constantan wire as compared to other materials of interest:

Cu_{55}-Ni_{44}-Mn_1 (Constantan, ISOTAN44)
Manufactured by Isabellenhutte Hesler, GMBH, KG-Germany
"Standardized" dimensions

- Length: 105 cm
- Diameter: 200±1µm
- Weight: 307.4 mg
- Resistance: 17.6Ω

Diffusion Coefficient of Hydrogen

Cu @ 200º C	10^{-6} cm/s
Cu @ 700º C	10^{-4} cm/s
Ni @ 200º C	10^{-7} cm/s
Ni @ 350º C	10^{-6} cm/s
For comparison:	
Pd @ 200º C	10^{-5} cm/s
Pd @ 420º C	10^{-4} cm/s
Pd @ 600º C	8 x 10^{-3} cm/s (not reproducible)

Catalytic Power of Wire Materials

Ni_1	+1.74 eV
$Ni_{0.1825}$ $Cu_{0.8175}$	+1.57 eV
$Ni_{0.375}$ $Cu_{0.625}$	+3.16 eV
$Ni_{0.625}$ $Cu_{0.375}$	+2.86 eV
$Ni_{0.8175}$ $Cu_{0.1825}$	+2.10 eV
Cu_1	-1.11 eV
For comparison:	
Ag_1	-1.42 eV
$Ag_{0.625}$ $Pd_{0.375}$	+0.42 eV
$Ag_{0.1825}$ $Pd_{0.8175}$	+0.51 eV
Pd_1	+0.51 eV

Mechanical Properties

ISOTAN44 has very good mechanical properties, especially with respect to aging effects. Cycles of low → high → low temperature H_2 absorption-desorption.

Appendix D2. Constantan Wire Preparation

The Constantan wire must be heated to remove the plastic insulation and oxidize a portion of the metal to make it LENR "active". Apparently at least a portion of the Cu component of the Ni-Cu alloy is oxidized to CuOx, resulting in a nano-structure in which LENR can occur.

- Insulation Removal
  - Removal by Joule heating
  - Current, I = 2000 mA
  - Time, t = 5 min
  - Power dissipated, P_{diss} = 70 W
  - Resistance ratio (with respect to reference value at 100 mA) increased only 1% (typical of Constantan)
  - Weight decrease = 13 mg
  - Resistance decrease = 17.16 to 17.02 ohm

Celani et al. reported a major advance in sample preparation in mid-2012 (after experiments starting in early 2011) with the assistance of an unidentified Italian company. The objective was to increase the amount of active material of small size (<< 100 nm) and to avoid the adverse effect of "leakage" of the smallest particles from the surface. In general, the smaller the particles at the surface, the better the total fraction with respect to the entire wire.

- Higher percent of active material (from 1-2% to 30%) achieved
- Increase in mechanical stability (no "leakage" of smaller – active – particles) also achieved
- Result of first thermal treatment
  - Increase P to 2500-3000 mA
  - Increase t at high power to 5-1000 s
  - Decrease cooling speed from 100 to <1 s
  - Role of O2 important (free air treatment)
  - Dramatic effect on growth of nanostructures and their dimensions
  - Temperature up to 1000º C or more (pure Cu melts at 1083º C)
- Selective oxidation of Cu at high temperatures (650-1050º C)
  - Segregation of Ni from CuO2
  - Cooling rate
- At surface and deeper into bulk
- "Strength" and aging tests
- Tri-dimensional shapes of geometry
- SEM examination
  - Multilayer structure
  - Up to 1000 layers
  - Layers 20-100 nm thick
- Skeleton type
  - Intrinsic potential for gas absorption
  - Topic of future paper, in preparation

Appendix D3. Overall Pre-Demonstration Experimental Timeframe

Celani and his coworkers apparently worked on their experimental approach for at least 18 months before the August 2012 demonstrations. A breakthrough was achieved in mid-2012 with improvements in the treatment of the Constantan wires to achieve more substantial LENR observations.

Initiation	February 2011
New Preparation Procedures	February 2012
Presentation at X International Workshop on Anomalies in Hydrogen-Metal Systems (April 2012)	April 2012
Production of Improved Submicrometric Materials	May 2012
Start tests in New Calorimeter	June 2012
Wire #1 Experiments Initiated	6 June 2012
Wire #2 Experiments Initiated	10 July 2012
Stop Experiments for Shipment to Austin and Daejeon	28 July 2012

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Appendix E. Supplemental Information for August Demonstrations

Supplemental information for the August demonstrations includes the equipment and materials supplied by NI and the timeline of activities for setting up the demonstrations.

Appendix E1. Summary of Equipment and Supplies Provided by NI

- NI PXIe-1062Q 8-Slot PXI Express Chassis with NI PXIe-8133 Quad-Core PXI Express Controller
- NI PXIe-4353 Thermocouple Input Module with NI TC-4353 Mini Thermocouple Connector Terminal Block
    - Used to measure 8 K-type thermocouples, 5 of which were distributed internal and external to the glass. Additional thermocouples were placed on the thermally and electrically insulated mica wire guides, inside the stainless-steel central rod of the apparatus, and as a reference for ambient temperature.
- 2x NI PXI-4071 Digital Multimeters
    - Used to measure voltage and current of both the monitor and active wire. Auto-range and auto-zero capabilities were used to provide good accuracy even at mV levels.
- NI PXI-2564 16-Channel Single Pole-Single Throw (SPST) Switch
    - Used to control which wire (active or monitor) received power, as we only had one power supply. It also allowed us to only use 2 DMMS, rather than 4, to measuring current and voltage across the active and monitor wires.
- NI 37-PIN Female-to-Female DSUB Cable For NI PXI-2564
    - Used to create a custom interface from the switch module to all connectors of the apparatus.
- NI PXI-4132 Precision Source Measurement Unit (SMU)
    - Used to supply constant voltage to the pressure transducer, although any PSU would work fine here. It is really overkill to use an SMU for this application, but a DAQ card did not provide the current needed through its AO channels.
- NI PXIe-6368 Simultaneous Sampling X Series Data Acquisition (DAQ)
    - Used only to measure voltage from the pressure transducer.

Appendix E2. Timeline of Demonstration Setup Activities

Before 26 Jul	Arrangements for Celani demo at NIWeek
Before 30 Jul	Informal discussions with Letts and EarthTech
26 Jul	Email to Letts requesting support
27 to 30 Jul	Acquire needed parts and gases
30 Jul	Initial work on improved LabVIEW support
30 Jul	Celani arrival in Austin
31 Jul	Introductory meeting with Celani at NI. Overview of the reactor/calorimeter
31 Jul	Meeting with Dennis Letts and Scott Little (EarthTech) for planning setup of demonstration.
1 Aug	Begin demonstration setup at Letts' lab
2 Aug	NI staff begin work at Letts' lab – PXIe interface with reactor/calorimeter and LabVIEW coding; begin long workdays (12 hours or more)
5 Aug	Setup complete and tested; first successful operation about 10:00 pm
6 Aug	Transport demonstration to Austin Convention Center in early morning; operation in time for start of NIWeek (about 11:00 am)
7 to 9 Aug	Demonstration continues through NIWeek to mid-day 9 August
9 Aug	Package apparatus for shipment to Daejeon