

Research Article

Advancements in the Production of Anomalous Heat Effect in Constantan Wires: Developing a Robust Experimental Protocol

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Abstract

This paper presents a comprehensive summary of a presentation delivered at the 24th International Conference on Condensed Matter Nuclear Science (ICCF24), which took place at the Computer History Museum in Mountain View, California, from July 25-28, 2022. Since 2011, our research team has been dedicated to discovering simple yet effective procedures for activating a specific material that we developed [1]. This material consists of surface-modified Constantan in the form of long and thin wires, utilizing Joule heating. Our main objective has been to generate measurable values of the Anomalous Heat Effect (AHE). In our most recent efforts, we have not only replicated our previous findings but also conducted new tests to explore potential isotopic effects. The results obtained have reinforced our interpretation of the AHE's main origin, aligning with the initial discoveries made by researchers in the United States, Japan, and Italy, some as early as 1989 [2], [3]. The impetus for this work stemmed from our desire to reaffirm the procedures we extensively discussed during the ANV8 Workshop held in Assisi, Italy, in December 2021. Our presentation at the Workshop, which garnered considerable interest within the LENR-AHE community, led to numerous inquiries, particularly regarding the reproducibility of our methods starting from the wire and its treatments. Consequently, we incorporated new experiments into our study, focusing on exploring any potential isotopic effects by employing H_2 and D_2 gases, in relation to the magnitude of AHE. The core geometry of our reactor remained consistent with the configuration we have developed since 2019, known as the “inverse coaxial coil” [4]. For energy balance calculations at various fixed input powers, we employed thermometry, which enabled faster measurements compared to conventional flow calorimetry. As reference points, we conducted preliminary experiments under helium gas conditions, maintaining similar pressures (typically exceeding 0.5 bar) to those used with the active gases (H_2 , D_2). In assessing the energy balance, we relied on temperature measurements taken at the external wall of the glass reactor. This surface was covered with multiple layers of thermally conductive thick aluminum foil, with the side

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facing the ambient environment coated in a high-emissivity (>90%) black compound capable of withstanding high temperatures (800 °C). The recorded maximum temperatures during the experiments were 900 °C internally and 380 °C externally, with a maximum applied power exceeding 150 W. The weight of the wire employed in our tests was 0.45 g. Key Findings: We successfully reaffirmed that a straightforward procedure involving high-power DC Joule heating over extended durations (50-150 hours) remains effective in activating virgin Constantan coils, provided the thin wire surfaces are appropriately treated, primarily with Low Work Function materials. Furthermore, we observed that the measured AHE during the cooling cycles from the highest power levels is contingent upon the time the reactor's core spends at these elevated powers. Notably, we identified a form of "positive memory effect" relating to AHE, which typically persists for 10-20 hours. Additionally, we discovered that the AHE increases as the number of cycles between high and low power levels is increased. We also observed that increasing the wire resistance through suitable "pre-conditioning" treatments enhances the magnitude of AHE. We speculate that this effect might be attributed to an increased surface area resembling a spongy texture, facilitating the flow of active gases, i.e., flux, in and out of the wire. In our most recent experiments, we measured higher AHE values (9 W) when utilizing D_2 gas compared to H_2 (5 W) at an input power of 130 W. Discussion and Future Directions: The AHE observed in our experiments is directly related to the voltage drop along the wire, with larger drops yielding more pronounced effects.

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Keywords:

1. Introduction

The Anomalous Heat Effect (AHE) observed in surface-modified Constantan wires has attracted significant attention due to its potential applications in energy generation and as a catalyst for further research in the field of low-energy nuclear reactions (LENR). In this article, we present the findings of our recent experiments aimed at reproducing and validating the activation procedures discussed during the ANV8 Workshop held in Assisi, Italy, in December 2021 [5]. Additionally, we investigate the influence of isotopic effects on the magnitude of AHE. By employing an "inverse coaxial coil" reactor configuration and implementing thermometry for energy balance calculations, we were able to analyze the relationship between AHE and the operational parameters of the system. Our results confirm the effectiveness of high-power Joule heating and prolonged activation times in producing measurable AHE. Furthermore, we explore the impact of wire resistance and cycling on AHE and provide insights into the potential underlying mechanisms. Through the incorporation of isotopic variations using H_2 and D_2 gases, we uncovered the influence of isotopic effects on the observed AHE values. Our study not only reinforces previous research findings but also contributes to the growing understanding of AHE and its applications in the field of LENR.

Building upon previous studies and discussions held at the ANV8 Workshop in Assisi, Italy, in December 2021, we embarked on a series of experiments aimed at reproducing and validating the activation procedures previously proposed. The Workshop provided a platform for in-depth discussions on the practicality and reproducibility of the activation process, as well as insights into potential improvements for enhancing the AHE.

In our study, we employed a reactor configuration known as the "inverse coaxial coil" which has been developed and refined since 2019 [4], [5], [6]. This setup offers advantages such as efficient heat transfer and improved control over operational parameters. To evaluate the energy balance within the system, we implemented thermometry techniques that allowed for rapid and accurate measurements. By monitoring the temperature at the external wall of the glass reactor, we were able to determine the temperature distribution and assess the overall energy transfer.

Our primary objective was to validate the activation procedures, involving high-power DC Joule heating and extended activation times, to activate virgin Constantan coils with surface modifications using Low Work Function materials. We aimed to reproduce the significant AHE observed in previous experiments and further explore its dependence on the reactor's operational history, wire resistance, and cycling behavior. Additionally, we investigated the influence of isotopic effects on the AHE magnitude by introducing H_2 and D_2 gases into the system.

The findings presented in this article contribute to the growing body of knowledge surrounding AHE and its potential applications. Furthermore, by exploring isotopic effects and their impact on the AHE, we aim to deepen our understanding of the underlying mechanisms involved. Ultimately, our research aims to pave the way for practical applications of AHE and its integration into future energy generation systems and LENR studies.

The motivation behind our research efforts is to find simple and effective procedures to activate the specific material we have developed. This material, based on surface-modified Constantan in the form of long and thin wires, exhibits the ability to produce measurable values of the Anomalous Heat Effect (AHE). Since 2011 [7], we have been working towards understanding and harnessing this phenomenon, which holds great potential for applications in various fields, particularly in the realm of low-energy nuclear reactions (LENR). In order to validate and refine our procedures, we undertook a series of experiments to reproduce the observed AHE and investigate isotopic effects. Our interpretation of the results further supports the notion that the AHE originates from specific material characteristics, which aligns with the findings of researchers from the United States, Japan, and Italy, dating back to as early as 1989.

2. Experimental Set-Up

The experimental setup utilized in our study closely resembles the configuration we have developed since 2019 [1], [6], [8], [7], [5], [9], known as the “inverse coaxial coil.” This reactor geometry, depicted in Figures 2, 3, and 4, offers several advantages for our investigations. To analyze the energy balance within the system, we employed thermometry techniques, which enabled faster measurements compared to traditional flow calorimetry.

It is important to highlight that we took certain precautions to ensure the reliability of our calorimetric approach. Firstly, the laboratory temperature is maintained constant at $22^{\circ}\text{C} \pm 1^{\circ}\text{C}$ through air conditioning. Furthermore, the reactor is shielded from direct sunlight. We minimize also additional errors that may arise from convection currents or room drafts by regularly monitoring the room temperature and air current speed using a Kestrel anemometer with a resolution of 0.1 m/s. Relative air humidity, typically within the range of 40-60%, is also carefully monitored. The combined uncertainty arising from the aforementioned potential sources of error is estimated to be approximately ± 1 W.

In Figure 1, we present the typical thermal behavior of our reactor in vacuum and when filled at room temperature with 2 atmospheres of different inert gases. Notably, when replacing the gas from one experiment to another, the temperature behavior, both internally and externally (reactor wall), follows a consistent trend associated with the thermal conductivity of the filling gas, as expected.

As reference points for energy balance calculations, we conducted experiments under helium (He) gas at the beginning of the tests, maintaining similar pressures to those of the active gases (H_2 , D_2). Our focus was on temperature measurements at the external wall of the glass reactor, as shown in Figure 2. To emulate black-body emission and account for conduction and convection phenomena, we covered the surface with multiple layers of thermally conducting thick aluminum foil, painted with a high-emissivity (>90%) black compound. This configuration enabled us to achieve maximum temperatures of 900°C internally and 380°C externally, while applying a maximum power of over 150 W. The weight of the wire used in our experiments was 0.45 g.

In the next sections, we will delve into the main procedures employed to induce AHE, the key results obtained, and potential explanations for the observed phenomenology, including the influence of hydrogen-induced Super Abundant Vacancies (SAV) [10], [11], [12] and the role of gas flux in specific materials. Furthermore, we will outline the direction of our ongoing experiments and the implications of our findings for the field of AHE research.

3. Reactor Design

Figures 2, 3, and 4 depict the reactor utilized in the experiment. The reactor consists of a straight tube made of thin commercial iron (magnetic) with an external diameter of 5 mm, as illustrated in Figure 3. In the innermost section of

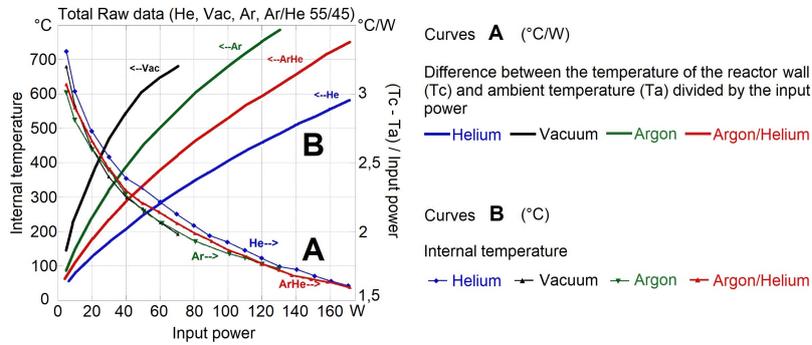


Figure 1. An overview of the internal temperature (T_{int}) of the reactor as a function of the input power (P_w), ranging from 5 to 170 W. This figure also presents the ratio of the temperature difference ($T_c - T_a$) to the input power (P_w). It is noteworthy that the internal temperature (T_{int}) increases as the thermal conductivity of the gases decreases, with the highest temperature observed in a vacuum. Specifically, the temperature order from highest to lowest is Vacuum > Ar > 50%Ar/50%He > He. Additionally, the ratio of temperature difference ($T_c - T_a$) to input power (P_{in}) reaches its maximum values when the reactor is in a helium atmosphere. These findings align well with accepted thermometry models, although it should be noted that our measurements do not account for potential heat losses at the extremities of the actual “reactor.”

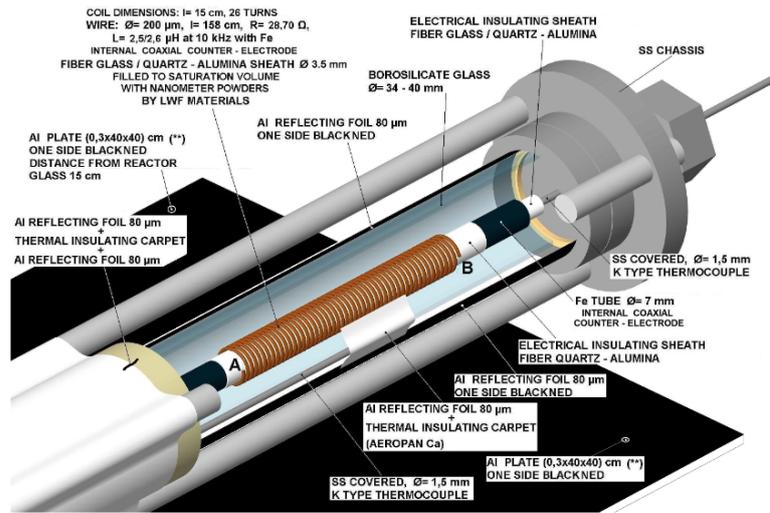


Figure 2. Schematic representation of the reactor body. The container is made of borosilicate glass with a thick wall (3.2 mm), specifically designed and tested for high-temperature mild pressure operations by Vetreria Scientifica Spaziani (Italy).

the tube, positioned at its center, a Type K thermocouple is located. The thermocouple is covered with a stainless steel (SS) layer and electrically insulated by quartz-alumina sheaths, as indicated in Figure 4. Additionally, a Constantan wire, insulated by glass sheaths (a special type known as SE-SI with a diameter of 1 mm), is coiled around the inner iron tube, as shown in Figure 4.

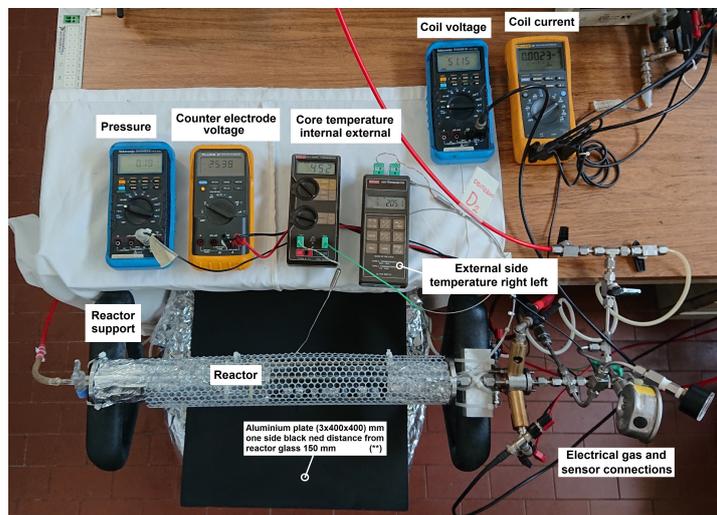


Figure 3. Photograph of the reactor, showing the protective stainless steel (SS) net used for safety purposes. The inner reactor core is our standard structure.

It is important to note that different types of insulation sheaths have been employed in the setup, each with specific characteristics, as described below:

- SE: This is a conventional glass sheath with a maximum operating temperature of 550 °C. It softens at 840 °C and undergoes fusion at 1275 °C. The composition of this glass is similar to that used in tungsten incandescent lamps, and it possesses the unique property of absorbing atomic hydrogen, as observed by Irving Langmuir in 1928. The decomposition from a molecular to atomic state is facilitated by Constantan, which is the most suitable material known for hydrogen decomposition.
- SI: This sheath is composed of quartz (80%) and alumina (20%). It can withstand continuous temperatures up to 1050 °C, remaining stable even above 1000°C.
- SE-SI: This is an unconventional sheath specially manufactured by SIGI-Favier Company based on our specific request. It combines the beneficial properties of both SE and SI sheaths. The SE and SI fibers, each with diameters ranging from 5-8 μm , are intertwined at a step of approximately 0.5 mm.

Thermocouples (Tc) are placed at the external wall of the reactor to measure temperature. Multiple layers of thermally conducting aluminum foil, with a high-emissivity black compound, cover the external surface for enhanced heat transfer and black-body emission emulation.

4. Procedures of Reactor Preparation at INFN-LNF

An innovative procedure incorporating bulk and surface treatments has been employed to induce the Anomalous Heat Effect (AHE). These procedures involve two main steps: a) the preparation of the “possibly active” material through physical-chemical processes to create a specific microstructure, and b) the activation phase. In gas phase experiments, the most extensively studied materials include Pd and its alloys, Ni, and Constantan (Cu-Ni-Mn). However, it is still possible that other transition elements and alloys may exhibit similar behaviors when suitably modified.

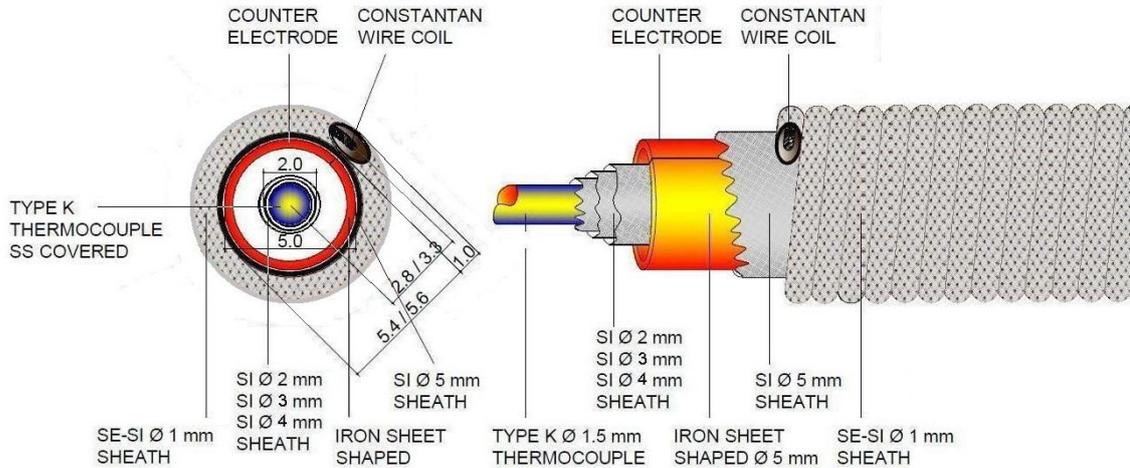


Figure 4. Detailed depiction of the inner core of the reactor. This standard and simplified configuration is utilized for pulsing tests to mitigate potential interferences arising from copper (Cu) tapes and stainless steel (SS) tubes. The schematic illustrates the coaxial coil design, featuring an inner iron (Fe) counter-electrode. The coil, with a wire length of 158 cm, typically consists of 75 turns, although it has recently been reduced to approximately 50 turns due to high voltage (HV) insulation challenges. In comparison to the ICCF23 version, the current core represents a simplified iteration that lacks infrared (IR) screening using aluminum foil and copper tapes, as well as thermal insulation.

The surface treatment of materials such as Constantan requires specific procedures to generate sub-micrometric structures, significantly increasing their surface area and resulting in a spongy-like morphology. While we have successfully addressed point a) through our expertise developed over 20 years, we have encountered challenges in developing simple and reproducible activation procedures (point b).

In previous observations, we found that our “modified” Constantan wires required prolonged conditioning at high temperatures and/or exposure to H_2 atmosphere, accompanied by a type of material stress similar to the traditional mechanical “cold-working” techniques employed mainly by Japanese researchers [13], [14], including our own work [15]. The cold worked materials used in these experiments were provided by Tanaka K. K. and IMRA Materials, both Japanese companies [14]. Similar experiments involved dynamic torsion of the electrode in situ [16], which resulted in measurable AHE.

The modified wires used in our study are composed of the Ni44-Cu55-Mn1 alloy (Constantan) and have a diameter of $200 \mu\text{m}$. Their surfaces undergo multiple cycles of high-temperature oxidations in ambient air to obtain sub-micrometric structures resembling sponges or coral-like formations. Subsequently, the wires are coated with several layers of water solution of nitrates containing Sr, Fe, K, and Mn, which are then dried and decomposed into oxides at elevated temperatures.

Furthermore, we observed that our High Peak Power Pulses (HPPP) with peak powers reaching 10 kW/g and currents flowing along the Constantan wire (length = 160 cm; weight = 0.45 g) exceeding 12 A (current density $J = 40 \cdot 10^3 \text{ A/cm}^2$), with a pulse width of $10 \mu\text{s}$ and repetition rates up to 2.5 kHz, were able to activate the wire [8]. Activation was achieved when the pulsing procedure lasted 5-8 hours with a mean power of approximately 90 W. The activated state persisted for several days even after returning to DC conditions.

However, the pulsing procedure, while highly efficient [17], has proved challenging for researchers worldwide, especially for independent replication in their own laboratories, particularly in academic settings.

Additionally, in the past, the simple DC conditioning procedures were not fully understood, and the control parameters were not adequately identified. Nonetheless, we obtained “promising indications” that using solely DC conditioning for extended periods could activate the wire.

Recent experiments have been aimed at identifying potential turning points for activation based on current density and wire temperature, necessitating meticulous systematic studies. The power was adjusted in close increments (0, 1, 5, 10, 20, and later-on 10 W steps, up to a maximum of approximately 130-140 W) while using He or H_2 gases at pressures of a few bars. One potential limitation of these experiments was the possibility of underestimating AHE values if the turning point for material activation occurred during the initial experiment conducted under hydrogen gas. Typically, the data from the first loading cycle are employed as calibration and considered the zero reference, excluding measurements conducted using He gas.

Interestingly, it has recently been discovered that even the first cycle under helium (He) gas cannot be considered a true blank due to the decomposition and absorption of hydrogen content from the liquid solution into the bulk during the pre-conditioning treatments of the wires in ambient air. These pre-conditioning treatments involve subjecting the wires to currents of up to 2.8 A at approximately 900 °C, estimated using the method of “color temperature” through visual observation. It should be noted that the initial pre-conditioning, which includes oxidation and the addition of LWF (liquid with suspended solids) materials, is performed before inserting the wire into the glassy sheath. After insertion, additional LWF materials are deposited on the surface of the sheaths, followed by heating up to 500 °C to facilitate water evaporation and decomposition of the nitrates into stable oxides, such as SrO.

This effect becomes evident during measurement cycles when the power applied to the wire exceeds 120 W.

Two main types of experiments were conducted to gain control over the procedure and understand the effects on the Anomalous Heat Effect (AHE):

- The first type aimed to improve the AHE values by increasing the conditioning time at high power.
- The second type involved inducing the “degradation” of certain characteristics of the conditioned wire, for example, through high-temperature vacuum degassing, followed by attempts to restore the previous “good” conditions.

5. First type of Experiments: Increasing Activation (see Figure 5)

Initially, four cycles labeled H2#1 to H2#4 were performed following calibration with helium gas and preceding to a vacuum treatment at high temperatures lasting over 15 hours.

Throughout the cycles, the same hydrogen (H_2) gas was maintained without cleaning it by vacuum or introducing fresh H_2 . Given the duration of each cycle and the relatively short reduction time, we can assume a nearly constant gas composition consisting of hydrogen and water. This approach aimed to avoid uncertainties arising from potential water production at the beginning of the first cycle, resulting from the recombination of H_2 with oxides on the material surface. By maintaining a consistent gas composition across the cycles, we ensured comparability among the different experimental runs. Additionally, by maintaining the same gas, despite the initial pressure reduction caused by oxide reduction and subsequent loading into the lattice, we sought to investigate if pressure reduction could influence the absolute value of loading and AHE values, particularly in relation to the time spent at high power under “strong” electromigration. It appears that electromigration is the dominant effect, provided that a certain gas pressure (approximately 0.5-1 bar) is present.

The main observation during these cycles was a continuous increase in AHE values (expressed in watts), on the right side of the curve in Figure 5 and a continuous decrease in R/Ro (on the left side of Figure 5). R/Ro represents the ratio of resistance (R) normalized to its initial value (Ro) under helium gas at very low power. This ratio is measured because in certain materials, such as Pd, the resistivity initially increases and then decreases with the addition and

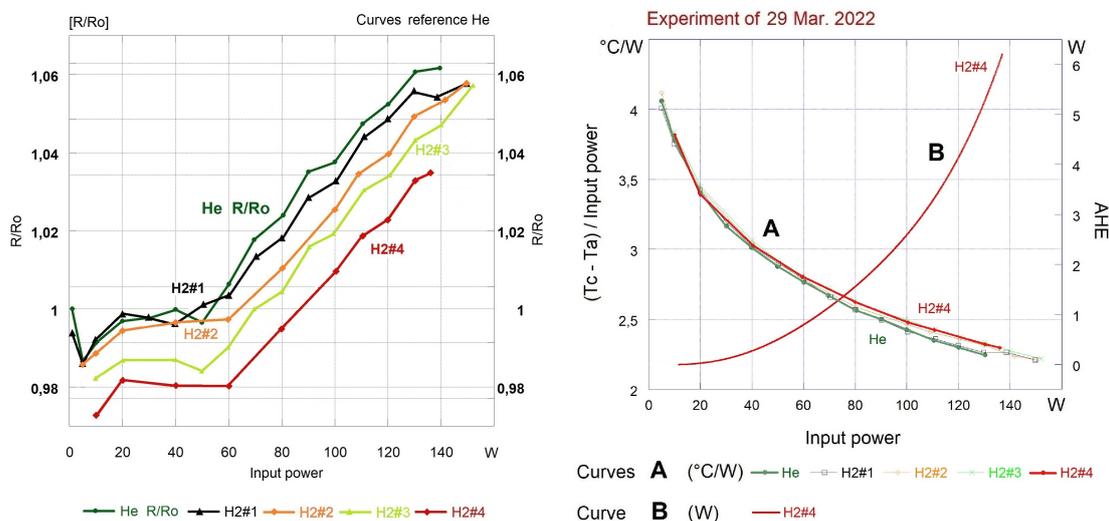


Figure 5. Activation procedure with increasing conditioning time (3 hours, 15 hours, 135 hours) at high power. The left plot depicts the progression of the electrical resistance ratio (R/R_o) of the wire across different experiments, serving as an indicator of the loading (i.e., hydrogen or deuterium absorption by the wire) compared to the initial resistance. On the right, a correlation between the Anomalous Heat Effect (AHE) and this resistance ratio is observed. These plots also illustrate the evolution of the $(T_c - T_a) / \text{Input Power}$ indicating an increasing AHE based on the number of loading/unloading cycles. The AHE tends to increase until the fourth experiment cycle (H2#4), which is followed by a high-temperature degassing under vacuum at 730 °C. Subsequently, hydrogen is reintroduced in the fifth cycle (H2#5), resulting in a slightly lower AHE. The subsequent run (H2#6) was conducted after introducing fresh H₂, with a wire conditioning time of 113 hours at an input power of 152 W (see Figure 6).

absorption of H or D, depending on the specific ratio of H/Pd (or D/Pd). Similar qualitative results have been observed in our experiments with Constantan wires since 2011.

- The performance, as indicated by the AHE, tends to improve with each conditioning cycle from H2#1 to H2#2, H2#3, and H2#4, suggesting a progressive increase in activation.
- Interestingly, the behavior of decreasing resistance and increasing AHE exhibited qualitative similarities to the historical observations made with palladium since 1990 [18].
- For the purpose of enhanced clarity, it is important to note that while the wire's resistance continues to exhibit an augmentation in response to the input power, there is a concurrent diminishing trend in resistance observed as one progresses from H#1 to H#4, owing to the incremental uptake of hydrogen.
- These results suggest a potential for enhancing AHE through repeated conditioning cycles and indicate the positive effect of long-term exposure to hydrogen gas on the modified Constantan wire. It appears that the dominant factor is the conditioning time at high power, which refers to the time the wire spends at high temperatures and large voltage gradients (V/cm). True AHE experiments are conducted after such conditioning times, gradually reducing the input power. The waiting time before conducting experiments is chosen to be similar to that observed under helium gas calibration to achieve temperature equilibrium, with an additional increase of 20-30% to ensure even more reliable results. Further details on conditioning time are provided in the caption of Figure 5.

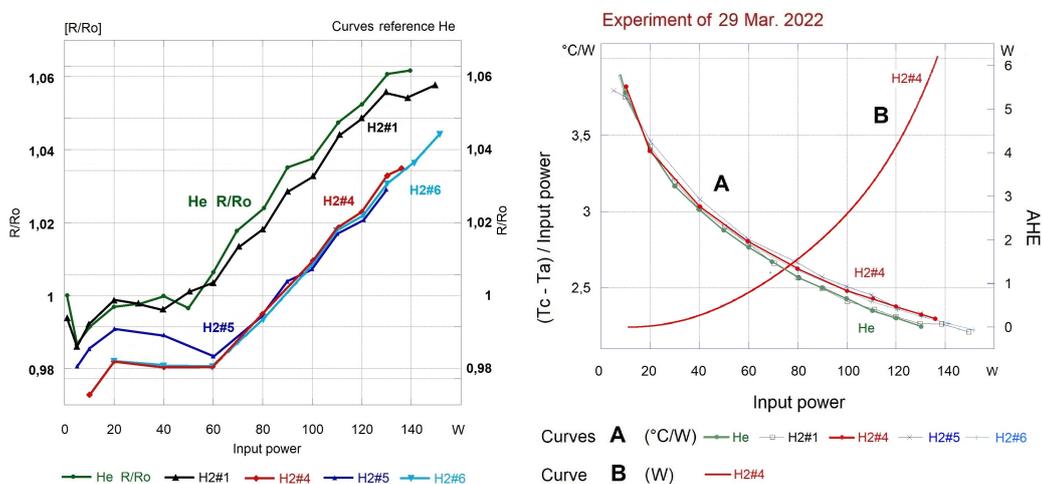


Figure 6. AHE and R/Ro Behavior with Vacuum Degassing and Refilling Cycles. This figure presents the behaviour of the Anomalous Heat Effect (AHE) and the resistance ratio (R/Ro) during cycles of vacuum degassing and refilling in the Constantan wire. The experiments involved cycles H2#4, H2#5, and H2#6. Vacuum degassing at high temperatures followed by fresh H₂ refilling was performed to investigate the effects on AHE performance. The results show that the AHE of H2#5 and H2#6 is lower compared to H2#4, indicating a partial recovery of the performances. The R/Ro values provide insight into the relative change in resistance normalized to its initial value (Ro) under He gas at very low power. These findings suggest that while some recovery of performance was achieved, it was not fully restored to the level observed in H2#4.

In this study, the analysis of Anomalous Heat Effect (AHE) curves involves employing a 4th order polynomial regression model to correlate temperature measurements with input power. To ensure the robustness and accuracy of this approach, we carefully select 10-15 experimental data points for each analysis. It is essential to note that during the initial runs, the measured AHE values were relatively modest. As a result, AHE has only been reported for the most productive experiments, specifically H2#4 and D2#12. For the remaining experimental runs, we report only the temperature difference between the reactor wall (T_c) and the ambient temperature (T_a), normalized by the input power, to identify potential occurrences of AHE.

6. Second Type of Experiment: Effect of Vacuum Degassing and Refilling Cycles (see Figure 6)

Following the completion of test H2#4, a dynamic vacuum at high temperature (730 °C) was applied for 15 hours. Subsequently, fresh H₂ gas was introduced into the system at the same pressure used in test H2#1, and experiment H2#5 was conducted.

- The results of H2#5 indicated a reduction in AHE values compared to H2#4, particularly at higher input powers. The decrease in performance was most prominent at elevated temperatures.
- This reduction in AHE performance could be attributed to several factors. Firstly, it is possible that the wire’s surface, which has undergone multiple treatments, may have become less effective in maintaining high AHE values at elevated temperatures. Additionally, prolonged vacuum conditions at high temperatures may have led to bulk modifications, such as diffusion of Cu and Ni within the wire’s composition, given the small diameter of the wire (200 μm).

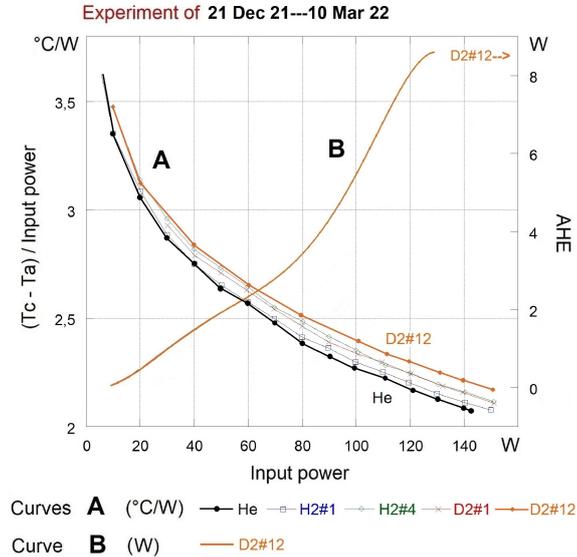


Figure 7. This illustrates the impact of substituting H₂ with D₂ on the behavior of the parameter $(T_c - T_a)/(\text{Input power})$ and AHE (anomalous heat effect). The most favorable outcomes were achieved after subjecting the system to 12 cycles of activation using high power and long durations. Specifically, the AHE under D₂ (experiment D2#12) yielded an impressive power output exceeding 9 W, whereas the AHE under H₂ (experiment H2#4) resulted in a power output of 5 W in the same experiment. It is important to note that the D₂ experiments were conducted after the H₂ experiments, potentially indicating a positive aging effect.

- An attempt was made to recover the high performance observed in H2#4 by changing the H₂ gas and subjecting the wire to a prolonged conditioning period of 113 hours at a high power of 152 W in experiment H2#6. However, this effort did not yield the desired results and further reduced the AHE performance.

In conclusion, the behavior of the low-cost material Constantan in terms of AHE and resistance variation (R/R_0) closely resembles that of the expensive material Palladium. This similarity allows us to leverage the extensive knowledge and research on Cold Fusion accumulated worldwide since 1989.

7. First Type of Experiment: Isotopic Effect (see Figure 7)

Isotopic Effect (3) (Experimental Run: 21 December 2021 - 10 March 2022).

During the extended period of operation under hydrogen and various high-power conditioning, we made a significant observation for the first time: an evident isotopic effect between hydrogen and deuterium. The specific experimental run lasted from 21 December 2021 to 10 March 2022. In previous experiments since 2011, the isotopic effects on Constantan wires after hydrogen absorption yielded inconsistent and often contradictory results, with AHE values under deuterium typically lower than those under hydrogen. In some instances, the deuterium values even fell below the calibration levels, resulting in an apparent “negative gain”.

Furthermore, we observed that the magnitude of the AHE depended on the wire’s previous “history” (resembling a memory effect), which could result in either a positive or negative impact on the AHE value. The highest recorded specific AHE value under D₂ was approximately 20 W/g of Constantan, occurring at wire temperatures ranging from

500-600 °C. The Constantan wire used in the experiment weighed only 0.45 g, and we can assume that the influence of specific glassy sheaths (several grams) and chemical coatings (<0.1 g) can be disregarded.

Taking into account these experimental findings, it becomes highly improbable to attribute the observed effects solely to unpredictable errors. The most plausible explanation is a deliberately controlled procedure, particularly in light of the consistent outcomes observed since July 2021 (as presented at ANV8, December 2021).

8. Superabundant Vacancies (SAV) as a Co-factor for Activation through Long-term Electromigration

The positive effects observed in experiments involving the flow of large current densities over extended periods, resulting in significant electromigration, can potentially be attributed to the intriguing phenomenon of Superabundant Vacancies (SAV) induced by hydrogen and/or deuterium [10], [11], [12], the primary gases employed in all Low Energy Nuclear Reactions-Atomic Hydrogen Effects (LENR-AHE) experiments. This hypothesis gains further support from the substantial increase in Anomalous Heat Effects (AHE) achieved through High Peak Power Pulses (HPPP) procedures.

Remarkably, one of our most noteworthy outcomes, published in Physics Letters A in 1996 [19], after some articles on simpler experiments [20], [21], [22], was obtained using the Pd-deuterium system, where pulsed electrolysis and electromigration were simultaneously employed. This historical finding underscores the potential role of SAV as an indirect yet potent mechanism contributing to the generation of AHE, complementing other established factors such as electromigration, Non-Equilibrium Metal Cathode Adsorption (NEMCA) [23], and the “Preparata effect” [24].

Superabundant vacancies have been identified as a novel phase that can form in various metals and alloys, including Ni, Pd, Pd-Rh alloys, Pd-Ag alloys, Ag, Rh, Pt, Au, Al, Cu, Cu-Ni alloys, Ir, Mo, Fe, Nb, Cr, Co, Mn, Ti, and Zr. These vacancies were first discovered in 1993 by Prof. Yuk Fukai and his Colleagues [25] at Tokyo University, Japan, through diverse methods such as wet electrolysis, high-temperature/high-pressure gas via anvil compression, co-deposited electrolysis, solid-state electrolysis (dry electrolyte), ion beam implantation, and plasma injection. The phenomenology of SAV, when applied to LENR phenomena, has recently undergone further development by Prof. M. Staker from Loyola University in the USA [10], [11], [12]. His studies provide confirmation that vacancies are generated through a phenomenon known as hydrogen-induced vacancy formation.

As the hydrogen activity (expressed as the D/M or H/M ratio, with M representing the metal) increases in metals and alloys, it leads to the creation and ordering of more vacancies. This state corresponds to the lowest free energy condition for the metal. Notably, this positive influence can be observed in Figure 5 and 6.

Electromigration, a phenomenon well-established since 1928 [26], also plays a role in the formation of surface-active vacancies (SAV) by facilitating the localized enrichment of the D/Pd or H/Ni ratio. When subjected to an electric current, it is believed that D⁺ or H⁺ ions migrate in the direction of the current flow. However, the counteracting influence of the “electron wind” also needs to be considered. In conclusion, further studies are necessary to validate our simplified explanation.

The attractive forces between vacancies and migrating ions lead to an augmentation of the local D/Pd or H/Ni ratio, thereby resulting in an increased presence of vacancies within that specific region.

In our research, we have utilized the same current employed for electromigration to measure the overall resistance of the PdD or NiH system, providing valuable insight into the D/Pd or H/Ni ratio. This simple methodology has allowed us to identify the optimal conditions for establishing a nuclear active environment (NAE), as defined by E. Storm. Remarkably, we have been following this procedure since 1991, unaware of the underlying phenomenology at that time.

9. Conclusions and Future Plans

In conclusion, we have successfully reconfirmed the procedure for the simple activation of surface-treated Constantan wires. As anticipated, this phenomenon is complex and has origins in both the surface and bulk properties of the

material. However, its effectiveness is limited by the requirement of prolonged operation at high power, often spanning several weeks.

Furthermore, we have identified the potential involvement of Superabundant Vacancies (SAV) as a hydrogen-enhanced co-candidate in explaining the origin of Anomalous Heat Effects (AHE). Nevertheless, in our opinion, the primary and final determinant of AHE generation remains the flux of the appropriate gas (H, D) through a suitable lattice. This finding has been consistently reported by researchers in the USA, Japan, Italy, and other countries since 1989 [3], [2], [27], [28].

It is worth noting that the gas flux is typically not spontaneous but requires external energy input. Therefore, our ultimate goal is to develop a procedure that minimizes the reliance on external energy. High Peak Power Pulses (HPPP) present a promising avenue for achieving this objective, and further optimization of this technique is warranted.

Drawing from our previous explorations of various operating points and the understanding of relevant chemical-physical conditions and phenomena (such as Child-Langmuir, Paschen/DBD, and skin effect), we aim to develop an energy-efficient reactor design suitable for practical everyday use.

Moving forward, our future plans involve conducting additional experiments to gain further insights into the underlying mechanisms of AHE and to refine our understanding of the interplay between surface and bulk effects. These efforts will contribute to the ongoing pursuit of harnessing cold fusion and anomalous heat effects for practical energy applications.

Acknowledgments

We would like to express our sincere gratitude to the Metallurgical Company in the North-Eastern part of Italy (NEMC) for their invaluable financial support and collaboration since 2011. Their independent cross-checking of our critical experiments in their own laboratories has significantly bolstered our confidence in the reported results.

We are also grateful for the ongoing collaboration with NEMC and SIGI-Favier (Italy-France) since 2017. Together, we have been working on the design and development of an original hybrid sheath (SE-SI) composed of Glass and Alumina-Quartz fibers. These sheaths, used for wire insulation in our experiments, possess exceptional thermal stability, operating continuously at temperatures up to 1050 °C. Their tailored geometry allows for the adsorption of significant amounts of Atomic Hydrogen, making them a crucial component of our experimental setup.

We would like to acknowledge Innovatiogen s.r.l. (formerly IFA, Roma-Italy) for their continued financial support, which has enabled us to cover laboratory consumables and travel expenses for conferences, workshops, and meetings, both within and outside Italy.

Special thanks are extended to the scientists involved in the CleanHME European project, led by Konrad Czerski (Szczecin University, Poland). We are particularly grateful for the fruitful collaboration with Prof. Bo Hoistad and his team at Uppsala University, Sweden, as well as Dr. Andras Kowacs from Broadbit Company. We are also indebted to Prof. Michael Staker from Loyola University, USA, for providing us with key insights into the Superabundant Vacancies (SAV) phenomenology.

Partial funding for this work has been provided by the European Union's Horizon2020 Framework Program under Grant Agreement #951974.

We deeply thank the Editor of the Journal, Prof. Jean Paul Biberian, and the Referees, because, thanks to their in-deep analysis/comments/criticisms/suggestions of our original manuscript, the paper was largely improved and is more understandable.

Disclaimer: The content and findings presented in this document are the sole responsibility of the authors and do not necessarily reflect the opinion of the entire CleanHME project.

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