NATIONAL SECURITY AGENCY
CENTRAL SECURITY SERVICE
FORT GEORGE G. MEADE, MARYLAND 20755-6000

FOIA Cases: 81729A, 83745A
16 March 2017

JOHN GREENEWALD
[redacted]

Dear Mr. Greenewald:

This responds to your Freedom of Information Act (FOIA) request of 9 July 2015, for Intellipedia pages on "COLD FUSION", and your request of 16 February 2016 for Intellipedia pages on "Low Energy Nuclear Reactions (LENR). As stated in our previous responses, dated 14 July 2015 and 14 March 2016, respectively, your requests were assigned Case Numbers 81729 and 83745. Copies of your requests are enclosed. For purposes of these requests and based on the information you provided in your letters, you are considered an "all other" requester. As such, you are allowed 2 hours of search and the duplication of 100 pages at no cost. There are no assessable fees for these requests. Your requests have been processed under the FOIA.

For your information, NSA provides a service of common concern for the Intelligence Community (IC) by serving as the executive agent for Intelink. As such, NSA provides technical services that enable users to access and share information with peers and stakeholders across the IC and DoD. Intellipedia pages are living documents that may be originated by any user organization, and any user organization may contribute to or edit pages after their origination. Intellipedia pages should not be considered the final, coordinated position of the IC on any particular subject. The views and opinions of authors do not necessarily state or reflect those of the U.S. Government.

We conducted a search of all three levels of Intellipedia for the requested topics, and located two documents that are responsive to your request. These documents are enclosed. Please note that the "Cold Fusion" article redirects to the "Low Energy Nuclear Reactions" article. Certain information, however, has been deleted from the enclosures.

This Agency is authorized by statute to protect certain information concerning its activities (in this case, internal URLs) as well as the names of its employees. Such information is exempt from disclosure pursuant to the third exemption of the FOIA, which provides for the withholding of information specifically protected from disclosure by statute. The specific statute applicable in this case is Section 6, Public Law 86-36 (50 U.S. Code 3605). We have determined that such information exists in this record, and we have excised it accordingly.

FOIA Cases: 81729A, 83745A

In addition, personal information regarding individuals has been deleted from the enclosures in accordance with 5 U.S.C. 552 (b)(6). This exemption protects from disclosure information that would constitute a clearly unwarranted invasion of personal privacy. In balancing the public interest for the information you request against the privacy interests involved, we have determined that the privacy interests sufficiently satisfy the requirements for the application of the (b)(6) exemption.

Since these deletions may be construed as a partial denial of your request, you are hereby advised of this Agency's appeal procedures. You may appeal this decision. If you decide to appeal, you should do so in the manner outlined below.

- The appeal must be in writing and addressed to:

  NSA/CSS FOIA/PA Appeal Authority (P132),
  National Security Agency
  9800 Savage Road STE 6932
  Fort George G. Meade, MD 20755-6932

- It must be postmarked no later than 90 calendar days of the date of this letter.
- Please include the case number provided above.
- Please describe with sufficient detail why you believe the denial of requested information was unwarranted.
- NSA will endeavor to respond within 20 working days of receiving your appeal, absent any unusual circumstances.
- Appeals received after 90 days will not be addressed.

You may also contact our FOIA Public Liaison at foialo@nsa.gov for any further assistance and to discuss any aspect of your request. Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows: Office of Government Information Services National Archives and Records Administration, 8601 Adelphi Rd- OGIS College Park, MD 20740, ogis@nara.gov, (877) 684-6448, (202) 741-5770, Fax (202) 741-5769

Sincerely,

Paul N
for

JOHN R. CHAPMAN
Chief, FOIA/PA Office
NSA Initial Denial Authority

Encl:
a/s

From:	donotreply@nsa.gov
Sent:	Tuesday, February 16, 2016 5:41 PM
To:	donotreply@nsa.gov
Cc:	john@greenewald.com
Subject:	FOIA Request (Web form submission)

Name: John Greenewald

Title: Mr.

Email: john@greenewald.com

Company: The Black Vault

Postal Address: [redacted]

Postal 2nd Line: None

Postal City: [redacted]

Postal State-prov: [redacted]ornia

Zip Code: [redacted]

Country: United States of America

Home Phone: [redacted]

Work Phone: [redacted]

Records Requested: To whom it may concern,

This is a non-commercial request made under the provisions of the Freedom of Information Act 5 U.S.C. S 552. My FOIA requester status as a "representative of the news media" however due to your agency's denial of this status, I hereby submit this request as an "All other" requester.

I prefer electronic delivery of the requested material either via email to john@greenewald.com or via CD-ROM or DVD via postal mail. Please contact me should this FOIA request should incur a charge.

I respectfully request a copy of the Intellipedia entry (from all three Wikis that make up the Intellipedia) for the following entry(s) (Or whatever similar topic may pertain if it is slightly worded differently):

Low Energy Nuclear Reactions (LENR)

Thank you so much for your time, and I am very much looking forward to your response.

Sincerely,

[redacted]

From: donotreply@nsa.gov
Sent: Thursday, July 09, 2015 7:18 PM
To: donotreply@nsa.gov
Cc: john@greenewald.com
Subject: FOIA Request (Web form submission)

Name: John Greenewald

Email: john@greenewald.com

Company: The Black Vault

Postal Address: [redacted]

Postal City: [redacted]

Postal State-prov: [redacted]

Zip Code: [redacted]

Country: United States of America

Home Phone: [redacted]

Work Phone: [redacted]

Records Requested: To whom it may concern,

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I respectfully request a copy of the Intellipedia entry (from all three Wikis that make up the Intellipedia) for the following entry(s) (Or whatever similar topic may pertain if it is slightly worded differently):

COLD FUSION

Thank you so much for your time, and I am very much looking forward to your response.

Sincerely,

John Greenewald, Jr.
[redacted]

[redacted]

(U) Cold Fusion

UNCLASSIFIED

From Intellipedia

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Redirect page
You have new messages (last change).
↳ Low Energy Nuclear Reactions
Retrieved from [redacted]

UNCLASSIFIED

- This page has been accessed 20 times.
- 2 [redacted] watching users
- This page was last modified 15:43, 17 March 2011 by [redacted] (b)(6)

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gclinipedweb7j

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(U) Low Energy Nuclear Reactions

UNCLASSIFIED

From Intellipedia

You have new messages (last change).

(U) **This page may not comply with Intellipedia:Classification policy.**

(U) Please add or correct the classification markings. Mark the front of all portions, including paragraphs, section titles, tables, links, and image captions. The banner classification should match the classification of the contents. See the discussion page for details.

(U) Per ICD 710 Paragraph G, Foreign Disclosure & Release (FD&R) markings are mandatory on classified intelligence information.

(U) Please **wikify** this page.

(U) This article has been flagged since September 2007.

This unclassified NMIC paper has been submitted for comment and contributions.

(U) *In February 2006, the National Intelligence Council's Scientific and Technical Intelligence Committee sponsored an open source literature review of LENR publications. This endeavor was not intended to be an exhaustive study of the subject matter but rather to provide a broad overview of the topic based on the existing scientific literature on the subject. A searchable Microsoft Access database was delivered that contains the over 300 LENR-related articles that formed the basis of this paper that was originally prepared in May 2006 by an analyst at NMIC.*

Low Energy Nuclear Reactions (LENR) refers to a variety of conjectured and unvalidated methods to induce nuclear fusion reactions outside the extreme pressure and energy conditions in which they are currently known to occur. More popularly known as **Cold Fusion**, it is also known by other terms such as "lattice-enhanced nuclear reactions", "chemically assisted

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nuclear reactions ", and "condensed-matter nuclear science". If Cold Fusion were to be proven possible it would be a revolutionary new clean energy source, but at present mainstream science has developed no conclusive, reproducable evidence that this is the case.[1].

Background

Interest in Low Energy Nuclear Reactions was invigorated by the 1989 reports from Drs. Stanley Pons (University of Utah) and Martin Fleischmann (University of Southampton, England) in which they claimed that fusion had occurred in experiments during the electrolysis of heavy water. Their findings were particularly surprising given the simplistic nature of the equipment required; a pair of electrodes connected to a battery and immersed in a jar of heavy water (D_2O). The excitement generated from this announcement was primarily due to the claims of heat production by nuclear fusion in these experiments, and the implication that it could have on the future worldwide energy supply. Scientists from around the world have attempted to repeat the experiments with mixed results.

Key Findings

Pons' and Fleischmann's announcement that they had produced "excess" heat in a palladium electrochemical cell, due to the fusion of deuterium (D), created a sea of controversy within the scientific community that remains to this day. Deuterium is an isotope of hydrogen and is widely abundant in nature. The fusion of deuterium releases a significant amount of energy, and if this event could occur in "less than extreme" conditions a new energy source would be available to meet the world's growing energy needs. The fusion of deuterium under "less than extreme" conditions was initially termed cold fusion but now is termed low energy nuclear reactions (LENR). Since Pons and Fleischmann's announcement, research programs in LENR have been supported by various universities, private industry, and government agencies worldwide.The fusion of two deuterium nuclei not only releases excess energy but will also produce 3He + a neutron, or tritium + a proton, or 4He + gamma ray emission depending upon which reaction pathway takes place.

The majority of mainstream scientists doubt that LENRs take place, but a small contingent of believers still advocates their occurrence. Excess Heat: Experiments conducted to measure excess energy release from LENR deuterium fusion have resulted in mixed findings. Some laboratories have claimed excess heat production, but most report negative results. Proponents of the LENR process believe that certain triggering issues are necessary to initiate the fusion process but at the present time these triggering events are not totally understood. Tritium and neutron production claims: A number of scientists have tried to detect the presence of the other by-products of deuterium fusion: He, neutrons, tritium, and gamma rays. Tritium production has been reported by a number of researchers but their production levels do not correlate with the amount of excess heat that was observed in their experiments. The majority of tritium detection experiments produced null results.

Many claims have been made for the production of neutrons in electrochemical cells but these

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measurements have been difficult to verify since cosmic-ray neutron fluctuations of 20% or more can be attributed to changes in solar activity or barometric pressures. However, even if the total number of neutrons detected is assumed to result from fusion reactions, the quantity of neutrons observed is well below the theoretical quantity that is predicted from observed heat generated.Helium and gamma production claims: Most LENR advocates believe that the deuterium fusion reaction pathway taken in their experiments produces 4He + gamma ray emission. A number of LENR researchers have claimed to detect helium production in their experiments that occurred temporally with the production of excess heat. However, a larger body of research searching for helium production yielded only negative results. Additionally, the quantity of helium detected in positive experiments was, in most cases, substantially below that of ambient air. No evidence has been presented to date that establishes gamma emissions in conjunction with helium production.

LENR advocates believe that the gamma energy is directly absorbed by the cathode lattice and released as heat.Heavy element transmutation claims: A number of researchers have reported the occurrence of heavy element transmutation in low-energy experiments. A variety of elements are claimed to exist after experimentation, which were not present at the onset of the experiment. Critics claim that these "new elements" are due to contamination. Also, critics are perplexed as to why other by-products of nuclear reactions such as radiation are not found with the transmutation phenomenon.Post script:There has been at least one late breaking development since the research for this paper was completed that supports the need for the intelligence community to continue monitoring LENR research. The development in question is a theory that was recently published by Lew Larsen (Lattice Energy, LLC) and Allan Widom (North Eastern University) that claims to explain many of the results that have been reported over the years and why so many of these results have been unrepeatable. The unique thing about their theory is that it makes some quantitative predictions, and the authors believe they can design experiments that if successful will support the theory. Furthermore, if their understanding of the phenomenon is correct, they claim that they will have a black box type heat source ready for sale in a finite number of years. Given the history of this field, it is impossible to know if these claims are reliable, but should they be, then great changes in the world can be expected in the coming decades. Therefore, because of the game changing potential of LENRs, it is our judgment that the intelligence community must continue to monitor this topic in order to give proper warning should a true breakthrough occur.

DISCUSSION

Introduction

Pons and Fleischmann first reported the production of "excess" heat in a palladium electrochemical cell in 1989 [2] They postulated that the "excess" heat was due to deuterium-deuterium (D-D) fusion, often referred to as cold fusion or also as a subset of LENRs. Since that date, numerous experiments have been conducted to prove and understand the mechanisms involved with the LENR process, with mixed results.

LENR experimentation has been directed at providing evidence of excess power, measurement of expected fusion by-products such as tritium and helium, and the transmutation of certain elements. A literature search was done to identify the major research activity that has been conducted and reported for LENRs. This discussion will address the key supporting publications and the questions that the research community has raised regarding their results.

Most commonly, the basis of LENRs is the fusion of deuterium at conditions much less severe than those

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found in the interiors of stars, i.e., cold fusion. The known fusion reactions of deuterium and its by-products are presented in Table 1.

TABLE 1
Deuterium Reactions and By-Products

#	Reaction	By-products	Energy Release (MeV)
(a)	D + D	3He + n	3.27
(b)	D + D	T + p	4.03
(c)	D + D	4He + gamma	23.85
(d)	D + T	4He + n	17.59
(e)	P + D	3He + gamma	5.49
(f)	P + T	4He + gamma	19.81

The "traditional" hot fusion ratio of deuterium is approximately 50:50 for reactions a and b while reaction c is only observed at a frequency of 10-7 less than reactions a and b. However, many proponents of LENR believe that reaction c is favored in their condensed matter reactions. Much experimental effort has been conducted to verify deuterium fusion by detecting excess heat in conjunction with the production of helium, neutrons, and/or the detection of tritium as proof that a nuclear reaction has occurred.

Findings of Excess Heat

A number of researches have claimed to observe "excess heat," or more precisely excess energy, from electrochemically charged palladium cells that cannot be accounted for in the thermal balance normally associated with water electrolysis. The basic components of these experiments consisted of a palladium cathode, a platinum anode, and a heavy water (D2O)-LiOD electrolyte, which are reported to produce excess power during electrolysis. Power was measured by temperature rises in the cell that were then converted into units of power. Excess power was defined as the output power minus the input power: the time integral of excess power is excess energy that was observed as excess heat.

The original Fleischmann and Pons (FP) experiment was conducted in an open cell, so corrections had to be made for evolved gases (D2 and O2) and any liquid loss carried out as spray. Determining the heat balance under these conditions is extremely complicated and prone to error. Subsequently, many experimentalists who tried to replicate the FP findings failed conclusively to produce any excess heat generation. Other researchers, in an attempt to eliminate open cell calorimetry errors, conducted experiments in closed cells in which the electrolysis products recombine in the cell. Results from these experiments were also mixed.

Current Density and Deuterium Loading

Based on the conflicting results from previous "excess heat" experimentation, various groups set out to determine the conditions that were necessary for LENRs to occur. McKubre et al. [3] examined the influence of the D/Pd loadings on whether "excess heat" could be observed. They determined that one criterion for observing anomalous power generation was the attainment of average deuterium loadings of

[redacted]

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between 0.9 or higher in the palladium cathode. One theory [3] is that as the deuterium loading reaches the 0.9 factor micro fractures occur within the palladium crystal lattice that enhance the diffusion of D from the metal so that the 0.9 loading is never achieved. Another factor that has been attributed to the observation of excess heat is current density. Experiments by McKubre et al. [4] showed that a current density of 265 mA/cm2 is needed before excess power is realized. A near linear increase in excess power was observed as the current density increased past this "threshold." Other researchers who attempted to meet these criteria failed to observe anomalous heat. Their results indicate that other factors, beside current density and D loadings, must come into play for excess energy to be observed.

Trace contaminants, triggering issues and duration of experiment: Various other factors have been mentioned as to why anomalous heat has not been observed in experiments in which the researchers have tried to faithfully replicate prior successful test results. Another explanation of negative findings is that trace contaminants in either the cathode or electrolyte may prevent fusion from occurring. The time element is also a crucial factor in observing excess heat. Some researchers have claimed to observe excess heat only after very long electrolysis times (several hundreds of hours) while others report excess heat results after a few hours of electrolysis. Some proponents of the LENR process believe that certain triggering issues are necessary to initiate the fusion process and at the present time these triggering events are not totally understood.

Excess Heat:

The energy density that has been reported from successful LENR experiments is typically given in terms related to the total cathode volume, due to the belief that the energy production occurs within the metal deuteride. Excess energy at the level of 130 MJ/cm3 has been reported by Gozzi et al. [5] and many other researchers have reported excess energy production around this general level. However one must be cautioned about claims of experiments that demonstrate "excess heat"; the levels of energy obtained are relatively modest representing between 0.2 to 4% of the total input energy. The inconsistencies in experimental set-ups (closed vs. open cells), purity of materials, variations in the time duration of experiments, and differing equipment for making calorimetric measurements may account for the apparent low frequency of occurrence of reactions.

The Coulomb Barrier

A final argument that has been made by critics of LENR is that for the deuterium fusion to occur, the Coulomb barrier must be surmounted or penetrated at low energies, so that the nuclei of the two deuterium nuclei come very close together. The concept that palladium, with its special ability to absorb large quantities of deuterium, might bring the deuterium atoms close enough together to induce fusion has been made by proponents of LENR. However, the closest D-to-D distance between deuterons in palladium is ~ 0.17 nm, whereas the bond distance in D2 gas molecules is ~0.074 nm. Therefore, even under high D loadings of the palladium the D-to-D spacing remains too large for any fusion reaction. The spacing requirement can be somewhat minimized by the quantum mechanical phenomenon of tunneling in which nuclei at greater nominal separation may sometimes exhibit very small separations on very rare occasions. However a separation distance an order of magnitude smaller than normal atomic spacing would be required for fusion to occur. This would require compression of the solid matter 10 fold; requiring enormous pressure.

Fusion Products

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Extensive research efforts have been made to detect the reaction products resulting from deuterium fusion that is proposed to be responsible for the observed "excess heat" in electrolytic deuterium-palladium cells. All known D + D fusion reactions will produce either tritium or helium, as illustrated in reactions a, b, and c of Table 1. Therefore, researchers have made attempts to detect tritium, neutrons, gamma radiation, and 4He at elevated levels to prove that a nuclear reaction is responsible for the observed "excess heat" in LENRs.

The following paragraphs discuss some of the relevant research that has been conducted along with comments from the scientific community regarding the findings from these experiments to validate the occurrence of fusion

Attempts to Measure Tritium

Production of tritium should occur in approximately half the of deuterium fusion reactions, if known fusion pathways are followed, and a number of researchers have reported finding significant amounts of tritium in electrolytic cells using palladium cathodes. The detection of tritium in these samples should not be surprising. The tritium content of normal water is around 10-18 relative to hydrogen, and in the normal production of heavy water (D2O) the tritium content is enriched. One would therefore expect to detect tritium since the D2O used for the electrolyte would naturally contain tritium. It is therefore important to determine the initial tritium content of the electrolytic cell prior to electrolysis before any conclusions can be drawn concerning the formation of additional tritium during the experiment. Additionally, during the electrolysis of heavy water additional tritium may also be formed. The majority of the initial reports that claimed to observe excess tritium, upon further examination, were accounted for by the electrolytic enrichment process.

Proponents of LENR do not completely agree that all of the detections of tritium are the result of natural occurrence and enrichment procedures. They conducted highly controlled experiments that attempted to measure tritium levels prior to electrolysis, calculate the tritium contribution from the electrolysis of heavy water, and eliminate the possibility of contamination of the cathode material. Many of the subsequent experiments that were conducted under highly controlled conditions produced null results. However, some researchers noticed that the tritium produced in electrolytic cells occurred in burst-like events, which were followed by longer periods of inactivity. These spikes in activity, when distributed over the total time of electrolysis, were generally lost in the total averaged tritium count. One publication [6] reported excess tritium, 100 times background, during one of the tritium bursts. Other groups have not been able to reproduce the experiments in which bursts of excess tritium have been reported. In fact, the 100 times background tritium findings occurred in only two of the experimenter's 70 tested cells.

Some proponents of LENR advocate nuclear production of tritium. However, they cannot correlate the reported elevated levels of tritium detected with the amount of excess heat that was observed. The tritium levels were substantially less than would be expected to produce the amount of power generated. The tritium levels found would only be responsible for milliwatt power levels, not the watt levels observed. Even when one considers that only 50% of the D fusion would follow in the tritium production pathway of reaction b of Table 1, the correlation between power produced and tritium levels observed do not agree. Another abnormality of the tritium experiments is that in those experiments in which the detection of neutron production was attempted along with tritium, the quantities of neutrons detected were inconsistent with the amounts of tritium produced. Neutron levels were generally an order of magnitude or two less than would be expected from the typical 50/50 D fusion pathway of reactions a and b in Table 1. These results cast doubt upon the D fusion to tritium pathway as being primarily responsible for the observed

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excess heat that has been reported during the electrolysis of palladium electrochemical cells.

Attempts to Measure 3He and Neutrons

Neutrons are a major product formed by the fusion of deuterium, if conventional pathways are followed, and are convenient to detect since they interact only with nuclei of atoms. A number of researchers have therefore tried to detect elevated neutron levels from metal deuterides. Fleischmann and Pons initially claimed the detection of neutrons from their proposed D fusion in electrolytic cells. They based their findings on the detection of gamma rays that were emitted by the capture of the neutron in the water bath surrounding their electrolytic cell. Fleischmann and Pons later retracted this claim stating that their results resulted form an artifact of the experimental apparatus. Many claims have been made for the production of neutrons in electrochemical cells, but most of these claims have been withdrawn or modified due to difficulties with detection apparatus. It should be noted that cosmic-ray neutron fluctuations of 20% or more could be attributed to changes in solar activity or barometric pressures. It is therefore extremely difficult to differentiate between claimed elevated neutron levels and those associated with variations of background levels.

The detection of generated neutrons is reported at levels that are not significantly higher than background and still do not correlate to the quantities that would be required to produce the amount of "excess heat" that was observed in LENR experiments. In addition, many other experimenters have failed to detect any elevated levels of neutrons during their LENR experiments. The lack of neutron levels commensurate with heat production leads one to believe that other processes that cannot be explained by the two most likely deuterium fusion routes are involved in the heat production.

Attempts to Measure 4He and Gamma Rays

The data previously discussed regarding fusion products, even where positive results are given, fall well short of those that would be expected from the levels of heat reported in experiments where the production of "excess heat" was claimed. The absence of quantitative energetic emissions leads to the speculation that a new process is somehow involved in which the nuclear energy from the deuterium fusion is converted directly into heat. Proponents of LENRs have turned their attention to the less likely D fusion pathway of D + D yielding 4He and gamma ray emission as the predominate nuclear reaction occurring during electrolysis experimentation. Although this reaction occurs naturally at a rate 10-7 less likely than the previously mentioned D fusion reactions, there has been an empirical study conducted that showed that this pathway could become predominate under certain conditions.

L. C. Case [7] reported that when gaseous D2 is contacted with a platinum-group metal catalyst (½% to 1% by weight) on activated carbon at super-atmospheric pressure with a temperature of between 130 to 300° C, fusion occurs. The author claims that this fusion process does not produce neutrons, 3He, or tritium but does produce 4He. The mechanism of this fusion reaction is not known, but the mechanism is very selective and gives different results than one would anticipate from typical D fusion reactions.

McKubre et al. [8] conducted experiments that were designed to test Case's claim and attempt to observe excess temperature. Helium production was measured using on-line high-resolution mass spectrometry. Pair cells of palladium on carbon catalyst were exposed to D2 and H2 gases for prolonged periods. These sealed stainless steel cells exhibited a wide range of behaviors, but in no case was increased 4He observed in cells containing H2. Elevated helium levels were observed in sealed D2 cells but the increase varied

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considerably both in times of production and in amounts. In three of the cells tested, the measured helium levels exceeded that of the ambient background. The elevated helium levels of one test cell were compared to its excess energy output and a clear temporal correlation was claimed.

Miles et al. [9] conducted experiments that attempted to correlate excess power with the production of helium during electrolysis using palladium cathodes. They collected eight electrolysis gas samples during excess power production, and an analysis of these samples by mass spectrometry showed the presence of 4He. Control experiments performed in exactly the same manner but using H2O + LiOH in place of the D2O + LiOD electrolyte gave no evidence of helium or excess power. The amount of helium detected in the eight samples correlated qualitatively with the amount of excess power and was within an order of magnitude of the theoretical estimate of helium production based on the fusion of D to form 4He. These experiments were conducted using open calorimetric systems, and the detected helium was only in the 1 to 10 ppb range (ambient background is in the 5 ppm range). Although the authors went to great lengths to avoid contamination, critics maintain that the measured helium amounts are questionable due to the relatively large ambient concentration in comparison to the detected amounts of helium. However, the detection of helium in eight out of eight samples in conjunction with no evidence of helium in the six control samples is consistent with the occurrence of a nuclear event.

Botta et al. [10] conducted several experiments that searched for unambiguous signals of nuclear ash from cold fusion devices. Their initial attempts were focused on the detection of neutrons, but their measured fluxes were very low and were not consistent with excess power. They then decided to concentrate their efforts on the detection of 4He. They analyzed the gas of two electrolytic cells that produced excess heat after a greater than 500 hour run, and detected 4He excess in one of the cells. The mass spectrometer scan of the cell that produced helium showed an increase of 25-30% of the M/e=4 peak after the emission of the gas from the cell (the scan had sufficient resolution to discriminate the D2 peak from that of the 4He). The authors stated that scans performed before and after gas emission showed that all peaks corresponding to the observed higher values of M/e were the same level or lower implying that contamination from the atmosphere could not be attributed to the increased peak value.

Gozzi et al. [11] also found 4He present in deuterium loaded palladium cathode cells after electrolysis. Their sampling and measurement of the gas stream coming out of the electrolytic cells was carried out online. This process helped to avoid potential atmospheric contamination and increase the number of measurements considerably. The sampling of 4He was performed after the deuterium removing system had reduced the deuterium content of the gas mixture coming from the cell. They observed bursts of 4He in the gas stream that time-correlated to bursts of excess energy. The measured quantity of 4He was in the tera atoms (1012 atoms) range. When these bursts were compared one at a time, the number of helium atoms detected per burst was on the order of what is expected from a 23.8 MeV per D + D reaction, implying that the energy balance was satisfied if reaction c in Table 1 occurred. On the other hand, the authors acknowledged that the low levels of 4He detected did not give the necessary confidence to state definitely that they were observing the fusion of deuterium to give 4He. They also concluded that their detected 4He was produced at the cathode surface. This determination was based on the analysis of X-ray film that was exposed during their electrolytic runs.

De Ninno et al. [12] designed experiments that examined the three conditions that have been associated with electrolytic cell deuterium fusion. The three conditions are: reaching a threshold D concentration in the palladium, the production of excess enthalpy, and the appearance of 4He. They divided their experiments into four phases:

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- Preloading phase—During this normal electrolysis phase, a small (~ 5 mA) current flows through the cell. The output power equals the power supplied by the electrolytic current and the number of 4He atoms compares to the background values of the detector.

- Loading phase—The application of an electrical potential across the cathode increases the deuterium loading over the threshold necessary for fusion to occur.

- Supercritical phase—After crossing the threshold, anomalies appear in the system. These anomalies are an increase in the cathode temperature above the previous equilibrium value and a significant increase of 4He from the baseline for some time onwards.

- Control phase—After some hours of cell operation, the cathode potential is switched off and anomalies disappear. 4He yield settles back to the initial zero value.

Results from their experimentation revealed that during phase 1 the D/Pd loading ratio gradually rises to a value of 0.7. This is determined by comparing the ratio of cathode electrical resistance R/R0 (where R0 is the resistance of the empty palladium matrix). When the cathode resistance ratio reaches a value of 2, a D/Pd loading ratio of between 0.7 and 1 is achieved and the system is at equilibrium, which can last indefinitely. During experimentation, the researchers applied a current to the cathode ranging from 10 to 40 mA and once the deuterium ratio reached 0.7 the researchers noticed a resistance drop signaling an increase in D loading (phase 2). When the cathode resistance ratio reached 1.4, anomalies started to occur within the cell (the beginning of phase 3). The authors state that a 1.4 cathode resistance ratio corresponded to a D to Pd ratio of 1. During phase 3, a significant deviation of 4He from baseline was observed from the first time interval of 40 minutes onward. The 4He level continually rose as long as the system was in phase 3. The temperature of the cathode also rose above the prior equilibrium value, signaling a source of enthalpy in the cell. These two anomalies were observed to occur simultaneously. After hours of cell operation, the cathode voltage was switched off (the start of phase 4) and both anomalies disappeared.

Although the result of the previously discussed experimentation detected helium production that occurs temporally with the production of excess heat, critics of LENR have not been convinced that nuclear reactions have taken place. They claim that a larger body of research searching for helium production has yielded only negative results. Another reason for skepticism is that the quantity of helium found in the positive experiments was, in most cases, substantially below that of ambient air. In spite of the fact that the researchers went to great lengths to avoid contamination, that factor cannot be overlooked. Skeptics are also dubious that the less likely deuterium fusion pathway (reaction c) would predominate, as opposed to the expected deuterium fusion pathways (reactions a and b) that lead to the production of tritium or neutrons. Critics also maintain that if the deuterium pathway that produces helium is followed, gamma rays should be detected as a reaction by-product. No evidence has been presented to date that establishes gamma emissions in conjunction with helium production.

Proponents of LENR argue that the gamma (23.85 MeV) energy is directly coupled into the cathode lattice, which is released as heat (thereby explaining why no gammas are detected and excess heat is observed). They base this belief on two assumptions. The first is an internal conversion process that allows an atomic electron of an excited nucleus to carry off the reaction energy instead of a photon. The second is the Mossbauer Effect in which the momentum (but not its energy) of a low energy photon is taken up by the entire lattice in a coherent mode. Critics counter that internal conversion processes occur in heavy atoms that have tightly bound inner electrons whereas the atomic electrons of helium are loosely bound and that

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the Mossbauer Effect occurs at low energies (<100 keV) not the 23.85 MeV associated with deuterium fusion into helium.

Transmutations as Evidence for Fusion

In the early 1990s a number of researchers reported the occurrence of heavy element transmutation in low-energy experiments. Transmutation reactions can be classified according to their characteristic products. Two basic types of reactions have been reported. The first type of reaction gives a large array of products with mass numbers extending across the periodic table. It is speculated that these reactions occur from multiple events leading to the formation of heavy compound nuclei that can decay into an array of elements. The second type of reaction yields specific products that result from the direct reaction of the electrode metal or its impurities and the deuterons.

Miley and Patterson [13], using thin-film nickel coated micro spheres reported finding Fe, Ag, Cu, Mg, and Cr, following a two-week electrolytic run, in concentrations greater than one would expect to be present due to trace contaminates in the initial film, electrolyte and other accessible cell components. They also found deviations from natural isotope distributions for select elements and stated that there was preliminary evidence for soft x-ray (<20 keV) or beta emission from the micro spheres after operation.

Miguet and Dash [14] conducted a microanalysis of palladium cathode material after electrolysis for 25 hours and found the unexpected elements of aluminum and titanium in localized concentrations inside the palladium. Previous work by these two researchers detected both silver and gold on the surface of heavy water electrolyzed palladium cathodes that they claim could not be attributed to contamination.

Iwamura et al. [15], of Mitsubishi Heavy Industries, have claimed to transmute trace carbon contaminates on multi-layer palladium, containing low work function material, into Mg, Si, and S. Experiments were conducted in which deuterium gas was diffused though either a (normal) Pd-only layer thin film or multi-layer palladium membrane that was composed of a Pd thin film (400 angstroms), low work function layer (CaO, 1,000 angstroms), and a palladium sheet (25mm x 25mm x 0.1mm). Test materials were placed in a vacuum chamber and their surfaces were analyzed by X-ray Photoelectron Spectroscopy to confirm that they were clean. D2 gas was presented into one side of the chamber so that the atoms would diffuse though the test material and into the vacuum side of the chamber. After a period from 2 days to 1 week of deuterium diffusion, the D2 side chamber was evacuated and surfaces were re-analyzed. Only carbon and palladium were found prior to diffusion and the number of C atoms did not change for the Pd?only material (normal). The multi-layer material gave entirely different results. Only C and Pd were present at the beginning of the experiment, but after 42 hours of diffusion Mg, Si, and S peaks appeared while the C peak decreased. At 116 hours of diffusion the S and Si quantities increased while the Mg decreased. The researchers duplicated this experiment with the only difference being the amount of C present being slightly greater. They observed the same results during this second experiment with the only variation being a shorter time (24 hours) of diffusion before the Mg, Si, and S peaks became apparent. They concluded that the results indicated that the behavior of C, Mg, Si, and S were reproduced qualitatively.

Szpak et al. [16] also reported evidence of nuclear reactions in the palladium lattice of electrochemical cells. They prepared Pd/D films in which they co-deposited these materials simultaneously onto substrates that do not absorb deuterium. Scanning electron microscopy (SEM) of these surfaces illustrated globules 3-7 μm in diameter that were arranged in short columns. Energy-dispersive X-ray (EDX) analysis of the

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surface showed that it had a composition, by weight, of 95.17% palladium and 4.83% oxygen. An external electric field, cell current 100 mA or greater, was maintained for at least 48 hours in the cell and the Pd/D structure was re-analyzed using SEM and EDX. Morphological changes were observed on the surface of the substrate, which now had molten-like features. Boulder-like and crater-like structures were now present. EDX analysis of the boulder-like structure revealed the presence of Al while adjacent regions contained only Pd and O. In the crater-like structures, Al, Ca, Mg and Si were detected at levels that the authors claimed exceeded the amount that could have been attributed to contamination. The authors further claim that these "new elements" are only found in regions of the surface that have undergone morphological change. If these "new elements" were simply deposited, they would be uniformly distributed throughout the surface and not localized.

Toriyabe et al. [17] claimed to induce nuclear reactions on palladium electrodes during light water critical electrolysis. To minimize the effects of materials electrodepositing from the anode, they made the anode from the same element as the cathode. Both anode and cathode were made from identical palladium wires taken from the same stock. The electrolyte solution was 1 M K2CO3. An experiment was conducted that lasted 7 days with a current density of 3.2 A/cm2 and after which both the anode and cathode were analyzed by EDX. The cathode only, after electrolysis, contained Fe, Ti, Cr, Mn, and Ni. Both electrodes contained Cu, Zn and Mg. None of these elements were detected in the sample prior to experimentation. The authors concluded that these elements were the products of transmutation.

Critics of these experiments state that, regardless of the researchers' claims, contamination is the reason that the "new elements" are found after experimentation. They argue that, without altering the present view of our current understanding of fundamental physics, no theory exists that would allow the Coulomb barrier to be circumvented during these experiments and that would be a prerequisite leading to the fusion pathway. Critics also wonder why other by-products of nuclear reactions such as radiation are not found with the transmutation phenomenon.

Sonofusion to Initiate a Pathway to Fusion?

The phenomenon of sonoluminescence has intrigued scientists for a number of years. In sonoluminescence, bubbles that are forced to expand and collapse by sound waves emit pulses of light. Some physicists have speculated that the compressive forces and extreme temperatures inside the collapsing bubbles are large enough to spark nuclear reactions. Sonofusion is a branch of LENR in which some researchers claim to have achieved nuclear reactions using sonic pressure waves. Sonofusion is based on bubble cavitation and is also termed "acoustic inertial confinement fusion" (AICF).

Taleyarkhan et al. [18] conducted cavitation experiments using deuterated acetone in which bubbles were nucleated by means of fast neutrons. The neutrons (14 MeV) were produced on demand from a pulsed neutron generator at a predefined phase of the acoustic pressure field. During this process, bubble nucleation centers up to ~ 100 nm are created and grown in an acoustic field at 19.3 kHz to ~ 1 mm before an implosive collapse. This approach provides a vastly increased energy concentration potential during implosions, resulting in significant increases in peak temperature, which the author claims could lead to nuclear fusion and thus detectable levels of nuclear particle emissions. The authors claimed that D-D fusion occurred based on their detection of tritium decay activity above background levels and the observation of 2.5 MeV neutrons. Control experiments with normal acetone did not result in tritium activity or neutron emissions. Many scientists doubted that Taleyarkhan's neutron detection was accurate, believing that the neutrons detected originated from the pulsed neutron generator. Two of his colleagues at Oak Ridge,

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Mike Saltmarsh and Dan Shapiro [19], tried to duplicate Taleyarkhan's findings. Their experiments failed to detect convincing evidence of tritium production, and they observed far fewer neutrons even though their neutron detector was much more efficient than Taleyarkhan's. Taleyarkhan, who claimed that the neutron detector was calibrated incorrectly, refuted these results.

Putterman et al.[20], using the same key scientific conditions as Taleyarkhan, measured neutron activity and the corresponding flashes of light simultaneously with nanosecond accuracy. Recording data nanosecond by nanosecond, Putterman did not find a single neutron close enough to a flash of light for it to be considered the result of nuclear fusion. Taleyarkhan recently (2006) published results in which the radioactive decay of dissolved natural uranium was used to nucleate bubble clusters in deuterated benzene-acetone mixtures. This completely eliminated the need for an external neutron source and removed any potential contamination due to the previously used source of neutrons. He claimed to measure, with multiple independent detectors, statistically significant emission of 2.45 MeV neutrons, while corresponding experiments with nondeuterated control liquids or heavy water produced null results. However, measuring neutrons on a small, laboratory scale has proven to be extremely difficult in the past, and background counts can fluctuate due to solar and barometric pressure changes.

Another researcher has claimed to observe nuclear events using bubble cavitation to produce low energy, high-density plasma jets. Roger Stringham [21] has used an electrically driven piezo device filled with D2O to produce an acoustic field resonating at 1.7 MHz that generates cavitation bubbles that act as micro accelerators during their final stage of collapse. The inertial compression of the jet via an electron induced magnetic field pinch effect on the plasma contents produces deuteron densities in the order of 1025 gm/cc. This plasma then implants high-density deuterons into a target lattice in a period of a few picoseconds. Stringham believes that the high-density deuterons in the target lattice experience reduced Coulomb repulsion due to the high-density charge screening, and it is in this environment that D fusion occurs. He theorized that deuterons fuse in transient spherical coherent ion traps producing an intense heat pulse. This heat radiates out from the lattice as a gaseous vapor to the surface boundary of the target where it bursts from the target surface as metallic vapor ejecta leaving a telltale signature vent site that can be detected by SEM. This researcher has claimed to detect 4He at levels 100 times larger than ambient concentrations when palladium is used as the target foil. SEM photographs of the target foil showed lattice vent sites on its surface after sonofusion. No penetrating radiation was measured during the many hours of cavitation, implying that all of the energy released from the deuterium fusion was released as heat.

Summary

It has been over 15 years since Fleischmann and Pons first claimed to have observed LENRs, and the debate as to their existence continues to this day. The majority of mainstream scientists doubt that LENRs take place, but a small contingent of true believers continues to advocate their occurrence. One problem that has prevented this debate from reaching a definitive conclusion is that a number of factors (variables) must be perfectly aligned, according to supporters, for LENRs to occur. If there is any deviation from this perfect alignment, the experiment will produce null results. Proponents claim that this is the reason for the lack of experimental reproducibility. Believers also witness the lack of reproducibility. They cannot predict in what time period LENRs will start, the duration of the LENR, or how much energy will be generated. The unpredictable nature of these reactions makes it extremely difficult to state conclusively that LENR do not exist. Concurrently, low-level contamination and/or background levels can often be used to explain the results from experimenters who profess observing LENR. Given the immature nature of the existing state-of-the-art (not yet validated) coupled with a lack of developed infrastructure to harness the energy output it is unlikely that LENRs will be a major contributor in meeting the world's future energy demands within the coming few decades.

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