A RESPONSE TO THE REVIEW OF COLD FUSION BY THE DOE

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ABSTRACT
Various critiques provided by reviewers assembled by the DOE to evaluate cold fusion are addressed. Important issues are clarified and some misunderstandings are corrected.

I. INTRODUCTION

Starting in May 2004, the DOE undertook to evaluate the phenomenon called cold fusion or more accurately Low Energy Nuclear Reactions (LENR). This evaluation was based on an oral presentation and on seven documents that were either written for the purpose or chosen to support the claims. A group of reviewers was chosen by the DOE to judge these submissions. The charges to the 18 reviewers who responded were:

1. Evaluate the experimental evidence presented for the occurrences of nuclear reactions in condensed matter at low energies (less than a few electron volts).
2. Determine whether the evidence is sufficiently conclusive to demonstrate that such nuclear reactions occur.
3. Determine whether there is a scientific case for continued efforts in these studies and, if so, to identify the most promising areas to be pursued.

Most reviewers were thoughtful and documented their comments very well. A variety of opinions were revealed that are also shared by the mainstream scientific community. Therefore, a response to those concerns, some accurate and some based on an understandable lack of knowledge about LENR, may help dispel some of the myths associated with this controversial subject. For a more comprehensive understanding, the reader is directed to several general reviews [1-4] that can be downloaded in full text at www.LENR-CANR.org.

Most reviewers raised concerns that this writer also shares. For example, some of the papers describing cold fusion are of poor quality; many do not give sufficient information to allow the results to be properly judged; most have not been peer reviewed; and frequently work is a rehash of what has already been done. With a few exceptions, these deficiencies have resulted largely from having to work without adequate funding, frequent rejection by most professional journals, and being required to show skeptics that the effects are reproducible based upon conducting many similar studies. While these reasons cannot excuse the lack of acceptable information, they do help explain the difficulties that have kept the field from advancing any faster.

We can also agree that the claims are not consistent with accepted knowledge about the well-known fusion reaction, nor about other observed types of nuclear interaction.

Normally, fusion and similar reactions require high energy for their initiation. Furthermore, as the reviewers frequently pointed out, the expected fusion reaction results in neutron and tritium production in equal amounts. If ^{4}He is produced, gamma radiation is also expected. Considerable experimental experience shows that these expectations are not realized. A satisfactory explanation for this conflict with experience is not yet available. Therefore, the reader has the choice of rejecting the claims out of hand because they are inconsistent with expectations or accepting them if experimental observation cannot be completely refuted. The choice is left to the reader. This paper is written for those who choose to base their opinions on experimental evidence.

Some reviewers noted, incorrectly, that little has changed since 1989. The following changes have occurred and will be discussed in more detail below.

1. A claim for anomalous energy production is now based on numerous results using a variety of calorimeter designs at many different laboratories world-wide,
2. Evidence for unexpected nuclear reactions, in addition to fusion, has been reported based on emitted radiation and accumulated reaction products,
3. Reproducibility using certain methods has now increased to significant levels,
4. A variety of methods can be used to initiate both anomalous energy and nuclear reactions of several types,
5. A rich collection of explanations is now being actively explored, although this work will not be addressed here.

In addition, the institutions listed below are presently involved in research on the subject involving both experimental and theoretical studies.[1] This list does not include private laboratories or institutions not presently reporting their work. Clearly, the subject has wide interest in many countries.

- LUTCH Federal State Unitary Enterprise, Podolsk, Russia
- Joint Institute for Nuclear Research, Dubna, Russia
- Institute in Physical -Technical Problems, 141980, Dubna, Russia
- P.N. Lebedev Physics Institute, Moscow, Russia
- Enikolopov Institute of Synthetic Polymer materials, Russian Academy of Science, Moscow, Russia
- “RECOM”, Russian Research Center “Kurchatov Institute”, Russia
- General Physics Institute, Russian Academy of Science, Russia
- Chelyabinsk State University, Russia

- Proton-21 in Kiev, Ukraine
- Kiev Shevchenko University, Kiev, Ukraine

- University of Lecce, Lecce, Italy
- La Sapienza University, Rome, Italy

[1] Based on authors who presented papers at ICCF-11, Nov. 2004.

- University of Siena, Siena, Italy
- University of Bologna, Bologna, Italy
- Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA), Rome, Italy
- Instituto Nazionale de Fisica Nucleare, Laboratori Nazionali di Frascati (INFN-LNF), Rome, Italy
- EURESYS, Rome, Italy
- ORIM Srl, Macerata, Italy
- Pirelli Labs, Milan, Italy
- Centro Sviluppo Materiali SpA, Rome, Italy
- State University of Genoa, Genova, Italy
- Liceo Scientifico "Leonardo da Vinci", Milan, Italy
- STMicroelectronics, Milan, Italy
- Department of Physics, University of Catania, Italy

- Hokkaido University, Sapporo, Japan
- Advanced Technology Research Center, Mitsubishi Heavy Industries, Yokohama, Japan
- Japan Synchrotron Radiation Research Institute, Japan
- Coherent X-ray Optics Laboratory, Spring-8/RIKEN, Japan
- Laboratory for Nuclear Science, Tohoku University, Mikamine, Sendai, Japan
- Center for Advanced Science and Innovation, Osaka University, Osaka, Japan
- Cold Fusion Research Laboratory, Shizuoka, Japan
- Division of Environmental Energy Science, Graduate School of Science and Technology, Kobe University, Japan
- Fukaeminami-machi, Higashinada-ku, Kobe, Japan
- Institute of Quantum Science, Nihon University, Tokyo, Japan

- Institute of Chemistry, Chinese Academy of Sciences, Beijing, China
- Tsinghua University, Beijing, China
- Institute of Plasma Physics, Hefei, China
- Changchun University of Science and Technology, Changchun, China

- Laboratoire de Recherches Associatives, Franconville, France
- CNAM - Laboratoire des Sciences Nucléaires, Paris, France
- CRMCN-CNRS, Campus de Luminy, Marseille, France

- Howard University, Washington, D.C., US
- Purdue University, Lafayette, Indiana, US
- SRI International, Menlo Park, CA, US
- Naval Research Laboratory, Washington, D.C., US
- Oak Ridge National Laboratory, Oak Ridge, Tennessee, US
- Lattice Energy LLC, Chicago, IL, US
- The Greenview Group, Pleasanton, CA, US
- Research Systems, Inc, Burke, VA, US
- Greenwich Corp., Arlington VA, US

- Low Energy Nuclear Laboratory, Portland State University, Portland, OR, US
- Research Laboratory of Electronics, MIT, Cambridge, MA, US
- Fusion Studies Laboratory, University of Illinois, Urbana, IL, US
- Montclair State University, Passaic NJ, US
- University of Minnesota, Minneapolis, MN, US
- First Gate Energies, Kilauea, HI, US
- JET Thermal Products, Wellesley, Massachusetts, US
- SPAWAR Systems Center, San Diego, CA, US
- Earth Tech International, Austin, TX, US
- Institut für Atomare Physik und Fachdidaktik, Technische Universität, Berlin, Germany
- Energetics Technologies, Omer, Israel
- University of New South Wales, Sydney, Australia
- University Lucian Blaga, Sibiu, Romania
- Monti America Corporation, Kameloops, British Columbia, Canada
- National Academy of Sciences, Belarus

To keep this review brief, only a small sample of references available at www.LENR-CANR.org are cited when more detail is required for serious evaluation. Although only a few cited papers are peer reviewed, other papers nevertheless contain useful experimental detail that readers are free to judge for themselves. The reader needs to keep in mind that considerable detail may be missing because page limitations are frequently imposed. This problem will be remedied in the future when funds and the mechanism become available to publish detailed reports of work and have them distributed through normal channels, as is routinely done in other fields of science.

II. DISCUSSION

Experimental evidence for claiming a novel phenomenon based on nuclear interaction has three sources:

1. Energy production is measured using a calorimeter. This energy is frequently much too large to be produced by normal chemical processes,
2. Elements are detected after the process that were not detected initially, and cannot be explained by some sort of contamination and/or local enrichment,
3. Radiation of various kinds is emitted when none should be found.

As should be expected so early in a new field, evidence is internally inconsistent and in conflict. Each kind of evidence will be discussed separately starting with calorimetry.

II.1 Calorimetry

Three different basic types of calorimeters have been used - Seebeck, flow, and isoperibolic. The reader is directed to a detailed description [5] if the techniques are unfamiliar. It should be noted that the first two types do not suffer from those errors associated with and used to reject early studies. In addition, these calorimeter types do not measure energy, as do other types, but only instantaneous power. Energy is obtained by integrating over some period of time. Nevertheless, anomalous power (excess heat) is an important observation if properly interpreted.

These three types of calorimeters all have different errors and different behaviors, yet the claimed effect shows the same basic characteristics. These similar patterns of behavior involve the effects of D/Pd ratio and applied current on heat production, and the fact that certain lots of palladium are more successful than others. In addition, the heat-producing process has now been replicated dozens of times in laboratories all over the world [4], sometimes obtaining positive results when the same batches of palladium are used in different laboratories. Therefore, one criteria used to establish that a phenomena is real has been met.

Three basic challenges were suggested by the reviewers:

1. Prove that claimed anomalous (excess) heat energy is not generated by a prosaic reaction.
2. Prove that this energy is not merely released after it has been previously stored during the course of the experiment.
3. Prove that the calorimeter is sufficiently accurate and sensitive to reliably measure the claimed energy.

Each of these challenges has been suggested before and thoroughly evaluated in various published papers. Nevertheless, a brief commentary will be made here.

II.1.1 Prosaic Source

This evaluation can take two forms. We can examine how the cell would behave if a prosaic source actually existed or we can examine the cell to determine whether a mechanism required for such a source exists. A collection of previously suggested prosaic sources of heat are evaluated in [1] and are shown not to apply. These are:

1. Release of dissolved hydrogen from the palladium,
2. Formation of H_2 from atomic hydrogen,
3. Incorrect correction factor for recombination of hydrogen (deuterium) and oxygen,
4. Release of stored stress,
5. Incorrect measurement of applied power,

6. Energy added by the Peltier Effect,
7. Energy stored in chemical compounds somewhere in the LENR reaction cell,
8. Measurement error caused by temperature gradients,
9. Measurement error caused by unstable conductivity of the cell wall,
10. Energy added by the Jahn-Teller effect,
11. Errors in calibration constant.

A few reviewers suggested the following possibilities for prosaic sources:

II.1.2 Chemical Storage of Energy in LENR Cells and Subsequent Release as Heat

Energy can be stored either as it would be in a battery or it can form an unstable compound that later decomposes. In both cases, the storage process would be obvious as a negative power being recorded by the calorimeter. Of course, the magnitude of such negative power might be too small to be considered important, but would represent significant energy if it occurred over a long time. Consequently, samples that take a long time to turn on suffer from this possible error. However, many samples produce power and integrated energy at such high levels that this issue no longer applies and some cells turn on immediately. Nevertheless, this source of error cannot occur if an energy storage mechanism is not available, an issue that will be examined next.

If energy were in fact stored as in a battery or even as in a capacitor, stored energy cannot be released unless the power supply is disconnected and the cell shorted. In practice, this is never done. If energy were stored by generating an unstable compound, this compound could be identified and detected in the electrolyte, on the electrodes, or somewhere else in the cell. No such compound has ever been found nor would the chemistry available in a LiOD + D_2O electrolyte allow formation of such a compound. One reviewer suggested that the deuterium stored in the cathode, upon release and while reacting with oxygen, might provide the observed energy. Three well established facts eliminate this reaction as a source of energy. First, the cathode does not deload significantly while current is flowing through the cell. Even when current stops, deloading is very slow and does not produce detected energy. Deloading is very easy to observe in most modern cells. Second, the released D_2 can only react with oxygen that is contained within the cell. Typical cells are very small and contain too little oxygen to generate detectable energy. Third, most modern cells are sealed and are connected to an external means for monitoring internal pressure. No pressure change or deloading is observed when excess energy is produced.

Another reviewer suggested that lithium depositing on the cathode might suddenly react to produce extra energy. It is an observed fact that lithium is not retained as a deposit on the cathode because of its high reactivity with water. Lithium is only chemically stable as a Pd-Li alloy, which forms very slowly as lithium diffuses into the metal. Once in the metal, it is essentially inert to further reaction except for the very slow dissolution of Pd-Li alloy when the lithium content gets sufficiently high. This reaction is proposed to be the source of palladium that deposits on the surface of the palladium as the nuclear active material, not as a direct source of excess energy.

II.1.3 Random Errors in Measurements of Heat

All measurements contain random error. If this error is too large, it can overwhelm a small signal. Two kinds of random error have been suggested to produce the apparent excess energy, variations within a calorimeter and variations between various independent studies.

Random error within an individual calorimeter is generally small, being less than 50 mW, and easy to determine. The more serious error is that produced by a fixed but unknown offset from zero. This error is hard to quantify and requires repeated calibrations to identify. Also this offset can drift with time, but this drift is always slow and generally in one direction, in contrast to a published speculation [6] to the contrary.

Great emphasis has been placed on comparing the number of successful and unsuccessful reports of heat production. This kind of analysis only makes sense if the successful results are assumed to be caused by an error based on random chance. Unfortunately, this kind of analysis is not appropriate because many different variables are involved, most of which do not have a random effect on the outcome. Consequently, such an analysis says nothing profound about the reality of the effect, only about the probability of a given researcher producing the desired effect. Success has been low in the past, but has been increasing as important variables are identified and controlled. Therefore, it is more logical to view the negative results as resulting from a failure to form nuclear active material rather than the positive results being caused by random error. This kind of logic is identical to that applied to many new phenomena. The anomalous effect is initially small and hard to replicate, dedicated study identifies the important variables, the effect then becomes large and robust - think of superconductivity and the transistor. In the very early days of semiconductors, before all the necessary solid state physics was understood, researchers experienced device-level reproducibility problems that were very similar to what is seen in LENR today.

II.2 Anomalous Element Production

Anomalous element production can be divided into three categories. They are the production of: (1) ^{4}He, (2) tritium, and (3) various transmutation products. Based on evidence to date, these products do not occur at the same time and under the same conditions. Therefore, the mechanism for their production may very well be different. For example, helium production seems to be associated with palladium, tritium formation has been found to apparently require a surface consisting of sharply pointed dendrites [7], and transmutation can occur under several different conditions, including low energy plasmas, light water and nickel electrolysis, and complex Pd/CaO heterostructures. Many exceptions can be found to these general observations, but the point is made that these reactions may not be alike in their required chemical environments.

An evaluator should ask, “Can anomalous nuclear reactions of any kind be initiated?" If any of these anomalous reactions can be demonstrated, conventional nuclear theory must be questioned and anomalous claims given greater credibility.

II.2.1 Helium

Helium is normally not found as a significant fusion product and, should it form, conservation of momentum requires emission of a gamma ray. Consequently, LENR researchers and critics were equally shocked when this element was found to correlate with energy production in the absence of gamma emission. Naturally, an air leak as a possible source was recognized immediately and steps were taken to reduce this possibility. Of course, because the amount of helium is so small compared to that in surrounding air, critics continue to use this possibility to reject the measurements. Until power production can be increased to levels that generate helium concentrations well in excess of the concentration in air, which has been accomplished in one case [8], this issue will apparently remain unresolved no matter how much care is taken. Five independent studies have now been reported, each showing the same general relationship to energy production [9, 10] [11-13]. The question remains, how many more studies are required before this claim can be accepted?

II.2.2 Tritium

Evidence for tritium production has been published numerous times. This “normal” fusion product is produced only at low levels and without the number of neutrons [14] expected on the basis of generally accepted nuclear theory. However, because it is infrequently measured, its production may be more common than is generally thought. Occasionally ^{3}He has been detected, which could have resulted either from tritium decay or from direct formation. Its origin has not yet been settled conclusively.

This evidence has been rejected based on the assumption that tritium was initially present in the palladium. This possibility was eliminated by repeated analysis of commercial palladium [15] and by observing the behavior of palladium that is known to contain tritium [16]. The tritium was proposed to be the result of contamination from the atmosphere, even thought the ambient concentration is too low for this to be a plausible source. This possibility was eliminated by using sealed cells [17] and by running blank cells at the same time as tritium was detected [18]. No one has since suggested a prosaic source that has stood the test.

A thoroughly peer reviewed study [19, 20] at Los Alamos National Laboratory demonstrates that tritium can be generated without neutron production and at modest energy in a gas discharge. Again, conventional theory cannot explain this result.

II.2.3 Transmutation

Evidence for transmutation is rapidly increasing and represents a relatively new and growing aspect to the LENR field. Most studies report the appearance of elements that were not present initially and frequently with anomalous isotopic ratios. These reaction products have been detected in cells containing deuterium [21-23] or light-water, [24, 25] as well as when gas discharge is used at low applied energy [26]. Recently, a very well funded and excellent study has been reported [27, 28] by Iwamura et al. at Mitsubishi Heavy Industries in Japan. These workers deposited cesium or strontium and later barium [29] on a foil consisting of alternate layers of CaO and palladium, with each deposited element studied in separate experiments. When D_2 was caused to diffuse through this composite, the initial elements were converted into praseodymium, molybdenum, and samarium, respectively. They were able to watch as the initial element disappeared from the surface region and another element grew in at the same rate. The product element had the same isotopic ratio as did the initial element. A variety of analytical techniques were used to identify the elements. The results imply that 4 deuterons were somehow added to Cs and Sr and 6 deuterons were added to Ba. Everyone acknowledges that this is hard to believe and creates many obvious unanswered questions. Nevertheless, the tremendous care and obvious expense applied to the work makes out-of-hand rejection inappropriate. Suggestions that the final elements merely diffused from the interior and the initial element was lost into the interior of the composite are at odds with normal diffusion behavior and with anomalous isotopic ratios being observed. Of course, trying to understand the mechanism for these reactions is a serious challenge, a problem that should not distract from the facts of the experimental observation. The basic observation has been replicated in Japan [30] and in Italy [31]. An attempt to replicate the claims is now underway at the Naval Research Laboratory. Mitsubishi's studies continue in Japan and are published as the patent filings [32] become public.

Radioactive isotopes, other than tritium, are seldom reported. When they are seen, their presence is difficult to reject especially when their half-life is short. Bush and Eagleton [33] produced a mixture of radioactive isotopes with an average half-life of 3.8 days in an electrolytic cell. Mizuno et al. [34] found what appeared to be ^{197}Pt after electromigration of D_2 in a solid oxide. Notoya [35] found evidence for ^{24}Na in an electrolytic cell containing Na_2CO_3 and H_2O using a Ni cathode. Gamma emitters were also found after ion bombardment [36]. Wolf [37] obtained a complex spectrum of gamma emissions after electrolyzing a cell containing D_2O with some Al, Ni, and B present. It is safe to conclude that radioactive elements may have been produced in other studies as well, but were not detected for lack of trying.

II.3 Radiation and Particle Emission

Energetic particles consisting of alpha, proton, triton, and neutron have been detected at very low but significant levels [38-43]. The issue is not whether these emissions are associated with energy production because they clearly are not. They might not even be associated with the environment that is proposed to produce the cold fusion reaction. The issue is whether a conventional explanation can be suggested that can account for these energetic emissions. If not, then we are presented with yet another conflict with conventional understanding. How these emissions are related to cold fusion, which occurs at rates about 10^{10} times greater, is a separate issue that cannot be resolved here.

III. GENERAL COMMENTS

Simple logic shows that if an anomalous nuclear reaction is to occur, it must do so in a very unusual environment. Obviously, such an environment, if it exists at all, is very rare in nature. For many years, bulk palladium containing a high concentration of deuterium was thought to be this environment. Consequently, considerable effort was devoted to a study of this metal with respect to its ability to achieve a high D/Pd ratio and how its structure might contribute to a nuclear mechanism. These efforts resulted in unsatisfactory theories of how a fusion reaction might occur in such a structure. More recently, considerable evidence has accumulated showing that the nuclear active environment (NAE) is actually a complex deposit of less than 1 mg/cm2 that forms on the palladium surface, [44] and perhaps on other metal surfaces. This deposit can be applied to Pd, Pt, Ag, or to many other inert elements. Under conventional conditions, reported studies show an unknown alloy involving Pd, Pt, and Li with perhaps other minor ingredients. Other alloys and compounds that do not involve any palladium may also be active [21, 45]. Therefore, all models based on the ideal properties of bulk palladium need to be reexamined.

One might ask, why is a high average D/Pd ratio in a bulk palladium cathode required when the activity occurs only at the surface? A high average D/Pd ratio is required to support the required very high D/Pd ratio at the surface because deuterium can be lost from the deposited layer into the palladium. The higher the average bulk composition, the higher is the deuterium composition at the surface. This especially high composition is required to initiate a nuclear reaction rate in excess of 10^{10} events/sec in order to produce detectable energy. Detectable transmutation and other processes can occur at much lower deuterium concentrations, hence at much lower rates.

Use of platinum and other metals that do not allow deuterium diffusion eliminate the problem of loss from the backside [46] of the active surface/interface. Once an active surface is formed, surface deuterium content does not depend on the properties of the substrate. Of course, a high composition is not the only requirement, so that attempts can fail if the required NAE is not also present in sufficient quantity.

The difficulty in replication results because formation of this NAE layer is not easy and depends on a number of variables that are not yet fully understood and controlled. For example, the active material apparently has a certain size range over which it is nuclear active. Continuous transport of platinum from the anode to the cathode and diffusion of lithium into the active layer can eventually change the crystallite size and composition causing excess heat production to start and eventually to stop. Even small concentrations of other unknown impurities can have an influence, both good and bad. In addition, temperature can affect important conditions within this layer, thereby increasing the rate of power generation as has been observed when temperature is increased.

Studies using ordinary hydrogen show that this isotope also appears to be involved in nuclear reactions, but under somewhat different conditions compared to deuterium, and gives different nuclear products. In this case, rather than “normal” fusion, the favored nuclear product is an element resulting from transmutation, i.e. a heavy nucleus to which one or more protons appear to be added. For example, evidence has been reported showing potassium being converted to calcium in an electrolytic cell [47, 48]. This possibility makes the use of light water as a null or blank rather risky.

The often-repeated complaint that LENR researchers ignore negative results is both unfair and untrue. Efforts have been made in various reviews [1] to understand how the positive results might have been produced in error and why negative results occur so often. Everyone doing work in this field has many negative experiments so that discovering why a particular experiment did not work is a very important task. Using mainly trial and error over the last 15 years, reasons for negative results are now much better understood. One logical reason is because the required, unique environment was not made. The anomalous effects become reproducible and robust, as observed, once this nuclear active material is present. The major unknown at this point is the nature of this material and how it can be created more predictably.

The question of magnitude was raised by several reviewers. Heat production is well below the need of many commercial applications. This being the case, what is the advantage of exploring such a superficially inefficient source of energy even if it were real? As noted above, present understanding places the nuclear activity in a thin deposit on the surface. This deposit is presently made over a period of time by a random process. Examination of surface of an operating electrode by an infrared camera shows random hot spots, indicating that only a small fraction of the surface is active. Nevertheless, power generation at levels in excess of 5 watts are occasionally measured. This means that power density of the active region is very high. In fact, it is high enough to cause local melting of palladium on occasion [49]. Once the nature of this active region is understood and can be made in large amounts, presumably power density can be increased to any level that is required for an application. Note that when the laser effect was first discovered it produced a trivial amount of optical power. Now it is used to cut steel.

IV. SUMMARY

Faults can be found in virtually any experimental paper. The issue is not whether each and every paper is perfect or that every experiment is without flaw. The issue is whether the weight of the evidence shows anomalous and important behavior. Is it reasonable to assume that dozens of trained scientists all over the world are all making mistakes in very conventional measurements only when the cold fusion field is examined, but not when they study other phenomena? Is it reasonable to demand significantly more positive than negative results before the claims are believed, even when the effect is known to require certain variables to be controlled, but which are frequently not controlled?

The generation of anomalous energy is now much more reproducible than in the past and has been shown to be associated with helium generation in some cases. Evidence is accumulating showing element production by transmutation. Energetic particles have been found emitted from material under conditions that should show no such emissions.

The d-d reaction has been shown to be sensitive to the chemical environment when it occurs at low energy. These anomalies taken together suggest at least several unexplained processes. The only issue that remains is whether these anomalies are important enough to understand sooner rather than later. Should the US government wait for the slow conventional funding process to work or should a special program be created? This question was answered in the negative before this collection of information was examined. Is there now any reason to change this opinion?

V. SUGGESTED APPROACH TO FUTURE STUDIES OF LENR

Now that accurate and stable Seebeck calorimeters[2] are readily available [50], combined with dozens of successful examples of excess energy production, proof of excess energy is no longer an issue and does not need to be repeated further. In fact, most published studies are now done with confidence that the anomalous results are real. Therefore, people look for excess power only to reveal information about the process, not to convince skeptics. This approach needs to continue. However, the need to predictably create the NAE, which is the source of the anomalous effects, remains a significant issue.

Four major issues are suggested as being important for further study and their resolution should lead to improved reproducibility of the effects. These are:

1. What is the nature of the NAE and how can it be created?
2. What mechanism(s) initiates ^{4}He production and under what conditions?
3. What mechanism(s) initiates transmutation?
4. What mechanism(s) produces energetic particles and how are they related to fusion and transmutation?

Future studies need to focus on the materials science aspect of the NAE, as recommended by several reviewers, and on exploring the relationship between the various nuclear reactions. For example, are alpha particles always associated with gaseous helium production or are they independent? Do any of the nuclear reactions produce X-rays that can be used to understand the mechanism? Such radiation is expected and has occasionally been detected, but has too low an energy to allow routine escape and detection from a typical cell.

Use of various techniques to stimulate the LENR effects, lasers for example, is expected to give insights into the mechanism. Also, as one reviewer suggested, a shift needs to be made away from using complex electrolysis to using simpler gaseous environments, where radiation can be detected more easily and some parameters better controlled. Such a shift will naturally occur once the NAE can be made by design rather than relying on it being formed by chance in an electrolytic cell.

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[2] A commercial Seebeck calorimeter can be purchased from Thermonetics Corp.
c/o Heinz Poppendiek, 7834 Esterel Drive, La Jolla, CA 92037. Phone (858) 453 5483

VI. POTENTIAL IMPLICATIONS FOR THE UNITED STATES

Besides the issues of whether a real phenomena exists, whether the field has been self-deluded, or whether the experimental results meet modern standards or not, another very important issue remains. If real, the claims promise a clean and inexpensive source of energy. Several other countries are supporting serious work on the subject in their belief that the claims are real. If they are correct and develop the promised energy before we do, this will have important consequences for the United States. The basic question is, "Is it prudent to ignore this possibility?" How will the DOE justify its lukewarm reaction to LENR in the face of accumulating evidence should this promise be realized elsewhere?

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