# **Experimental Status of LENR**

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#### **Goals & Outline of this Presentation:**

Provide background on LENR Experiments

Give a few examples of promising approaches to repeatable LENR experiments that could be understandable and acceptable to the broader scientific community

Provide a brief summary of the entire LENR field.



#### **Fundamental Considerations for any LENR Experiments:**

What was done? **Equipment, Materials and Protocols** 

What was found in the original & subsequent experiments ?

#### **Experimental Approaches to LENR: The Reactants, How to Join Them and What to Measure**



The two most common combinations of reactants are Pd with D and Ni with H. The two most common ways to get the Protons or Deuterons are electrolysis of water and dissociation of hot H<sub>2</sub> or D<sub>2</sub> gases.

Materials change during LENR experiments due to loading.

## LENR experiments require bringing together hydrogen isotopes and materials.



Adequate concentrations are needed for sufficient reactions for measurements. Reaction mechanisms require interactions of reactants, which require motions. 4

# **Challenges to Highlighting Particular Experiments:**

What factors are most important in identifying "repeatable LENR experiments that could be understandable and acceptable to the broader scientific community"

Multiple factors are important, including:

The complexity of experiments is a factor.

The types of measurements play a major role.



The magnitude of produced LENR thermal power is important both scientifically and practically.

The types of nuclear products that are measured provide important information on reactions.

# **Particular Experiments Worth Detailed Attention:**

Arata and Zhang:

"Double Structure Cathode" Electrochemical Experiments Measured both LENR heat and nuclear products

Swartz:

Electrochemical Loading of Palladium Coil PHUSOR<sup>TM</sup> Dry Loaded Two-Terminal NANOR<sup>TM</sup> Careful Calibration and LENR heat measurements Storms:

Electrochemical Loading of Compacted Powders. Temperature-dependent LENR heat measurements.

Transmutation Experiments.

Helium, which is correlated with heat generation. Production of Other Elements

### There are MANY other worthwhile experiments to consider !

## **Methods for Calorimetry during LENR Experiments:**



#### Noise limits the performance of LENR calorimeters

#### "Double Structure Cathode" from Arata and Zhang



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## **Replication of Arata Experiments at SRI International**



M. C. H. McKubre, F. Tanzella, P. Tripodi1 and P. L. Hagelstein "The Emergence of a Coherent Explanation for Anomalies Observed in D/Pd and H/Pd System: Evidence for <sup>4</sup>He and <sup>3</sup>He Production" in 8th International Conference on Cold Fusion, Lerici (La Spezia), Italy: Italian Physical Society, Bologna (2000)

#### **Swartz PHUSOR<sup>TM</sup> Electrochemical Experiment**



M. Swartz and G. Verner, "Dual Ohmic Controls Improve Understanding of 'Heat after Death'" Transactions American Nuclear Society, vol. 93, pp. 891-892 (2005)

## Swartz NANOR<sup>TM</sup> Dry Mixture Experiment



M. R. Swartz, "CF/LANR Excess Heat Activates Shape Memory Alloys" presented at ICCF-23 (June 2021)

## Storms' Electrochemical and Gas Experiments



Production of LENR power by electrochemical and gas loading of solid and compacted powder samples of Palladium and Nickel. Temperature variation experiments that give activation energies.

E. Storms, "The Nature of the D+D Fusion Reaction in Palladium and Nickel", ICCF-23, June 2021 12

#### **Temperature Variations: Plots from Tsinghusa University**



0.0035 13

23.64 °C

0.003

56.50°C

0.00305

0.003

Ni-Pd & H

Pd-Au & D

0.00295

0.0025

# **Methods for Measuring Reaction Products** in LENR Experiments:

new elements during and after an experiment elements present before the experiment Need to measure -

Many Analytical Methods are Available:

https://en.wikipedia.org/wiki/List of chemical analysis methods https://en.wikipedia.org/wiki/List of materials analysis methods These web sites list over one hundred methods, many relevant to measurement of LENR products. Only about two dozen methods have been use for the study of LENR reaction products.

The detection limits of various analytical methods vary widely. They depend on the features of the method and the instruments.

Composition (and Structure) of materials varies in space and time.

#### Noise limits the performance of Analytical Methods.

## **Helium Production in LENR Experiments**

#### In ordinary (hot) D-D fusion, one in ten million events produces a He-4 and a 23.8 MeV gamma ray.

#### Helium is Produced in LENR Experiments AND Correlated with the Production of Energy in the Same Experiments:



## **Production of Other Elements in LENR Experiments**

G. H. Miley, "Possible evidence of anomalous energy effects in H/D-loaded solids – Low energy nuclear reactions (LENR)", Journal of New Energy, Vol 2 (3-4), pp. 6-13 (1997) T. Mizuno, T. Ohmori, and M. Enyo, "Isotopic Changes of the Reaction Products Induced by Cathodic Electrolysis in Pd", Journal of New Energy, vol. 1 (3), pp. 31-45 (1996)



# **Summary on Experimental Status of LENR**

Diverse global experiments for one-third of a century have shown LENR occur and they do, indeed, involve nuclear reactions.

The experiments pose a challenging scientific problem, and indicate significant practical promise at the time when new clean energy sources are needed.

Past experiments have suffered from being uncoordinated, and from lack of funding for needed parametric studies and for the employment of available modern tools.

The results have suffered from ignore-ance by the broader scientific community due to the bad reputation of the field and lack of funding. The single most important claim from one-third of a century of experimental research on LENR is:

# Nuclear reactions can be caused by use of chemical energies.

Thermal energy is measured that cannot be explained by known chemical reactions: 2000 eV/atom and 50 kW/cm<sup>3</sup>

**Products that cannot come from chemical reactions:** Tritium, Helium and Many Other Nuclei.

**Exciting New Science** 

Experimental Results Suggest Practical Promise:

Getting MeV by using eV enables high energy gains, and high energy gains portend low-cost power.

**Experiments have shown that LENR have other promising features:** 

High power densities. Lack of dangerous radiation. Little radioactive waste. No greenhouse gas emission.

**Potential Clean Energy** 

### **Potential LENR Advantages and Impacts**

**High Energy Gains Sustained ("Burning") Reactions Production of Heat and Generation of Electricity Opportunities for Optimization Potentially Safe Operation Fail Safe Operation seems Possible Likely Radiation Safety No Input Radioactive Materials Adequately Safe Input Chemicals Possibly Beneficial Waste Negligible Radioactive Waste No Chemically Dangerous Waste No Greenhouse Gas Emission Less Environmental Degradation Possible Silent Operation High Energy Density Lightweight Systems Portable Energy Systems Scalability (Diverse Power Levels)** 

**User Friendly (like HVAC Systems) Adequately Low Capital Cost Low Operational Cost Easy Operation and Refueling Long Times Between Refueling Long Operational Lifetime Abundant Hydrogen Fuel Abundant Nickel or Other Fuels** Low Cost Power: 5 cents....\$100+ **Distributed LENR Generators Relief for the Power Grid Fewer Large Power Stations Easy Disposal of LENR Generators Rapid Adoption Once on the Market Many Potential Applications Proliferation of Electricity Lifestyle Improvements Better Connectivity and Education Production of Clean Water Historical Health Improvements** 

http://www.infinite-energy.com/images/pdfs/NagelIE103.pdf

## **Information on LENR**

The International Conferences on Condensed Matter Nuclear Science have been a primary global forum for the field over the decades since Fleischmann and Pons announced their ability to produce excess heat energy. The meetings were initially known as the International Conference on Cold Fusion, with the abbreviation of ICCF, which has been retained. The primary topic of the field came to be called Low Energy Nuclear Reactions (LENR), although there are about twenty other names for the subject [1]. Links to the proceedings of many of the ICCFs are on the web [2]. Proceedings of the recent ICCF conferences are published by the Journal of Condensed Matter Nuclear Science [3]. An index to the JCMNS volumes is available [4]. Proceedings of the 21 annual meetings of the Japan Cold Fusion Research Society are on line [5]. Information on many of the fourteen International Workshops on Anomalies in Hydrogen Loaded Metals is also on the internet [6]. The 25th Russian Conference on Cold Nuclear Transmutations and Ball Lightning was held in October of 2018 [7].

- [1] Infinite Energy magazine, Issue 113, pp. 9-21 (2014).
- [2] http://newenergytimes.com/v2/conferences/LENRConferenceProceedings.pdf
- [3] https://www.iscmns.org/CMNS/publications.htm.
- [4] http://coldfusioncommunity.net/jcmns/
- [5] http://jcfrs.org/newe.html
- [6] https://iscmns.org/work14/index.htm
- [7] https://iscmns.org/conferences/25thrussianconference/

# **More Information on LENR**

Several web sites are devoted to presenting information on LENR. One has a library with thousands of articles, many of which can be downloaded [8]. There have been months when the average rate of *downloading* papers from that site was about one per minute. A 2009 tally of papers by Rothwell, the keeper of the web site, is available [9]. There have been over four million downloads of LENR papers from that one web site. Many papers are available from the International Society for Condensed Matter Nuclear Science [10]. Other web sites are also useful resources on LENR, including the New Energy Foundation [11], the New Energy Times [12], Cold Fusion Times [13], Cold Fusion Now [14] and the ColdFusionCommunity [15]. Note that some sites, and even current papers, continue to use the original name of the field, that is, "cold fusion". Information on, and links to 48 refereed LENR papers from one laboratory since 1991, are on the web [16]. There are also many books on LENR, two each by Storms & Kozima, & a 2020 book edited by Biberian. Diverse information and commentary is available on the LENR Forum [17].

- [8] lenr.org = lenr-canr.org.
- [9] J. Rothwell, "Tally of Cold Fusion Papers" (2009). Search "tally" at lenr.org.
- [10] https://www.iscmns.org/library.htm.
- [11] http://www.infinite-energy.com/whoarewe/whoarewe.html
- [12] http://news.newenergytimes.net/.
- [13] https://theworld.com/~mica/cft.html
- [14] http://coldfusionnow.org/.
- [15] http://coldfusioncommunity.net/portal/
- [16] https://www.academia.edu/17964553/Condensed\_Matter\_Nuclear\_Science\_October\_2015
- [17] https://www.lenr-forum.com/