Scientific and Commercial Overview of ICCF17

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Introduction

The topic of low energy nuclear reactions (LENR), initially and still known as "cold fusion," remains outside of the recognized fields of scientific inquiry. But, this awkward and unsustainable situation does not deter many people from working on or simply being interested in LENR. There are hundreds of scientists and engineers globally who spend significant time on the experimental or theoretical study of these reactions. And, there must be additional thousands who are monitoring developments in the field. Overall, the level of interest is apparently increasing as the commercial availability of power and energy generators based on LENR seems to become more imminent.

There have been many conferences on LENR since the field began in 1989. The primary international series retains the cold fusion label. The 17th International Conference on Cold Fusion (ICCF17) was held in the Daejeon Conference Center in Korea during August 12-17, 2012. The website for this conference was very effective: http://www.iccf17.org.

Conferences in this series typically have 100 to 250 participants. Because of the increasing interest in LENR and uncertainty in the number of attendees, planning for ICCF17 was especially challenging. Due to the delays in the commercial availability of LENR generators, the number of participants turned out to be quite typical. There were 157 attendees from 19 countries at the conference.

The Chairman of ICCF17 was Professor Sunwon Park from the Department of Chemical and Biomolecular Engineering of the Korean Advanced Institute of Science and Technology (KAIST in Daejeon, Korea). The Co-Chairman was Dr. Frank Gordon, who is the retired Head of the Research and Applied Sciences Department of the U.S. Navy SPAWAR Laboratory (San Diego, California). Thanks to their efforts, the conference had a particularly broad base of supporting organizations.They included the International Society for Condensed Matter Nuclear Science, the Korean Institute of Chemical Engineers, the Korean Nuclear Society, the Korean Institute of Metals and Materials, the Korean Research Institute of Chemical Technology, the KAIST Energy, Environment, Water and Sustainability Initiative, the New Energy Foundation, the Korean Tourism Organization and the Daejeon International Marketing Enterprise.

The two organizers opened the conference with a Plenary Lecture having an apt title, given the scientific character and practical promise of LENR: "Cold Fusion—From the Laboratory to the World." The beginning of their abstract is worth attention: "The objective of ICCF17 is to allow international groups of scientists to present their data to further the collective understanding of scientists working in the field, and so that skeptical members of the mainstream scientific community, the media and the public will see the evidence that 'cold fusion' is real." They went on to write: "Ultimately, the reality of cold fusion will be determined by the public acceptance of commercial devices. People and companies who continue to deny the existence of cold fusion will become irrelevant as the applications are placed into service."

This conference was, like its 16 predecessors, essentially a scientific meeting. There were 46 oral and 43 poster papers on the agenda, close to all of which were presented during the conference. Of these, 48 were reports on experiments, 26 were on theory and 15 were on other topics. ICCF17 did have a major difference from earlier meetings in this series. On the first day of the meeting there were scheduled or presented three papers by major companies working to bring LENR products to market. Their progress and status were of great interest. Hence, even though the bulk of ICCF17 was scientific in nature, the commercial aspects of the meeting will be reviewed first. Then, papers on most of the usual topics covered at these conferences will be discussed. As is always the case for reports at an ICCF, many papers have multiple strong features, including the loading methods and what was measured. So, there is some arbitrariness in which of the sections below to discuss them. However, almost all papers presented, or scheduled but not presented, are reviewed in the following.

Commercial Activities

Three companies were slated to give early featured papers at ICCF17. The first was NichEnergy SRL of Milan, Italy. That is the company based on the research for two decades by

Professor Francesco Piantelli of the University of Siena. It was disappointing that Professor Piantelli did not permit the presentation to be made, as scheduled, by Peter Mobberley of Advanced Energy Technologies in the UK. It is noted that there was a detailed presentation by NichEnergy at the 10th International Workshop on Anomalies in Hydrogen Loaded Metals in Siena in mid-April of this year. Graphics from that talk and much other information on LENR can be accessed from the website of that conference: http://www.iscmns.org/work10/program.htm. The current situation for NichEnergy is unclear.

The talk from Defkalion Green Technologies S.A. of Athens, Greece was given as scheduled by Menelaos Koulouris, who is leading the product development effort in the company. After the talk, Defkalion's Chief Technology Officer, John Hadjichristos, joined the discussion from Greece via Skype video. The Defkalion presentation was essentially the same as they gave a week earlier in Austin, Texas, but was still well received at ICCF17. Defkalion seems to be behind its own published schedule for research and development, and is moving to Canada in the fall of this year. However, they expect to have their Hyperion product on the market in 2013. More information is available on the company's website: http://www.defkalion-energy.com/

The final featured commercial presentation was from Brillouin Energy Corporation in Berkeley, California. It was given by Francis Tanzella of Stanford Research International (SRI). The President and Chief Technology Officer of Brillouin, Robert E. Godes, responded to questions from ICCF17 participants over Skype audio from California. Brillouin and SRI signed a contract about the time of ICCF17 for SRI to do thorough tests on a prototype of the "Hot Tube Boiler," which is being developed by Brillouin. That is good news, since most of the tests of prototype LENR generators have not been sufficiently thorough to be confident of the claimed performance. Work by Brillouin to date has mainly involved electrochemical systems with special pulsing of the cathodes to initiate, control and stop power production. Now, the company is also interested in developing gas loading approaches to commercial LENR generators. Their website is: http://www.brillouinenergy.com/

The reality of commercialization of LENR is still very contentious, as can be seen from many negative and otherwise skeptical blog postings. Tyler van Houwelingen (AzulStar, Inc.) did a web-based review of the status of the commercialization of LENR. He addressed and scored three issues: (1) the reality of LENR being a means to produce energy, (2) the scaling to commercial levels and the associated controllability, and (3) the possibility that anticipated LENR power sources are far superior to all existing forms of energy production. His presentation elicited critical comments relating to the interpretation of the materials he reviewed. That was a reflection of the strong feelings engendered by LENR commercialization even at such a conference.

A panel discussion on "Commercialization and Worldwide Impact of LENR" was held at the end of the conference. The moderator was the conference Co-Chairman Frank Gordon. Members of the panel included Larry Forsley (Global Energy Corporation), Thomas Grimshaw (University of Texas), Jed Rothwell (lenr-canr.org), Francis Tanzella and Tyler van Houwelingen. Dr. Gordon started the discussion by asking the panel if this community is ready for commercialization, and what should be done about it. The panelists generally did not think that commercialization is imminent, despite pronouncements by a few companies to the contrary. One panelist thought that commercial production of LENR energy generators might take a decade. The next question to the panel asked what they want to see happen in the field in the near future. The ensuing discussion focused on a key requirement in the field, namely achievement of adequate control of current experiments and, later, products. The enduring need for reproducibility was also noted, although controls over energy production were most discussed by the panelists.

An open discussion followed responses to the moderator's questions by the panel members. It was noted that low-grade energy, such as might be produced by early LENR generators, has a myriad of applications. Scalability of LENR power sources was also discussed. Accuracy in reporting facts was cited as a general need in the field, since even a few errors contribute to skepticism. Safety was an issue for some participants. Forsley stated that there remains an open question about fast energy releases. Concerns about potential litigation over intellectual property, and about governmental actions, were also expressed. Either of these unknowns might impede the rapid commercialization of LENR generators. Grimshaw asserted that public welfare requires bringing LENR generators to market quickly. Rothwell noted that the public will probably demand such devices, if they prove to be as good as hoped. He expects that the impact of LENR energy will be more profound than the microprocessor revolution. Michael McKubre (SRI International) highlighted the polar opposites of commercialization preceding understanding, driven by the potential utility of LENR, versus the possibility that it is irresponsible to sell a nuclear device without adequate understanding. Yeong Kim (Purdue University) stated that it might even be dangerous.

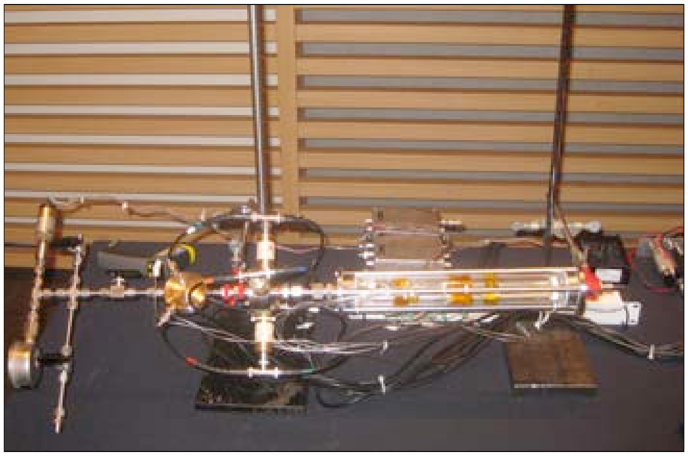
There were other presentations from companies at this conference. However, they did not feature the company, but rather provided their research results. Those papers are discussed below. It is worth noting that the companies presenting scientific results varied from startups, such as ChrononixUSA, Global Energy Corporation and Lenuco LLP, to giants like Mitsubishi Heavy Industries and Toyota Motor Corporation.

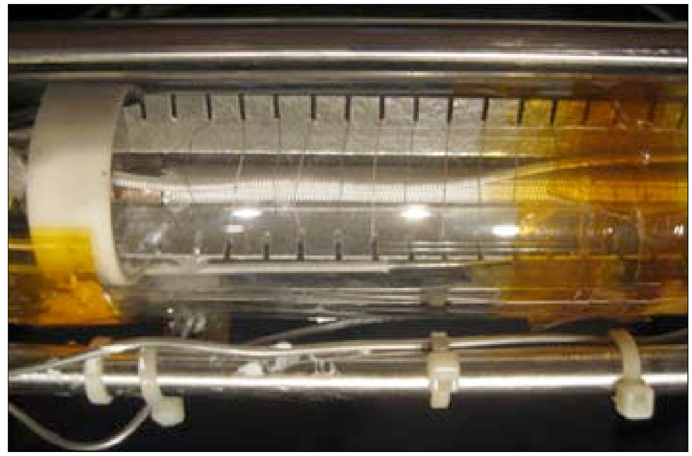
An appreciation of the commercial interest in LENR can be gained by reviewing the 21 companies currently listed at the website: http://www.fusioncatalyst.org/fusion-base/fusion-companies/. The number of companies active in the field now is at least twice as many as two years ago.

Demonstration by Celani

There have been only a few exhibits and demonstrations at previous ICCFs. Reiko Notoya had a Ni light-water electrochemical cell on display at ICCF3. At ICCF10, Mitchell Swartz and Gayle Verner (Jet Energy Inc.) ran a demonstration of their LENR PHUSOR™ at a site near the meeting. It produced excess power of about one-third of a watt with an energy gain of 2.3. At that same conference, Dennis Letts (LettsLab) controlled an experiment in his Texas laboratory over the internet from the podium during his presentation.

ICCF17 was distinguished by having a sophisticated demonstration operating in the meeting room throughout the conference. Francesco Celani from the Frascati National





Laboratory took his experiment from Italy to the National Instruments meeting in Austin, Texas, the week before ICCF17, and operated it successfully there. Then, he moved it to Daejeon, and charged it at KAIST with seven atmospheres of hydrogen gas prior to the conference. During ICCF17, it was available for close inspection, and also had nearby a LabVIEW display on a monitor, which showed the recent and current operating conditions for the setup. The demonstration was powered by 48 watts and produced up to 18 watts of excess power during the conference.

The left figure shows an overall image of the transparent tube containing the experimental materials and hydrogen gas. The close-up photograph shows the notched mica that supported two separate wires, both wound helically, as in the double helix of DNA. One was a heater wire used for calibration purposes made of an "inert" material. The other was the active wire with a specially treated and proprietary surface. The base composition of the active constantan wire producing excess heat was $Cu_{55}Ni_{44}Mn_1$. Since the conference, Celani's experiment has been the subject of much discussion and some criticism. But, it represents the high water mark for demonstrations at conferences in the ICCF series. A big question now is whether any company will have an operating prototype or product at ICCF18.

Gas Loading

There are three reasons for expecting that the first commercial LENR generators will employ gas loading. Electrochemical loading requires more complex equipment than gas loading. And, both plasma and beam loading involve a significant initial expenditure of energy to produce ions. Also, the use of gas loading has been shown to produce usefully high temperatures. Most of the companies now working toward commercialization of LENR products either use, or plan to use, gas loading. Because of the relative simplicity and possible early commercialization of gas loading methods for LENR, there were several papers on that approach to loading at ICCF17. Celani's demonstration using gas loading of a specially treated wire sample was just described. The other papers on gas loading are reviewed in the rest of this section. Most of these papers used nanometer-scale particles as materials. They are scientific studies, not closely related to the engineering developments for gas loading products now in progress at several companies.

There is great interest in, and activity on, gas loading of nano-scale powders in Japan. Two ICCF17 papers were from a ten person team including researchers from Kobe and Osaka Universities, Technova Inc. and Santoku Corporation. The paper by Akira Kitamura *et al.* was concerned with repetitive loading and unloading of Pd and Pd-Ni nano-powders with H or D, in order to understand and enhance the reusability of such materials. The group has studied many different materials in the past five years. This paper focused on a ternary oxide Cu-Ni-ZrO_2 and porous silica with Pd-Ni inclusions. Loading ratios in the as-received porous silica materials as high as 3.5, and absorption energies of 2.5 eV/Pd atom, were measured. Cycling, baking and de-oxidation processes were performed. Those methods reduced both the loading and absorption energies. However, forced oxidation restored much of the loading ability. The same team used the Cu-Ni-ZrO_2 studied in the first work, and also Ni-ZrO_2, with gas loading and temperatures as high as 500°C to measure excess heat. H proved to be more effective than D for producing energy. The Cu-containing ternary was ten times more effective than the material without Cu. The second paper reports observation of as much as 800 eV of excess energy per Ni atom.

Tatsumi Hioki and four others from the Toyota Central R&D Laboratories studied heat generation for both H and D with nano-Pd in silica materials. Zeolites and folded sheet mesoporous (FSM) silica were used as hosts for the Pd. Repetitive pressurization and depressurization were employed for both gases and both materials. An isotope effect on heat generation was seen for the two materials. It decreased with cycling for the zeolite, but not the FSM. The decrease for zeolite was attributed to migration of the Pd to the surface. The Pd in the FSM was trapped. So, the authors conclude that maintenance of nano-sized Pd particles is required for excess heat production. In related work, Seunghwan Seok and Do Hyun Kim from KAIST prepared silica materials with Pd particles in the 3-4 nanometer range on their surfaces. The Pd particles were made by using an ultrasonic sonochemical process. Having the small particles on the silica substrate prevents agglomeration and deactivation.

David Kidwell (Naval Research Laboratory) has been producing and maintaining Pd particles with sizes less than 2 nanometers by use of zeolite substrates. He cycled the H_2 or D_2 pressure and measured the heat that is produced or absorbed. Anomalous differences between the two gases were seen in the past. However, some of the heat difference might be due to the chemical process of H-D exchange, with adventitious water being the source of the protons. Kidwell also used alumina substrates. In that case, the abnormal excess heat with D persisted for 8-10 cycles and then decreases linearly. That variability was attributed to possible particle growth. Next, Pd nano-particles were prepared from atoms during pressurization. This approach resulted in days of excess heat, more than is available from H-D exchange. The possibility of it being due to other chemical reactions is being explored.

Peter Mobberley (Advanced Energy Technologies) is seeking to replicate Ni-H gas loading experiments. He uses a commercial Ni powder with particle size near 2 micrometers, which is made by the barrel for batteries, fuel cells, other electrical applications and pigments. The Vale INCO Products material is described on the web as follows: "T255™ is a high purity nickel powder with a fine, three-dimensional filamentary structure." Mobberley is performing thermal and radiation measurements during his continuing experiments.

A report by Jian Tian *et al.* that used gas loading and produced noteworthy levels of heat is discussed in the section below on excess heat.

Plasma Loading

The four means of loading protons or deuterons onto and into materials involve electrochemical, gas, plasma or beam techniques. They start with the H or D in, respectively, liquid, gaseous, plasma or vacuum conditions. This ordering also applies to the number of experiments that have been reported in the field since its inception in 1989. Some experiments do not fall neatly into these categories because the H- or D-containing material undergoes phase transitions during the experiment. The employment of arcs within liquids is one example. The use of cavitation to load materials is another.

Roger Stringham (First Gate Technologies) has been using ultrasound-induced cavitation bubbles to induce LENR for over 15 years. In those experiments, the material foil is immersed in heavy water in the experimental cell. Application of MHz ultrasound to the cell induces cavitation bubbles that collapse on the surface of the foil, injecting it with deuterons. In the course of bubble production and collapse, the deuterons start in the liquid, transition to the gas phase and then become plasmas. Stringham measured the input electrical power and output thermal power. He reported achievement of 90 W of output for 50 W of input, that is, a power gain of 1.8. Post-run micrographs of the Pd target foils show many ejecta sites about 50 micrometers in size. Stringham ascribed his observations to the formation of transient Bose-Einstein clusters. One of the attractive features of such ultrasound experiments, besides good performance, is their compact size. The experimental cell is only a few inches in diameter and thickness, and is relatively inexpensive. More research with this approach should be done.

Excess Heat

The different kinds of evidence for the occurrence of LENR have different credence to different people, depending on their interests. For example, measurements of transmutations, or the emission of energetic particles or radiation, are of great scientific interest, but might not be of practical value in the near future. That is, they tend to interest only scientists. However, the generation of excess heat is important for both scientific and pragmatic, even commercial, reasons. So, reports on power and heat generation are of widespread interest. They are reviewed in this section.

As usual at conferences in this series, there were numerous reports of excess heat at ICCF17. Rick Cantwell of Coolescence LLC studied the papers made available before the conference, and compiled a very useful summary of reports of excess heat. It constitutes Table 1 of the Appendix. The wide variety of approaches to, and results from, LENR experiments is clear from Cantwell's tabulation. There were reports at the conference of excess heat production for both gas and electrochemical approaches to loading. Two of the gas loading papers, and five papers on electrochemical loading, are summarized in this section. In addition, a new approach using pre-loaded two-terminal devices is described at the end of the section.

Jian Tian and five collaborators from Changchun University performed experiments in which two Pd wires were wound on coaxial ceramic tubes in a double-jacketed chamber. D_2 gas at a pressure of about 90% of one atmosphere filled the chamber interior, and water flowed between the inner and outer walls. The inner ceramic was wound with a Pd wire 0.5 mm in diameter and 210 cm in length. It was the active wire in the system. The outer wire was the same diameter and 400 cm long. It served as the "triggering" wire. Currents up to 8 A were put through that outer Pd wire. An average excess power of 87 W was measured during a run of 40 days. It released a total of 300 MJ. The ratio of output energy to input energy was about 1.2. The experiment gave excess power in 16 out of 16 successive triggering attempts, each about two hours in duration. Data indicating transmutations were also obtained, as noted in the following section.

George Miley, with two others from the University of Illinois, and a colleague from the University of New South Wales, reported on the use of D and H clusters in gas loaded nano-particles to produce excess heat. Three different materials—only designated as Types A, B and C—were studied. With D_2 gas, pressures up to about 100 psi were employed. A temperature rise upon D unloading of 50°C was observed. Energy gains greater than unity were achieved in six of seven experiments. The highest gain values were 11.5, 12.0, 12.2 and 15.1 in the series of experiments. Comparison of the measured energy outputs with those from other non-LENR power sources are given in the paper.

Dawn Dominguez and ten colleagues from the Naval Research Laboratory, the Naval Surface Warfare Center, NOVA Research Inc. and the ENEA in Italy reported on results obtained from about 300 electrolysis experiments. $Pd_{90}Rh_{10}$ electrodes were mostly employed. Metals and metal salts were added to the electrolyte to shorten the onset time for heat production. Excess heat exceeding 1 kJ was obtained in 5% of the experiments with the Pd-Rh cathodes. In one experiment, 10 kJ (40% excess) was generated during 90 minutes. Another gave two excess heat bursts for roughly an hour each, the first yielding about 43 kJ and the second about 35 kJ. Oddly, RF emission was measured at the time of the two separate heat pulses. Hard radiation measurements gave nothing but background. Power gains as high as 40 were measured in one of the runs. Vigorous checks of the equipment and results showed that the excess heat measurements were not instrumental artifacts.

Michael McKubre and three coworkers from SRI International and MIT performed calorimetric measurements of the destructive stimulation of fine Pd and Ni wires. Palladium wires 50 micrometers in diameter were highly loaded with D by electrolysis, then coated with Hg in the same cell to prevent escape of the entrapped deuterons. Sometimes, co-deposition of Pd and D was also employed to insure high vacancy densities in the samples. The wires were then transferred quickly to a liquid nitrogen dewar. After nearly constant nitrogen evolution was attained, the loaded wires were subjected to short electrical pulses that destroyed them. The released energy resulted in additional nitrogen evolving as gas, which was measured. For electrical input energies of 1 J, the measured output energies were as high as 2.25 J. Substantial energy gains were obtained for seven Pd-D and two Ni-H experiments. For 30 experiments, the released energy was larger than could be accounted for by chemical effects.

Melvin Miles (Dixie State College) performed experiments on the co-deposition of Pd and other transition metals in both H_2O and D_2O solutions. His approach to co-deposition was to use ammoniated solutions. They gave him excess heat in earlier Pd-D experiments. Significant excess power was observed again with the Pd-D system, but not with Ni, Ru or Rh in either light or heavy water. A total excess enthalpy of 170 kJ was measured. It exceeds that obtained in any of his earlier co-deposition experiments with deuterated ammonium.

Sanjai Sinha from ChrononixUSA reported on electrolysis experiments involving various metals in both light and heavy water solutions. His work involves modulating the cathode by use of deformations and stresses, as well as application of electric, magnetic, electromagnetic and acoustic fields. The goal is to produce energy localization by triggering, modulation and shocking of the cathode. Application of high (40 kA/cm^2) current densities was favored. Small (30%), but clear and reproducible, amounts of excess heat were measured even with gold and heavy water (but not light water).

Alexander Karabut (Samar+ Company) reported excess heat production in high voltage electrolysis experiments of D-loaded materials in light water. Pd, Re coated with Pd and nano-structured Pd were employed in the experiments. Pulses with voltages of 500 to 2500 V, and currents between 0.3 and 2 A, provided the excitation. Heat capacity and flow calorimeters were used. Excess powers from 120 to 280 W were observed. Energy gains of 2 to 3.4 resulted. During the experiment, X-rays were measured. Impurity elements both lighter and heavier than Pd were measured after the runs.

Stanislaw Szpak and Frank Gordon, both of the U.S. Navy SPAWAR Laboratory, provided a report on forcing the Pd-H system into a nuclear active state. They performed co-deposition experiments. It was verified that the Pd-D system becomes active without application of external fields, as in their earlier experiments. The Pd-H system with no applied fields does not undergo nuclear reactions. However, if an external magnetic field is applied, or the cell current modulated (or both), even the Pd-H system is nuclear reactive. The authors report that they observed "catastrophic thermal events" in three out of ten experiments. In one case, the cell deformed and electrolyte was lost to evaporation. A time-temperature curve during one of the thermal runaways was presented. It pointed to film boiling, which caused loss of the electrolyte. An energy release of 10 eV/Pd atom was inferred. In another case, the cell damage suggested to the authors that "explosive fragmentation" of the Pd-H deposit had occurred.

Mitchell Swartz had two papers at ICCF17, one co-authored by and both presented by Peter Hagelstein (MIT). In the first, the two report on a radically new configuration for production of LENR and measurements of the resulting heat. The second paper is by Swartz, Gayle Verner and Jeffrey Tolleson, all of Jet Energy, Inc. Both papers contain useful summaries of earlier work, especially the demonstration at ICCF10, which was conducted by Swartz.

The name for the new devices produced by Swartz and his colleagues is NANOR™. They are two-terminal devices a few millimeters in diameter and a few centimeters long. The devices are pre-loaded with nano-scale particles of ZrO_2, an alloy of Zr (~66%), Ni (0-30%) and Pd (5-25%), and D_2 and H_2. The weight of the active material was less than 100 milligrams. The methods for preparation and characterization of the devices were not disclosed. The D/Pd ratio was stated to be 1.3, but the method of determining that was not given. Possibly, that was the chemical composition as loaded into the devices. A new driver system, based on a microcontroller, was employed to excite the device to produce excess energy. The authors emphasize that their approach separates the loading and activation steps. That was also done by McKubre and his team for the loaded and exploded wires, as discussed above. Swartz demonstrated a NANOR™ during a course on LENR at MIT in January 2012, and then let it run for the following two months with daily recalibration. The energy gain varied between 5 and 16 during the multi-month run. At the course, the energy gain was 14.1. Generated power was up to about 20 mW, a small value but clearly documented. Scaling of NANORs to higher powers was not discussed. A new calorimeter was built and calibrated for this work. The sophisticated electronic means used by Swartz to measure the electrical input and the thermal output of the reported experiments were documented in the two papers.

There is much electrical science and engineering that is relevant to electrolytic and other LENR experiments, which is not getting enough or, in many cases, any attention. Several researchers have done and reported cyclic voltammetry. Very few have performed impedance spectroscopy on electrochemical LENR experiments. Noise measurements have not been done, as far as this author knows. Also, as noted later, there is a need for modern analyses of the data recorded from LENR experiments and tests, whatever the type of data.

Transmutations

It is likely, although not quantified, that there are more papers on measurement of heat in LENR experiments than on measurements of the three other classes of evidence. Nonetheless, there is a large total literature on the (a) analysis of reaction products, (b) detection of energetic particles and radiation and (c) observations of various low-energy phenomena, all three of which indicate the occurrence of LENR. Of these, there are probably more papers on analyses of reaction products, which is the focus of this section.

LENR experiments have produced two major types of transmutation data. The first and most common category requires determination of the absolute or relative amounts of specific elements or isotopes by pre- and post-run analysis of elemental or isotopic concentrations, ideally with spatial resolution. Observations that the quantities of elements after an experiment are greater than the amounts present before the experiment are taken as evidence of nuclear reactions. This class of LENR experiment requires careful and often expensive low level analyses of several elements or isotopes of interest before and after an experiment. Besides the labor and cost of such work, there is an enduring problem that the apparent increase in a concentration might be due to production of a non-uniform distribution of the entity of interest during the experiment. That is, no new atoms might be produced, but atoms already present and not detected before the experiment can be brought above detection thresholds, or into a region subjected to analysis, by processes during the experiment.

The second type of transmutation experiment does not require such sophisticated analysis of elemental or isotopic concentrations on absolute or relative bases before and after experiments. It uses mass spectrometry to measure the distribution of isotopes relative to each other for one element, often only after an experiment. The natural distributions of isotopes are well known and little variable. So, if an anomalous relative distribution of a set of isotopes for some element is observed, there is a significant probability that indeed nuclear reactions occurred during the experiment. Such isotopic shifts have been observed in many LENR experiments.

The papers on transmutations at ICCF17 included a review of the subject, a few reports on permeation experiments and other articles on various types of LENR experiments. The review of transmutations and isotopic shifts by Mahadeva Srinivasan (retired from Bhabha Atomic Research Center) was essentially an update of the comprehensive survey of the field, which he and colleagues produced early in 2011 and gave at ICCF16. After some general observations on experimental methodologies, the new review summarizes data from Russian glow discharge experiments, electrolysis experiments by Miley, Mizuno and their collaborators, the permeation experiments of Iwamura and colleagues, and experiments on bio-transmutations by Vysotskii and coworkers. It is noted that the reviewed results can be explained by capture of multiple deuterons and by fission reactions. The data and these ideas sternly challenge theorists to explain them.

For the past dozen years, Yasuhiro Iwamura and his team (Mitsubishi Heavy Industries Ltd.) have performed experiments in which deuterons from D_2 gas permeated foils of Pd containing buried layers of oxides, especially CaO. Various elements were deposited on the surfaces of the foils before the runs. Those elements were found to decrease in concentration while other elements appeared during the experiments. Transmutations were found as follows: Cs to Pr, Ba to Sm, W to Pt and Sr to Mo. In some cases, anomalous isotope distributions of the created elements were measured. At ICCF17, Iwamura reported results from experiments in which the deuterons were created electrochemically rather than gotten from the gas phase. That approach gave a higher surface density of deuterons on the foil. Ten to one hundred times larger rates of transformation of Cs to Pr were obtained. Gamma rays were measured during the long (10^5 second) runs. Peaks at 511 keV, the energy emitted during electron-positron annihilation, were sometimes seen.

There were two other papers that reported transmutations due to permeation experiments. Naoko Takahashi and coworkers (Toyota Central R&D Laboratories) performed an experiment with D_2 gas of the type done by Iwamura. Pulsed laser deposition was used to produce the CaO layers in Pd foils, and Cs was put into the foils by implantation or on the foil surfaces electrochemically. The amounts of Pr measured in D_2-permeated samples were an order of magnitude larger than in samples that were not permeated. The conversion rate of Cs to Pr was 0.1%, substantially smaller than seen earlier by Iwamura and his team.

Bin Liu and others (Shenhua Group Corporation Ltd. and Tsinghua University) performed permeation experiments using Pd foils 100 micrometers thick, which had no additional oxide or other layers. D_2 gas at 4 MPa supplied deuterons to the foil heated to 300°C. Loading and de-loading was performed 80 times. X-ray analysis of the samples after the experiment showed anomalous distributions of Si and Cu at some locations. It remains to be proven that the appearance of those elements was not due to diffusion from the experimental apparatus. The paper by Jian Tian, already reviewed above in the section on excess heat, also showed some local surface features with concentrations of unexpected elements, specifically Ag, Sn, Pb and Ca.

Edward Esko (Quantum Rabbit LLC) has pursued a particular type of glow discharge transmutation experiment for many years. His paper at ICCF17 reported the results from use of a cylindrical copper anode into which a Pb insert was pressed, with Li and S granules placed on top of the Pb. A glow discharge was started in neon, which was later replaced by oxygen during the run. The test ran 14 minutes with voltages between 45 and 70 V and currents in the range of 5.4 to 7.5 A. Commercial inductively-coupled plasma analyses were made on both the starting and post-run materials, but the locations of the materials sent for analyses were not specified. Concentrations of K reportedly increased by a factor larger than 494, with Au increasing by a factor greater than 112. Assuming these increases were due to transmutations, the paper offers ideas on how they could occur by fusion (for K) or fission (for Au).

D.S. Baranov and O.D. Baranov studied the production of short-lived isotopes in experiments with Bi salts. Generation of ^{210}Bi, ^{212}Bi, ^{214}Bi and ^{212m1}Bi was reported. Six independent decay characteristics of the two ^{212}Bi nuclei were identified. Macroscopic cluster emission from the samples was also observed. A model was provided to explain the measurements.

Two papers by Alexander Didyk (Joint Institute for Nuclear Research) and Roland Wisniewski (National Center for Nuclear Research) reported the very detailed results of irradiations of targets in D_2 at a pressure of about 3000 atmospheres. Gamma rays with energy of 8.8 MeV struck a Pd target, as described in one paper. Gamma rays with energies of 10 - 23 MeV irradiated Pd and Re targets, as recorded in the second paper. Analyses of the Pd and other parts of the experiment were made, and chemical changes of several components were reported. The authors examined the possibility of and, in some cases, the cross sections for many nuclear reactions. They proposed a model involving chain fusion and fission reactions. The relevance of this work to LENR is not clear.

G.V. Tarasenko from the Caspian State University had a poster on "Geological Aspects of Cold Fusion." It provided a model of the earth, and then focused on spherical concretions that are ascribed to electrical discharges in the earth's crust. Tarasenko provided a circuit diagram for a laboratory instrument to mimic natural discharges. He mentioned experimenting with asphalitic-resinous substances, but did not provide detailed results. Work by others, not presented at ICCF17, is concerned with the occurrence of LENR within the earth. It is based on unusual isotope ratios seen in the effluent of volcanoes and on some theoretical ideas. This, like many parts of the field, merits additional attention.

The papers on transmutation synopsized above had to do with the formation of one heavy element from another. However, there is an important part of the field involving the production of tritium in LENR experiments. That radioactive element is relatively easy to quantify before, during and after experiments. That it can be formed by conventional D-D fusion does not detract from the value of tritium measurements. There was one paper at ICCF17 by Kew-Ho Lee and his colleagues (Korean Research Institute of Chemical Technology and the University of Science and Technology) on changes in tritium content in experiments using the co-deposition of Pd and D. Two different $PdCl_2$-LiCl chemistries were employed for the co-deposition on mesoporous Ni substrates. A liquid scintillation counter was used to quantify the tritium in the electrolyte before and after the runs of 65 to 168 hours duration. Interestingly, the tritium count rate decreased from values near 500 counts per minute (CPM) before the runs to rates near 200 CPM afterwards. The authors also loaded Pd foils with deuterons without co-deposition. In those experiments, the count rate was 10 CPM prior to and 167 CPM after the experiments. Additional experiments by this group and others are desirable because of the importance of tritium production to the field.

Particle and Electromagnetic Emission

Critics of the field of LENR, especially some physicists, are reluctant to accept excess energy or evidence of transmutations as proof of the existence of LENR. Their rejection of measured values of excess heat seems to be due to (a) unfamiliarity with (distaste for?) calorimetry or (b) unwillingness to adequately study the large body of relevant literature. Ignoring measured evidence for nuclear reactions based on chemical analysis suffers from two similar shortfalls. However, such critics seem to recognize that chemistry cannot lead to the emission of energetic particles or hard electromagnetic radiation. That is, the appearance of neutrons, fast alphas or other particles, or X-rays or gamma rays, is more acceptable to many people. Hence, there have been many LENR experiments that sought to dynamically measure such entities. Success in detecting such particles and radiations is not rare. The papers at ICCF17 that included such reports are reviewed in this section.

Songsheng Jiang and seven colleagues (China Institute of Atomic Energy and Tsinghua University) performed a complex and careful set of experiments and obtained remarkable neutron data. They employed samples of uranium deuteride and D-loaded Ti. The materials were surrounded by 88 ^{3}He neutron detection tubes in a polyethylene moderator. Care was taken to measure both noise and cosmic ray induced counts. The paper cites "cycling" without describing in detail what was varied. Bursts of neutrons were measured in a short time window. Up to 2800 neutrons were observed in a 64 microsecond interval for Ti loaded with deuterium. Such bursts raise again the question of whether they are due to near-simultaneous uncorrelated events or else involve some type of sequential (chain) series of reactions.

Mark Prelas and Eric Lukosi (University of Missouri) reported on neutron emission from Ti in deuterium gas that was thermally shocked from liquid nitrogen temperature to 100°C. Interestingly, the experiment was done in 1991. These researchers used a pair of ^{3}He detectors. Here also, very high count rates for neutrons were observed. Two million neutrons were recorded in five minutes. Both the Jiang *et al.* and Prelas-Lukosi papers stand in marked contrast to most of the experiments in the field that sought to produce and measure neutrons. Normally, only small neutron count rates have been obtained. It remains to be learned if the D-loaded Ti common to both experiments reported at ICCF17 was key to such intense neutron production, or if the protocols used (cycling and thermal shocking) caused the large measured intensities.

Yuri Bazhutov and five collaborators (Terrestrial Magnetism, Ionosphere and Radiowave Propagation Institute RAS and Lomonosov Moscow State University) measured radiation emission from a variety of materials loaded with mixtures of hydrogen and deuterium gases. The samples included $LaNi_5$, Ni and Be. Neutrons were recorded using one ^{3}He tube. X-rays were measured with Geiger counters. Those counters and a NaI(Tl) scintillator coupled to a photomultiplier tube registered gamma rays. Gas pressures up to 100 atmospheres and temperatures as high as 650°C were employed. Synchronous bursts of radiation were recorded in two Geiger tubes. Neutron pulses exceeding 100 per minute were observed for short periods for $LaNi_5$ and Ni samples. For some runs, roughly one-half million neutrons were registered in about one hour. Again, these are remarkable results, worthy of further investigation to determine the fundamental cause, that is, the mechanism which leads to such intense neutron emission.

Pamela Mosier-Boss (Visiting Scientist at MIT) presented another important paper of a different kind. Earlier co-deposition of Pd and D using CR-39 plastic track detectors as time-integrating sensors for energetic particles indicated the following emissions: 2.45 MeV neutrons due to D-D fusion, 3-10 MeV protons, 2-15 MeV alpha particles and 14.1 MeV neutrons. Her ICCF17 paper summarized the earlier observations and addressed the criticisms of the interpretations of the results obtained with the CR-39 detectors. In particular, it was shown that the observed tracks were not the result of chemical damage. The shape of the etched tracks and the absence of measurable X-ray emission were also defended. The observed neutrons, protons and 2-7 MeV alpha particles were tied to D-D fusion reactions. Interestingly, the 7-15 MeV alpha particles were ascribed to fissioning of the Pd nucleus.

Another study reported at this conference used CR-39 detection of energetic charged particles. H. Aizawa and his co-workers (Iwate University) made an electrochemical cell in which the Ni cathode was in contact with the CR-39 plastic on the dry side and the H_2O or D_2O electrolyte on the opposite side. They observed anomalous increases in the etch pit density in two out of five H_2O experiments and one out of seven D_2O experiments.

Several laboratories found earlier that the cross section for conventional D-D fusion in beam experiments is much higher at low bombardment energies (near and below 1 KeV). Results from such experiments have often been reported at conferences in this series. They have the interesting feature that the cross section enhancement depends on the target material, that is, the solid lattice influences the fusion probability, similarly to how LENR depend on the materials involved.

Jiro Kasagi (Tohoku University) has done a great deal of work on cross section enhancements at low energies. In recent years, he measured the interactions of relatively slow deuterons with liquid Li. The liquid metal is essentially a very dense plasma of positive ions and conduction electrons. The electrons screen the D+ ions incident on the target. Kasagi found earlier that the D-D fusion cross section is substantially enhanced by D+ charge screening in the liquid target. He and his colleagues also found that application of ultrasound to the liquid target, which creates micrometer-sized cavities due to cavitation, further enhances the fusion probability. For this conference, Kasagi summarized the results of work with liquid Li targets and provided a phenomenological model for screening effects on the D-D interactions.

At ICCF17, Vladimir Vysotskii (Kiev National Shevchenko University) and two colleagues from the Lomonosov Moscow State University reported on bombarding stainless steel targets with ions containing one or more deuterons. They found that the neutron yield increased by 20-25 times in going from D_2+ to D_3+ projectiles. It is still unclear what, if any, relevance such beam experiments have to mechanisms that lead to LENR, which occur at much lower energies.

The last of the particle emission experiments reported at ICCF17 was quite different from the others. Vladimir Vysotskii and four colleagues, again from the Lomonosov Moscow State University, sought to observe evidence of the reaction $^{11}B + p = {}^{4}He + 8.7$ Mev. Hydroborate samples were employed. These were initially characterized by differential scanning calorimetry, thermogravimetric analysis and infrared spectroscopy. A neutron spectrometer was used to capture the effects of thermally-induced phase transitions in ulexite and inderborite. A small number of counts was interpreted as due to alpha particles having energies of tens of keV.

For many years, Alexander Karabut has reported collimated X-ray emission in the range from 0.6 to 10 keV from a glow-discharge LENR experiment. The effect occurs with different plasmas (H_2, D_2, He, Ar, Kr and Xe) at 1-5 torr, and diverse cathodes (Al, Sc, Ti, Ni, Zr, Nb, Mo, Pd, Ta and W). Currents up to 300 mA and voltages in the range of 1.5 to 4.3 kV were used. Spectra are recorded up to 20 hours after the experiment has been turned off. Karabut reports that, "All experimental results have 100% reproducibility."

The very wide variety of experiments and results already noted challenge theoreticians, who are seeking to understand LENR mechanisms within a consistent framework. We now turn to such efforts, as reported at ICCF17.

Theoretical and Computational Studies

Theories about the mechanisms, energetics and kinetics for LENR abound. In fact, theory is one of the most active and important of the many arenas within the field of LENR. However, it is also one of the most complex and confusing topics in the field. In an attempt to introduce more order into the theoretical aspects of LENR, the organizers of ICCF17 made an innovative and effective move. They scheduled a panel discussion by leading theoreticians from five countries, and boldly asked an experimentalist to moderate the session. The panelists were Peter Hagelstein (MIT), Yeong E. Kim (Purdue University), Xing Zhong Li (Tsinghua University), Andrew Meulenberg (Universiti Sains Malaysia), Akito Takahashi (Technova Inc.) and Vladimir Vysotskii (Kiev National Shevchenko University). The moderator was Michael McKubre of SRI. He prepared five questions in advance of the panel discussion, and gave each of the theorists a few minutes to respond to those queries during the session.

The questions from McKubre were as follows:

1. What experimental results does the theory seek to address?
2. What is the underlying physical mechanism?
3. What are the critical assumptions?
4. How well does prediction compare with experiment?
5. What experimental test can be performed to falsify your theory?

Each of the six theoreticians on the panel did answer each of these five questions. Kim stated that he has made some theoretical predictions that are now waiting for experimental tests. More design and conduct of critical LENR experiments to test theories are needed. McKubre then asked each panelist additional specific questions on their ideas. The open discussion brought out other worthwhile points. It is hoped that the organizers of the conference will transcribe the recordings of the theory panel discussions and include them in the proceedings.

In addition to the unprecedented panel discussion of LENR theories, there were eight oral talks and 18 poster presentations on theory, modeling and data analysis. Hence, theoretical and related talks represented the single largest activity within ICCF17, as at recent conferences in this series.

A detailed summary of each of the theoretical papers at this conference would, by itself, run to several pages. And, for many readers short of time or background, even important theoretical details are not particularly useful at this point in the development of the field. Hence, most of the theoretical papers are not reviewed in detail here. Rather, they are listed in Tables 2 and 3 of the Appendix. Table 2 shows papers by the theoreticians who were on the theory panel, as listed above. Table 3 records the titles of most of the rest of the papers on theory. The tabulated articles are true theoretical papers containing concepts and their elaboration in most cases, and their implications in some cases.

Many of the papers in Tables 2 and 3 deserve detailed attention. However, one of them is unique and reviewed here. As noted above in the section on particle and electromagnetic emissions, Alexander Karabut recorded soft X-ray emission by using a wide variety of gases and materials in glow discharge experiments. Peter Hagelstein and Irfan Chaudhary have focused on the Karabut experiment as a means to test some of their ideas relevant to LENR. They believe that the observed independence of gas and material is due to having Hg from the pumping system deposit on the cathode. Hagelstein and Chaudhary ascribe the measured X-rays to coherent energy exchange between highly excited acoustic phonons and the 1565 eV transition in ^{210}Hg. Design of an experiment to test this idea is relatively straightforward. It should be done soon.

There were also two papers closely related to theory, one an empirical model of experimental evidence and the other a statistical analysis of data from the literature. They are now summarized.

Ab initio theories will ultimately lead to understanding of LENR and optimization of experiments and products. However, the history of science shows that empirical models are useful, either by themselves or as steps toward understanding. The well-known model by McKubre and his colleagues, and its agreement with electrochemical experiments, shows the importance of loading (the D/Pd ratio, called X), the current density (mA/cm^2) and the rate of change of loading (dX/dt). At this conference, Dennis Letts and Peter Hagelstein presented another empirical model for electrochemical experiments. It relates excess power to the number of vacancies in the cathode, the Larmor frequency of deuterium in the cathode due to an external magnetic field, the energy yield per reaction, and a function based on applied laser frequencies and energies. Results from the model agree remarkably well with measured excess power from 40 experiments, which was in the range from 0 to about 1.4 W. The model also gives enticing agreement with the time history of power production during a single experiment. It raises several questions that are discussed by the authors. Those questions deserve experimental attention.

There are three bothersome tendencies that plague the field of LENR. One is theoretical ideas put forward in papers reporting experiments, which tend to detract attention from the laboratory results. Another is incomplete experimental papers. Close examination of reports on LENR experiments shows that many of them have omitted information on key parameters or procedures. Finally, there has not been adequate exploitation of available experimental data. Application of modern data analysis methods is relatively straightforward, and should be done more. Such data mining can quantify conclusions and lead to new indications of relationships.

There was one paper on data mining. Several sets of transmutation data across the periodic table appear similar, but have not been compared quantitatively. Felix Scholkmann (Zurich, Switzerland) and this author did such a comparison of data from teams lead by George Miley and Tadahiko Mizuno, and a collaboration between Scott Little and Hal Puthoff. We found that these data sets are indeed correlated with each other, and also with a theoretical result of Widom and Larsen. Peaks in transmutation rates as a function of atomic mass at 67, 121 and 200 amu passed statistical testing. David Kidwell suggested that the similarity of the data sets is due to contamination from the environment. As a result of that idea, we plan to perform statistical correlations of the same major LENR results ascribed to transmutations with the distribution of elements in the earth's crust.

Theory is one of the two largest and most dynamic topics within the field of LENR. The lack of any single theory that quantitatively explains diverse phenomenon from LENR experiments is the root cause for much of the uncertainty in the field. The other major area in which there are many questions and diverse opinions is materials for LENR experiments. There were some papers on materials at ICCF17, which are reviewed in the next section.

Materials

The complexity of materials in LENR experiments is daunting. Both their composition and structure are likely to be critically important to producing energy, and each is essentially infinitely variable. It seems highly probable that control of both the chemical makeup and the physical structure of materials will be necessary for adequate reproducibility and control of LENR experiments and commercial generators.

There is a basic tension concerning LENR materials. Much work has indicated that it is at least desirable, and maybe even necessary, to have materials with nanometer-scale dimensions to produce excess power and heat. A few of the papers on materials at ICCF17 dealt with nano-materials. Some have already been summarized in the section above on gas loading. However, nano-scale materials can be delicate because they change significantly in short periods at high temperatures due to diffusion and agglomeration by sintering. If, indeed, it is necessary to have and maintain materials with structures on the order of nanometers to reliably produce LENR, the long-term use of commercial energy generators will be very challenging. At present, none of the higher-power prototypes has run for commercially significant periods of months. Systematic study of materials issues for LENR is still dominantly in the research phase, as illustrated by the papers discussed in the rest of this section.

Oxides, sometimes buried in metals and sometimes coating nano-particles, have been an important part of many successful LENR experiments. Jean-Paul Biberian (Aix-Marseilles University), Iraj Parchamazad and Mel Miles (both from the University of LaVerne) reviewed several such experiments at ICCF17. They note that running electrochemical LENR experiments in Teflon or polymer coated cells does not produce excess heat. However, the use of glass cells does lead to oxide formation on the cathodes, and excess heat in many cases. Slow dissolution of the glass puts ions into the electrolytes that deposit on the cathode. It is also possible that boron added to Pd promotes superficial oxide formation and leads to quicker production of excess heat. The authors note that oxide coatings lead to high electric fields at the oxide-metal interface. However, it cannot be said now if this leads to LENR, or specifically where the reactions occur.

Dawei Dong and his colleagues (Xiamen University and Huazhong Normal University) addressed the production of nanoparticles of Pd in aqueous solutions at mild temperatures. The nano-particles were then formed into composites with carbon. The resulting composites were characterized with transmission electron microscopy, X-ray photoelectron spectroscopy and mass spectrometry prior to their electrochemical loading. "Abnormal" behavior was observed for different Pd particle sizes, cathode loading and laser triggering.

John Dash and J. Solomon (Portland State University) took another approach to the production of fine structures on the surfaces of Pd and Ti foils before experiments in a heavy water electrolyte. The foils were first cold rolled and then annealed at temperatures up to 700°C prior to electrolysis. Scanning electron microscopy and analysis were used to examine the films before and after the experiments. Structures on the scale of 1 micron were seen. It was found that heating the Pd foils to 700°C for 40 minutes maximized the observed excess power of about 1 watt.

Yuri Bazhutov and eight others from the Kurchatov Institute and Lomonosov Moscow State University worked with a relatively complex five-element material LaNiCuCeAl to study loading with both H and D. The precise composition of the intermetallic alloy was not provided. Pressures from 0 to 70 atmospheres, and temperatures between 30 and 700°C, were used. Neutrons, X-rays and gamma rays were measured during the experiments. Additional information on this work is unavailable. More LENR work with complex materials, such as those used for hydrogen storage in vehicles and other applications, is needed.

The last three papers on materials, just noted, are part of the large but rather disjointed literature on materials for LENR experiments. Most of the studies have not been adequately related to similar work from other conferences or publications. There is a real need for summaries of material studies for LENR, similar to the paper on oxides by Biberian and his colleagues.

Instrumentation

For all LENR experiments, there are four types of apparatus. The first includes systems used in the preparation of materials before an experiment. The other three are active during an experiment: the container or chamber in which the experiment is performed, the equipment used to drive the experiment and the instrumentation employed to capture data from the experiment before, during and after it is run. The instrumentation employed for all experimental studies reported at ICCF17 varied widely, and was very sophisticated in some cases. Reference has been made above to the equipment used for a few experiments. Here we note some papers that had mostly to do with instrumentation relevant to LENR experiments.

Calorimeters for measurement of excess power and energy have been central to the study of LENR since 1989. Several different types of calorimeters were employed. Of these, isoperibolic calorimeters have gotten a great deal of attention. This is partly due to the fact that Fleischmann and Pons used them, and partly due to their good performance. At ICCF17, Miles gave a review of such calorimeters. It began by citing the seven different power terms needed for complete numerical description of the behavior of isoperibolic calorimeters. They are the powers into or out of the entire system, specifically the electrochemical power, the excess power, heat transfer by conduction and radiation, power supplied by a heater, the transport of energy out of a system by gases leaving it and pressure-volume work. Miles documented that, if all terms are taken into account, it is possible to measure excess power with an accuracy of +/- 0.0001 Watt. He analyzed the terms taken into consideration by three major groups that were energetically and publicly critical of "cold fusion" in 1989: two of the seven terms were included by CalTech, three by MIT and two by Harwell. There were other problems with their experiments and reports, besides the incomplete work documented by Miles.

Kidwell and his colleagues (Naval Research Laboratory) reported on the development and performance of new calorimeters that are useful for both electrochemical and gas loading approaches to producing LENR. The instruments were designed for stern control over the materials that come into contact with the electrolyte, mainly by use of the plastic polyether ether ketone (PEEK). The cells are designed to permit introduction of additives to the electrolytes during operation. Six such cells have been run simultaneously for screening cathode materials.

Measurements of heat, and also determination of the results of transmutation reactions, do not satisfy some critics of the existence of LENR, as already noted. Many such critics demand the measurement of fast particles, which can only be due to nuclear reactions, because they cannot be the result of chemical effects of any kind. Hence, there is much literature on attempts and measurements of neutrons and charged particles, as well as detection of X-rays and gamma rays.

At ICCF17, Lukosi and his collaborators (University of Missouri) reported on the development of a diamond-based detector for measurements of particles and energetic photons from LENR experiments. Diamond has a wide band gap, which favors low noise detection of energetic particles. These researchers deposited diamond-like carbon (DLC) on the thoroughly cleaned surface of a 3 x 3 x 0.5 mm diamond plate. That layer served as a contact. In order to avoid radiation absorption by any electrolyte between a cathode and to maximize the geometry for interception of emitted particles, they deposited 0.1 micrometers of Pd over the DLC. The resulting combination of active material and detector can also be used for gas loading experiments, which were done in this study. Highly variable count rates were measured during a run with deuterium. Partial delamination of the Pd was experienced, and further work continues.

Protocols

The procedures used for experiments with particular materials and instrumentation are generally determined by a combination of published experience and a researcher's particular views of what is useful. Like materials and instrumentation, they vary widely. For example, in electrochemical LENR experiments, the values of the applied voltages or currents at any time, and their variations over time, have been very diverse. There were two papers specifically on procedures presented at ICCF17.

X.F. Wang and Yoshiaki Arata (Osaka University) addressed the practical problem of the reuse of expensive nano-particles of Pd coated with ZrO_2. Earlier, Arata and Zhang showed that such particles produce excess heat and ^4He. However, the He diffuses slowly in materials. It has orbital electrons that make it much larger than bare H or D, which diffuse very quickly. Hence, He stays within the particles and restricts the absorption rate of deuterium. Then, the high loading required for LENR cannot be achieved and excess heat production ceases. In order to reuse nano-particles for heat production, the authors built a heating facility that can reach 1300°C. However, they found that, even at the highest temperature, the ^4He was not completely released. Work on this problem continues.

One of the enduring challenges for LENR experiments, which do not show large values of excess power, is to insure that small observed power levels are not due to chemical effects. For experiments in which both H and D are used sequentially, there is an issue of the exchange of protons and deuterons, and the energy associated with such exchanges. Olga Dimitriyeva and her colleagues at Coolescence LLC reported on the employment of a bakeout protocol for alumina powder impregnated with Pd prior to gas loading experiments. They found that 35 hours of heating *in situ* at

390°C was sufficient to drive off water that came from contact with air during loading of the material into the system.

At this point in the field, there is a great deal of knowledge about what is required for both electrochemical and gas loading experiments. The need for high loading and disequilibrium to produce excess heat in electrolysis experiments is strongly based and widely recognized. Many experiments have shown the efficacy of using electromagnetic and other fields, and ultrasound. However, the overall subject of experimental protocols still requires a great deal of additional work to sort out what is absolutely necessary and what is simply helpful in order to produce excess heat.

Reviews of Work by Individuals

In science, there is a common progression of publications from conference papers to letters to archival articles to topical reviews to monographs to encyclopedias and textbooks. Eventually, that evolution will apply to LENR, as it already does to other fields of science. One step in that direction is for individuals to summarize what they have done and learned over the years of studying LENR. Edmund Storms did so five years ago with the publication of his book *Science of Low Energy Nuclear Reaction: A Comprehensive Compilation of Evidence and Explanations about Cold Fusion*. The book contains his research story, in addition to very useful compilations of work on specific topics in the field.

At ICCF17, Jean-Paul Biberian did a service for the field by recounting the many and diverse experiments he performed over the past two decades. He and his colleagues have done LENR experiments using electrolysis with proton conductors or plasmas, and Fleischmann-Pons isoperibolic or mass flow calorimeters. Interestingly, Biberian reported on his experimental attempts to understand an explosion that happened in his laboratory with an open cell. Thrice, he triggered purposeful explosions using a mixture of hydrogen and oxygen, but the test cell was not damaged. Biberian concluded, "It is therefore possible that in this case the explosion was of nuclear origin: some kind of a chain reaction."

The case for scientists, who have worked on LENR for many years, writing a review article on their research has two legs. The first is a service to the community of people interested in what was done and found in a particular laboratory. The other is the fact that several people in the field are approaching a point of diminishing research efforts on LENR. An example is Stanislaw Szpak of the U.S. Navy SPAWAR Laboratory. It is good that he has written a book on his studies of LENR, which should be published soon.

Other Important Topics

It is very possible that LENR will evolve from its current phases of scientific research, initial engineering and nascent commercialization to becoming important economically, socially and even politically. Hence, it is timely to give early consideration to such larger and longer-term issues, as was done nicely at ICCF17.

Intellectual property (IP) for LENR is already very important, and will become more so in the coming years. A current and evolving list of patents relevant to LENR can be found at: http://www.fusioncatalyst.org/fusion-base/fusion-patents/. It might be a couple of decades before the early patents on aspects of LENR are sorted out by the courts. That was the case for the initial patents on the laser. It is good news that Patent Attorney David French (Second Counsel Services) has become active in the LENR field. Patent attorneys have a large role to play in the commercial development of LENR. French gave a presentation at the International Low Energy Nuclear Reactions Symposium (ILENRS-12, Williamsburg, Virginia) in July and a poster at ICCF17. His paper on IP has two major parts, the basics of patents and processes to get them being the first. The second part is a partial review of a patent application by Robert Godes of Brillouin Energy Corporation. French's paper is must-reading for anyone who is seeking protection for any aspect of LENR, as well as for others concerned with the growing patent literature on LENR.

Participants in the conference benefited from another new type of paper not given at previous conferences in this series. It dealt with the potential economic impacts of LENR generators in energy markets. Alexander Kleehaus (Ecorium GmbH) and Christian Elsner (CHM) employed a Monte Carlo simulation code to determine the possible business and social-economic values of LENR technology. Values in Euros were computed for the cost of ownership by two or more persons in a home with LENR for heating alone and for both heating and electricity production. Validation of the results from the model will follow. Impacts on the current energy infrastructures, and on the economies and citizens of countries, were discussed.

However the commercialization of LENR develops, it is likely that government regulations and other impediments to licensing and use of the new technology will arise. Larry Forsley addressed such anticipated problems. He noted that companies that view LENR as competition will promote regulations to slow down adoption of LENR energy. The discussion following Forsley's talk brought out a variety of opinions. Mahadeva Srinivasan noted the possibility of LENR growing rapidly in countries with urgent energy needs and little regulation, notably India. Attention was also given to the negative public view of the word "nuclear" in LENR. Andrew Meulenberg stated that governments would have to admit that nuclear reactions occur in order to use their nuclear regulations to influence the adoption of LENR technologies.

Assuming that near-term LENR generators work reliably and cost-effectively, and are not overly impacted by IP or regulatory matters, there are other larger aspects to consider. Thomas Grimshaw is a Fellow of the Center for International Energy and Environmental Policy at the University of Texas. He has been studying the broad implications of LENR for several years. At ICCF17, he gave two papers. The first argued for an evidence-based approach to rational policy development regarding LENR, using accepted levels of evidence from the legal field. In the second paper, Grimshaw called for proactive public policy planning based on results from using the methods of technology assessment. Even though low-cost, safe, distributed and reliable sources of heat based on LENR would have great public benefits, there is the possibility that secondary impacts, some unanticipated, might negatively impact adoption of the technology. Like the technical sides of commercialization of LENR, the policy aspects are dynamic and of uncertain resolution.

There were two papers of a futuristic character. Posters by

Edward Lewis (sciencejunk.org) projected that LENR theory might be developed in the next 20 years and major industries based on LENR would appear in 40 years. The basis for these expectations is the author's view that there is an 80 year interval between major scientific revolutions and, implicitly, that period is needed for the development and use of new technologies. Lewis also presented evidence and arguments in one of his posters that LENR are due to what he called "plasmoid" activity.

Jed Rothwell plays a central role in the advancement of the science, engineering and commercialization of LENR. He maintains the remarkably useful website lenr-canr.org. Rothwell stated at ICCF17 that the site has about 1200 papers that can be downloaded and another 3000 that are indexed but not available for download. Currently, 9700 papers are downloaded weekly. Such activity on this one website, and also the recent appearances of many new websites on LENR, have led to the belief that the subject is being monitored by thousands of interested people. Eight years ago, Rothwell considered the prospects of LENR in his book *Cold Fusion and the Future*. It remains worthwhile reading for those interested in the potential impacts of this new source of energy. Rothwell's book is freely available on the web at: http://lenr-canr.org/acrobat/RothwellJcoldfusiona.pdf

Honoring LENR Pioneers

As is widely known, Professor Martin Fleischmann started the intense interest in "cold fusion" with Stanley Pons at their infamous press conference on March 23, 1989. Martin died on August 3, very shortly before this conference. Hence, the organizers of ICCF17 scheduled a talk by Michael McKubre to commemorate the activities and accomplishments of Professor Fleischmann. He had worked with Fleischmann at Southampton University during 1976-78. McKubre characterized Fleischmann as a rare person with a skill set of both creativity and wisdom, who saw farther faster than others. To quote McKubre, "He was also the most highly innovative person I ever knew." McKubre surveyed the early career of Fleischmann, when Martin was part of the groups that essentially started the field of electrochemistry. He showed a few group photos of those remarkable research teams.

This author enjoyed the good nature and remarkable creativity of Martin Fleischmann at most of the conferences in this series. Martin was interesting and fun to be around, both personally and professionally.

A tribute to Martin Fleischmann, including statements from many leaders in the field, was published in *Infinite Energy* #105, available at: http://www.infinite-energy.com/images/pdfs/Fleischmannobit.pdf

Professor John O'M. Bockris was also a long-time leader of the field of electrochemistry. He moved quickly after the 1989 press conference to conduct "cold fusion" experiments. He and his team made rapid and significant early progress, including what might be the first measurements of tritium. During ICCF17, Professor Bockris was honored with the Preparata Medal from the International Society for Condensed Matter Nuclear Science. He responded with comments in a videotaped statement. It was noteworthy that he emphasized work on transmutations, not only for their scientific value, but also because of its possible practicality. Professor Bockris has an immense intellectual bandwidth, as evidenced in his 2005 book entitled *The New Paradigm: A Confrontation Between Physics and the Paranormal Phenomena*.

Pre-Conference Tutorial

Several of the previous conferences in this series have had one-day schools in advance of the conference. Until ICCF17, they were on the weekend immediately prior to the first day of the conference. ICCF17 was distinguished by holding the tutorial on the Friday before the conference in order to attract more people from Korean industry. There were about 44 attendees, mainly from Korea, as hoped. Thirteen of them were students. Instructors for the tutorial were Jean-Paul Biberian, Peter Hagelstein, Yeong Kim, Michael McKubre, Michael Melich, Mahadeva Srinivasan and this author. The tutorial was modeled on a commercial short course held by NUCAT Energy LLC in October 2011. Its content and results are described at: http://www.infinite-energy.com/iemagazine/issue100/nucat.html.

Additional Questions and Comments

There are several really fundamental unresolved questions that burden and enliven the study of LENR. They were not highlighted at ICCF17. That is simply a fact, and not an indictment of the excellent conference. Questions are normal for a field of science. In fact, most sciences have more questions than answers. That is the case for research on LENR. Several specific questions about LENR deserve more discussion, theoretical development and experimentation. They are candidates for focused attention at ICCF18 and beyond. A list of some of the primary questions follows:

Q1. Is there only one, or more than one, basic physical mechanism(s) active in LENR experiments to produce the diverse measured results?
Q2. Is excess heat from electrochemical loading and gas loading experiments due to the same basic mechanism(s)?
Q3. What are the keys to making and maintaining materials that produce excess heat regarding both composition (notably impurities) and structure (vacancies, dislocations and other defects)?
Q4. Are nano-scale structures or particles sizes necessary, or merely desirable, for occurrence of LENR?
Q5. Are protons and deuterons interchangeable in at least some effective heat producing experiments?
Q6. Do LENR occur on or near surfaces or in the bulk of materials or in any locations?
Q7. What is the role of oxide-metal and other interfaces in LENR experiments?
Q8. Is the excess heat due entirely or only partially to nuclear reactions, and, if partially, what other mechanism(s) contributes to the heat output?
Q9. Does the kinetic evidence for nuclear reactions (neutrons and charged particles) arise from the heat-producing reactions?
Q10. What is the basic reason for the lack of reproducibility in many LENR experiments?
Q11. What are the control parameters for production of excess power, and which of them are most useful scientifically and practically?
Q12. What are the roles of electrical, magnetic, electromag-

netic, ultrasound and other applied fields in LENR experiments?

Q13. Do resonances of any kind (electrical, mechanical or chemical) play a role in production of excess heat and causation of transmutations?

Q14. What are specific transmutation rates, and might they be commercially significant?

Q15. Is the destruction of radioactive waste from fission reactors by LENR possible and practical?

Other scientists in the field could add many more questions to this list. Engineers, who are developing prototypes and products, could also raise other questions. The author of this overview would be glad to receive such questions. He plans to write a separate article on major issues regarding LENR, with comments on each of them. The motivation for that article has two aspects. The first is to compile a compact list of primary concerns to those who are studying LENR, or working toward products based on LENR. Such a list should be useful to people from scientists to investors. The other motivation is to develop a program plan for the funding of research and development on LENR. It is possible, and maybe not very distant, that U.S. government agencies would want to formulate programs to address fundamental questions on LENR. The National Science Foundation, the Department of Energy and the Department of Defense are candidates. Of course, it is also possible that agencies in other countries will take the lead on advancing the science and engineering of LENR, regardless of what happens in the U.S.

At this conference, and many times earlier, there was discussion of the development of a "lab rat" experiment for LENR. It could be used by many people to reliably produce excess energy. Doubters, critics, the curious, students, teachers and scientists are all potential users of such an experiment. The terminology "lab rat" comes from biological studies, which use standard animals for diverse experimental studies to reduce the variability in the results. This author prefers the terminology "standard experiment" in place of "lab rat." Different LENR experiments get attention as candidates for a standard approach to showing anyone that LENR are effective for producing energy. There remain two problems now. No experiment is reliable (reproducible) enough to perform the needed function. And, different scientists have different opinions on what might be closest to useful as a standard experiment at this moment. Eventually, there might be kits on the market for one or more standard LENR experiments.

ICCF17 was marked by a very useful advance in handling of the proceedings. For past conferences in this series, it took one to two years to produce and distribute the proceedings. The papers are a major resource in the field. However, with the increasing pace of the field in the past two years, the organizers of ICCF17 recognized that long delays in availability of the proceedings would not serve the field optimally. Hence, they requested and received most of the papers in time to distribute them at the conference. The papers were provided on USB flash memories the shape and size of business cards, a thoroughly modern and very convenient means of distribution.

The organizers of ICCF17 retained a photographer to record all events related to the conference, including the cultural tour on the Saturday before the conference. For the first time in the ICCF series, the conference photos are available on the web at http://www.iccf17.org. Videos of the talks are also available to the speakers.

One non-technical aspect of ICCF17 is worth noting. In recent years, the International Society for Condensed Matter Nuclear Science (http://www.iscmns.org/) had an evening membership meeting during each ICCF. That was not the case at this conference. It remains an open question whether that organization, or some other existing or new entity, will be the focus for the scientific field involving LENR and closely related disciplines.

Looking Ahead: ICCF18

The International Advisory Committee for the ICCF conferences dominantly consists of chairmen and co-chairmen of past meetings in this series. At each conference, it determines the chairman and, hence, the location of the next conference. The committee met during ICCF17. Professor Robert Duncan and Dr. Annette Sobel, both of the University of Missouri at Columbia, provided a very well organized proposal to the committee members. The committee readily accepted their proposition. Hence, ICCF18 will be held in Columbia, Missouri, the week of July 19, 2013. The University of Illinois, in the person of George Miley, and Purdue University, represented by Yeong Kim, will join the University of Missouri in the organization of the conference. The website for ICCF18 is already available at: http://research.missouri.edu/iccf18/index. It is probable that, if any LENR products have been marketed prior to ICCF18, there will be a larger than usual attendance and considerable press coverage at that conference.

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Appendix: Tables of Papers at ICCF17

As with previous conferences in this series, there were several reports of excess power and energy given in Daejeon. Table 1 summarizes them. It was compiled by Rick Cantwell of Coolescence LLC.

Tables 2-3 show theoretical papers given at ICCF17. The diversity of ideas, and the global nature of the search for understanding of what has been seen in LENR experiments, are both evident from these theoretical papers. Table 2 highlights the papers presented by members of the Theory Panel, while Table 3 shows other theoretical papers given at ICCF17.

Table 1. Reports of excess power from ICCF17.

Organization & Author or Presenter	System and Loading	Excess Power or Heat	Power or Energy Gain	Duration of Experiment	Type of Calorimetry
Brillouin Tanzella	Pd/H_2O & Ni/H_2O Electrolysis with axially pulsed cathode current	As much as 63W	Power gain up to 2	Few hours	Thermometry & mass flow with heat loss add-back
Changchun University Tian	Pd in D_2 gas with resistive heater	87 W average and 300 MJ	Energy gain of 1.2	40 days	Thermometry
ChrononixUSA Sinha	Pd wire with axial current in D_2O or H_2O with NaOH	60 eV/Pd atom	Not Reported	1 Hour	Modeled xPower based on thermometry
Coolescence Dmytriyeva	H & D loading of Pd on various oxide supports	~30 J excess with D	Not Applicable	< 60 minutes	Thermometry in isothermal chamber
Defkalion Koulouris	Proprietary Ni powder with spark ignition	Up to 92 Watt-Hour per cyle	Energy gain up to 23	6 weeks (no data disclosed)	Not Disclosed
Dixie State College Mel Miles	Pd/D co-deposition in ammonia electrolyte	200 mW	Not Reported	250 hours	Open cell & isoperibolic calorimeter
First Gate Tech. Stringham	Pd in D_2O with ultrasonic loading	40 W	Power gain of 1.8	Not Given	Mass flow calorimetry
Frascati National Lab Celani	H-Loaded $Cu_{55}Ni_{44}Mn_1$ with treated surface	Demo at ICCF17 gave 18 W	~1.3	Days	Thermometry
Jet Energy Inc. Swartz	Nanor™: Sealed nano ZrO_2+NiPd with D and DC current	60 mW	Energy gain 5-16	Weeks	Thermometry
Kobe University Kitamura	H & D loading of silica-included PdNi	2 eV/atom	Not Applicable	100 minutes	Water mass flow
Kobe University Sakoh	H & D into CuNi on ZrO_2 (~$Cu_{12}Ni_{88}$)	4 W max 800 eV/Ni atom	Not Applicable	100 hours	Thermometry
Lenuco Miley	Proprietary nano Pd + D. Cycled pressure to maintain heat	Excess energy up to 4 kJ	Energy gain up to 15	Minutes	Thermometry
NRL - Dominguez Electrolytic Loading	D_2O electrolysis of PdRh with metal & metal oxide powders	Bursts of up to ~10 W with up to 70 kJ	Up to 40	Minutes to hours. Max ~ 20 hours	Hart calorimeter (water mass flow)
NRL - Kidwell Gas Loading	D loading of nano Pd grown *in situ* on alumina spheres	0.1 mW/g	Not Applicable	Days	Hart calorimeter (water mass flow)
Samar+ Company Karabut	Pd, Re coated Pd and nano-Pd electrolysis	Excess powers of 120-280 W	Energy gains of 2 - 3.4	Not Given	Heat capacity and flow calorimeters
SPAWAR Szpak	Pd-D and Pd-H co-deposition	10 eV per Pd atom	Not Given	Not Given	Thermometry
SRI McKubre	Electrolytically loaded, sealed & exploded in LN_2 by electrical pulse	Excess energy up to 1.2 J	Energy gain up to 2.2	Sub-Second	LN_2 mass loss
Toyota Hioki	H & D loading of Pd on zeolite and Pd on FSM	~80 J excess with D	Not Applicable	< 100 minutes	Water mass flow

Table 2. Papers presented by the members of the ICCF17 Theory Panel.

Authors	Affiliations	Title
Hagelstein	MIT	Molecular D_2 Near Vacancies in PdD and Related Problems
Hagelstein & Chaudhary	MIT / U of Engr. & Technology, Lahore	Models for Excess Heat in PdD and NiH
Orondo & Hagelstein	MIT	Basic Physics Model for PdH Thermodynamics
Hagelstein & Chaudhary	MIT / U of Engr & Technology, Lahore	A Model for Collimated X-Ray Emission in the Karabut Experiment
Kim	Purdue University	Conventional Nuclear Theory of LENR in Metals: Alternative Approach to Clean Fusion Energy Generation
Li, Dong & Liang	Tsinghua University	"Excess Heat" in Ni-H System and Selective Resonant Tunneling
Meulenberg & Sinha	Universiti Sains Malaysia / Indian I. of Science	New Visions of Physics through the Microscope of Cold Fusion
Meulenberg & Sinha	Universiti Sains Malaysia / Indian I. of Science	Deep-Electron Orbits in Cold Fusion
Meulenberg & Sinha	Universiti Sains Malaysia / Indian I. of Science	Deep-Orbit-Electron Radiation Emission from $^4He^{*\#}$ to ^4He
Meulenberg	Universiti Sains Malaysia	Femto-Atoms and Transmutation
Takahashi	Technova and Osaka University	Physics of Cold Fusion by TCS Theory
Vysotskii, Vysotskyy & Adamenko	Kiev National Shevchenko University / "Proton 21" Kiev	Application of Correlated States of Interacting Particles in Nonstationary and Periodical Modulated LENR Systems
Vysotskii	Kiev National Shevchenko University	On the Possibility of Application of the Widom-Larsen Theory for Analysis & Explanation of Rossi Experiments

Table 3. Other theoretical papers presented at ICCF17.

Authors	Affiliations	Title
Bazhutov	Russian Academy of Science	Erzion Model Interpretation of the Experiments with Hydrogen Loading of Various Metals
Cook & Dallacasa	Kansai University / Verona University	LENR and Nuclear Structure Theory
Godbole	Unaffiliated, Germany	Low-Energy Electroweak (EW) Physics (in Cavities) in Lattices and Fluids
Hora, Miley, Prelas, Kim & Yang	U. New South Wales / U. Illinois / U. Missouri (Columbia)	Surface Effect for Gas Loading Micrograin Palladium for Low Energy Nuclear Reaction LENR
Mizuno	H. Engr. Application & Development, Sapporo	Theoretical Analysis of Chemically Assisted Nuclear Reactions (CANR) in Nanoparticles
Naitoh	Waseda University	Quasi-Stability Theory: Revealing Various Atomic Breakups and Cold Fusion
Numata	Tokyo Institute of Technology	Search for Advanced Simulation Model of Cascade Vortices Under Beneath the Electrode Surface
Numata	Tokyo Institute of Technology	Numerical Simulation of Vortex and Cascade of Vortices Appeared Under Beneath the Sub-Surface layer
Szumski	Independent Scholar, USA	Nickel Transmutation and Excess Heat Model Using Reversible Thermodynamics
Tsuchiya	Tokyo National College of Technology	A Self-Consistent Calculation for the Two Species of Charged Bosons Related to the Nuclear Reactions in Solids