Scientific and Commercial Overview of ICCF18

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ICCF is short for the International Conference on Cold Fusion. That abbreviation was first used for the third conference in the series in 1992. In 2002, the proceedings of ICCF9 were called Condensed Matter Nuclear Science (CMNS). Since then, some of the conferences have also borne that title. ICCF18 retained the historical label and numbering system, but employed a new conference title: "Applying the Scientific Method to Understanding Anomalous Heat Effects: Opportunities and Challenges." This conference title emphasized an operational aspect of the research, rather than a name for the field. The focus on scientific methodology and understanding is entirely appropriate at this stage in development of the field. The science remains a vexing and challenging endeavor spanning several disciplines

The variety of titles for the ICCF conferences reflects the evolution and present status of the field. Currently, there remain tensions in the field over terminology. This is due to two primary reasons, the first of which is personal and country predilections for various monikers. But, the more basic reason for the variety of names is the persistent lack of understanding of the fundamental mechanisms that produce excess heat in a wide variety of experiments. A summary of the names known to this author is in the appendix. If any names applied to the field are omitted, an email pointing them out would be welcome.

Of the many names, the two current favorites seem to be "cold fusion" and "low energy nuclear reactions" (LENR). Cold fusion is used by people who believe that it aptly describes the mechanism for at least some of what is observed, and by those who like the historical term with its broad name recognition. However, "cold" is a relative adjective, and many people do not believe that fusion is the central mechanism, or do not like the bad reputation that dogs the term "cold fusion." LENR is widely employed, although "low" is also unspecific. Room temperature is low compared to the temperatures required for "hot fusion," but high to many other temperatures used in science and engineering. Further, there are reasons to question if all of the energy released in LENR experiments is due to nuclear reactions. That point will be addressed below. Nonetheless, LENR will be used often in this overview.

Status of the Field

Before considering ICCF18 in detail, it is useful to give a very brief summary of the three major parts of the field, namely science, engineering and business. The topic by any name has been a field of science since before the remarkable press conference by Fleischmann and Pons on March 23, 1989. The two parts of the science of LENR, experimental and theoretical, are very different in their state of development. In the almost quarter-century since the announcement, excess heat has been observed hundreds of times in very different experiments in laboratories in several countries. The data shows that it is possible to produce nuclear reactions at ordinary temperatures. But, although the experimental situation is very solid, the theoretical side of the science is still quite wide open. There are very roughly three dozen theories on the mechanisms behind LENR. But, none of these has been adequately tested, and there is no consensus on the theoretical aspects of LENR. It might be that one or more of the extant theories turns out to be the needed conceptual and computational explanation of LENR. Alternatively, the key insight might remain to be published.

The engineering side of the field also has two parts. The design, fabrication and testing of experimental LENR systems is very well developed. Over two decades of attacks by critics, and good laboratory practices by experienced and skilled researchers in the field, have resulted in some very sophisticated and well-engineered laboratory systems. Their use has also been first-rate in many cases. In contrast, the prototypes revealed by a few of the companies seeking to develop products for a large market have been relatively crude. This is primarily due to the apparent haste with which those companies are seeking to develop shipped products. It is highly likely that the actual first generation products will be much better engineered.

The business of LENR has yet to develop. That is, no one is making money now by mass marketing of products based on LENR. There are two types of companies involved in the field to very different degrees. Small companies, mostly start-ups, are devoted entirely to the development and commercialization of LENR. These companies vary widely in their size, funding and approaches to selling LENR heat or electrical generators. Some large companies are monitoring very closely the current progress in LENR science, engineering and business. A few are actively involved in the field, but most of the big companies are watching and waiting until it is clear that LENR generators will be adequately controllable, safe and reliable to receive serious market acceptance.

This background serves to explain the setting for ICCF18 and many of its characteristics. So, now we can focus on the conference itself.

Summary of ICCF18

The conference was held on the campus of the University of Missouri in Columbia, Missouri during July 21-27, 2013. The chairman was Robert V. Duncan, who is the Vice Chancellor for Research at the University. The Co-Chairman was Professor Yeong E. Kim from the Department of Physics at Purdue University. The Program Organizer was Dr. Annette Sobel, who is Director of the National Security Innovation Center at the University of Missouri. There were 215 participants, of which 14% were students. The attendees came from 21 countries, which tied for the most for any of the ICCF. The large fraction of students and number of countries represented both reflect the evolution of the field. The 85 oral presentations included two keynote presentations. Forty poster papers were also presented. The conference included five technical panels and a few exhibits. ICCF18 was distinguished by tours of five laboratories over three days for a total of 23 hours. Included was the Missouri University Research Reactor, a 10-megawatt facility called MURR. Memberships of International Advisory, National Steering, Local Organizing and Technical Program Committees are available at the conference website: http://iccf18.research.missouri.edu/

Among the several innovations for ICCF18 is a very useful posting of the conference abstracts and many of the presentations on a University of Missouri website: https://mospace.umsystem.edu/. Those materials can be found easily by using "iccf" in the search box of that site. There are almost 100 such postings in mid-October 2013. Similarly, and very importantly, videos of presentations at ICCF18 are available on the Cold Fusion Now website: http://coldfusionnow.org/. Click on "CFN at ICCF18."

As with recent conferences in the series, ICCF18 embraced commercial aspects of the field in addition to the dominant scientific research topics and results. Because there is wider interest in applications of LENR generators than in the scientific details, we will address commercialization in the next section. Then, the work of two research groups with major impacts on ICCF18 will be noted prior to the detailed review of the science of LENR. Later sections will address the panel discussions, honorees, perspectives on the field and five conference-related events.

Commercialization

As already noted, there is significant interest in the possibility of commercial LENR power generators by companies devoted solely to that development, by companies that want to contribute to a new industry based on LENR, and by companies that might use LENR systems. The intersection of such interest with ICCF18 had four facets. First, there was a demonstration during the conference by one of the new companies striving to develop and sell LENR-based systems. Second, there were conference participants from many companies of diverse sizes. Thirdly, the idea of a new Industrial Association for LENR companies, and other interested organizations and people, was put forward during the conference. Finally, costs for a LENR generator for homes were discussed. Each of these is described briefly in the following paragraphs.

Defkalion Green Technologies (http://defkalion-energy.com/) was located near Athens, Greece, until late last year. Now, the DGT headquarters is in Vancouver, Canada, with their European R&D Center in Milan, Italy. During ICCF18, the company demonstrated their Release 5 (R5) reactor in two separate runs performed in Milan and streamed to the conference site over the internet. Prior to the runs, the DGT Chief Technology Officer, John Hadjichristos, provided a remote tour of the laboratory. He described both the test set-up and the protocol to be employed. For the first run, the reactor was filled with argon. That run was performed to show that the diagnostics for the measurement of both the input electrical power and the output thermal power were working properly. Hydrogen filled the reactor during the second run of three hours duration. The performance of the second run was phoned late in the day to Professor Michael Melich (U.S. Naval Postgraduate School). He had arranged for the demonstration. Melich reported that the maximum output power measured by the flow calorimeter was 5.2 kW, with an input power near 2 kW. That is, there was a power gain of about 2.6 at some unstated time during the run. More information on DGT experiments can be found early in the section on Theory below. Coverage of the Defkalion demonstration at ICCF18 is available at: http://peswiki.com/index.php/Event:2013:July:Defkalion_Demonstrations#Blog

This demonstration showed that Defkalion can operate their R5 reactor on-demand, although their runs during ICCF18 were short compared to their usual ten hour runs because of the time limitations at the conference. What is needed now is for the company to publish the time histories of the input and output powers for both runs. That will permit quantitative determination of the ability of their equipment to provide proper power balance for the argon run and the overall energy gain for the hydrogen run. It is also desirable for calibration information to be provided for all of the sensors employed, as well as the raw current, voltage, temperature and flow rate data. Having such data will greatly strengthen the acceptance and value of the Defkalion demonstration performed at the time of the conference.

ICCF participants representing companies have been common throughout the series of conferences. However, the attendance by company personnel was remarkably high at ICCF18. Of the participants who were listed on the published roster of attendees, 42% had company affiliations. This included Robert E. Godes, President and CTO of Brillouin Energy Corporation, who is devoting full time to development of LENR products (http://www.brillouinenergy.com/#). Other participants were individuals from large companies which might become involved, such as Jostein Alvestadt from Statoil ASA, the Norwegian oil company (http://www.statoil.com/en/Pages/default.aspx). And, there were participants from very small companies who are doing or planning research on LENR. One example is Roger Stringham from First Gate Energy in Hawaii, long a major contributor to the field. In short, there is growing business interest in the development of LENR generators and their

Robert Duncan addressing the conference, which was well organized and attended.

myriad potential applications. Lists of most LENR and some other related companies are on the web at two sites: http://www.fusioncatalyst.org/fusion-base/fusion-companies/ and http://www.newenergytimes.com/v2/commerce/LENR-Companies-and-Commercial-New-Energy-Research.shtml.

Industrial associations represent the interests of companies and individuals working in particular industries. There are over seven thousand such trade associations in the U.S. alone. There is even an association for association leaders (http://www.asaecenter.org). In the energy arena, the U.S. Energy Association (http://www.usea.org/) is part of the World Energy Council (http://www.worldenergy.org/). The U.S. association has member associations that support coal, oil, gas, nuclear, wind, solar and other energy industries. It is clear that, if LENR generators are sold in large numbers, a new industry based on their design, production, distribution and maintenance will be created. So, one can ask if any of the existing energy associations will serve the interests of the new LENR industry. The answer to that question is almost certainly no. Given competition between energy sectors and the remaining antiquated and obsolete bad reputation of LENR, none of the current energy associations will stand up for LENR products and interests. The National Energy Institute (http://www.nei.org/) services the nuclear fission industry. It refused an offer to even listen to a summary of the progress, status and promise of LENR. In short, existing energy associations will not represent LENR at all, let alone optimally.

Given the situation, and the possible emergence of a new LENR industry in the next few years, Steve Katinsky and this reviewer formulated a concept for a new industrial association devoted to LENR, which we presented at ICCF18. The possibility elicited considerable interest, so we plan to form the organization before the next conference in this series. The first goal of the association will be to strengthen existing scientific organizations within the LENR community, specifically the International Society of Condensed Matter Nuclear Science, the *Journal of Condensed Matter Nuclear Science* and some of the major sources of scientific information on LENR, notably the website lenr-canr.org.

George Miley and five colleagues at the University of Illinois at Urbana-Champaign focused on one of the major advantages driving commercialization of LENR sources. That is the potential availability of distributed energy sources free of dependence on giant central facilities and the grid. The provision of heat and electricity to homes by a thermal source powering an electrical generator is one of the main attractions of LENR. The Illinois group envisioned 7 kW heat and 1.5 kW electrical sources. They expect that early units should cost about $3000 to buy, and would require $500 every six months for reloading of nano-particles. They project operational costs of 7 cents per kWHr, which is about half of current rates in many areas. Payback of the installation cost could be achieved in three years. If such cost performance, and other features such as compact sizes, no greenhouse emission and reliability, are achieved, the team anticipates hundreds of billions of units will be sold annually. The work reported by the group was done in support of LENUCO (http://coldfusioninformation.com/companies/ lenuco/)

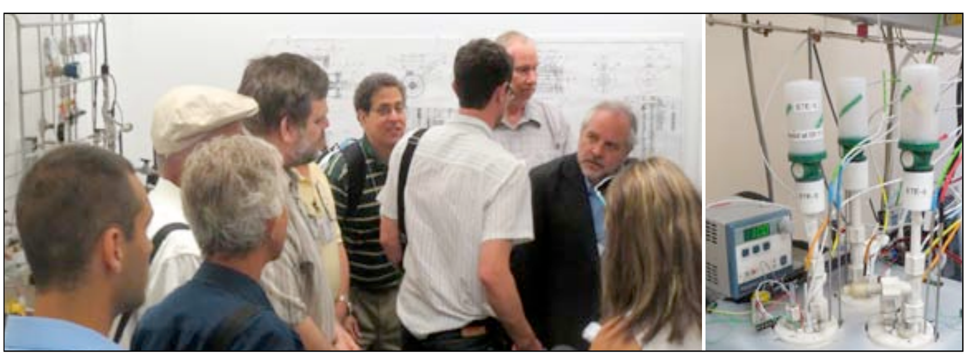
Before turning to the scientific details from the presentations and posters, two relatively new research organizations that had major roles in ICCF18 will be described briefly.

Sidney Kimmel Institute for Nuclear Renaissance (SKINR)

SKINR was founded early in 2012 at the University of Missouri (http://www.infinite-energy.com/resources/kimmel.html). Kimmel has been a generous supporter of cancer research, and more recently turned his attention to clean energy research. He funded the company Energetics Technologies in Israel for several years to do research on LENR. Next, Kimmel gave the University of Missouri $5.5M to perform interdisciplinary research on LENR, so the institute that bears his name was created.

Graham Hubler, formerly leader of a large group at the Naval Research Laboratory, became Director of SKINR earlier this year. He gave a presentation on the organization, activities and results from the Institute. SKINR scientists conduct research in several departments of the University of Missouri and its MURR nuclear reactor, the largest reactor at a university in the U.S. Seven professors in the Departments of Physics and Astronomy, Electrical and Computer Engineering, Nuclear Engineering, and Radiology are affiliated with SKINR. The Institute has a very long list of scientific initiatives. They include work with applied magnetic fields, study of hydrogen permeation kinetics and measurement of soft X-rays. SKINR scientists have achieved a 40% success rate in producing energy using cathodes prepared at the University. Excess powers obtained with cathodes from ENEA in Italy have ranged up to 19 W during a 17 hour run. Their maximum energy gain to date is 4, more than ample for some commercial applications.

Tours of the SKINR laboratories in both the Department of Physics and the Department of Electrical Engineering, as well as the reactor, were conducted during ICCF18. Capabilities, which ranged from materials preparation and characterization to electrochemical and gas loading LENR experiments, were on display. It is clear that SKINR has much of both the scientific expertise and the modern equipment needed to grapple with the multi-disciplinary challenges of LENR. Because of SKINR and related capabilities, the University of Missouri has the most comprehensive academic program to attack the riddle of what is happening in LENR experiments. It is a welcome evolution for the field so that, once again, there are major capabilities for LENR research at a large research university.



Left: Conference participants discussing a point during one of the laboratory tours. Right: Three LENR electrochemical cells in operation within an insulated calorimeter.

Martin Fleischmann Memorial Project (MFMP)

This project was borne out of contacts made last year at ICCF17 in Daejeon, Korea. It consists of a small group of relatively young entrepreneurs and researchers, a welcome addition to a field that has a fairly high average age. Further, the Project is being conducted in an open source fashion, in contrast to the very proprietary approaches by some organizations working on LENR. The MFMP calls this model Live Open Science (LOS). The website of the MFMP is http://www.quantumheat.org/index.php/en/. The choice of "quantum heat" as the website name for the Project is interesting, since energy from chemical reactions is also due to interaction of quanta, specifically atoms and molecules. The MFMP calls excess energy from LENR experiments "New Fire." Here again are examples of the diversity of terminology used to characterize the field.

The stated goal of the MFMP is "to facilitate the widespread replication and validation of New Fire experiments, such as Francesco Celani's, at reputable research institutions around the world." Their interest in Celani's gas-loaded wire experiment is directly traceable to the demonstration of that experiment at ICCF17. Recently, the group broadened its experimental capabilities. The design of a well-engineered system, which is to be built, was shown at ICCF18. The MFMP is funded by three sources. One is "crowd funding" through their website: http://www.quantumheat.org/index.php/en/donate/donate-2. The second is the considerable efforts by the Project Facilitators at their own expense without reimbursement. And, the Hunt Utilities Group LLC also provides funding. The Hunt Group does research on what they call "Resilient Living" (http://www.hugllc.com/).

There was one technical presentation by Mathieu Valat from the MFMP at ICCF18. It is summarized below in the section on Gas Loading as done by Celani. In addition, the MFMP had a comprehensive presentation in the panel on Entrepreneurial Efforts, which is also described below. An article on the MFMP by Ruby Carat was published by this magazine in the last issue: http://www.infinite-energy.com/images/pdfs/NewFire.pdf

Scientific Overview

Like the earlier conferences in the series, ICCF18 was primarily a scientific conference. The following sections provide information on the technical papers given, or scheduled to be given, at ICCF18. No distinction is made between oral and poster presentations. But, summaries of the two keynote addresses are given first in the rest of this section.

The opening keynote talk was presented by Dr. James Truchard, the co-founder, President and CEO of National Instruments. Its annual turnover exceeds $1B. His company sells instrumentation and software for sensing and control in many major industries, including scientific research. As a result, Dr. Truchard is open to new areas of science. He evidenced interest in "cold fusion" soon after its announcement. National Instruments' focus on LENR has increased significantly in the past two years, as the possibility of commercial generators based on the effect has improved. Last year, the company highlighted LENR at its annual convention, which included a presentation by Robert Duncan, chairman of ICCF18. The address given this year by Dr. Truchard was not actually a scientific presentation. Rather, it dealt with the company and its instrumentation, which is already widely used for LENR and other research.

The second keynote address was given by Dr. David Kidwell, a chemist at the Naval Research Laboratory (NRL). He is an important member of a group at that laboratory, which has been doing research on LENR since 1989. The team has performed a wide variety of electrochemical and gas loading experiments, and given a great deal of attention to materials issues central to achieving reproducible and controllable heat generation. They reported at ICCF17 that they observed excess heat (beyond 1 kJ) in 5% of 117 electrochemical experiments with $Pd_{0.9}Rh_{0.1}$ cathodes. Dr. Kidwell reviewed that and other experimental work at the NRL, and their efforts to reproduce transmutation results reported by Mitsubishi Heavy Industries. But, the main thrust of his presentation was to encourage skepticism when it comes to examining experimental LENR results. There are 60 of Kidwell's graphics available on the MOSpace website noted above.

Now, we turn to the detailed scientific reports given at ICCF18. They constitute the next dozen sections of this overview. As always, there is some arbitrariness regarding which papers to discuss in what sections. For example, an electrolysis experiment in which energetic particles were measured could be reviewed in sections on either the method of loading or the means of measurement. After the sections on specific technical topics, additional aspects of ICCF18 will be summarized.

NANOR®-Type Components

It is well known that experimental research on LENR employs either of two dominant methods of loading hydrogen isotopes into materials. Electrochemical loading of deuterons into palladium was the initial and remains a very widely studied approach. Gas loading of protons onto and into nickel has also gotten great attention, since it seems to offer the most practical method of commercial LENR generators. Dr. Mitchell Swartz (JET Energy Inc.) has performed much research on electrochemical loading methods for both nickel and palladium systems. In those aqueous systems, he developed an electrode configuration, called a PHUSOR®-type cold fusion cell.

Recently, Swartz developed a two-terminal electrical device termed the NANOR® cold fusion component, because it depends on nano-scale materials. It was reported at ICCF17 that NANORs® are a few millimeters in diameter and a few centimeters long. They contain nano-scale particles of ZrO_2 and other materials forming an alloy of Zr (60-70%), Pd (5-30%) and Ni (0-3-%) before oxidation and loading, to which is added deuterium. The proprietary method of preparing these devices has not been revealed. However, it is clear that neither their formation nor their operations are conventional electrochemical loading or gas loading. That is, they are preloaded in some fashion, and then operated subsequently to produce excess power over long periods of time. Swartz ran a NANOR® for several months during and after an open demonstration at MIT in 2012. This separation of the preparation and operation steps is likely to apply to most commercial LENR devices. Information on NANOR®-type components is available at http://www.std.com/~mica/nanortechnology.htm.

Swartz and eleven colleagues had three papers at ICCF18, in addition to a presentation in the Entrepreneurial Efforts

Panel, which is described below. The primary paper included a review of earlier work, plus many new results. Swartz surveyed excess power data from high impedance Ni-H_2O, and Ni-D_2O electrochemical experiments, some performed as early as 1994. He briefly presented the results of experiments with static applied magnetic field intensities. The new results from NANORs® include his discovery and development of cold fusion excess heat amplification, and also restoration of energy gain in LENR systems. The team used rapidly pulsed ("fractionated" in time) magnetic fields in the range from 0.02 to 1.5 Tesla with 100 microsecond rise times. Power gains were determined by three methods. The energy gains were demonstrated to vary with input power, consistent with Swartz's discovery of Optimal Operating Point (OOP) manifolds. The maximum energy gain was near 20. Absolute excess power values for the initial NANORs® were still less than one watt.

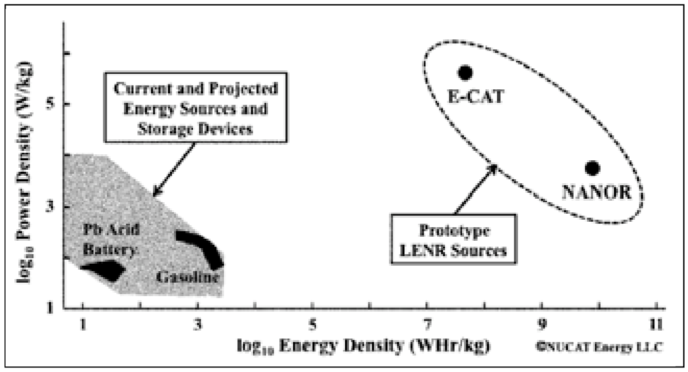
Swartz revealed a new device called the M-NANOR®. He asserted that two processes are active in his current devices. The first is "cold fusion" by coupling to phonons, which are collective excitations of ions in a lattice. And, the second is magnetic (presumably magnon) coupling and amplification, where magnons are collective excitations of the electron spins in a lattice. Hence, the M appears in the name of the new devices.

Low powers may not be practically useful in the near term. However, M-NANORs® are projected to yield tens of watts. Even now, the ability to operate NANORs® for long times, their high power and energy gains, and the new information on emissions that can only be from nuclear processes (next paragraph) are all very important to advancing the understanding of LENR.

Swartz, a physician trained in radiation therapy, also reported in two of his papers on the measurement of energetic radiations from operation of NANORs®. The devices were run over a period of several weeks with an *in situ* Geiger-Müller system using a СИ29БГ tube, TTL serial converter and three autonomous microprocessor systems to control the NANOR® driving and perform generalized data acquisition. The energy range of the gamma detector was not specified. However, it reached to the gamma emission of ^{40}K at about 1.5 MeV. Peak bursts as high as 25 nanosieverts/hour were observed only during the production of excess heat.

CR-39 particle detections were also performed by Swartz and his team. Those data also indicate emission of energetic quanta, that is, the occurrence of nuclear reactions. It was found that the pit counts fell off with increasing distance from the active NANOR®. Additionally, the CR-39 chip closest to the operating NANOR® essentially gave an image of the device. Given the measured low level of energy deposited of the penetrating ionizing radiations emitted by NANORs®, the radiation levels were described by Swartz as "of lower biological impact than typical background sources."

Swartz showed more than five dozen graphics during his talks at ICCF18. Over half of them were time series of power and energy into and out of his experiments. Many of them contained remarkable data on the performance of NANORs®. The information in one of them deserves special attention. The figure shows the performance of various energy systems, plus data from two new LENR sources. All the information on the plot, save for the NANOR® performance, is from a graphic based on tests of Rossi's E-CAT. It is on the web at: http://pesn.com/2013/05/20/9602320_VINDICATION--3rd-Party-E-Cat_Test-Results-show-at-least-10x-gain/. The point for the NANOR® is from Swartz's primary ICCF18 paper. The E-CAT currently puts out roughly one thousand times as much power as a NANOR®. But, that difference is not the major point. Rather, the immense increases in both power and energy densities for LENR compared to conventional and developmental energy systems is the central message.



Log-log plot of the gravimetric power and energy densities of known and expected energy sources and storage devices (in the gray region) in relation to data from recent reports on the performance of developmental LENR generators, the E-CAT and NANOR®.

Electrolytic Loading

The number of papers on loading of protons or deuterons into cathode metals was relatively small at ICCF18. Two will be reviewed in this section. Others can be found in sections below.

Arnold Isenberg (Advanced Oxide Ionics) reported on diverse electrolysis experiments using light water with nickel cathodes. His goal is to understand the dynamics of gas evolution in LENR experiments. Thin foil cathodes, some spiral and some planar, were employed. Particular attention was given to the character of the nickel surfaces, which included both shiny and matte characteristics. It was concluded that, during hydrogen gas evolution, metastable surface conditions were created, which lead to emission of surface phonons. Such phonons are central to some LENR theories. Isenberg believes that micro-mechanical effects might be responsible for triggering energetic thermal events. He called for better engineering of mechanically stable supports for thin cathode structures in LENR experiments.

William McCarthy (retired) reported on "Water-Free Replication of the Pons-Fleischmann Effect." In his approach, hydrogen was quenched into copper-based electrode alloys by use of pressure and temperature prior to assembly of the cell. Two such electrodes were put into a cell with a textile separator between them. The textile was made conducting by soaking it in oil-based liquids in which very fine particles of an electrical conductor were suspended. This approach, essentially a low Q capacitor, avoided the disruption of the electrical distribution on the cathode surface due to bubble formation. The fine conducting particles created very small current-carrying regions, which overall provided a more uniform and stable current distribution than in ordinary water-based electrolytes. Energy gains measured with a Seebeck calorimeter of about 15% were reported, which increased "disproportionally" with the increasing electrical current. The excess power appeared "almost immediately" and "more consistently" than in the usual electrochemical approaches to LENR. Total power input was typically a few hundred milliwatts, so power production was roughly on the scale of one hundred milliwatts or less.

The gas loading experiments to be discussed next fall into two categories. The first might be called "conventional" in which the protons or deuterons wind up on and in the materials. The second class is permeation experiments in which the hydrogen isotopes pass through the metal of interest. These two classes will be discussed in turn, starting with experiments of the type introduced by Celani and his colleagues.

Gas Loading ala Celani

Just as interest in the original electrochemical loading of deuterons into palladium has been decreasing over the years, the attention to gas loading of protons into nickel has been increasing over the same time period. There were five papers at ICCF18 that dealt with aspects of the gas loading experiment that Francesco Celani (Frascati National Laboratory) reported on and demonstrated at ICCF17.

The first of the papers was by Celani and a group of a dozen collaborators from four laboratories in Italy and the UK. They reported further progress and developments in experiments with surface and bulk modified wires of constantan alloys ($Cu_{0.55}Ni_{0.44}Mn_{0.01}$). Surface structures with 400 to 700 multilayers were used. The wire diameter was 200 micrometers and the length about 1 meter. Celani and his colleagues developed a way to retain H in the wires, even up to 600 C. The team observed variations of 100X in the resistive thermal coefficient. Excess powers of about 18 W were measured during ICCF17. The volume of the wire was about 3 x 10^{-3} cm^3. Hence, Celani's power density was roughly 6 kW/cm^3. This is much greater than the power density in nuclear fission reactors, which are up to about 1 kW/cm^3 of fuel rod volume.

In the second paper, Ubaldo Mastromatteo (STM Microelectronics) and Celani measured the resistive and thermal characteristics of a constantan wire, again with 200 micrometer diameter, but this time 25 centimeters long with only two nano-structured surface layers. A large change in resistance was seen, but not with an untreated wire. Less power was required to reach specific temperature with treated wires, for example, 1.2 W less at 350 C. X-ray analyses of wires that showed excess heat revealed the presence of elements unrelated to the original wire composition in areas that underwent surface morphological changes. Elements found were similar to those reported by other LENR researchers using different materials.

Mathieu Valat, Bob Greenyer and Ryan Hunt of the MFMP reported on their work to replicate Celani's results, as given during ICCF17. Their primary cell was similar to that of Celani. Some differences in cell design and protocols were explored to improve the credibility of the experimental results. An identical dummy cell was used as a baseline. The wires were characterized before and after the experiments with scanning electron micrography and energy dispersive spectrometry. The group reported that they were "confident of 6 W of excess power for 48 W input."

Another replication of the Celani experiment was performed by Cun-Kui Gong and Gui-Song Huang of Delta Energy Technologies in China. Details are unavailable.

The last of the five papers on the Celani experiment was given by Thomas Grimshaw from the University of Texas and three colleagues from National Instruments. Their main thrust was to analyze the equipment, protocols and results obtained with this type of experiment in activities in six laboratories. They asserted that the effects observed by Celani may not be as robust as initially indicated in the 2012 demonstrations. The group called for recalibration of the Celani reactor each time it is set up for a run. They are also wary of interpreting changes in resistivity of a wire as certain indications of the degree of loading, as is commonly done for the Pd-D electrolytic system. Such detailed scrutiny of the Celani-type experiments is highly desirable, given the importance of the reported results.

Gas Loading of Nano-Particles

The gas loading of nano-particles of palladium and other materials in LENR experiments has a long history. Most of such work is traceable to the double-structure cathode experiments of Arara and Zhang in the early 1990s. They used electrolysis to produce high pressures of D_2 inside of a hollow palladium cathode, which contained palladium nanoparticles. Excess heat and the production of helium isotopes was reported. The pair pioneered the use of oxide-coated nano-particles, which helps defeat particle agglomeration by sintering during experimental runs. Research using gas loading of nano-particles continues, and was reported at ICCF18 in four papers from three laboratories.

Two papers were from the collaboration between Technova Inc. and Kobe University. Their experiments are done by loading and deloading of deuterium and hydrogen into and out of nano-composite materials in separate but similar chambers, one for H and the other for D. Many nanomaterials coated with ZrO_2 have been studied. They included Ni, $Pd_{0.125}Ni_{0.875}$ and alloys of nickel with copper at various compositions. The first paper was presented by Akira Kitamura. It had five collaborators. Anomalous exo- and endo-thermic effects due to loading and unloading of nickel nano-composite materials were observed at temperatures as high as 573 K. Those results were characterized as "interesting, even astonishing." Bursts of heat were measured at a level of 600 eV per atom of H. For a material designated H-CNS/Al_2O_3, up to 24 W of excess power was measured for 124 W of input power. Integrated heat corresponding to about 1 keV per nickel atom was also seen. Abrupt desorptions with energies of 50 to 80 eV per nickel atom were observed in "pre-treatment" runs at 573 K. Three experimental improvements are being emplaced to continue the work: a chamber with a sample that is ten times larger, a Quadrapole Mass Spectrometer for analysis of the residual gas in the 1-6 Dalton range, and a flow calorimeter with oil having a boiling point of 390 C. Schematics and calibration data for the oil-flow calorimeter were presented.

The second Technova-Kobe paper was by Akito Takahashi and nine other researchers. They performed a re-analysis of the time-dependent data obtained by the collaboration. That work resulted in the energy per atom values reported in the paper given by Kitamura. The authors considered the possibility of displacements of multiple nickel atoms during desorption, which might account for about 40 eV per atom of heat absorption during the hot pre-treatment runs. They speculated that the defects formed by such processes could harbor clusters of H or D atoms. Their presence in the post-treatment runs might result in production of anomalous heat of nuclear origin. Post-treatment runs were made in the 373 to 573 K range without observation of further abrupt heat sink desorption events. During those runs excess power was observed, which had a "rather monotonous" history. No increase in neutron counts and only a "very slight" increase in gamma ray counts were observed.

Tadahiko Mizuno is now affiliated with the Hydrogen Energy Engineering Applications and Development Company. He has long contributed to the science of LENR, but was unable to attend this conference. His paper reported on a method for controlling chemically-induced nuclear reactions in metal nano-particles. He used gas loading, and then irradiated the nano-materials with electrons from a glow discharge plasma to produce LENR. Emissions of neutrons and gamma rays were observed, as well as the production of products evidencing transmutations. Mizuno believes that the combination of H or D loaded nano-particles, and the incident electron flux, will result in the control needed for a practical energy generator. That is, turning off the plasma will stop the production of energy. Mizuno observed near breakeven or excess heat in 25 out of 50 runs, sometimes over 50 kJ. Details of all the 25 runs are in Mizuno's paper. A preprint is on the web at lenr-canr.org under NEWS.

The final paper on gas loading was from the group at the University of Illinois headed by George Miley. The lead author was Tapan Patel and there were seven co-authors. The group has been pressurizing 2 gram samples of nano-particles containing various unspecified compositions of nickel, palladium and zirconium with hydrogen and deuterium from room temperature up to 300 C. They report maximum observed excess power density as follows:

Composition	Gas	Max Power W/gm
Pd-Zr	Deuterium	15
Pd-Zr-Ni (High Ni and Pd)	Hydrogen	21
Pd-Zr-Ni (High Ni and Low Pd)	Hydrogen	7.8

Two runs were made for each of five temperatures. It was found that the peak output correlated approximately linearly with the starting temperature. The group presented another paper on their materials, which is discussed in the section below on Materials Preparation and Characterization.

Gas Permeation

Interest in experiments, with D_2 gas permeation of thin foils composed mainly of palladium, took off after the transmutation reports in 2002 in ICCF9 by Yasuhiro Iwamura and his colleagues from Mitsubishi Heavy Industries (MHI). There were two papers on permeation experiments at ICCF18.

Iwamura, Tsuruga and Ito, all from MHI, reported on recent progress in their permeation transmutation experiments. They summarized both their earlier results on transmutations of Cs into Pr, Ba into Sm and W into Pt, among other LENR products. Their paper referenced experiments that reportedly reproduced some of their observations. In particular, they view the work done at the Toyota R&D Center as "almost complete replication experiments on transmutation of Cs into Pr." In the past few years, the MHI group has been seeking to improve transmutation rates by increasing the surface deuterium density and by changing the surface electronic structure. The first of these is done by using an electrochemical (liquid) means, rather than a gaseous atmosphere to provide deuterons to the input surface of their complex Pd foil. The observed concentration of the transmutation product Pr increased from around 1 nanogram/cm^2 to 1 microgram/cm^2 in some runs.

At ICCF18, the MHI group exhibited numerous high-resolution gamma ray spectra from two experiments, which ran about one week each. During the run E16, they measured sharp peaks at 609.5 and 511.5 keV. The latter is the positron annihilation peak. It was observed during the second and third periods of the run at high currents, but not during the initial low-current period of the experiment. In the E28 run, they measured six gamma ray peaks in the 507.4 to 1445 keV range. These did not match known gamma ray energies. The gamma ray work will continue.

The group at Tsinghua University in Beijing led by Xing Zhong Li has been performing permeation experiments for 15 years. At ICCF18, they described the evolution of their program regarding the calorimeter used, the triggering mechanism, and the geometry and composition of the material being used. Zhan Dong and his four colleagues reported the results of permeation of D_2 through long, thin-walled tubes of a quaternary alloy containing Pd, Ag, Au and Ni. That flux resulted in anomalous heat, which lasted several hours. About one hour into a run at 150 C, the temperature began to oscillate with a period of 1.6 minutes and exponentially increasing amplitude that reached +/- 1.4 C at the two hour mark. The authors state that the system would have become unstable were it not for the proportional-integral-derivative controller. The Ni-Cr heaters inside the alloy tube (the pumped volume) developed a negative temperature coefficient of resistance in the 150 C run. The temperature oscillations were attributed to that condition.

Plasma Experiments

Gas and plasma loading are related because the constituent ions of a plasma generally begin an experiment as a gas. The use of plasmas to supply protons or deuterons to materials in LENR experiments has advantages and disadvantages. On the plus side, the high temperatures in a plasma will break H_2 and D_2 molecules into atoms. And, once the power is cut-off, plasmas cool rapidly, so the power that excites and maintains a plasma in an LENR experiment provides a mechanism for the control of the reaction rate and power output. However, production of plasmas is more energy consumptive than merely supplying a gas to a material surface. And, plasmas tend to be dirty because they can erode chamber walls and become contaminated. Different types of plasmas have been used in LENR experiments, especially glow discharges and arcs. The interest in using plasmas for such experiments has increased substantially in recent years. That was reflected by having four papers in this arena at ICCF18.

Jean-Paul Biberian presented a paper with four colleagues on plasma electrolysis experiments. Higher temperatures and pressures are part of such experiments. Reactivity increases with temperature and pressure. Electrical energy put into the cell was measured with a 70 kHz wattmeter, and the output thermal energy was computed from the measured weight of water that was lost as dry steam during the run. The chamber was capable of holding 10 bar at temperatures up to 177 C. The central cathode was a rod of tungsten with 2% thorium, which was 2 mm in diameter. In a run of almost an hour with 404 W input, 21 W of excess power was measured.

R.C. Gupta presented a related paper on arc plasmas in electrolytes. His earlier work had indicated about 50% excess heat. In more recent experiments, an energy gain of 7 was obtained. The ICCF18 paper contains a good list of relevant references, including some reports of producing iron by transmutations in arc experiments.

Yuri Bazhutov and seven colleagues submitted a paper on calorimetric and nuclear analyses of anode plasma electrolysis. Unfortunately, Bazhutov was unable to obtain a visa to attend ICCF18. The abstract of their paper states that the experiments were driven by 200 to 600 V and 1 to 10 A. A nickel foil served as the cathode and 6 mm tungsten or niobium rods were the anodes. Diagnostics included thermometry, tritium detection by scintillation counting, gamma ray scintillation detectors, He-3 neutron counters, photographic emulsions and solid-state track detectors. Results of the experiments are not available to this reviewer.

Roger Stringham reported on recent progress in his two-decade long study of cavitation loading driven by ultrasound. The deuterons that wind up in a target foil begin as heavy water and pass through gas and plasma phases prior to implantation. Hydrodynamic collapse of cavitation bubbles during the plasma phase leads to deuterium loading of the foil. Stringham's early work used 5 kg resonators operating at kHz frequencies. He now employs resonators running at MHz frequencies, which weigh only 20 gms. A flow calorimeter using D_2O showed that 43 W of excess power was produced for a 15 W acoustic input. Stringham projects a scaling to 400 W excess power by use of a resonator that weighs 50 grams. His experiments are conducted within a black box, which permits the use of the sonoluminescence as a diagnostic of the experiment. He obtained a linear relationship between the excess power and light emission. That is, the calibrated sonoluminescence intensity gives a measure of excess power. Stringham also provided computed data on the dynamics of the energy production. He calculated that individual "events" produce 3.8×10^{-12} J each at a rate of about 10^{13} events per second. This corresponds to 38 W. Cavitation LENR experiments deserve more attention than they are receiving. They are relatively compact and produce excess power with high reproducibility.

Particles and X-Rays

Both particles and X-rays play two roles in research on LENR. In the first, they are incident on samples in experiments to probe conditions or cause effects. In the second, they are emitted from the active materials in the experiments. At ICCF18, there were two papers on incident ion beams, four reports on the emission of particles from diverse LENR experiments and three papers on emissions from experiments that do not certainly involve LENR. Of these, the measurements of emissions from LENR experiments are most germane to understanding the mechanisms active to produce nuclear reactions at low temperatures.

John Gahl and Peter Norgard are part of the SKINR. They are using 8.4 MeV beams from the cyclotron at the University of Missouri to measure the cross sections for (d,p) reactions on three isotopes, Pd-108, -109 and -110 and (d,n) reactions on Pd-110. Cross sections have been measured below the Coulomb barrier and compared with computed values. The measurements exceed the expected values.

There have been many reports of enhanced D-D fusion cross sections at low incident ion energies, down to around 1 keV, which is far below the energy at the maximum (about 40 keV) for such reactions. These higher-than-expected cross sections indicate screening energies as large as 600 eV in some cases. As had been the case at several ICCFs, Jiro Kasagi (Tohoku University) reported the results of incident ion experiments at multi-keV energies. He and Y. Honda bombarded D_3^+ ions onto solid and liquid indium targets. They found dramatically different curves for d(d,p)t reaction spectra for the two states of the target. For a beam energy of 15 keV, the solid gave a symmetric peak centered about 2900 keV. In contrast, the spectra from the liquid target was much wider (about 2700 to beyond 3100 keV) and very asymmetric (peaking at around 3050 keV). The authors hypothesized a cooperative colliding process. During that process, one of the Ds in the incident ion first collides with an In atom, and is scattered so it could fuse with another D from the same projectile. They computed the spectrum that would result from this mechanism. It was found to be in good agreement with the measured spectrum. While such results are interesting physics, their relevance to understanding LENR is still unclear. This is due to the large energy gap between room temperature (about 0.025 eV) and beam energies near 1000 eV and higher.

In 1991, Mark Prelas conducted a LENR experiment at the University of Missouri in which 42 grams of titanium sponge were thermally shocked. One of the four runs produced as many as 2.25 million neutron counts per second during 5 minutes. Those results were first reported last year at ICCF17. At the current conference, Charles Weaver and five colleagues, including Prelas, reported on similar recent experiments. This time, three forms of titanium were employed—sponge, granules and dehydrided powder. As before, liquid nitrogen (LN) was used to produce the thermal shocks. Loading of the titanium was accomplished using pressurized deuterium gas. Five types of radiation detectors were used, including He-3 and BF3 neutron counters, a NaI detector, CR-39 chips and a thermoluminescent dosimeter. For one run, a neutron burst was observed during the loading phase at LN temperature. In a 10 minute run, 1.5 million counts (uncorrected for the detector efficiency and geometry) were recorded. The dehydrided titanium proved to be the best host material for neutron production. The authors surmise the release of deuterium during the phase change within a lattice might produce high densities in defects, causing nuclear reactions.

Dazhuang Zhou and three colleagues from the National Space Science Center of the Chinese Academy of Science, plus a colleague from Tsinghua University, another from a company and two more from the former LENR group at the U.S. Navy Laboratory in San Diego, studied energetic particle emissions from LENR co-deposition experiments. CR-39 track detectors were used in the work at the Navy Laboratory and Tsinghua University. Such detectors are useful for high Linear Energy Transfer (LET) particles, either incident charged particles, or charged particles released by neutron bombardment. LET values above 5 keV per micron (water) are registered in CR-39. Ordinarily, the number of tracks per unit area, and often, their size, are the primary results from using track detectors. Earlier, the Space Science Center group developed a LET Spectrum Method for quantifying results from individual tracks. They conclude that the LET spectra obtained from CR-39 detectors near co-deposition experiments, and the particle energy distributions, provide strong evidence for the generation of energetic particles by LENR.

Alberto Carpinteri and three colleagues from the Politecnico di Torini in Italy studied hydrogen embrittlement as a root cause of LENR. They provide a mechanical explanation for evidence of nuclear reactions, namely piezonuclear fissions. They reported the measurements of neutrons and alpha particles during electrolysis experiments in light water with Ni-Fe and Co-Cr electrodes.

There were two papers on radiation emission, which did not evidently involve LENR. In the first, Yuri Bazhutov and five colleagues from three institutes in the Moscow Region shined light on solutions of LiOH, NaOH and Na_2CO_3. The sources were a laser (5 mW) and Light Emitting Diodes (0.6 to 10 W). Emission of up to 100 neutrons in millisecond bursts was detected with He-3 counters in a paraphine moderator. Tritium was measured with "water solution" probes. Neither X-rays nor gamma rays were detected.

Vladimir Vysotskii and Anna Kornilova had earlier reported the emission of soft X-rays outside (from the surface) of a chamber carrying high-speed jets of oil or water in which cavitation occurred. Their paper at ICCF18 reported the registration of 1-5 keV X-rays, where the energy was dependent on the chamber material. They attribute the production of such radiation to a two-step process: (a) the shock waves in the cavitating liquid induce shock waves in the chamber walls and (b) those secondary shock waves produce X-rays when they interact with atoms on the exterior surface of the walls. Quantitative estimates of the effectiveness of such a mechanism are needed.

Keith Fredericks of Restframe Labs presented a paper that was not clearly related to LENR, but contained some unusual images of tracks in Kodak emulsions. He attributes them to motions, sometimes regular and sometimes erratic, of tachyon magnetic monopoles. The case for that attribution was not made. Fredericks listed seven other laboratories which reported odd tracks in various media. Another is known, namely Nanospire Inc. These phenomena deserve further study. But, they may or may not turn out to be related to LENR.

Data Analysis and Mining

It is common in science and engineering to subject data from experiments and tests to further analysis in order to wring additional information out of it. This has not been done as commonly as is desirable with data from LENR experiments. Similarly, results from diverse LENR experiments usually have not been mined and compared to extract trends or other information. Two papers at ICCF18 dealt with data analysis and mining.

Felix Scholkmann and David Nagel had done a statistical analysis of three transmutation data sets, which appeared to be alike. At ICCF17, they reported that the data on LENR rates as a function of atomic number were indeed statistically similar. For ICCF18, the same authors compared transmutation data with the distribution of elements in the earth's crust. The study was motivated by a concern that the transmutation data sets reflected dirt from the environment rather than actual LENR products. It was found that the reported transmutation rate data did not correlate with the abundance of elements in nature. However, that does not rule out two possibilities: (a) the contaminants in the laboratories were different than outdoors and (b) that the source of the measured elemental distributions after LENR electrolysis experiments was in the electrolyte, and not due to transmutations.

The rates at which reactions occur are critical to their applications. This is the case for chemical reactions, such as those occurring in oil refineries and drug manufacturing plants. It is no less true for nuclear reactions that occur, for example, in fission reactors. There had been no compilation of the rates that were scattered through the experimental and theoretical literature on LENR. The relevant literature was mined by Nagel, with results reported at ICCF18. He presented a compilation of five experimental and two theoretical rates, which were obtained under particular and very different circumstances. They ranged widely from 10^6 to 2 x 10^{11} Hz. There is clearly a need for more work to narrow this distribution, or to show the reasons for such a wide variation in the rates at which LENR occur. Maximum attainable and sustainable rates are of great practical importance for power generation. The larger rates in the compilation were used to estimate the amounts of valuable elements, such as Pt, which could be produced in reasonable times in order to profit from LENR products. Similarly, those rates were employed to compute the amounts of radioactive waste from fission reactors, which could be rendered benign by involving them in LENR. Neither the production nor destruction of elements of interest appears to be commercially viable or affordable in the foreseeable future.

Materials Preparation and Characterization

There are two large topics that are at the core of experimentally controlling and exploiting LENR and, distinctly, understanding it. They are materials and theory. This section addresses papers on materials given at ICCF18. Theoretical papers are reviewed in the following section. There were ten papers specifically on materials, although several others also had a strong materials component to them. For example, Mizuno's paper contained important information on preparation of nano-materials for LENR experiments. It was already reviewed above in the section on Gas Loading of Nano-Particles. Four of the ten papers discussed in the following paragraphs dealt with nano-materials, two of those about nano-porous and nano-particle materials, and two on the use of carbon nano-tubes (CNT) for LENR experiments. Surfaces of foils and other materials in such experiments are very important, so there were five papers on the preparation or modification of materials surfaces. Finally, one paper on the phase diagram of the Pd-D system was given at ICCF18.

Porous and Particulate Nano-Materials

Tatsumi Hioki and six collaborators from the Toyota Central Research and Development Laboratory addressed hydrogen absorption properties of Pd-doped porous nano-materials. Their interest in such materials sprung from electrochemical and gas loading work done elsewhere, which showed (a) high D/Pd ratios favor heat production, (b) nano-scale Pd particles absorb more H than bulk Pd and (c) there is an isotope effect for heat generation in Pd-doped porous materials. Last year, the group reported on reproducible isotope effects during hydrogen pressurization of two types of nano-materials. They were Pd-doped zeolites with pore sizes of about 1.1 nanometers and Folded Sheet Mesoporous (FSM) Silica with pore sizes in the range of 1.5 to about 2 nanometers. Their paper at ICCF18 gave results on measurements of the hydrogen absorption capacity of such materials, as determined by a volumetric method. Non-doped materials served as references for the work. Measurements were done with a thorough cyclic procedure, so as to permit separation of the absorption capacity of the Pd from that of the matrices. The H/Pd ratios obtained are as follows: bulk Pd (~0.65), Pd-doped FSM (~0.80) and Pd-doped Zeolite (~1.0). Next, the team will tackle the origin of the reported isotope effect in absorption and desorption energies of H and D in Pd-doped nano-porous materials.

Anais Osouf and seven colleagues from George Miley's group at the University of Illinois reported on composition measurements and imagery of nano-particles used in their gas loading experiments. They pressurize nano-materials consisting of alloys containing nickel, palladium and zirconium with hydrogen or deuterium. The compositions and excess heat results were summarized above in the section on Gas Loading of Nano-Particles. In their materials paper, the group was concerned about changes in nano-materials during LENR runs. Such changes could be a show-stopper for practical commercial heat production by LENR. If nano-materials are needed for LENR to occur, and high temperatures favor high power production, it will be difficult to maintain the proper materials conditions due to diffusion and sintering. The Illinois group used Secondary Ion Mass Spectroscopy (SIMS) to determine compositions and Scanning Electron Microscopy (SEM) to obtain images of their materials before and after runs, one of 40 hours. The SIMS data indicated the presence of elements after runs, which were not seen in the starting materials. Care was taken to determine the influences of contamination from the pressurization system during high temperature operations. The SEM images did show evidence of coagulation during the runs.

Carbon Nano-Tubes

These are arguably the most studied and best known nanomaterials. Because of their open structures, they have long been studied as hydrogen storage materials. A large group centered at the University of Missouri and led by Peter Pfeiffer has been working on that topic, independent of LENR. It now collaborates with scientists in the SKINR. The group includes 26 researchers in six organizations within the University, two U.S. industrial laboratories and two universities in France. The program seeks to develop materials with high surface areas, high storage densities and high binding energies, properties that overlap what is desirable for LENR.

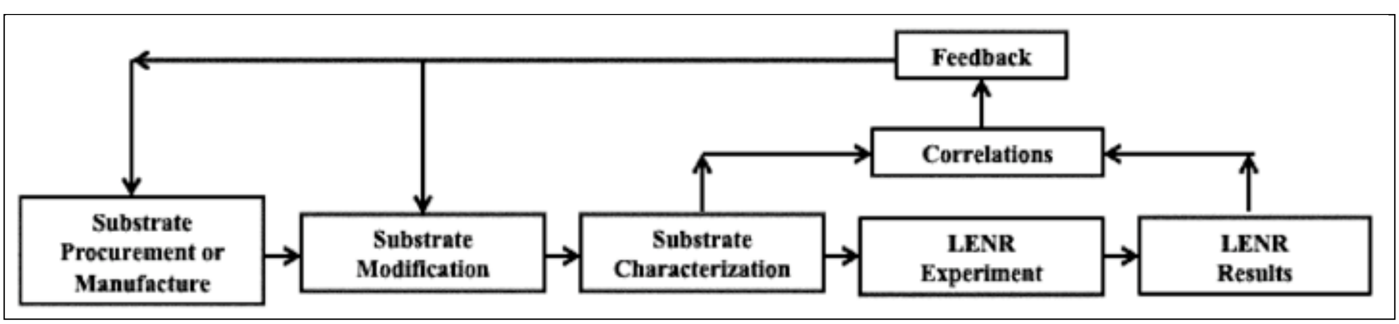
Pfeiffer gave an overview of their activities and results at ICCF18. He began with an outline of the various ways to store hydrogen, including three materials-based approaches. They are complex hydrides, chemical hydrides and adsorbents. Pfeiffer then showed a graphical summary of the volumetric and gravimetric hydrogen storage performance of diverse materials. The rest of the talk reviewed a remarkable variety of experimental and computational approaches to hydrogen storage, and what was found by their use. It ended with LENR-specific work on loading of hydrogen into palladium foils at pressures to 200 bars and into sandwiches of palladium with single-wall CNT at pressures to 100 bars. Temperatures in the range from 77 to 750 K are accessible in the equipment at the University of Missouri. Sample sizes fall in the range of 100-200 mg. Excess heat releases as small as 5 J should be observable. Recent work showed that boron doping raised the H_2 binding energy from 5 kJ/mole on undoped carbon to 10^{-14} kJ/mole on doped surfaces.

The second talk on the use of CNT was also from the University of Missouri (SKINR and the Department of Electrical and Computer Engineering). Shahab Shervin and six colleagues are developing Pd cathode materials with embedded single-wall CNT for enhanced hydrogen loading. They are hoping to achieve high loading levels while avoiding Pd embrittlement and thin film delamination. They start with a Pd substrate and overlay a thin film of CNT on it by either of two methods, electrophoretic deposition or drop casting. Next, electrodeposition of Pd covers the CNT matrix. The resulting structure has good adhesion. The new layered materials are being used for both electrochemical and gas loading LENR experiments.

Surface Preparation and Modification

The five papers on tailoring of surfaces to enhance excess heat production all had the same overall goal. The figure shows the sequence of steps for the work. Some means was used to affect the type and scale of features of the structures on surfaces. These were characterized prior to LENR experiments. The results of the experiments were correlated with the surface characteristics. Then, feedback into the materials production sequence could be affected. In the first paper, palladium nano-structures were produced on other materials. The other four papers described means to produce and modify foil surfaces, some of which were alloys, but mostly relatively pure palladium. The motivation behind all of this work is the knowledge that surface characteristics influence loading and production of excess thermal energy. Higher surface areas, due to fine-scale surface structures, are expected to be beneficial.

Two papers on the preparation and modification of the



Flow diagram for preparation of material surfaces for LENR experiments.

surfaces of materials for LENR came from the ENEA group led by Vittorio Violante. In the first, Emanuele Castagna and five collaborators reported on a study of the electro-catalytic properties of Pd-based nano-structured materials. That work was aimed at fuel cell applications, specifically the replacement of platinum catalysts now in use with cheaper palladium materials. However, the methods and materials should be directly relevant to LENR. The research seeks to control the structure and distribution of Pd nano-particles. Electrodeposition and sputtering were the two main processes for production of the materials. Several techniques were used for characterization of the resultant films, including SEM, Energy Dispersive X-ray Analysis (EDXA), testing for stability in acidic solutions, and cyclic voltammetry in both acid and alkaline solutions. It was found that the electrochemical "real surface areas" for Pd can be within a factor of 2 of those for Pt, and that oxidation effectiveness of the new Pd materials are competitive with values for Pd catalysts produced by other means.

Stefano Lecci and four collaborators from ENEA offered the second paper on materials. It was on preparation and analyses of cathodes for electrochemical LENR experiments. The research continued the pioneering work at ENEA, reported at a recent ICCF, which related the structure of cathode surfaces to their ability to produce excess heat. In the current paper, the iterative measurement of surface morphologies and excess heat continued. New alloys were examined for their efficacy in energy production. They included Pd materials that contained Rh (13%), Copper (5%) and Fe (4%). SEM gave surface images, EDXA produced the chemical analyses and Electron Back Scatter Diffraction was used to learn crystal orientations. Rolling, followed by annealing, produced foils 50 micrometers thick. Many results from the characterization techniques were presented. Data on heat production using these materials was not part of this paper. More information on ENEA can be found in the section below on the panel devoted to ENEA.

John Dash and two colleagues from Portland State University described the preparation and measurement of surfaces for electrochemical loading using a thermal means to structure them. Their idea was that increasing the areas of Pd surfaces would produce an increase in the surface loading capacity. They worked with Pd foils that had been cold rolled to 250 µm thickness. Two foil strips 1 x 4 cm were produced. One of them was subjected to a Bunsen burner flame with temperatures up to 1000 C. It was seen that, for the temperature range above 700 C, dense micron-scale structures developed. Those structures varied depending on the temperature. They were attributed to spinodal decomposition of oxide phases that grew on the foil surfaces. The samples were subjected to SEM and EDXA analyses. Each pair of foils was then made the cathode in identical electrochemical cells. Early measurements indicated that the cell with the enhanced-area foil produced 300 mW of excess heat. This paper won the Best Poster Award.

Joseph Mathai and seven colleagues from the SKINR took another approach to the same goal of increasing the porosity of palladium films. They co-sputtered nickel and palladium onto palladium foils. Then, ferric chloride was used to dissolve the nickel from the alloy thin films. EDXA confirmed that the nickel was completely removed by that process. SEM images revealed the existence of a micro- and nano-porous surface structure. Cyclic voltammetry showed that the surfaces were highly active electrochemically. Foils prepared by this new method will be used in electrochemical LENR experiments. They may also be effective in gas loading conditions.

Scott Mathews of the Catholic University of America and three collaborators took yet another new approach to production of palladium surfaces with fine structures and high surface areas. They focused a laser with pulse lengths of 90-200 femtoseconds, and up to 30 µJ per pulse, at rates of 200 kHz onto foil surfaces. The structures that resulted depended on the energy per pulse and the number of pulses placed on a given spot. They ranged from structures with some roughly straight and parallel regions, plus some disordered character, to topographies that were very random and appeared sponge-like. Fourier analysis of SEM images of the microstructures showed that the separation of the almost parallel lines was about 400 nanometers. Spacings of features in the sponge-like areas varied from about 200 to 500 nanometers. The SEM images showed features as fine as 20 nanometers on the foil surfaces. A Seebeck calorimeter has been built and calibrated to test the ability of the laser-processed foils to produce excess heat.

The last paper specifically on materials was by Peter Hagelstein and P. Orondo, both at MIT. While the overall phase diagram of Pd and D is well known, the stability of the lattices in the two phases (Pd and Pd-D) is not thoroughly understood. At issue is the relaxation time of the lattices of the two phases, which is paced by diffusion of vacancies. Addition of D to Pd stabilizes the vacancies. At high loading, thermodynamic equilibrium favors the vacancy phase. At low or intermediate temperatures, this has little effect, since it is hard for the vacancy phase to form. However, at high temperatures for loading of solid Pd materials, or even at low temperatures for co-deposition with high loading, the vacancy phase can form. It is then necessary to include that phase in the Pd-D diagram. Put simply, the normal two-element equilibrium phase diagram is not entirely adequate. There is a third component, namely vacancies, so a ternary phase diagram is most appropriate. And, achievement of equilibrium during dynamic LENR experiments is not always possible. Hagelstein and Orondo are seeking to understand the influence of the more complex diagram on the production of high loading and LENR.

Theory

As with recent conferences in this series, theoretical papers were the largest single category of works. This time, 28 out of 125 presentations and posters were on concepts for LENR and their elaboration. Once again, it was challenging to sort these contributions into sensible groupings. The first set of papers below was by leading theorists in the field, who elaborated on ideas and results they had presented at earlier conferences. These are followed by six papers based on theories involving coherent effects. Then, a new line of work on linear distributions of hydrogen isotopes is reviewed. The next grouping deals with so-called compact objects and their potential implications. Then, papers exclusively on the nuclear level, which are based on the lattice model, are examined. The final grouping includes seven papers that do not fit nicely into the earlier categories.

Yeong E. Kim of Purdue University has long been developing the idea of a Bose-Einstein Condensate (BEC) of H or D nuclei. His paper at ICCF18 dealt with theoretical analysis and reaction mechanisms for experimental results from nickel-hydrogen systems. It included substantial measured results from experiments by Defkalion Green Technologies, so the CTO of that company, John Hadjichristos, was co-author.

Fabrication of the fuels used in the DGT R5 reactor was discussed. First, a proprietary method is used to restructure the nickel lattice from the usual FCC form to a C4 (Rutile) structure. Then, the resulting powders, which are about 5 micrometers in size, are distributed into a porous material to protect them from the high temperatures of the glow discharge plasma. The supporting material is a nickel foam with openings about 200 micrometers in size. The plasma disassociates H_2 molecules and is also a control mechanism. The temperature in the reactor increased from about 180 C to about 850 C during a triggering sequence. One of the more remarkable reported results is the increase in magnetic fields 20 cm from the reactor from 0.6 to 1.6 Tesla after each of the triggering cycles. Another is the statement that excess heat was obtained only with even-numbered isotopes of nickel, but not with ^{61}Ni. Gamma ray spectral measurements showed nothing outside of the 50-300 keV range. The intensities of emission within that range were not stated. Time histories of two experimental runs were presented, one with an energy gain of 1.5 and the other with a gain of 4.1. DGT asserted that the R5 reactor has reliable controls and high reproducibility, and can be called a "breakthrough."

Kim then went on to expand his BEC concept to the idea of a Boson Cluster State (BCS) in which nuclear fusion occurs. He provided an equation for the rate of reactions in a BCS. Then, he hypothesized that the magnetic fields due to triggering produce magnetic alignments of atoms in regions on the surfaces of the nickel powders. The result is the brief development of Localized Magnetic Traps (LMT) for Boson Clusters, where the nuclear reactions occur. This sequence was used to explain the production of energy, the absence of hard gamma rays, and the effectiveness of only even numbered isotopes of nickel, which are bosons. A new on-line real-time mass spectrometer, which will be employed by DGT in their laboratories in Vancouver and Athens, was described. This paper ended with an extensive outline of plans for future research by DGT. They included cooperation with the scientific community. The DGT-Kim collaboration is a good example of such cooperation. It is a fairly rare and most welcome activity in research on LENR.

Akito Takahashi from Technova Inc. and Osaka University has also made many contributions to the field. At ICCF18, he spoke on the nuclear products of cold fusion as explained by his Tetrahedral Symmetric Condensate (TSC) theory. That theory is based on the idea of four deuterons simultaneously occupying a single femtometer-scale region within highly-loaded metals. The talk began with a comparison of measured radiation emissions and his predictions for both Metal Deuterium Energy (MDE) and Metal Hydrogen Energy (MHE). Agreement is very good. Next, Takahashi showed the three steps in LENR that have to be quantitatively understood: the initial state interactions, the excited nucleus and final state interactions. The bulk of his paper was on application of the TSC to the MDE case. It included some of the most detailed considerations of mechanisms, energetics and rates available in LENR theoretical literature. In particular, he dealt with complex nuclear vibration modes having as many as about 15,000 independent waves. Their energy could lead to 24 MeV being parsed into 1.5 keV packets and bursts of low energy photons (called BOLEP). Such a scenario might explain the few microsecond pulses of soft X-rays measured by Karabut in glow discharge experiments. Takahashi ended by applying his ideas to the MHE case. For that, he provided predictions of the emission rates of neutrons, 8 keV X-rays and also gamma rays relative to the amount of heat released.

Xing Zhong Li from Tsinghua University presented a summary of some of his theoretical work. His title "Applying the Scientific Method to Understand Anomalous Heat Effect" echoed the theme of the conference. Li discussed six important aspects of and related to LENR. They are (a) neutrino detections, (2) internal conversion electrons, (3) radio-frequency emission and magnetic field fluctuations, (4) three deuteron reactions, (5) results from solid-state track detectors and (6) the ^{6}Li + P resonance. Li envisions overcoming the Coulomb barrier by resonance effects involving the weak interaction. He notes that neutrino detection would be a way to verify such action. So, he reviewed recent progress in neutrino detection and gave the requirements for a preliminary experiment.

***Coherent Mechanism*s**

The idea that cooperative effects are fundamental to LENR dates from the earliest days of the field. A wide variety of such effects involving coherent motions of electrons and, especially, ions has been advanced over the years. Many of them focus on phonons, due largely to the work of Peter Hagelstein. He and Irfan Chaudhary had four papers in this arena, and Hagelstein alone authored another. These are described in the following paragraphs. Then, a paper on coherent correlated states by Vysotskii and Vysotskyy is summarized.

The first Hagelstein-Chaudhary paper is a useful overview of more than a decade of theoretical research on LENR. The core vision is the coherent dynamics in nuclear states for which it is possible to coherently exchange energy with highly-excited phonon modes in a lattice. That is, the nuclear (MeV) and lattice (meV) levels of a lattice can be coupled. Either the nuclear quanta would be fractionated into those of the lattice, or the lattice phonon quanta would be up-converted to the level of nuclear energies. Early in the program, the focus was on a "toy" lossy spin-boson model. It enabled demonstration that a large quantum from a two-level system (such as a nucleus) could be fractionated into a very large number of small oscillator quanta (phonon surrogates). The next phase of the work was a generalization of that model, called the donor and receiver model. It was sufficiently sophisticated to account for excess heat in LENR experiments. Hagelstein and Chaudhary believe that a single mechanism is behind all the diverse observations in LENR experiments. It expresses itself differently under varying conditions. A main thrust of this paper is to examine which of the observations might be explained by the current model. The authors go through many LENR effects in relation to their ideas, ranging from heat production to transmutations and the emission of X-rays and gamma rays. They state that it might be possible to produce energy without hydrogen or deuterium being present. Their model suggests

^3He production in Ni-H experiments, which is testable.

There are several important issues that attend elaboration and exploitation of the model just described. One is the central problem of coupling between excitations at the nuclear and lattice levels. Hagelstein and Chaudhary had studied such coupling many times. But, they found that it was absent in the non-relativistic case. In one of their ICCF18 papers, they focused on such coupling with relativistic dynamics. It was found that strong coupling can, indeed, link nuclear and lattice states, and explain coherent dynamical processes at the basis of LENR. However, it is not the entire story. That is, it is unable to allow as much up-conversion from lattice energies as is needed to explain data from a particular experiment described in the next paragraph. Another issue has to do with the phonon side of the model. This forced attention to phonon exchange models in two pictures, those of Born-Oppenheimer and Bloch. A new model was developed in which the ability to fractionate large quanta is determined by the level of phonon fluctuations from interactions with the electronic degrees of freedom. It permits distinguishing contributions due to screening and those from phonon exchange. Matrix elements associated with off-diagonal sector Hamiltonians due to phonon fluctuations are obtained. They are used to evaluate coherent energy exchanges for fractionation of large energy quanta.

The theoretical work of Hagelstein and Chaudhary is fundamentally aimed at understanding the causes and products of LENR. However, they have identified a way to test the core requirements of their model by using observations from a high-current glow discharge experiment performed by Alexander Karabut. That experiment was actually motivated by interest in LENR, but it resulted in measurement of 1.5 keV collimated X-rays, a surprising effect compared to excess heat, transmutation products or energetic particles. Hagelstein calls this experiment "one of the most important in the field of condensed matter nuclear science." The results are thought to demonstrate coherent energy transfer between highly-excited vibrational modes near 50 MHz and the 1575 eV nuclear transition in ^{201}Hg. That is the smallest energy transition from the ground state to another level of any stable nucleus. Mercury might have been present in Karabut's apparatus due to its use in diffusion vacuum pumps. Hagelstein and Chaudhary have used the theoretical concepts and results described above to compute probabilities for up-conversion from lattice energies to the nuclear level and subsequent emission of X-rays. The nuclear energy level determines the X-ray energy. The observed collimation might be due to near-simultaneous X-ray emission as in a phased-array antenna. A more controlled version of the Karabut experiment is planned.

The last paper at ICCF18 on coherence as the basis for LENR was given by Vladimir Vysotskii and Mykhail Vysotskyy, both at Kiev National Shevchenko University. It considered the creation and effects of Coherent Correlated States (CCS) including damping and fluctuation mechanisms. The goal of the work is to understand the possibility of dramatically increased tunneling probabilities through the Coulomb barrier, which would lead to greatly increased nuclear reaction rates. The central idea is the possibility that the momentum fluctuations of a nucleus at various levels in a potential well might be correlated, that is, synchronized with periodic phasing of fluctuations to form CCS. If that condition could be achieved, the authors compute that nuclear reaction rates could be increased over the normal tunneling levels by values exceeding 10^{200}! Dephasing of the required fluctuations would lead to large decreases in such extreme values. Nevertheless, the authors think that this mechanism might explain the large nuclear reaction rates at ordinary temperatures, which are far beyond what conventional cross sections permit.

The Vysotskii-Vysotskyy paper includes the application of the basic ideas to understand the increase in LENR rates observed by Letts, Cravens and Hagelstein (*Condensed Matter Nuclear Science*, Vol. 3, pp. 59-76, 2010). In that experiment, THz radiation at specific frequencies produced large increases in production of excess heat. Two of the measured peaks aligned with optical phonon energies in palladium. The experimenters thought that this was evidence for the role of phonons in causing LENR, as discussed above. Vysotskii and Vysotskyy compared the measured results with calculations based on CCS. Their calculations produced two pairs of peaks, which were quite well fit to the LENR data. So, the authors reinterpret the measured data as evidence for CCS rather than for phonon involvement.

Linear Arrays of Atoms

Many types of locations and arrangements of protons or deuterons on and in materials have gotten attention over the years. Linear arrangements of hydrogen atoms in crevices, voids and empty linear channels within solids were considered in 1999 by K.P. Sinha of the Indian Institute of Science. In the recent past, there has been a burst of interest in linear sequences of H or D nuclei as the geometry necessary for inducing LENR. There were three papers at ICCF18 which dealt with this arrangement.

Edmund Storms (Kiva Labs) recently developed a concept for LENR based on linear arrays of H or D. Storms stated that they have the following characteristics: (a) gaps in lattices with critically small dimensions are created by stress relief, (b) H or D nuclei assemble in the gaps to form a covalently bonded chain (called by Storms a Hydrotron), (c) the lines of atoms resonate with emission of many weak coherent photons from each nucleus, and (d) the electron that "reduces the Coulomb barrier is sucked into the final product nucleus after most of the energy is lost" (and a low energy neutrino is emitted). There are several aspects of this model that require calculations and comparison with results of various types of experiments. The third and fourth steps, in particular, call for realistic simulations using molecular dynamics codes.

Andrew Meulenberg, of the Science for Humanity Trust, and Sinha presented an ICCF18 paper on a composite model for LENR in linear defects of a lattice. It brought together two concepts. The first was the 1990 idea of Schwinger that cold fusion requires a formulation that includes electric and nuclear forces in a single wave function, all parts of which are coherent. That is, the normal Born-Oppenheimer separation of atomic and nuclear forces has to be abandoned. The second idea was from the 1999 Sinha paper. It contemplated paired electrons such that D+ and D- attract each other within a one-dimensional sub-lattice. The composite model includes a linear defect in which a line of protons or deuterons exists during high loading, with lateral confinement by the host lattice. Variable spacing of the H or D in the linear arrangement enhances fusion probability. Phonons allow the released nuclear energy to be absorbed by the nearby lattice. In another paper at ICCF18, Meulenberg provided a "pictorial description" for LENR occurring within linear defects in a lattice. It included results of calculations of the electrostatic Coulomb potential at nuclear distances.

Compact Objects with Deeply Bound Levels

There is a body of theoretical work on mechanisms for LENR that envisions the formation of objects which are intermediate between atoms and nuclei in both their size and binding energies. They have protons or deuterons at their core and associated electrons. Their formation would release energies much larger than the binding energy of hydrogen, but still very small compared to nuclear energies. Concepts and theories for compact objects have been advanced by Randall Mills, Jacques Dufour, Horace Heffner, Sinha and Meulenberg, and Frederick Mayer and John Reitz. The last pair predict formation of an object they call a Tresino with two electrons around a proton or deuteron. The electrons are thought to be spin aligned, so that magnetic coupling supplies binding energy sufficient to stabilize the arrangement. The orbital radius is computed to be 386 femtometers, with a binding energy of 3.7 keV. There were three papers by Meulenberg on compact objects at ICCF18, plus three other related papers, as reviewed in the following paragraphs.

Andrew Meulenberg has been working for many years with Sinha on deep orbits in hydrogen and helium. Such orbits result from evaluation of the Dirac Equation, and are referred to as Deep Dirac Levels (DDL). They have high binding energies (up to 507 keV) and close proximity (within femtometers) to radiating protons in the deuterium and helium nuclei. The existence of DDLs is not generally accepted due to mathematical considerations and the fact that they have not been observed experimentally. However, Meulenberg and Sinha have argued that the DDLs explain many of the observations from LENR experiments.

At ICCF18, Meulenberg had two closely related papers. One of the papers included a list of ten important DDL electron characteristics. The two papers dealt with the coupling of radiation from nuclear protons to deep orbital levels, and thence, to the lattice. That is, he was concerned with the absorption and emission of radiation by deeply-bound electrons. The goal was to explain how nuclear energies can be coupled to the lattice without emission of energetic radiations. The envisioned process involves near field electromagnetic coupling between nuclear dipoles and the co-confined DDL electrons. The DDL electrons then couple energy to electrons bound to nearby Pd atoms. A "steady loss" of energy is envisioned, which precludes the population of nuclear orbits that could lead to emission of gamma rays. Many numerical results were given in these papers.

The third paper by Meulenberg on compact objects dealt with "femto-helium" and transmutations. It sought to explain differences between the behaviors of the Ni-H and Pd-D systems. In the process, the first- and second-order differences between the two systems were enumerated. Meulenberg considered what he called short range transmutations involving H, D and H_2, and long range transmutations with D_2. Possible reactions for the short range case were detailed.

Mizuno has a concept of what is causing LENR, which he included in his experimental paper on LENR in nano-particles (reviewed above). He thinks that hydrogen acts like a heavy electron inside of metal nano-particles. If that happens, the interaction of the heavy electron with a proton will produce an entity with a small radius, which can move closer to neighboring nuclei. As in muon-catalyzed fusion, that decrease in inter-nuclear distances will increase tunneling probabilities and fusion rates. Mizuno's paper is available at lenr-canr.org under NEWS.

Nagel and Roy Swanson considered implications of the existence of the hypothetical, but still unobserved compact objects. Production of compact objects in LENR experiments would result in release of energy without nuclear reactions. However, the resulting compact objects could then, in a second step, enter into nuclear reactions, again similar to muon-catalyzed fusion. If formation of compact objects is indeed the initial step in the production of excess heat, the total amount of excess energy E_T depends on the number N_C of reactions that form compact objects, the energy E_C released per formation of a compact object, the fraction f_N of the compact object formation reactions that lead to subsequent nuclear reactions, and the energy E_N released per nuclear reaction: $E_T = N_C\{E_C + \Sigma f_N E_N\}$. The summation is over the number of subsequent distinct exothermic nuclear reactions. The values of f_N can range from zero (no secondary nuclear reactions) to unity (when a particular nuclear reaction follows each compact object formation event). The fraction of the excess heat due to nuclear reactions, namely $(\Sigma f_N E_N/E_T)$, can be as low as zero or as high as nearly unity. The two-step processes imagined here can explain some of the wide variety of observations from LENR experiments. It contrasts with some concepts in which energy is released gradually, such as Storms' linear model, Meulenberg's DDL picture and Takahashi's BOLEP.

Steven E. Jones was at Brigham Young University in 1989 at the start of this field of research. He is now with S&J Scientific Co. His paper at ICCF18 also discussed two distinct effects, one being low-level D-D fusion in metals and the other anomalous excess heat. Jones characterized the first effect as confirmed and now fully repeatable. He considers the anomalous heat to be a "real but separate phenomenon." Like others, he wants heat to be found to be contemporaneous with measurements of some nuclear products and

Akira Kitamura and David Nagel *(Photo by Marianne Macy)* in the "same amount." Jones allows that the anomalous heat might be from some other forms of energy in the universe. He described how he and others are pursuing non-conventional experimental approaches to understand the source by using ordinary light water. Information similar to what Jones presented at ICC-18 is on the web at http://pesn.com/2012/11/19/9602225_Steven_Jones_replica--Pons_and_Fleischmann_XS_Heat_not_from_fusion/

Nuclear Lattice Model Simulations

Norman Cook of Kansai University has studied the application of the Nuclear Lattice Model to understanding LENR transmutation data for several years. The sequence and occupancy of nuclear states in the independent nuclear particle model, in good agreement with experiments, is the basis for the lattice model. Eugene Wigner observed in 1937 that the entire pattern of states in the independent nuclear particle model corresponds to the symmetries of a face-centered-cubic (FCC) lattice. Later, Cook and Valerio Dallacasa showed how the FCC Nuclear Lattice Model could be the basis for quantum nucleodynamics (QND). The Lattice Model is detailed in Cook's book *Models of the Atomic Nucleus*. That book provides excellent reviews of the various alternative concepts for nuclear structure and reactions.

Cook was author or co-author of four papers at ICCF18. In the first, he reviewed the basis for the Lattice Model, and then showed how it can be considered as the structural basis for QND. Then, in the second paper, Cook and Dallacasa gave the results of simulations of nuclear transmutations due to LENR, which were based on the Lattice Model. Earlier, that model had been applied successfully to simulate the distribution of products from the fission of isotopes of uranium and plutonium. The simulations reported at this conference dealt with changes in the isotope distributions of palladium due to only depletion of some of the normal isotopes. For a mean depletion of 86.13%, the distribution from the simulation matched data obtained by Mizuno in a LENR experiment. This success implies the involvement of all of the isotopes of Pd in LENR. The authors then reported on similar simulations for nickel in an alloy SUS304. If they computed the distributions resulting from strong depletion of all Ni isotopes except for ^{61}Ni, the simulated distribution matched other data from Mizuno. They considered the depletion of isotopes of other elements in that particular alloy, specifically Cr and Fe.

The Nuclear Lattice Model was used to try to understand piezonuclear fission reactions in a paper by Carpinteri and three others, Cook included. The group has been concerned with two types of evidence. The first is from neutron emission up to one thousand times background levels, and unexpected chemical changes from compressive loading of various natural materials, such as granite, basalt and magnetite. The other kind of evidence is the distribution of iron and aluminum mines on the globe, and the evolution of the earth's crust. Those features and that process reflect particular distributions of nuclides and possible nuclear reactions that might produce them. This paper reported on simulations of piezonuclear fission reactions using the Nuclear Lattice Model. Seven fission reactions predicted by the model were compared with the geological evidence. Overall, the model has been applied with apparent success to (a) neutron-induced fissions of the very heavy nuclides of Pu and U, (b) Pd and Ni, intermediate mass elements in LENR reactions, and (c) splitting of lighter elements in particular rocks, including Fe, Ca and Mg.

The fourth theoretical paper by Dallacasa and Cook was not directly on LENR, but on an aspect of nuclear theory. It considered the magnetic force between nucleons.

Other Theory Papers

Thomas Passell dealt with evidence for deuteron stripping in metals that absorb hydrogen. In such processes, the neutron from an energetic deuteron stays with a target nucleus, transmuting it to a nucleus one Dalton larger, and the proton is ejected. At very low (eV) energies, such stripping reactions are about one million times more probable than reactions that require entry of the deuteron into a nucleus. Passell tabulated the 23 elemental materials known to absorb and transport hydrogen isotopes, plus the energy releases Q from the top ten isotopes that will enter into stripping reactions with deuterons. He cited a variety of evidence from LENR experiments leading to the idea that deuteron stripping reactions are responsible for measured excess heat. Then, he examined the potential results of such reactions in Pd and Ti. Passell provided a Figure of Merit of stripping reactions on individual isotopes of Pd and Ti, including the percent abundance and the Q values. He listed seven advantages of the hypothesis that excess heat is from stripping reactions and three problems with the idea.

Ken-ichi Tsuchiya and Aska Okuzumi from the Tokyo National College of Technology reported on calculations of the quantum states for positively charged bosons in ion traps within solids. Included are a harmonic potential to represent the ion trap and a repulsive potential between the bosons. Iterative (self-consistent) calculations were performed by alternatively solving Schrodinger's and Poisson's equations. Deuterons trapped in Li and Ni were considered, and nuclear reactions rates obtained.

Thomas Barnard, sponsored by Coolescence LLC, considered the high-energy bond of D_2 by use of Feynman's integral wave equation. After discussing numerous dynamical possibilities, he computed the electron energy as a function of deuteron separation on the picometer to femtometer scales.

Heinrich Hora (University of New South Wales), Miley and Prelas provided a model for two picometer clusters of deuterons. They sought to explain the emission of nuclear reaction products in experiments at the University of Missouri. The thermal shock measurements, already described above in the section on Particles and X-rays, recorded 62 million neutrons within five minutes. They postulated a remarkable nuclear reaction in which one ^{108}Pd nucleus would react with as many as 164 deuterons in a Bose Einstein cluster to give a doubly magic nucleus with a long half-life and 42 ^{3}He nuclei.

John C. Fisher continued to develop his neutron cluster (isotope) theory. He considered sequential reactions in which the number of neutrons in a cluster grows. Then, he applied his model to explain production of heat and helium, transmutations, heat after death and some data from Focardi, Hagel and Piantelli.

Yuri Bazhutov of the Russian Academy of Sciences provided interpretations, based on particles he calls Erzions, of diverse observations he obtained using light, heat and plasma stimulation of LENR. He considered numerous potential nuclear reactions.

Computational Science

There are many kinds of science regarding both topics and techniques. Some are primarily experimental, such as physics and chemistry. Others, notably biology, use a mix of laboratory and observational functions. Some sciences are dominantly observational, particularly astronomy. The science of LENR falls primarily in the realms of physics, chemistry, and to a lesser extent biology. Earlier, there were only two branches for most physical and chemical sciences, experiment and theory. With the emergence of powerful computers in the past half century, a third branch has been added, namely computational science. Numerical "experiments" are now commonplace. Sophisticated software is used to understand the structure and dynamics of matter in many areas of science. That is also true for the study of LENR. Three papers at ICCF18 fall into this category.

Olga Dimitriyeva of Coolescence LLC used a complex computational tool, Quantum Espresso, to study the absorption of hydrogen and deuterium in transition-metal alloys. That capability is, according to its website, "an integrated suite of Open-Source computer codes for electronic-structure calculations and materials modeling at the nanoscale. It is based on density-functional theory, plane waves, and pseudopotentials." This software has the great advantage of being able to specify a complex atomic structure and then compute its stable configuration and energetics. The work reported at ICCF18 focused on three characteristics of the nuclear active environment and associated figures of merit. They are (a) high loading ratios, (b) presence of dopants or impurities and (c) structural morphology. The H or D absorption energies are measures of the first two factors, and the H-H and D-D separations are relevant to the dislocations, voids and cracks on LENR materials. Dimitriyeva found computationally that loading of Pd with H reduces the surface adsorption energy. It was also seen that near-surface doping of Pd with Rh improves surface mobility of H, even if reaching high loading ratios is not possible. Many calculations were done on the separation of H nuclei in loaded Pd with and without monovacancies. It was found the high loading and sublayer doping decreases H-H separations. At a monovacancy, that separation can be as small as 0.07 nanometers. This 70 picometer separation is still large compared to nuclear dimensions, which are in the range of femtometers.

Joseph Peter Goukas of the Human Services Agency of Ventura County in California has a long interest in LENR. At ICCF18, he presented views on modeling LENR environments by computational chemistry. He noted that some computational models, which treat nuclei as points, might create artifacts that appear as small and deeply bound orbits. However, such compact objects do not result when the nucleus is modeled as a distributed, albeit very small charge distribution. Goukas provided a list of software packages that might be applied to the modeling of LENR environments, but have yet to be used. They include NWchem, a computational chemistry software, and LAMMPS, a molecular dynamics package for surfaces, defects and charged particle motions. He favors ECCE, Avogadro or GaussView for visualization, Python for programming, and Scientific LINUX as an operating system. The overall goal of this work is to arrive at a standard suite of *ab initio* software for modeling conditions related to LENR. Goukas hopes that availability of results from such computations can suggest ways to trigger LENR.

Craters with diameters in the range of 1 to 100 micrometers have been imaged on the surfaces of cathode materials after many electrochemical experiments. They can only be formed by many nearly-simultaneous and co-located LENR events. But, it is not known whether those events are independent reactions that happen to be near each other in time and space, or they are causally related, as in a chain reaction. Estimates of the energy releases necessary to form craters have been made in earlier work. Recently, Ruer published an analytical paper on crater formation in the *JCMNS*. At ICCF18, George Sacco and Nagel provided results of the first computational simulation of crater formation. It was done using the Solid Works software. Various amounts of energy (10 nJ to 100 μJ) were released in a small volume (5 x 10^{-14} cm^3) over diverse times (1 nsec to 10 μsec) at depths into materials ranging from 0 micrometers (on the surface) to 5 micrometers. Plots of temperature vs. time were computed, as were the volumes in which the melting point of Pd was exceeded. The rapid temperature rises indicated that the vaporization point would be reached well before thermal conductivity could redistribute the released energy, even for release times as short as 1 nsec. Hence, crater formation is dominated by explosive release of pressure due to vapor formation. The next phase in the computer simulation of craters would be performing calculations using a code such as CTH to obtain videos of the process.

Instrumentation

One of the chronic problems with research on LENR is the need for better instrumentation. There are many instruments that could be built specifically for such research, if money were available. Similarly, there are existing tools that could be brought to bear on the science of LENR, if support were adequate. These shortfalls notwithstanding, there are usually a few talks on instrumentation at conferences in this series. Such was the case for ICCF18. Some of the papers already reviewed above contained significant work on development and use of new instrumentation. Four papers specifically on instrumentation are summarized here. The first described a system for both powering and measuring electrochemical LENR experiments. The other three were on methods for diagnosing the results of such experiments.

Kamron Fazel (Naval Research Laboratory) designed and built a compact and low cost combination power supply and data acquisition (DAQ) system for electrochemical LENR experiments. He calls it Power and Sense. Where most power and DAQ systems for LENR cost thousands of dollars and occupy volumes of one or more cubic feet, Fazel's system should sell for a few hundred dollars and have a volume well under one cubic foot. The system includes a computer board from Analog Devices and runs LabVIEW. It will deliver up to 15 V and 2 A in potentiostatic, galvanostatic and constant power modes. There are 10 channels for 24 bit analog-to-digital conversions. This system should prove useful for educational as well as research purposes.

Charles Weaver presented progress on the development of diamond radiation detectors. The work is being done by a team of seven people in the SKINR. They are using 3 x 3 x 0.5 mm single crystal diamonds. The several cleaning and coating steps needed to turn the commercial diamonds into radiation detectors were described. The group is using two modes with the detectors. One is to measure the count rate with a single-channel analyzer feeding into LabVIEW. The second is energy dispersive, with the results plotted using GENIE2000. They have achieved an energy resolution of 2.4% at 5.2 MeV. There remain problems with the performance and reproducibility of these developmental detectors. Weaver outlined the steps that the group plans to take in the near future, both in terms of making and using the detectors.

Nikita Alexandrov is an independent researcher, who is developing a novel diagnostic for LENR experiments. It could be very useful for real-time *in situ* measurements of singular events. Craters observed in cathode materials after experiments indicate the sudden release of substantial energy due to near-simultaneous LENR events. This new diagnostic is designed to yield three types of information on such events—the magnitude of the acoustic emission during their formation, their time of occurrence and the location of the events on the surface of active materials. The system consists of a square matrix of nine small piezoelectric sensors that can be pressed against the back of the active foil material in a LENR experiment, and some fast electronics for each of the sensors. The outgoing acoustic wave from an event will strike the different sensor at different times, depending on their relative locations. This enables location determination by triangulation. Calculations show that the system should be able to determine event locations to within less than 1 mm, and maybe as precise as 1 micron, depending on the speed of the electronics. Knowing those locations would permit correlation with the positions of craters observed in post-run images obtained with a scanning electron microscope. Alexandrov provided a nice comparison of the performance expected from his system with eight other types of diagnostics for LENR research.

Sveinn Olafsson of the Science Institute University of Iceland described another creative approach to instrumentation for LENR experiments. It is a variable micro-nano-gap instrument for chemical reaction studies and the mimicking of possible structures in nuclear active environments. The design is based on earlier work Olafsson has done with unconventional scanning tunneling microscopes. The concept involves two surfaces at the ends of wires 2 micrometers in diameter, which are polished to mirror-like finishes. The surfaces will face each other in gas or liquid environments. They can be moved relative to each other down to gaps as small as 1 nanometer by using piezoelectric actuators. Experiments will be performed to determine variations in tunneling electrical conductivity as a function of the gap size for Pd hydride wires and other materials. It is hoped to determine the transition from bound H_2 molecules to H atoms as the gap is decreased. Density functional theory calculations were performed for Ni (111) surfaces to address that stability limit. Binding energies for various gap sizes were reported.

Tom Claytor and Tom Passell ***(Photo courtesy of Cold Fusion Now.)***

Panels During the Conference

This completes the detailed review of the scientific papers submitted to, presented and discussed at ICCF18. But, there was another form of technical discourse. Eight panels focused on specific topics during the conference. This section summarizes their content. Beyond the panels, there were other conference events of interest. They are reviewed in subsequent sections, before a concluding section.

The number of panels was greater than at other conferences in the series. The format of the several panels during ICCF18 was also somewhat unusual. They were mainly short presentations, most complete with projected graphics, by the panel members. Many of the panelists were chairmen or co-chairmen of past ICCFs. For most panels, there was relatively little discussion among panel members or interactions with the audience. Nevertheless, the panels were interesting and useful because they concentrated on important topics in the field. The panels are discussed here in order from the more technical to the less technical. The two panels on Entrepreneurship and Innovations and on Career Opportunities were examined in more detail in the article by Marianne Macy in Issue 111 of this magazine. The panel "CMNS—The Way Forward" closes this section, as it did the conference.

Tritium Measurements

Tritium is a particularly important product of LENR. It has a relatively short radioactive half-life of 12.3 years, so it is not found in significant concentrations in the environment. And, being radioactive, it is quite easy to measure quantitatively. Hence, tritium is a particularly good signature of the occurrence of nuclear reactions during an experiment. Michael McKubre, the Chair of this panel, started by noting that tritium was discovered early after the Fleischmann and Pons announcement in three LENR laboratories, those of John Bockris at Texas A&M University, Mahadeva Srinivasan at the Bhabha Atomic Research Center (BARC) and Edmund Storms at the Los Alamos National Laboratory. Thomas Claytor, also at Los Alamos then, was among several researchers who reported early and strong tritium observations. These last three researchers were on the panel.

Storms started by reviewing concerns about tritium measurements that have been raised. They include contamination, purposeful introduction of tritium into an experiment and mistaking chemiluminescence for tritium activity in scintillation detection measurements. He also listed the importance of tritium results. Prime among them is the fact that the measurement of tritium can be unambiguous. It is essentially a "smoking gun" for nuclear activity. Its appearance without comparable levels of neutrons indicates that hot fusion is not producing the tritium. Further, production of tritium serves to limit viable theories of the mechanisms active in LENR.

Srinivasan reviewed tritium results obtained at BARC from 1989 to 1996. His talk included 26 graphics, with many details on the types of experiments, the materials used, the kinds of measurements and the results. He addressed two important kinds of measurements on tritium from very different experiments. One came from immersion of deuterated titanium lathe shavings in liquid nitrogen. Four out of one thousand chips evidenced significant tritium activity. The other was a disc of titanium that had served as the anode in a plasma focus experiment with an atmosphere of deuterium. Auto-radiographs of that sample taken over five years gave reproducible images, which indicated the presence of significant tritium at what appeared to be grain boundaries. Srinivasan also summarized a considerable body of evidence for production of tritium in nickel-hydrogen electrolysis and gas loading experiments. Those experiments had a success rate of almost 50%.

Thomas Claytor is the one scientist who is still working on experiments seeking to produce tritium, in collaboration with researchers at Coolescence LLC. They are using plasma cells containing nickel within calorimeters, seeking to correlate tritium and heat production. While at Los Alamos, Claytor performed glow discharge experiments with a variety of materials in a deuterium atmosphere. Cathodes of Pd containing Rh(5%), Co(5%) and B(0.18%) gave the best and reproducible results for production of tritium.

Neutron and Radiation Production

Like tritium detection after LENR experiments, measurements of neutrons or energetic radiations during such experiments provide important evidence of nuclear reactions. Hence, this panel provided further information to support the conclusion that it is possible to induce nuclear reactions in experiments conducted at low temperatures (energies). It was chaired by Xing Zhong Li.

The first speaker was John Gahl from the cyclotron group at the MURR nuclear reactor on the campus of the University of Missouri. He and his colleagues are using 8.4 MeV deuteron beams of less than 20 mA from the GE PETrace cyclotron to bombard stacks of thin Pd foils, which contain interleaved Ti foils as monitors. They are in the process of measuring the production of protons and neutrons in reactions on isotopes of palladium in order to obtain cross sections for such events. The values obtained to date are generally larger and extend to lower energies than those predicted using the TAYLS OMP model. Proton capture is substantially more likely than neutron capture for ^{110}Pd, in contrast to the Oppenheimer-Phillips model. The reverse is true if the nuclear subshell has neutron vacancies. The continuing work will include better characterization of the cyclotron beam and refinement of the cross section measurements.

Graham Hubler cited several unusual nuclear phenomena related to LENR. They included low-energy and short half-life emission from metastable isotopes of tantalum and thorium, the high cross sections for D-D reactions at low (few keV) energies, neutron halos in nickel, and triple deuterium (D-D-D) reactions, which are enhanced by twelve orders of magnitude. He recommended putting radioactive isomers into palladium cathodes in electrolytic experiments to explore LENR mechanisms.

Frank Gordon summarized his presentation as follows: (a) multiple LENR experimental protocols with various instrumentation recorded charged particles and neutrons, (b) while the fluxes of such radiation were low, such emission did occur, and (c) more experiments and theoretical work are needed to achieve understanding. He provided a good compilation of the experiments, which produced data on emission of nuclear radiations, and cited a few relevant patents. Micrographs were presented which compared triple tracks observed in CR-39 from LENR experiments with tracks from D-T neutrons above 9.6 MeV. The similarities in the appearance of the tracks from the two sources are striking.

Thomas Passell focused on evidence for deuterium stripping in hydrogen loaded metals. He touted the use of multiple experiments to screen for significantly active materials in LENR experiments. Passell has run 100 glow discharge experiments using film and thermoluminescent dosimeters to search for emission of energetic radiations. Some of his experiments have been operating for more than four years.

Transmutations in Biological and Chemical Systems

The field of LENR has an abundance of mysteries. The most basic is the ability to induce nuclear reactions with chemical energies. That ability has been demonstrated in a wide variety of experimental and materials systems with various protocols, which is also remarkable. Of all the different types of LENR experiments, one stands out as especially vexing and potentially important. That is the ability of living organisms to induce nuclear transmutations. It is far from the best proven or the best understood part of the field. Biologically-induced LENR was the subject of a panel chaired by Jean-Paul Biberian, the editor of the *Journal of Condensed Matter Nuclear Science*. He recently wrote a comprehensive review of the field of bio-transmutations. The paper, with 38 references, is at *J. Condensed Matter Nuclear Science*, Vol. 7, pp. 11-25 (2012). It shows that interest in bio-transmutations developed long before the field of LENR. The earliest work on biological production of inorganic materials dates from the 19th century. Recent work employing modern analytic techniques provides evidence for nuclear reactions induced by living matter at ordinary temperatures, which is hard to dismiss.

Vladimir Vysotskii was the other panel member. He and Alla Kornilova (Moscow State University) have long collaborated on the experimental study of LENR in biological systems. In 2003, they published a book, *Nuclear Fusion and Transmutation of Isotopes in Biological Systems*. It was followed in 2010 by a second book entitled *Nuclear Transmutation of Stable and Radioactive Isotopes in Biological Systems*. At ICCF18, Vysotskii gave a comprehensive overview of the subject. It included some old but important Mossbauer spectra that can be interpreted as not only showing, but also quantifying bio-transmutations. He also presented data on deactivation of the radioactive isotope Cs^{137}. Vysotskii showed the first page of a Russian patent, which he, Kornilova and I.I. Samojlenko were granted in 1996. It is entitled "Method for Producing Stable Isotopes Due to Nuclear Transmutation, such as Low-Temperature Nuclear Fusion of Elements in Microbial Cultures."

ENEA Workshop

Many researchers in the field are working alone or with very few other scientists. There are great advantages to having larger groups of researchers attacking the same or closely-related problems. Different people bring important complementary skills to the research. And, there is a fundamental human inclination to having a team spirit in research, as in sports and business. Earlier, we emphasized two research groups that have recently become prominent in the field, namely SKINR and the MFMP. But, they are not the only major teams attacking LENR. There are very capable groups at two government laboratories, NRL in the U.S. and ENEA in Italy. The NRL work was described by David Kidwell in his keynote address and reviewed above.

The group at ENEA got deserved attention during one of the panels at ICCF18. That team is led by Vittorio Violante, who chaired the Panel. It was populated by Emanuele Castagna, a senior researcher at ENEA, and leaders of organizations which have collaborated closely with ENEA scientists in recent years. They included Robert Duncan, Graham Hubler and Michael McKubre. ENEA data from experiments that gave 25-30% excess power were shown. Excess power required loading ratios of D/Pd of 0.9 or higher. It was not observed with hydrogen, and required specific material characteristics. They included surface morphology, grain orientation and grain boundary size. ENEA scientists identified the role of some contaminants, which improved material control. Electrochemical impedance spectroscopy was performed during the LENR experiments, which revealed "dramatic changing" of the electronic structure of the cathode surface. Resonating circuit components appeared during the production of excess heat. The bottom line for the ENEA work is the central importance of materials in production of LENR and their systematic approaches to materials problems.

The panels reviewed above were highly technical in nature. There were three other panels on important topics closely related to LENR, which are summarized next.

Entrepreneurial Efforts Panel

Now that the commercialization of LENR appears to be nearer, there is more interest in the relatively small and new companies that might bring LENR generators to market as early as the coming few years. The panel consisted of a series of competitive presentations from six companies and organizations. Matt Trevithick chaired this fast-paced panel.

The parade of presenters from small companies started with Robert Godes, the Founder, President and CTO of Brillouin Energy Corporation. It has raised over $4M since 2009, and now has eight full-time employees. Godes calls their process Controlled Electron Capture Reactions (CECR). The core material used to run the reaction is not destroyed in the process, which can be turned on and off. So far, they have achieved power gains of 2, and believe that they can achieve gains of 20. Gains exceeding 10 will permit electrical generation. Their business model is to license their patented technology to major appliance and other industrial companies.

Sunwon Park, Frank Gordon and Mitchell Swartz

Next, Matt McConnell presented an overview of the activities and results of Coolescence LLC. In 2005, he cofounded the company with Rick Cantwell. It has raised $8M of angel funding since that year. McConnell characterized the company as the "unluckiest" company in the field. They have attempted 11 replication experiments without success. Those included electrolysis, gas loading and glow discharge experiments. They consider the company a research organization, with nothing ready for investment yet. McConnell noted the possibility of both safety and regulatory concerns when LENR generators do come to market. Some of us think that such issues are unavoidable as products based on LENR become available. In fact, they might even impede early commercialization.

Mitchell Swartz is the founder of Jet Energy Inc. and Nanortech Inc. He has been developing two-terminal devices called NANORs® in the past several years. During this panel presentation, Swartz stated that the devices contain a ZrO_2 "cookie" with chips of PdD in the cylindrical core. Information on NANORs® is available at http://www.std.com/~mica/nanortechnology.htm. Swartz informed conference attendees that he had formed a new company in July called Nanortech Inc. to develop and produce the NANOR-type technology. That company projects business in excess of $20M in its fourth year, with sales into educational, heating and battery arenas. Their new electrically driven, preloaded CF/LANR components are called M-NANORs®, and are slated to produce 100 W of power. However, now during development, they are unstable at the 10 W level. Another goal is to achieve electrical-to-thermal energy gains of 20 with no carbon footprint. Swartz stated that the intellectual property portfolio of his companies covers both core technologies and design patents. Patents and applications involve techniques to produce high energy gain, activation methods and processes for quality control. Additional technical details are in the section above on NANORs®.

Nicolas Chauvin was the fourth entrepreneur to describe his company, called LENR Cars. The company has $60K this year and a budget of $200K next year. They are striving to use LENR to charge the batteries of electric cars. Chauvin showed their expectation of driving 20,000 km between refueling, which will cost only €200. The 100 kg generator being designed would employ thermoelectric modules to convert heat from LENR to electrical power. Their plan is to sell prototypes in the short term, then licenses to intellectual property in the mid-term, followed by manufacturing products with major partners in the longer term. Chauvin described what he calls an "LENR Ecosystem," which includes LENR Cars for transportation, a financial company LENR Invest, and LENR Cities, a joint venture linking research and industry.

Next, Max Fomitchev-Zamilov, the president of Quantum Potential Company, described their efforts to develop an energy generator based on *hot* fusion. The process is cavitation-induced fusion, in which small bubbles produced sonically collapse to central temperatures sufficient to cause well-known D-D fusion. The company has raised $600K to date and now has seven employees. They have a two-prong program, computational and experimental. MatLab and Mathematica have been used to develop analytical models, which were augmented with molecular dynamics simulations. The company has a prototype generator which has generated neutrons in three out of 40 tests. They project that a generator about the size of an oil barrel will produce 100 kW of low grade heat. Now, Quantum Potential Company is seeking $562K to develop and operate an "on demand fusion demonstration."

The last presentation in this series was not by a company, but by the consortium of researchers called the Martin Fleischmann Memorial Project. It employs an open source approach to commercializing LENR. During this panel, Tyler Van Houweilingen and Robert Greenyer described the four phases planned by the collaboration. They are Science, Validate, Market and Enhance. The MFMP has already received orders for the prototype LENR demonstration apparatus and the development reactor with its electronics. This presentation included many photographs of experimental equipment and their new modular experimental LENR reactor. It is designed to accommodate various fuel configurations, triggering mechanisms, high temperatures and flow calorimetry. Information on the MFMP was provided in a separate section above and in the section on Gas Loading ala Celani. More material on the goals and results of the MFMP is at http://www.quantumheat.org/index.php/en/

The ICCF18 attendees voted for the groups they thought were best. There were 126 ballots. The MFMP won the competition. It was stated that two-thirds of the attendees had voted them for first or second place. Clearly, this active and enthusiastic group of young scientists, engineers and entrepreneurs resonated with the conference participants.

Entrepreneurship and Innovations

This panel was timely because there is an abiding need for creative work in the field, both in research and for development of products. It was populated by three people who are very experienced in commercialization of new technologies. The first was Matthew Trevithick, a graduate of MIT, who has been an entrepreneur and now is a venture capitalist at Venrock. In between, he was a member of Project Cobalt, which did research on LENR in order to commercialize such reactions as an energy source. He believes that LENR now lacks what he called a "forcing function" to motivate already-interested venture capitalists. He stated that successful clean energy companies require investments of $100M or more.

Mark Johnson was the second panelist. He taught materials science and entrepreneurship before joining ARPA-E. There for four years, his current focus is largely on grid-level energy storage technologies. Johnson emphasized the technical and economic difficulties facing new companies in the area of clean technologies. That was illustrated with a graph showing that half a year after their Initial Public Offering eight of nine clean technologies were "underwater," that is worth less than at their IPO. Johnson provided a few succinct tips for success in bringing a new technology to market. They included being realistic, asking excellent questions, building a community and planning for the future. Johnson closed with the "Heilmeyer Questions," which have been used at the U.S. Defense Advanced Research Projects Agency since 1975. They are available on Wikipedia under "Heilmeyer Catechism": http://en.wikipedia.org/wiki/George_H._Heilmeier

Michael McKubre, Mahadeva Srinivasan and Matt Trevithick prior to the Panel on Career Opportunities.

Douglas Moorehead rounded out this panel. He has a degree in Materials Science from MIT and an MBA from Harvard, plus a military background (Navy Special Forces). He is now the COO of Earl Energy LLC, which specializes in off-grid energy solutions for government and industrial customers. Small LENR generators could have a great impact as deployable and distributed sources of thermal and electrical power. Moorehead lamented the secrecy within the field. Team formation, as well as credibility, is key to progress in commercializing LENR. In response to a question from Trevithick, Moorehead noted that the military pays the most per kilowatt-hour of any large energy user. Energy sources in the 1-5 kW range represent a multi-$B market. LENR heat and electrical generators could capture a significant share of that market, if they prove to be highly reliable.

Emerging Career Opportunities in CMNS

A very different panel was convened at the end of the second day of the conference. It was populated by senior members of the field to inform students and others interested in LENR about how careers can develop. They included Robert Duncan, Graham Hubler, Michael McKubre, Mahadeva Srinivasan and Matt Trevithick. Annette Sobel served as Chair of the Panel. She asked the members to recount highs and lows during their long careers, and told her story as well. There were only a half dozen young people in attendance. But, that allowed the panel time to interact with each of them. The audience included many conference participants, who found the stories of the panel members fascinating and the student's interest invigorating. More details on this panel were provided by Marianne Macy in the last issue of this magazine.

CMNS—The Way Forward

The conference ended with a forward looking perspective on the field of Condensed Matter Nuclear Science. It was offered by a panel populated largely by past chairs of conferences in this series. This topic is very timely, given (a) the lack of adequate theoretical understanding and (b) the possibility of commercialization of LENR generators in the next few years, that is, exploitation before understanding. The panel was chaired by Mahadeva Srinivasan. In brief remarks, he gave an overview of the study of LENR in India, which had a fast start but was shut down in the mid 1990s. Some interest returned due to ICCF16 being held in Chennai in 2011, chaired by Srinivasan. Currently, there is little research on LENR, but some early industrial interest in India.

Jean-Paul Biberian, chair of ICCF11 in Marseilles in 2004, spoke next. He gave a survey of the history of LENR research in France. At one time, he was forbidden to work on the subject by the CNRS, the giant government research organization in France. There is essentially no research on LENR in that country now, outside of his university. Besides editing the *JCMNS*, Biberian has been active in informing government agencies of the status of the field. He wrote a book on LENR, which was published in French last year. A story about the book was carried by this magazine, including a translation of the Preface written by Stanley Pons. That article is available at http://www.infinite-energy.com/images/pdfs/BiberianBook.pdf.

Akira Kitamura of Technova Inc. and Kobe University made the case for needing more young researchers working on LENR. He also provided a timely and comprehensive listing of the dozen laboratories in Japan now working in this field, and categorized them according to the types of work they are doing. Included are electrolysis, gas loading, discharge (plasma) loading, permeation, beam-target interactions and theory. Kitamura used some of the results being obtained by his team to make the point of the need for more collaborations, especially cooperation between governments and private organizations.

Xing Zhong Li organized ICCF9 in Beijing in 2002. He presented an overview of his theoretical work on hot and cold fusion. Li is particularly interested in the possibility of using neutrino measurements as diagnostics for LENR experiments.

Vittorio Violante was Chairman of ICCF15 in Rome in 2009. He began with a retrospective on LENR work in Italy. He also emphasized the need for collaborations given the paltry support of the field and its inter-disciplinary character. Violante gave some details on the 2010 Bi-Lateral Agreement between ENEA and the U.S. Department of Defense. It had its roots in collaborations between his laboratory and SRI International in 1995. He noted that there is growing interest in the European Union, and that LENR researchers have credibility in that arena. Nevertheless, funding is inadequate. Violante also emphasized the need for more young researchers in the field.

Edmund Storms explaining his view of the locations in materials where LENR occur.

Sunwon Park was the organizer of ICCF17 in Daejeon, Korea in 2012. His view of the way forward started with a global perspective, including climate change. He noted the possible impacts of LENR on modern cities, transportation and communications. Park presented a compilation of the strengths and weaknesses of the field, and both the opportunities for and threats to the field. He has already met with the political leadership of Korea, but as is the case in the EU, U.S. and elsewhere, those contacts have not resulted in LENR programs.

Michael McKubre was chairman of ICCF4 in Hawaii in 1993. He cited the need for answers to the basic questions: who, what, when, where and how for LENR research and development. McKubre called for new experiments which go beyond the things already done in the field. He cited the urgency with which some people, for example Sidney Kimmel, view the development of commercial LENR generators.

Robert Duncan completed the Way Forward Panel in place of Yuri Bazhutov from Moscow, who was unable to attend ICCF18. Duncan called for self-criticality and objectivity in the field. Results produced by this field have to be highly reliable, given the propensity for criticism of work on LENR.

This panel, coming at the end of the conference, did elicit several comments from the participants. David French noted the big gulf between academic research and commercial funding. Nicolas Chauvin asserted that it is easier to get funding for reduction of radioactivity than for production of energy. Robert Greenyer touted the educational and public relations side of the field. He favors "time stamped history," such as being provided by the MFMP from its on-going experiments. There seemed to be considerable support for the view that an energy gain (thermal out divided by electrical in) as low as 2 at temperatures of even 100 to 200 C would be useful for heating and, hence, commercially viable.

Honorees

Three major contributors to the field over the years were honored at ICCF18. Two recipients were planned in advance of the conference, and one was not.

Edmund Storms deservedly received a Distinguished Scientist Award, which was presented on the first morning of the conference. He is well known for his many contributions to the field, starting with numerous papers on experimental results. Storms has also written several useful reviews and a book entitled *The Science of Low Energy Nuclear Reaction*. He is arguably the best read of scientists in the field, and is given to participating in discussions on the CMNS Google Group moderated by Haiko Leitz. In recent years, Storms has turned to evaluating theoretical explanations of LENR. He found them unsatisfactory for different reasons, and has gone on to propose that LENR occur in cracks on the surfaces of materials. Many of his views of this possibility were presented and critiqued in Issues 108 and 109 of this magazine.

Pamela Mosier-Boss received the 2013 Preparata Medal of the International Society for Condensed Matter Nuclear Science at the banquet for the conference on Thursday evening. She has been one of the two main contributors to the highly-successful research program at the SPAWAR Navy Laboratory in San Diego. The other is Stanislaw Szpak. They have published over 30 peer-reviewed journal articles on LENR. The group has reported evidence of excess heat, tritium, transmutations, and emissions of X-rays, neutrons and charged particles from Pd-D co-deposition experiments. After receiving the medal, Mosier-Boss recounted the ups and downs of LENR research over the years, and detailed an exchange with one critic of the research. After her comments, Frank Gordon, former leader of the SPAWAR LENR research group, gave an interesting retrospective on Mosier-

Boss and the group. An article by Christy Frazier about the award to Mosier-Boss and Gordon's comments was already published in this magazine: http://www.infinite-energy.com/images/ pdfs/BossPreparataMedal.pdf

John Dash is one of the continually productive experimentalists in the field. He received the Best Poster Award for the conference. Dash has led a research group populated by high school, undergraduate and graduate students over many years. They reported numerous worthwhile results at past ICCFs, including excess heat, transmutations and craters on cathode surfaces after experiments.

Perspectives

There were two events at ICCF18 which were rooted in the science of LENR, but went well beyond technical topics. One offered perspectives on the field and the other dealt with intellectual property. They are summarized here.

Jed Rothwell gave a very interesting luncheon speech on the first full day of the conference. He maintains the indispensable collection of scientific and related papers in the field at lenr-canr.org. There are over 2000 papers available on that site. They have been downloaded at rates exceeding one per minute during some months. The talk was titled "Lessons from Cold Fusion Archives and History." It is available at http://lenr-canr.org/acrobat/RothwellJlessonsfro.pdf. Rothwell views the field as chaotic due to inconsistent, and sometimes contradictory, experimental results and the lack of a widely-accepted theory. However, he asserted that, historically, such chaos is symptomatic of an emergent field of science.

Rothwell addressed the reality of "cold fusion." He reminded the audience of the 1991 quotation by a distinguished German electrochemist, Heinz Gerischer: "There are now undoubtedly overwhelming indications that nuclear process take place in metal alloys." Rothwell provided references to three papers, with the assertion that they do teach how to reproduce LENR. That part of the talk included exhibiting a table from a paper by Melvin Miles and K.B. Johnson, which summarized sources of Pd materials for electrochemical experiments, and indicated which ones did or did not produce excess heat. Rothwell also examined some failed LENR experiments, and the lessons they provided. The talk ended by focusing on unfounded assumptions, and used experience from genetics to illustrate the problems they cause.

David French, a Canadian patent lawyer, gave a poster on intellectual property for LENR. The title of the paper was "Patenting Cold Fusion Inventions before the U.S. Patent and Trademark Office." That topic has two major attributes: (a) importance and (b) complexity. The importance is basically due to patents being required by investors in order to protect the monies they deploy in a new commercial field, such as LENR. The complexity has two bases. One is the intrinsic complications of patent laws within any country and between countries. The other has been the difficulty of obtaining patents on LENR and related topics in the U.S. Some patents in the field have been issued, but the situation is not consistent, with many patent applications ignored or rejected.

French asserted, on the basis of personal exchanges with the USPTO in 2012, that the Office will issue "properly drafted" patents on cold fusion if the applications have good disclosures and evidence that the asserted procedures will operate as represented. That is, it has to be shown that the alleged invention actually works. Because of the controversy surrounding the field, it is not an area in which a patent can be issued on the basis of some insight. Applicants must give proof of operability. French provided advice on how to answer requirements for evidence from an Examiner in the USPTO. He also summarized some general advice on seeking patents in any field, which also apply to LENR. It seems certain that intellectual property will be increasingly important in this field, and part of future conferences in this series.

Participants at ICCF18 who were at ICCF1. They are (L-R): Claytor, McKubre, Kim, Melich, Li, Passell, Hagelstein, Hubler, Nagel, Barnard, Srinivasan and Tanzella. *(Photo by Marianne Macy)*

Some of the participants in the National Instruments Workshop after ICCF18.

Related Events

There were some new activities associated with ICCF18, along with two familiar features. Those two will be discussed first, followed by short descriptions of the other items.

Tutorial schools immediately prior to the conference have been held at most of the conferences from ICCF10 onward. These day-long sessions give newcomers to the field a chance to learn more background on the materials presented at the main conference. The school also gives participants a chance to meet and talk with the instructors, who tend to be very busy during the conference itself.

This year, the LENR Introductory Short Course was held on the Sunday prior to the Welcome Reception that evening. It was hosted by the National Security Innovation Center in the University of Missouri College of Engineering, where Annette Sobel is the Director. The course was organized and introduced by Nagel. The session included talks on both of the primary means of loading hydrogen isotopes onto and into materials. Michael McKubre covered "Pd-D Electrochemical Loading and Heat Data" and Michael Melich addressed "Ni-H Gas Loading and Heat Data." Mahadeva Srinivasan gave a presentation entitled "Transmutation Data and Issues." Both of the major problem areas that vex researchers in the field were part of the course. Vittorio Violante covered "Materials Status and Challenges" and Peter Hagelstein lectured on "Theoretical Status and Challenges." A topic new to such short courses proved very popular. David French addressed "Legal Aspects and Intellectual Property." He had a very dynamic interaction with the participants. Overall, the Short Course dealt with the general situation and the major parts of LENR science, and one of the central aspects of the coming commercialization of LENR.

As always, there was a conference banquet one evening for ICCF18. It offered good food and fellowship, in addition to a few speeches and award presentations. That evening, the attendees of ICCF1 in 1990 were asked to assemble for a photo. Some of the scientists pictured have been to most or all of these conferences. After all the years of grappling with the mysteries of LENR, we are close professional friends and, in some cases, also personal friends.

Exhibits, usually by vendors, are a part of many scientific conferences. But, they have not had much of a presence at earlier conferences in this series. At ICCF18, there were three exhibitors. They were well located in an area with many tables, where attendees could have coffee and discussions. The New Energy Foundation (http://www.infinite-energy.com/whoarewe/whoarewe.html) had one booth, where they sold magazines, books and other items. That was shared with Cold Fusion Now (http://coldfusionnow.org/). The Martin Fleischmann Memorial Project had a very popular display of equipment and information. It included current and coming experimental set-ups for gas loading of nickel, as done by Celani and others, plus some new approaches.

The organizers of ICCF18 provided a survey to the participants at the end of the conference. It contained 20 questions about the entire conference, and parts of it, such as the several panels, the laboratory tours, the poster session and the exhibits. Other questions dealt with timing for submission of papers, the facilities, costs and the registration process. It asked about the most and least beneficial aspects of the conference, solicited additional topics for ICCF19 and, interestingly, asked attendees if they would be willing to mentor students in the field. The results from the questionnaire should be useful to the organizers of the next conference.

The final new feature of ICCF18 was a pair of post-conference workshops sponsored by National Instruments. The first was three days on "Graphical System Design for Control, Measurement and Diagnostics." It taught the use of LabVIEW software to control and monitor LENR and other experiments and processes. The second, a two day workshop rounding out the week after the conference, was on "Data Acquisition and Signal Conditioning." That workshop taught how to use National Instruments hardware and software to acquire data from LENR experiments. The analysis and display of the data could then be done using LabVIEW. These workshops were offered by National Instruments at deeply discounted rates. The company provided laptops for use by participants, as well as disks with software and hard copies of their educational materials. Nineteen conference participants took advantage of the National Instruments workshops.

Conclusion

ICCF18 was a highly successful scientific conference. The quality of the presentations and of the many discussions was very satisfactory. The breadth of the field was once again evident. Trends in both the research and commercialization of LENR occur gradually. This conference continued an increase of interest in using nano-materials for LENR, and in magnetic fields, both applied and produced during experiments. Work on nano-materials and magnetism is likely to increase for both scientific and business reasons. The recent interest in commercialization has had a great impact on the field in the last few years. That trend is likely to continue.

More significant experimental data was added to the mass of relevant information already available, which shows it is possible to induce nuclear reactions with chemical energies. Several of the fundamental controversies in the field got deserved attention. However, some significant aspects of the field were not covered.

It is the opinion of some people, this reviewer included, that the mechanisms behind LENR will be found to be important in other areas of science. This is certainly not a new idea. Two theoretical papers can be cited as evidence. In one, F.J. Mayer and J.R. Reitz applied ideas, which were developed to explain LENR, to two major current problems in science, the heating of the earth and the nature of dark matter (*Intl. J. Theoretical Physics*, Vol. 45, 2006). In the second, Y.N. Srivastava, A. Widom and L. Larsen did similarly for the dynamics of exploded wires and the solar corona (*Pramana*, Vol. 75, pp. 617-37, 2010). It is unfortunate that none of these scientists was at ICCF18. Also, several leading experimenters in the field could not come, even researchers from the U.S. Nonetheless, the conference was full of new results and many exciting discussions.

The commercial side of ICCF18 was very good, even though some leading engineers and businessmen in the field also were not in attendance. Works of significant commercial potential were presented. Nano-materials seem to be important in the production of LENR, but it will be hard to maintain their efficacy for long times at high operating temperatures, for example, greater than 200 C. The technique reported in the paper by Mizuno for *in situ* preparation of nano-materials within a LENR reactor seems especially promising. That might be the first study to address the preparation of materials in place within a LENR reactor, as could be needed for commercial power generators. It seems likely that the fraction of papers in coming conferences in this series which are devoted to commercialization will increase significantly.

Trevor Dardik presented to the International Advisory Committee a proposal for ICCF19 on behalf of Anthony Lagata. The committee readily agreed that the next conference will be held in Venice in March of 2015. By then, initial commercial LENR energy generators might be available to early adopters.

The bottom line for LENR now and in the future is the possibility of having sources of power and electricity that have several very desirable features. Prime among them is the ability to produce power at many useful levels for countless applications without significant radioactive waste or greenhouse emissions. The possibility of having relatively small and distributed sources of energy could have a global impact in a class with the importance of cell phones. LENR sources will have to be cost-effective, safe and reliable. Those traits will be proven only by use of early commercial LENR generators.

Appendix on Terminology

The naming of the field of "cold fusion" and its sub-topics is still very much in flux. Most of the titles given to the field over almost 25 years since its announcement are tabulated here. Those at the bottom have been conjured by companies active in the arena. The field is considered part of "Condensed Matter Nuclear Science." A refereed electronic journal serves the field: http://www.iscmns.org/CMNS/CMNS.htm

Terminology	Comments
Cold Fusion	Original and recognized name, but incomplete.
Low Energy Nuclear Reactions	Low is a relative term and unclear. LENR.
Lattice Enabled Nuclear Reactions	Clear and specific, but little known. Still LENR
Lattice Assisted Nuclear Reactions	Also accurate, but little used. LANR
Chemical Assisted Nuclear Reactions	Many chemists like this. CANR
Cold Fusion Phenomenon	Little used.
Cold Fusion Nuclear Reactions	Little used.
Cold Nuclear Transmutations	A Russian favorite. CNT
Low Energy Nuclear Transmutations	Little used. LENT.
New Hydrogen Energy	A major past Japanese program. NHE
Metal Deuterium Energy	A current program in Japan. MDE
Collective Multi-Body Nuclear Reactions	Only suggested and not used.
Condensed Matter Nuclear Reactions	Only suggested and not used.
Low Energy Chemical Reactions of Atoms	Only suggested and not used.
Lattice Induced Nuclear Excitation.	Only suggested and not used.
SANER	**SA**fe **N**uclear **E**nergy **R**elease. Not used.
Fleischmann-Pons Effect	Clear, but applies only to heat generation. FPE
Fleischmann-Pons Heat Effect	Explicitly excludes transmutations. FPHE
Anomalous Heat Effect	Relatively new and little used. AHE
Catalyst Induced Hydrino Transition	Due to Blacklight Power Inc. CIHT
Deuterium Permeation Induced Transmutation	Due to Mitsubishi Heavy Industries.
Rossi Effect	Due to Leonardo Corp.
Controlled Electron Capture Reaction	Due to Brillouin Energy Corp. CECR
Heat Energy from Nanoplasmonic Interactions	Due to Defkalion Green Technologies. HENI
LeClair Effect Nuclear Reactions	Due to Nanospire Inc. LENR

About the Author

David J. Nagel is a Research Professor in The George Washington University, and CEO of NUCAT Energy LLC. He has participated in all of these conferences, and chaired ICCF14 in Washington, DC. In writing this overview, he functioned as an informed reporter and commentator, and not as a referee or judge of the papers at ICCF18. Helpful communications with Mitchell Swartz, and detailed comments on the draft by Michael Melich and Steve Katinsky, are greatly appreciated.

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