Scientific Overview of ICCF16

David J. Nagel*

Summary

ICCF16 was held in Chennai, India from February 6-11, 2011. The conference was heavily impacted by a demonstration in Italy, about three weeks before it began, of a 10 kW boiler with an energy gain exceeding 10. Significant theoretical and experimental progress was reported in about 50 papers at ICCF16. There was also early interest in the engineering aspects of practical sources of power based on low energy nuclear reactions (LENR). This conference was distinguished by a set of three satellite meetings. The first was a pre-conference tutorial school. And, there were two post-conference workshops. One of those was on materials for LENR experiments, which was held in a nearby resort city. The other was at a university in Chennai. It focused on biologically-induced nuclear transmutations. About 500 people participated in the conference and other meetings. Many were Indian scientists, who are considering the possibility of joining the field. Over half of the attendees were students from Indian technological institutes and universities. The conference and associated meetings were very successful scientifically and socially. The organizer's goal of informing many Indian scientists and technologists about LENR was certainly achieved. It seems likely that research in this field will restart in India after a 20 year hiatus. Importantly, Korea had a delegation of senior scientists at the meeting. They have plans to resume active research programs on LENR. Addition of India and Korea to the list of countries studying low energy nuclear reactions is a very nice prospect.

1. Background

This conference had a dual name, as did other recent conferences in this series. It was both the 16th International Conference on Cold Fusion (ICCF16) and the 16th International Conference on Condensed Matter Nuclear Science (CMNS). Most appropriately, it was co-sponsored by the International Society for Condensed Matter Nuclear Science, which is called the ISCMNS (iscmns.org). The terminology "condensed matter" is not familiar to many people. It is a term invented by the American Physical Society in 1947 to embrace both solid-state and liquid-state physics. It recognizes their many similarities, which are due to the atoms in both those phases of matter having similar interatomic separations. The "nuclear science" part of CMNS rec-

The delegates from ICCF16. *(Photo courtesy of ICCF16.)*

ognizes the fact that the field deals with the nuclear aspects of matter, specifically nuclear reactions. Hence, CMNS spans fundamental entities with sizes from nanometers down to femtometers, a challenging range of physical scales to treat theoretically.

It is widely accepted now that the term "cold fusion," which was initially used to describe the nuclear reactions cited by Fleischman and Pons 22 years ago, is at least not useful. The subject of interest is broader and better described as a diverse class of nuclear reactions. Because they occur at temperatures (energies) dramatically lower than those in hot fusion, the terminology low energy nuclear reactions (LENR) is now commonly used. As with the range of size scales in CMNS, there is a vast difference between the temperatures for hot fusion (around 100 million degrees) and LENR (generally less than 1000 K). So, while the word "low" is not specific, it discriminates between the temperatures and equivalent energies of hot and "cold" fusion.

As the number indicates, this was the 16th conference in the ICCF series, which began in 1990. The ICCF string of conferences has been a primary venue for presentation and discussion of work in the field, whatever it is called. There are other important conferences on the subject. The Russians have held a series of 16 conferences embracing what they call Cold Nuclear Transmutations, as well as ball lightning. There have also been nine conferences in Europe organized by the ISCMNS. Besides these dedicated conferences, sessions on LENR have been held at conferences of major intellectual societies, notably the American Physical Society and the American Chemical Society.

The ICCF conferences have usually been held on a three continent rotation: North America, Europe and Asia. ICCF16 was the fifth such conference held in Asia and the first in India. It was one of the three smallest conferences in the series, but might have reached directly the most people of any of the conferences. This apparent contradiction was due to the organizers of ICCF16 arranging for the three satellite meetings. The first was a tutorial school the weekend before the conference. After the conference, there were workshops on "Materials Issues in LENR Devices" and "Biological Nuclear Transmutations: Historical Perspective and Applications." In all, about 500 people attended the main conference and its associated meetings.

2. Context for ICCF16

Scientific conferences are set in particular circumstances, of course. The status of the field, and the situation in the larger world, determine the context for any conference. The situation for ICCF16 was a combination of two factors, one long-term and evolutionary, and the other recent and possibly revolutionary.

Much to the surprise of people who think that "cold fusion" was discredited and went away about 20 years ago, the field has grown relentlessly, albeit not steadily. Each ICCF has provided more experimental evidence that it is indeed possible to produce nuclear reactions by the use of low (chemical) energies. Also, many new theories about the mechanism(s) at the root of LENR have been developed and elaborated over the years. Essentially, more "bricks" were added to the "edifice" of CMNS with the passing of each conference in this series. So, ICCF16 was expected to result in more public information about the production and understanding of LENR, which it indeed did. Those of us who have gone to most of the ICCF long ago gave up hoping for some dramatic experimental or theoretical breakthrough, which would make the field a legitimate topic for inquiry in the eyes of the broader scientific community. An experiment, which was reproducible and gave relatively high levels of excess power, or a theory that explained the many experimental observations in the field, were desired from each of the ICCF, but did not materialize. That was also the case for ICCF16.

Another possibility, which might give the field attention and respectability, could be the announcement of an energy generator based on LENR that might before long become a revolutionary practical product. In an interesting quirk of timing, such an announcement happened less than a month before ICCF16. On January 14, 2011, Sergio Focardi and Andrea Rossi conducted a demonstration in Italy for a few dozen specifically-invited people. The pair showed operation of a 10 kW device, in which energy was generated by LENR. The device apparently had an energy gain exceeding 10. The "energy gain" is defined as the ratio of the total energy from the device divided by the total energy put into it, essentially the energy amplification factor. For the Italian demonstration, the input energy was electrical and the output energy was thermal (steam).

The Focardi-Rossi demonstration greatly influenced the discussions at ICCF16. There were two presentations added to the Plenary Session of the conference about the demonstration. Francesco Celani from the Italian INFN (National Institute of Nuclear Physics), who was at the demonstration to measure gamma ray intensities, described his experiences. He noted that the public demonstration on January 14, with its energy gain greater than 10, never became self-sustaining. Celani stated that he was told that a run with the device on the day before had achieved gains exceeding 100 and might have been self-sustaining. He was concerned that the temperature was not measured precisely at the device output. But, Jacques Dufour (CNAM Laboratoire de Sciences Nucleaires) was another attendee at the demonstration. Dufour reported privately at ICCF16 that he had touched the output hose, and it felt very hot, possibly 70°C. By itself, that indicates a substantial energy gain. Celani stated that Ni and H are thought to be catalysts for the nuclear reaction of some other element(s). The composition and geometry of the key elements in Rossi's device are not known, and there was much private discussion of the possibilities during ICCF16.

Michael Melich from the U.S. Naval Postgraduate School next gave some remarks on the Rossi demonstration, and on the approach taken by Rossi to commercialization of his technology. Melich supports the idea of this community helping Rossi. Rigorous testing of his devices, both prototypes and products, by LENR researchers skilled in such measurements seems sensible. This author believes that the device demonstrated by Focardi and Rossi operates essentially as claimed. But, that remains to be better proven with more data. More thorough testing is also needed to determine, for example, its reliability over long times.

3. Opening Sessions

After an elaborate lamp lighting ceremony to begin the conference, the Inaugural Session included remarks by luminaries of science within India. Two leaders of long and productive research programs on LENR then provided their views in the Plenary Session. That session also included reports of the activities in this field within Italy, Japan, Russia and the U.S., major countries in which work is now being done in the field. Korea, which hopes to resume research on LENR, offered to host a future ICCF. This section is a brief summary of some of the main points made by the five primary speakers.

Bikash Sinha, former President of the Indian Physics Association, asserted that "cold fusion" is not dead. And, he noted that hot fusion is a long way off. There is now the possibility of serving humanity with distributed energy sources based on LENR. The scientific community should keep an open mind regarding LENR, according to Sinha.

Mustansir Barma gave the Inaugural Address. He is the Director of the Tata Institute of Fundamental Research (TIFR). The TIFR is the most prestigious basic physics research organization in India. Professor Barma began by stating that the development of this field is a scientific puzzle. The key question remains: how can condensed matter influence nuclear reactions? Put another way, how can chemical energies (eV) and size scales (nanometers) cause nuclear reactions (giving MeV) to occur on nuclear size scales (femtometers)? The disparity of scales in both size and energy is at the heart of the problem.

Mahadeva Srinivasan, Bikash Sinha, Mustansir Barma, William Collis and L.V. Krishnan on opening day. *(Photo courtesy of ICCF16.)*

Robert Duncan is Vice Chancellor for Research at the University of Missouri. He was scheduled to give the Keynote Address, but could not attend the conference due to travel problems. Michael Melich read his remarks. Duncan emphasized that the poor state of affairs regarding LENR is due to "a widespread failure of the scientific method." He noted that the method is all we have and all we need to "see this discipline come to full fruition, whatever the end point might be." Duncan recalled the early history of what are now two large and commercially important technologies, solid-state devices and high-temperature superconductors. Lack of reproducibility dogged the initial commercialization of both technologies, much as it now does for LENR. At the end of his remarks, Duncan called for patent reforms to make it possible for inventors and investors to protect LENR intellectual property.

Michael McKubre (SRI International) gave the first technical overview talk. He began by noting some of the main findings from LENR research from the past 22 years. They primarily include the reality and nuclear origins of excess heat, and observations of nuclear products, which are not dangerous. McKubre asserted that the objections of critics are losing ground. However, the field retains a stigma, which is a core problem impeding its funding and development. McKubre cited three things that are needed now. The first is ordinary scientific publication of LENR results, that is, acceptance of good papers by relevant journals. He also favors public involvement, much as NASA is able to do effectively. Finally, McKubre envisions an engineering model of LENR to advance it toward commercialization.

The second technical overview was by Edmund Storms (Kiva Labs). He summarized most of the main evidence for the reality of LENR. His list included many replications of LENR experiments, plus high quality measurements of large magnitudes of excess heat, and measurements of nuclear products, such as helium. Storms noted that all plausible artifacts, which critics said caused the observations in LENR experiments, have been rejected. In his view, rational skepticism of LENR can now be due only to ignorance of results in the field. Storms noted the value of theories in reducing the parameter space for experimentalists. He emphasized the need for theories that deal with reality.

Storms introduced a qualitative but basic approach to understanding the temperature dependence of LENR reactions rates. It expresses the rate of energy production by LENR as the product of three factors: the number of nuclear active regions, the reaction rate in each region and the square of the concentration of reactants, that is, deuterons in Pd for D-D fusion. The reaction rate within nuclear active regions increases at high temperatures. But, low temperatures favor higher concentrations of deuterons within a Pd lattice. Hence, there is an optimum region for heat production that should be between low and high temperatures.

Contributed papers on theory and experiments are reviewed in the next two sections. Then, the few presentations on two topics relatively new to this conference series are summarized. They are analytical methodologies and early engineering aspects of LENR.

4. Theoretical Reports

Theory, whatever the topic, has a pair of clear characteristics. The first has to do with its goals. They are two in number, to explain the results of past observations, or to predict the outcomes of future experiments. The second general characteristic of theory is its time evolution. A theory starts with a concept, an idea about how nature might behave. To go forward, it is necessary to write down equations based on the concept. By themselves, those equations are not particularly useful, however interesting they might be to some people. The equations become useful when they serve as the basis for computations that provide results for comparison with experiments, past or future. Two types of computations are especially important in understanding experiments and testing theoretical ideas. They are parametric variations, that is, quantitative determinations of the sensitivity of some measurable quantity to changes in the input conditions of an experiment. LENR experiments have often been done as a function of "loading," the ratio of the number of deuterons in an electrochemical cathode to the number of palladium atoms in the cathode. The other computational outputs that are particularly useful are time histories of the measurement of some important quantity, such as excess power. There are many examples of temporal variations of measured quantities in the literature on LENR.

It is fair to ask theoreticians who propose mechanisms for LENR about each of the steps in the elaboration and application to their ideas. Put another way, did any of the theoreticians at ICCF16 produce parametric or temporal curves using the equations embodying their concepts? The answer is the same as it has been for earlier conferences in this series, essentially no! That is not to disparage the theoreticians. Rather, it is a description of the state of affairs regarding theories of LENR.

It is a surprising fact that, after 22 years of serious conceptual and some computational efforts on about two dozen theories of LENR, there are almost no parametric or temporal comparisons of theoretical computational results with experimental data. The single example of a direct confrontation of theory and experiment in this field is the comparison of George Miley's transmutation data as a function of nuclear mass with the neutron optical potential model computations of Allan Widom and Lewis Larsen. The key idea is that, as the nuclear mass and diameter D increases across the periodic table, there is a peak in transmutation rate at each D where an integral number of wavelengths for the neutron in nuclear matter fits within D. The comparison does support the idea that neutrons are involved in observed LENR transmutation rates. But, it is not a complete validation of all of the ideas that constitute the Widom-Larsen theory of LENR. By the way, Miley's mass dependence of transmutation rates seems to be qualitatively in agreement with similar data from Tadahiko Mizuno. However, a direct comparison of those two data sets has not been and should be made.

There was one instance of a theoretical parametric variation reported at ICCF16. Scott Chubb (*Infinite Energy* Magazine) provided an analysis of magnetic field effects on excess power from Pd-D electrochemical experiments performed by Dennis Letts. It was found experimentally that having the magnetic field B normal to the surface of a cathode foil increases excess power compared to the situation where the B vector is parallel to the foil surface. Chubb did not arrive at a full explanation of this effect. However, he was able to estimate gestation times for electrochemical production of excess power as a function of the size of the nuclear active regions in the cathode. He found that the triggering time in LENR experiments scales as the cube of the crystallite size, being roughly 1 msec for regions about a half nanometer in dimension and almost 12 days for a volume about half a micrometer in size. The paper on magnetic triggering of excess heat by Chubb and Letts was given by Michael Melich. Another paper by Chubb, which was not presented, elaborated on ion band state theory. It was entitled "Roles of Crystallite Size, Electromagnetic Fields and Deuterium Flux in Triggering Excess Power in PdD."

The data of Mizuno played a role in the theoretical paper by Norman Cook (Kansai University) and V. Dallacasa (Verona University) in this conference. Earlier, they employed a lattice model of nuclei to explain the asymmetry in the masses of fission fragments of uranium and plutonium. The lattice model was able to rationalize the unequal distribution of atomic masses, unlike the liquid drop or other models of nuclei. This is significant because there are over 30 models of nuclear structure. Only the lattice model explains the skewed distribution of the mass of fission fragments from heavy nuclei. At ICCF16, they applied the lattice model to address the fissioning of the Pd + D system, and found a symmetrical distribution around the element chromium. The comparison with Mizuno's transmutation data was generally favorable. It remains to compare the use of the lattice structure model of nuclei to explain transmutation (and other) effects in one part of the periodic table with the optical model used by Widom and Larsen across the entire periodic table. In another paper, Dallacasa and Cook addressed localization effects for low energy deuterons in a lattice. Strong localization was found to require ordered structures for the nucleons in the lattice.

Over the years, much theoretical attention has been given to small atomic structures, sometimes called hydrinos. In general, these are entities in which electrons are bound to nuclei more compactly than in normal atoms. At ICCF16, Jacques Dufour of CNAM Laboratoire de Sciences Nucleaires postulated bound states between a metal atom and a hydrogen isotope, with sizes on the scale of picometers. He then envisioned reactions between the virtual neutron state of the shrunken hydrogen atom and nuclei in the lattice. Little heat production but significant nuclear signatures, including gamma-ray and particle emission, are expected. Because of the picometer size of the bound states in this theory, Dufour refers to the nuclear reactions as "pico-chemistry."

Andrew Meulenberg (Universiti Sains Malaysia) and K.P. Sinha (Indian Institute of Science) presented another unconventional approach to explaining LENR at the ICCF16 in terms of particular combinations of particles. They envision electron pairs, called lochons, in a hydrogen naught ($n = 0$) orbit, with properties akin to muonic hydrogen. The key similarity is small orbital radii, which permit the protons in molecular hydrogen (or deuterium) to be much closer together than normal. This leads to both similarities and differences with muon-catalyzed fusion. They were described in the report by these authors. In another paper, Sinha and Meulenberg addressed the effects of quantum-correlated fluctuations to produce enhanced tunneling within palladium heavily loaded with protons or deuterons.

Yuri Bazhutov (Ionosphere and Radiowave Propagation Institute) continued to develop his theory of Erzions, which has been presented in earlier ICCF and Russian conferences. Erzions are complex particles on the scale of quarks, which are hypothesized to explain data from space and LENR experiments. Bazhutov proposed the existence of a neutral Erzion atom, essentially super heavy hydrogen. It was computed to have a binding energy of 70 keV and an orbital size near 8 fm. Possible nuclear reactions involving this new atomic form were explored. The emission of some alpha particles and strong neutron fluxes was predicted.

R.C. Gupta (GLA University) provided a "possible explanation of how Coulomb repulsion is overcome" in LENR experiments. He made a modification of the Lorentz formula for the case of the interaction of a magnetic field with a stationary charge. The new effect, which he terms the "Gupta-Dinu effect," is a natural outcome of relativity theory. The magnitude of the effect for individual interactions is small. But, Gupta notes that the large number of electrons flowing in some LENR experiments produces a total force strong enough to overcome the Coulomb barrier.

Arunachalam Lakshmanan of the Saveetha Engineering College addressed the compatibility of ionic crystal lattice-assisted fusion and thermonuclear fusion. He is concerned about linking proton-proton fusion at low temperatures to hot fusion, that is, reaching the latter process via the former process. Lakshmanan seeks to understand an experiment in which a solution of Mg_2SO_4 is subjected to cavitation to product nano-crystals. The accumulation of the energy of hydration to reach hot fusion temperatures and P-P fusion is hypothesized in this model.

Vladimir I. Vysotskii (Electrodynamics Laboratory "Proton-21") and S.V. Adamenko (Kiev National Shevchenko University) presented work on a universal mechanism that makes LENR possible due to correlated states of interacting particles. The presence of partial correlations of their different eigenstates produces a correlated "superpositional" state. This leads to coherent summation of momentum fluctuations of the eigenstates, and reduction of the Coulomb barrier.

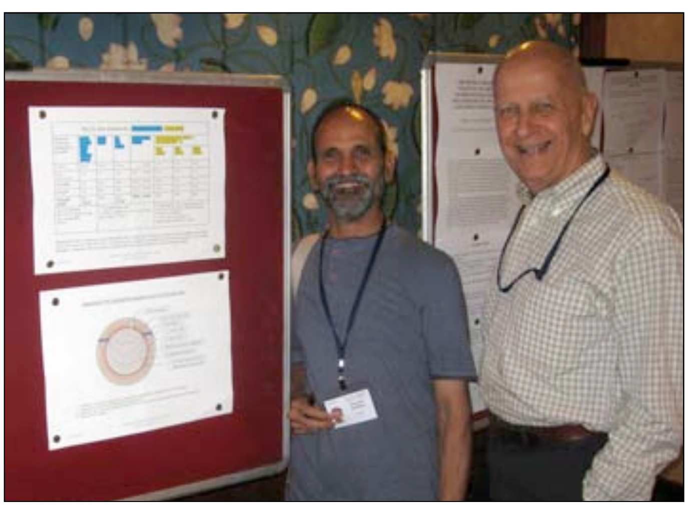
In another paper, Vysotskii and M.V. Vysotskyy (Kiev National Shevchenko University) addressed the reasons for large-size neutron-nucleus "molecules" and related anomalies for long-distance LENR. Their theory leads to the concept of relatively distant potential wells, which make possible the existence of quasi-stationary neutron-nuclear entities analogous to molecules. These, in turn, can produce fusion and fission reactions.

Fulvio Frisone (University of Catania) addressed the core problem of D-D fusion. He developed a coherence model involving the three plasmas within a lattice: electrons, ions and deuterons. The model leads to deuteron-phonon-deuteron interactions reminiscent of the electron-phonon-electron interactions that form Cooper pairs in superconductors. In Frisone's theory, phonon exchange leads to spacings between deuterons that are in the range of 0.016 to 0.07 nm, greatly increasing the fusion probability.

Vasudev Godbole (B.Y. Zentrum Germany) theorized that LENR might be explained by the smearing of the deuteron or hydrogen wave functions in a lattice of heavier ions with chargeless quarks. He has designed an experiment using coated Pb nano-particles subjected to a fast pulse of energy, possibly from a Van de Graaff accelerator.

There were a few theoretical papers scheduled but not presented at ICCF16. Brief synopses of those papers from their abstracts follow.

Peter Hagelstein (Massachusetts Institute of Technology) and Irfan Chaudhary (Lahore University of Engineering and Technology) modeled the excess heat generated in LENR experiments. They assumed that the emission of alpha particles was commensurate with the measured heat. Then, they computed the yields of various reactions that would follow from such energetic alpha particles moving within a lattice. Their main result is that it should be possible to detect the presence of those particles through their effects, if they exist in numbers and with the energies indicated by the measured heat.



Vasudev Godbole (left) with the author. *(Photo courtesy of David Nagel.)*

Irving Dardik and Shaul Lesin (Energetics Technologies) provided an abstract on "The Theoretical Basis of SuperWaving LENR." Experiments in their laboratory in Israel, at SRI International in the U.S. and at ENEA in Italy, all based on superwaves, have been very successful in producing excess heat. In those experiments, a novel current driving function, formed of a self-similar pattern of waves with fractal character, was employed. Those complex waveforms are termed superwaves. Their use provides different dynamics in electrochemical cells, leading to significant excess heat production in many experiments.

It seems to this author that there is a need for culling out some of the two dozen LENR theories, and much increased attention to the concepts that survive scrutiny. Some of the theories seem to be at odds with observations. As already noted, there is a need for computations of parametric and temporal variations for comparison with existing data. Almost all LENR theories have not been adequately compared with information from experiments other than LENR. Reducing the number of theories getting active considerations is not easy, either technically or practically. However, it would speed progress and improve the reputation of the field in the broader scientific community.

Overall, presentations and scheduled papers on theory constituted about 30% of ICCF16. Experimental papers contributed somewhat over half of the conference. Those presentations are summarized in the next section.

5. Experimental Reports

Qualitatively, the overall situation at ICCF16 for experimental presentations was much like earlier conferences in the series. There were some reports of new types of experiments and others that were extensions of experiments, which were reported earlier. The classification of LENR experiments is somewhat arbitrary. One way to categorize them is by the means used for "loading," that is, the bringing together of either protons or deuterons with a metal lattice. Another approach is to bin them by what was measured, regardless of the means of loading. The organizers of ICCF16 employed both approaches, with sessions on electrochemical and gas loading, mainly with heat measurements, and other sessions on analysis of transmutation products and particle measurements. That format will be followed in this section. Separate attention will be given to the central issue of materials at the end of this summary of experimental reports at ICCF16.

Electrolysis Experiments

It is widely known that this field started with electrochemical loading of deuterons into Pd and excess heat measurements using calorimeters. Those two processes are still significantly studied. They and other approaches were reported at ICCF16.

Melvin Miles (Dixie State College) has been studying co-deposition in Pd-D systems using an ammonia chemistry similar to what is employed commercially for deposition of Pd. An issue in such work is the possible role of shuttle reactions. They are chemical reactions in which a substance produced at one electrode is consumed at the other electrode. His paper on an experimental study of possible shuttle reactions resulted in nine lines of evidence against the significance of such reactions. Miles also presented the results of experiments producing co-deposition of ruthenium. He found no excess heat for either H_2O or D_2O in those experiments.

Ashraf Imam (Naval Research Laboratory) produced two kinds of alloys, Pd with B and Pd with both B and Ce. Interestingly, Miles and Imam obtained U.S. patents on the materials in 2004 and 2008. At ICCF16, they presented an overview of the materials and the calorimetric experiments done with them. The Pd-B materials gave excess energy, in contrast to the Pd-B-Ce materials, which did not exhibit excess heat. The excess energy from the Pd-B materials started relatively quickly in the experiment, even at low current density and low cell temperature.

Triggering, that is, initiation of LENR has long been a topic of interest. Such control of excess power production is necessary for both understanding and applications. Francis Tanzella, Jianer Bao and Michael McKubre (all of SRI International) reported on a study of stimulation of LENR in PdD_x wires at liquid nitrogen (LN) temperatures. They achieved loading ratios (D/Pd) near unity, and then electrochemically sealed the D inside of the Pd wires. The wires were put into LN and exploded with electrical pulses with 10^5 A/cm^2. The amount LN boil-off indicates quantitatively the deposition of electrical energy and the production of energy. Excess energy was observed from D-loaded wires.

In a new type of experiment, Brian Roarty (Los Altos, CA) and Carol Walker (Ojai, CA) reported a protocol for silicate-based LENR using various electrodes, including Pd, Ag, Au and Pt. Pd worked best. Electrical (direct current or radio-frequency) and optical (light from white LEDs) inputs provided the stimuli to push the cell temperature over the boiling point for solutions containing silicates. Evidence of nuclear processes includes (a) fast temperature transients, (b) scanning electron micrographs showing that parts of the Pd electrodes exceeded their boiling points, and (c) measurement of transmutation products using Auger and X-ray analyses.

Yuri Bazhutov and his colleagues from several Russian organizations reported calorimetric and nuclear phenomena in plasma electrolysis experiments. Voltages of 200 to 700 V and currents of 1 to 10 A drove reactions in 5 to 10 M NaOH. Ni foils were the cathodes and W rods the anodes. Thermocouple calorimetry evidenced heat production. Tritium was measured with a scintillation system. A radiometer detected hypothetical particles, which the group calls Erzions.

R.C. Gupta (GLA University) has an academic background in welding. He and his students conducted an experiment using an arc plasma from a welding power supply within a saline solution. They did an energy balance, and report 25% more energy was observed than was supplied electrically. This excess energy is attributed to LENR.

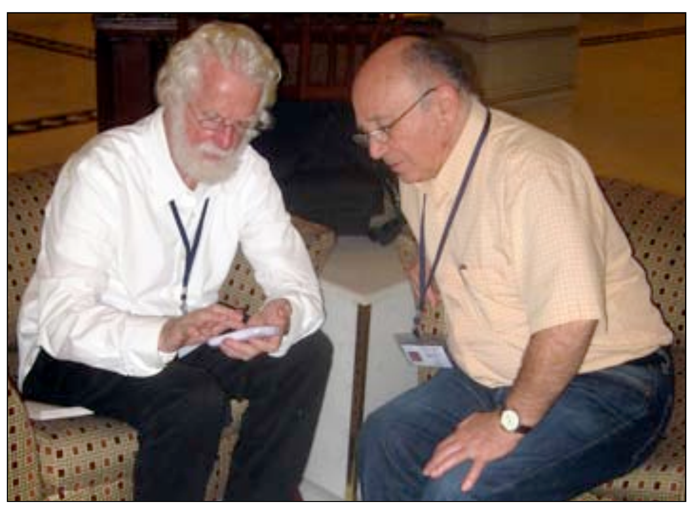
Genadi Tarasenko (Caspian State University of Technology and Engineering) performed experiments using an electric discharge in a solution of water with soda ash. He reported that oil, coal and diamond chips resulted. The results lead him to conclude that LENR occur in the earth's crust.

One of the few unfortunate aspects of ICCF16 was the inability of Chinese scientists to make it to the conference. Wu-Shou Zhang (Chinese Academy of Science) was to present a paper on "Progress of Reproduction of Excess Heat in Pd/D_2O and D_2SO_4 Electrolytic Cells." His abstract reports that excess heat is observed after electrolyzing for only a few hours. Another paper that could not be presented was entitled "The Observation of Abnormal Phenomena in a $Pt(H)/K_2CO_3/Pd$ System During Its Electrolysis and Triggered by an UltraSonic Generator" by Jian Tian *et al.* (Changchun University of Science and Technology). Observation of low levels of excess power is reported in their abstract. Spectrophotometer data indicated that K was converted to Ca and energy. Ultrasound produced cavitation and quenched the production of Ca and heat.

Several Russian researchers, who submitted abstracts, were also unable to participate in ICCF16. D.S. Baranov and O.D. Baranova (UIHT Russian Academy of Sciences) provided an abstract with the title "Production of Neutron-rich Bi Isotopes and Hypothesis About Formation and Decay of Long-living Nuclear Molecules." Electric fields were applied to solutions of Bi salts. New isotopes, such as ^{212}Bi, were observed. Streams of 5 μm particles from the experiment were also found. The isotope data was interpreted as indicating the existence of long-lived nuclear molecules. Their properties were considered.

Electrochemical loading of D into Pd remains the most studied of the means to bring together solids and either hydrogen or deuterium nuclei. However, the experiments

Genadi Tarasenko *(Photo courtesy of ICCF16.)*



Roger Stringham and Jean-Paul Biberian *(Photo courtesy of David Nagel.)*

are relatively complex. They involve equipment ancillary to the core cell that is similar to what is called the "balance of the plant" for fuel cells.

Gas Loading Experiments

The already high interest in gas loading was greatly increased by the demonstration by Focardi and Rossi prior to the conference. And, it is thought likely that the first commercial energy generators based on LENR would use gas rather than liquid (electrochemical) loading. Cyclic loading and deloading of H or D into and out of nano-materials are part of many contemporary gas loading experiments.

Francesco Celani and his co-workers at the Italian INFN reported progress in a series of experiments spanning three years. Their system works at relatively high temperatures (more than 300°C) where the Carnot efficiency for conversation of thermal energy to mechanical work is favorable. They use long (50-100 cm) and thin (100 µm) Pd, Ni or Pt wires at pressures not exceeding 10 atmospheres. The wires are coated with nanometer scale materials to improve loading and act as catalysts. The materials are Pd or a mixture containing B, Ba, Sr and Th. They obtained 5 W of excess power at 550°C, equivalent to a power density of 400 W/gm of Pd. With Ni and H, they measured 26 W at 850°C, which corresponded to 1,800 W/gm of Ni.

Olga Dimitriyeva and her collaborators from Coolescence and the University of Colorado at Boulder sought to understand the mechanisms for heat generation during deuterium and hydrogen loading of Pd nano-materials. They observed heat production (liberation) with finely divided Pd supported on alumina powders. Varying the pressures and loading rates produced correlations between the exothermic and endothermic aspects of the experiments. It was shown that the generated power is proportional to the pressurization rate times a quantity they called "fuel." There are two types of fuel that can trigger either exothermic or endothermic reactions, depending on the gas (deuterium or hydrogen) used in the experiment. Heat generation during the pressurization phase is most likely of a chemical nature.

David Kidwell and his colleagues at the Naval Research Laboratory have been doing conceptually simple experiments loading and deloading Pd sub-nanometer particles within zeolites with both hydrogen and deuterium gas. Excess heat is observed with deuterium but not with hydrogen. It is possible that the observed heat can arise from exchange of D for H in –OH or H_2O present on the substrate. Four spectroscopic techniques were employed to address this possibility. It was found that the D-H exchange cannot account for the excess heat observed with deuterium gas. Kidwell and his team also sought to detect nuclear products. ^{4}He, X-ray, light and particle measurements were employed. No evidence of ^{4}He ash or energetic processes was obtained.

Ashraf Imam and his collaborators (Naval Research Laboratory) aimed to reproduce the results of Yoshiaki Arata and his colleagues. Pd-Ni-Zr materials were reported by Arata *et al.* at ICCF15 to produce more excess heat with deuterium than with hydrogen. However, others did not see excess heat in commercial materials of similar composition. That was also the case for Imam *et al.* Hence, they made, characterized and evaluated a large series of materials. They have not been able to adequately reproduce the preparation of oxidized Pd-Ni-Zr nano-materials. Heat evolution is observed, but some of it is explicable as the formation of Zr hydrides. Further, the heat measurement experiments were not consistent with each other. It was noted that the materials might be useful for hydrogen storage.

A large Japanese collaboration from Kobe University and Technova is also doing gas loading experiments stimulated by the work of Arata. They are working with a wide variety of nano-materials containing Pd, Ni and Zr. They have a twin system in which hydrogen is used on one side and deuterium on the other. Both sub-systems permit the forced de-oxidation and controlled oxidation of samples. The time dependencies of the absorption and desorption of the two gases, and the associated energetics, are measured. At ICCF16, Akito Takahashi reported on their studies of three different metal-oxide composites. Some differences between hydrogen and deuterium behavior were reported by the group.

Y. Arata and two colleagues (Osaka University) submitted an abstract to ICCF16, but were unable to attend the conference and present the paper. Their title was "Evaluation of Vibrator on Production of Helium and Energy in the 'Solid Fusion.'" Their apparatus was improved in two ways, by inclusion of an ultrasonic agitator and by addition of an outer low vacuum chamber to decrease thermal losses. Heat and helium were measured using the new set-up.

Two papers from researchers in China were scheduled but not presented. The first was by Q.M. Wei and a group from Tsinghua University. Their title was "Excess Heat in Long Thin Palladium Tube at Room Temperature Using Gas-Loading Method." The team has been doing gas loading and permeation experiments with deuterium and Pd for 20 years. Over those years, the work evolved from using low temperatures (77 K) and high pressures (9 atmospheres) to using high temperatures (140°C) and low pressures (80 kPa). Earlier, they found a correlation between excess heat and deuterium flux. Their new results show that the excess heat cannot be of chemical origin.

The other abstract on gas loading from China was by Jian Tian and his colleagues (Changchun University of Science and Technology). The title was "Excess Heat Triggering by Pumping Effect in a H-Pd Gas Loading System." Tian *et al.* had measured excess heat in an earlier experiment, but could not sustain power densities exceeding 10 W/cm^3. After redesigning the initial experimental set-up, they sought excess heat for six years. Even at low input and output powers, and very low loading ratios (0.014), power densities of 50 W/cm^3 were obtained during 100 sec bursts.

The final paper on gas loading was also not presented. Sergey Tsvetkov from Zarechny in the Sverdlovsk Region of Russia submitted an abstract entitled "Initiation of the Cold Fusion Reactions by Air Components." Deuterium and the components of air were reacted with Ti. The experimental results pointed to the release of heat and neutrons. The application of this methodology for the transmutation of nuclear waste was envisioned.

This conference might have had more interest in gas loading, on a relative basis, than any of the earlier ICCF. It seems likely that attention to gas loading will continue to grow.

Measurements of Transmutation Products

Many LENR researchers think that heat measurements for any method of loading are merely inferential for the occurrence of nuclear reactions. They prefer the measurement of the products of such reactions, often called "nuclear ash." Detection of reaction products generally requires sensitive measurement of low levels of specific elements or isotopes before and after experiments. Such work is both challenging and expensive.

Among the most important and provocative efforts on transmutations have been the studies reported by Yasuhiro Iwamura and his colleagues (Mitsubishi Heavy Industries) during the past decade. The experiments use deuterium permeation of complex nano-structured Pd-based foils. In the paper presented at ICCF16, a new technique was brought to bear on the determination of the H distribution in the foils. Micro-beam Nuclear Resonant Analysis was used to measure the three-dimensional H isotope distribution during permeation. The group also reported early results on transmutation of W. Band structure calculations are being used in an effort to understand the environment in which the transmutations occur.

John Dash (Portland State University) was among the earliest workers to report the production of pits on cathode surfaces from heavy water electrolysis, and the appearance of unexpected elements in their vicinity. Dash and his colleagues had reported that mass spectra from electrode materials showed inversions of isotopic abundances. In his ICCF16 paper, he presented the results of experiments in which the cathodes had been scratched prior to their use in experiments. Energy dispersive X-ray analyses were made in and near the scratches. Localized concentrations of silver were found within scratches. They were interpreted to indicate that LENR are not confined to the outermost layers of the cathodes. Mathieu Valat, also from Portland State University, reported on Pd isotopic variations after LENR experiments. The data were obtained by ion milling and secondary ion mass spectrometry. Preliminary results are in agreement with published results of similar studies.

Yuri Bazhutov and a team of coworkers from five Russian institutions observed large densities ("swarms") of pits in plastic solid-state detectors exposed in space. They interpret the observed pits as due to interactions of Erzions with the plastic detector materials.

Another paper from Russia that could not be presented at the conference was "Stimulation of Low-Energy Nuclear Reactions in the Gas Discharge" by Irina Savvatimova of the Federal State Enterprise Scientific Research Institute "LUCH." The abstract reports that a variety of diagnostic methods was used to identify elements and their isotope ratios. Changes in isotope ratios as high as 1,000 were reported.

The number of reports of transmutation reactions is already large, and grew significantly as a result of ICCF16. It will be interesting to learn over the years (decades?) whether or not the ability to transmute elements becomes practically important for remediation of radioactive waste or any other purpose, such as the production of technologically valuable elements.

Particle and Other Measurements

To some scientists, the best evidence of the occurrence of nuclear reactions in LENR experiments is the observation of energetic particles. This inclination is due to the fact that chemical processes cannot generate fast ions, neutrons, gamma-rays or X-rays. So, there were some papers on nuclear particle and radiation detection at ICCF16.

Two new types of experiments, for which particle detection was the primary measurement, were presented at ICCF16. In one, A. Manuello and his colleagues from Politecnico di Torino and the INFN (National Institute of Nuclear Physics) detailed the results of tests in which neutron emission was detected by both bubble detectors and ^{3}He counters during compression tests of granite and basalt specimens. Peaks in neutron intensity were observed at the times of fracture. The authors conjecture that iron undergoes piezonuclear fission reactions to yield Al, or else Mg and Si. Their hypothesis was reported to be confirmed by energy dispersive X-ray analysis. Implications for the abundance of iron in the earth's crust were discussed.

Andrea Petrucci and his colleagues of the University of Roma Tre and Institute of Nanostructured Materials have done piezonuclear experiment for the past six years. They irradiated solutions of iron in water with ultrasound, and observed neutron emission. That work led to the experiments reported at ICCF16. They recently subjected iron bars to ultrasound, expecting small bubbles within the bars to be affected similar to cavitation bubbles in water. Different neutron spectra were obtained without and with the ultrasound. Further, circular damage regions appeared on the surfaces of the bars. X-ray microanalysis of the affected regions showed variations in the concentrations of several elements, compared to undamaged regions.

Roger Stringham (First Gate Energies) has been performing sonofusion experiments and reporting the results at sequential ICCF for many years. The collapse of an acoustically-produced cavitation bubble on the surface of a solid material causes a small and fast "beam" of particles from the liquid to impinge on the solid. The result is the production of heat and the ejection of atoms from the solid with the formation of high areal densities of pits. Stringham attributes the results to the transient formation of Bose-Einstein condensates. He routinely achieves production of excess heat.

Jirohta Kasagi and his colleagues from Tohoku University, Lanzhou University and the Toyota Central R&D Research Laboratories have done ion beam experiments to determine D-D fusion cross sections at relatively low incident energies (around 1 keV). Kasagi found over the years that there is a very significant and growing increase in the fusion cross section as the beam energy is decreased. In that work, they determined the environmental (solid-state) effects on the penetration of the Coulomb barriers, that is, on the ability of incident D ions to tunnel *into* a target nucleus and fuse with another D nucleus. At ICCF16, Kasagi reported the early results of a new kind of experiment to determine the ability of alpha particles to tunnel *out of* the nuclear potential well of a decaying radioactive nucleus. Deuterons with 15 keV bombarded a plate of ^{147}Sm, which emits alpha particles with a long half-life. The fast transient effects of the incident ion tracks change the environment in which a radioactive decay can occur. The initial ratio of the alpha particle count rate with and without the beam was 1.25 +/- 0.31. This suggests the existence of a dynamical screening effect due to the incident ions. Better statistics will be obtained in the continuing experiment.

Two papers from Russian scientists on particle and X-ray measurements could not be presented. The first was by Ivan Chernov and his colleagues from the National Research

Tomsk Polytechnic University and three other Russian institutions. It was titled "Fusion of Deuterium Nuclei in TiD Systems Stimulated by X-Rays." This team measured emission of energetic protons and alpha particles from D-D fusion in Ti/Ti:D_x targets that had been irradiated with X-rays. Substantial increases in the rate of D-D fusion were observed in comparison to earlier experiments in which an electron beam was used instead of X-ray irradiation.

Alexander and Elena Karabut from the Samar+ Company and the Moscow Power Engineering Institute, respectively, have studied the emission of X-rays from materials exposed to plasmas for several years. They provided an abstract entitled "Research into Excited Long Lived 0.6-6.0 keV Energy Levels in the Cathode Solid Medium of Glow Discharge by X-ray Spectra Emission." Many different cathode samples were subjected to a high-current glow discharge. X-ray spectra from the materials were measured using a bent crystal instrument with photographic recording. The X-ray emission was reported to persist for as much as 20 hours after the current producing the glow discharge was turned off.

The measurement of energetic particles from LENR experiments has two sides. If such particles were produced in easily-measured amounts, they would be very useful scientifically. But, the emission of energetic photons, neutrons or ions is not attractive from the viewpoint of applications.

Materials Considerations

The electrochemical calorimetry measurements using electrodes of Pd-B and Pd-B-Ce by Imam and Miles have already been noted. There was a great deal of attention to nanometer-scale particles and metal-oxide interfaces at ICCF16. Now, we turn to the four papers at ICCF16 that were specifically on materials.

Currently, the large and productive multi-institutional collaboration in Japan studies nano-materials and uses them in simultaneous hydrogen and deuterium gas loading experiments. Akira Kitamura (Kobe University) reported on the study of Pd-Ni-Zr materials. He and his colleagues tested six different types of metallic and oxide-coated metal nanomaterials. Several techniques were employed, including imaging methods (SEM, TEM and laser Raman microscopies), an analytical technique (Proton Induced X-Ray Emission, PIXE) and X-ray diffraction. Some structural changes were observed after absorption experiments.

The metal-oxide interfaces were the focus of a talk by Dawn Dominguez and her colleagues (Naval Research Laboratory). It asked and addressed the question of whether or not such interfaces are necessary for LENR. They play a role in the gas permeation experiments of Iwamura and his coworkers, as well as in the several nano-particle experiments following Arata's lead. The salient point is that large electric fields (approaching 10 V/nm) can exist in oxides, such as zeolites. Dominguez provided data that showed the observation of excess heat only when oxide interfaces were present.

Vittorio Violante and his coworkers from ENEA CR Frascati and SRI International have played a leading role in the study of Pd foil materials for electrochemical experiments for several years. In particular and importantly, they correlate material properties with the achievement of excess heat in electrochemical cells. At ICCF16, Violante showed that two observed material characteristics favor production of excess heat. The first is a <100> orientation of the surface grains on the foils. This is reasonable since the <100> face of Pd is more open than either the <110> or <111> faces. The second is a particular power spectral density of surface roughness obtained from Atomic Force Microscope measurements. A rationale for this observation remains to be developed. Emanuel Castagna from the same team gave a paper elaborating on the correlations between surface properties and the generation of excess heat. The group also ascribes importance to the nature and content of impurities and defects. These are not adequately known and, hence, cannot be correlated with the production of excess heat.

There is much more about the effects of materials on the course of LENR experiments than could be presented in the main conference. So, the organizers of ICCF16 scheduled a workshop for a day and a half right after the conference. It was held at a resort about 30 miles south of Chennai. Over 50 Indian and foreign scientists participated in the workshop entitled "Materials Issues in LENR Devices." Presentations by a few of the ICCF16 attendees were largely reruns of their talks at the main conference for the benefit of the Indian researchers who could not attend ICCF16. Presentations by leading Indian scientists showed some of their remarkable research capabilities, which might be brought to bear on the study of LENR. The application of their expertise could significantly advance the field.

There has been strong interest in the transmutations of materials in LENR experiments for most of the history of the field. Hence, another post-conference workshop was held at the SRM University in Chennai. It was titled "Biological Nuclear Transmutations: Historical Perspective and Applications." Experiments have shown that elemental transmutations occur in a wide variety of low temperature experiments. This workshop focused only on those due to the action of living entities. It had more than 350 participants, most of them students. Reviews of data in the field were presented. The possibility of using biological processes to remediate waste from fission reactors was also discussed.

This author believes that it is both timely and very desirable to write reviews of the various types of experiments on LENR. Such consolidation of knowledge on the different means of loading and on results from the numerous ways of making measurements would serve the community of active researchers. It would also greatly facilitate entry into the field by new experimenters. There are two recent examples of such reviews. An excellent compilation of gas loading experiments with 158 references was written by Jean-Paul Biberian for ICCF14, and is available in the proceedings (p. 370) of that conference: (http://www.iscmns.org/iccf14/ProcICCF14a.pdf). A new and very useful compilation on transmutations with 101 references was distributed at ICCF16. It is entitled "Low Energy Nuclear Reactions: Transmutations" and was written by Mahadeva Srinivasan, George Miley and Edmund Storms. The article is a chapter in the *Wiley Encyclopedia of Energy and Technology* (Volume 1) edited by Steven Krivit.

6. Analysis of Data

LENR is a field rich with experimental data, and much of it is published. Most LENR data might still be available electronically from the experimenters who acquired the data. Since many LENR scientists are late in their research careers, this availability might not last for too many more years.

Data analysis has always been a part of the experimental study of LENR. However, it has not generally been a theme at any of the ICCF. Such was also true at ICCF16. That is, there were no sessions specifically on data analysis. But, there were four papers in various other sessions, which are summarized here.

For the past few years, Rodney Johnson and Michael Melich (U.S. Naval Postgraduate School) have been using probabilistic methods of scientific inference ("Bayesian networks" in particular) to evaluate the strength of the evidence from LENR experiments. At ICCF14, they employed eight papers from a data base compiled by Dennis Cravens and Dennis Letts to compute a likelihood ratio of about 10-to-1 in favor of the reality of the Fleischmann-Pons effect. At ICCF16 they reported that computational limitations, which restricted the size of the data base that could be examined, had been overcome. The key step was discovery of a mathematical relationship that allowed easy and exact computation of the likelihood ratios. When the entire Cravens-Letts data base was used, the likelihood ratio was unrealistically large, a sure signal that something important was absent from the analysis. The most likely suspect was "publication bias," the tendency of research communities to publish only results that affirm their view of the "truth." Current work by these authors employs a new inference model (network), which includes publication bias and will yield a more realistic likelihood ratio.

Melvin Miles and Peter Hagelstein offered a paper on a new analysis of the MIT calorimetry, details of which were published in 1990. They found an experimental design error that led to the major heat loss pathway from the calorimeter being out the top rather than into the constant temperature heat bath surrounding the experiment. This accounted for the high sensitivity of the MIT system to room temperature variations and to electrolyte levels. The MIT calorimeter was about 400 times less sensitive than the Fleischmann-Pons dewar calorimeter as a result of its poor design.

There are some reports of diurnal effects on the output of LENR experiments. Felix Scholkmann (University Hospital Zurich), Tadahiko Mizuno (Hokkaido University) and David Nagel (The George Washington University) provided a new analysis of data from a high-pressure and high-temperature electrolysis experiment by Mizuno. The D/Pd loading ratio, pressure and temperature were measured in that experiment and varied on a daily basis. The new study resulted in quantitative measures of correlations between the measured values. However, it did not shed any new light on whether the diurnal variations are artifactual or not. The analysis did provide an example of the statistical analytical methods that can (and should) be brought to bear on LENR data.

Data on the character and size of the craters that occur in cathode materials in many LENR experiments were analyzed by Nagel. Simple estimation of the energy required to melt or vaporize the volume of material in the observed craters provides one way to obtain the energy required to form them. A new method for deducing such energies was developed. It involves extrapolation of known large crater sizes and energies to the 1-100 μm range of observed LENR crater diameters. Energies for crater formation in the range from nJ to mJ were obtained. The mechanism of crater formation remains unknown.

It seems that there are many opportunities to perform more analysis on data from LENR experiments. Numerous algorithms and codes for operations, like Fourier transforms to obtain the frequencies that might be hidden in time-series data, are available. Such analyses can be performed during and after the experiments.

7. Early Engineering

Past ICCF did not have substantial attention to the engineering design, fabrication and testing of LENR energy generators. In contrast, ICCF16 did contain a few papers that went beyond the usual scientific studies. This trend reflects the general maturation of the field, and also the impact of the Focardi-Rossi demonstration shortly before the conference.

Concerns over experimental reproducibility, triggering and control of LENR experiments have been a major part of the field since its beginning. Given the existence of energy-producing devices based on LENR, a new concern has arisen recently. It can be termed validation, that is, the experimental testing of an existing LENR power source to ascertain its characteristics and to prove that it works as claimed by an inventor.

David Knies (Naval Research Laboratory) presented a paper at ICCF16 by Kenneth Grabowski and other colleagues, which outlined procedures for robust testing of LENR energy sources. Thoroughness, and the ability to answer all criticisms with data, are hallmarks of that paper. The abstract of the paper asserted, "Such validation testing is a prerequisite to the sale of existing or evolved prototypes, acquisition of any rights to intellectual property, or investment in the further development of technology embodied in the existing prototypes. Prospective customers and investors should demand to learn the performance characteristics, and be able to review the results of such rigorous tests." Methodologies for thoroughly-calibrated and redundant measurements using mass-flow calorimetry were presented.

Kamron Fazel (Pennsylvania State University) and Nagel looked ahead to the engineering optimization of sources of energy based on LENR. It takes energy to produce energy. In the case of gas loading devices, energy must be expended to achieve the high pressures required in some devices. This paper provided a graph of the initial energy expenditure for pressurization as a function of the system volume and the final pressure. Optimization of energy production was the focus, but it was noted that the many engineering "ilities" are also candidates for improvement of LENR energy sources. They include adaptability, availability, compatibility, dependability, durability, maintainability, operability, portability, predictability, recoverability, reliability, scalability, stability and usability.

Igor Goryachev and Vladimir Kuznetsov from the Kurchatov Institute had two papers at ICCF16 on important potential applications of LENR, including and going beyond energy production. The first was on using such reactions to remediate radioactive waste from fission (and later hot fusion) reactors. It is but one of many applications of LENR envisioned by these authors. The range of contemplated reactors and their uses are listed at: http://www.cpfi.by.ru/CAPR%20site.files/CAPR%20Hystory.htm. The second ICCF16 paper by Goryachev and Kuznetsov dealt with desalination of sea water. Their approach is not the usual method of making energy to distill water. Rather, they believe that it might be possible to transmute the atoms of salts present in sea water into silicon oxide and gases. Necessarily very large-scale facilities are envisioned.

Scientists working on LENR are very familiar with the plethora of names associated with the field. The core reasons for that uncertainty are lack of knowledge of the detailed mechanism(s) causing LENR and the natural human desire to be the one to name the field. Now that energy sources based on LENR are becoming a reality, the question of what to call them arises. LENR might come to be understood also as "Low Energy Nuclear Reactors." But, calling devices, in which low energy nuclear reactions produce power, "reactors" could lead to confusion with fission sources of nuclear power. Generic names, such as energy "sources" or "generators" would be serviceable, but lack distinction. Maybe, only specific product names, such as Rossi's ECat (energy catalyzer), will be employed. But, there will probably emerge a general name for LENR power sources, especially if a new nuclear power industry develops because of these reactions. SANER (SAfe Nuclear Energy Release) is one possibility to describe the processes active in LENR experiments and energy sources. Time will tell.

8. Comments and Conclusions

There are two engineering aspects of LENR generators that need attention. One is an analysis of potential applications as a function of the output power levels. It is assured that the applications of such devices will be power dependent. It is not yet clear over what power range individual LENR devices might operate. However, enough is known about the current and potential LENR energy sources to make early engineering estimates of their utility. The other related engineering characteristic that needs attention is very fast energy releases, that is, high power outputs for short periods of time. For chemical energy sources, there are large differences in applications between (a) controlled burning of gas, oil or coal, (b) employing propellants for missiles and launch vehicles, and (c) the use of explosives for mining or weapons. It remains to be seen if LENR will release energy over such diverse power ranges, and if brief and very high-power releases can be reliably controlled.

Returning to more near-term concerns, there seemed to be something of a bimodal distribution of opinions at ICCF16 about the Rossi demonstration. There was great interest, of course. The demonstration might be the beginning of the end of isolation and derision of the field. However, there were and remain concerns about the thoroughness of tests of Rossi's devices, and other similar sources, which might emerge. Now, when it appears possible to produce significant powers with LENR in compact devices, it seems likely that competitors will emerge before too long. That expectation was stated by P.J. King (ReResearch). All tests of new LENR sources should be thoroughly planned, conducted, analyzed and reported. A checklist for how to conduct rigorous performance validation tests is available on the web: http://www.lenr-canr.org/acrobat/NagelDJchecklistf.pdf

ICCF16 provided more reports of steady theoretical and experimental progress toward understanding and using LENR. The conference exhibited the usual evolution as new topics got added and older ones, such as coherence effects, received less attention. A comment was made that past critics of the field have been defeated, although they might not realize that yet. The point is that scientists in the field have diligently responded to and laid to rest diverse concerns about the conduct of major LENR experiments.

A perspective on the potential practical importance of LENR energy sources can be obtained by comparing hot and "cold" fusion. A paper by Nagel in the last issue of this magazine, which was also presented at ICCF16, provides a vivid contrast. Energy gains [= (energy out)/(energy in)] of over 25 were reported by Energetics Technologies at ICCF11 over six years ago for the Pd-D electrochemical system. Last year, Focardi and Rossi reported energy gains as high as 415 in the Ni-H gas loaded system. This year, those authors demonstrated a device with an energy gain exceeding 10. It is possible that LENR energy gains will be greater than 1,000, even without burning. Reliable achievement of self-sustaining, that is, burning LENR reactions could lead to enormous energy gains. That would be the nuclear equivalent of using only one match to set afire and burn a heap of logs.

The International Thermonuclear Experimental Reactor (ITER) is the next large hot fusion experiment. The goal of that project is an energy gain of 10. ITER will cost about $20B and take another ten years to reach maturity. If it works as hoped, other larger experiments will be needed before hot fusion produces commercial power from very large stations, which will produce substantial radioactive waste. By comparison, LENR offers the possibility of small, distributed, safe and green energy sources that do not give significant radioactive waste. Hot fusion may not produce useful power for three or four more decades, if it ever achieves that capability. By contrast, LENR power sources for industrial and even consumer use might be common in one or two decades. It seems that LENR sources of nuclear energy will be substantially better for the environment than large hot fusion reactors.

In conclusion, it is clear that ICCF16 was a very successful conference, despite its relatively small size. The organizers, led by Mahadeva Srinivasan, are complimented for the conference and for the three satellite meetings. A few other ICCF have had preliminary schools. However, the innovations of the organizers of ICCF16 in scheduling two post-conference workshops, and also an impromptu, but significant seminar and panel discussion at the Indian Institute of Technology (Madras), insured that, in the words of Srinivasan, a large "footprint" was left in India. It seems highly likely that experimental study of LENR will again be pursued at some very capable institutions in India.

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About the Author

David J. Nagel is a Research Professor in the School of Engineering and Applied Science of The George Washington University in Washington, D.C. He attended all of the ICCF, chaired ICCF14 and provided the conference summary for ICCF15.

*Email: nagel@gwu.edu