20th International Conference on Condensed Matter Nuclear Science

Part 2: Theory and Other Topics

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In the last issue of this magazine, an introduction to ICCF20 was provided.[1] It acknowledged the two scientists who organized the conference, Professors Jirohta Kasagi and Yasuhiro Iwamura, both from Tohoku University in Sendai, Japan. Figure 1 provides images of them. In that first part of the conference summary, roughly half of the papers given at ICCF20 were reviewed in detail. The rest of the review follows below. This part starts with a long discussion of the many theoretical ideas advanced at the conference. Theory is one of the most important and most complex parts of the field of LENR. After the review of theoretical papers at ICCF20, papers on applications, some diverse topics and policies relevant to LENR will be summarized. Other activities associated with ICCF20 are noted, prior to a few general comments on the field. The section numbers in this Part 2 are a continuation of those in Part 1 of the conference review.

9. Overview of Theories About LENR

The understanding of LENR is both a scientific and a practical problem. Knowing both the mechanism(s) that cause LENR and the factors that influence their rates are basic to really understanding how it is possible to cause nuclear reactions with chemical energies. Such knowledge will enable engineers and businessmen to more efficiently develop commercial thermal and electrical power generators based on LENR. This dual situation, where LENR is both a marvelous scientific challenge and a promising commercial technology, has been the case from the earliest days of the field.

Prior to reviewing individual papers on theory and related topics from ICCF20, two preliminary topics relevant to theory will get attention. The first is a review of the overall characteristics and roles for theory in scientific research. Then, a singular paper from 1994 on theories for "cold fusion" will be noted. It provides a good perspective from which to consider current theories about LENR.

There is no consensus in physics, chemistry, biology and other scientific arenas on what constitutes a theory.[2] One definition of theory from Google is "a supposition or a system of ideas intended to explain something, especially one based on general principles independent of the thing to be explained."[3] A closely related word is hypothesis, defined by Google as a "supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation."[4] There have been extensive discussions on the CMNS GoogleGroup moderated by Haiko Leitz about the meanings and status of theories for LENR. That discussion aired various views of theory regarding LENR, but never came to closure. This reviewer favors a pragmatic approach to ways to understand LENR. It involves a sequence of steps, each of which is explained briefly in the following paragraphs.

A theory about any scientific observation starts with a

Figure 1. Professor Kasagi at the entrance to the Clean Energy Research Laboratory sponsored by Tohoku University and Clean Planet, Inc. Professor Iwamura with his wife Michiko (on the left) and their daughter Misa during the conference excursion.

concept, an idea of what is happening to cause the measured results. In the case of LENR, the concept must include the reactants, their origins, what causes them to react, relevant conditions and, ideally, the results of the reactions. Without such a concept and its associated details, there can be no explanation of the mechanisms behind LENR.

The second step in elaboration of a theoretical concept about reactions is to write down the equations that make explicit two things. The first is simply the equations for the reactions, showing the reactants and products. This is trivial, given an adequately developed concept. The second involves writing down the equation that governs the rate of the reaction. This is far from trivial, since it requires a clear, even if tentative, determination of what actually determines the reaction rate, and how it depends on relevant parameters, such as temperature, pressure, diffusion constants, impurity distributions and many other potential factors. In the case of LENR, the means to surmount, partially dodge or avoid the Coulomb barrier are central to the governing equations for reaction rates.

Having the relevant equations for a mechanism for LENR is major progress toward a useful theory. However, the implications of the concept cannot be compared with reported experiments, or used to design new experiments, without numerical evaluation of the equations. Many choices are required to get numbers for comparison with experiments past or future. Algorithms, programming languages and computers must all be determined, along with choices of specific parameters that enter the governing equations, before getting numerical values of use to understand available data or predict the outcomes of new experiments.

The above steps are generally applicable. The sequential development of a theory for LENR is especially challenging, since the relevant parameters are not all known. That is especially true for some aspects of the key materials, such as cathodes in electrochemical experiments. And, even if the production of excess heat attributable to LENR occurs in an experiment, it is commonly neither steady nor controllable. However, these challenges do not relieve the LENR theoretician from having to produce an adequately thorough concept, all of the needed equations based on it, and numerical evaluations of those equations.

Examination of the theoretical literature on LENR shows that almost none of the theoretical ideas satisfy the multistep procedure just outlined. That was the case in the early years of the field and remains the situation. It is still worthwhile, however, to reexamine early ideas on LENR mechanisms to see if any of them should be further developed. A good way to do that is to consider a little known early review on LENR theories.

An outstanding example of thorough attention to how LENR works is in a 1994 paper by V.A. Chechin, V.A. Tsarev, M. Rabinowitz and Y.E. Kim entitled "Critical Review of Theoretical Models for Anomalous Effects (Cold Fusion) in Deuterated Metal." It has been available since 2003 at: https://arxiv.org/abs/nucl-th/0303057. The paper reviews and assesses individual theoretical ideas that had been advanced in the first five years of the field. The abstract of the paper reads: "We briefly summarize the reported anomalous effects in deuterated metals at ambient temperature, commonly known as 'Cold Fusion' (CF), with an emphasis on important experiments as well as the theoretical basis for the opposition to interpreting them as cold fusion. Then we critically examine more than 25 theoretical models for CF, including unusual nuclear and exotic chemical hypotheses. We conclude that they do not explain the data."

The paper by Chechin *et al*. did three things: (a) reviewed the experimental data available at that time, (b) examined the theoretical basis for being critical of the empirical results, and (c) analyzed 25 models that sought to explain LENR, finding all of them deficient. The final section of the paper states: "We conclude that in spite of considerable efforts, no theoretical formulation of CF has succeeded in quantitatively or even qualitatively describing the reported experimental results. Those models claiming to have solved this enigma appear far from having accomplished this goal…we have been limited largely in investigating the consistency of the theories with the fundamental laws of nature and their internal self-consistency. A number of the theories do not even meet these basic criteria. It is imperative that a theory be testable, if it is to be considered a physical theory."

The number of diverse theories about LENR that were already in play in 1994 is large. Most of them are no longer under active development for a variety of reasons. But, it is possible that some of them contain ideas that ought to be developed along the lines sketched above. In any event, the methodology used by Chechin and his colleagues continues to be applicable to theories about LENR, including those presented at ICCF20.

10. Classification of LENR Theories

The many theories about the mechanism(s) behind LENR are not entirely independent of each other. Some of them share common characteristics, which can be used as a basis for categorization and comparison. Hence, there has been interest in the field in classifying LENR theories into groups. Such categorization cannot be done uniquely, since some individual theories share features with other theories that are very distinct from each other. However, classification does introduce some order into the diverse collection of LENR theories.

Edmund Storms of Lenergy LLC published seven classes of LENR theories in his second book.[5] They are summarized here to provide the architecture for discussion of the theories presented at ICCF20:

1. *Clusters of Deuterons*. Storms adopted the viewpoint that LENR are due to D-D fusion, so he grouped together the theories that involve two or more deuterons in proximity to each other. He included in this class Bose-Einstein condensates, which can contain large numbers of deuterons.
2. *Resonance*. Strictly speaking, a resonance occurs in a physical, chemical or biological system when it can store energy interchangeably between two different forms, for example, as kinetic and potential energy in a pendulum. Storms applied this term more generally to oscillatory phenomenon involving electrons, ions and plasmas within lattices.
3. *Neutrons*. Since the beginning of the study of LENR, it was recognized that the electrostatic repulsion (the Coulomb barrier) between deuterons or other ions could be avoided by neutron transfers. Hence, some LENR theories focus on the production or other acquisition of neutrons.
4. *Special Electron Structures*. This category involves hypo-

thetical structures, which have sizes and binding energies intermediate between nuclei and atoms. They are sometimes called "compact objects."[6] Their initial formation could produce excess heat without any nuclear reactions. However, like atoms and molecules containing muons, their small size permits closer approach of the nuclei within a compact object to neighboring nuclei. That reduces the distance for tunneling, and increases secondary nuclear reaction probabilities, with additional energy production.

5. *Transmutations*. This term is used to represent nuclear reactions other than "fusion" between light nuclei. There is a considerable body of evidence on the production of elements of intermediate and heavy masses in LENR experiments. LENR theories for such reactions must explain how the Coulomb barriers much higher than that for D-D fusion are overcome or avoided.

6. *Tunneling*. This is a quantum mechanical phenomenon in which quanta can move (tunnel) through barriers impenetrable in classical physics due to the nature of their wave functions. It is the means by which nuclei can penetrate the Coulomb barrier to produce any nuclear reaction. Tunneling is central to some theories of LENR.

7. *Cracks and Special Structures*. Storms and others believe that LENR must occur outside of the interior of a lattice. They focus on superficial micro-cracks or cavities as the sites where LENR occur. Such theories center on the location of the reactions, as well as the mechanisms that must occur in such positions in order to cause LENR.

The taxonomy developed by Storms is not universally accepted because the features he used to bin individual theories into the seven categories are not unique, and because his review of theories is not comprehensive. However, it is the best such categorization, covers many theories and is a good starting point for discussing and comparing LENR theories.

11. Theoretical and Computational Papers at ICCF20

We now turn to the theoretical ideas and computational results presented at ICCF20, and the status of their development. The order in which the papers are summarized is not an assessment of the quality of the work, but rather an attempt to group papers on similar topics.

Storms had an abstract in the ICCF20 book, even though he was not at the conference to present the material, entitled "How to Search for the Explanation of LENR." The abstract began with a summary of the history of the field. Regarding the claim that it is possible to initiate nuclear reactions with chemical energies, Storms wrote: "Nevertheless, after 27 years of determined effort in spite of widespread rejection, the claim can be accepted as valid...Now we must either reject the obvious or accept the impossible." Storms noted the durable problems in the field of (a) explaining how to overcome the Coulomb barrier and (b) rationalizing the coupling of energy released by LENR into solids without emission of energetic radiation. After a short summary of the types of evidence for LENR, Storms stated: "This paper will identify limitations all explanations much acknowledge...New concepts are revealed by the LENR phenomenon and these can be used to suggest a logical explanation." This approach to understanding possibilities for mechanisms causing LENR is detailed in Storms' second book.[5]

Vibrating Atom Theories. Consideration of phonons and other vibrational excitations in materials have been part of the theoretical literature on LENR from the early 1990s. There were some papers in this genre presented at ICCF20, which will now be reviewed.

Peter Hagelstein from the Massachusetts Institute of Technology and Irfan Chaudhary from the Lahore University of Engineering and Technology presented a paper with the title "Models for Quantum Mechanical Composites, and the Coupling between Center of Mass and Relative Degrees of Freedom." The authors began with a summary statement: "We have developed models to account for excess heat and other anomalies. Approach is based on the notion of massive up-conversion and down-conversion…between large nuclear quanta and large numbers of low-energy vibrational quanta." They proposed a relativistic approach to the up- and down-conversion processes in 2011, and recently discovered that similar approaches have been used in other areas of physics in the past. This paper focused on phonon-nuclear coupling. It included the fundamental relativistic equations with the nucleus treated as an entity with internal structure. A homo-nuclear diatomic molecule was used as a test case for application of the formalism. The authors listed these advantages and characteristics for that case:

- Interested in simplest possible version of problem involving phonon-nuclear coupling
- Work with nuclear transitions in two nuclei (fewest possible)
- Work with identical nuclei (energy levels degenerate)
- Make use of diatomic molecule (simplest system that can vibrate)
- Would like electric dipole (E1) transition if possible
- Would like lowest energy nuclear transition, to maximize effect

Hagelstein and Chaudhary chose to work with two atoms of ^{181}Ta. That isotope was chosen because it has a very low energy nuclear level at 6.24 keV with an electronic (E1) multipolarity. Nuclear, molecular and coupled states were considered and transfer of excitations from one Ta atom to the other was envisioned. A potential experiment was described. It involves a radioactive ^{181}W source on a vibrating beam made of ^{181}Ta. That W isotope would decay to ^{181}Ta. To quote the authors, "Stimulation by vibrations has the potential to cause excitation transfer," meaning that they "would expect less emission at the location of the source." Emission of 6.24 keV photons at the location of the ^{181}W and along the beam without and with vibration could indicate excitation transfer due to phonon (vibrational) coupling to the nuclei. This paper also included consideration of diatomic molecules containing ^{57}Fe in an argon matrix. Their Mossbauer spectra have been measured, and similar experiments for ^{181}Ta were envisioned.

Volodymyr Dubinko from the NSC Kharkov Institute of Physics and Technology (KIPT) in the Ukraine, Denis Laptev from the B. Verkin Institute of Low Temperature Physics and Engineering, also in the Ukraine, and Klee Irwin of Quantum Gravity Research in the U.S. presented a paper on "Catalytic Mechanism of LENR in Quasicrystals Based on Localized Anharmonic Vibrations and Phasons." Dubinko also had a poster presentation with the title "Radiation and Electromagnetic Formation of Localized Anharmonic

Vibrations as a Method to Trigger LENR." The two papers overlapped significantly and will be reviewed together here. The work focused on the theory of Localized Anharmonic Vibrations (LAV) for chemical and nuclear catalysis and the "design of new materials enriched with LAV sites and methods of LAV excitation leading to LENR."

The presentation began with the history of the study of LAV, going back to a 1969 paper by Ovchinnikov, who found localized behavior in two coupled anharmonic oscillators. The concept of LAV in regular lattices dates from 1994, where large anharmonic atomic oscillations called Discrete Breathers (DB) were found outside of normal (non-localized) phonon bands. The core idea for the application of DB versions of LAV has been applied to deuterons in Pd lattices to create what are termed NanoColliders. A "reaction-rate theory with account of the crystal anharmonicity" was developed by Dubinko and others in 2011. In the ICCF20 paper, the authors addressed the question: "How to extend LAV concept to include Quantum Effects and Tunneling." They considered means to increase tunneling due to increasing the quantum noise, that is, the zero point oscillations, by temperature increases. They reviewed and built upon early LENR theoretical research by Schwinger. The work resulted in graphs of localization probability distributions as a function of displacements from 0 to 0.3 nanometers, and potential depths as a number of oscillation periods. The authors identified sites of LAV formation as the Nuclear Active Environments first noted by Storms. The paper went on to present the results of Density Functional Theory simulations of Pd-H nanoclusters. H-H-H chains in such clusters are thought to be viable sites for LAV excitation. Imaging of other materials (quasicrystals of $Al_{72}Ni_{20}Co_8$) was cited as evidence of LAVs.

The experimental part of the presentation by Dubinko and his colleagues was concerned with laboratory means to make Nuclear Active Environments. A photograph of the materials research group at the KIPT showed eight people. They use cryo-milling and fast cooling (to 10^6 deg K/sec) to produce sample materials of NdFe alloys for hydrogenation and "electromagnetic driving" experiments. The EM driving is thought to excite LAVs that catalyze LENR. The authors conclude the experimental part of the work with this summary of their progress (their words):

• New method of the low-temperature catalysis of LENR has been proposed, which is based on the excitation of LAVs in metal hydrides by irradiation or electromagnetic triggering.
• Specially designed new material, based on amorphous Nd-Fe composition apparently shows abnormal heat production under hydrogenation plus electromagnetic triggering.
• Presented results give further evidence for the LAV driven LENR in special disordered structures.

The paper by Dubinko included one graphic on a new international collaboration to study LAVs as a pathway to technology. That effort involves seven institutes in six European countries. The source of funding is the Horizon 2020 program, the EU Framework Programme for Research and Innovation.

Tunneling. Quantum mechanical tunneling of reacting particles is the basis of some theories of LENR. That is the case for theoretical work from the Ukraine, which was presented at ICCF20.

V.I. Vysotskii and M.V. Vysotskyy of the Kiev National Shevchenko University presented a paper with the title "Formation of Coherent Correlated States: The Universal Method of Explanation of LENR Paradoxes and Solving of LENR Problems." The paper started with a good summary of the main challenges to understanding LENR. The authors wrote, "Among well-known LENR problems and paradoxes three are the most important:

• The mysterious, for 'standard' nuclear physics, effect of abnormally high (giant) Coulomb barrier transparency for light, intermediate and heavy charged particles at low energy.
• The very essential change of ratio of reaction channels probability with total suppression of 'radioactive' channels (including the total absence of radioactive ash).
• Sharp suppression of intensity of gamma-ray radiation during LENR.

It is very important also that these effects were observed in different material environments (crystals, amorphous solids, liquids, different biological substance, gas, low temperature plasma, etc.). The report discusses the physical mechanism (formation of coherent correlated states, CCS, of interacting particles) that allows to explain both all these effects and the possibility of their realization in different environments."

Vysotskii and Vysotskyy reviewed the standard treatment of tunneling through the Coulomb barrier. They then used the Heisenberg-Robertson uncertainty relationship to show how with CCS, there can be large energy fluctuations leading to high probability of barrier penetration. Given such important effects of CCS, the paper then dealt with means to produce such states. Three cases were considered: (a) periodic limited deformation of a potential well, as can be driven by a laser, (b) monotonic deformation of a potential well, for example, by crack formation, and (c) by "pulse action" on a particle, with application of a magnetic field being one possibility. The paper then went on to consider the reasons for suppression of radioactivity and gamma radiation, both effects based on application of the CCS concept. The conclusion of the paper listed three graphics with details of the success of the CCS picture. The first two bullets were:

• Formation of coherent correlated states (CCS) is the universal method to increase greatly the probability of nuclear reactions at low energies.
• Process of CCS formation is possible only at nonstationary change of the structure of a quantum system (increase or decrease of the size of the microcracks, microcavities, nanowells, areas of particles quantization, dimensional nanoscale pits in the volume of growing biological system and other objects). This process is absolutely impossible in any systems with similar (but static!) structure.

Given the breadth of the successes claimed by the use of CCS, two potential actions appeal to this reviewer. The first is for Vysotskii and his colleagues to design experiments that might provide more-or-less definitive tests of the approach. The second is for other scientists interested in LENR to join in the exploration of the establishment and effects of CCS.

Special Electron Structures. Unusual arrangements of nuclei and electrons have long been part of efforts to understand LENR.[6] Research involving such structures was presented at ICCF20.

Andrew Meulenberg, supported by the Science Trust for Humanity, Inc., has been working on an approach to understanding LENR for about ten years, first with K.P. Sinha and now with Jean-Luc Paillet of the Aix-Marseille University. Their approach involves study of deeply bound electron orbits that arise as solution of the Dirac equation, the fundamental quantum mechanical equation that includes both spin and relativistic effects. Meulenberg and Paillet had one poster and two oral presentations at ICCF20. The first was an overview entitled "Implications of the Electron Deep Orbits for Cold Fusion and Physics: Deep-Orbit-Electron Models in LENR—Present and Future." This paper started with a list of "accepted CF observations" that the authors explain by use of concepts based on Deep Orbit Electrons:

• Changes in fragmentation ratios for the D+D → ^{4}He CF nuclear reaction.
• A "fast" decay process for transitions from excited nuclear to ground states.
• A high-probability p-e-p → d reaction.
• Excess nuclear energy is transferred to the lattice.

They went on to add a list of "not-yet fully-accepted CF observations" that they also explain:

• Formation of femto-atoms and femto-molecules.
• Transmutations without the known "hard" radiation (particulate or photonic).
• Non-photonic energy transfer from s-orbit atomic electrons to low-lying nuclear states.
• Selective attraction of femto-atoms and molecules to radionuclides (nuclear remediation).
• "Preferred" transmutation pathways in CF.

Meulenberg and Paillet noted the four "physical bases for, and the consequences of, mathematical predictions of deep orbits." They also gave four "theoretical concepts contributing to deep orbits." Each of the four was detailed. They included:

• Symmetry breaking (giving a phase change).
• Sequestration (or isolation of effects).
• Elementary-particle mass changes to below its rest mass (energy conservation).
• Relativistic enhancement of the Coulomb potential (dynamic vs. static).

The authors noted that "None of these concepts is esoteric, but neither are they commonly used."

The overview paper by Meulenberg and Paillet included key points on the deep orbit electrons and "femto-atoms" containing them. They are, quoting the authors:

• To an atomic electron, the nucleus is a "speck" in the distance. To a deep-orbit electron, the nucleus is the constant horizon.
• Deep orbit electrons reduce the mass and repulsive energy of nuclear protons to allow D+D → ^{4}He as preferred reaction.
• Femto-atoms can combine to form neutral femto-molecules.
• Deep orbit electron energy transfer to and from nearby nuclei: proximity coupling and strong EM fields with comparable frequencies (like internal conversion and its inverse).

This first paper included a list of 17 earlier publications on the deep orbit approach to understanding LENR.

The second paper from Meulenberg and Paillet was entitled "Advance on Electron Deep Orbits of the Hydrogen Atom." It began with the statements: "Femto-atoms and deep-orbit electrons can:

• Facilitate cold fusion inside condensed matter.
• Avoid nuclear fragmentation in a D-D fusion process.
• Increase the rate of energy transfer between an excited nucleus and the surrounding lattice.
• Create femto-molecules that can also move freely within the lattice and be attracted to and combine with lattice nuclei for transmutation without energetic radiation."

The core of this paper had two features. The first addressed both theoretical and experimental arguments against the existence of electrons in deep orbit. The second dealt with the mathematical details of the deep orbit solutions of the Dirac equation. A list of open questions about this approach to understanding LENR was provided. This paper ended with the statement: "Cold fusion provides strong evidence for the existence of these electron deep levels in condensed matter and these levels provide a basis for understanding CF and for physics and chemistry research beyond CF."

The Meulenberg-Paillet poster at ICCF20 was on "Physical Reasons for Rejecting Arguments against Deep-Dirac Levels." The paper began with the statement that "Limitations to contemporary models of Coulomb and nuclear interactions have previously been identified...Nearly 80 years ago, relativistic quantum mechanics provided a means to overcome these limitations: deep orbit electron levels." The authors note that such levels have been ignored because, prior to the discovery of "cold fusion," they were not needed to explain available physical data. But, now they "provide a solid theoretical basis for CF…and for new fields in femto-physics and nuclear chemistry." The poster went on to examine some of the limitations, and discuss the extension of two "commonly accepted" models in order to understand LENR. Eventually, the approaches of Meulenberg and his colleagues will have to make contact with specific material systems and reaction rates.

LENR, by itself, is complex both experimentally and theoretically. It is also related to some other complicated topics that are being actively explored as new energy sources. One of the most prominent of those is called the "hydrino" by its inventor Randell Mills. He is a medical doctor, who published a book in 1990 containing a theory about new, deep lying states in hydrogen, which have fractional principal quantum numbers. Superficially, those states have some common features with entities being studied in the LENR field by Meulenberg, Paillet and several others. However, the formation of hydrinos is a process not involving deep levels or nuclear reactions. Mills has been very active in developing commercial energy generators based on hydrino formation. His company, now called Brilliant Light Power, has received \$110M in funding. The science and business of the organization and its operation are detailed in a recent book *Randell Mills and the Search for Hydrino Energy* by Brett Holverstott.

Mills does not participate in LENR conferences, because his theory does not involve nuclear reactions. However, there was a presentation at ICCF20 closely related to Mills' ideas. It was titled "Fractional Energy States of Hydrogen" by Stewart Kurtz from The Pennsylvania State University and Trey Morris of Howard University. Their stated goals were given as "Derivation of fractional principal quantum states for solutions of the non-relativistic Schrödinger equation and the relativistic spin-zero version of the Klein Gordon equation." They studied states for which quantum number **n** ranges up and down from 1, namely **n** = 1, 2, 3, 4, …137 and **n** = 1/p, where p = 2, 3, 4, …137. The authors sought to introduce a meta-energy "p-ladder," which would bridge the chemical to nuclear energy gap, and serve as a model for LENR reactions.

The Kurtz-Morris paper provided historical and mathematical background on their subject. They gave computational results from the Schrödinger equation for energies and radii of the fractional quantum number states. The radii ranged from $a_0/137$ (386 fm) to a_0 (52.9 pm) to $137a_0$ (7.25 nm) as **n** varied from 1/137 through 1 to 137. Plots of cumulative released energies vs. transition times were provided for chemical (<10 eV) to nuclear (0.51 MeV) energies for three cases of the number of time units per transition. The authors concluded, "This provides a multi-step means of producing electron capture seen in LENR experiments in plasmas and liquids and solids starting from Rydberg energy chemical processes." As with most theories about LENR, this approach has not yet been developed to the level of making predictions about absolute reaction rates as a function of relevant conditions and parameters.

A short abstract in the ICCF20 Abstract Book by V.K. Ignatovich from FLNP JINR in Dubna was titled "On Singular Bound States with Continuous Spectrum in Hydrogen Atoms and Cold Nuclear Fusion." It was not presented at the conference, but deserves attention as more research on special states of hydrogen. The author asserts that "the hydrogen-like atom can have continuous spectrum of singular bound states with zero angular momentum." He went on to write, "Relation of these states to possible cold fusion nuclear reactions and to the physics of stars is discussed."

Hot or Dense Conditions. Many theories of LENR mechanisms have involved special conditions of temperature or density. The few of them represented at ICCF20 are now summarized.

Lutz Jaitner is an independent researcher in Germany. He presented a poster with the title "Condensed Plasmoids: The Intermediate State of LENR." A condensed plasmoid (CP) is a collection of nuclei in a line surrounded by a high density of electrons in a cylindrical configuration. Strange patterns have been observed on the surfaces of materials in diverse experiments, which are attributed to the motion of these hypothetical plasmoids. Jaitner's research involves quantum mechanical modeling of such systems in order to understand their binding, dynamics and effects. His poster at ICCF20 described his approach to such modeling. It included the equations he uses, and described a simulator he has written for performing CP computations. He has made that simulator available on his website: http://www.condensed-plasmoids.com/. Incidentally, that site contains very good pages on "LENR Players" and "History of CP and LENR." Jaitner concluded his poster with the following somewhat-edited points:

- Coulomb repulsion of the nuclei is compensated by strong electron screening at all inter-nucleic distances down to the femtometer range.
- Intrinsic currents can exceed 10 A through a cross section of less than 1 square picometer.
- Electron velocities are deeply relativistic along the axis.
- Weak interaction of nucleons is greatly increased by extraordinary electron densities and speeds.
- Excited state energies of the nuclei are damped away by near-field electromagnetic interaction with many electrons.
- CP are self-organizing their shape to closed-loop coils, as this minimizes their magnetic energy.

The connection between LENR and condensed plasmoids needs elaboration. It is possible that CP exist, as envisioned, but are not active in LENR. But, they might be at the core of LENR. This reviewer is reminded of the linear arrangements of protons or deuterons that Storms envisions in cracks on the surfaces of materials, and wonders if they and CP have anything in common.

Katsuaki Tanabe from Kyoto University had an abstract in the book handed out at the conference. The paper was on "Plasmonic Concepts for Condensed Matter Nuclear Fusion." The author "proposed and numerically investigated a scheme to provide high-density optical or electromagnetic energy to fusion-fuel materials." He noted that semiconductor or solid-state lasers provide power densities "several orders" of magnitude higher than power densities in electrochemical LENR experiments. Tanabe computed plasmonic field enhancement factors due to coating spherical sub-wavelength particles of palladium, nickel and titanium with some unstated material. The calculations were done as a function of wavelengths in the 200 to 2000 nanometer range for ambient conditions with D_2 and D_2O. Field enhancements up to 15 were calculated. The author wrote, "This approach aims at initial local ignition of nuclear fusion reaction enabling the generated heat there to trigger subsequent reactions throughout the fuel materials."

Francesco Celani from the INFN-LNF in Rome, and Antonino DiTommaso and Giorgio Vassallo of the Universita degli Studi Palermo, had a poster at ICCF20 entitled "The *Zitterbewegung* Interpretation of Quantum Mechanics as Theoretical Framework for Ultra Dense Deuterium and Low Energy Nuclear Reactions." *Zitterbewegung* means "trembling motion" in German. Their abstract reads: "This paper introduces a *Zitterbewegung* model of the electron by applying the principle of Occam's Razor to the Maxwell's equations and introducing a scalar component in the electromagnetic field." They do this in order to "study the structure of UltraDense deuterium, the origin of anomalous heat in metal-hydrogen systems and the possibility of existence of 'super-chemical' aggregates at Compton scale." This paper takes the electron to be a current loop with circumference equal to its Compton wavelength of 2.43 picometers. That dimension is much larger than the "classical" size of an electron, namely 2.82 femtometers.[7] The proton is similarly pictured as a current ring of positive charge rotating at the speed of light on a circumference equal to the proton Compton wavelength of 1.32 femto meters. The authors note that "each nickel lattice cell may act as a resonant cavity and as an 'energy emission analyzer' in presence of Rydberg State Hydrogen…" Rydberg matter was discussed in Part 1 of this conference review.[8] It is a state of "ultra-dense deuterium" with an internuclear distances between deuterium nuclei of about 2.3 picometers.[9] The ideas in this paper are used to calculate that distance, with excellent numerical agreement. The authors assert that those concepts can be applied to explain heat generation in the nickel-hydrogen system. It remains for them to use their ideas to compute LENR rates for the nickel-hydrogen or other systems.

Bose-Einstein Condensates. The idea that LENR occur in clusters of deuterons making up Bose-Einstein Condensates (BEC) has been studied for many years, primarily by Yeong Kim from Purdue University. He was co-author of the 1994 review of LENR theories noted above in Section 9. Kim could not attend ICCF20, but two of his abstracts were available. The first paper was titled "Theoretical Analysis and Reaction Mechanisms for Experimental Results of Deuterium Permeation Induced Transmutations." In that work, Kim focused on reactions reported from experiments by Iwamura and his colleagues in Mitsubishi Heavy Industries, notably $^{133}Cs + 4D \rightarrow {}^{141}Pr$. Kim applied his theory of "Bose-Einstein Condensate Nuclear Fusion," called BECNF, which is based on "quantum mechanical scattering theory and the optical theorem" to the case of "a cluster of multiple-deuterons moving through crystal layers." Results of his calculations were not available in the abstract.

The second abstract by Kim was on "Predictions of Theory of Bose-Einstein Condensation Nuclear Fusion of Hydrogen-Lithium Aneutronic Fusions in Metal Systems." The work sought to explain "recent experimental results of anomalous isotope changes in hydrogen-lithium aneutronic reactions: $^{6}Li(p,\alpha)^{3}He$ and $^{7}Li(p,\alpha)^{4}He$." The same formulation was used for this study as for the work on creation of Pr, which was described in the preceding paragraph. The author wrote, "No *absolute* reaction rates can be predicted by the BECNF theory at present…however, theoretical prediction for *relative* rates of aneutronic fusion reaction are possible using the BECNF theory."

Ken-ichi Tsuchiya from the National Institute of Technology in Tokyo College has also been studying BEC as the explanation for LENR. He presented a poster entitled "Explanation of Nuclear Reactions in Solids by Solving Many-Body Problems of Charged Bose Particles Trapped at the Bottom of the Harmonic Potentials." The paper was based on the view that deuterons accumulated in a palladium lattice can be regarded as charged Bose particles trapped in the harmonic potentials due to the lattice. Tsuchiya wrote: "Based on Kim's theory, we calculated the quantum distribution of charged bosons trapped in a harmonic ion trap. As a result, we obtained the quantum distribution of D+ and Li+, which depend on the mass of the trapped ions." The work required self-consistent solution of Kim's equations with two cycles per computational iteration. Hence, the calculations did not always converge rapidly. The location of the maximum probability for each ion was found to depend on the mass of the ions. Tsuchiya views the resulting quantum distributions as forming a basis for the understanding of LENR.

Two fundamental aspects of BEC theories for LENR remain puzzling to this reviewer. The following is from the Wikipedia article on BECs[10]: "A Bose-Einstein condensate is a state of matter of a dilute gas of bosons cooled to temperatures very close to absolute zero (that is, very near 0 K or -273.15°C). Under such conditions, a large fraction of bosons occupy the lowest quantum state, at which point macroscopic quantum phenomena become apparent. It is formed by cooling a gas of extremely low density, about one-hundred-thousandth the density of normal air, to ultra-low temperatures." The states envisioned by Kim and Tsuchiya are neither dilute nor cold. It may be possible that something resembling a normal BEC might form at high densities and temperatures, but that does not guarantee adequate time for the occurrence of LENR.

Exotic Particles. The history of theories about the mechanism(s) underlying LENR includes some very unconventional ideas. Among them are concepts for unusual particles, often called "Exotic Nuclear Particles." As usual at these conferences, there were some papers on such entities at ICCF20.

Yuri Bazhutov is from the Scientific Research Center of Engineering Physical Problems in Moscow. He has been studying evidence for and characteristics of particles he calls Erzions for many years. A review[11] of experiments relevant to Erzions states, "The concept of an Erzion, a massive hadron, was first formulated in 1981. Existence of such a stable particle was postulated to explain energy spectra of cosmic-rays muons." Bazhutov could not attend ICCF20, but he provided an abstract entitled "Erzion Interpretation of Rossi and 'Lugano' Experiments with 'Hot E-Cat' Cell." He proposed that the Erzion model provides a theoretical explanation for "the generation of excess heat, new chemical elements and isotopes" in those experiments." He asserts that his model explains both of the experiments noted in the title of the abstract. Beyond that, he states "the Erzion Catalysis Model has further great predictive opportunities for essential optimization for future power installations."

William Collis, the founder and Chief Executive of the International Society for Condensed Matter Nuclear Science, had a poster at ICCF20 on "Minimal Exotic Neutral Particle Models." He sought to understand reactions involving both the Erzions of Bazhutov, just discussed, and the Poly-Neutrons postulated by John Fisher in papers at earlier ICCF meetings. Collis provided the following summary of his paper by email: "Collis' ENP (Exotic Neutral Particle) theory takes a common subset of the Bazhutov and Fisher theories and postulates catalyzed neutron transfer. The major improvement is that unobserved prompt and residual penetrating radiation is not predicted." In his abstract, Collis wrote the following interesting statement: "Amongst pure elements, it is shown that only Li, C, W and Pt can sustain chain reactions." The possibility of chain reactions in LENR experiments has long been of interest and remains open to question.

Nuclear Structure Models. The study of nuclear reactions of any type starts with the structure of the reactant nuclei. There are four types of nuclear models: (1) Independent-

Particle Models, (2) Collective Models, (3) Cluster Models, and (4) Other Models. This is a remarkable situation after a century of study of the nucleus. Some nuclear structure theorists hope that the experimental discoveries from LENR experiments, especially transmutation data, will beneficially impact the study of nuclear structure.

Norman Cook from Kansai University in Japan is among specialists in nuclear structure who follow developments in LENR for useful clues to the details of nuclear structure. In his book *Models of the Atomic Nucleus*, Cook contrasts the various classes and types of nuclear models. His presentation at ICCF20 included a summary of nuclear models, which cited the existence of over 30 "mutually exclusive" models. Cook wrote this list of classes of models and some specific ideas:

- Gas-phase models: Fermi gas model, independent-particle model (IPM), shell model, etc.
- Liquid-phase models: liquid-drop model, droplet model, etc.
- Cluster models: alpha cluster model, interacting boson models, etc.
- Lattice models: simple cubic, body-centered cubic, face-centered cubic, etc.

The situation in nuclear structure theory is remarkably like that of the situation for theories of LENR in one respect. There seems to be a surplus of ideas, and a need for unification (in nuclear theory) and clarification (in LENR theory).

A basic question asks: what is the connection between nuclear models and LENR? Cook hopes that the empirical evidence from LENR experiments will cast light on the various nuclear theories. So, he focused on the nuclei relevant to LENR experiments. He wrote: "In light of the isomorphism between the nuclear lattice and the conventional IPM, reasonable deductions can be made about the lattice structures for ^{6}Li, ^{7}Li, $^{58-64}$Ni, and $^{102-110}$Pd." Cook provided lattice models for ground and excited state of lithium isotopes. He suggested that the following nuclear reaction might be active in LENR experiments: The ^{7}Li (0.478 MeV in the first excited state) + p $\rightarrow$ ^{8}Be $\rightarrow$ 2 alpha particles (without gamma emission).

Philippe Hatt is an independent scientist in Belgium and another nuclear theorist. He presented a pair of posters at ICCF20. The titles of his papers were "Cold Nuclear Transmutations Study of Various Atom Nuclear Structures" and "Structure Anomaly of Palladium Nucleus." He is concerned about the relationships between various nuclei and their binding energies. Hatt wrote the following somewhat edited basis: "Nuclear structures are based on their binding energy in relation to the binding energy of: The alpha particle (*i.e.*, 28.325 MeV), the deuteron (*i.e.*, 2.2246 MeV), the triton (*i.e.*, 8.482 MeV) and helium-3 (*i.e.*, 7.7182 MeV). Also, a new type of binding energy is introduced, called NN, which is part of the alpha particle binding energy. This binding links the two neutrons within the alpha particle, creating a di-neutron." Hatt then went on to show "how it is possible to build, step by step, the structure of these various nuclei," starting with helium-4 and related nuclei, including Be-8, C-12 and O-16. He then built up more complex nuclei and discussed the energetics of some transmutation reactions.

In his second poster, Hatt wrote: "My hypothesis is therefore that the alpha particle loses a mass of 28.325 MeV at the moment of its constitution as a result of the fusion between 2N and 2P," where N = neutron and P = proton. The core of Hatt's view of LENR was given as follows, again with some editing: "There is a tendency to create α particles from N and P. Deuterons which enter the nucleus take places in the two empty shells (1P+1N). As there is a natural tendency to create an alpha particle, these deuterons are absorbed by the nucleus and transmuted in a new alpha particle, this operation releasing energy. The Coulomb forces are less strong than the nuclear interaction creating the alpha particle. This new alpha particle replaces the last alpha particle of palladium, and as consequence this last alpha particle is expelled. So, there is creation of an alpha particle, and expulsion of one existing alpha particle. In case this α particle is not expelled because it is too solidly bound to the nucleus, a transmutation occurs, adding one alpha particle to the palladium element. In case the deuteron is taking the place in one shell only a transmutation occurs as well, adding one proton and one neutron to the element to create a new one." He discusses the structure of each of the Pd isotopes. Details of Hatt's ideas can be found on his website: http://philippehatt.com/. It contains "an essay on the unifying theory of natural forces and atomic nuclei binding energy." The website shows the good agreements between measured binding energies and those Hatt computed with his methodology.

There is a common challenge for any of the theories of nuclear structure, namely to use them as the basis for nuclear reactions. Cook suggests one reaction, as noted above. But, he has no information on the rates (probabilities) of that reaction, and how they might depend on conditions in low temperature (energy) experiments. Hatt discusses some specific reactions, but also does not deal with reaction rates or conditions conducive to the reactions.

Nuclear Reaction Models. While nuclear structure models have little to say about nuclear reaction models, the inverse also tends to be true. Some of the papers at ICCF20 dealt with potential reactions without details on the nuclear structures that are involved in those reactions.

Dimitri Alexandrov from Lakehead University in Canada presented a paper with the title "Interaction of Both Protons and Deuterons with Valence d-electrons in Transition Metals." His approach is based on the band structures of such metals. He states that both isotopes behave as bare nuclei, protons and deuterons, if "temperatures reach certain specific values for given transition metal." That is, the ions do not form hydrides or deuterides, but propagate "as particles through the crystal lattice." He found in his calculations that "energy pockets for electrons exist and that valence d-electrons are localized in these pockets." Alexandrov further states that the localized electrons behave as heavy electrons in terms of the propagating protons and deuterons. He asserts that the effective masses of the localized d-electrons can become greater than the masses of both protons and deuterons. The heavy electron interactions with the ions are possible "only if unpaired electrons participate in these couplings." The separations between electrons and ions are said to be "less than 2 fm." The author states that reactions of protons with electron-deuteron pairs will produce ^{3}He and reaction of deuterons with such pairs leads to production of ^{4}He. This paper was dominantly conceptual without estimates of reaction rates.

Daniel Szumski is an independent scholar from California. His theoretical poster on nuclear reactions was entitled "Laws of Nature are Precise and Reproducible." Szumski envisions interactions and energy exchanges between nuclear levels, similar to those between molecules within solids, and treats them as an "imperfect" thermodynamic process. He applied this approach to analysis of the transmutation data published by Miley and his colleagues. Five classes of nuclear reactions were considered. Electrode designs were offered, for which addition of particular isotopes during excess heat runs would have predictable effects. Those results were obtained with a computer program based on the "Least Action" principle. That dictates that each step of the multi-step reaction process involve the smallest mass or energy change. Applications for excess heat production, isotope production and stabilization of radioactive waste were noted by Szumski. There are two concerns with this line of research. The relatively minor one is the lack of computed rates of postulated reaction sequences, when such rates are central to any of the three applications. The major concern is the assumption that multi-body nuclear reactions can occur at low temperatures, for example $^{61}Ni + ^{107}Ag + 2\ ^{2}H$ to give ^{172}Yb. There is no experimental evidence for such reactions, and they are highly unlikely theoretically. Details of Szumski's theory and his calculations are at his website: www.LeastActionNuclearProcess.com

Other Theories of LENR. Some of the presentations and posters at the conference do not fit into the categories above. So, they are now considered separately.

Jean-Francois Geneste is the Chief Scientist of AirBus, the large international defense and aerospace manufacturer in Europe. He is relatively new to the LENR field, and has introduced a novel theoretical approach to explaining the energy source due to such reactions. His first presentation on LENR was described as follows: "In the Toulouse conference of the ISCMNS in October 2015, we have presented a theory of LENR which is based on combinatorial games theory." His second paper was presented at the Satellite Symposium in Xiamen, China, the week prior to ICCF20. That paper, with Jenny D. Vinko of the Hydrogen Energy Research Agency, was on "Symmetries, Entropy and Order." It focused on the differences between symmetric views of matter from within a material system and dissymmetric views of the same system from outside of the system. Geneste described the existence of a paradox in the material world, which he proposed to solve by "introducing in physics non-Archimedean geometry." That is an unfamiliar mathematical concept. The complexity of this approach is compounded by Geneste then invoking something called the Banach-Tarski paradox, another mathematical idea, which is called a "paradox" only because it is counter-intuitive. It is proven mathematically that the surface of a sphere can be broken up in such a manner that it can then be put back together in a different way to yield two copies of the original. The authors of the paper in China then stated, "Now, if we consider an isolated system, we can write the Boltzmann equation. Applying the Banach-Tarski paradox to this equation in the space of phases implies that we have infinite energy!" The ideas underlying the paper in China have been published in the book *The Universal Universe* by Geneste.

At ICCF20, Geneste and Vinko presented a paper on "A New Approach to Heat Entropy and Order," which built on the ideas in their earlier two papers. The authors started this paper with some of the basics of thermodynamics and statistical mechanics. They wrote: "Entropy is interpreted as disorder. Since $dS=\delta QT$ we can create heat if we create disorder at constant temperature. Disorder today is viewed by mathematicians as indistinguishability." They then consider mathematical order relations with varying degrees of order and disorder. The authors next seek a connection between the mathematical relationships and entropy. To quote them: "What we call entropy therefore is an equivalence class of order. It is characterized by a number. So that our entropy decreases when the order decreases. We can fix this by taking the inverse to come back to something more in line with physics." This raises their following questions: "What is the link between our entropy and the one of physicists? Is there a way to have a match? How does a system evolve? By steps individual or bigger steps, that is, by Poisson and Markov processes or Levy flights?" These questions are not all answered. The authors make contact with standard physics as follows: "The Nernst principle says that entropy decreases to zero when temperature decreases to zero. This means that there is a link between order and temperature. Zero temperature brings us near total order." After considering open systems in relation to the universe, Geneste and Vinko note the following about different types of order: "There are the geometric, topological and chemical orders. There also are the ones linked to fields (73 of them in physics today!). Then, both fusion and fission should be linked with order. The only way to it for fusion is through non-Archimedean geometry. Catalyzers trivially are disruptive agents of pre-existing order. Outside chemistry, thermodynamics deals with topological and geometrical orders only."

Turning to energy, Geneste and Vinko write (somewhat edited): "We start from $\delta Q=TdS$ and we consider energy creation at constant temperature, hence creation of disorder. We have seen above we can have several orders at stake. So the global order can be written as a tensor produce of orders. Now, let us assume we have raw material which presents an order relative to such a tensor product of orders and it has some energy potential which depends on the order at stake." They go on as follows: "Let us assume our universe is either Euclidean or hyperbolic and therefore will become asymptotically cold. This implies Zermelo's theorem (a result from game theory), which means that in the cold universe, there is a total order. According to our theory, this means that there is potentially at least as much energy which can be extracted from the cold universe as from the hot one of the Big Bang! For LENR, this means that at any moment, if we do not play with the current rules but with Zermelo's ones, then we can extract as much energy as we want at any moment!" It is clear that the ideas presented by Geneste and Vinko are very general, without obvious or compelling linkages to LENR. It remains to be seen if they can use their concepts to indicate specification reactants and reactions, which might occur during LENR. If so, they might be able to go on to predict reaction rates.

Ken Naitoh from Waseda University in Tokyo presented a poster on "A New Theory for Describing and Stabilizing Cold Fusion." He wrote, "In ICCF17, we proposed a quasi-stability theory explaining the inevitability of child atoms generated by cold fusion. Today, the new theory based on a nonlinear differential equation on deformation of parent atom X(t) with time t, is derived by statistical fluid mechanics." Results derived from this approach "clarify the reason why decreasing sizes of particles such as palladium will result in a little more stable cold fusion" and "numerical simulation on a supercomputer shows a concrete methodology for stabilizing cold fusion…" Naitoh further writes, "Thus, the new theoretical model leads to a new idea toward reliable occurrence of cold fusion. The idea is super multi-jets colliding with pulsation, which results in strong point-compression around CF reactor center." The experimental paper based on the theoretical concept and calculations is reviewed next.

Naitoh and four colleagues from Waseda University presented a laboratory paper entitled "Primitive Experimental Tests toward Futural Cold Fusion Engine Bases on Point-Compression due to Super Multi-Jet Colliding with Pulse (Fusine)." Naitoh and his colleagues have been doing theoretical and computational research, as well as experiments with an unusual approach to causing LENR. They have 14 gas jets aimed at the same point. Pulsing them produces pressures over 60 MPa and temperatures of 2000 °K, when the jets collide with each other. This paper is a progress report on their experimental program. They measured the pressures resulting from the collision of the gas jets. Then, they added a "hydrocarbon fuel" to the system, which resulted in chemical reactions. The light from the reactions was imaged. Since LENR ordinarily involve a metallic lattice, it is not clear how these researchers expect to produce such reactions by their method.

G.V. and M.G. Tarassenko from the Caspian State Universities of Technology and Engineering have been studying potential links between the structure of the earth and cold fusion. Their poster at ICCF20 was titled "Cold Fusion on the Basis of the Model of the Planet Earth." They discussed the motion of materials within the earth, and the production of electricity that they believe arises from the motions. The appearance of spherical rock formations, called concretions, is offered as evidence of ball lightning within the earth. Electricity and cold fusion in the earth are thought to be drivers for the production of oil and coal. The Tarassenkos wrote: "The evidence of hydrocarbon formation with the help of cold fusion is based on carrying out experiments with arc discharger at cathode at battery water solution adding titanium powder. After some time after burning arc discharger there was strong smell of acetylene." The ideas in the Tarassenko's paper do not seem to be amenable to testing by comparison with geophysical data. Possibly, results from a detailed computational model of the earth, which included their ideas, would shed some light on the correctness of their view that cold fusion is needed to explain oil and coal production.

Tetsuo Sawada from Nihon University presented a paper entitled "The Big-Bang, the Magnetic Monopole and the Nuclear Cold Fusion." The author began by noting "the magnetic monopoles are produced abundantly in the process of the big bang, however the density of the monopole decreases rapidly as the universe expands and today it becomes the rare particle. The magnetic monopoles are believed to distribute not uniformly in space." Magnetic monopoles are not observed on earth, so Maxwell's equations are not symmetric in electrical and magnetic objects. Assuming the existence of monopoles, the magnetic equivalent of electric charges, Sawada wrote the symmetrized Maxwell's equations and solved the Schrödinger equation assuming the existence of magnetic monopoles, denoted *e.

The essence of the work by Sawada was stated as follows: "Magnetic Coulomb field produced by the magnetic monopole can attract the particles with the magnetic dipole moment such as the proton, the neutron or the deuteron. On the other hand, α-particle cannot be attracted, since its spin is zero. By solving the Schrödinger equation with the Hamiltonian, we can determine the distorted outgoing wave of the α-particle, and also the wave functions of the bound states of p - *e, n - *e and d - *e, which are calculated by the standard method. It is interesting to consider when two deuterons are trapped by the same magnetic monopole *e, since the orbit radius of d is around several fm., two deuterons must fuse to becomes more stable α-particle, and it is simply emitted. So the fresh magnetic monopole *e remains, it starts to attract surrounding deuterons again. In this way *e plays the role of the catalyst of the nuclear cold fusion: $d+d \rightarrow \alpha$." That is, Sawada believes that LENR are catalyzed by magnetic monopoles, and their rarity explains reproducibility problems in LENR experiments. If he is right, then LENR experiments could serve as detectors for magnetic monopoles. If that were proven to the satisfaction of the larger community of physicists, it would have a dramatic impact on the teaching of physics. The situation for Sawada reminds me of that for a theory put forward by Hubler at ICCF19. He envisioned the energy seen in LENR experiments as being due to Dark Matter. If that turns out to be the case, LENR experiments would be detectors for such matter, again with a large impact on physics.

Rafael Tumanyan and Vanush Davtyan from the Armenian Technological Academy had an abstract in the book for ICCF20, although apparently their paper was not presented. It was titled "New Type Cold Fusion." They wrote, "We consider in this report a possibility of cold fusion in alloys where the vacancies can be used as centers of accumulation of fuel." Their idea apparently is that, by control of alloy composition, the density of vacancies can be made higher than the usual thermal values, "which gives a possibility to obtain higher output power." It must be noted that the role of vacancies, and production of "super abundant" vacancies, have already received significant theoretical and experimental attention in the LENR field.

Another abstract for a paper not presented was by Leo H. Sapogin and two colleagues from the Moscow Technical University. It was titled "E-Cat of Andrea Rossi and Unitary Quantum Theory." The abstract was mostly a summary of major events in the history of LENR. The authors concentrated on equations for oscillating charge in an external potential. Their solutions for this situation included the usual stationary states and also two new situations in which the energy of the oscillating particle either decreases to a minimum or increases indefinitely. They state that "in the E-Cat reactor grains of nickel powder have caverns with size of tens of Angstrom…which work as potential wells." They state that a proton "with adequate phase" can penetrate into such "caverns." The authors wrote, "as a result of proton numerous blows against cavern's walls we obtain heat generation." No LENR rates are given in the abstract.

Data Analysis and Numerical Simulation. Computations play three critical roles in the study of LENR. One is for the evaluation of equations that embody various theoretical ideas, in order to produce numbers for comparison with experiments. Some of the theories reviewed above were subjected to such computations. Another is for analysis of experimental data, so that additional quantitative information can be extracted from the data. Computational data analysis was a part of some of the experiments detailed in the first part of this review. Third is the use of computers to model, or simulate, the behavior of LENR experiments. There were two papers that fall into this last class.

One largely mathematical paper at ICCF20 dealt with modeling of experiments to make comparisons with measured data. It was presented by Ken-ichi Okubo and Ken Umeno from Kyoto University, with the title "Physical Model of Energy Fluctuation Divergence." This paper was based on a 1993 publication about strong intermittent behaviors of a particular type of Hamiltonian. The ICCF20 paper compared the distributions of an unknown data series and the theoretical distribution derived in the new paper. The authors concluded "we suggest that such intermittent phenomena of energy fluctuation, like [the earlier paper], are related to cold fusion phenomena." They did not elaborate on the reasons for that expectation. It is hoped that the authors will expand on the connection of their mathematical developments and LENR.

G.S. Zolotov and A.V. Lavrov of the Independent Moscow Research Lab LLC in Moscow had an abstract with the title "Numerical Simulation of Temperature Distributions in Parkhomov-Type Reactors." The material was not presented at the conference, so a short summary of their abstract follows. The experiment they simulated involves nickel powder and the compound $LiAlH_4$ in a cylinder that is raised to high temperatures (about 1000°C) to decompose the compound, liberate hydrogen and induce LENR. The numerical research sought to "verify temperature distributions and heat fluxes under various conditions." Code written by the authors included direct and reverse radiation of surfaces and powders, heat conduction coefficient dependencies on temperature, material, gas loading, chemical heat production from oxidation and hydride formations, and the electrical resistivity of heaters and its dependence on temperature. Results from the code were checked against an experiment by the authors using a reactor with "dummy loading." Agreement between measured and simulated temperatures of 10% was achieved. The authors concluded their abstract by noting: "A heat production model of LENR effect can be included in order to simulate excessive heat in the reactor core."

Discussion amongst Theoreticians at ICCF20. An unscheduled feature of ICCF20 was a group discussion of LENR theories organized by Andrew Meulenberg. It occurred during the poster session on Tuesday afternoon of the conference. A photo of the group by Steve Katinsky, founder of LENRIA Corporation, is shown in Figure 2. The collegial discussion touched on many topics. It is clear that those who are doing theoretical and computational research on LENR share a common goal to understand the basics of the phenomenon.

It must be noted that there are many theories of the mechanisms that cause LENR, which were not represented at ICCF20. That is understandable, of course, since not all theorists can attend all LENR meetings. However, it is important to remember that the theories, which were aired at ICCF20 and described above, are set in a much larger and competi-

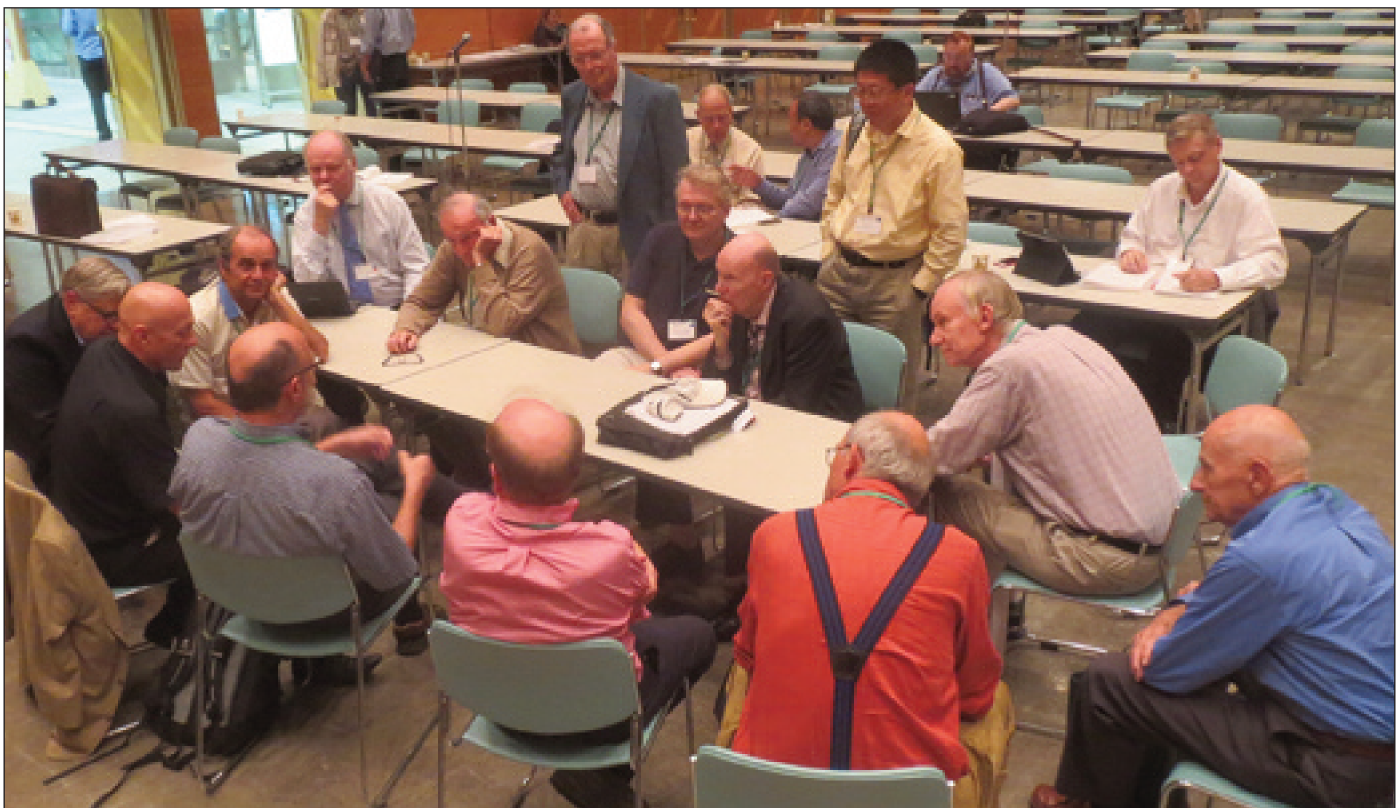

Figure 2. Photograph taken during the unscheduled discussion of LENR theories at ICCF20.

tive context.

This reviewer was involved in the production of a tabular summary of all the theories presented at ICCF14; see page 476 of this link: http://www.iscmns.org/iccf14/ProcICCF14b.pdf. It would take considerable effort to put all available, both active and inactive, LENR theories into such a format. However, such a matrix would be valuable for experimentalists and others interested in LENR. It may turn out that the eventual understanding of LENR will involve a synthesis of ideas that are already published.

Topics Related to LENR Theories. There were some theoretical and computational presentations that were not specifically on mechanisms for LENR. They are now reviewed.

Hagelstein also had a poster on "Statistical Mechanics Models for PdH_x and PdD_x." It dealt with the occupancy of the octahedral (O) and tetrahedral (T) sites within Pd. He produced a generalized Lacher-type model for O-site and T-site occupation, and found that it is not possible to account for alpha-phase solubility data without T-site occupation. This approach enables modeling of H/Pd and D/Pd above unity loading. It showed that the phase diagram is not physically reasonable without T-site occupation. The model is consistent with neutron diffraction data. The O-site to T-site excitation energy at low loading was obtained.

Melvin Miles of the University of LaVerne in California presented a poster on "The Eyring Rate Theory Applied to Cold Fusion." He started by noting that thermodynamics shows that fusion reactions are possible at room temperature, and have large, negative Gibbs energy. Going beyond thermodynamics to kinetics, the Eyring Theory applies to rates of processes, including ordinary chemistry, electrochemistry, diffusion and viscosity. Miles determined numerical values for the kinetics of two deuterons reacting to form ^4He, including the Gibbs energy change, the change in enthalpy and the activation energy. The last of these is similar to the activation energy for diffusion of deuterons in Pd. That led Miles to postulate that "the D + D fusion reaction in palladium may be controlled by the diffusion of D atoms (or D+ ions) into some fusion reaction zone." He went on to note that the potential fusion reaction zones include two near surface possibilities, the primary double layer in the electrolyte near the surface of the cathode, which might be rich in Li+ ions, and a secondary layer immediately within the cathode materials, which has high concentrations of both electrons and deuterons.

12. Applications of LENR

The two core reasons for interest in LENR are clear, since it is a scientific riddle with the promise of practical applications. Either of these motivations is enough to engage many scientists, engineers and business developers in the topic. Understanding of LENR has yet to be achieved, so trying to develop a testable theory of the mechanism(s) behind LENR appeals to many scientists. Fame could result. Beyond that, the empirical data base on LENR shows that the reactions can have several desirable features, including high gains, and freedoms from significant prompt radiation, residual radiation and green house gases. If LENR generators can be developed that are reproducible, controllable and safe, they ought to achieve regulatory approval and customer acceptance. They would have many applications. Fortune awaits successful product developers.

There are generally a few papers on applications of the power and energy from expected LENR generators at an ICCF conference. Such was the case at ICCF20. They are reviewed in the following paragraphs.

Jed Rothwell has provided crucial service to people interested in LENR for a long time. His maintenance of the website lenr.org makes much of the literature on the subject readily accessible. The rate at which articles are *downloaded* from that site sometimes exceeds one per minute for an entire month. His 2004 book *Cold Fusion and the Future* provides a visionary picture of the impacts of LENR. It is freely available at http://lenr-canr.org/acrobat/RothwellJcoldfusiona.pdf.

At ICCF20, Rothwell offered a poster paper entitled "Cold Fusion Will Lower the Cost of Both Energy and Equipment." The cost of energy is due to both the costs of fuel and the machinery needed to generate energy from the fuel. Rothwell states, "Cold fusion will lower the cost of energy because the fuel costs nothing." He then goes on to make the case that mass-production of small, distributed generators "is likely to fall by a factor of 200, from $2,000/kW to $10/kW." He likens the expected transition from large, expensive electrical generating stations (with the necessary distribution grid) to small and distributed LENR generators to two historical transitions. One is the shift from water wheel and steam engines to small electrical motors. The second is the replacement of mainframe computers by personal computers. The paper based on Rothwell's ICCF20 poster is available online.[12]

Igor Goryachev is affiliated with the Russian Academy of Science in Moscow. He was unable to attend this conference. However, two of his abstracts appeared in the printed book of abstracts. They were done with V.D. Kuznetsov from the Center for Applied Physical Research in Dubna. The first paper was titled "Technology of Processing and Conditioning Uranium and Plutonium Fission Products and Liquid Radioactive Waste." The paper reviews a technology called GREMIS developed in the Center in Dubna. That process involves an inorganic glass sorbent that can capture radioactive waste from water or inorganic acid phases to produce a glass sand that entrains the waste elements. But, the authors note, producing a more stable matrix for radioactive waste does not solve the basic problem. They envision the use of LENR to fully neutralize radioactive elements. An earlier publication by Kuznetsov on remediation of nuclear fission waste was summarized. It involves the use of electromagnetic (EM) radiation to initiate nuclear reactions of problematic waste elements. The authors write "the newly discovered method of electromagnetic impact on radioactive materials…results in transforming unstable isotopes into stable ones…" They add "…low energy nuclear transmutation is actually a threshold nuclear reaction of resonance nature and of exothermic type which makes it energetically advantageous." It is not clear from the abstract if the EM process could be performed on the glass encapsulated waste. The state of development of the concepts is not stated.

The second abstract by Goryachev and Kuznetsov has the title "Implementing Innovative Technologies for Cleaning Sea Areas from Solid Pollution." The authors began by summarizing existing technology for shipboard waste destruction based on plasma arcs. They envision 10 MW electrical generators powered by low energy nuclear transmutation of oxygen obtained from distilled water. The generators would weigh 25 tons and consume 27 grams of water each day. The authors and their colleagues have already done significant conceptual design and cost estimating for a ship with three of the LENR-powered generators. The status of the actual development of the core generators is not given in the abstract.

V.F. Zelensky of the Kharkov Institute of Physics and Technology in the Ukraine had two abstracts for posters at ICCF20. The title of the first was "Nuclear Fusion Reactions in Vacuum and in Matter and Two Ways of Nuclear Fusion Energy Mastering." The author invokes the formation of "Gryzinski quasi-molecules" to create conditions favorable for nuclear reactions. They are called "transitional formations." Papers published in *Physics Letters* and *Nature* by M.J. Gryzinski are cited. The quasi-molecules "operate the abnormal internal γ-conversion. This eliminates restrictions and prohibitions associated with the γ-quantum radiation." The author notes that the reactant nuclei still have to overcome the Coulomb barrier. The author describes the production and absorption of "bineutrons" in the "reaction zone." He terms it "chemonuclear fusion." Evidence for the validity of these views is offered in the second paper.

The title of the laboratory paper by Zelensky is "Pilot Chemonuclear Fusion Energy Generator Development and Testing ('Control Experiments')." The measurements were carried out during 2013-3015. The prototype generator was based on a "gas discharge installation." It contained "HD-Nickel," an atmosphere of 85% D_2 and 15% H_2, and the heat-generating material ("a pseudo-composite") with "micro cracks, ruptures, pores, etc." Such conditions are created on the nickel surface by gas discharge processing in the experimental chamber. The experiment yielded 35 W of thermal power with an energy gain ("efficiency") of 1.8-1.9. Bineutron absorption by the isotopes of nickel is used to explain the observation that there is a "Reduction on concentration of all nickel isotopes except ^{62}Ni isotope where concentration growth is observed." That idea is also used to explain the isotopic results in one test of a Rossi reactor.[13]

Valesca Feltrin from the Universidade Federal de Santa Maria in Brazil and this author studied an important potential application of the energy from LENR. Our poster was entitled "Production of Clean Water using Energy from LENR." One billion people do not have routine access to clean water. The medical and human costs of the unavailability of safe water are staggering. Bad water can contain (a) dissolved materials, which are removable by distillation, ion-exchange or reverse osmosis, or (b) suspended materials or (c) biologicals, both of which can be cleaned up by distillation, filtering or flocculation. Biologicals can also be destroyed by chemical treatment. The authors tabulated published values for the energy required to produce one liter of clean water. It was found that a 1 MW LENR generator could produce enough energy in one day to make (at 100% efficiency) about 90,000 liters of water, enough for the daily drinking and sanitation needs of 4,500 people. A more complete study is needed, including the energy costs of pumping the water, in addition to cleaning it.

13. Other Diverse Reports

Hidemi Miura, an independent researcher in Japan, presented a poster with the title "States of Hydrogen, Oxygen and Magnesium Atom in or with Cubic Ice-Crystal-like Water Clusters." His simulations were done with the computer program MOPAC, which is a semi-empirical Molecular Orbital Method that is run on a personal computer.[14] This research is motivated by (a) reports of refractory metals like Ti and W melting quickly when exposed to a torch burning oxy-hydrogen generated electrolytically under vibratory (pressure-reducing) excitation, and by (b) evidence of transmutations occurring under such conditions if electrolytes containing alkali or alkaline-earth solutions are used. Such evidence is taken to indicate the occurrence of LENR. Experimental data showing a distribution of water clusters that peaked in the range of 10 to 20 molecules was cited. The computational work showed that clusters containing ten water molecules are bound with energies per molecule of about 5% of the binding energy of H and OH in water. When three atoms were added to such a cluster, it was found that the cluster is stable and the H atoms "collided together in strong oscillations." The author stated, "We are studying whether these strong H collisions cause nuclear fusion and high burning temperatures on the metal surfaces."

Slobodan Stankovic is another independent researcher. He is from Swiss Oxyhydrogen Energy, and presented a poster entitled "Measurements of Temperature and Electron Density of the Oxyhydrogen Flame." He wrote, "This research is a part of a bigger project, which is the use of the oxyhydrogen gas issued from the water electrolysis, not as a fuel but as energy carrier...The oxyhydrogen gas, also known as HHO or the Brown's Gas, is very popular among experimentalists, because of the ability to easily build a setup for its production and use it readily for certain experiments. But beyond that, there are very few in-depth studies or analyses of its strange behavior and its extraordinary properties." He employed Moiré deflectometry to measure the temperature of HHO flames. He "discovered that the temperature of the oxyhydrogen plasma ranges between 130-150°C." That low temperature is interesting since such a flame "can melt metals like Tungsten that require a temperature of around 3500°C." Unlike Miura, Stankovic does not explicitly implicate LENR in the odd behavior of HHO flames.

Shinsuke Ono is from the Koushiryoku Laboratory Ltd. in Japan. His poster was on "Simulation of the Neutron Generator with a Nickel-Hydrogen System." His computations used "only standard physics of electron capture and the Compton Effect." The reactor design consisted of four parts, a vacuum vessel, two nickel electrodes and an applied voltage source of at least 0.79 MV. The positive electrode was "absorbed" with hydrogen, which is supplied from the outside. The key assumption about operation of the reactor is the ability to produce neutrons from protons, electrons and 0.78 MeV. The simulation yielded two noteworthy results. First, after one hour with the applied voltage, nuclear reactions continued spontaneously without further voltage input. That is, "burning" was possible. Second, an energy gain exceeding 500 is possible, along with various transmutation products. Ono is seeking partners with facilities to build and operate a reactor based on his simulations.

14. Policies about Energy and LENR

The study of LENR is interesting on many levels—scientific, technical, engineering, safety, regulatory, intellectual property, other legal, personalities, businesses, other organizations, countries and high-level policy. Interestingly, ICCF20 essentially began and ended with presentations on policy.

In the opening session, Dr. Takao Kashiwagi presented an overview of the "Present Status of Hydrogen Energy Policy in Japan." He is a Distinguished Professor in the Tokyo Institute of Technology and Chairman of the Advanced Co-Generation and Energy Utilization Center of Japan. His presentation began with an overview of the mix of electricity sources projected for Japan in 2030. Energy from hydrogen was highlighted because it can provide energy savings and security, reduce environmental loading and promote industrial development. Kashiwagi then went on to detail all phases of the production, storage, transportation and utilization of hydrogen. For example, the use of three methods for electrolysis to produce hydrogen were considered. The employment of fuel cells for many applications, including cars and homes, was highlighted. This presentation provided part of the context for the eventual use in Japan of power generators based on LENR.

The last presentation of the conference was on policies in the U.S. regarding LENR. Thomas Grimshaw from the Energy Institute of the University of Texas at Austin and this author presented a paper entitled "Responsibilities of U.S. Government Agencies for Support of Low Energy Nuclear Reactions." The paper has two major points. First, there are many organizations in the national government with responsibilities for energy production and use, and related factors such as environmental protection. The paper lists 30 such agencies in both the Congressional and Executive Branches of the government. Second, it was noted that current policies regarding LENR are greatly out of synch with the present status of the field. Government agencies are still operating under policies established early in the field, that is, about 1990. Those policies fail to recognize LENR as a legitimate field of scientific inquiry, even though it has a strong empirical data base and great potential practical promise. Hence, there is scant government funding of LENR in the U.S. The paper recommends that the responsible agencies recognize the current status of LENR and update their policies to be consistent with the reality and promise of the field.

15. Other Functions at ICCF20

A General Meeting of the International Society for Condensed Matter Nuclear Science (ISCMNS) was organized and held by Bill Collis on the Monday evening of the conference. Collis is the founder and Chief Executive of the Society. It was started in 2003, and has served the field in a variety of ways. A major contribution is the maintenance of a library on the web with about 1400 full papers. The link to the ISCMNS Library is https://www.iscmns.org/library.htm. Another great service to the field is the organization of meetings. Collis announced the planning for the 12th International Workshop on Anomalies in Hydrogen Loaded Metals to be held near Asti, Italy, during June 5-9, 2017. See https://www.iscmns.org/work12/index.htm for details. That website states, "The purpose of the workshop is to bring together international experts to present their results and encourage discussion. The emphasis is on experimental innovation, methods, instrumentation, diagnostics and theory. In addition there will be afternoon discussions on topics of interest including explanations for the anomalies."

A meeting of the International Advisory Committee (IAC) was held on Tuesday evening. That Committee consists of the Chairmen and Co-Chairmen of previous ICCF, or their representatives. It exists to decide on the chairman, location and potential timing of the next conference in the series. The IAC meeting in Sendia was attended by 16 principals and a few others. Some topics of general interest were discussed prior to determining the characteristics of ICCF21. They included (a) the publication of ICCF proceedings in the *Journal of Condensed Matter Nuclear Science*, which is edited by Jean-Paul Biberian, (b) the medals awarded by the ISCMNS and (c) the possibility of support for scientists to attend ICCF21, depending on the quality of their submitted abstracts. Dewey Weaver was at the IAC meeting to represent the company Industrial Heat LLC. On behalf of that company, he tentatively offered to host ICCF21 in Raleigh, North Carolina, in June 2018. He said that a decision will be finalized in March 2017. After the meeting, the IAC members and some of their wives enjoyed a remarkable nine-course dinner at a nearby restaurant.

There were two other very pleasant social and cultural events during the week of ICCF20. The Excursion was held on Wednesday afternoon. It began with a bus ride to Shiogama, where we boarded a boat for a cruise to Matsushima. The cruise passed many interesting small islands during the hour-long trip. Matsushima is the site of many fascinating caves with religious statues, and the Zuiganji Temple. It is described as "one of the most famous Zen temples, and is well known for its beautifully gilded and painted sliding doors. Zuiganji Temple was originally founded in 828 as a temple of the Tendai sect, and was converted into a Zen temple during the Kamakura Period (1192-1333). After years of decline, Zuiganji Temple was restored to prominence by the feudal lord Date Masamune, who rebuilt it as his family temple in 1609."[15]

The very nice conference banquet was held on the Thursday evening of the conference in the nearby Hotel Metropolitan. After the banquet, a trio of musicians entertained the conference participants and guests by marvelous playing of three-stringed instruments called "shamisen." Bill Collis presented the Preparata Medal of the ISCMNS to Jirohta Kasagi for his many scientific contributions to the field over the years. Also at the banquet, the conference organizers recognized two participants, who participated in all 20 of the ICCF meetings. They are Francesco Celani from Italy and this reviewer. We received nice certificates and Pokeman T-shirts!

16. Commercial Status

The Abstract Book distributed at the conference has 98 abstracts. Most of the presentations were from research and academic organizations, academies, institutes, agencies, projects and centers. However, 25 of the abstracts listed the authors or co-authors with company affiliations. Hence, it is clear that, even though the study of LENR is still dominantly a scientific field, there is great commercial interest in the subject.

LENRIA Corporation, the Low Energy Nuclear Reactions Industrial Association, was represented at ICCF20 by its cofounders Steven Katinsky and this reviewer. It is still in the stage of advocating for LENR, both for awareness and funding. Membership will be sought when interest in LENR becomes more widespread. LENRIA published calendars in 2016 and 2017, which show the global character of research and development of LENR. The 2017 version is available from *Infinite Energy*: http://www.infinite-energy.com/store/index.php?main_page=index&cPath=9

Intellectual property in various forms, including patents and trade secrets, will be as important to the commercialization of LENR, as it is for any new and promising technology. The field is fortunate to have actively involved David French, a Patent Counsel from Canada. He is very familiar with the U.S. Patent and Trademark Office. French often attends LENR conferences, but could not be at ICCF20. However, the Abstract Book included something he wrote entitled "Patents in the Land of LENR." That abstract began by noting the issuance of a U.S. patent to Leonardo Corporation, based on an invention of Andrea Rossi, in August 2015. That was a surprise because the case was not handled by normal procedures. It was followed by an international filing under the Patent Cooperation Treaty (commonly called the PCT).[16] French asked the question: "Will these or any other patent filings eventually have a controlling impact on developments in the field of LENR?" He sought to provide a review of key patent principles, so that those interested in protection of Intellectual Property on LENR will "understand correctly what patents can and cannot accomplish." French has been following the lawsuit brought by Rossi against the LENR-development company Industrial Heat LLC. That lawsuit and many associated machinations have provided background noise in the field of LENR for one year. At the end of his abstract, French wrote: "The paper will conclude with a projection as to the impact that prospective future patents in the LENR field may have on commercialization of LENR around the world."

It has long been hoped that commercialization of LENR generators to supply thermal and also electrical power would be only a few years away. While earlier products are conceivable, it seems optimistic to expect significant commercialization before about a decade. Reproducibility, controllability, types of safety, regulatory approval and consumer acceptance are all issues that must be confronted prior to commercial success of LENR.

17. Conclusion

One key topic presented at ICCF20 does not fit the categorizations given above. For that reason, and also because it deserves special attention, it is reviewed here. The Martin Fleischmann Memorial Project (MFMP) is important in ways that go beyond LENR. That organization began when a group of relatively young and enthusiastic scientists, engineers and businessmen with interest in LENR met at ICCF17 in Korea in 2012. They "self-assembled" into the MFMP, and have contributed significantly to the field in the past few years.

Robert Greenyer from the MFMP presented a poster paper at ICCF20 with the title "Live Open Science, Experience in LENR Research and Techniques for Future Application to Advance the Scientific Method." His abstract reads: "The 'Live Open Science' (LOS) method lays bare the motivation, development, raw data, analysis and discussion surrounding research undertaken. LOS leverages the connective, collaborative and distributive nature of the internet. Its purpose is to accelerate the scientific method and stimulate disclosure as well as mitigate the waste of effort and low efficiency associated with many disconnected teams working on the same research in private silence."

There is great and growing interest in "STEM" education in the U.S. and probably in other countries.[17] STEM stands for Science, Technology, Engineering and Mathematics. It is possible that the MFMP will become a formal part of the STEM effort. That would give students (and their teachers) the opportunity to watch scientific research in real-time. Watching sports is more engaging compared to only reading about the results. Possibly, watching LOS would stimulate young people to go into research, maybe even on LENR!

Overall, ICCF20 was a very successful and pleasant conference. The variety of experiments, theoretical ideas and applications presented and discussed at the conference is noteworthy. LENR remains an exciting area of scientific research and an emerging technology with great commercial promise. However, there remain topics relevant to the field that are cause for concern. The absence from this conference of some key players in the field, both individuals and organizations, was not good news. More critical is the fact that some very good research groups in the field are unable to produce LENR despite having very good scientists and adequate support.

Funding remains a problem for almost all organizations and individuals working in the field, whatever their successes in the laboratory or in the development and testing of theoretical concepts. At the start of ICCF20, McKubre said that "Our field is not limited by money." While that is true on a large scale, many of the efforts in the field, which were represented at ICCF20 or not, are inadequately funded. More support could bring into the field many new researchers with fresh ideas, as well as significant capabilities. Large synchrotron x-radiation and available neutron sources could be exploited, if more funding were available. Work on LENR remains interesting and challenging on all levels from financial to scientific, technological, engineering, intellectual property, commercialization and public relations.

18. Comments by the Reviewer

This is the sixth ICCF for which I have provided a detailed review of the papers and activities. All of those reports have been published in this magazine. It is time to acknowledge the expert editorial and other assistance by Christy Frazier, without whose hard and enlightened work this magazine would not exist. My reports on the earlier ICCFs can be found in the following issues of this magazine: 88 (ICCF15), 96 (ICCF16), 106 (ICCF17), 112 and 113 (ICCF18) and 122 (ICCF19).

Preparation of these ICCF reports takes a lot of time, thought and work. Many people know that I am a scientist and engineer, so I am asked why do I function mainly as a reporter and commentator regarding the ICCF meetings? I do that for three reasons. One is to provide a service to the field for people who could not participate in the conferences. Another is to document a significant part of the history of the field, a topic that will get attention from historians of science long into the future. The last reason is personal. It is not possible, at least for me, to assimilate the many relevant details of all presentations and posters during the conference. Writing a review of an ICCF forces me to pay detailed attention to each of the papers. Doing that increases my knowledge of the field, with all of its diversity. It allows me to "connect some dots." Here is one example. At an earlier ICCF, Jacques Dufour introduced the concept of "pico-chemistry." That topic came up again in the ICCF20 paper by Francesco Celani and his colleagues. Also at this conference, Andrew Meulenberg and Jean-Luc Paillet spoke of "femto-chemistry." How are these related? Are the ideas that will ultimately lead to the understanding of the mechanisms of LENR already in circulation? Detailed study of the LENR literature might lead to answers to such questions.

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