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Research Article

Development of a Cold Fusion Science and Engineering Course

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Abstract

For three consecutive years, an introductory non-credit short course was taught on the science and engineering of cold fusion (CF). It reviewed its origin, extent, basis and substantial experimental proof of the observed excess energy (XSE) from active cold fusion (lattice assisted nuclear reactions) systems. The range of CF technologies spanned from early aqueous CF/LANR systems to recent day nanomaterials. While academic officials are slow to recognize cold fusion and its viability, the fact is that the subject and its science have entered the academic domain, and students can learn that the phenomenon is real and reproducible.

Keywords: CF academic course, CF curriculum, CF education, CF training, LANR academic course, LANR education, LENR academic course, LENR education

1. Introduction

Education plays a critical role in the development of any science and technology, and it is especially significant in an emergent, controversial field like cold fusion. What heightens its difficulty here, however, is that the scientists and others interested in learning more about the field are almost always under an intense barrage of unfair criticism and blistering attacks from competing interests and skeptics. Despite this major obstacle, just as it has been important to have occasional cold fusion open demonstrations, it is important to create (and expand) cold fusion education in the classroom.

This report describes how a complicated and new alternative energy subject-matter was tailored to a college course-work program, and was offered as an introduction to cold fusion during its Independent Activities Period (IAP), designed for students to engage in topics outside-of the-normal-curriculum.

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2. Experimental

The goal has been to increase the number of well-trained cold fusion scientists, researchers and theoreticians by introducing a range of material science, physics and engineering to them with the hope of expanding awareness, educational excellence, and the science and technology needed to develop and proceed with this energy-efficient technology. Enrollment was open with permission from the instructors, Prof. Peter Hagelstein, PhD, MIT Professor of Electrical Engineering and Dr. Mitchell Swartz, ScD, MD, of JET Energy Inc. IAP at MIT, for those not familiar with it, is a special four-week program where students can choose from a vast array of non-credit and for-credit short coursework offered only during the month of January of each year. CF-101 was a non-sign up, non-credit introductory course open, to MIT and non-MIT students, alike, as well as the public. The CF/IAP classes generally extended over two weeks.

A brief summary of the content was published in *Current Science* [1], and this paper goes considerably further to enable and encourage others to adopt and expand the curriculum. Here is the scope of what was covered during January, 2013. Prof. Peter Hagelstein began with an overview of how cold fusion began, its science, the structure, materials and output of the Fleischmann/Pons (F/P) effect, and skeptics' arguments. He reviewed the origin, extent, and basis of the observed excess energy (XSE) from active CF/LANR systems. He spoke about the roles of palladium, palladium hydrides (palladium filled (aka "loaded" with an isotope of hydrogen), and the method/difficulties of metals actually loading with hydrogen. He then clearly detailed some of the exact reasons why F/P succeeded whereas so many "good scientists from good laboratories" could not initially replicate their experiments in the early 1990s. Generally, they were unable to achieve the requisite highly loaded palladium, which is unconditionally required for achieving active, deuterium fusion which is the desired cold fusion effect.

Prof. Hagelstein explained that the big issue was that the experiments were attempted at the "best" labs by very good scientists, and they were not able to confirm it; that the effect itself is unexpected, and in contradiction with what would be expected from condensed matter physics and from nuclear physics. One member of the class pointed out that even the Harwell data clearly demonstrated a 10–15% excess power during the portion of the run shown. Prof. Hagelstein explained that such a small amount was insufficient for them (as were the bursts of excess energy in only the heavy water side of their setup). Like the other famous groups, they too, could not report positive results. This report describes how a complicated and new alternative energy subject-matter was tailored to a college course-work

Figure 1. Students and interested researchers develop their science and engineering skills about cold fusion, isotopic loading of metals, and calorimetry during the "Introductory Cold Fusion IAP Course" offered at MIT in 2013 (photocredit: Gayle Verner).

program, and was offered as an introduction to cold fusion during its Independent Activities Period (IAP), designed for students to engage in topics outside-of the-normal-curriculum (Fig. 1).

To understand how success was achieved, Prof. Hagelstein then moved the discussion along to kinetic issues involving the loaded/loading palladium deuteride (PdD) lattice, including its dynamic structure and the roles of lattice expansion. He clarified how deuterium goes in via the Volmer reaction, and out via the Tafel reaction and through cracks. In "good" cathodes, the internal leaks are minimized, which can reduce the level of internal leaks by more than 1000. At ENEA, Frascati, Violante, and his team anneal to samples, so as to get grain sizes on the order of the foil thickness, which, thus, minimizes internal leaks. To further underscore the importance of adequate loading, Hagelstein also referred to the SRI experiments which showed that excess heat *only* appeared when the loading ratio was, at least in, or above, the 0.85–0.9 range. Also supporting the need for high loading, he discussed the results of the Energetics group from Israel, who have used the Dardik-discovered Superwave.

Prof. Hagelstein proposed conditions under which deuterons in the metal are stabilized (or not), and how ^{4}He* might form for its nanosecond of existence in the metal. Since the electron density is too high, there is no site in the lattice where fusion can occur, except possibly at vacancies, where the electron density is lower. Because vacancies are actually stabilized with H or D addition, at a loading of 0.95 near room temperature, so vacancies then become thermodynamically preferred. Supporting that, since vacancies diffuse very slowly, they are also made on new surfaces, which is done by codeposition, he said. In the codeposition experiments, (going back decades) excess heat turns on within an hour after initiating codeposition. Later, he spoke of activation of CF/LANR and detailed the Dennis Letts' laser "beat frequency" terahertz region experiments which activate the desired reactions.

On Wed., January 23, Prof. Hagelstein explained how the loaded palladium hydride lattice, with sufficient flux and activation energy, is able to highly overcome the Coulomb barrier and then "chop up" the 24 MeV energy of freshly made helium (the so-called excess energy) into smaller energy quanta which the phonons (lattice vibrations) can then deliver coherently, in tandem, to the lattice. This enables the excess heat production in F/P and (variant) CF/LANR experiments.

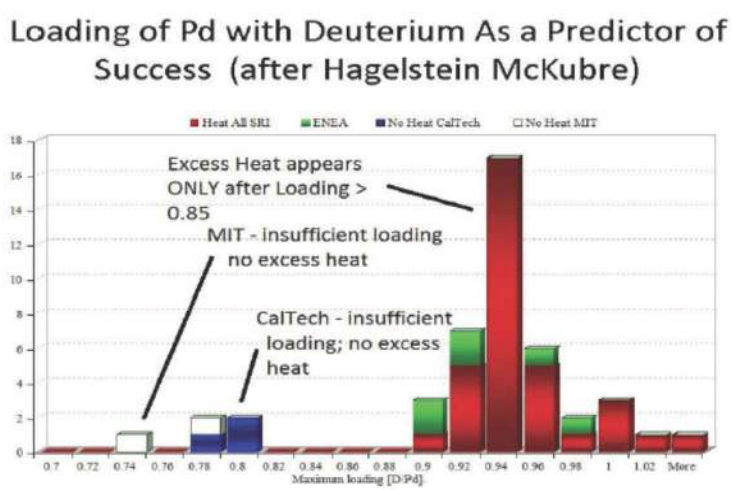

Figure 2. The success of cold fusion experiments has generally depended upon the loading achieved of the Group VIII metal. This is because in cold fusion, excess heat *only* appears when the loading ratio is very high. This graph shows that with increased loading (right-hand side of the data) there was historically a much greater likelihood of having seen cold fusion's excess heat.

Dislocations and cracks in the average cathode generate many pathways that include many internal leaks. These can become "superhighways" of hydrogen loss, can appear suddenly, and can end active samples, as they reduce stress internally. Generally, they were unable to achieve the requisite highly loaded palladium, which is unconditionally required for achieving active, deuterium fusion which is the desired cold fusion effect (Fig. 2).

On Thursday, Jan. 24th, Prof. Hagelstein continued about the several meticulous experiments which documented that helium (^{4}He) is made as the product of cold fusion from the deuterium which is loaded at very high levels into the palladium lattice. He showed this for three sets of experimenters including Dr. Mel Miles at the US Navy, and Dr. Len Case (working independently) from N.H., and at SRI in Calif., where it was also measured.

Prof. Hagelstein said that even the rate of helium production is also commensurate with observed excess power of cold fusion experiments, as was reported years ago in Italy by Gozzi. Furthermore, he said, regarding ^{4}He measurements that Bush and Miles demonstrated it was there; Gozzi showed that it was correlated in time with the excess power; SRI provided important confirmations, but beyond that they made the best measurement in his view of the Q-value. The issue is that some of the He is retained in the PdD (which was obvious from the Gozzi experiment).

One class attendee asked why there were not more of these experiments done. Prof. Hagelstein quickly pointed out that helium measurements are difficult because of both atmospheric contamination and confusion with materials of similar mass (that is D_2), and that meticulous efforts are required to shield the experiments from the atmosphere (by metal flasks, for example) and that expensive equipment is required to make the discriminating measurements required.

As a result, this type of work is very hard to do, he said, and expensive, and simply put, there has not been enough funding.

He also talked about the problem of helium occupancy at important choke-points in the lattice which must be empty as required for active, excess heat-producing, cold fusion systems. He proposed that the big advantage that the NANOR®-type CF/LANR components (JET Energy's) have is that the helium does not have to diffuse very far, so that the power level can be much higher.

Prof. Hagelstein discussed the activation energy required to get the desired reactions. He went through the data of several experimenters in the field including Dennis Cravens, who demonstrated observation of heavy water cells increasing output with a temperature rise. Hagelstein then followed that up with corroboration from other experimenters, including early recognition of this effect, an increase in excess power in time following a brief temperature rise (usually due to a calibrating pulse), as was seen by Fleischmann, Storms and Swartz.

Regarding activation energy, Prof. Hagelstein discussed the Dennis Letts laser experiment which activates specifically required, key phonon modes in the lattice – compressional optical phonon modes when the beat frequency is around 8.5 THz, and compressional optical phonon modes when the beat frequency is ~16 THz.

Prof. Hagelstein introduced the cold fusion/LANR Hamiltonian and the role of orbitals of hydrogen. Next, he related to the Hamiltonian he developed to also include the roles of deuteron flux through, and loading into, the palladium citing work by Mitchell Swartz and Akito Takahashi. He then explained how Corkum's mechanism led him to further understand his own, developing spin boson model which was derived from the work of Cohen–Tannoudji, and which explained how the 24 MeV from the ^{4}He* is chopped up into tiny amounts, and then delivered to the loaded palladium lattice. This is where there is then the appearance of the "excess heat" as the excited helium (^{4}He*) returns to its own ground state (^{4}He) as the energy is converted to THz phonons, and then thermalized to produce that heat.

Hagelstein's Take Away Message is that the lattice is key, and the physicist's theories are really not inconsistent with cold fusion, after all. He demonstrated exactly where it was insufficient to explain CF/LANR in the absence of his later discovery of the role of destructive interference and other loss and dephasing issues. Those loss mechanisms occur in the real loaded lattice.

On Friday, Prof. Hagelstein focused on the mathematical models and physical models for coherent energy exchange under conditions of fractionation, and on the Karabut collimated X-rays, which appears to show this effect, and expanded his CF/LANR Hamiltonian to now include coupling parameters.

Prof. Hagelstein continued with relativistic physics. Examination of the very strong coupling between the center of mass momentum and internal nuclear degrees of freedom is normally eliminated by a generalized Foldy–Wouthuysen rotation. However, under conditions of destructive interference such as in the lattice filled with lossy bosons, it does not appear appropriate. The Take Away Message was that his corrected condensed matter nuclear science (CMNS) Hamiltonian with all the additions is finally becoming very close to describing accurately what is actually being observed in CF/LANR

After a weekend break, lectures resumed on Mon., Jan. 28, led by Dr. Mitchell Swartz. He continued the talk regarding substantial experimental proof for cold fusion (lattice assisted nuclear reactions). Dr. Swartz presented what many consider the well-researched, evidence for existence (and development) of cold fusion in an understandable four plus hours (two each day) of scientific detail, not only reviewing decades of CF/LANR experiments but also presenting many how-to's of the successful processes.

He then shifted to hot fusion which unfortunately has a long history of technical and engineering failures. By contrast to hot fusion, cold fusion does not make any significant amount of dangerous radiation, he said, nor does it make other materials radioactive. It has zero carbon footprint. It could change everything.

He then discussed yet another reason why CF/LANR is so important – its energy density. He directed the class to the hard facts that the helium (^{4}He) production is in quantitative agreement with the XSE, as Mel Miles, Case, and SRI had measured; and that the rate of He4 production is commensurate with the power, as the Gozzi experiment had demonstrated.

Dr. Swartz continued, talking about the materials involved in CF/LANR. He taught how loading is achieved with either an applied electric field intensity acting upon water, separating out the deuterium, which with palladium, comes from the surrounding heavy water.

In the next session, after Dr. Swartz surveyed the methods of calibration of heat-producing reactions and systems, he detailed how there are now available many types of controls, time-integration, thermal waveform reconstruction, noise measurement and additional techniques, which are used, and is needed, for verification.

He then spoke at great length of the importance of the role of deuteron flow (flux) and explained the differences between flow calorimetry which can be inaccurate under some conditions where it is not calibrated, and the preferred methods of measuring excess energy. Having discussed the materials, and methods of measuring excess energy accurately, he segued to many examples of actual excess heat generated by a variety of CF/LANR systems. He showed graphs that were derived, using aqueous nickel and palladium systems.

Dr. Swartz returned to the concept of deuteron flux. Then using the Navier–Stokes equation, he developed the flow equations for both protons and deuteron flow in "conventional" cold fusion and in its variant, codeposition, where there is also flux of the palladium ions into the cathode which builds up a loaded compartment of active material. The concept of deuteron flux then led to metamaterials, a major improvement of CF systems. He focused on the salient advantages of the LANR metamaterials with the PHUSOR®-type system, stating that it is one prime, extremely useful, example with high output.

Dr. Swartz then shared another of his discoveries – Optimal Operating Point (OOP's) manifolds that organize CF/LANR output by the amount of input power. He explained how he discovered the OOP experimentally and showed how in all CF/LANR systems, no matter what the product (helium4, heat, or tritium production), and no matter what the system (palladium with heavy water, nickel with ordinary water, and nanomaterials) all of these when plotted as a function of input power demonstrate a series of dots which assemble and show a distinct pattern.

He went through the different regions, and showed where the reactions turn on and off, and how by plotting out the experiments this way, one could show consistency and reproducibility, time and time again. He demonstrated that OOP operation has shown the ability to determine the products of CF/LANR, and why OOP manifolds demonstrate that CF is a reproducible phenomenon, applicable to science and engineering. He also said that he had found OOPs in other colleague's experiments where they had not, and showed that their data also fit these curves.

Returning to the experimental results and engineering methods developed to control cold fusion, he then surveyed "heat after death" and its control for several useful applications, including the use of CF/LANR systems to drive motors. The important Take Home Point, he said, was that there is an extraordinary amount of data and information from it that has been collected over the years.

Emissions and energy derived from CF systems is how Dr. Swartz led the lecture on Tues., Jan. 29, 2013. He continued with the discussion of experimental results, now beginning with the near infrared emissions from active LANR devices, and the use of CF/LANR engines to generate electricity.

He finally focused the class from aqueous cold fusion to the nanomaterials in CF/LANR, now holding worldwide intrigue. Of particular interest was his discovery of a new type of dry and preloaded nanomaterials, a CF/LANR material which is producing phenomenal excess heat output.

After discussing these novel characteristics and electrical breakdown (avalanche) issues, which electric drive regions actually generate excess energy, he presented the development of several types of the NANOR®-type CF electronic components. He concluded with introduction to advanced driving circuits that were shown to have excess energy documented by temperature rise, heat flow, and calorimetry; heralding their revolutionary potential to change the energy landscape in circuits, distributed electrical power systems, artificial internal organs, propulsion systems, space travel, and more.

3. Results

According to the participants, the course was a success. At the beginning of the two week course, Room 4-153 in the Electrical Engineering building was nearly packed with a blend of about 35–40 students, as well as entrepreneurs, engineers, physicists, and "curious" members of the community, as the class size ebbed and flowed throughout the six-day event. Attendees came from as far away as Spain, China, Germany, and Switzerland. But they also traveled from California, Pennsylvania, New York, and throughout Massachusetts. Many said the course was "great" and reported also they were glad they came. If others disapproved, no one said so publicly.

4. Conclusion

While MIT officials still reportedly do not recognize cold fusion or its viability, the fact that it has entered the academic domain, albeit through the less-structured IAP agenda, is certainly noteworthy, both for those scientists working for its public acknowledgement and for the appearance of a place to go and get an education in this field. Twenty-seven years later, one can now walk into an MIT classroom, listen to academic lectures on the subject, and learn that the phenomenon is real and reproducible. And while it is still controversial, cold fusion seems to have found a fit, albeit tight, in the academic world.

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