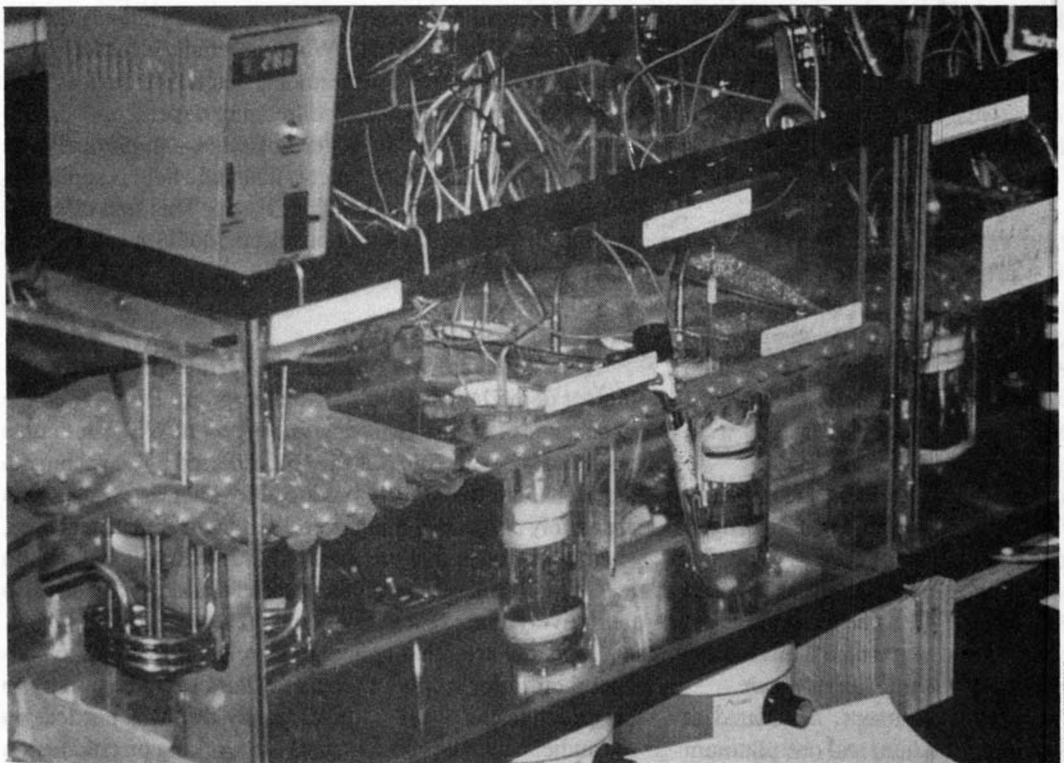
Cold fusion is a revolution in science

by Carol White

This author attended the Second Annual Cold Fusion Conference held in the beautiful alpine setting of Como, Italy from June 20 through July 4, on behalf of *21st Century Science and Technology* magazine. Contrary to the deliberate disinformation campaign—led by the *New York Times, Nature* magazine, and the European Center for Nuclear Research (CERN)—which seeks to describe cold fusion as a dead issue, the conference established stunning confirmation that cold fusion is indeed a nuclear phenomenon. My collaborators on coverage of the conference were Jonathan Tennenbaum, director of the Fusion Energy Forum in Germany, and Evanthia Frangou and Giuseppe Filipponi of the independent Italian-language science journal *Ventunesimo Secolo*. It was the consensus of this team that the discovery of cold fusion is the most important scientific event of the latter half of this century. It is a unique experiment which calls into question all of existing quantum theory.

For five days, 200 scientists met to consider a wide range of results confirming the reality of that process known as cold fusion. Cold fusion pioneers Martin Fleischmann and Stanley Pons were there to report on their newest, highly successful experiments. For the first time, using a palladium-silver alloy, they were able to guarantee the repeatability of their experiment. (See also, *EIR*'s interview with Dr. Fleischmann, April 19, p. 22.)

Fusion scientists from major laboratories in Japan, Los Alamos in the United States, and Frascati in Italy reported on neutron findings. The presence of helium-4 was reported on by a team from the Naval Weapons Center in China Lake, California, and incontrovertible evidence of the production of tritium was reported by the director of the National Cold Fusion Institute in Utah, which is now, unfortunately, closed down for lack of funds—the result of a lying press campaign against the center. Unfortunately, Dr. M. Srinivasan of India was unable to attend to report on the extensive experimental program in his country. Present were working scientists from Japan, China, Italy, Russia, Romania, Hungary, Sweden,



Ramtanu Maitra

A bank of cold fusion cells at Texas A&M. Initially, the electrochemistry group looked for neutrons and found nothing. When they sent samples of the electrolyte for a routine test with a liquid scintillation counter, to their amazement, two cells were producing as much as 1.6×10^6 counts per minute of tritium, which is about 10^{10} atoms of tritium produced per second. To check this anomalous result, the cells were sent to four other labs, including Los Alamos National Laboratory, and all confirmed the presence of tritium. Nevertheless, the science mafia accused Texas A&M of "spiking" the cells.

Australia, Spain, and Germany, as well as a good delegation from the United States.

The atmosphere in Como was jubilant, although there were many disputes—especially in the area of theory. This was a group of men and women who had been tested, not only by the demands of science, but by the necessity of standing up to the abuse of the leading controllers of science in the United States and Great Britain—of whom John Maddox, the editor of *Nature,* acted as the leader of the pack. Maddox's camp follower Douglas Morrison, of the European high-energy physics laboratory CERN, attended the conference as a representative of the opposition, but his abrasive presence was easily overlooked in the environment, which was happily preoccupied with advancing the frontier of scientific knowledge.

The first cold fusion conference took place in Salt Lake City, Utah, on March 28-31, 1990, about a year after the original Fleischmann-Pons announcement. The results reported were extremely encouraging. At this second conference, the evidence confirmed that cold fusion is here to stay, real and important from any scientific point of view, and most probably of great technological value for the future. A third conference is planned to be held in early autumn of next year in Japan. Financial sponsorship for the Italy conference came from the Electric Power and Research Institute of the United States (which is also financing research in the U.S.), from the Japanese Technova, Inc., from a number of scientific research institutes in Italy, and from the commercial corporation Ansaldo Componenti S.p.A.

Dr. Robert Bush, a professor of physics at California State Polytechnic University in Pomona, compared the conference favorably to the one held a year before. In a recent interview, he said:

"The conference was a signal success, and certainly a feather in the cap of the Italian organizers [Bressani, Preparata, et al.] and the rest of the international advisory committee. The general message conveyed by the conference was that, far from fading away, cold fusion research appears here to stay and is getting stronger. Thus in contrast to the situation at the First Annual Conference, where there were many reported failures to see the excess heat effect, essentially the vast majority of groups reporting are now able to achieve the Pons-Fleischmann effect of excess heat.

"In addition, the reproducibility is much greater than before. To be sure, many of the groups who previously were unable to achieve the excess heat effect have now discontinued their efforts.

"Any list of highlights of the meeting for me, would have to include the following: 'Boil-off results' achieved by Pons and Fleischmann, in which tremendously large amounts of heat were generated in a few hours time in a palladium cathode to boil off the electrolyte in the calorimeter. There were 11 successive events achieved of this type, so that reproducibility is essentially 100%. Moreover, this effect, which necessitates excess heat production on the megajoule levels, leaves no room for doubters."

Bush also puts Soviet results and the finding of helium-4 high on his list of successes over the year. He is also justly enthusiastic about his own experiment, in which he achieved high excess heat and a high percentage of excess power with cathodes consisting of thin films of palladium electroplated onto silver.

Cold fusion's first two years

On March 23, 1989, Martin Fleischmann and Stanley Pons announced to the world that they were able to achieve the fusion of deuterium molecules at room temperature through a process of electrolysis. Their research had come out of a decades-long study of the anomalous behavior of hydrogen diffusion in palladium—which, in fact, is used industrially for purifying hydrogen.

Indeed, before World War II, scientists had already speculated that the ability of palladium to concentrate hydrogen might allow cold fusion to take place. Palladium will concentrate the volume of gaseous hydrogen to a density 800 times greater than it is in the atmosphere. This phenomenon is yet to be understood, but it was a natural step which Fleischmann and Pons took to substitute heavy water for light water.

In their table-top laboratory experiment, conducted at room temperature, they use one palladium and one platinum electrode. The plasma that is formed as a result of this approaches the density of the plasma found in the core of stars, where fusion reactions occur continuously.

One hypothesis that has been generated by another team independently working on cold fusion effects, led by Steven Jones from Brigham Young University, is that cold fusion also occurs at the center of the Earth, where temperatures approach those at the photosphere of the Sun. Jones uses electrodes and electrolytes that were designed to replicate geological conditions rather than to generate heat (which he does not report), so that his cold fusion experiments are essentially different in character from those of Fleischmann and Pons, although important in their own right.

Thermonuclear fusion, which takes place when a hydrogen bomb is detonated, occurs at temperatures of hundreds of millions of degrees. Controlled thermonuclear fusion in the laboratory—as with the tokamak at Princeton University or the Joint European Torus—also occurs at these high temperatures, which are needed to compensate for the fact that the plasma fuel, deuterium and tritium, has an extremely low density, as compared to the compression within stars or in the palladium cathode. In both room-temperature and high-temperature fusion, the nucleus of a new element is created by the fusing of two existing nuclei: For example, with the fusion of two deuterium nuclei (isotopes of hydrogen), a helium nucleus is formed. At the same time, energized particles and large amounts of heat are released.

Understanding how this cold fusion process occurs, may also give us a window on biological processes, where chemical reactions occur at room temperatures and heat flow is carefully controlled through a body chemistry heavily dependent upon catalytic effects. (Water, after all, is the key component in body tissue. Furthermore, diagnostic devices such as nuclear magnetic resonance imaging depend upon variation in the "structure" of water in tissues—in particular on the time of spin relaxation when a magnetic field is applied—to determine the relative health of tissue. This spin effect is, in turn, dependent upon the potassium-sodium salt balance in the tissue.)

Experiments in Japan

The conference was opened by Dr. Hideo Ikegami, coordinator of the Japanese cold fusion program. He reported the wide range of experiments ongoing in Japan. While he doubts that excess heat results, of the sort reported by Fleischmann and Pons, are themselves produced by nuclear events, he is absolutely convinced that the array of nuclear products (i.e., charged particles that are emitted), such as protons, tritium and neutron emissions, at their expected energy, all establish definitively, the existence of "cold" fusion.

Japanese scientists appear to have great freedom to conduct their experiments, a state of affairs sadly beginning to disappear in the West—a discrepancy that was not lost on the audience. Over 100 scientists are working on cold fusion experiments in Japan, although some of these are doing so on their own time. They are organized into 20 groups, which span 40 universities and institutes. One decided advantage they have is that free materials are supplied to them by Tanaka Precious Metals Co., according to their individual specifications.

Ikegami represents the standpoint of many physicists internationally, who tend to evaluate cold fusion results in terms of the parameters of thermonuclear fusion. Unlike the vast majority of physicists in the West—particularly those in the field of fusion—he is so persuaded that cold fusion truly exists, that he describes Fleischmann's idea of using the palladium lattice to concentrate deuterium to densities at which fusion becomes a possibility at room temperatures, as one idea in a million.

Ikegami's point of view is completely at odds with the vast majority of experimenters in the field who are primarily electrochemists. They are convinced that there is no way that the excess heat—particularly in the amounts achieved by Fleischmann and Pons—could have been produced chemically. Therefore they contend that this is a crucial experiment, which will lead to new theoretical breakthroughs in order to explain all of the anomalies which have surfaced, especially the excess heat.

Several experiments which Ikegami reported upon were extremely exciting. At NTT Basic Research Laboratories in Tokyo, neutron bursts of 1 million neutrons have been observed, in gas phase experiments which are 100% reproducible.

In order to simulate the potential structure in the electrolyte, a surface barrier is created in the palladium. Magnesium-oxide is used to coat one side of a palladium plate that is loaded with deuterium. The other face of the palladium plate is coated with a thin film of gold in order to prevent the deuterium from escaping. After the palladium is loaded with deuterium, a vacuum is suddenly created in the chamber, causing high neutron bursts and an explosive release of the gas. The temperature at the plate rises to as high as 800°C, and the palladium plate is deformed. This experiment has also been performed with hydrogen gas, at which time the heat release also occurs. However, there are no neutron bursts nor charged particles.

Clearly, a change of state is occurring with the sharp pressure change. Similar experiments have been conducted by Franco Scaramuzzi of Frascati Laboratory in Italy, and by the Menlove team at Los Alamos National Laboratory in New Mexico, working with Steven Jones. These involved loading deuterium gas into titanium chips, where the loading was followed by raising the temperature by 600°C, from 200° to 800°C. In these experiments, liquid nitrogen was used to subject the titanium deuteride chips to repeated cooling and warming cycles. It is in the warmup phase that the neutron emissions occur. Neutron bursts here, however, were much lower than those detected at NTT (from 30 to 300 neutrons). A similar technique was developed by the Soviet, Zelensky group in Kharkov, as early as April 1989; however, they used an ion-implantation technique rather than gas diffusion.

Participants also heard extended presentations from Menlove and from the scientists at Gran Sasso and Frascati laboratories in Italy. In all of these instances, the main emphasis was upon proving that the neutrons that were detected were products of the experiment, rather than being picked up from background sources. These experiments give incontrovertible evidence that cold fusion does exist. Later on in the conference, Franco Scaramuzzi from Frascati emphasized that as much attention to detail was necessary in treating the materials in gas-loading as in electrolysis experiments. He gave a detailed description of the preparation of the titanium-deuterium gas system.

Whereas, in some instances, the Japanese are using the most sophisticated neutron detection equipment available, even with a relatively simple detection system, they have achieved impressive results. Ikegami described his own research at the National Institute for Fusion Science at Nagoya, where he used such a simple design. His intention was to dispel any doubt that neutron bursts were genuine fusion events, and not from cosmic radiation or artifacts of the experimental design. His experiment consists of palladium rods and a gas-loading design. He found significant neutron emissions in bursts of 30-60 neutrons per 100 seconds. These occurred four times during five-day periods, in several of the experiments.

He uses three electrically independent detection systems. One is placed at a distance from the cold fusion source in order to determine if there is background radiation or unexpected spurious radiation. The other two detectors are also electrically independent The neutron bursts were time-correlated, and could not—according to Ikegami—have originated from spurious sources. The detectors are adjusted in such a way as to pick up neutron bursts, which are rare events, and will only show up as 10% above background if they are averaged over a long period of time. The effectiveness of the detection system depends upon having the dwell time (the collection time period) correctly set, and geometric factors. There was a clear time coincidence between what was observed on each of the two detectors—confirming that the detection was not an artifact of the detector.

The most recent news reported from Japan, on June 19, was that neutrons were detected in the underground Kamiokande research neutrino-detection facility, verifying neutron emissions previously reported by Steven Jones. Jones's results were deprecated by the "experts" from *Nature,* who claimed that the neutrons could have come from cosmic radiation. Kamiokande's results were the second independent confirmation—the first having come from Los Alamos.

The Kamiokande facility is a kilometer below ground, in the Kamioka mine. The influence of cosmic rays is, accordingly, very low. At Kamiokande, the cosmic neutron level (the so-called background level) is 1 neutron per 18,000 seconds, which means that there is less than 1 chance in 100 million that researchers will see just one neutron in a period of 128 microseconds; yet, six times they detected more than two neutrons within that time period (128 microseconds was the duration of the collection, or dwell-time, of the experiment.) Not only did they absolutely confirm Jones's assertion that he had produced neutrons, but Ikegami believes that there must also have been single neutron events, which would substantiate the neutron emission rates which he found in his own experiments.

Important results from the past year were also reported by A. Takahashi, from Osaka University. These were electrolysis experiments, and he used pulsed power in order to trigger excess neutron emissions. His team also reported finding tritium and helium, in increasing amounts as the duration of the experiment increased, so that they were getting 1.5 times more helium by the third month than at the beginning. They also got anomalous heat burst. They detected both helium-3 and helium-4, with a greater ratio of the former to the latter. This, again, is the kind of result which is more in line with traditional thermonuclear fusion than some of the other results, which will be reported on below.

Fleischmann and Pons press on

A dramatic high point of the conference was the talk by Stanley Pons. Despite the fact that Fleischmann and Pons are trying to patent their process and therefore have kept many details under wraps, on this occasion they revealed some things about their experimental techniques that were not generally known before. More to the point, the very fact that they were pressing on with their work despite a witchhunt against them, conducted with equal vigor by the U.S. press and such groups as the American Physical Society, was a unifying factor, in a body of researchers who by-and-large had sharp disagreements with each other.

Cold fusion is a new science, and there are many sharp disputes raging among scientists and theorists about what is happening, why it is happening, and how to explain it on the most fundamental level. There is also a definite competitive spirit, as different groups vie to establish their own patents and glean a share of what limited funding is still available. Nonetheless, there is a common purpose among them—to pursue the truth at whatever cost—a commitment not usually so profoundly in evidence at scientific gatherings.

For myself, the meticulous detail necessary to achieve positive results in this intricate experiment was also extremely impressive. This came out not only in the presentation by Pons, but was a theme repeated time and again by the speakers—particularly the electrochemists. These experiments are not simple, even though they actually can be done on top of a table. It is not surprising that they still cannot be repeated at will, and only 20-40% of most cold fusion experiments to date have proven successful.

The basic experiment is highly nonlinear, so that even small changes in the initial conditions—changes of which the experimenter may be unaware—will make the difference between its success and failure. Furthermore, the preparation of the palladium used in the cathode, the regulation of the current, the necessity of achieving a high concentration of hydrogen in the palladium cathode, the composition of the electrolyte, the time for various phases of the experiment, and calorimetry measurements, all require upon meticulous care and sophisticated skills. Clearly, many of the physicists who plunged in to replicate the experiment in the heady first days after the March 23, 1989 announcement, were way over their heads in the world of electrochemistry.

Many scientists became discouraged with cold fusion, after only weeks of trying to replicate the work of Fleischmann and Pons. However, on average, they themselves take three months to complete just one experiment—which also explains why the number of experiments they report is relatively low.

Pons discussed how he and Fleischmann analyzed their data in order to counter charges that they were overestimating the heat gain (enthalpy). They estimate that they can have at most a 2.72% calibration error. They also reviewed details of the design of the calorimetry which they employed. Even relatively obvious things, like the difference between the temperature of the heat bath and room temperature, have apparently been overlooked by experimenters who failed to achieve results. Similar problems arise in the choice of calorimeter (a heat-measuring device), since the size of the palladium electrode is only one cubic centimeter.

Then there is the geometry of the cell. They choose cells with small diameters relative to the length of the cell, and they consider this to be key to success in obtaining excess heat (although experimenters in Japan have found that the reverse is true with regard to neutron generation). Most recently, Fleischmann and Pons have used a palladium-silver alloy in order to increase the stability of the electrode, and they report virtually total repeatability: positive results in 10 out of 11 tests, with one ambiguous result. Rumors circulating at the conference that the "ambiguity" occurred because the experiment actually blew up, appeared to be corroborated by Fleischmann's comment about the difficulty in developing calorimeters capable of withstanding higher heats, with the design constraints of his experiment. He pointed out that there was no question that they got excess heat and a boil-off, but that they could not estimate how long the experiment could have continued had the electrolyte not boiled off.

A crucial point that Pons raised was that the heat transfer in the experiment is highly nonlinear: It does not occur in a quasi-steady state in the cell, and it is also extremely responsive to pulsing of the power, or even simple upshifts and downshifts of current. A crucial point here was his statement that were the reaction steady-state, this would imply "that there are no reactions, and that there is no change in the mass of the cell occurring—and we are just totally convinced that it's just not true." In this regard, he pointed out the fallacy of the usual practice of linearizing differential equations by making such assumptions. He concluded by reviewing a few heat bursts which showed an extraordinary heat gain. Interestingly, the pair have used two platinum electrodes to establish a control, in place of one platinium and one palladium electrode.

He described the situation this way: "The important point here is that you are putting in [on average in terms of energy], including the boiling region, somewhere on the order of 16 volts and 0.8 amps, so that amounts over this 20-minute period here, where you observe the liquid totally boil out . . . something around 15,000 or 16,000 joules in total input. And totally neglecting heat transfer by any other mechanism—conductive or radiation, just neglecting that—you have a power output during this period of time, between the time it reaches the boiling point and boils out, that must have consumed on the order of 140,000 joules. . . . [But there must have been] at least another 90,000 joules of just radiation or conduction out of the cell, but not even considering . . . [that] you are still only putting in 15-16,000 joules, and you are getting out approximately 10 times that much energy in this time.

"We have reported on, and have seen this effect on several other occasions, but this one is the shortest time [two hours] in which the cell contents has boiled out. The others, in the worst case, generated approximately 50% excess energy during this electrolysis period, during the boil-out period. This, of course, does not occur with platinum electrodes.

You can certainly take platinum electrodes, crank up the current, and just put in as much power as you need to boil out all of the D_2O—or H_2O as well—and, to within a few percent, you get pretty much a clean heat balance, as you would expect just from joule heating and radiation from the circuit," had only an electrochemical reaction taken place.

Independent corroboration

At this point Pons turned the microphone over to Dr. Wilford Hansen, a physicist from Utah State University, who had been commissioned by the Fusion Energy Council of the State of Utah to conduct an independent study of unreleased data of Pons and Fleischmann. Reflecting on the witchhunt against cold fusion, which is continuing in the United States, he began with the comment: "Last January I was asked to do an independent study, an analysis, of some unreleased data of Pons and Fleischmann. My colleagues warned me not to do this—it was a no-win situation. Whatever that might be, I now have a report, and I have brought copies of that for Pons and Fleischmann to read. It is also being reviewed by some other people. I would like to tell you about it before the world grabs it and burns it, and me with it. But soon it will be out."

He then proceeded to verify the statistical methods used by the team to determine the production of "excess" heat—as much as 100 times more than any which could be attributed to a known chemical reaction. He chose eight cells; two were controls, which used hydrogen and showed no excess heat. The rest were intended to be heat cells and used deuterium as an electrolyte. Of these, five of the six, in his words, "showed definite excess heat." He determined that the whole set of experiments was impressive: In one cell, 6,000 electron volts of power were generated per palladium atom—1,000 times beyond any effect known to chemistry. As a point of comparison, with only five electron volts, a palladium electrode will be heated to its boiling point and vaporize.

Fleischmann added to Pons's report by revealing that the team is now using a palladium-silver alloy for a cathode, and that this is giving them a repeatable experiment. What is key here seems to be the stabilization of the palladium, which is otherwise quite brittle. Robert T. Bush and R.D. Eagleton also reported success by plating a thin film of palladium onto silver cathodes.

Much of Pons's talk was devoted to showing how—from the accurate measurements over several-day periods—they were entitled to extrapolate the profile of the heat balance for the total experiment. In the future, several scientists plan to measure net energy gain over the entire experiment. While Pons did not report that they measured the total inflow and outflow of energy of the four, five, or even up to eight weeks during which electrolysis takes place, nonetheless they can show such extremely high energy gains during days in which energy bursts occur, that it is virtually impossible to explain this, unless a nuclear process is assumed to be occurring. (Considering the experience and reputation of both scientists, the supposition that they are making some gross blunder of the kind involved with misreading their instruments is not really tenable. In any event, although such accusations have been bandied about, no one has come up with a plausible hypothesis of what sort of error this might be.)

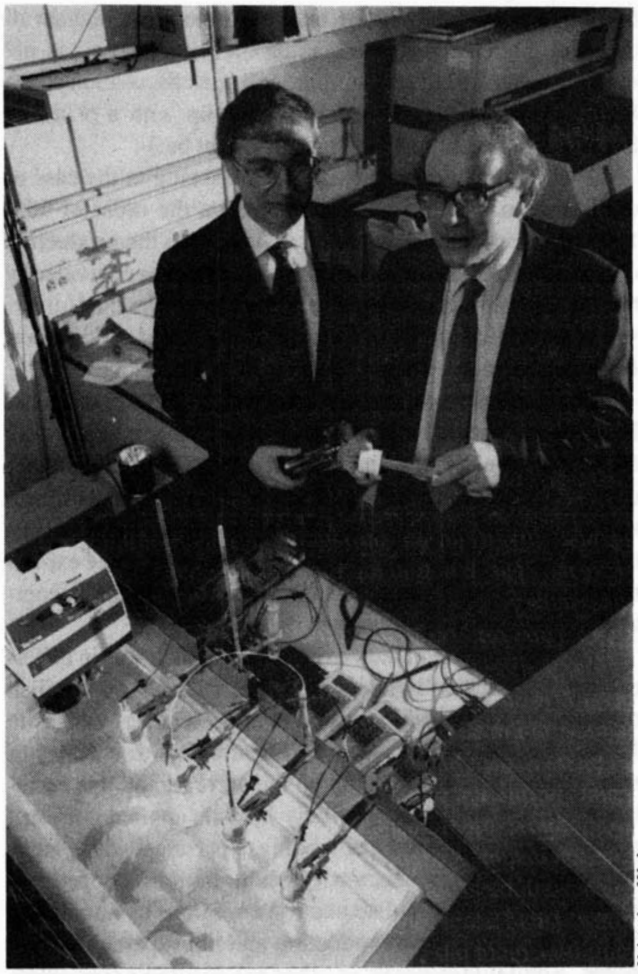
The kind of energies which we are seeing in the case of the Fleischmann-Pons experiments is on the order of 600-1,500% excess power, which translates into the production of excess energy on the level of 20 megajoules or equivalently 6 kilowatt-hours of energy. Bor Yann Liaw from the University of Hawaii, John Bockris from Texas A&M, and Robert Bush have also shown energy gains of this magnitude.

The generation of excess heat which Fleischmann and Pons report appears to scale approximately quadratically with the current density, leading them to prefer thin, 1 millimeter diameter cathodes. When the diameter is increased to 8 mm, no excess power is generated. Furthermore, the current must exceed 100 milliamperes per square centimeter if the experiment is to succeed. An increase in average excess heat generated correlated to an increase in the current.

This key feature in their experiment, which was in different ways replicated by Bockris at Texas A&M, the Italian experimenter F. Celani and a team at Frascati, as well as in Japan, was the responsiveness of heat bursts to changes of state. Thus, they would ramp up the current, and this correlated with the heat gain; similarly Bockris applied pulses of power; and Celani—in a gas-loading experiment with a high-temperature superconductor (yttrium barium copper oxide)—was able to stimulate neutron emissions by alternating the gas through a superconducting and nonsuperconducting phase. Similar techniques in other gas-loading experiments using titanium targets involved rapid temperature changes or the creation of sudden vacuums. For example, the NTT group in Japan achieved large neutron bursts when they lowered gas pressure in the vicinity of the palladium.

There is an interesting difference between experiments using electrolysis and those in which the deuterium is introduced into a tube directly. In the case of electrolysis, there are more problems concerning the purity of the material, but, on the other hand, the ability to control the voltage at the electrodes allows the palladium lattice to be loaded in approximately an atomic ratio of one-to-one with the deuterium. This loading ratio—or at least the achievement of a loading ratio above 7.5—appears to be crucial in guaranteeing success in the experiment.

The application of 120 millivolts of electrical power to a palladium electrode through electrolysis is equivalent to raising the partial pressure (in gas dynamic terms) to 100,000 atmospheres. With a gas-loading experiment, the highest loading ratio (between deuterium and palladium) that is achieved is in the range of 0.6 or 0.7, while with electrolysis it is possible to load the palladium electrode with an equal number of deuterium atoms. On the other hand, the electroly-



Stanley Pons, left, and Martin Fleischmann, with their initial cold fusion experiment.

sis experiments have an upper limit to the temperature which they can achieve, which is determined by the boiling point of the water. This lowers the Carnot efficiency of the process from the point of view of possible technical applications. (The Carnot efficiency refers to the fact that heat "flows" from high to low temperature, so that the ability to use the heat to accomplish work is a function of the temperature difference. The obvious model for this is the steam engine.) Experimenters at the University of Hawaii overcame this temperature limitation by conducting electrolysis with molten salts, but this is a highly corrosive process that presents its own problems: While they reached an impressive temperature of over 300°C, they were only able to repeat their experiment successfully on two occasions.

The question of the tritium

Dr. Fritz Will, former director of the National Cold Fusion Institute (NCFI) in Utah, reported on his and his collaborator K. Cedzynska's experimental findings of tritium in cells that replicated significant aspects of the Fleischmann-Pons experiment. Will is also formerly the president of the prestigious Electrochemical Society, and, like many of those present, a highly respected electrochemist. (See also *EIR*'s interview with Dr. Will, April 19, p. 24.)

Tritium is found on Earth only in trace amounts, and therefore these experimental results are important confirmation that fusion—or at the least, nuclear reactions—are taking place in these cells at the palladium cathode. Tritium is the heaviest isotope of hydrogen, with a nucleus which contains one proton and two neutrons; compare this with deuterium, which has one proton and one neutron, and hydrogen with just one proton. In typical thermonuclear fusion between deuterium molecules, either tritium or the next highest element in the table of elements, helium-3, which has a nucleus containing two protons and one neutron, are formed. However, a nuclear reaction producing the amount of tritium found—according to existing theory—can account for only one-millionth of the heat actually generated experimentally. Clearly, then, some other process must be occurring, in order to account for the excess heat.

For this reason, Dr. Will was particularly happy with the finding by the Naval Weapons Center of helium-4, even though these are yet to be confirmed. He believes that these will break the stalemate in which it was otherwise impossible to refute critics who maintain that there may be a mechanism of mechanical or chemical energy storage at work that is consistently being overlooked by experimenters, particularly those who report energy excess in the amount of 10-20%. These critics speculate that a small error, for example a 10% error in the calculation of the power might be accumulated over a period of a million seconds to create the appearance of a small but significant energy excess. So far only Fleischmann and Pons, the team at the University of Hawaii—in two experiments which they have been unable to repeat—and Robert Bush have reported a sufficiently high heat excess to obviate such an error factor.

Many cold fusion researchers had predicted that this might be the explanation for the otherwise anomalous results. The amount of helium-4 produced is much more consistent with the excess heat. In fact, in Dr. Will's opinion, the discovery of helium-4, as reported by the NRL team (and by the Spring 1991 issue of *21st Century Science & Technology*), is the single most important development reported at the conference.

There is, of course, also the possibility that some kind of nuclear reaction other than fusion is taking place. This is considered by Frederick J. Mayer and Peter Hagelstein, who each have different theories on the subject. Their contention is that neutrons can be transferred from the deuterium directly into other elements such as the palladium, lithium, or even contaminants. If true, this would open the door to a new mode of transmutating the elements.

Lastly, there is a possibility, which Dr. Will rejects out of hand, that there is some unknown chemistry involved.

Dr. Will describes himself as a conservative scientist, who is satisfied that there is good experimental data. However, he is maintaining an open mind on the origin of the excess heat, since no evidence has yet to be presented by anyone, with the exception of the experiments at the Naval Weapons Center, that would account for the low level of nuclear products.

Many different people, from various points of view, expressed frustration at the Como conference, about the failure of any demonstrated theory to explain the anomalous results. Notwithstanding, it was difficult not to agree with Martin Fleischmann and John Bockris, when they asserted that heat is, after all, the most important aspect of cold fusion. As Fleischmann said, we cannot uninvent an explanation or a new science. Ironically, in the same way that some of the physicists were uncomfortable with such bold assertions, the electrochemists failed to appreciate the beauty of nuclear findings, particularly the most recent showings in Japan and at Los Alamos.

Dr. Will's own work in establishing the presence of tritium in closed cells, modeled upon the general outlines of the Fleischmann-Pons deuterium-palladium electrolysis experiment, is unique: It totally accounts for the tritium found in the cell, before and after the experiment in each of the three possible phases—metallic, liquid, and gaseous—in which it occurs.

The finding of tritium by Dr. Will is no isolated occurrence: Tritium findings have been reported by the Bhabha Atomic Research Center (BARC) in Bombay, and by Storms and Talcott at Los Alamos, and particularly by Bockris at Texas A&M. However, in no case has the experiment been so precisely controlled as to put an end to the doubt that the tritium was somehow present at the inception or introduced extraneously while the experiment was in progress. Clearly then, a nuclear event is occurring in these cells. Dr. Will's work should have put to rest some of the skepticism about the reality of cold fusion which has been generated in honest members of the scientific community.

Although he was able to work only with four tritium cells, he found complete repeatability. A crucial element, according to him, was the loading ratio of hydrogen or deuterium to palladium atoms, which was one-to-one. No tritium was found in any of the light-water, control cells. Here, again, is a strong confirmation that there was nuclear action occurring in his experiment—as opposed to a merely chemical reaction—since only by a transformation of the nucleus of deuterium could the tritium have been formed. By using a closed-cell system, the environment in which the experiment took place was controlled.

The tone of the institute's summary report submitted by Dr. Will is modest, emphasizing what work is yet to be done. At Como, he emphasized that it is now necessary to develop techniques of on-line measurement of the production of tritium, as it occurs, which he was not able to do. Nonetheless, his work was not only an outstanding research success, but it underscores the loss to science of the forced closing of the NCFI. The institute's inability to get continued funding must be attributed to the deliberate, vicious slander campaign which has been waged against cold fusion researchers, begun little more than a month after March 23, 1989, when Fleischmann and Pons announced their astonishing results.

Breakthroughs at Stanford Research

There has been a rumor that there will be a dramatic report coming from the cold fusion scientists at Stanford Research Institute by the end of the year to the effect that they are able to turn their experiments on and off at will by controlling electrochemical conditions. Hence, the report from SRI's Michael McKubre was listened to with great interest. His work is being sponsored by the Electric Power Research Institute (EPRI), and for this reason, much of the work of his group is proprietary. Nonetheless, his talk was of great interest, because it is a well-known secret that his experiments have been extremely successful and, therefore, participants were trying to glean everything they could about what he was really doing.

McKubre primarily devoted his discussion to answering critics who asserted that in all probability the excess heat was not nuclear in origin—a contention which he, as well as Fritz Will, flatly rejects. Another question which came up was whether electrodes should be coated with palladium dust to "blacken" them, or whether they operate best in a clean environment.

McKubre began by emphasizing, as had many before him, that the loading ratio, which is the number of deuterium to palladium atoms in the palladium lattice, must be close to one. In fact, during the discussion period, he admitted that SRI researchers only get positive results when the loading ratio is above 0.9. To understand how to achieve a high loading ratio, however, it is first necessary to determine what occurs at the interface between the palladium and the electrolyte medium. He was not apologetic about the fact that, despite making nuclear measurements, at SRI they do not find significant amounts of tritium or other nuclear products. For him too, heat is key. He devoted the beginning of his presentation to a detailed explanation of how calorimetry works and why he is sure that the excess heat he measures is not an artifact of the measuring apparatus. His groups measure the entire energy of the system. They are concerned with the flow rate (dm/dt, which is the change in mass over change in time). They attempt to maintain a constant current by adjusting the voltage to compensate for changes in the electrolyte as the experiment proceeds, and so on.

Thence, the question arises about potential sources of systematic error which might occur because of the nature of the calorimeter. He analyzed why such errors could account for an error on average of 10%, and of 25% maximally, in any particular reading. These figures, however, are significantly below the percent of excess heat generated by his experiments. One method they use to check for error is to interchange resistors, which are used to measure heater and electrochemical power; thus, if the electrochemical reading is too high because of a mechanical error, switching the resistors should show a discrepancy between the reading of excess energy that is generated by electrochemical input power and the heater power, before and after the change.

They are also careful not to underestimate the amount of mass change over time, since this would result in an apparent excess amount of heat generation. Another key feature of their design is that where they ran control cells (which was not in every experiment), they multiplexed them to a single multimeter: In other words, the two cells were placed in series in the same calorimeter. McKubre made the strong assertion in this regard: "When we are running light experiments, experiments in series produce excess heat in one and not in the other. It is very hard to attribute that to an error in the multimeter. An error in the multimeter should show up in all the cells that we are running."

McKubre also emphasized that they needed to run a typical cell around 2,000 hours in order to have a successful experiment. On average, his team's experiments are getting something like 250% excess energy, in terms of the electrical input, which is somewhat more than 45 megajoules per mole. Furthermore, they have never seen an energy deficit during an experiment. He raised the question: If the excess heat is the result of a mechanical malfunction of the heat calibration, why would there not be an equal number of deficits as energy excesses? His team has never observed excess energy in light-water experiments, although it is his estimation that they have yet to do a sufficient number of these to establish the point definitively.

His conclusion: "We are unable to account for the excess temperature by any artifact that we have considered, and we are unable to account for it by any chemical or mechanical processes that we are aware of." In the discussion period, he also emphasized that he had achieved high repeatability. He asserted that this depended upon accurate control of the initial conditions—state of the electrodes, loading ratio, and control of the current.

Breaking the stalemate

Melvin Miles commanded attention when he described the details of the experiment which he and G.C. Ostrom from the Naval Weapons Center ran in collaboration with Ben Bush (no relation to Robert Bush) and J.J. Lagowski of the Department of Chemistry at the University of Texas in Austin. Using an apparatus very similar to the initial Fleischmann-Pons electrolytic cell, this group succeeded in detecting helium gas, using a mass spectrometer.

Miles's group had expected to find helium-3; instead, they were surprised to find helium-4. The finding, however, was in accord with several theories: It is otherwise difficult to account for both the small amounts of neutrons and tritium compared to heat generated in cold fusion experiments, and also for the fact that there is as much as a discrepancy of 10 million between the amount of tritium discovered, and to the amount of neutrons. This runs counter to the branching ratio observed in thermonuclear fusion, where it is equally probable for either helium-3 or tritium to be produced.

They are convinced that what they are observing is a surface reaction, because, among other things, the helium is detected in the gas above the electrolyte rather than mixed in with it. Unlike Fleischmann and Pons, they are successfully using a massive palladium electrode, which they struggled to keep uniform. They feel this allowed them to get results more quickly than Fleischmann and Pons—although it should be noted that they do not see comparable excess heat. Miles et al. believe that the nuclear reaction which is occurring is a surface effect, because the helium is found outside the electrode. Excess heat generated was only about four times what might have been expected from the amount of helium that was generated. This is an outstanding result.

The experiment was carefully controlled. While the experiment was done at Naval Weapons Center in China Lake, California, measurements were made at the University of Texas: Lagowski, in Austin, never knew in advance what cells he was being sent, and his group was even deliberately given cells filled with nitrogen, to test their apparatus and make sure that they would report a null result. In any cell with excess heat at or above 0.14 watts, helium was detected; in any cell with less than that amount, it was not detected. Seven out of ten cells they worked on gave excess heat to a maximum of about 30%.

Miles announced during his presentation that he had just received a facsimile transmission from his collaborator Ben Bush; Bush reported that when he performed the experiment with a palladium cathode that had been blackened with palladium black, he achieved excess heat within about two hours. This would be seen as confirmation that cold fusion is a surface effect by Robert Bush, John Bockris, and Miles—although they were already convinced that this would be the case. Robert Bush reported that he platinizes his electrodes. Others at the conference, such as Will and McKubre disagreed, and they contended that the best results come from a palladium rod which is shiny rather than coated.

Robert Bush agreed with Ben Bush that the addition of palladium chloride to blacken the surface should cut down loading times and work more efficiently than smooth, shiny palladium, once an optimal loading ratio has been reached. He believes he also has confirmation of predictions (according to his theoretical model) of the discovery by Franco

Scaramuzzi of a neutron emission line at a temperature of about 120°C. Robert Bush had predicted that such a line would show up at 126°C. He had not been aware of Scaramuzzi's results before coming to the conference.

Slander campaign

John Bockris, of Texas A&M, has taught many of those now most eminent in the field of electrochemistry, not the least of them Martin Fleischmann. He has a worldwide reputation, yet he has not remained untouched by the vicious climate against cold fusion being created in the United States. Journalist Gary Taubes has spread the slanderous story, in a forthcoming book debunking cold fusion to be published by Random House, that Bockris allowed one of his students to manually place tritium into a sample in order to pretend that cold fusion occurred. While Taubes has, of course, no credibility among anyone who is familiar with Bockris or his work, nonetheless, he is using the financial clout of a large publishing house to try to force Bockris into a no-win situation, where he, an individual with relatively small resources, will be pitted in court against Random House.

Nonetheless, Bockris is a fearless individual. He and Martin Fleischmann, in my view, are outstanding in their unwillingness to compromise on the question of cold fusion. Yes, the results were anomalous compared to thermonuclear fusion, which they see as a challenge to theorists, rather than requiring them to defend the validity of the Fleischmann-Pons experiment.

As opposed to the physics community, Bockris points to the discrepancy between tritium and neutron detection as *proof* that the result—cold fusion—cannot be evaluated in terms of *thermo*nuclear fusion, and that it therefore represents a new type of nuclear reaction. He also points out that cold fusion has an advantage over thermonuclear fusion: It does not produce the same amount of charged particles, which would make containment of the radiation necessary. Since it is established that the excess heat is produced in these experiments, far in excess of any known chemical reaction, then this must be a nuclear event, whatever the problems with detecting tritium or neutrons.

Even though Fleischmann believes that excess heat is the key parameter for asserting that cold fusion takes place, nonetheless he did point to the need for more general access to tools, such as mass spectrometers, so that helium-4 could be detected more generally.

In his presentation, Bockris presented evidence showing a correlation between electrical pulsing and heat generation, and he also showed pictures of the evolution of the palladium electrode during electrolysis as part of a detailed study of the fugacity of deuterium as it penetrates the palladium electrode. "Fugacity" is a term used by chemists to describe internal pressure. A major problem for experimenters, is embrittlement at the palladium electrode, since cracking can stop the reaction; however, he considers the possibility that there can also be locally high current densities, at voids on points where cracking occurs, where fusion may take place. These spread as the reaction time advances. This means that there are probable locally high current densities.

Bockris also hypothesizes that the dendritic and cauliflower-like formations which grow on the surface of the electrode may may also be the locus of cold fusion reactions. Dendrites were found to be about 2 microns high. In order to keep the reaction going after these formations emerge, it is necessary to step up the current. He believes that the palladium is thickly encrusted with impurity metals, particularly platinum (which has migrated from the anode), which penetrate the palladium within a few weeks.

He described several experiments with heat bursts. Electric pulses of 5 seconds duration would trigger heat bursts, apparently correlated with electrode charging. Some bursts were also triggered when electrolysis was stopped, as the liquid of the electrolyte was used up. Pulsing correlated to heat burst in five experiments. The two highest actually terminated the burst before the electric pulse was stopped. These occurred between 110 and 350 hours of electrolysis, and excess heat varied from around 8-23%.

Bockris's own cold fusion experiments have focused upon the palladium-deuterium relationship; nonetheless, he pointed to the need to look at a number of transition metals, because, even though they do not concentrate deuterium or hydrogen to the same degree as palladium, nonetheless cold fusion occurs within them at a lower rate. He is also extremely interested in a Japanese patent taken out last year, which specifies a number of alloys of the superconducting genre, as possible mediums for cold fusion.

Soviet and other national programs

V.A. Tsarev from the Soviet Union reported that the witchhunt against cold fusion by *Nature* magazine put a "freeze" on what had looked like a promising cold fusion program, which originally had 45 institutes engaged in the work. *Nature* notwithstanding, Soviet researchers have apparently also developed another means of provoking the emission of neutrons, by what they call "nuclear mechanofusion." One such device involved the fracturing of ice made from deuterium oxide. Similar experiments were done with lithium oxide. There is presently some effort to bridge the two devices with a fracture model, in order to explain at least some of the nuclear reactions which occur during cold fusion. The Soviets are also pursuing the geophysical and astronomical implications of cold fusion reactions, even were these to occur only on the low levels reported by Steven Jones. According to this view, the primordial Earth would have been composed of about 60% hydrogen, and hydrogen would have comprised 4.5% of the total mass of the planet. Other elements would exist as hydrides, and therefore the number of cold fusion events would be high.

Both the Republic of China on Taiwan and the People's

Srinivasan: 'A new door has opened'

It was a sad loss to the conference that Dr. M. Srinivasan could not attend. In the April 25 issue of the Indian journal *Current Science,* he published an open letter in which he reviewed the prospects of cold fusion. No doubt his remarks at the conference in Como would have been along the same lines. Dr. Srinivasan, the head of the Neutron Physics Division at the Bhabha Atomic Research Center (BARC) in Bombay, unlike many physicists, fully endorses the conclusions of Martin Fleischmann and others: that excess heat, as well as the presence of neutrons, tritium, and helium, is of nuclear origin (see *EIR,* April 19, page 25). His summary conclusions state the case:

"While physicists find it easy to accept that D-D reactions at the 'Jones level' (10^{-20} to 10^{-23}/s/d-pair/d-pair) can possibly occur in deuterated solids, there seems to be still considerable reluctance on their part to accept the idea that the 'excess heat' generation in electrolytic cells could indeed be of nuclear origin. So far the main justification for the nuclear origin of 'excess heat' had been the argument that the magnitudes of both excess power (W/cm^3) and (MJ/mole) involved are such that it is orders of magnitude more than what can be explained on the basis of known chemical phenomena (reaction enthalpies, phase change effects, stored energy release, etc). However the recent observation of significant quantities of He-4 in the off gas stream of electrolytic cells generating excess power, besides a marginal excess of He-4 in one electrolyzed Pd button should perhaps begin to convince the scientific community that proof of excess heat being of nuclear origin is now on hand. However this information is not yet widely known.

"In the judgment of this reviewer the infant field of 'cold fusion' is rapidly acquiring the status of a respectable new branch of science, and the mysteries behind what this author and a growing number of 'converts' firmly believe is one of the most fascinating scientific breakthroughs of our times is slowly being unraveled. Indeed the humble 'battery and bottle' experiment may well have unexpectedly opened the door to uncharted new realms of physics and nuclear technology."

Republic on the mainland have ambitious cold fusion programs. They have favored gas-loading experiments, and interestingly, observe a bluish glow at the tip of the palladium cathode, which may be a signal for helium. This occurred at the Southwestern Institute of Nuclear Physics and Chemistry in China. According to Zing Zhong Li, who is from Tsinghua University in Beijing, they are seeing particles with energies greater than 5 MeV and, in some cases, charge numbers greater than 2. If it is borne out that there are emissions of particles with charges greater than 2, this would weigh the balance heavily in favor of those theorists like Mayer and Hagelstein, and Professor Yang of Hunan Normal University, who believe that what is occurring is a neutron transfer, not the fusion of two nuclei.

A laboratory in Romania had also achieved positive results in cold fusion experiments.

What the future may hold

It is certainly premature to speculate about technological applications of cold fusion at this time. In general, the heat which is generated in the experiments has still to go much above the boiling point of water, but neither the potentialities nor the scientific implications of this discovery have yet unfolded.

While the electrolysis experiments are of great scientific interest, it may well be that the most successful applications will be based upon gas-loading devices; we may well find, as is emerging in high-temperature superconductors, that ceramic alloys will replace palladium or titanium. If it is true that the deuterium in the palladium lattice is in a coherent state, as many theorists now suggest, then perhaps someday a cold fusion cell will produce lased light instead of heat. Another possibility is the undetected existence of slow neutrons, which could be used immediately to breed nuclear fuels.

There is, however, one exceptional experiment, which would show immediate applicability were it repeatable. At the University of Hawaii, Bor Yann Liaw and a team of experimenters generated heats at 350-400°C, using a molten salt electrolytic cell.

Replacing heavy water, they used lithium chloride and potassium chloride salts in which a small amount of lithium deuteride was dissolved, to act as the main current carrier. The deuterium in this case was dissociated at the anode (the positive electrode), to become a negative ion. In this way, a reducing environment was created, in which the surface oxides on the palladium were removed. This had the advantage of facilitating the deuterium reaction. Liaw notes—as had Bockris—that many transition elements and their alloys can also absorb substantial amounts of deuterium, but are prevented from doing so in water solutions, because they have an oxide surface layer.

They achieved excess power levels as high as 25 watts for an input power of 1.68 watts—a power gain of 1,500%. Unfortunately, it has only succeeded on two occasions. However, positively, a control experiment based on lithium-hydride did not produce excess heat.

Excess power increased with current density, and one heat burst lasted for four days, generating 5 megajoules of energy. The experiment only stopped because the lithium-deuteride was exhausted.

In this case, the positive electrode (the anode) was made from palladium, and it was found after the experiment to contain 4×10^{10} of helium-4. This impressive amount is far more than that present in a control sample of palladium; however, it is seven orders of magnitude less than the amount which would be expected on account of the heat generation. The amount of excess heat which was generated, calculated in watts per gram of fuel, compares favorably with light-water reactors. Similarly, when this is calculated in terms of watts per cm^3 of fuel—600 watts per cm^3 of fuel—the comparison is still in favor of the molten-salt cell, that is, four to one. In a review paper, BARC's M. Srinivasan compares the potential of the molten-salt cell to the Canadian-designed Candu heavy-water nuclear power plant.

Legitimate questions exist

The cold fusion debate is complicated by the fact that not all of the criticisms are coming from its enemies: There are legitimate disagreements among scientists about what the process is, how it happens, how to optimize it, and so on.

In an interdisciplinary gathering like this was, one problem is that the electrochemists and the physicists do not always understand each other's working assumptions. Thus, the physicists look for charged particles; look askance at heat results and the chemists' assertion that excess heat generated during experiments leaves no possibility of a merely chemical reaction; and they are less impressed by neutron detection. When it comes to theory there are practically as many theories as experimenters.

No one still has any clear idea about about just what is happening in the experiment, even with regard to such apparently simple questions as whether the action is occurring on the surface of the deuterium lattice, or just below the surface, or is an effect involving the whole volume. Not only does this lacuna affect experimental techniques, but it also raises the question of how measurements are best evaluated, as energy per cm^2, or energy per cm^3.

Of course, to some degree and in some manner, the reaction involves the total volume and near surface, as well as the surface itself. The deuterium first concentrates on the surface of the palladium, but then diffuses through the volume. It also concentrates irregularly within the lattice, causing cracking which can impede the reaction, but perhaps creating points of concentration which allow cold fusion to take place. Researchers have intense disagreements about the role of impurities in the experiment: Some theorists like Mayer believe these impurities to play a crucial role, because they act as neutron donors or acceptors; others believe that the impurities enlarge the surface of the palladium electrode, and thereby foster cold fusion, which they believe to be entirely a surface effect. For those who believe it is a volume, or only a near-surface effect, such plating of the surface prevents the circulation of the deuterium and would impede the reaction.

Once a crucial experiment, such as the Fleischmann-Pons discovery, has challenged the basic assumptions held by scientists, it is to be expected that there will be a period of great turmoil, from which existing theories will be transformed to accord with the new understanding. This, of course, is how science progresses, by means of the succession of hypotheses, each of which expresses more profoundly man's understanding of the universe. In the course of such a shakeup, whole series of experiments are designed to test and refine competing hypotheses.

In the arena of fundamental theory, scientists also have profound differences, many of which have already been reported on in *EIR*, and will continue to be in the future. For the moment, the spotlight is rightly placed on the wealth of experimental data which is being assembled. In any event, on the most fundamental level, no theory can succeed without first facing the vicious assumption inherited from Isaac Newton, and incorporated into quantum theory: that the universe functions on the basis of disorder, chance, and therefore irrationality, which is most clearly expressed in the so-called Second Law of Thermodynamics.

Dr. Heinz Gerischer of the Max Planck Institute, who recently retired as director of the Fritz Haber Institute, is perhaps the most eminent electrochemist living today. He was invited to speak as an unprejudiced observer. In fact, as he admitted in his address, he was invited as someone who had accepted the mainstream line that cold fusion was a dead letter. However, after reviewing the available material before the conference and then attending the sessions at Como, he changed his view. He would repeatedly resort to the image of confirmed religious "believers" to describe some of the conference participants; yet, turning his irony on himself, when it came to cold fusion, he described himself, humorously, as an agnostic. However, he echoed the "believers." when he expressed the conviction that the anomalies in the ratio of charged particles to the production of excess heat, is in fact, evidence of the occurrence of a new nuclear process. Echoing the thoughts of many at the conference, he said: "If these quantities are correct, if a revolution in the nuclear theory has to combine solid state theory with nuclear force, we have a fantastic, new discovery."

Author's Note: The Fall 1991 issue of 21st Century Science & Technology *will have a report on the Como conference which includes pedagogical graphic material, of help to the general reader in understanding more about the issues involved in cold fusion.*