EIR Science & Technology

Fusion advances could lead to an economic revolution

Charles B. Stevens reports on the exciting developments surrounding the net energy production from fusion reactions achieved by Professors Fleischmann and Pons.

On Friday, March 31, 1989, Professor Stanley Pons presented, for the first time, the scientific details of his experimental demonstration of the generation of net energy from hydrogen nuclear fusion reactions to a seminar presentation at the University of Utah. A little more than a week previously, Professor Pons and Prof. Martin Fleischmann of the University of Southampton in England made the first public announcement of their stunning achievement of harnessing the virtually unlimited energy potentials of nuclear fusion. With the presentation on March 31 and the release of various scientific preprints, the stage is set for other scientists around the world to duplicate and further explore this new method of generating nuclear fusion.

While some laboratories have already reported qualitative confirmation of the Fleischmann-Pons work (such as the report presented by Professor Steven E. Jones of Brigham Young University in Utah at a seminar at Columbia University in New York City, which also took place on March 31), it is only now with the release of the scientific details that it has become clear why there would be difficulties in obtaining an immediate experimental confirmation, as was attempted by scientists at the Lawrence Livermore National Laboratory in California. Also, the actual prospects for immediate applications have become much clearer.

In a word, the Fleischmann-Pons results promise to revolutionize presently hegemonic scientific theories. They also point to the incredible potentialities of fusion power to transform every aspect of technology. Vast quantities of cheap, clean fusion energy could be realized, virtually without limit, at costs many orders of magnitude below current costs. If this (with allied technologies) is developed and applied, it could lead to an increase of the total world economic output by orders of magnitude within a very short period of time.

It is of interest to note that the major experiment described by Fleischmann and Pons was apparently performed two years ago. The release of the data now represents a very welcome opportunity to give the whole fusion program a "shot in the arm" and at the same time is a necessary corrective to the kind of pessimism spread by the environmentalist disaster mongers. The greatest benefit of the experiments may be in giving a new generation of youth confidence in a future with new frontiers for discovery and limitless potentialities for technological and economic growth.

Three-week buildup

On Monday, April 3, Professor Pons was interviewed on ABC's "Good Morning America" television broadcast. In the accompanying background news report, the experimental apparatus used by Dr. Pons was shown. This was a simple electrochemical bath, like that used in high schools for the generation of hydrogen and oxygen gas. A platinum anode and a palladium cathode are placed in heavy water and a small electrical current is run through the water. The heavy hydrogen that is generated is slowly absorbed by the palladium metal cathode.

Most significantly, Dr. Pons pointed out in this interview the most important experimental detail which explains why others had been unable to duplicate his results in the previous week: It is necessary to run the current through the electrochemical cell for three weeks before sufficient heavy hydrogen has been absorbed by the palladium electrode. After this period of time, the absorption level becomes sufficiently high to support a significant rate of the heavy hydrogen nuclear fusion reactions.

As Dr. Pons noted, it will therefore take scientists, who have now been given the full scientific details, about three weeks to fully duplicate the experiments. Already the kind of scientific explosion is going on which greeted the announcement of high-temperature superconductivity. There is one caveat. In this case, the very accessibility of the technology to accomplish the experiment can be dangerous, since the materials being worked with here are highly explosive, as one well-known laboratory which should have known better, has already found out. that major practical applications are imminent. As was reported on the broadcast, one could actually go out and get the appropriate materials to set up such a fusion energy system in the basement to heat the house. *But it is strongly recommended that this not be done.* The full story on how the energy is being generated in the palladium electrode has not been determined, as Dr. Pons reported. And this must be fully explored before scaled-up versions can be safely utilized in ordinary applications. astounding results of Fleischmann-Pons speak for themselves and can even be understood by the layman in terms of many of their implications. We will begin, therefore, with these, as reported on March 31.

Experimental results

The energy generation is reported to exceed 10 watts per cubic centimeter of the palladium electrode in which deuterium-deuterium nuclear fusion is taking place. Deuterium (D) is the heavy isotope of hydrogen, whose nucleus contains one neutron and one proton. Ordinary hydrogen (H) has a nucleus which contains only one proton. There also exists a third hydrogen isotope, tritium (T), whose nucleus contains two neutrons and one proton. H_2O (water) in which the H is replaced by D or T is called heavy water because these isotopes of hydrogen are heavier and the molecular atomic weight of the D_2O is therefore greater than H_2O.

Experimental runs with this level of fusion output have been carried out for more than 120 hours. The total energy output that is measured is therefore in excess of 4 million joules per cubic centimeter of the palladium electrode. Fleischmann and Pons note that, "It is inconceivable that this could be due to anything but nuclear processes."

This experimentally demonstrated level of power density output is already quite respectable. Projected designs for magnetic confinement fusion power reactors have reactor core power densities ranging from a few to ten watts per cubic centimeter.

In terms of net energy production, the experiment is generating upwards of 10 times the energy input utilized to keep the cell in operation. That is, the experiment is at 1,000% of breakeven—10 times beyond breakeven energy generation.

Some relative measure of how significant this achievement is, and what can be expected in terms of projected economic impact, can be judged by comparing the actual costs for the Fleischmann-Pons experiment and those for more conventional approaches to fusion. The simple tabletop electrochemical cell would cost no more than a few hundred dollars and can be put together within a few hours. Facilities to achieve this level fusion breakeven based on

Texas A&M, Georgia Tech confirm Utah fusion

Scientists from Texas A&M and Georgia Tech announced April 10 that they had carried out experiments which seem to confirm the experiments on producing nuclear fusion reactions at room temperature in simple electrochemical cells which were announced at the end of March by Drs. Martin Fleischmann and Stanley Pons.

At Texas A&M, Dr. Charles R. Martin, Dr. Kenneth N. Marsh, and Dr. Bruce E. Gammon showed reporters an apparatus that they said yielded from 20-80% more energy than had been put in. While Texas A&M only made heat energy measurements in this exceedingly quick replication of the original Fleischmann-Pons experiments, which had been carried out over a period of years, the Georgia researchers had made measurements on a similar palladium electrode chemical cell of the neutron output. Dr. James Mahaffey, leader of the Georgia Tech group, noted, "Our data convinced me that we are making neutrons in that vessel. There is no way to get neutrons unless something nuclear is going on."

These early confirmations have not yet revealed what the actual nuclear reaction is that is generating the net energy, though hydrogen, lithium-hydrogen fusion remain the only likely candidates, given the reaction products that are measured.

The Georgia experiments appear to have shed some light on why it may take two to three weeks of running the low electrical current through the cell before the fusion reaction begins to produce substantial energy output as reported by Fleischman and Pons. The Georgia researchers first baked their palladium electrode at 600°C. This drove out impurity gases already absorbed into the palladium metal. They then put the "cleaned" palladium rod into the water bath and achieved fusion much faster.

conventional magnetic fusion and laser pellet approaches are currently projected to cost hundreds of millions of dollars and take many years to construct. This represents a general reduction in capital costs by a factor of 1 million and in construction time by a factor of 50,000.

The experiments only used deuterium. Mixing in the other heavy isotope of hydrogen, tritium (T), could lead to generating the more energetic D-T reaction. The deuterium-tritium reaction is generally much easier to achieve than the D-D reaction. In general, it is found that, given the same conditions, the D-T reaction will take place at a rate hundreds of times faster than the D-D reaction with a resulting energy output 100 to 1,000 times greater. This would mean that the palladium electrode could achieve energy-density outputs in excess of 10 kilowatts per cubic centimeter. This power density would be 100 times greater than that of existing plutonium nuclear fission fast breeder reactor cores.

The experimentally derived scaling laws indicate that the general condition of ignition and thermonuclear burn are rapidly being approached. In fact, the last experimental run reported by Fleischmann and Pons, with the largest palladium electrode resulted in "a substantial portion of the cathode fused (melting point 1,554°C), part of it vaporized, and the cell and contents and a part of the fume cupboard housing the experiment were destroyed."

As reported by Dr. Pons, their experiments indicate that with a palladium electrode of 1 cubic centimeter size and a cell electrical current density of several hundred milliamps per square centimeter, full ignition may occur. This could mean that a table-top micro-hydrogen bomb could be generated. That is, with ignition, the fusion reaction becomes self-feeding and within a few billionths of a second most of the available fusion fuel is reacted.

If ignition and burn does take place, this would mean that construction of pure fusion hydrogen explosives would be relatively straightforward. Even if only a minute amount of fusion fuel were burned up initially leading to the generation of a few tens of megajoules this would be sufficient to trigger a conventional thermonuclear ignition and burn in a much larger quantity of fusion fuel. It would therefore be possible to make hydrogen explosives of any desired scale without the need of any type of nuclear fission (atomic bomb) trigger.

It should be noted that while the types of techniques needed for such a scale-up have been demonstrated by the countries currently possessing fission-triggered thermonuclear weapons, it does involve extremely sophisticated scientific and technological capabilities.

The most significant result from these experiments is that most of the energy being generated is coming from an apparently hitherto unknown nuclear process or processes. That is, in the experiment, the reaction products output for the ordinary D-D reaction are measured in terms of the tritium and neutron output. But this output does not match up with the total energy output. It is therefore crucial to determine what the nuclear energy generation process is that is producing most of the output. This will be done in future experiments.

Nuclear fusion

At ordinary conditions found on the surface of the Earth, nuclear fusion takes place at a very slow rate. In a deuterium molecule, for example, where the equilibrium distance between the two deuteron nuclei (a deuteron is a deuterium atom) is about 0.74 Angstroms (one Angstrom is one-billionth of a meter), the D-D reaction occurs at a rate of about one reaction every 10^{62} years per molecule. If the distance between the nuclei can be reduced, even for a brief time, the fusion reaction rate can be greatly increased.

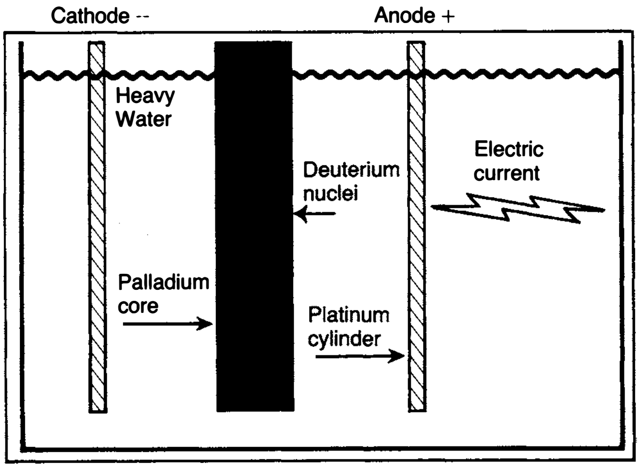
One way to do this would be to simply heat the nuclei to temperatures of millions of degrees Centigrade. And given that temperature is a measure of the average relative velocity, at these high temperatures the nuclei have very high relative velocities. This means when two nuclei collide, they will approach each other to within a much closer distance than 0.74 Angstroms. (The two nuclei have positive electrical charges and strongly repel each other.) At this smaller distance of approach, the nuclear fusion rate increases very substantially. And in this way substantial rates of nuclear fusion are apparently generated in the stars, hydrogen bombs, and previous laboratory experiments.

It is extremely difficult to obtain fusion in this manner. The fuel must be heated to these extreme temperatures—in excess of 100 million degrees Centigrade. Furthermore, the fuel must be confined and insulated against substantial rates of heat loss at these extreme temperatures.

The two previous chief methods of doing this were magnetic and laser fusion. In magnetic fusion, a bottle or trap made up of intense magnetic fields is used to confine and insulate the hot fuel. Microwave and/or other types of systems are then used to heat the confined hydrogen fuel to the required temperatures. In order to produce conditions sufficient for energy breakeven, which occurs when more fusion energy is generated than the energy invested in heating the fuel to fusion temperatures, the magnetic bottle and required heaters involve systems of a fairly large size and cost. The projected minimum cost for a magnetic fusion experiment which just reaches the energy breakeven point is hundreds of millions of dollars.

Fusion ignition occurs when the rate of fusion energy output is sufficient to maintain the fuel temperature without the need of external heating devices. Fusion ignition occurs well beyond simple breakeven. It is currently projected that it would cost several billion dollars to construct a magnetic fusion ignition experiment.

In laser fusion, intense beams of laser light are directed onto a minute pellet containing hydrogen fusion fuel. The incident laser light is absorbed by the pellet surface and ablated. This causes the remaining pellet material to be



Researchers used a simple electrode to drive fusion fuel (deuterium nuclei) into a palladium metal rod.

"crushed"—imploded—so that the hydrogen fuel is compressed to extremely high densities. The implosion process also heats the core of the pellet, igniting fusion there. If the density is sufficiently great, the pellet will burn up before it blows up. In this case only the inertia of fusion fuel provides confinement. The process is therefore called inertial confinement fusion, as compared with magnetic confinement fusion.

The hydrogen bomb is also based on inertial confinement fusion. In this case the x-ray burst from an atomic fission bomb is used to compress and heat a large quantity of hydrogen fusion fuel. The atomic bomb x-ray burst has millions of times more energy than laboratory lasers generate. Therefore, the atom bomb can compress and heat a much larger quantity of hydrogen fusion fuel. This greater fuel mass means that there is a greater inertia, and this in turn means that the confinement time is greatly increased. Therefore, in hydrogen explosives, the fusion fuel need not be compressed to the super-high densities required for laser pellet fusion.

The general measure for approaching breakeven and ignition for both magnetic and inertial fusion is that of the energy confinement time-fuel density product. For breakeven, this product must be greater than 100 trillion. That is, at a density of 100 trillion hydrogen fuel nuclei per cubic centimeter, and an energy confinement time of one second, breakeven will occur. Alternatively, at a density of 10^{23} nuclei per cubic centimeter, the energy confinement time can be less than one-billionth of a second. Fusion ignition requires products ten times greater.

The easiest fusion reaction to ignite is that of deuterium-tritium:

$$D + T = He\text{-}4 + n \ (17.6MeV)$$

In this case, the two heavy hydrogen isotopes fuse to form the next heavier element, helium-4. A high energy neutron (n) is also generated. The total energy output per reaction is 17.6 million electron volts (MeV, one joule of energy is equal to about 6 trillion MeVs. That is, about 300 billion D-T fusion reactions will generate one joule. If this takes place over a second, then fusion is being generated at a rate of one watt.)

The next easiest reaction to ignite is that of deuterium-deuterium, which involves two possible paths, each of which occurs at about the same rate:

$$D + D = He\text{-}3 + n \ (3.2MeV)$$

$$\text{or} \quad = T + p \ (4.0MeV)$$

where the products are either helium-3 and a 2.45 MeV neutron (n) or a tritium nucleus and a proton. The D-D reaction requires a confinement-density product 100 times greater than D-T, or, in other words the D-T reacts at a rate 100 times faster than D-D under the same conditions of temperature and density. Other possible reactions listed below generally require even higher confinement-density products than D-D and/or much higher ignition temperatures:

$$D + He\text{-}3 = He\text{-}4 + p \ (18.3MeV)$$

$$Li6 + D = Li7 + p \ (5.0MeV)$$

where Li6 and Li7 are lithium-6 and lithium-7 isotopes of the chemical element which follows helium, lithium.

The experiments

Professor Fleischmann of the University of Southampton and Professor Pons of the University of Utah are electrochemists who have carried out extensive work on isotope separation of deuterium from ordinary water. Of the hydrogen found in nature, such as in sea water (H_2O), 0.015% is the heavy isotope deuterium. In other words, the ratio of H to D is about 6,500 to 1. Even at this low level of occurrence, there is a sufficient quantity of deuterium in one gallon of sea water to generate via fusion the equivalent energy of about 300 gallons of gasoline. Canada's Bruce plant currently extracts sufficient amounts of deuterium from water to produce more than the energy equivalent of the world's total output of electricity per annum.

Electrolysis has been a standard method for generating hydrogen and oxygen for more than 100 years. This process is often demonstrated in high school chemistry classes. The configuration consists of a bath of water and two metal electrodes. The electrodes are stuck into the water and a small electrical current is passed between them, through the water. Small amounts of various salts are dissolved in the water to increase the electrical conductivity of the water.

With the proper metal electrodes, hydrogen gas is generated at the cathode—the negatively charged electrode—and oxygen gas at the anode—the positively charged electrode. The strange behavior of electro-generated hydrogen when utilizing palladium metal electrodes has been studied for more than 100 years. In particular, the palladium metal electrode can absorb large quantities of hydrogen gas. And when the hydrogen diffuses into the solid palladium, it can still maintain a high degree of mobility despite the fact that the hydrogen is trapped inside the dense crystalline lattice of the palladium metal.

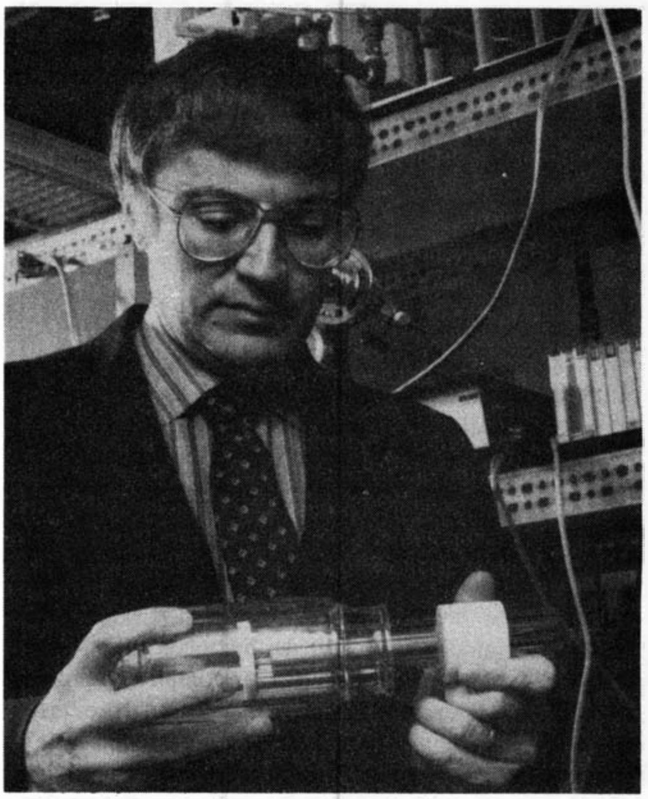
In fact, the palladium has an astronomically high chemical potential for absorbing hydrogen. This is so high that the hydrogen can be confined within the palladium metal lattice on time scales equivalent to 100 thousand to 1 million years. This is in spite of the fact that the hydrogen has a high mobility within the lattice and moves about at high relative velocities.

The hydrogen absorption properties of palladium are truely spectacular. The density of hydrogen atoms per cubic centimeter within the palladium metal can attain levels equal to, if not in excess of that only found in solid hydrogen ice, which occurs only at temperatures near absolute zero, −273°C.

In his presentation, Dr. Pons noted that it has been found in experiments that when both ordinary and heavy hydrogen is absorbed within palladium, they exhibit a high degree of separation. He noted that this can only be explained if the hydrogen and deuterium ions in the lattice behave like classical oscillators (delocalized species). Or, in other words, the hydrogen and deuterium are free to move rapidly about within the palladium lattice. Given that the two different isotopes of hydrogen would tend to have the same temperature level within the lattice, or in other words the same energy level, the ordinary hydrogen would have a velocity of about 1.4 times that of the deuterium. This is because the deuterium ion has twice the mass of the ordinary hydrogen ion. Therefore, if they both have the same energy, the ratio of their average velocities would be about $\sqrt{2}$, that is, about 1.4.

This great difference in velocity leads to a substantial separation of the ordinary hydrogen and deuterium within the lattice. Thus, the high separation factor found in palladium electrodes permeated with ordinary hydrogen and deuterium is strong evidence of the great mobility of hydrogen within the lattice. Given this high mobility and the very high compression of hydrogen gas within the palladium there arises the possibility that there would be very many close collisions between the hydrogen ions. Therefore it is possible that substantial amounts of nuclear fusion could take place within the palladium.

As Dr. Pons related, a wide variety of experiments were carried out in small electrochemical cells. Various shapes and sizes of electrodes were examined at various electric current levels. The total current run through these electrodes was about one watt. The measured total output of nuclear reaction generated heat was about 4 watts. But a large portion of the electric current is not lost, so that the total gain was



Dr. B. Stanley Pons, Professor and Chairman of Chemistry, University of Utah

about tenfold. And now that the full scientific details have been disclosed, it should take no more than four weeks for researchers around the world to confirm these results.

Qualitative confirmation

Already, though, it is reported that two Hungarian scientists have reproduced the Fleischmann-Pons results. But full details have not been reported. Another group at Brigham Young University, headed by Dr. Steven E. Jones, has reported seeing minute amounts of fusion at rates of about 100 trillion times less than that of Fleischmann and Pons. The Jones group results were also presented on Friday, March 31 in a lecture held at Columbia University in New York City.

The Jones group had apparently independently taken up exploration of electrolytic fusion in a search for alternative paths to "cold" fusion. This group had previously carried out extensive research on muon-catalyzed fusion.

The muon is a short-lived elementary particle generated with high-energy particle accelerators. The short-lived muon effectively acts like a heavy electron, because it has the same charge as the electron and about 200 times the mass. It is found that if the muon is introduced into molecular hydrogen gas which contains deuterium and tritium, the muon can displace one of the ordinary electrons within the hydrogen molecule. When the muon does this, it will reduce the internuclear distance by a factor of 200. This reduction from the normal separation of 0.74 Angstroms is sufficient to increase the rate of fusion by 80 orders of magnitude. And during its lifetime, the muon can catalyze upwards of 150 fusion reactions. But the energy cost of generating the muon is still greater than this fusion energy output.

But because of their work on muon cold-catalyzed fusion, the Brigham Young group had developed very sensitive instruments for detecting extremely small quantities of fusion reactions.

The search for cold fusion

In the search for alternative routes to cold fusion, the Jones group came across two bodies of data that indicated that fusion was taking place naturally within the lattices of solid materials. The first set of evidence derives from studies of the distribution of impurity isotopes found in various metal alloys and diamonds. Laser-slicing of diamonds has found that while the helium-4 isotope is smoothly distributed throughout the crystal, the helium-3 isotopes are deposited in concentrated spots. This implies that nuclear fusion may be producing the helium-3. Concentration anomalies of helium-3 have also been reported in metal alloys. (The metal alloy anomalies were reported by Soviet scientists in 1978. They concluded that the most likely explanation was that some form of cold fusion was taking place in the metal lattice.) Jones notes that electrolytic refining of these metals in deuterium-bearing water could have provided the conditions needed for cold fusion.

The second set of evidence derived from geophysics. First of all, geologists have found anomalies in the distribution of the ratios of helium-3 to helium-4 found in the Earth's crust. High values of the helium-3 to helium-4 are found in volcanoes and other active tectonic zones. That is, they are found in the geological "hot spots." Furthermore, recent measurements of the internal temperatures have found levels much higher than previously projected by most geological models. Also, measurements of the abnormally high concentrations of tritium in the atmosphere near the site of the February-March 1972 Mauna Ulu volcano eruption gives further evidence for fusion taking place within the interior of the Earth.

The Jones group then began to experimentally explore a variety of mixtures of materials in electrolytic cells to see if nuclear fusion may be taking place. Their reported experimental results show that minute amounts of fusion take place with a wide variety of materials. But the experimental setups were not designed to maximize the rates of fusion. Nor were they run for a sufficient period of time to get the same type of effects that Fleischmann and Pons have observed.