FUSION facts

A Monthly Newsletter Providing Factual Reports On Cold Fusion Developments

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A. CREATING A WORKING FUSION CELL.

HISTORY.

Professors Martin Fleischmann and B. Stanley Pons announced on March 23, 1989 that they had discovered nuclear fusion in an electro-chemical cell, Salt Lake City, Deseret News, 3/24/89). By April 10, 1989, scientists at Texas A&M had duplicated the Fleischmann-Pons Effect (Salt Lake City, Deseret News 4/10/89).

Nuclear physicists and other scientists at many other research universities have not achieved the replication of the F-P Effect. However, one of the more recent successes was achieved by Prof. Glen Schoessow at the University of Florida (a nuclear physicist). Why has it been so difficult for some researchers to replicate an experiment that Pons and Fleischmann claim can be performed with little more equipment than might be used in a freshman chemistry laboratory?

One strong hint: The biography of John O'Mara Bockris of the Department of Chemistry at Texas A&M lists the following: "Research: Hydrogen on and in metals, metal deposition and dissolution; adsorption at solid electrolyte surfaces, ..., electrode processes; energy science; photoelectrochemistry; bioelectrochemistry." Source: Dialog Chemical Abstracts Database.

In the 51 pages of publications for Bockris are the following titles (1966-1989):

* "Electro-permeation of hydrogen into metals."
* "Fuel Cells: Their Electrochemistry."
* "Modern Electrochemistry, an Introduction to an Interdisciplinary Area." Vols. 1 and 2.
* "Hydrogen embrittlement and hydrogen traps."
* "Thermodynamic analysis of hydrogen in metals in the presence of an applied stress field."
* "Basic aspects of electrocatalysis."
* "Theory of tunneling in electron and proton transfer reactions."
* "Solid metal-solution interface."
* "Hydrogen/metal interactions with special reference to electrochemical approaches."
* "Towards new materials in energy conversion."

CAVEATS ON PALLADIUM.

Those who have replicated the F-P Effect have reported on various treatments of the palladium rods:

* Palladium .5 mm dia wire - as received.

(Successful but took 100 hours to stabilize) [1].
* Palladium .5 mm dia wire - annealed at 950xC for 1 hr. and furnace cooling in vacuum.
* (Successful and stabilized in about 50 hours - many experiments) [1].
* Palladium coin-shaped cathode. Cycled several times with heating and cooling in vacuum. Strongly suggests using cast palladium. [2].
* Purge the hydrogen gas out of the palladium. Don't expose the palladium to air after treatment. Charge (load) the palladium at low current densities and then raise the current. Submerge the palladium completely in pure deuterium oxide. [3].

References:

[1] Appleby, et al. "Evidence for excess heat generation rates during electrolysis of D2O in LiOD using a palladium cathode - a microcalorimetric study." Workshop on cold fusion phenomena, 5/23/89, Santa Fe, NM.
[2] Prof. Robert Huggins, Stanford. Press interview. Tapping the Zero-Point Energy, Paraclete Publ. Provo, Ut, 1989.
[3] Rabinowitz, Elect. Power Research Inst. at Responsive Energy Technology Symposium and International Exposition, June 19-23, 1989 Santa Clara, CA.
[4] Moray B. King in Tapping the Zero-Point Energy, pp 143 ff. Paraclete, Provo, Ut, copyright 1989.

CHECK LIST OF CRITICAL CONDITIONS.

1. Palladium rod must be cast or properly made and then annealed in high temperatures and cooled in a vacuum. If not, experiment may fail.
2. Avoid sharp edges or else the experiment may be uncontrollable.
3. Avoid hydrogen, carbon and air after Pd rod has been cooled in a vacuum. Exposure to deuterium gas is advisable after cooling in vacuum. Even slight contamination can cause experiment to fail.

4. Proper charging current should be used. Palladium rod expands with creation of deuteride and low charging rates (60 mA/sq cm of Pd surface). Best experts get 80% to 90% "good" Pd rods.

5. Allow sufficient charging time. Charging time will vary strongly with Pd rod diameters.

6. Use high purity (99.5%) deuterium oxide in the fusion cell and keep the heavy water away from exposure to air. Submerge the Pd rod completely in the heavy water.

7. To achieve high D/Pd ratios the Pd rod surface must be "poisoned" to help prevent the deuterium from leaving the rod. The normal electro-chemical cell environment must be augmented with appropriate chemicals at the milli-mole level. Reportedly, iron and cyanide are appropriate. Unless the rod surface is properly prepared the experiment will fail.

8. The 0.1 mole lithium deuteroxide added to the electrolyte (heavy water) must be pure. The lithium is an important part of the electrochemistry of the fusion cell.

9. Raising the fusion cell current level to above 150 mA/sq.cm. reportedly represses the nuclear reaction that produces neutrons.

10. Using nickel anodes is reported to enhance the nuclear reaction that produces tritium. The platinum anode appears to be the best choice if neutron output is desired.

11. Use a current control device to control the current (as contrasted with a voltage control circuit). Keep the current below any critical level. A reasonable current is 600 mA/sq cm of Pd rod surface.

12. Use small diameter Pd rods for early attempts because the charging time can get very large for larger rods. One experimenter reported 140 days charging time for 5 mm. dia. rods.

13. Treat the experiment as an electrochemical catalytic process that is sensitive to any contamination. Especially avoid carbon. Even a finger tip contact with the electrolyte can cause the experiment to fail.

14. Consult a good electrochemist on electrical connections and the use of dissimilar metals. The electrical connection with the submerged Pd rod is reported to be critical. Note: Compare this developing science to the earliest days of experiments with semiconductors where there were many failures and unexplained results.

B. SOLID-STATE FUSION IMPACT ON ENERGY INDUSTRIES.

In the United States there has been considerable interest in the replication of the Fleischmann-Pons Effect (obtaining excess heat in a palladium cathode in a properly configured electro-chemical cell). Although more than 20 research teams have replicated the Fleischmann-Pons Effect (FPE) there has been little impact on the energy industry. The Department of Energy has yet to decide if the FPE has commercial potential.

In England, the Harwell laboratories reported negative results (after expending over $400,000 in research funds). Most other European countries, except Italy, have had minimal success in replicating the FPE. The European energy industry appears to be little affected by the discovery of solid-state fusion.

In contrast, India and Japan have replicated the FPE and have dramatically modified their energy research and development objectives.

ENERGY IMPACT ON NATIONAL POLICY - INDIA AND JAPAN.

The following discussion is based on conversations with Ramtanu Maitra, Editor of FUSION ASIA (NewDelhi) and a contributing consultant to FUSION FACTS.

Immediately after the University of Utah arranged to announce the important discovery of solid-state fusion by Fleischmann and Pons, scientists in both Japan and India began working on replication of the FPE. By May 10, 1989 a large article in the **India Times** (Bombay) reported on the successes of the Indian scientists. By July 31, 1989 Japan successes led to a cold fusion workshop. The next day, it was announced that 80 scientists from 15 universities had been assigned to work on cold fusion.

Reportedly, three national coordinating groups have been formed in Japan to coordinate experimental, theoretical, and applicational projects. Currently in India there are 18 teams of four research workers in at least three national research laboratories working on solid-state fusion. One research team is working on enhancing the production of neutrons for medical and scientific purposes. One team has designed and/or is building a five-foot-long cathode of palladium mesh.

This surprisingly large scale-up of the fusion cell is based on calculations showing the energy density achieved in a fusion cell is comparable to the energy density achieved in a coal-fired power plant.

A STUDY IN CONTRASTS.

The exploitation of India during its colonial period has left a nation with a large population, minimal industry (as compared to USA or Japan), a good educational system with a high English-language literacy, and a strong desire to be industrially independent.

Japan, in contrast, has emerged as the post-World War II leader in manufacturing and marketing of high technology products. Japan now has one of the world's highest standards of living, a large positive balance of payments, and a strong national desire to achieve in the development of important new technologies.

Japan's goals appear to be global and driven by wealth accumulation, while India's goals appear to be centered on solving its internal development problems using its own human resources. India's national policy is more directed to internal survival and raising the standard of living internally than to global marketing.

These two dissimilar nations have emerged as two of the best organized and most successful in developing early international leadership in this exciting new area of solid-state fusion. Both nations have undertaken strong roles under national direction for the development and exploitation of cold fusion phenomena. Both approaches will strongly impact the energy industries in their own countries. By setting an active example in energy development, India may strongly influence the national energy policy of many other developing nations. Japan's intense and early activities may encourage reciprocal action by some of the nations of the West.

It is even possible that the United States will reduce the level of internal suspicion among the grantees of the Department of Energy and proceed to develop a sensible national energy policy that embraces the discovery of solid-state fusion.

ENERGY INDUSTRY IMPACT IN INDIA.

The coal fields of India are located in the northwestern corner of the country. Coal-fired power plants can be placed near the coal and electricity transmitted over long distances (incurring large power losses) or the coal can be transported long distances to power plants.

The discovery and application of solid-state fusion and the almost immediate replication of the discovery is expected to rapidly impact the development of the energy industry in India in the following ways:

1. A national policy has been (or will be)established to emphasize the development of small power plants that can be placed in rural or mountainous regions.

2. Research and development funds for nuclear energy will be quickly switched to new solid-state fusion successes.

3. Intense research will ensue to develop alternative metals or alloys to use in fusion cells instead of palladium.

4. The early development of efficient small (1- Megawatt to 25 Megawatt) electrical power plants will be achieved.

5. The building of further coal-fired power plants will be curtailed or limited to sites near the coalfields.

6. The construction of further nuclear fission power plants will be curtailed.

7. The geological search for solid-state fusion metals will greatly increase.

8. The construction of heavy water extraction plants will become a high priority.

ENERGY INDUSTRY IMPACT IN JAPAN.

The successful development of solid-state fusion technology by Japanese consortia of scientists,engineers, government, and industry will lead to the following:

1. Japan will form the world's best organized effort to develop solid-state fusion technology.

2. The filing of a large number of important patents in all patent signatory countries.

3. An intense effort to extract and market heavy water on a world-wide basis.

4. An intensive study of, and early publication of, the engineering parameters for fusion system design.

5. The establishment of an international marketing organization for the commercial exploitation of solid-state fusion systems.

6. The delivery of the first commercially practical fusion energy systems to the world.

7. An intense diplomatic and commercial effort to help emerging nations to install solid-state fusion energy systems.

8. A significant improvement in Japan's favorable balance of trade.

9. A significant increase in Japan's influence among the world's emerging nations.

10. A progressively stronger increase in Japan's national wealth.

IMPORTANT POLICY DECISIONS FOR THE UNITED STATES.

Two groups in the United States are theoretically capable of organizing the efforts that could lead to a world-wide leadership in the production and distribution of solid-state fusion energy systems --the federal government and a consortium of industry.

The federal government performs best when the issue is one with strong public demand caused by a problem becoming a crisis. It is difficult to believe that the world's leading consumer of recreational (and medicinal) drugs and the nation that has a 25% dropout rate before high school graduation will demand a cold-fusion power policy.

It is difficult to imagine that industry will voluntarily establish a viable energy consortium in view of competition and a structure of laws to discourage such cooperation.

However, if a majority of the members of the U.S.Senate and the U.S. House of Representatives were to recognize the following:

1. Solid-state fusion is the greatest discovery of the century.
2. The economic impact of cold fusion will be far greater than has occurred for any other discovery.
Then maybe the industrial competitive might of the U.S. could be unleashed.

Were this scenario to become a reality (probability about zero) then the United States could again emerge as the world's economic leader and could, with intelligent White House leadership, emerge as the world's political leader.

WORLD UPGRADE TO CURRENT U.S. ENERGY CONSUMPTION.

The per capita energy use in the United States of America (Britannica Year Book 1990) is about 8 tons of oil equivalent per person per year.

If it is assumed that the average energy consumption of the world's population in 2010 will be about the same as the current per capita energy consumption in America, then it would require about ten times the current world-wide energy production.

The current production of energy, using fossil fuels and some nuclear energy, has led to an almost intolerable impact on the world's environment. It is not environmentally possible for the world to produce ten times the current energy from fossil fuels. The damage to the earth's atmosphere would cause dramatic adverse effects on weather, climate, crops, and on the capability of the earth to maintain current life forms.

The only viable alternatives are the production of energy from nuclear reactions. The buildup of nuclear contamination from fission power plants is becoming a problem. The production of power from hot fusion is not currently feasible; however, large amounts of government funds are being spent to create an economic source of power from hot fusion.

The recent discoveries and rapid advancements being made in cold (or solid-state) fusion appear to be a viable technology for the clean production of power. Research results in the next year are likely to demonstrate whether the world's population can enjoy the energy standard of living that is now enjoyed by the United States.

C. CALCULATING ENERGY FROM DEUTERIUM FUSION.

THE USE OF EINSTEIN'S EQUATION ($E = M \times C^2$) IN FUSION.

The well known equation developed by Einstein that relates the inter- changeability of matter and energy is the following:

$$E = M \times C^2.$$

Where E is energy (in ergs); M is mass at rest (in grams); and C is the speed of light (in centimeters per second).

The above equation is used to determine the amount of energy that could be released when a known amount of matter is converted into energy, such as in a nuclear reaction.

THE CONVERSION OF MASS TO ENERGY IN NUCLEAR REACTIONS.

In the nuclear reaction equation below, the atomic mass of deuterium and of helium is well known and can be obtained from the Handbook of Chemistry and Physics. The equation with the mass units is as follows:

D + D	--> 4He	+ energy.
2.0140 + 2.0140 =	4.0026 +	0.0254
atomic mass of deuterium	atomic mass of helium 4	mass fraction that must be changed to energy.

The values for the above nuclear reaction were obtained from the Handbook of Chemistry and Physics from the "Table of Isotopes."

In the nuclear reaction above, the amount of mass of the two deuterium atoms is larger than the atomic mass of the helium 4 atom. If this fusion reaction is to occur, the excess mass fraction must be converted to energy.

According to the current understanding of nuclear physics, the above nuclear reaction is not understood, has not been observed, and therefore is not readily accepted as the explanation for the heat that is being experimentally measured in a fusion cell. Under current understanding of nuclear physics,the energy would be expected to be released in the form of an energetic "photon" or "gamma ray." Current theory, which is strongly supported by hot fusion experimental evidence, does not explain how this nuclear reaction can release heat energy into the metal lattice of a palladium rod. Current theory does not allow for the mass of 0.0254 atomic mass units to be converted into a spectrum of energy such as number of photons. Such a condition, were it to exist, could explain the source of heat observed in the palladium rod experiments.

By using Einstein's equation, the atomic mass fraction of 0.0254 atomic mass units can be found to be 0.00003796 ergs or 3.796 x 10E-5 ergs. If one electron of atomic mass 1/1837 is converted to energy, the value would be 8.2 x 10E-7 ergs. Therefore, the amount of energy produced by this nuclear reaction would be the equivalent of the conversion into energy of about 46 electrons.

NOTE: To make the calculations, the atomic mass units must be converted into the equivalent number of grams. One electron has the mass of 9.1 x 10E-26 grams. An atomic mass unit is equal to 1.6606 x 10E-24 grams.

The calculation of 0.0254 x 1.6606 x 10E-24(converts to grams) x 3 x 10E10 x 3 x

10E10 (the value of speed of light squared) gives the value of 3.796 x 10E-5 ergs per each pair of deuterium atoms that fuse.

CALCULATION: ENERGY FROM ONE GRAM OF DEUTERIUM OXIDE.

If we use 1 gram of deuterium oxide (D2O) and all of the deuterium is converted to helium 4 by the above reaction, we can calculate the amount of energy produced. First, there would be two deuterium atoms consumed (having a combined weight of 4.028 atomic mass units). For each pair of deuterium atoms 3.796 x 10E-5 ergs of energy would be produced. Now compute how many deuterium atoms are available in a gram of deuterium oxide or heavy water.

Avogadro's number is the number of molecules that are present in one gram-molecular weight of a substance and is equal to 6.022 x 10E23. Heavy water consists of D2O or two molecules of deuterium with atomic weights of 2 each and one oxygen with an atomic weight of 16. The gram-molecular weight would be 20 and would consist of 6.022 x 10E23 molecules of D2O and would include 12.044 x 10E23 atoms of deuterium.

One gram of D2O would have 1/20 the number of atoms in one gram- molecular weight or 12.044 / 20 x 10E23 = 6.022 x 10E22 atoms of deuterium in one gram of heavy water.

Each two deuterium atoms could produce 3.796 x 10E-5 ergs, therefore 6.022 x 10E22 x 1/2 x 3.796 x 10E-5 equals 11.43 x 10E17 ergs. There are 10E7 ergs in one joule. The answer in joules is 11.43 x 10E10 joules produced by 1 gram of heavy water. A joule is also equal to 2.788 x 10E-7 kilowatt hours.

The number of kilowatt hours of energy that could be produced by the fusion of all pairs of deuterium atoms in one gram of heavy water is 11.43 x 10E10 times 2.788 x 10E-7 equals 31,870 kilowatt hours. For normal home use (about 500 to 700 kilowatt hours of electrical energy per month), 31,870 kw. of converted energy from the above nuclear reaction would supply power for 46 to 64 months or from four to five years.

The cost of one gram of heavy water is about fifty cents to one dollar. (However, the cost of a practical fusion reactor might be several thousand dollars.) The above calculations demonstrate why there is such an intense interest in solid-state fusion. The results also provide some concept of the enormous energetic nature of nuclear reactions as compared to chemical reactions.

From a practical viewpoint, it is unlikely that all the energy in a gram of heavy water will be converted to useable energy. However, if only ten percent of the energy is produced, the amount of energy is still dramatically large and the fuel cost is dramatically low.

D. FIC'S POSITION PAPER - AUGUST 1989 REVISION.

As announced by Fusion Information Center, Inc. (FIC) in its June 9, 1989 press release, the discovery of solid-state fusion has been confirmed, there are more than one nuclear reaction occurring, and the process has commercial applications.

The following position paper has been prepared to provide a "given" foundation as a basis for the development of technological impact studies. Each issue of FUSION FACTS will summarize the impact that the development of fusion energy systems is expected to have on various industries.

THE ROLE OF PALLADIUM.

Solid-state fusion reactions occur near the surface and within the metal lattice of a palladium electrode immersed in an electrolyte made up primarily of deuterium oxide (heavy water). Other metals or a combination of metals will probably support fusion reactions in the future. Currently all successful investigations have used palladium or titanium. The successful use of titanium is from a verbal report from Maitra in New Delhi, India.

Palladium has an atomic number of 46 and anatomic weight of 106.4. Palladium melts at 1551 degrees Centigrade and boils at 3140 degrees Centigrade. The specific gravity is 12.02 and has a valence of 2,3, or 4. Palladium is the least dense and has the lowest melting point of the platinum group of elements.

OCCURRENCE.

Palladium occurs in the earth's crust in about twice the amount of platinum. It is found in platinum placers in the Ural Mountains of the U.S.S.R.; in South Africa; to some extent with river platinum placers in the northern portion of South America,Australia, Ethiopia, and North America. The only currently operated palladium mine in the United States is located in Montana. Palladium is sometimes found with nickel-copper deposits of South Africa and Ontario. Some palladium is produced at the Kennecott mine near Salt Lake City, Utah.

PROPERTIES.

Palladium has the unusual property of being able to absorb up to 900 times its own volume of hydrogen(and deuterium) at room temperatures and pressure. Hydrogen and deuterium readily diffuse through heated palladium, and palladium therefore can be used as a filter in the purification of these gases.

Finely divided palladium is used as a catalyst in hydrogenation and dehydrogenation reactions. It is alloyed with gold to make white gold for the jewelry trade. Like gold, palladium can be beaten into sheets as thin as 1/250,000 inch.

Palladium has recently ranged in price from $140 per troy ounce to near $200.

NUCLEAR REACTIONS.

When palladium is properly prepared and used as a cathode (connected to the negative terminal of a battery) immersed in heavy water (deuterium oxide)together with a platinum or a nickel anode (connected to the positive terminal of the same battery), deuterium ions can be packed into the palladium metal lattice. Under some conditions the palladium deuteride (similar to palladium hydride that is formed in palladium when hydrogen is used) supports one or more nuclear reactions. These reactions are not as yet fully understood.

Under the proper experimental conditions, within a specific type of palladium metal lattice (crystal structure) the deuterium atoms periodically fuse and the resulting energy shows up as heat in the palladium electrode. The nuclear reactions are beginning to be understood and controlled. Three known or suspected nuclear reactions are being reported:

Deuterium + deuterium --> helium 3 + neutron + energy.

Deuterium + deuterium --> tritium + proton + energy.

Deuterium + deuterium --> helium 4 + energy.

The first two reactions have been previously observed in hot fusion experiments in almost equal numbers. In some types of fusion cells the neutron-producing reaction ceases when the current is raised to exceed 150 mA/sq cm of cathode surface. The third reaction has not been previously observed and is controversial. However, the helium 4 produced is the isotope of helium normally found in nature. The later reaction is the most favored and the most energetic.

The following indicates how the energy produced can be calculated:

Deuterium + deuterium = helium 4 + Energy
2.014 + 2.014 = 4.0026 + 0.0254
(Second line is atomic mass units).

See above section C for calculating the nuclear energy from deuterium fusion.

The above mass fraction (0.254 mass units) when converted to energy appears as heat in the palladium electrode. One or more of the three nuclear reactions (or a similar nuclear reaction) are responsible for the production of up to fifty times as much heat output in the fusion cell as compared to the energy input into the fusion cell.

Other nuclear reactions are taking place in the palladium, but the helium 4 reaction is preferred because there are no other atomic byproducts such as the expelling of a neutron (atomic particle with the mass of a hydrogen atom but having no charge) or the production of tritium (which is radioactive). Large amounts of neutrons are harmful to living tissue and are not a desirable byproduct. Tritium gas is poisonous when ingested. Tritium is also radioactive but the nuclear byproduct is a beta particle which can easily be shielded.

There is now proof that the neutron-producing reactions can be controlled by varying the current flow through the fusion cell. In addition, the use of a nickel anode appears to enhance the production of tritium, while a platinum anode seems to favor the heat production which is probably due to the helium 4 nuclear reaction.

For this position paper, it is assumed that the solid-state nuclear fusion reactions can be controlled and that a reasonable level of energy can be safely produced.

NUCLEAR GENERATION OF HEAT.

The current embodiments of experimental solid-state fusion power are producers of low-level heat (low temperatures as compared with industrial boilers that produce super-heated steam). For the current fusion power to become practical, engineers will design devices that will produce more heat and be able to remove or use the heat at higher temperatures. Alternatively, the fusion heat will be directly converted to electrical energy.

The current experiments are producing a reported 50 to 60 watts of heat energy per cubic centimeter of palladium. A desired goal is to achieve 1,000 watts of energy per cubic centimeter of palladium. The engineering techniques (heat exchangers) used to get 1,000 watts of heat out of a cubic centimeter of palladium have not been fully designed.

PRACTICAL ENERGY LEVELS.

For the purposes of this position paper, it is assumed that a practical design of a palladium/deuterium nuclear reactor can be produced that will remove 100 watts-hours of heat energy per cubic centimeter of palladium per hour from initial fusion reactors. Later improvements will be made.

Ten cubic centimeters of palladium will produce one kilowatt of power per hour in a properly designed nuclear reactor. With some inefficiencies, this power could be converted into about one horsepower of heat energy.

An engineering estimate for weight is that 10 to 100 pounds of reactor will be used per usable horsepower. If a fusion reactor were to be used to power an American automobile, the reactor would weigh 100 to 1,000 pounds. The reactor energy may be used to charge batteries in order to make an auto with simplified parts (as compared to the complex internal combustion engine used today). Alternatively, a fusion reactor could create steam to run a steam-driven auto.

PROBLEMS AND TIMING OF SYSTEM DEVELOPMENT.

Some reports cite erratic results (similar experiments do not produce the same results), bursts of energy (heat is not produced uniformly), and even meltdowns of experiments. The current lack of a scientific theory of what is happening in the palladium adversely affects the design of experiments. The technology is similar to early days of solid-state semiconductor work in the development of useful transistors. However, these problems will rapidly be resolved.

Other unknowns, such as whether or not the crystal lattice of the palladium is gradually destroyed, and the changes in deuterium movements under experimental conditions, require more experimental and theoretical efforts. These are considered to be problems that will affect the timing of the eventual developments of usable solid-state fusion systems and not whether such systems are eventually developed.

The current experimental state of solid-state fusion indicates that solid-state fusion energy systems can be designed which have at least the same energy density (power generated per cubic meter of plant) as is achieved in coal-fired power plants.

EARLY ENGINEERING DESIGN GOALS.

For the purposes of making technological impact predictions, it is assumed that engineers can produce usable energy using a solid-state fusion nuclear reactors. The estimate of size and weight (an early engineering design goal) is 100 pounds in weight and two cubic feet in size for each kilowatt or horsepower of power.

Later design goals would be to reduce this weight and volume by a factor of ten to achieve a reactor often pounds per horsepower and packaged in a smaller volume of space.

It is forecast that initial commercialization will be for smaller solid-state fusion systems where the production of low levels of heat (of the order of 100 to 200 degrees Centigrade) is sufficient. Therefore, home heating and cooling applications and applications for the direct conversion of heat to electrical power are expected to precede the larger industrial applications of solid-state fusion systems.However, scale-up experiments for power generation are already being done in India and by a small corporation in Tennessee.

COSTS OF OPERATION.

For the purposes of calculating energy costs in 1989 prices, the following assumptions will be made:

* Palladium will cost $200 per troy ounce.

* Deuterium will cost $1,000 per gallon.

* The conversion efficiency of deuterium to usable energy will be 10 percent.

* The maintenance costs will be 10 percent per year of initial fabrication/installation costs.

* Services for purifying and recasting palladium will be readily available and are included in the "maintenance costs."

* Initially, it will require ten cubic centimeters of palladium to produce a continuous one kilowatt-hour of energy.

CONVERSIONS FOR CALCULATIONS.

1 cubic centimeter of palladium weighs 106 grams.

1 troy ounce is 31.1 grams.

1 cubic centimeter of palladium weighs about 3 troy ounces.

1 cubic centimeter of palladium will cost $600.

ENGINEERING ESTIMATES.

Early reactors will cost $10,000 per kilowatt and reduce to $1,000. Maintenance costs will be $1,000 per kilowatt per year and reduce to $200 per kilowatt per year. The cost of capital will be 10 percent per year.

The cost of fuel will be about $0.01 per kilowatt hour. The energy values are roughly 300 gallons of fuel oil per gallon of ordinary water or two million gallons of fuel oil per gallon of deuterium oxide. At 10 percent efficiency and at $1,000 per gallon, the equivalent cost of fuel would be about one cent for the energy equivalent in one gallon of fuel oil.

CALCULATION OF COSTS FOR HOME SOLID-STATE REACTOR.

Utah Power and Light reports that the average Utah home uses 550 kilowatt-hours of electrical energy per month. Assuming a cost of $0.10 per kilowatt-hour, the average monthly electrical bill would be $55.

Assuming that a home solid-state fusion reactor produced continuous power and used storage batteries for peak load, the initial cost of a one kilowatt reactor installation would be $10,000. At 10 percent interest rate the cost of capital would be $1,000 per year. The maintenance cost would also be $1,000 per year. This $2,000 cost would exceed the typical electrical home bill of $550 per year.

However, as the costs of the solid-state fusion reactor lowered, the home fusion reactor would become a viable alternative as compared to the current cost of electrical power.

Calculations based on a fusion reactor that would cost $1,000 to buy and install and $200 per year for maintenance show that the annual cost (including cost of capital) would be about $300 per year. This amount would be considerably less than the cost of electrical power.

The above calculations do not consider the cost of "fuel" because fuel costs are negligible in comparison to equipment costs, cost of capital, and maintenance costs.

In general, it is expected that the combination of rapid engineering developments of solid-state fusion systems together with the relatively low entry cost to the manufacturer for entering the business will lead to the effective construction and use of medium and small solid-state fusion reactors within three to five years.

NEW DISCOVERIES WILL SUPPORT SOLID-STATE FUSION.

No scientific paper has reported the successful use of any metal other than palladium to replicate the effect discovered by Pons and Fleishmann -- that excess heat was generated. A verbal communication with Mr. Maitra, editor of FUSION ASIA reports that titanium cathode with sodium chloride produces excess heat.

A reasonable technological forecast is that metals other than palladium will be found to support solid-state fusion. It is likely that optimum results will be found by using a combination of metals (an alloy) that will support solid-state fusion but be more predictable and less expensive.

The position of this paper is that the combination of the results of intense interest, plenty of research funds, and many scientists working in the field will lead to rapid development of solid-state fusion systems.

Therefore, the following developments are expected:

* The discovery of other metals or of alloys that will support solid-state fusion.

* Increases in output temperatures in operating fusion reactors.

* Improvements in direct heat-to-electricity conversions.

* The gradual lowering of the costs of fusion reactors.

* The control of the type of nuclear reaction taking place. (For example, neutron production decreases or stops when the cathode current is increased.)

* A continuation of the low cost of entry into the solid-state fusion industries.

* A rapid growth in specialty companies to serve the industry, for example, in production and marketing of heavy water, reactor electrodes, safety devices, instrumentation, etc.

* The rapid development of engineering prototypes of new systems based on solid-state fusion developments.

E. DISCOVERY OF THE FLEISCHMANN-PONS EFFECT.

Professors Martin Fleischmann and B. Stanley Pons announced on March 23, 1989 that they had discovered nuclear fusion in an electro-chemical cell. The announced result of over four years of research work, funded by the inventors, began with conversations at the kitchen table and while hiking in the mountains near the University of Utah. The idea - having an admitted billion-to-one probability of success - and the dedication of these eminent scientists have forever changed the world. (Salt Lake City, Deseret News, 3/24/89.)

By April 10, 1989 scientists at Texas A&M had duplicated the Fleischmann-Pons Effect (Salt Lake City, Deseret News, 4/10/89.)

Later researchers in the following institutions also found excess heat and/or measured nuclear by-products of solid-state fusion:

Case Western University
University of Washington
University of Florida
Stanford University
U. of C. at Santa Barbara
Portland State University
University of Minnesota.

In addition, researchers in Beijing, India, Japan, Czechoslovakia, Sao Paulo, Hungary, Moscow, Mexico, and Rome have also replicated all or part of the now famous experiment.

Furthermore, several corporate research labs (including two in Utah) have replicated the PF Effect but have not chosen to publicize their achievements.

Nuclear physicists and other scientists at many other research universities have not achieved the replication of the F-P Effect. However, one of the more recent successes was achieved by Prof. Glen Schoessow (a nuclear physicist) at the University of Florida.

At least three universities in the United States are receiving corporate research grants to further the studies of solid-state fusion. In contrast, several research laboratories under the direction of eminent scientists have either failed to replicate the FPE or have chosen not to report their findings.

EDITORIAL COMMENT:

True science is based neither on faith nor emotion. It is therefore interesting to note that the scientific decision makers in the U.S. Department of Energy appear to be slow in evaluating the scientific results obtained at various institutions including Los Alamos, Oak Ridge, and Brookhaven.

It is a matter of history that bureaucrats are reluctant to react to dramatic changes in savings and loan institutions, housing developments, rising medical costs, etc. Has the existing preference for the status quo affected the nation's energy policies?

It is strongly urged that members of the DOE committees who are making policy statements pay less attention to the measurements of neutron emission and more attention to the following scientific evidence:

1. It is difficult to make a fusion cell that will readily produce neutrons.

2. The preferred nuclear reaction appears to favor the production of tritium (at least for some palladium cathode preparation protocols).

3. Tritium is being produced in copious amounts by many fusion cells.

Regardless of previous nuclear observations, the nuclear reactions occurring in a solid-state fusion cell do not follow the traditional expected nuclear reactions. Finding that dramatic new discoveries do not follow tradition is the essence of scientific advancement. DOE, with its many eminent scientists should be the first to welcome this new scientific advance. Onward and forward DOE! Denying reality is a zero-win game. Editor.

F. PALLADIUM CATHODE CHARGING TIME.

Various experimenters have used various sizes of palladium rods in their experimental work to replicate the Fleischmann-Pons Effect (PFE). For example, Appleby (Texas A&M) reported on a series of experiments using 0.5 cm. dia. palladium wires. Pons, et al have used a variety of rod diameters. Huggins (Stanford) used coin-shaped rods. Universita' di Roma' used a rectangular rod 5 mm. by 6 mm. by 20 mm. and reported charging times of 150 hours. Charging times from 40 hours to over 100 days have been reported.

VARIABLES AFFECTING CHARGING TIME.

The following variables appear to affect charging time:

1. Palladium cathode dimensions and shape.

2. Cell current (usually measured in mA per sq. cm.of Pd surface).

3. Preparation of the palladium cathode.

4. Surface condition or treatment of palladium cathode.

CURRENT THEORY TO EXPLAIN CHARGING TIME.

The loading of deuterium or deuterons into a palladium lattice and the extent of deuterium loading appears to be a direct function of the following:

* A palladium rod, properly prepared, can be placed in a deuterium gas atmosphere and absorb about 900 times its volume of deuterium.

* The same Pd rod connected to a cell according to the FPE protocol will absorb up to about 0.6 to 0.7 ratio of D to Pd atoms. This appears to be the upper limit of D loading that can be expected by normal electrochemical means.

* With proper poisoning of the Pd rod (to enhance the absorption of deuterons), certain surface treatment of the rod must be accomplished. While precise formulas are either unknown or unpublished, it appears that lithium, iron, cyanide, and sulfur may play strong roles in this surface treatment. See Flanagan and Oates (Can J of Chem. v.53, p

694, 1975) for some discussion in the older literature.

With proper cell preparation (both electrically and chemically) the loading of the palladium appears to occur with the following steps:

1. Initially in the PF cell, the deuterium evolved from the heavy water flows into the Pd rod. (Few minutes).

2. Deuterium gas is evolved at the surface of the Pd rod and some enters the Pd cathode and the rest bubbles up through the electrolyte. (Several or many hours or days.) A loading of about D/Pd ratio of 0.6 to 0.7 is achieved.

3. If the surface of the Pd rod is properly treated so as to help prevent the diffusion of D from the Pd lattice into the electrolyte, then further slower diffusion of D into the Pd rod occurs. (Several more hours or days.) Note: A loading of about D/Pd ratio of .95 to 1.0 is expected to be necessary for a successful replication of the FP Effect.

The loading of deuterons into the palladium lattice appears to proceed rapidly at first and then more slowly as the number of available sites in the Pd lattice decrease. The function appears to be asymptotic.

The literature is not precise on the required ratio of D/Pd that is necessary to achieve fusion and produce excess heat.

PLOTTING CHARGING TIME.

Preliminary information suggests that a suitable engineering plot for deuterium charging time would be three dimensional using TIME, Pd ROD DIAMETER (or Pd thickness), and CHARGING CURRENT.

The fusion cell current, during charging time,should be low so that the internal pressures in the palladium lattice caused by the building of palladium deuteride do not cause too much lattice cracking or distortion.

After the appropriate charging time is achieved,it is suggested that the fusion cell current be raised to above 500 mA/sq. cm. so that neutrons are not produced. More than one investigator has stated that the fusion reaction:

D + D ---> 3He + n + energy

is curtailed by raising the fusion cell current.

G. MISCELLANEOUS NOTES.

CONTROL OF FUSION CELL NUCLEAR REACTIONS.

Fusion cells can be "tuned" to favor the production of neutrons or the production of tritium.

The following is a summary of some conversations with successful experimenters:

Using a platinum anode favors neutron production, while using a nickel anode favors tritium production.

It appears to be more difficult to make a cell that produces neutrons than to make a cell that produces tritium.

If a cell is producing neutrons, raising the cell current appears to end the production of neutrons. This control of nuclear reactions appears to be reversible.

A cell tuned to the production of tritium may produce sufficient tritium to explain the excess heat observed.

In at least some cells the combination of the production of neutrons and the production of tritium are not sufficient to explain the excess heat produced.

FUSION FACTS would like to publish any other observed means of controlling nuclear reactions in a fusion cell. Your comments will be appreciated and may result in free issues of FF. Ed.

CONTRIBUTIONS WANTED:

Free computer courseware with 40 concepts to understand solid-state fusion will be awarded to contributors whose material is used.

FUSION CONCEPTS TAUGHT BY COMPUTER COURSEWARE.

Technical staff of the Fusion Information Center have announced the August 1, 1989 release of a SOLID-STATE FUSION tutorial diskette that will run on desk-top computers compatible with International Business Machines desk-top computers.

About forty concepts from physics and chemistry are presented so that the user can review (or learn) the ideas important to solid-state fusion. The courseware is student-interactive, concept-based, and is supplied on either 3 1/2 in. or 5 1/4 in. diskettes.

Exposure to high school or college basic physics and chemistry courses are recommended as pre-requisites for this courseware. INFOFIND, a search and retrieval program, together with an index of all non-trivial words and the complete text of the tutorials, is also provided. The introductory price is $99 (two diskettes). The first 200 subscribers to the FUSION NEWSLETTER will receive these diskettes at no additional cost.

Hal Fox Editor-in-Chief
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Paul Prows Departmental Editor
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PREVIEW OF THE AUGUST 1989 ISSUE OF FUSION FACTS:

- *SOLID-STATE FUSION IMPACT ON ENERGY INDUSTRIES.*
- THE FUSION INFORMATION CENTER'S POSITION PAPER - AUGUST 1989 REVISION.
- CALCULATING THE ENERGY AVAILABLE FROM DEUTERIUM FUSION.
- COMING EVENTS OF FUSION INTEREST.
- HISTORY NOTE: THE DISCOVERY OF THE FLEISCHMANN-PONS EFFECT.
- CALCULATING CHARGING TIME FOR PALLADIUM DEUTERIDE.

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