



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : G21B 1/00	A2	(11) International Publication Number: WO 92/08232 (43) International Publication Date: 14 May 1992 (14.05.92)
(21) International Application Number: PCT/US91/07909 (22) International Filing Date: 25 October 1991 (25.10.91) (30) Priority data: 608,289 2 November 1990 (02.11.90) US (71)(72) Applicant and Inventor: HEREDY, Laszlo, A. [US/ US]; 41 Mirador, Irvine, CA 92715 (US). (74) Agents: SZEKERES, Gabor, L. et al.; Klein & Szekeres, 4199 Campus Drive, Suite 700, Irvine, CA 92715 (US). (81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European pa- tent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (Euro- pean patent), HU, IT (European patent), JP, LU (Euro- pean patent), NL (European patent), SE (European pa- tent), SU ⁺ .		Published <i>Without international search report and to be republished upon receipt of that report.</i>
(54) Title: ELECTROSTATICALLY PROMOTED COLD FUSION PROCESS (57) Abstract Deuterium gas is introduced and maintained under pressure in a reactor containing a relatively large number of electrode pairs separated from each other by thin walled insulator members, connected to a variable high voltage direct current power source. At least one set of electrode pairs comprises a transition metal, such as palladium, which is capable of forming a deuteride. Sufficient voltage is applied to the electrodes to trigger a nuclear fusion reaction in the deuterium which is absorbed in the transition metal electrodes, and excess heat of the reaction is captured by suitable heat exchangers operatively associated with the reactor. Both sets of the electrodes may comprise transition metal, and both are preferably provided in a powder form to increase surface. The polarity of the electrodes is reversed periodically to maintain or promote the fusion reaction, and the powdered electrodes are agitated from time-to-time to bring fresh transition metal powder in contact with the insulator members.		

+ DESIGNATIONS OF "SU"

Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland			SN	Senegal
CI	Côte d'Ivoire	KR	Republic of Korea	SU ⁺	Soviet Union
CM	Cameroon	LI	Liechtenstein	TD	Chad
CS	Czechoslovakia	LK	Sri Lanka	TC	Togo
DE	Germany	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

ELECTROSTATICALLY PROMOTED COLD FUSION PROCESS
BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to a "cold fusion" process.
5 Deuterium gas is converted to a metal deuteride by
absorption into the lattice of such metals as palladium,
titanium or other transition metals. These metal
deuterides, preferably in the form of powders, are placed
into compartments, which are separated by ceramic sheets
10 made of a material of high dielectric constant. The metal
deuteride powder substrates in the compartments are
connected, alternately, to the positive and negative
leads of a direct current power source. This arrangement
is similar to that of the electrodes in a multi-layer
15 ceramic (MLC) capacitor.

An important aspect of this invention is that, using
this electrode arrangement, positive and negative
electrical charges of high electric charge density are
obtained on those metal deuteride particles, which are in
20 contact with or are near the surface of the separator.
The electrodes and separators, described above, are
assembled inside a pressurizable container which is filled
with deuterium gas at the desired operating pressure and
temperature.

25 Another important aspect of this invention is that
the deuterium gas pressure, the electric charge density
over the surface of the metal deuteride particles, the
polarity of the electric charge, and the time period over
which the electric charge is applied, are optimized to
30 create reaction conditions which are favorable to the
nuclear fusion of deuterium. Fusion of deuterium nuclei,
with the release of huge amounts of energy, takes place
when the deuterium concentration and negative charge

density reach a threshold level in the lattice of the electrically charged transition metal deuteride electrodes.

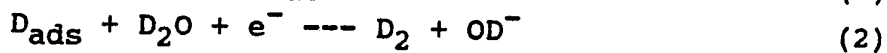
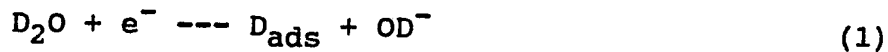
In another embodiment of this invention, porous ceramic sheets or ceramic coated screens are used to contain the transition metal deuteride powder particles. In this case, electric discharge takes place between oppositely charged electrodes when a certain charging voltage is applied. The electric discharge causes local supersaturation of deuteron particles in the transition metal lattice, and thereby promotes deuterium fusion.

Still other important features of this invention are means to supply fresh metal deuteride particles to those regions of the compartments which are next to the dielectric ceramic sheets, to provide for uninterrupted operation of the fusion process over long periods of time.

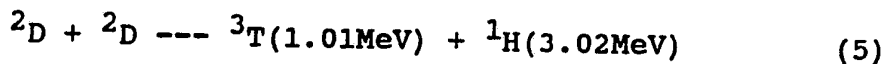
2. Prior Art

In the field of energy conversion research, one of the most desirable and also the most ambitious goals has been to achieve the fusion of deuterium nuclei under less extreme conditions than those used in "hot fusion", which requires very high pressures, and temperatures over one million degrees. Until the recent disclosure of an electrochemical technique by Pons and Fleischmann (M. Fleischmann and S. Pons, Electrochemically Induced Nuclear Fusion of Deuterium, J. Electroanal. Chem. 261 301 (1989), and numerous news reports in scientific and other journals), it has been generally accepted that nuclear fusion of deuterium can be carried out only under "hot" conditions. The Pons-Fleischmann disclosure was the first indication that "cold" fusion of deuterium might be possible under the very much milder conditions of ordinary electrolysis. According to their report, the following

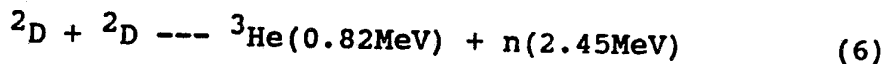
reactions take place, when heavy water is electrolyzed using palladium electrodes:



Most of the adsorbed deuterium (formed in Step 1) diffuses into the palladium lattice (Step 3), forming palladium deuteride, PdD_x , which has metal-like properties. In this system, consisting of Pd and PdD_x , the deuterium exists as positively charged deuterons, since the electrons of the deuterium are taken up by the conduction band of the palladium. The deuterons in the lattice have high mobility, and are under high compression due to the overpotential at the palladium surface. These conditions favor close collisions of some deuterons, with the possibility that a few of these collisions lead to nuclear fusion:



or



According to Pons and Fleischmann several of their experiments indicated that nuclear fusion reactions have indeed taken place. They also reported, however, that the measured neutron flux and tritium production were much less than expected on the basis of the observed thermal effect. They concluded that reactions (5) and (6), which are predominant in "hot" fusion reactions, represent only a small part of the overall reaction scheme in their system, where the bulk of the energy release may be due to hitherto unknown nuclear reactions.

After more than a year of intensive testing by the authors as well as by many independent laboratories,

however, it appears that the original claims of Pons and Fleischmann could not be verified, and the reported early data could not be reproduced (Numerous news reports in scientific and other journals). Thereafter it was generally concluded in the art that this electrochemical method could not produce fusion reactions to a significant degree, and cannot lead to a viable process of power generation.

It has been known that the palladium deuteride can be produced not only by the electrochemical method described above, but also by simply exposing palladium metal to deuterium gas at various pressures and temperatures. Since more information is available about the formation of the analogous hydrogen derivative, palladium hydride, this information is summarized here briefly (W. M. Mueller, J. P. Blackledge and G. G. Libowitz, Metal Hydrides, Academic Press (1968)). The composition of palladium hydride, PdH_x , as a function of hydrogen pressure, at two different temperatures, is shown in Table 1. Analogous palladium deuterides have somewhat lower deuterium contents compared to the hydrides. For example, at 20 degrees C and 1 atm. pressure, the respective compositions are: for the hydride, $\text{PdH}_{.69}$; and for the deuteride: $\text{PdD}_{.65}$

Table 1..

Correlation of Palladium Hydride (PdH_x) Composition with H_2 Pressure at 18 Degrees C and 100 Degrees C

(P (atm))	X	
	18 Degrees C	100 Degrees C
1	0.69	0.59
10	0.74	0.66
100	0.79	0.73
500	0.82	0.77
1,000	0.84	0.80

Several researchers conducted tests to attempt cold fusion with palladium deuteride prepared by exposing palladium metal to deuterium gas at different pressures and temperatures (numerous news reports in scientific and 5 other journals). It has been found that no fusion reaction takes place under these conditions. Recently, however, Wada and Nishizawa reported bursts of neutron emissions from a deuterium filled reactor containing two palladium rods, when the system was stimulated by high 10 voltage alternate current discharge between the rods (N. Wada and K. Nishizawa, Nuclear Fusion in Solids, Japanese Journal of Applied Physics, 28, (11) L 2017 (1989)). Immediately after stimulation, a neutron flux of several hundred times background was observed for a few seconds. 15 Neutron emission continued for more than one minute before it died down to background level. This burst of neutron emission was followed, without further stimulation, by several additional neutron emission periods of similar duration but lower intensity. A second stimulation again 20 resulted in neutron emission. This, however was of significantly lower intensity than the first one, and after a few more low-intensity emission periods, the neutron emission stopped. Further stimulation by electric discharge did not result in more neutron emission. Many 25 cracks and holes were observed on the surface of the used palladium rods when they were examined by a scanning electron microscope.

The deuterium gas used in this experiment was analyzed by mass spectroscopy before and after the fusion 30 experiment. The purity of the deuterium feedstock was 99.4%. After the reaction, the resulting gas mixture contained 82.2% D₂, about 9% of gases with mass number 3, 7% with mass number 2 and a few tenth of 1.0 % with mass

numbers 1, 5 and 6. This product gas composition as well as the neutron emission definitely indicates that nuclear fusion reactions have taken place.

The authors Wada and Nishizawa theorized that the nuclear fusion reactions resulted from supersaturation of the solid solution of deuterium in the palladium matrix. When the excess deuterium is released as D_2 gas, very large pressures are created at the beginning of the nucleation of deuterium gas bubbles. This creates conditions favorable to nuclear fusion. High voltage discharge between the palladium rods stimulates this process and thereby nuclear fusion as well.

Another experimental approach for achieving deuterium-deuterium fusion was reported by L. Friedman et al. of Brookhaven National Laboratory (R. J. Beuhler, G. Friedlander and L. Friedman, J. Phys. Chem. 94, 7665 (1990)). Their method, called cluster-impact fusion, involves bombarding a solid target, such as titanium deuteride, with ionic clusters of D_2O molecules. Expected fusion products were detected, such as 3-MeV protons and 1-MeV tritons, the signature of one D-D fusion pathway. They also detected smaller amounts of He-3, one of the characteristic products of the other D-D fusion pathway. The authors concluded that the fusion reactions are induced by the impacts of D_2O ionic clusters on the surface of the titanium deuteride. This impact can result locally in very high compression, high temperature and pressure for a very short period, and these conditions cause a low level of fusion reactions to take place.

OBJECT OF THE INVENTION

It is an object of this invention to provide a process for "cold" nuclear fusion of deuterium, used in the form of deuteride of a transition metal, the process

being characterized by electrostatically charging the transition metal deuteride to create conditions which are favorable to the fusion of deuterium nuclei.

Another object of this invention is to provide a
5 "cold" fusion process which can be used to produce heat for power generation, such that the process can be operated without interruption over long periods of time.

Still another object of this invention is to provide unique reactor designs and operating conditions for
10 achieving continuous heat generation in the fusion reactor.

Other objects and advantages of this invention will become apparent in the course of the following detailed description.

15

SUMMARY OF THE INVENTION

In accordance with the broad aspects of this invention, deuterium (D_2) gas is subjected to reaction conditions such that the deuterium undergoes nuclear fusion. The heat generated in the exothermic fusion
20 reaction is utilized principally for electric power generation. The deuterium feed gas used in this process enters a pressurizable reactor, which contains several narrow compartments filled with powdered (or like finely dispersed) palladium or another transition metal.

25 Alternatively, plates or sheets of palladium or of another transition metal can be used as electrodes in these compartments. The walls of the compartments are made of a ceramic material of high dielectric constant, such as barium titanate. Metal wires, which are alternately
30 connected to the negative or positive terminals of a direct current (dc) power source, are immersed into the powdered metal in each compartment. Heat exchanger coils are operatively associated with the reactor, to regulate

the temperature and to recover the heat generated in the reactor by the nuclear fusion. Water, or any other convenient heat transfer fluid can be used for this purpose.

5 According to the process of this invention, palladium deuteride is prepared in situ by contacting the palladium powder with deuterium gas at the desired pressure and temperature. When the saturation composition of the palladium deuteride is reached, the dc power source is
10 switched on. As a result, thin surface layers of those palladium deuteride particles which are in contact with or near the ceramic/dielectric separator surface, acquire large positive or negative electric charge densities in the alternating compartments. In the positively charged
15 compartments, the positive charge density in the surface layer increases deuterium absorption there, while negative surface charge density in the other, alternate, compartments reduces deuterium absorption. Another important aspect of the utilization of electrostatically
20 charged palladium deuteride particles according to this invention, is that in regions of high electron density, in the negative electrodes, the distance between deutron nuclei in the palladium matrix is reduced, and thereby the probability of deutron collisions leading to fusion is
25 increased. Therefore, in the preferred embodiment of this invention a cyclic operation is conducted: in one cycle high deutron concentration is built up on the surface layer of the positively charged particles, while at the same time the deutron concentration is somewhat reduced
30 on the surface of particles in the other electrode compartments which are negatively charged. In the other cycle the polarity of the compartments is reversed, and those palladium deuteride particles which have the highest

deuterium concentration, will be negatively charged. At this moment, the best attainable conditions are reached for deuteron fusion, which begins and then continues as long as the deuterium concentration in the palladium 5 deuteride remains above a certain threshold level. At that point, the polarity is reversed again and the whole process is repeated.

After a certain number of cycles the intensity and the duration of the fusion reaction will start to decline 10 due to changes in the structure of the metal matrix, passivation, structural damage or accumulation of by-products of the fusion reaction. At this point the palladium deuteride powder in each compartment is stirred, by means of properly constructed stirring devices 15 installed in the compartments along with the dc current leads, to bring fresh particles to the reactive region near the ceramic/dielectric separators. This way the fusion reaction is sustained for long periods of time.

In another embodiment of this invention, porous 20 ceramic sheets, or ceramic coated screens are used to contain the transition metal deuteride particles. In this case, electric discharge takes place between oppositely charged electrodes when a certain charging voltage is applied. The electric discharge causes local 25 supersaturation and compression of the deuterons in the transition metal lattice, and thereby promotes nuclear fusion.

The features of the present invention can be best understood together with further objects and advantages by 30 reference to the following description, taken in connection with the accompanying drawings, wherein like numerals indicate like parts.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1, 2, 3 and 4 show different reactor designs for carrying out "cold fusion" of deuterium in accordance with the basic concepts of this invention. In each design, there are shown transition metal substrates, in the form of thin plates, or powders, separated by or contained between sheets made of ceramic/dielectric materials; electrical leads connecting the metal substrates to a dc power source; a containment vessel holding said compartments; means for supplying deuterium gas and removing gaseous by-products; and means for recovering the heat generated by the fusion reaction. The reactor designs preferred for extended continuous operation of the process of this invention are shown in Figure 3 and Figure 4. In these designs transition metal deuteride powders are used as electrode materials, and each electrode compartment is equipped with an agitator device. The agitators or stirrers are used periodically to remove passivated or exhausted electrode materials and to supply fresh, active metal powder to the area in contact with the ceramic separators.

More specifically:

Figure 1 is a schematic drawing showing the basic design of the cold fusion reactor of the present invention;

Figure 2 is a schematic drawing showing the basic design of the cold fusion reactor of the present invention in which several parallel-connected positive and negative electrodes are used;

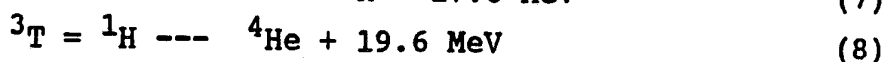
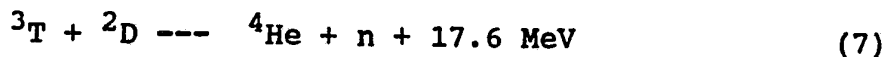
Figure 3 is a schematic drawing showing a preferred embodiment of the cold-fusion reactor, and

Figure 4 is a schematic drawing showing another preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following specification taken in conjunction with the drawings sets forth the preferred embodiments of the present invention. The embodiments of the invention disclosed herein are the best modes contemplated by the inventor for carrying out his invention, although it should be understood that various modifications can be accomplished within the parameters of the present invention.

10 This invention provides a process for "cold" fusion of deuterium, principally for the purpose of producing heat which then can be used for electric power generation. The process has the potential of revolutionizing the electric power industry. A quick approximate calculation 15 shows that the entire energy requirement of the United States in the year 2020 could be supplied by D-D fusion reactors using 5000 tons of deuterium gas D_2 (or 25,000 tons of heavy water (D_2O)) per year. This amount is about fifteen times the present annual D_2O production rate 20 (Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 7, page 551), and represents a very tiny fraction of the D_2O which can be obtained from sea water (about 0.0145% of the hydrogen atoms in water is the "heavy" isotope, deuterium). If the fusion reaction can be conducted in 25 such a manner that the tritium formed in reaction (5) further reacts with deuterium (reaction 7), or with hydrogen, also formed in reaction 5, (reaction 8), then the deuterium requirement is reduced by a factor of five because of the extremely high energy release from 30 reactions 7 and 8.



The deuterium fusion reactor can also be used for the

production of tritium from deuterium.

The basic concept of this invention is described as follows:

The repulsive forces between deuteron nuclei are so great that in deuterium gas no collisions between these nuclei can take place to cause nuclear fusion reactions. It is known that deuterium forms metal-like deuterides with transition metals, such as palladium or titanium. In the transition metal deuterides, such as palladium deuteride, the electron of each deuterium atom is taken up by the conduction band of the palladium, and positively charged deuterons are formed, which are highly mobile in the palladium lattice. The average distance between deuterons in the palladium lattice is somewhat less than in deuterium gas, because the conduction band electrons screen the repulsive nuclear forces to some extent. Furthermore, spin-spin interaction between the deuterons in the palladium lattice also results in an attractive force. These screening and attractive forces, however, are still overwhelmed by the coulombic repulsion between the positively charged deuteron nuclei and prevent nuclear fusion reactions from taking place.

According to the basic concept of this invention, electrostatically charged transition metal deuteride plates or electrode structures containing transition metal deuteride powders are used to enhance the probability of close deuteron collisions which result in nuclear fusion. Suitable transition metals include Pd, Ti, Ni, V, Nb, and Ta and their alloys with other metals. With reference to palladium deuteride electrodes, increased electron density of the surface of the negative electrodes gives stronger screening of the repulsive forces between the positively charged deuteron nuclei, and thereby creates more

favorable conditions for deuteron collisions. At the same time, the increased positive charge density on the positive electrodes increases chemisorption of deuterium due to the withdrawal of electrons from the palladium deuteride. These phenomena are exploited by using a cyclic operation as follows.

During that period when fusion reactions take place on the negative electrodes, high deuteron concentration builds up in the positive electrodes. In accordance with the invention, when the rate of the fusion reaction in the negative electrodes decreases below a desirable level, the polarity of the electrodes is reversed, and fusion reaction begins to take place on the surface of the other set of electrodes which momentarily are switched from positively to being negatively charged. Alternatively, a direct current pulse of reverse polarity can be applied for the required period of time. This cyclic operation can be repeated many times, and a desirable, steady level of fusion reaction can be maintained.

The basic principles involved in the design of a fusion reactor according to this invention are illustrated in Figure 1. The key components of the electrically grounded (D) reactor (C) are thin metal plates E and G. They are separated from each other by insulator F which is made of a ceramic material of high dielectric constant, such as barium titanate. Plate E is made of palladium or some other transition metal e.g. titanium which forms alloy-like deuterides with D₂ gas. Plate G can be made of a common metal, such as copper or aluminum. The two metal plates are connected, respectively, to the negative and positive terminals of a variable voltage power source M, by means of electrical leads K and L through a switch N. Thus, the two metal plates are connected to the power

source the same way as electrodes are in a ceramic capacitor. The electrode leads penetrate the reactor wall via ceramic or other insulating feedthroughs, R. An electric insulator layer, J may be installed inside the upper and lower walls of the reactor. Also, an electric insulator plate (not shown) may be placed, if necessary, between the electrode E and the reactor wall C to prevent sparking. Deuterium gas is fed to the reactor at the desired pressure through feed port H. Used deuterium, containing reaction products such as tritium, helium and hydrogen, can be removed through exit port I and sampled for analysis at point Q. The reaction heat can be removed from the reactor by means of a water cooled jacket, with cooling water inlet at A and outlet at B. Temperature and pressure gauges P and S are installed in the reactor. A number of radiation detectors (not shown) are placed next to the reactor to monitor neutron emissions, and, appropriate radiation shields (not shown) and other safety devices (not shown) are installed.

Figure 2 shows the design of a multi-electrode reactor for deuterium fusion. The individual electrodes in this reactor C are constructed the same way as those shown in Figure 1, except that active electrode plates E are placed on both sides of the ceramic/dielectric insulators F. The counter electrodes G are located inside the insulators along the center line. The active electrodes are connected parallel to a common lead K, and, similarly, the counter electrodes to another common lead L. The two electrical leads are connected, respectively, to the positive and negative terminals of a variable voltage power source M. The electrode leads penetrate the reactor wall via ceramic or other insulating feedthroughs, P. An electric insulator layer, J, may be installed

inside the upper and lower walls of the reactor. The active electrodes in this design are made of thin palladium plates, attached to or deposited on the ceramic/dielectric insulators. The reactor is
5 electrically grounded (D). The reactor is filled at the desired pressure and temperature with deuterium gas through feed port H. This same port serves also to remove periodically the used deuterium, mixed with reaction products, such as tritium, helium and hydrogen. The heat
10 generated in the reactor is removed by means of a water cooled jacket (water inlet: A, water outlet: B) or some other type of heat exchanger.

Figure 3 shows a preferred embodiment of the design of a deuterium fusion reactor in which PdD_x powder
15 electrodes are used. Two sets of electrodes are used, one carrying negative and the other positive charge. In electrode set A the PdD_x powder is contained inside thin walled rectangular boxes C made of ceramic insulator/dielectric materials such as barium titanate.
20 The PdD_x powder in electrode set B fills the rest of the volume of cell J, which is made of a metal of high electric conductivity such as copper. The powdered palladium deuteride substrates in the two sets of electrode compartments are separated from each other by
25 the ceramic walls of boxes C. Each vertical compartment between the ceramic separators contains an electrode lead (F' for electrode set B and G' for set A), which can also serve as an agitator device to periodically mix the palladium deuteride powder in the electrode compartments.
30 These electrode leads are connected to the main electrode lines F and G, respectively. These main electrode lines are connected, to the positive and negative terminals of variable voltage power source H.

Cell J is mounted inside pressurizable reactor E, which is grounded (K). The main electrode lines F and G enter the reactor via insulated penetrations L. Deuterium gas is supplied through feed port I which also serves for
5 the periodic removal of spent deuterium containing by-product gases such as tritium, hydrogen and helium. The cell wall and the reactor wall are kept separated from each other by electrically insulating spacers D. Appropriate heat transfer means (not shown) are mounted
10 near the reactor wall to transfer the heat produced in the fusion reactor to an electric power generating unit.

Figure 4 shows another preferred embodiment of the reactor, in which the walls of electrode compartments K are made of porous ceramic materials or ceramic coated
15 screens. The active electrode material F such as palladium deuteride in powder form, is contained in these compartments which are alternately charged to positive or negative potentials, respectively (electrode sets A and B). The electrodes are supported by insulating spacers D.
20 Similarly to the design of the first preferred embodiment, the electrodes are mounted in a pressurizable reactor C, which can be operated at pressures higher than 1 atm. Each compartment contains an electrode lead, G, which can also be used as an agitator or stirrer. The electrode
25 leads are connected to the positive and negative terminals, respectively, of a variable voltage power source, I. The two main electrode leads enter the reactor through insulated penetrations H. Deuterium gas is supplied and by-product gases are removed through gas port
30 J. The reactor is equipped with a water jacket or other heat exchanger (not shown) to remove the heat generated in the reactor. The reactor wall is grounded (L).

The objective of using electrode compartments made

with porous or ceramic coated screen walls is to periodically impose electric discharge between oppositely charged neighboring electrodes. This is accomplished by operating the cell (reactor) at a potential below the 5 discharge voltage, and periodically increasing the potential to such a value where electric discharge occurs. Some experimental observations indicate that electric discharge promotes the fusion reaction.

The invention will be still better understood by 10 reference to the following examples which illustrate embodiments of the process of this invention, and should not be construed as limiting the scope thereof.

Example 1

A fusion reactor of the type illustrated in Figure 2 15 is used in this example. The reactor contains five electrode structures, each of approximately 10 cm x 10 cm geometric surface area. The average thickness of the palladium metal layer on the active surface is approximately 10^{-4} cm. Previous measurements have shown 20 that the inner approximately 10^{-6} cm thick palladium layer (nearest to the ceramic separator) is the most active region for the fusion reaction. The reactor is filled with deuterium gas under 10 atm. pressure. After the power supply is turned on, and the cell voltage is 25 increased gradually, fusion reaction begins to take place at a cell voltage of about 200 V., as evidenced by heat evolution and neutron emission.

Shortly after the first observation of neutron emission, heat evolution is observed. Cooling water is 30 turned on. At a cooling water flow rate of approximately 0.1 liter/min. the reactor operates for more than one hour with an average cooling water exit temperature of 80 degrees C, before the rate of heat evolution begins to

decline significantly. At this point the reactor is shut down by reducing the cell voltage to zero, and the deuterium gas pressure to 1 atm. It is calculated, theoretically, assuming that reaction (5) is predominant, that fusion of all the deuterium in the inner 10^{-6} cm thick layer of the palladium electrodes would generate approximately 1.73×10^6 kcal of heat energy, capable of heating 21.62 kg of water from 20 degrees C to 100 degrees C. Of course, if deuterium in this reactive layer is replenished by absorption and diffusion of deuterium to the active region, the fusion reaction can go on indefinitely as long as passivation or other damage of the active palladium layer does not occur. On the basis of this calculation, approximately 20 % of the deuterium in the reactive surface layer have reacted when the reaction rate starts to decline.

Example 2

A fusion reactor of the type illustrated in Figure 3 is used in this example. Cell J inside the reactor contains five rectangular ceramic boxes C, each with a geometric cross sectional area of $10 \text{ cm} \times 10 \text{ cm} = 100 \text{ cm}^2$. The reactor is filled with deuterium gas under 10 atm. pressure at room temperature. Electrode set A is connected to the positive, and electrode set B to the negative terminal of the variable voltage power source H. After the power supply is turned on, and the cell voltage increases gradually, fusion reaction begins to take place at a cell voltage of about 250 V as evidenced by neutron emission. Heat evolution also begins at about this time. Cooling water is turned on as heat evolution begins. At a cooling water flow rate of 0.1 liter/min. the reactor operates for about 30 minutes before the heat evolution begins to decline. At this point the cell voltage is

reduced to zero, and then the polarity is reversed, so that electrode set A is connected to the negative and B to the positive terminal. The rate of heat evolution soon reaches the original (starting) level and continues for about 30 minutes before it begins to decline. At that point the electrode polarity is reversed again. This procedure is repeated several times for example approximately three times. This mode of performing the fusion process illustrates the principle that conditions favorable for fusion are obtained when first high deuterium concentration is attained at the positively charged electrodes, followed by a step of connecting these same electrodes to the negative terminal to create high electron density in the reactive surface layer.

15

Example 3

A fusion reactor of the type illustrated in Figure 3 is used in this example. The first three cycles of this process are performed the same way as in Example 2. After completing the third cycle, however, the process is not terminated but cycling is continued substantially longer. A noticeable decrease in performance (fusion) occurs between cycles No. 15 and 20. At this point, the reactor is shut down by reducing the cell voltage to zero and the pressure to approximately 1 atm. The contents of each electrode compartment are mixed using the agitator or stirrer devices installed in the cell compartments. Then the reactor is started up again by increasing the deuterium pressure to approximately 10 atm. and the cell voltage to approximately 250 V. As a result, fusion and associated heat generation are resumed at the original level. Cell operation is then continued as described in Example 2 and in this example.

This example illustrates the principle that reduced

reactor performance is increased to the original, starting level by stirring the palladium deuteride powder in the electrode compartments, and thereby transporting fresh active electrode material powder to the area next to the ceramic wall of each compartment.

Example 4

A fusion reactor of the type illustrated in Figure 4 is used in this example. The active electrode material, in this case powdered palladium deuteride, is contained in rectangular boxes having porous ceramic, or ceramic-coated screen walls. The reactor is filled with deuterium gas at approximately 10 atm. pressure. After the formation of PdD_x of equilibrium composition, the power supply is turned on, and the cell voltage is gradually increased to a value near the discharge potential. Slow fusion reaction begins at this point as evidenced by neutron emission and heat generation. The cell voltage is then increased for a period of 10 seconds above the value of the discharge potential. As a result, there is a significant increase in the rate of the fusion reaction. After a few minutes, when the rate subsides to the original baseline level, the procedure is repeated with the same result. When, after several cycles, the overall fusion reaction rate begins to decline from cycle to cycle, the cell is shut down by reducing the cell voltage to zero and the pressure to approximately 1 atm. The active material is mixed, using the electrode lead/stirrer devices. Operation is then started again by increasing the deuterium pressure to 10 atm. and the cell voltage to a value slightly below the discharge potential. Operation is then continued with periodic increases of the cell voltage above the value of the discharge potential. It is found that after stirring the active electrode material,

the reactor regains its original performance.

Thus, it can be seen, that the present invention provides a deuterium fusion process, which can be conducted under operating conditions similar to those of
5 ordinary chemical reactions. Furthermore, the designs and operating examples show that fusion can be performed under such conditions which make uninterrupted long-term operation possible for heat production, which then can be used for electric power generation.

10 It will, of course, be realized, that various modifications are possible in the design and operation of the present invention without departing from the spirit thereof. For example, deuterium pressures of several hundred atm. can be applied to increase the rate of
15 fusion; ceramic separator/dielectric materials, which are more effective than barium titanate, can be used; mixing methods for the active electrode material other than those described in the figures and operating examples can be applied. Thus, while the preferred design and mode of
20 operation of the invention have been explained, the invention may be otherwise practiced within the scope of the teachings set forth herein, as this will be readily apparent to those skilled in the art.

WHAT IS CLAIMED IS

1. A process for the fusion of deuterium and associated generation of energy, the process comprising the steps of:

5 in a reactor having a plurality of electrode pairs, each pair comprising two members separated from one another by an insulator member, and each electrode pair having one member connected to the positive and the other member to the the negative
10 terminal of a variable high voltage direct current source, at least one of the members of each electrode pair being made of a transition metal capable of forming deuterides with deuterium gas, and heat exchanger means for withdrawing heat energy from the
15 reactor

introducing and maintaining deuterium gas in the reactor at a pressure greater than 1 atmosphere for the purpose of contacting the electrodes with said deuterium gas and thereby forming transition metal deuterides with the electrodes which comprise
20 transition metal;

charging the electrodes from the high voltage direct current source with sufficient voltage to trigger fusion reaction between deuterium nuclei
25 absorbed in at least some of the transition metal electrodes, and

withdrawing heat energy from the reactor with the heat exchanger means.

2. The process of Claim 1 where the transition
30 metal of the electrodes is selected from the group consisting of Pd, Ti, Ni, V, Nb, and Ta and the alloys of said transition metals with other metals.

3. The process of Claim 2 where the insulator

member comprises a ceramic material of high dielectric constant.

4. The process of Claim 3 where the ceramic material comprises a titanate.

5 5. The process of Claim 4 where the ceramic material comprises barium titanate.

6. The process of Claim 2 further comprising the steps of periodically reversing the polarity of the electrodes.

10 7. The process of Claim 2 wherein the transition metal electrodes comprise powders of transition metal.

8. The process of Claim 7 further comprising the steps of periodically agitating the transition metal electrodes thereby supplying electrode material powder to 15 reactivities zones in the proximity of the separators.

9. The process of Claim 2 where the steps of charging the electrodes includes the steps of charging the electrodes with sufficient voltage to trigger fusion but below the discharge potential of the electrodes, and 20 periodically sufficiently increasing the potential difference between the oppositely charged electrodes for a set time period for electric discharge to occur between oppositely charged electrodes.

10. The process of Claim 9 wherein the transition 25 metal electrodes comprise powders of transition metal and the process further comprises the steps of periodically agitating the transition metal electrodes thereby supplying electrode material powder to reactivities zones in the proximity of the separators.

30 11. The process of Claim 2 where each member of each electrode pair comprises a transition metal.

12. A process for fusing deuterium and thereby generate energy, the process comprising the steps of:

- in a pressurizable reactor having a plurality of thin walled chambers having walls comprising electrically insulating ceramic material of high dielectric constant, and having transition metal powders capable of forming deuterides with deuterium gas on opposite sides of the walls, said transition metal powders comprising electrode pairs connected respectively to the positive and negative terminals of a variable high voltage direct current source, whereby a relatively large surface of the insulating ceramic material is in contact with the transition metal powder electrodes, the reactor also having heat exchanger means for withdrawing heat energy from the reactor
- introducing and maintaining deuterium gas in the reactor at a pressure greater than 1 atmosphere for the purpose of contacting the electrodes with said deuterium gas and thereby forming transition metal deuterides with the electrodes which comprise transition metal;
- charging the electrodes from the high voltage direct current source with sufficient voltage to trigger fusion reaction between deuterium nuclei absorbed in at least some of the transition metal electrodes,
- periodically reversing the polarity of the electrodes, and
- withdrawing heat energy from the reactor with the heat exchanger means.
13. The process of Claim 13 further comprising the steps of periodically agitating the transition metal electrodes thereby supplying electrode material powder to reactive zones in the proximity of the ceramic walls.

14. The process of Claim 13 where the step of charging the electrodes includes the steps of charging the electrodes with sufficient voltage to trigger fusion but below the discharge potential of the electrodes, and
5 periodically increasing the potential difference between the oppositely charged electrodes for a set time period sufficiently for electric discharge to occur between oppositely charged electrodes.

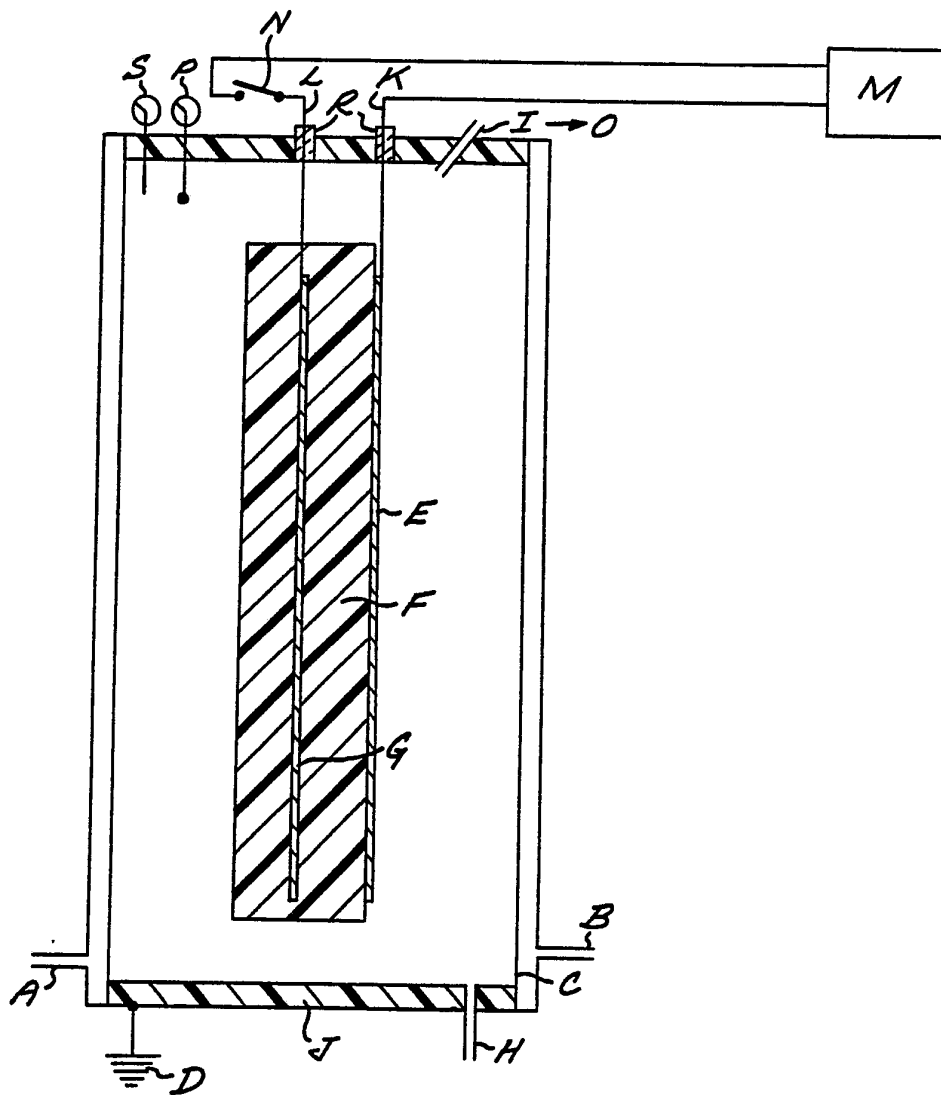
15. The process of Claim 12 where the transition
10 metal of the electrodes is selected from the group consisting of Pd, Ti, Ni, V, Nb, and Ta and the alloys of said transition metal with other metals.

16. The process of Claim 12 where the ceramic material comprises a titanate.

15 17. The process of Claim 16 where the ceramic material comprises barium titanate.

1 / 4

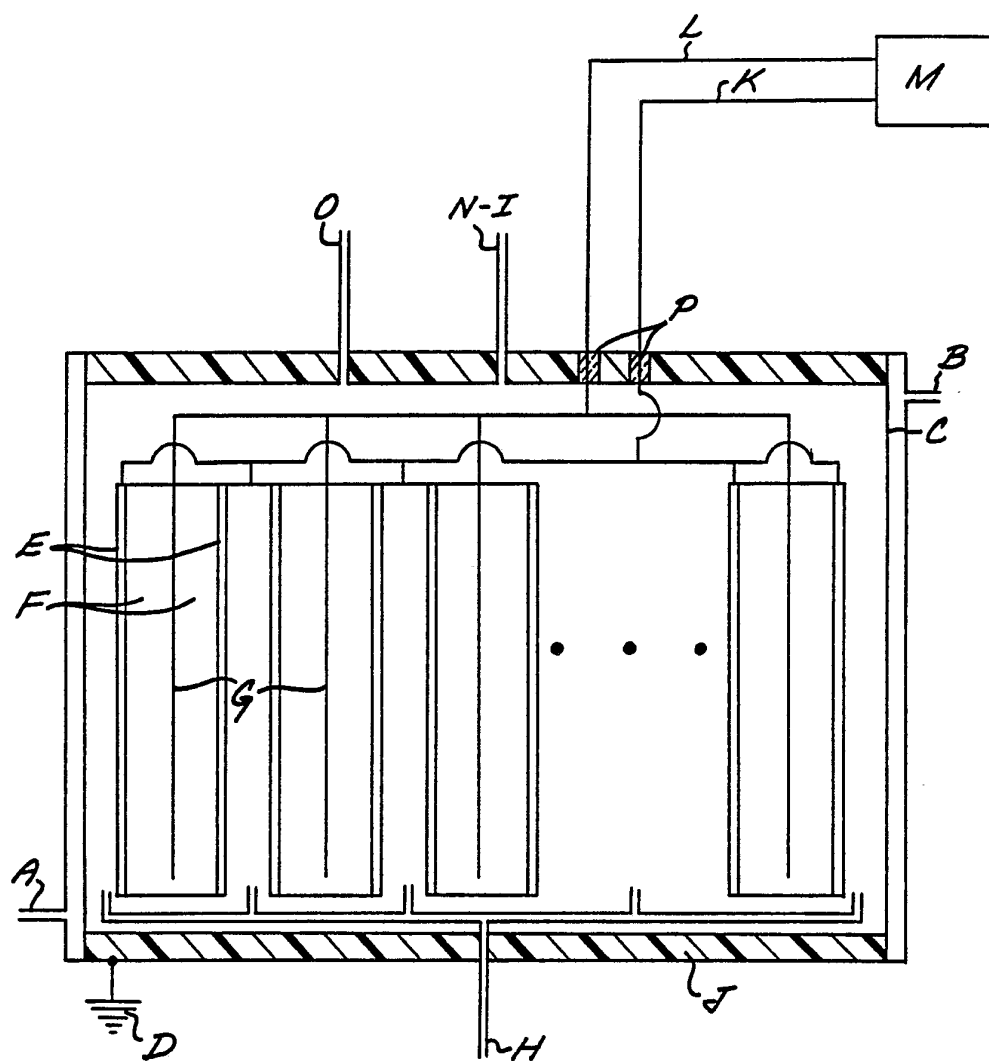
FIG. 1



SUBSTITUTE SHEET

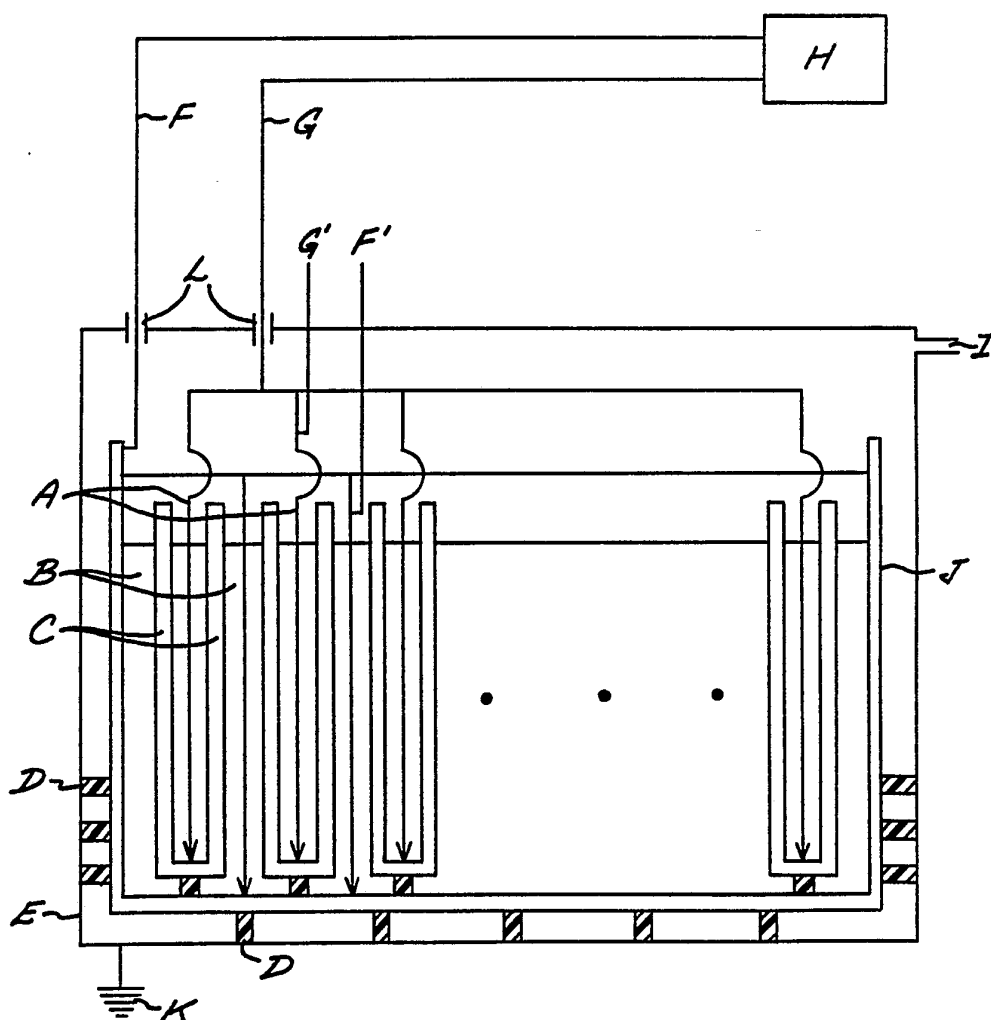
2 / 4

FIG. 2



3/4

FIG. 3



SUBSTITUTE SHEET

4 / 4

FIG. 4

