(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 September 2009 (03.09.2009)

PCT

(10) International Publication Number
WO 2009/108331 A2

(51) International Patent Classification:
A61K 38/22 (2006.01)

(21) International Application Number:
PCT/US2009/001213

(22) International Filing Date:
25 February 2009 (25.02.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/066,959 25 February 2008 (25.02.2008) US
Not furnished 25 February 2009 (25.02.2009) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, **IL,** IN, IS, **JP,** KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, **TJ,** TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, **IT,** LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: A HYBRID FUSION FAST FISSION REACTOR

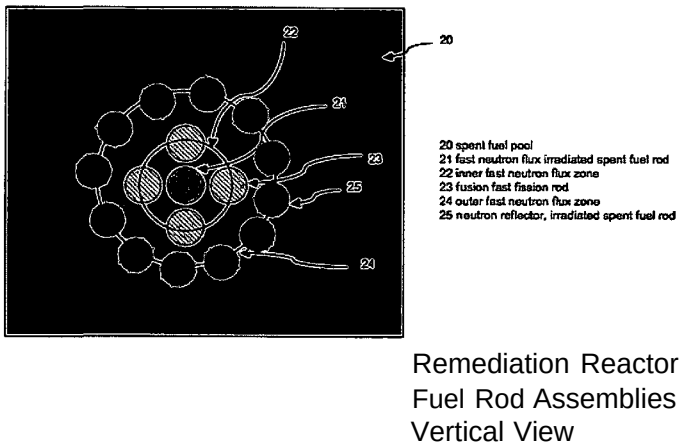

Figure 6

(57) Abstract: A hybrid nuclear fusion fast fission reactor is disclosed. The hybrid reactor may include an electrolyte solution comprised of PdCI2 a conductive salt and D2O, an anode of a noble metal, a cathode consisting of a conductive high Z (atomic number greater than 46) material wound around a deuteride-forming actinide nuclear fuel element, a power source providing constant current to the + anode and the - cathode, an applied power profile for fabricating the PdD nanoalloy, and a co-deposition of a PdD nanoalloy on to the high Z cathode winding as well as the nuclear fuel element. A preferred embodiment stablizes the actinide deuteride nuclear fuel element from hydrogen isotope de-loading. A preferred embodiment initiates deuterium-deuterium fusion in the deuterized fuel element and fissioning deuterized fuel element actinides. A preferred embodiment includes surrounding spent nuclear fuel elements with deuteride nuclear fuel elements that will fast fission the spent fuel elements. Another preferred embodiment includes surrounding the deuteride nuclear fuel elements with spent fuel elements as fast neutron reflectors that will also fission.

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A Hybrid Fusion Fast Fission Reactor

Title of the Invention

A Hybrid Fusion Fast Fission Reactor

Cross Reference to Related Applications

The present application claims priority on and to US provisional patent application number 61/066959, entitled "A Process for A Nuclear Fission Reactor", filed on February 25, 2008 by Lawrence Forsley

Statement Regarding Federally Sponsored Research or Development

Not Applicable

Field of Invention

This invention relates generally to the field of nuclear energy and more specifically to a hybrid fusion fast fission nuclear reactor.

Background of the Invention

[001] Conventional nuclear fission reactors "burn" ^{235}U through thermal neutron fission chain reactions as first taught by Fermi and Sziliard in US Patent 2,708,656 which is hereby incorporated by reference in its entirety. In addition, they breed fissile ^{239}Pu from neutron capture on fertile ^{238}U and subsequent β decays of ^{239}Np to ^{239}Pu. Both ^{235}U and ^{239}Pu will sustain a fission chain reaction after the fission neutrons are slowed, or moderated. However, the most common uranium, ^{238}U, and thorium, ^{232}Th, isotopes, will not sustain a chain reaction primarily due to their high neutron absorption cross-section as compared to their fission cross-sections. However, in order to fission ^{235}U and ^{239}Pu, the 1 MeV fission neutron energy must be moderated to .025 eV, where, for example, the ^{235}U fission cross section at 1 MeV is approximately 1 barn but increases

to 580 barns for a moderated thermal neutron at .025 eV.

[002] One MeV fast fission neutrons are moderated to thermal energies typically using either light or heavy water (CANDU reactor). Fast fission reactors also depend upon a fissile chain reaction, but they require higher ratios of fissile fuel than light water reactors, because there is no moderator. They can breed fissile fuel from fertile actinides using the increased fission neutron flux while the fast neutrons will fission both fissile and fertile nuclei, but with greatly reduced efficiency due to the, 500 times smaller fission cross-sections. The neutron fission cross-section, coupled with the neutron absorption cross-section and neutron energy cross-section dependencies are the driving factors in designing and controlling any fission reactor dependent upon a chain reaction in fissile material.

[003] Water, graphite and other low atomic number materials have been used as neutron moderators, where the lower the atomic number the fewer the number of neutron scatterings required to thermalize, or moderate, the fission neutron kinetic energy. Hydrogen, being a single proton, has nearly the same mass as a neutron, making it the best moderator. Deuterium, having a proton and a neutron but twice the mass of a neutron, is nearly as good.

[004] Titanium, scandium, uranium and other metal hydrides are routinely used to store hydrogen isotopes since they form hydrides ranging from TiH_2 to Th_4Hi_5. Uranium will readily take up hydrogen isotopes at standard temperature and pressure (STP) and the hydrided form, UH_3 will easily dissociate and free the hydrogen isotopes at modest temperatures (400^0C). However, these gas loaded, hydrided forms are at comparatively low hydrogen isotope concentrations as compared to what one skilled in the art can accomplish using electrolytically loaded metal hydrides as taught by Tripodi in US Patent Number 7,033,568 ['568] which is incorporated by reference in its entirety.

[005] Besides the use of graphite, light water or heavy water to moderate neutrons one method incorporates hydrogen into the fuel rod as a hydride as taught by Simnod in US Patent Number 3,1 54,845 which is incorporated by reference in its entirety. This is the

basis for the General Atomic TRIGA reactor. These reactors are safer than conventional light water moderated reactors due to the negative temperature coefficient of the *in situ* neutron moderator. More recently, Peterson filed US Patent Application number 20080069289 which is incorporated by reference in its entirety for the Hyperion safe reactor using a uranium, thorium or mixed fuel reactor with hydrided actinide fuel elements that rely upon the positive temperature dependence of hydride dissociation giving rise to a negative moderation coefficient. Consideration was also given to incorporating a hydrogen-deuterium gas mixture to tune the reactor neutron moderation coefficient.

[006] Consequently, there is considerable experience with hydrided actinide fuel rods. Indeed, conventional light water reactors even avoid fuel hydriding because the fuel rod swells, damaging the cladding unless precautions are taken, as described by Simond.

[007] Conventional fission reactors, whether moderated with light water, heavy water, graphite or other material depend upon a sustained chain reaction in fissile material via moderated fission neutrons. Even fast fission reactors, without a moderator, rely upon a fissile actinide chain reaction. The method taught herein removes the neutron energy fission dependency, the need for a chain reaction and the need for fissile fuel.

[008] An alternative reactor design uses fertile fuel, ^{232}Th, to breed fissile fuel, ^{233}U, through neutron capture. However, this breeder reactor requires a source of neutrons. One method is to surround a fissile core, or "pin" with fertile fuel elements, and over time swap out the spent inner elements for the newly fissile outer elements. New fertile fuel can then be placed on the perimeter to breed fissile fuel by neutron capture. Other reactor designs have been modified specifically to burn spent fuel, such as the CANDU and fast fission reactors. However, all of these reactors depend upon fission neutrons that are too fast to efficiently fission fissile material without moderation, and to slow to efficiently fission fertile material.

[009] Alternatively, an external source of very fast neutrons can be used such as from a laser fusion reactor (Slough, J. ."Suitability of Small Scale Linear Systems for a Fission-

Fusion Reactor, Breeder, and Waste Transmutation", *J. of Fusion Energy,* 27:1 15-1 18. (2007)), a tokamak or an advanced accelerator. The first two employ either deuterium-deuterium or deuterium-tritium fusion to produce very fast neutrons at 2.45 MeV and 14.1 MeV, respectively. The accelerator produces GeV protons that shatter lead nuclei in a "log" producing fast spallation neutrons. In each of these systems spent fuel or fertile fuel surrounds the neutron source that either fissions or breeds fissile fuel. However, none of these systems have been found to be economical, despite over 40 years of laser fusion, tokamak and advanced accelerators operations.

[010] Previously, Forsley and Patterson explored the electrolytic deuteriding of uranium and thorium (Forsley, "Electrocatalytic Reduction of Radioactivity in the Uranium Thorium System", *Proceedings of the ICCF-VII Conference,* (1997), Vancouver, Canada). Patterson was issued US Patent 5,672,259, "System with electrolytic cell and method for producing heat and reducing radioactivity of a radioactive material by electrolysis". However, his electrolytically-d riven radioactive reduction may have with only diluted radioactivity within the fluidized bed system.

[01 1] Recently, Boss (Boss, *et al,* "Triple Tracks in CR-39 as the result of Pd-D Co-deposition: evidence of energetic neutrons", *Naturwissenschaften,* (2009) Vol 96:135-142) documented the production of deuterium-deuterium (2.45 MeV) and deuterium-tritium (14.1 MeV) fusion neutrons using palladium co-deposition on non-hydriding metals. These energetic neutrons were observed and spectrally resolved using solid state detectors identical to those routinely used in the ICF (DoE lnertial Confinement Fusion program) experiments (Seguin, FH, *et al.* "Spectrometry of charged particles from inertial-confinement-fusion plasmas" *Rev Sci Instrum.* 74:975-995. (2003).

[012] Boss, *et al,* filed U.S. Provisional Patent Application Serial No. 60/919,190, on March 14, 2007, entitled "Method and Apparatus for Generating Particles", which is incorporated by reference in its entirety and Serial No. 11/859,499, ['499] "System and Method for Generating Particles", filed on September, 21, 2007, which is incorporated

by reference in its entirety. Although that patent teaches a method to generate neutrons and describes in general terms their use, this embodiment teaches another means to fast fission a natural abundance uranium deuteride fuel element driven by DD primary and secondary fusion neutrons within said fuel element. Consequently, a heavily deuterided actinide can be its own source of fast neutrons, with an average neutron kinetic energy greater than 2 MeV and greater than the actinide fission neutron energy. Such energetic neutrons are capable of fissioning both fertile and fissile material. There is no chain reaction. There is no concept of actinide criticality. Purely fertile material, like ^{232}Th or non-fertile isotopes, like ^{209}Bi, may fission producing additional fast neutrons and energy up to 200 MeV/nucleon fissioned.

[013] This results in considerable environmental, health physics, and economic savings by using either spent nuclear fuel, mixed oxide nuclear fuel, natural uranium or natural thorium to "stoke the fires of a nuclear furnace" and is the basis for our Green Nuclear Energy technology, or GNE (pronounced, "Genie"). GNE reactors may consume fertile or fissionable isotopes such as ^{232}Th, ^{235}U, ^{238}U, ^{239}Pu, ^{241}Am, and ^{252}Cf, and may consume fission wastes and activation products *in situ* without requiring fuel reprocessing. GNE reactors may consume spent fuel rods without either mechanical processing or chemical reprocessing. In this regard, GNE reactor technology may be an improvement over proposed Generation IV fission reactor technologies (http://nuclear.energv.aov/aenlV/neGenlV1 .htmh under development.

GNE may: improve safety *(no chain reaction),* burn actinides *(reduced waste)* and provide compatibility with current heat exchanger technology *(existing infrastructure).* By employing a novel, *in situ,* very fast neutron source, GNE constitutes a new Generation V hybrid reactor technology, combining aspects of Generation IV fast fission reactors, the DoE Advanced Accelerator reactor, and hybrid fusion/fission systems. It may eliminate the need for uranium enrichment and fuel reprocessing and, consequently, the opportunity for nuclear weapons proliferation through the diversion of fissile isotopes.

Advantages of the embodiment of the invention

[014] It may be an advantage of one or more of the embodiments of the invention to provide a safer nuclear reactor.

[01 5] Another advantage of one or more of the embodiments may be to provide a nuclear reactor with an internal source of fast neutrons.

[016] Another advantage of one or more of the embodiments may be to provide a nuclear reactor that operates with fertile or fissile fuel.

[017] A further advantage of one or more of the embodiments may be to provide a nuclear reactor that consumes its own nuclear waste products.

[01 8] A further advantage of one or more of the embodiments may be to provide a means to fission spent fuel rods.

[01 9] Yet another advantage of one or more of the embodiments may be to co-generate heat while consuming nuclear fission products and unspent nuclear fuel.

[020] Still yet another advantage of one or more of the embodiments may be to co-generate power from a conventional steam/water cycle

[021] Other objects and advantages of the present invention will become apparent from the following descriptions, taken in connection with the accompanying drawings, wherein, by way of illustration and example, an embodiment of the present invention is disclosed.

Summary of Invention

[022] In accordance with a preferred embodiment of the invention, there is disclosed a means to fabricate a highly deuterided actinide fuel element by the electrolysis of a heavy water solution (D_2O) consisting of PdCb and a conductive salt with a cylindrical anode of a noble metal, a cathode consisting of a conductive high Z (greater than atomic number 46) material that doesn't form a deuteride, wound around a less electrically conductive actinide metal fuel element, a power source providing constant current to the + anode and the - cathode, an applied power profile for fabricating a PdD nanoalloy, by the co-deposition of a PdD nano-alloy on to the high Z cathode winding

and said fuel element resulting in nuclear fission of the said fuel element using fast neutrons produced within the PdD nano-alloy and primary and secondary deuterium-deuterium fusion reactions within said fuel element. The resulting fission and fusion heat can be used to generate power.

[023] An alternative embodiment results in a heavily deuterided actinide fuel element that is electrolytically loaded and then sealed against isotopic hydrogen desorption, requiring no further electrolytic loading. Said sealed loaded fuel element may then be pulsed by an external acoustic, thermal, radio-frequency or other source providing short duration impulses resulting in periodic actinide metal lattice deuteride loading excursions and consequent neutron generation. This embodiment may be operated independently of an electrolytic bath but with a thermal bath to remove the heat from said loaded fuel element fusion and fission processes.

[024] Either embodiment may be used in a conventional nuclear spent fuel pool with a plurality of said deuterided fuel elements surrounding one conventional spent nuclear fuel element in a ring or other other geometry, or a plurality of said spent fuel elements further surrounded by an outer perimeter of spent fuel elements acting as fast neutron reflectors causing there to be a higher percentage of fast neutrons at the center of the ring or similar geometry of a plurality of deuterided fuel elements . Said inner spent fuel elements and outer perimeter spent fuel elements will undergo neutron capture and fission with the highest percentage of fission occurring in the center where the neutron flux and neutron energy is highest. The resulting fission heat can be used to co-generate heat in a conventional nuclear power plant where the spent fuel elements are stored.

[025] The invention describes a hybrid nuclear fusion fast fission reactor in a vessel comprising an electrolyte solution comprised of PdCb a conductive salt and D_2O; an anode of a conductive noble metal provided within said electrolyte solution; a cathode comprising a conductive high Z (atomic number greater than 46) material

wound around a metallic actinide nuclear fuel element; a power source providing constant current to the + anode and the - cathode; an applied power profile for fabricating the PdD nano-alloy; and an electrolytically co-deposited PdD nano-alloy on to the high Z cathode winding and on said fuel element. The said cathode is wound around said fuel element and acts as a neutron generator. Said cathode is comprised of a composition of the non-deuteriding series selected from the group consisting of platinum, gold, mercury, lead and bismuth. The nuclear fuel element is electrolytically deuterided beyond the actinide-deuterium beta phase adapting it, by the electrolytic loading of deuterium, to provide lattice fluctuations which initiate primary and secondary deuterium-deuterium fusion reactions at sites in the actinide metal lattice producing fast neutrons. These fast neutrons fission the actinides comprising said nuclear fuel element.

[026] A deuterided fuel element can be sealed with an amalgam of compounds to prevent isotopic hydrogen deloading through desorption. It further comprises an apparatus for pulsed control that produces acoustic, thermal, radiofrequency or other emanations attached to the deuterided fuel element that periodically enhances the local actinide-deuterium loading resulting in deuteron fluctuations. These fluctuations produce primary and secondary deuterium-deuterium fusion reactions and neutrons.

[027] These neutrons fission the actinides comprising said fuel element. A plurality of said deuterided fuel elements can be arranged to irradiate and fission a spent nuclear fuel element, or a plurality of nuclear spent fuel elements, with fast primary and secondary deuterium-deuterium fusion reaction neutrons. A plurality of said spent nuclear fuel elements can be arranged around said deuterided fuel elements to act as fast neutron reflectors while also fissioning said spent fuel elements. A nuclear spent fuel pool comprised of a plurality of said spent fuel elements and deuterided fuel elements as with a method for removing heat generated by the primary and secondary deuterium-deuterium fusion reactions in said deuterided fuel elements and from fast neutron fission of said spent fuel elements.

Brief Description of the Drawings

[028]The drawings constitute a part of this specification and include exemplary embodiments to the invention, which may be embodied in various forms. It is to be understood that in some instances various aspects of the invention may be shown exaggerated or enlarged to facilitate an understanding of the invention.

[029] Figure 1 Uranium Hydride Phase Diagram.
[030] Figure 2 Loading Fuel Rod, Horizontal View
[031] Figure 3 Loading Fuel Rod, Vertical View
[032] Figure 4 Loaded Sealed Fuel Rod, Horizontal view
[033] Figure 5 Sealed, Loaded Fuel Rod with Control Transducers, Horizontal View
[034] Figure 6 Remediation Reactor, Fuel Rod Assemblies, Vertical View
[035] Figure 7 Gamma Ray Spectra ID, Background
[038] Figure 8 Gamma Ray Spectra ID, Pd:D:U:D Reactor Operation
[039] Figure 9 Background Gamma Ray Spectra
[040] Figure 10 Pd:D:U:D Reactor Gamma Ray Spectra

Detailed Description of the Preferred Embodiments

Detailed descriptions of the preferred embodiment are provided herein. It is to be understood, however, that the present invention may be embodied in various forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but rather as a basis -for the claims and as a representative basis for teaching one skilled in the art to employ the present invention in virtually any appropriately detailed system, structure or manner.

Fabrication of Fuel Element

Figure 1 shows a Uranium-Hydride phase diagram. As taught by Tripodi, a hydride loaded electrolytically can approach and exceed unit stoichimetry in the palladium system and similar loading may go into the mixed beta and gamma phases in uranium and thorium hydrides. These fuel elements may be sealed and retain their hydrogen isotope loading for over two years with insignificant hydrogen isotope losses.

There are three phases of fabrication.

Figure 2 shows a horizontal view while loading the fuel rod. cross-section of the method where 11 indicates the cathode electrical feed wire attaching to the high Z cathode, 14, and 12 indicates the anode feed wire. The cathode feed wire 12 is attached to a noble metal cylindrical screen that is the anode. The high Z conductive wire, 14, wrapped around the high Z material, 13, is fabricated from an element (Z>46) or alloy and preferentially from, or containing, platinum, gold, mercury, lead or bismuth. The high Z material, 13, is preferentially a fertile or fissile material that may be a new or used fuel rod. 15 indicates the electrolyte which consists of PdCI2, a conductive salt and D2O. 15 can be comprised of metal salts instead, in which case the voltage on the cathode, 11, and the anode, 12, are reversed. The molten salts in the alternate embodiment may consist of eutectic KCI and LiCI salts.

The PdD nanoalloy formed around the spiral wound cathodic electrical conductor and neutron generator, 14, is as taught in the patent application of Boss ['49]. This patent application also describes the protocol for generating the PdD nanoalloy. The steps by which this occurs consists of first applying a low current, < .1 mA, until such time as the first neutron signal is detected, whereupon the current can be slowly raised but should not exceed .5 mA. These current densities are dependent upon the surface area provided by the anode and the cathode.

Figure 3 shows a vertical cross section of loading the fuel rod.
Figure 4 shows a representation of sealing a loaded fuel rod after Tripodi ['568]
Figure 5 shows a sealed fuel rod with two transducers that can be piezoelectric in nature.
Figure 6 shows a possible configuration for nuclear waste remediation. The deuterated elements are 20 arranged to maximize the fast neutron flux at the center. At the center are conventional spent fuel elements, 21, and the elements, 20, are surrounded by a perimeter of additional spent fuel elements, 24. The elements, 24, act as fast neutron reflectors. The elements in 24 are periodically swapped with the elements 21 that experience a faster fission burnup due to the higher fast neutron flux at the center

Operation of the Reactor
Data taken by JWK during one of several runs of an electrolytic nano-nuclear cell designed to generate a fast neutrons and use them to fission natural abundance uranium (.7% ^{235}U, 99.3% ^{238}U, .055% ^{234}U). The data sets in this report show time-integrated measurements taken with a 105% cryogenically cooled germanium detector. Germanium is the "gold standard" for identifying gamma ray emitting radioisotopes.

Data Sets:

The cell operated for over two weeks at a constant current below 1 mA. The first,

background, gamma spectroscopy set (Figure 8) was taken prior to operation, for a total of 5,585.8 seconds, or over VA hours. The second data set (Figure 9) was taken while the cell operated within 6 cm of the gamma ray detector for a total of 8,214.26 seconds or over 2 hours.

The background shows two background lines, potassium-40 (^{40}K) and a ubiquitous uranium daughter, protactinium-234m (^{234m}Pa). The second set of data shows the gamma lines emanating from the cell and includes both of the background lines. A natural abundance .5mm uranium wire incorporated into the cell cathode.

There is a large distinction between the natural radioactive decay daughters of the ^{235}U and ^{238}U isotopes and their nuclear fission products. These distinctly different gamma ray signatures are reflected in the data set summaries and are itemized here:

Isotope	Name	Source
$^{85}Kr_{36}$	Krypton	fission
$^{85}Sr_3S$	Strontium	charged particle, thermal or neutron activation
$^{92}Sr_{38}$	Strontium	fission
$^{109}Cd_{48}$	Cadmium	fast or thermal neutron activation
$^{125}XeS_4$	Xenon	charged particle, thermal or neutron activation
$^{131m}Xe_{54}$	Xenon	thermal neutron activation
$^{137}Cs_{55}$	Cesium	fission
$^{139}Ba56$	Barium	fission
$^{139,}Cess$	Cerium	fast or thermal neutron activation
$^{141}Ce5_8$	Cerium	fission

Other gamma ray lines associated with $^{95}{}_{Z7}r_4o$, $^{95M}NUb_4l$ and $^{i\ 140}$Las7 isotopes have also been observed. The $^{95}Nb_4l$ is a beta decay daughter of $^{95}Zr_{40}$ that, in turn, decays to a stable isotope, molybdenum-95, $^{95}Mo_4{}^{2-}$

The heat flux generated by both the radioactive decay, neutron-induced fission and

deuteron-enhanced nuclear reactions can be used for the co-generation of power through a conventional water/steam cycle heat exchanger.

While the invention has been described in connection with a preferred embodiment, it is not intended to limit the scope of the invention to the particular form set forth, but on the contrary, it is intended to cover such alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

Claims

What is claimed is:

1. A hybrid nuclear fusion fast fission reactor in a vessel comprising:

an electrolyte solution comprised of PdCb a conductive salt and D_2O;

an anode of a conductive noble metal provided within said electrolyte solution;

a cathode comprising a conductive high Z (atomic number greater than 46) material wound around a metallic actinide nuclear fuel element;

a power source providing constant current to the + anode and the - cathode;

an applied power profile for fabricating the PdD nano-alloy; and

an electrolytically co-deposited PdD nano-alloy on to the high Z cathode winding and on said fuel element.

2. A hybrid nuclear fusion fast fission reactor as claimed in claim 1 wherein said cathode wound around said fuel element acts as a neutron generator and said cathode is comprised of a composition of the non-deuteriding series selected from the group consisting of platinum, gold, mercury, lead and bismuth.

3. A hybrid nuclear fusion fast fission reactor as claimed in claim 1 wherein the nuclear fuel element is electrolytically deuterided beyond the actinide-deuterium beta phase.

4. A deuterided nuclear fuel element adapted by the electrolytic loading of deuterium to provide lattice fluctuations which initiate primary and secondary deuterium-deuterium fusion reactions at sites in the actinide metal lattice producing fast neutrons.

5. A deuterided fuel element as claimed in claim 4 where said fast neutrons fission the actinides comprising said nuclear fuel element.

6. A deuterided fuel element as claimed in claim 5 then sealed with an amalgam of compounds to prevent isotopic hydrogen deloading through desorption.

7. The deuterided fuel element of claim 6 further comprising an apparatus for pulsed control that produces acoustic, thermal, radiofrequency or other emanations attached to the deuterided fuel element and periodically enhancing local actinide-deuterium loading resulting in deuteron fluctuations producing primary and secondary deuterium-deuterium fusion reactions and neutrons.

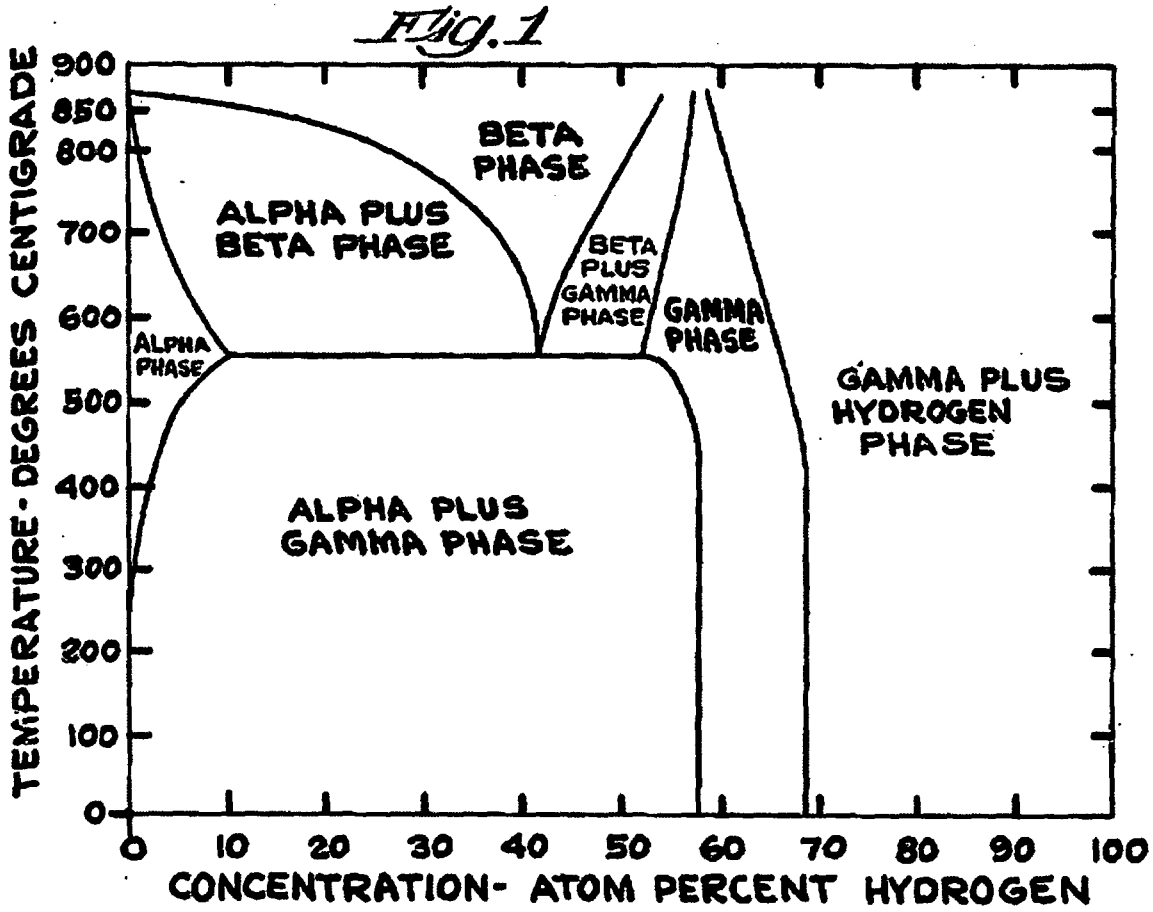
8. A deuterided fuel element as claimed in claim 7 where said neutrons fission the actinides comprising said fuel element.

9. A plurality of said deuterided fuel elements as claimed in claim 8 arranged to irradiate and fission a spent nuclear fuel element, or a plurality of nuclear spent fuel elements, with fast primary and secondary deuterium-deuterium fusion reaction neutrons.

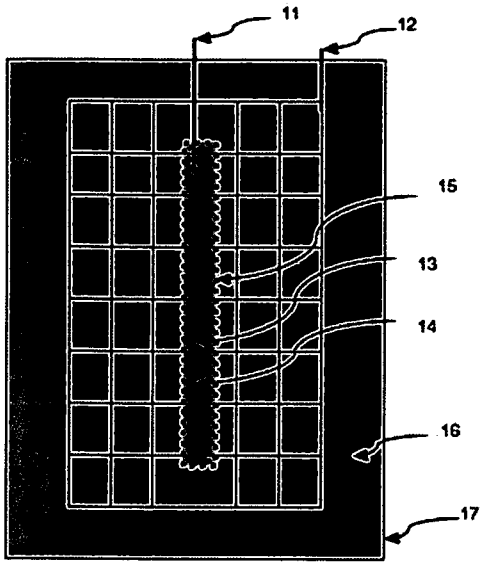
10. A plurality of said spent nuclear fuel elements arranged around said deuterided fuel elements claimed in claim 9 to act as fast neutron reflectors while also fissioning said spent fuel elements.

11. A nuclear spent fuel pool comprised of a plurality of said spent fuel elements and deuterided fuel elements as claimed in claim 10.

12. A method for removing heat generated by the primary and secondary deuterium-deuterium fusion reactions in said deuterided fuel elements and from fast neutron fission of said spent fuel elements.



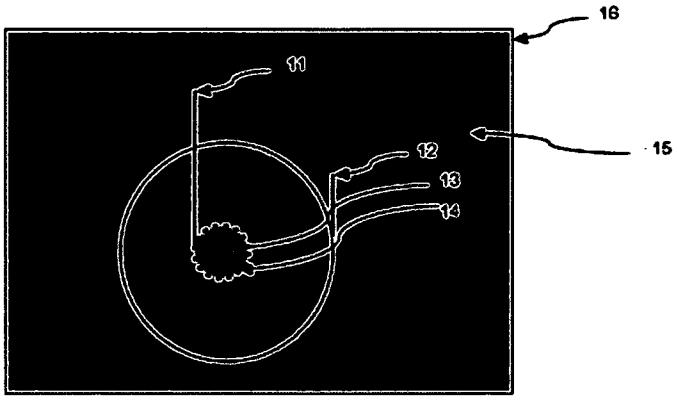
Uranium Hydride Phase Diagram



11 non-hydriding cathode electrical feed wire
12 anode electrical feed wire
13 actinide deuteride (after loading) fuel rod
14 wound non-hydriding cathodic electrical conductor and neutron generator
15 palladium-deuterium nano-alloy
16 co-deposition conductive electrolyte solution
17 container

Loading Fuel Rod
Horizontal View

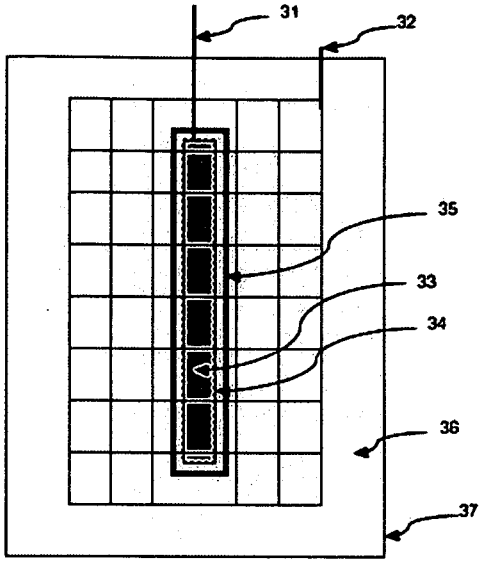
Figure 2



Loading Fuel Rod
Vertical View

11 non-hydriding cathode electrical feed wire
12 anode electrical feed wire
13 actinide deuteride (after loading) fuel rod
14 cathodic electrical conductor and nano-alloy neutron generator
15 electrolyte solution
16 container

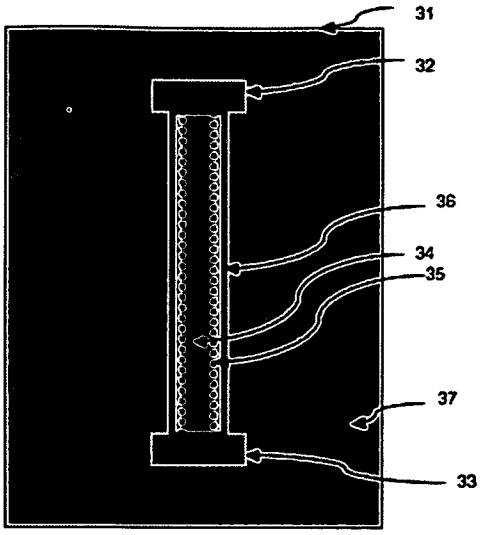
Figure 3



31 non hydriding cathode electrical feed wire
32 anode electrical feed wire
33 actinide deuteride fuel rod (after loading)
34 electrolytically deposited zirconium or palladium nano structure
35 impermeable hydrogen seal
36 conductive electrolyte
37 container

Sealed, Loaded Fuel Rod Horizontal View

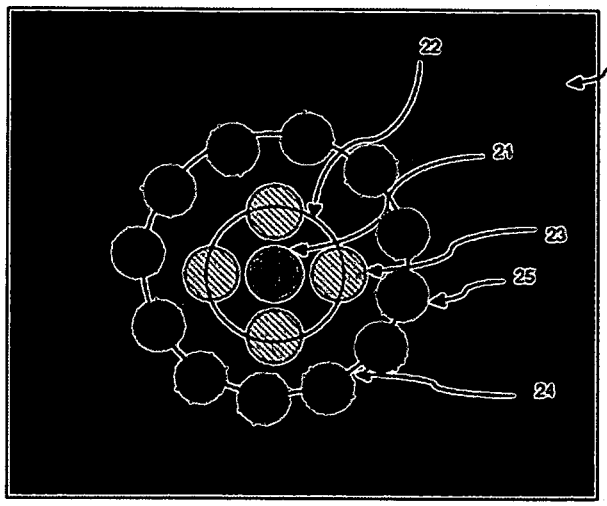
Figure 4



31 container
32 acoustic, RF, or piezo control driver
33 acoustic, RF or piezo control driver
34 actinide deuteride fuel rod
35 co-deposited palladium or zirconium nano-alloy
36 sealant
37 thermally conductive heat bath

Sealed, Loaded Fuel Rod With Control Transducers Horizontal View

Figure 5



20 spent fuel pool
21 fast neutron flux irradiated spent fuel rod
22 inner fast neutron flux zone
23 fusion fast fission rod
24 outer fast neutron flux zone
25 neutron reflector, irradiated spent fuel rod

Remediation Reactor Fuel Rod Assemblies Vertical View

Figure 6

Figure 7

Gamma Ray Background

```
**************************************************************************
*****  I N T E R F E R E N C E  C O R R E C T E D  R E P O R T  *****
**************************************************************************
5,585.8 seconds LIVE TIME COUNTING

                Nuclide       Wt mean          Wt mean
Nuclide          Id           Activity         Activity
Name          Confidence     (uCi/Unit)       Uncertainty

K-40            1.000      5.449243E+000   2.268045E-001 Background
PA-234M         0.879      1.390016E+000   2.066242E-001 U Background

! = nuclide was corrected for parent/daughter
? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at  1.000 sigma
```

Symbol Element

KR Krypton
SR Strontium
CD Cadmium
XE Xenon
CS Cesium
BA Barium
CE Cerium
HG Mercury
BI Bismuth
PB Lead
RN Radon
RA Radium
AC Actinium
PA Proactinium
U Uranium

Figure 8
Gamma Ray Spectra ID of Pd:D:U:D Reactor Operation

****
***** INTERFERENCE CORRECTED REPORT *****
****

8,214.26 seconds LIVE TIME COUNTING

	Nuclide Name	Nuclide Id Confidence	Wt mean Activity (uCi/Unit)	Wt mean Activity Uncertainty	
	K-40	0.992	6.104118E+000	2.131553E-001	Background
	MN-54	0.919	5.078209E-003	9.354862E-004	
?	KR-85	0.967	8.529362E+000	2.315760E-001	Fission
?	SR-85	0.967	3.694596E-002	1.003133E-003	
	SR-92	0.719	4.490020E-003	1.550005E-003	Fission
	CD-109	0.973	7.432117E-003	2.667791E-002	
	XE-125	0.994	4.124608E-002	4.385455E-003	
X	XE-131M	0.933			
	CS-137	0.964	5.855709E-002	2.975822E-003	Fission
X	BA-139	1.000			
	CE-139	1.000	3.098985E-003	8.576497E-004	
	CE-141	0.985	1.104948E-002	1.547654E-003	Fission
	HG-203	0.995	2.637490E-003	7.604617E-004	
	BI-212	0.859	1.901431E-001	9.705893E-003	U daughter
	PB-212	0.744	5.622476E-002	3.268582E-003	U daughter
	BI-214	0.976	4.646924E-001	8.313599E-003	U daughter
	PB-214	0.814	1.259150E-001	3.449960E-003	U daughter
X	RN-219	0.401			
	RA-226	0.937	8.063866E-001	8.286913E-002	U daughter
	AC-228	0.835	1.805738E-001	4.567774E-003	U daughter
	PA-234M	0.978	7.933861E+000	3.145948E-001	U background
X	U-235	0.812			

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

Figure 9

Background Gamma Ray Spectra

Background plot on bottom with upper plot expanding K-40 line showing peak sharpness.

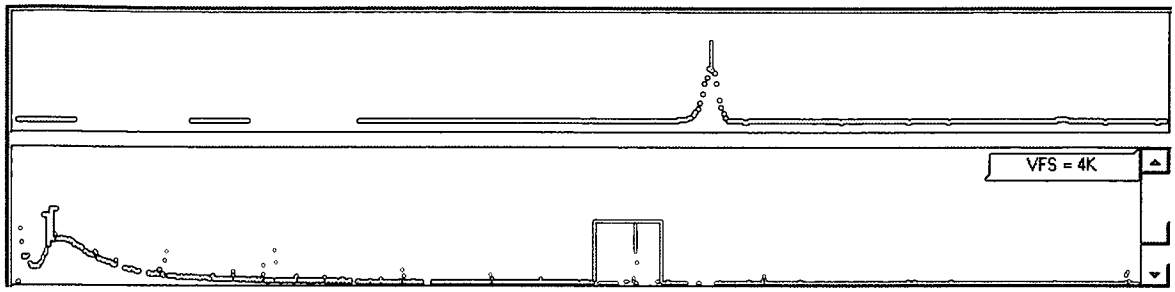
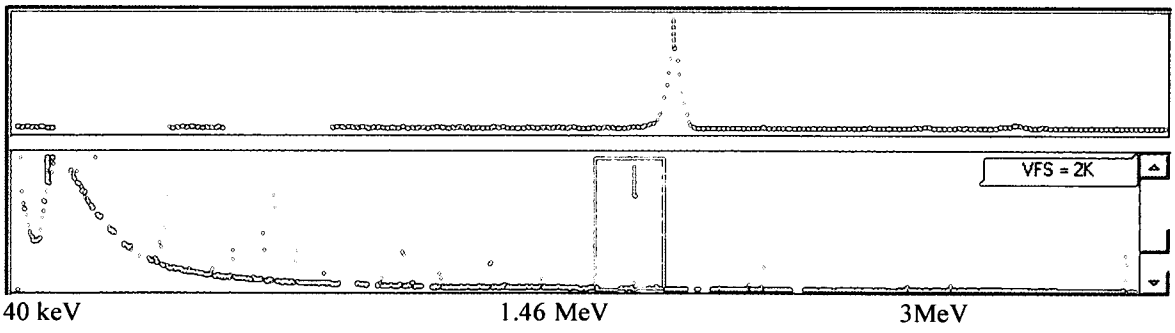


Figure 10

Pd:D:U:D Reactor Gamma Ray Spectra

Running cell plot on bottom, again with upper plot expanding the K-40 line. Note the significantly larger number of lines at the lower energies.



Many of the lines in the lower half of the lower plot are associated with various daughters of uranium decay. However, there are also many fission peaks as noted in the identification.