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(57) Abstract

Propulsion apparatus employs "cold fusion" of deuterium absorbed in a metal host lattice (7) to generate a heated momentum exchange effluent stream from the deuterium itself and/or to heat a momentum exchange fluid to provide a propulsive impulse upon exhausting through a nozzle (9). Thermal efficiency of a propulsion apparatus and an energy generating apparatus employing such "cold fusion" of deuterium in a metal host lattice (7) is improved by using a deuterium (hydrogen)-absorbing metal lattice alloyed or compound with one or more of W, Re, Mo, Tu, Ti, Ir and C to raise the lattice melting point and permit higher "cold fusion" temperatures.

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COLD FUSION PROPULSION APPARATUS AND ENERGY GENERATING APPARATUS

Field Of The Invention

The present invention relates to power generation and propulsion and, in particular, to "cold fusion" power generating devices and propulsion devices.

Background Of The Invention

Specific impulse is the measure of thrust generated per weight (mass) of propellant used. Current chemical propulsion devices (rockets) are approaching their theoretical limits in terms of specific impulse. For example, one of the more successful chemical propulsion systems includes liquid oxygen and hydrogen and exhibits a specific impulse of generally 400 to 500 sec. One of the limitations of such a chemical system is that, for a given amount of energy or heat available for the chemical reaction, the specific impulse is limited, in part, by the molecular weights of the effluent gases.

Another major constraint on chemical propulsion systems is that systems which have a high specific impulse inherently have a low thrust and, likewise, systems with high thrust normally exhibit a low specific impulse. This situation is unfortunate since high thrust is required in the lower stages of a space mission but high specific impulse is beneficial in subsequent higher stages (in space or orbit) of the mission. For example, high thrust is required to lift the system from the earth while, once lifted or in orbit, only low thrust is required and is advantageous from a fuel efficiency standpoint. Unfortunately, provision of high specific impulse in the upper stages of a mission lowers the available thrust in the lower stages of the mission.

What is needed is a propulsion apparatus which does not suffer from these disadvantages. In particular, a propulsion apparatus not solely of the chemical type and thus not limited by the molecular weight of the effluent products would be desirable. Also, a propulsion system which exhibits a higher temperature of effluent products to increase specific impulse would be desirable. Moreover, a propulsion system which exhibits both high thrust and high specific impulse or, alternatively, a variable thrust and specific impulse, would be desirable.

With respect to power generating apparatus, recent work by Stanley Pons, University of Utah, and Martin Fleischmann, the University South Hampton, indicates that a metal host lattice of palladium can absorb deuterium ions in an electrolytic cell where the palladium is rendered cathodic in an aqueous solution of deuterium oxide and LiOH. The confinement of the deuterium boseons within the Fermi sea of metal electrons appears to promote a nuclear transformation/reaction (currently known as "cold fusion") where tritium and helium isotopes are released along with heat and other energetic forms, although the exact physical theory is uncertain at present. To date, the particular type of reaction product/energy emissions from the palladium cathode have varied depending upon the experimental configuration employed.

For some applications, especially for applications in space environments, the thermal efficiency of such a "cold fusion" power generating apparatus is extremely important since any inefficiencies appear as rejected heat which is extraordinarily difficult to discard in space environments. Since the thermal efficiency of a power generating apparatus is governed by the temperature differentials due to thermodynamic constraints, it would be desirable to provide a "cold fusion" power generating apparatus with a relatively high operating temperature and thus a high thermal efficiency for particular use in space environments. Moreover, it would be desirable to supply deuterium to the metal host lattice in a more practical manner not limited by the boiling point of "heavy" water (e.g., 101°C) used heretofore by Pons and Fleischmann in practicing the "cold fusion" process.

It is an object of the present invention to satisfy these needs and desires.

SUMMARY Of The Invention

The invention contemplates a propulsion apparatus employing "cold fusion" of deuterium absorbed in a metal host lattice to generate a heated momentum exchange effluent stream directly from the deuterium itself and/or to heat a momentum exchange fluid flowing relative to the metal host lattice to provide a propulsive impulse when exhausted.

In one embodiment of the invention, a propulsion apparatus employs "cold fusion" of deuterium absorbed in a metal host lattice to generate a momentum exchange effluent stream therefrom comprising any heated unconsumed (unfused) deuterium and products resulting from nuclear transformation of the absorbed deuterium and means for exhausting the effluent stream to provide a propulsive impulse.

In another embodiment of the invention, a propulsion apparatus employs "cold fusion" of deuterium absorbed in a metal host lattice to generate heat in the metal lattice for heating a momentum exchange fluid (e.g., a gas, liquid, plasma, etc.) flowing through one or more passages in the metal lattice and means for exhausting the heated fluid to provide a propulsive impulse. The momentum exchange fluid preferably has a molecular weight below 50; e.g., hydrogen, oxygen, air, water, helium, ammonia or carbon dioxide and mixtures thereof.

In another embodiment of the invention, first and second reactive fluids (e.g., preferably hydrogen and oxygen) are supplied to respective first and second passage means through one or more metal host lattices capable of absorbing deuterium for the generation of heat in the metal lattice by nuclear transformation of the deuterium therein. The first and second fluids are heated as they pass through the respective first and second passage means. Means is provided for mixing the heated first and second fluids such that they react exothermally. The reaction products are then exhausted through suitable means, e.g., through a nozzle, to provide a propulsive impulse.

In the aforesaid embodiments of the inventive propulsion apparatus, means is preferably provided between the metal host lattice and the source of deuterium and/or the source of momentum exchange fluid for regulating the quantity (or flow) of deuterium and/or momentum exchange fluid for the purpose of varying the thrust and specific impulse of the propulsion apparatus.

The invention also envisions improving the thermal efficiency of a propulsion apparatus and an energy producing apparatus employing "cold fusion" of deuterium absorbed in a metal host lattice by virtue of supplying the deuterium as deuterium gas or plasma to a deuterium (hydrogen)-absorbing metal lattice alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C to raise the melting point of the metal lattice to permit higher "cold fusion" temperatures in the metal lattice.

In the aforesaid bodiments of the invention, the metal host lattice can be rendered cathodic relative to a source of deuterium gas or plasma or a deuterium-bearing fused salt electrolyte. The electrical potential applied to the metal host lattice may be varied to control and throttle the "cold fusion" of deuterium in the metal host lattice.

Brief Description Of The Drawings

Figures 1-5 are schematic illustrations of various embodiments of the invention.

Detailed Description Of The Invention

Fig. 1 illustrates one embodiment of the invention using deuterium directly as a momentum exchange effluent stream or medium. In particular, a liquefied deuterium storage vessel 1 is connected to a deuterium gas reservoir 3 through a control valve 2 to supply deuterium to the reservoir 3. Pressurized deuterium gas (e.g., at 1000 psi) is released from the reservoir 3 through a regulating valve 6 for supply to the upstream side 7a of a deuterium (hydrogen)-absorbing metal host lattice 7 described hereinbelow for absorption into the metal lattice 7. An optional electrical connection can be made from either the reservoir 3 or a grid 4 within the reservoir 3 to a positive terminal V+ of a DC voltage supply 5 while the negative terminal V- of the D.C. voltage supply 5 is connected to the metal host lattice 7. However, with the proper selection of deuterium gas temperatures, flow rates, pressures and the metal of metal host lattice 7, deuterium absorption into the metal lattice 7 is achievable without use of the DC voltage supply 5 (i.e., it may be eliminated) so as to avoid space charge repulsion in the deuterium effluent stream in the exhaust nozzle 9.

As mentioned, pressurized deuterium gas (e.g., at 1000 psi) is released from the reservoir 3 through the regulating valve 6 for supply to the upstream side 7a of the metal host lattice 7 for absorption therein. Other isotopes of hydrogen can be used in conjunction with the deuterium. The deuterium gas may be supplied by a pulsing technique wherein the valve 6 is opened until a deuterium gas pressure build-up is detected (as a result of gas heat-up by cold fusion in the metal host lattice) and then shut off until the pressure drops to selected level whereupon the valve is again opened. A nuclear transformation/reaction of the absorbed deuterium occurs in the metal host lattice 7 in accordance with the aforementioned "cold fusion" process to generate energy (and heat) in the metal host lattice 7. Any heated unconsumed deuterium and products of the nuclear transformation/reaction of deuterium (e.g., tritium and helium isotopes) are allowed to exhaust (i.e., to escape and expand) from the downstream side 7b of the metal host lattice 7 as a momentum exchange effluent stream or medium and are conducted through the exhaust nozzle 9 (which is designed to match the Mach considerations as known in the art) to provide a propulsive impulse or force. The nozzle 9 can be used to vector the effluent stream.

Use of any unconsumed deuterium and the nuclear transformation products of deuterium directly as the effluent stream in the above-described propulsive apparatus of the invention provides a simple and yet effective means for providing a propulsive impulse. The metal host lattice 7 is made so that diffusion of the absorbed deuterium through the entire thickness thereof can be achieved within a reasonable time frame. For example, the time must be long enough for confinement-induced fusion ("cold fusion") to be initiated and maintained in the metal host lattice 7 yet short enough for any unconsumed (unfused) absorbed deuterium and the aforementioned nuclear transformation products to escape or expel from the downstream side 7b of the lattice 7 as an effluent stream.

Use of deuterium gas (or plasma as will be described herebelow) avoids a severe temperature limitation placed on the "cold fusion" process when an aqueous solution of deuterium oxide and LiOH is used; i.e., the temperature of the process is not limited by the boiling point of heavy water (101°C) at ambient pressure. As a result, the invention envisions using the "cold fusion" process in the propulsive apparatus described hereinabove at much higher temperatures, such as preferably between about 1000°C and about 3000°C. An embodiment of the invention where the metal host lattice 7 achieves a temperature of 1000°C is expected to provide a specific impulse of near 800 sec, which constitutes a gain of 2 or more over the specific impulse achievable with conventional chemical systems.

In the embodiment of the invention described hereinabove as well as hereinbelow, the metal host lattice 7 may comprise a Pd sheet approximately 2mm to 6mm in thickness. The Pd sheet can be formed to present a large surface area on upstream side 7a to the deuterium gas released from the reservoir 3 and on the downstream side 7b to the exhaust nozzle 9 to increase through-put and thus the thrust level of the propulsion apparatus. Other configurations of the metal host lattice 7 can be used in practicing the invention.

In lieu of palladium as the metal host lattice 7, other deuterium (hydrogen)-absorbing metals can be used, such as, for example, Ti, Ni and Mg and alloys thereof one with another (e.g., Ni with 10 w/o Mg). Preferably, however, in accordance with another aspect of the invention, the metal host lattice 7 comprises a deuterium (hydrogen)-absorbing metal, preferably one or more of the metals Ti, Pd, Ni and Mg, alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C to provide a metal host lattice having a melting temperature of about 1800°C and above. When carbon is used to raise the melting temperature, the metal host lattice 7 may comprise a carbide of one or more of the aforementioned metals. When the metal host lattice 7 is made of these higher melting point alloys/compounds, correspondingly higher "cold fusion" temperatures can be achieved (e.g., about 1000°C to about 3000°C) and will result in enhanced thermal efficiency and the possibility of even greater specific impulses.

In lieu of using deuterium gas as a source for absorption into the metal host lattice 7, the invention contemplates using a deuterium plasma or deuterium-bearing fused salt electrolyte to provide a supply of deuterium to the metal host lattice 7. For example, in Fig. 2, a conventional plasma generator 30 is shown downstream of the deuterium gas reservoir 3 and the valve 6 to establish a deuterium plasma for contacting the upstream side 7a of the metal lattice 7 to introduce absorbed deuterium into the metal lattice 7. In Fig. 3, a fused salt electrolyte (e.g., LiH/LiD) 31 is shown as a source of deuterium adjacent the upstream side 7a of the metal lattice 7 for the same purpose. In these figures, like features of Fig. 1 are represented by like reference numerals.

Although the D.C. power supply 5 is optional in the aforementioned embodiments of the invention , it may be possible to employ the power supply 5 as a means of controlling/throttling the "cold fusion" reaction in the metal lattice 7; e.g., by varying the electrical potential applied on the metal lattice 7 to control the quantity of electrons/absorbed deuterium in the metal lattice.

A preferred propulsion apparatus for space applications is shown in Fig. 4 and exhibits both high thrust and high specific impulse or, alternatively, a variable thrust and variable specific impulse. In Fig. 4, like features of Fig. 1 are represented by like reference numerals primed.

In this embodiment of the invention, a low molecular working fluid is disposed in a storage vessel 11' and functions as a momentum exchange fluid (working fluid). The storage vessel 11' is connected through a valve 12′ to a passage 14′ so as to flow the working fluid through the passage 14′. As shown, the passage 14′ is formed within a suitable high temperature tubular member 13′, such as, for example, a W or Al_2O_3 tube, disposed in the metal host lattice 7′. The material of the tubular member 13′ is selected to have a reasonably high thermal conductivity and a low permeability to deuterium absorbed in the metal lattice 7′ to substantially prevent absorbed deuterium from mixing with the momentum exchange fluid passing through the passage 14′. The tubular member 13′ is in direct thermal contact with the metal host lattice 7′ so as to transfer heat to the momentum exchange fluid as it passes through the passage 14′. The tubular member 13′ and the passage 14′ may be of any suitable shape. The heated momentum exchange fluid is allowed to expand and exhaust through nozzle 9′ to provide a propulsive impulse.

Deuterium gas under pressure (e.g., 1000 psi) is supplied to the metal host lattice 7′ from storage vessel 1′ through a valve 2′ as described hereinabove for the embodiment of Fig. 1. Similarly, the metal lattice 7′ can be biased cathodically (negatively relative to the deuterium gas source) by

D.C. power supply 5′ as described hereinabove for the embodiment of Fig. 1. Heat is generated in the metal host lattice 7′ by "cold fusion" of the deuterium absorbed therein.

In the embodiment of Fig. 4, the metal lattice 7′ (i.e., the "cold fusion" energy generating means) is isolated from the momentum exchange fluid by the tubular member 13′. The tubular member 13′ (or other means for forming one or more passages) is so provided as to form one or more passages through the metal lattice 7′ for passage of the momentum exchange fluid and yet provide an interface through which the absorbed deuterium cannot pass into the momentum exchange fluid. In this way, the momentum exchange fluid can absorb thermal energy from the metal lattice 7′ without disrupting the "cold fusion" reaction/transformation in the metal lattice 7′. At the same time, the momentum exchange fluid can be throttled by valve 12′ to vary both the thrust and specific impulse of the propulsion apparatus.

Since the available thermal energy is limited by the available fusion energy, the temperature reached by the momentum exchange fluid will be limited by the flow rate of the momentum exchange fluid through the passage 14′. At higher flow rates, higher thrust will be achieved at the expense of lower specific impulse (i.e., lower average energy available to the exhausted fluid). At lower flow rates, higher specific impulse will be achieved with a corresponding decrease in thrust. Momentum exchange fluids having a low molecular weight, preferably below 50, are preferred. Preferred low molecular weight momentum exchange fluids for use in the embodiment of Fig. 4 include H_2, O_2, air, H_2O, He, NH_3, and CO_2 and mixtures thereof. The first six of these (i.e., H_2, O_2, air, H_2O, He, NH_3,) have desirable trade-offs between low molecular weight and storage properties. The latter of these (i.e., CO_2) has desirable storage properties (e.g., storable as dry ice) and is easily obtained both on earth and on Mars, thus leading to interplanetary uses by spacecraft.

Fig. 5 illustrates still another embodiment of the invention for providing a high thrust fusion/chemical propulsion apparatus. This embodiment includes first and second storage vessels 50,52 for first and second chemically reactive momentum exchange fluids (working fluids); e.g., preferably H_2 in vessel 50 and O_2 in vessel 52. The momentum exchange fluids are flowed through respective flow control valves 54,56 and through respective passages 60,62 formed by tubular members 70,72 in thermal contact with respective first and second metal host lattices 80,82; e.g., in the same fashion as described hereinabove for Fig. 4. Pressurized deuterium gas (e.g., 1000 psi) is supplied to each metal lattice 80,82 from a common storage vessel 90 via respective valves 100,102 such that each metal lattice 80,82 absorbs deuterium and generates thermal energy via the "cold fusion" process described for the embodiments of Fig. 1-4. The first and second reactive momentum exchange fluids are heated as they flow through the passages 60,62 and the fluids at elevated temperature are then conducted to a mixing chamber 110 where they can chemically react in exothermic fashion upon mixing. The reaction products are allowed to expand and escape from the mixing chamber 110 through the exhaust nozzle 112 to provide a propulsive impulse.

In this way, the temperature of the reaction products (exhausted through nozzle 112) can be increased to a level which is not achievable by either fusion or chemical reactions alone. In particular, the fusion energy supplied to momentum exchange fluids flowing through passages 60,62 is additive to the energy available from the exothermic chemical reaction to raise the temperature of the reaction products exhausted through the nozzle 112. To this end, the first and second momentum exchange fluids (in vessels 50,52) should be chosen so that the reaction products in the mixing chamber 110 do not disassociate or are not at lower energy levels. Although H_2 and O_2 are described hereinabove as the momentum exchange fluids, other momentum exchange fluids, which are stable at elevated temperatures and result in stable reaction products, may be used.

Moreover, the energy available from the fusion process can allow access to chemical reactions that would normally be unavailable. For example by elevating the energy states of either or both working fluids, the reaction times can be reduced to the benefit of the nozzle design. Also solid materials, such as Li, can be liquefied or vaporized to react with the second fluid, for example oxygen. In this latter case, solid Li greatly reduces the storage volume and the weight of the associated storage vessel.

While certain preferred embodiments of the invention have been described hereinabove, those skilled in the art will recognize that various modifications and changes can be made therein for practicing the invention as described in the following claims.

I Claim

1. A propulsion apparatus for rocket, spacecraft and terrestrial use, comprising

(a) means for providing deuterium to a metal host lattice capable of absorbing said deuterium for the generation of heat within the metal lattice by nuclear transformation of the deuterium therein, and

(b) means for exhausting as an effluent stream from the metal lattice any heated unconsumed deuterium and products of the nuclear transformation to provide a propulsive impulse.

2. The apparatus of claim 1 wherein said means for providing deuterium to the metal host lattice comprises means for delivering deuterium gas or plasma to the metal host lattice.

3. The apparatus of claim 2 wherein the metal host lattice is rendered cathodic relative to a source of the deuterium gas or plasma.

4. The apparatus of claim 1 wherein said means for providing deuterium to the metal host lattice comprises a fused salt electrolyte.

5. The apparatus of claim 1 wherein the metal host lattice comprises one or more of the metals Ti, Pd, Ni and Mg.

6. The apparatus of claim 1 wherein the metal host lattice comprises a deuterium-absorbing metal alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C to increase the melting point of said metal host lattice, thus allowing a higher temperature to be generated in said metal host lattice.

7. The apparatus of claim 1 further including means for regulating the quantity of deuterium provided to the metal host lattice for varying the thrust and specific impulse of the propulsion apparatus.

8. The apparatus of claim 1 wherein said means for exhausting includes a nozzle means through which any heated unconsumed deuterium and the reaction products exit to provide the propulsive impulse.

9. The apparatus of claim 2 further including a holding tank for holding pressurized deuterium gas for delivery to the metal host lattice as controlled by valve means between said holding tank and said metal host lattice.

10. A propulsion apparatus for rocket, spacecraft and terrestrial use, comprising:

(a) means for providing deuterium to a metal host lattice capable of absorbing said deuterium for generation of heat within the metal lattice, the metal lattice having passage means,

(b) means for supplying a momentum exchange fluid to the passage means to heat said momentum exchange fluid; and

(c) means for exhausting the heated momentum exchange fluid from the passage means to provide a propulsive impulse.

11. The apparatus of claim 10 wherein said passage means is formed by a deuterium-impermeable hollow member disposed in said metal host lattice for transferring heat from the metal host lattice to the momentum exchange fluid.

12. The apparatus of claim 10 wherein the momentum exchange fluid has a molecular weight less than 50.

13. The apparatus of claim 12 wherein the momentum exchange fluid comprises one or more of hydrogen, oxygen, air, water, helium, ammonia and carbon dioxide.

14. The apparatus of claim 10 wherein said means for providing deuterium to the metal host lattice comprises means for delivering deuterium gas or plasma to the metal host lattice.

15. The apparatus of claim 10 further including means for regulating the flow of the momentum exchange fluid to the passage means to vary the thrust and specific impulse of the propulsion apparatus.

16. The apparatus of claim 10 wherein the metal host lattice comprises one or more of the metals Ti, Pd, Ni and Mg.

17. The apparatus of claim 10 wherein the metal host lattice comprises a deuterium-absorbing metal alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C to increase the melting point of said metal host lattice, thus allowing a higher temperature to be generated in said metal host lattice.

18. The apparatus of claim 10 wherein said means for exhausting includes a nozzle means through which any heated unconsumed deuterium and nuclear reaction products thereof pass to provide the propulsive impulse.

19. The apparatus of claim 10 further including a holding tank for holding pressurized deuterium gas for delivery to the metal host lattice as controlled by valve means between said holding tank and said metal host lattice.

20. A propulsion apparatus, comprising:

(a) metal lattice means capable of absorbing deuterium for the generation of heat therein and having a first passage means and a second passage means,

(b) means for providing deuterium to said metal lattice means,

(c) means for supplying a first reactive fluid and second reactive fluid to the respective first passage means and the second passage means to heat the first fluid and the second fluid, the first fluid and the second fluid being reactive in exothermic manner at elevated temperature,

(d) means for mixing the first fluid and the second fluid after they are heated so as to exothermically react the first fluid and the second fluid, and

(e) means for exhausting the reaction products of the reacted first fluid and the second fluid to provide a propulsive impulse.

21. The apparatus of claim 20 wherein said metal lattice means comprises a first metal lattice and a second, separate metal lattice and wherein said first passage means is in said first metal lattice and said second passage is in said second metal lattice.

22. The apparatus of claim 20 wherein the first fluid is hydrogen and the second fluid is oxygen.

23. The apparatus of claim 20 wherein said mixing means comprises a mixing chamber connected to said first passage means and said second passage means for receiving the first fluid and second fluid after heating.

24. A thermal energy generating apparatus, comprising:

(a) a metal host lattice comprising a deuterium-absorbing metal alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C, and

(b) means for providing deuterium to the metal host lattice for absorption into the metal host lattice and generation of heat therein by nuclear transformation of the deuterium therein.

25. The apparatus of claim 24 wherein said means for providing deuterium comprises means for delivering deuterium gas or plasma to the metal host lattice.

26. The apparatus of claim 24 wherein said means for providing deuterium comprises a deuterium-bearing fused salt electrolyte.

27. A method of generating a propulsive impulse, comprising the steps of:

(a) supplying deuterium to a metal host lattice for absorption therein and generation of heat within the metal host lattice by nuclear transformation of said deuterium, and

(b) exhausting as an effluent stream from the metal lattice any heated unconsumed deuterium and products of the nuclear transformation so as to provide a propulsive impulse.

28. A method of generating a propulsive impulse, comprising the steps of:

(a) supplying deuterium to a metal host lattice for absorption therein and generation of heat within the metal host lattice, and

(b) passing a momentum exchange fluid through one or more passages in the metal host lattice to heat the momentum exchange fluid, and

(c) exhausting the heated momentum exchange fluid from the passage as to generate a propulsive impulse.

29. A method of generating a propulsive impulse, comprising the steps of:

(a) supplying deuterium to a metal host lattice means for absorption therein and generation of heat within the metal host lattice, and

(b) flowing a first reactive fluid and a second reactive fluid through respective first and second passages in the metal host lattice means to heat the first reactive fluid and the second reactive fluid,

(c) exothermically reacting the heated first reactive fluid and the heated second reactive fluid, and

(d) exhausting the reaction products of the reacted first reactive fluid and the second reactive fluid to generate a propulsive impulse.

30. A method of generating energy comprising, supplying deuterium as a gas or plasma to a metal host lattice comprising a deuterium-absorbing metal alloyed or compounded with one or more of W, Re, Mo, Ta, Ti, Ir and C and transforming the deuterium in the metal host lattice to generate heat.

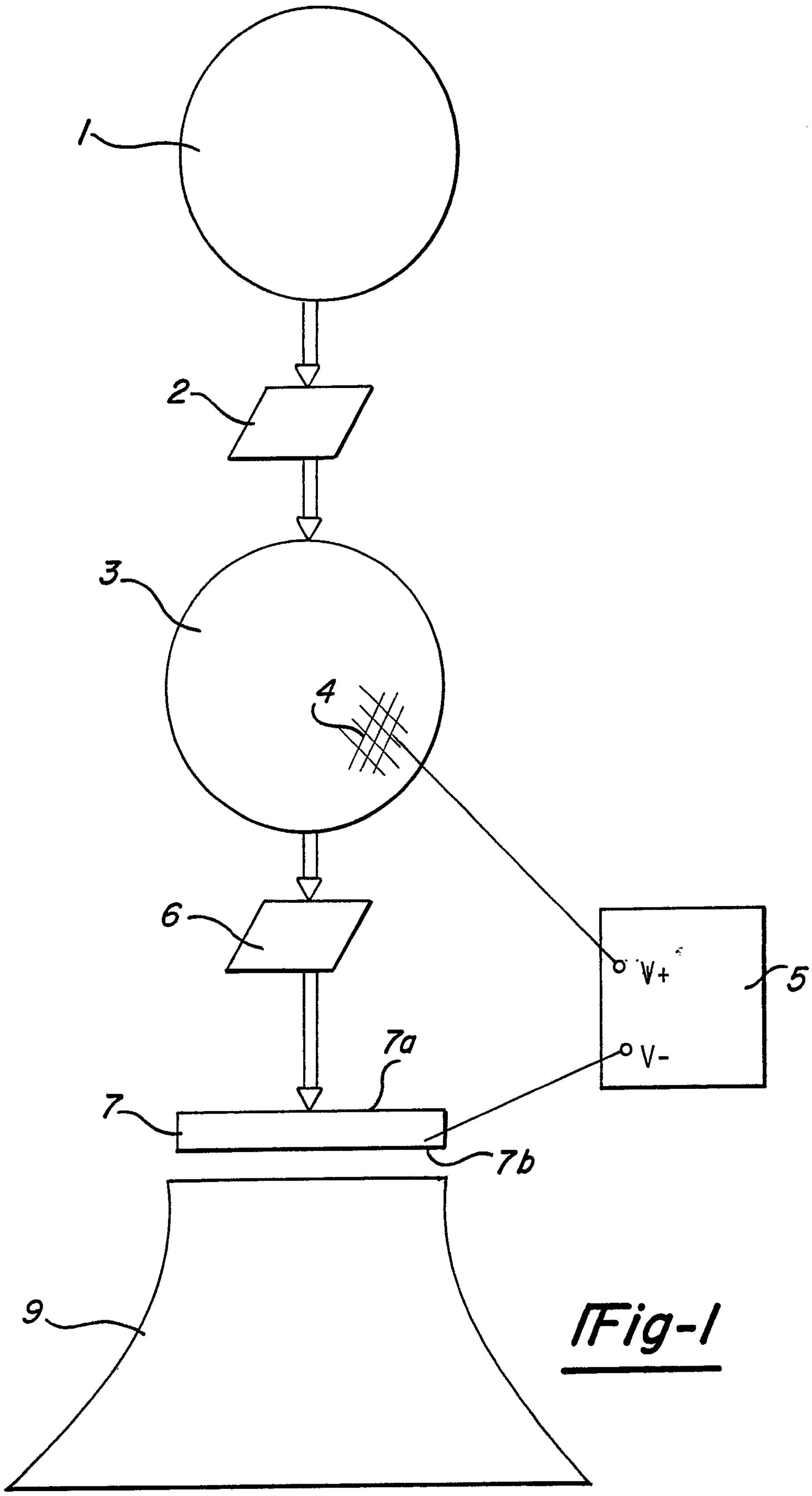

Fig-1

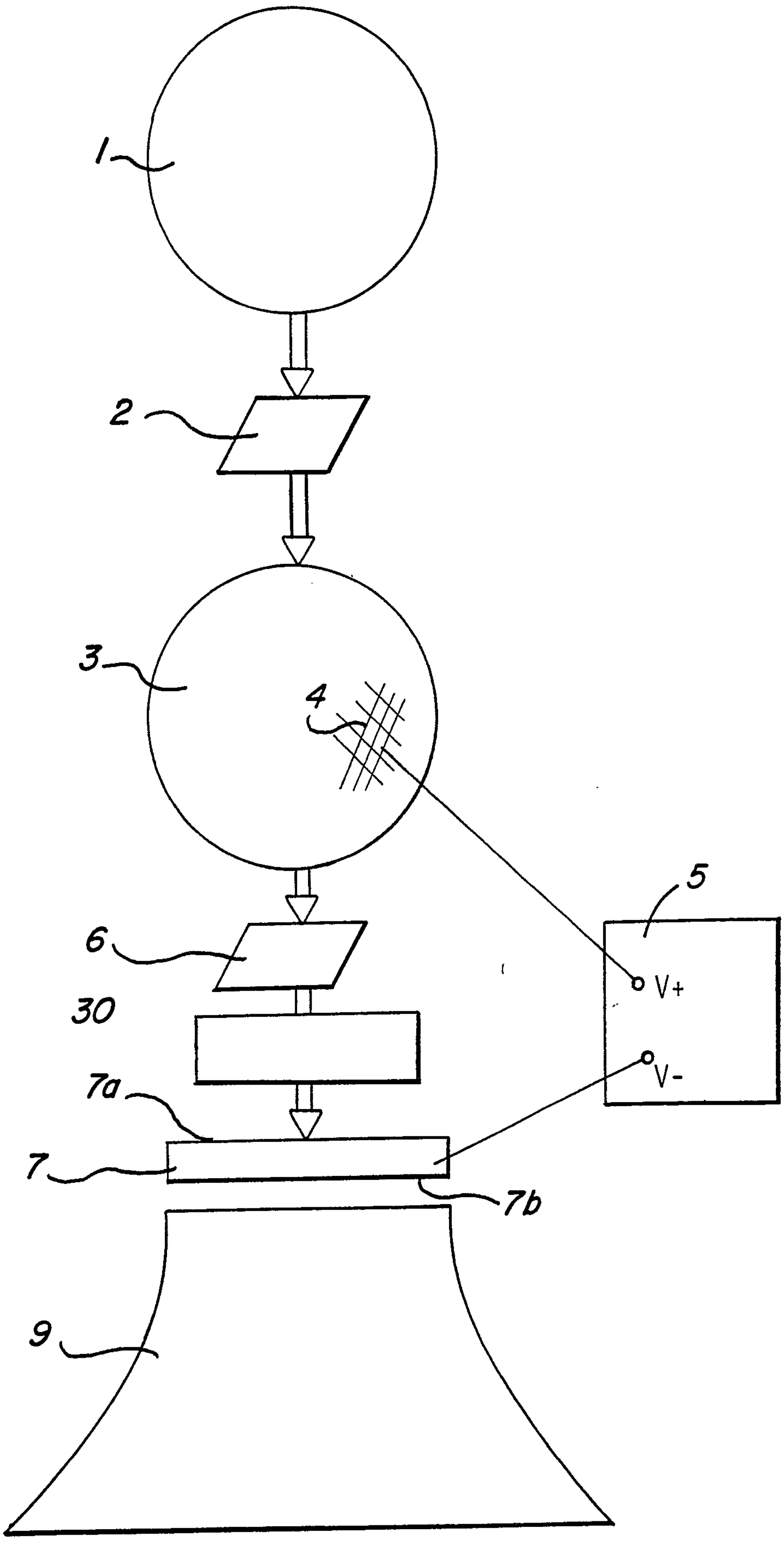

FIG-2

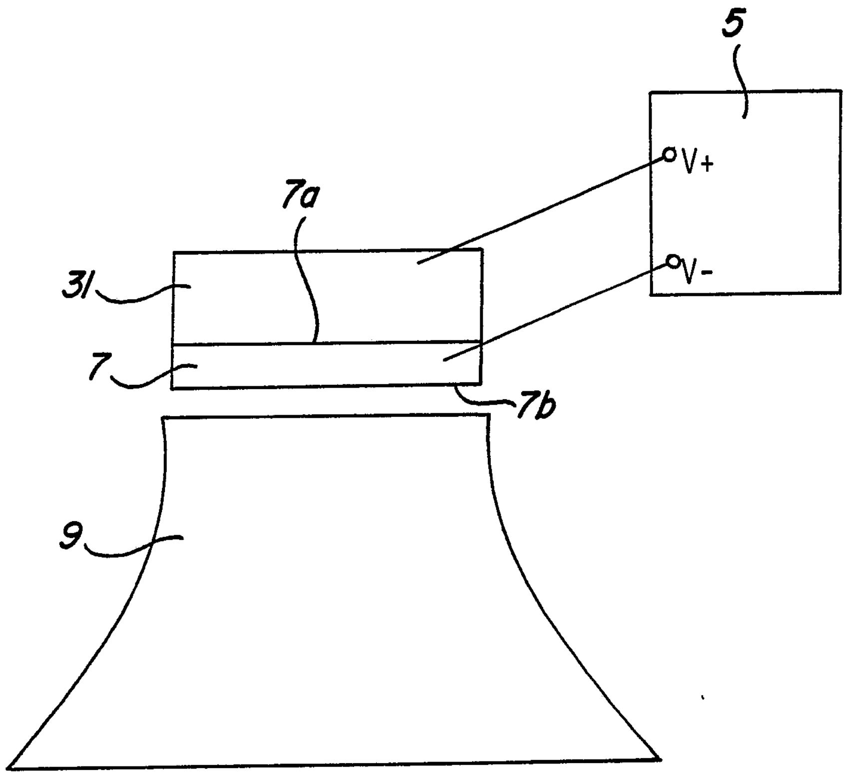

Fig-3

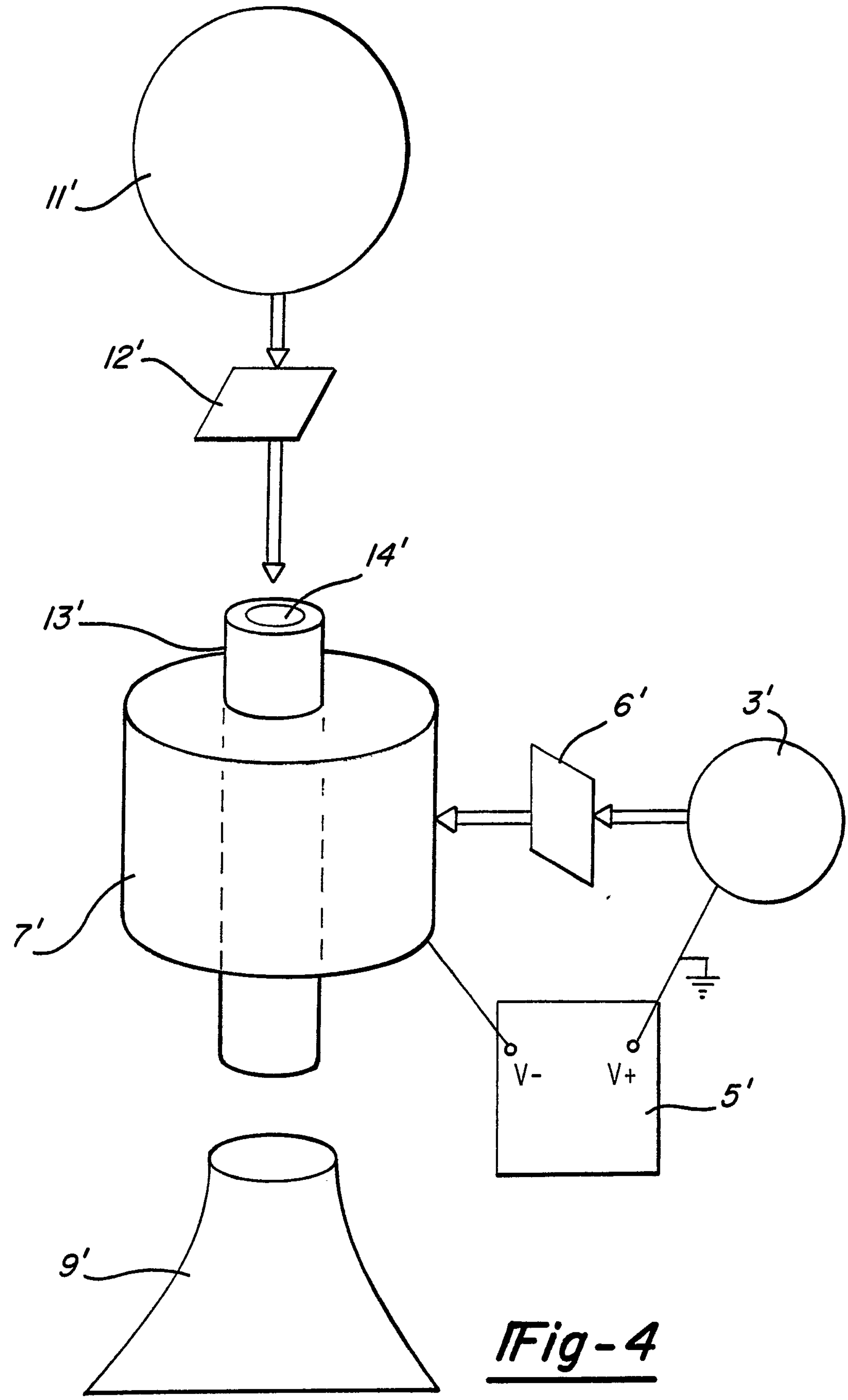

Fig-4

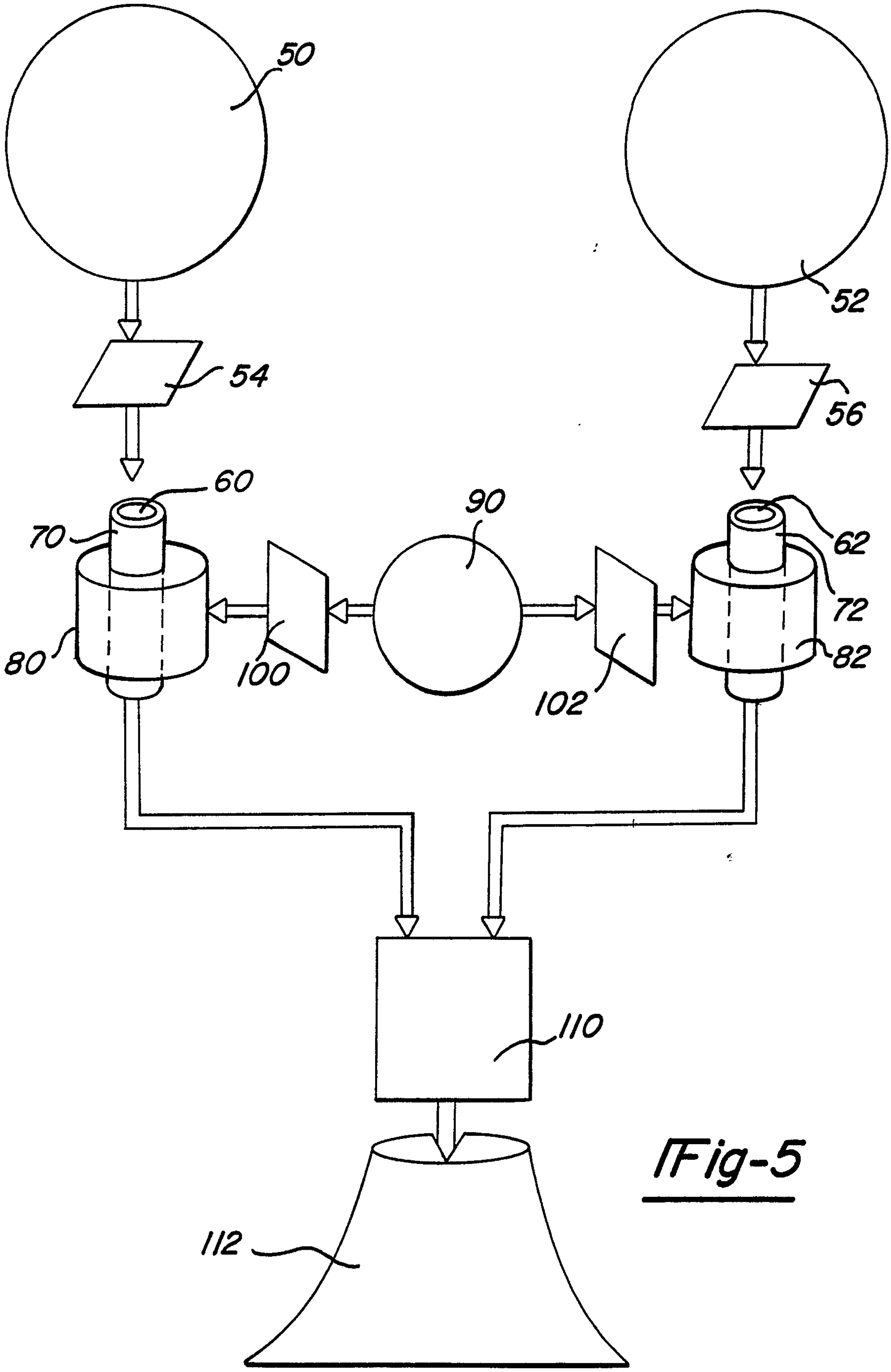

Fig-5