(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 370 587 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **21.07.93** (51) Int. Cl.5: **F01K 25/00**

(21) Application number: **89203332.5**

(22) Date of filing: **19.03.87**

(60) Publication number of the earlier application in accordance with Art.76 EPC: **0 275 619**

(54) **Apparatus for generating electric energy using hydrogen storage alloy.**

(30) Priority: **23.12.86 JP 315614/86**

(43) Date of publication of application:
30.05.90 Bulletin 90/22

(45) Publication of the grant of the patent:
21.07.93 Bulletin 93/29

(84) Designated Contracting States:
DE NL SE

(56) References cited:
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US-A- 4 358 931

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Description

This invention relates to apparatus for generating electric energy using a hydrogen storage alloy.

Heretofore, generation of electric power by means of a gas turbine using a source of heat of middle-low temperature levels has been effected by evaporating a pressurized, condensible heat transfer medium such as water, freon gas or natural gases, introducing the resulting vapor into the gas turbine for driving same, condensing the vapor discharged from the gas turbine, and reheating the condensed liquid heat transfer medium for vaporization and for recirculation into the gas turbine. The conventional method, however, requires the use of a heat transfer medium whose boiling point is considerably lower than the temperature of a heat source because the boiling point is constant under constant pressure. Further, in order to condense the vapor of the heat transfer medium discharged from the gas turbine with high efficiency, the temperature at which the heat transfer medium is condensed is required to be considerably higher than the temperature of a cooling source. For the above reasons, it is necessary that the difference in temperature between the heating and cooling sources is considerably large. Thus, it is actually difficult to drive a gas turbine in the above-described manner with practically acceptable efficiency and cost when using a heat source of middle-low levels (50 to 150 °C) and a cooling source of about 10 to 30 °C.

It is the prime object of the present invention to provide an apparatus suitable for the effective generation of electric energy using a heat source of a middle-low temperature.

US-A-3943719 discloses a power system which utilizes a hydrogen storage alloy which is capable of absorbing hydrogen upon being cooled and of releasing the absorbed hydrogen upon being heated. The hydrogen storage alloy is contained within a plurality of heat exchangers which are connected by valve-controlled conduits for admitting either heating medium or cooling medium, depending on the phase in the cycle of each particular heat exchanger. The hydrogen which is generated during each dehydrating phase in a heat exchanger is passed by a valve-controlled conduit to a gas turbine, which may be used to generate electricity, while the hydrogen leaving the turbine is returned to another of the heat exchangers in the series so as to be reabsorbed by spent alloy in that heat exchanger in readiness for a subsequent dehydriding phase. By appropriate synchronized supply of either heating medium or cooling medium to the heat exchangers in turn, a continuous supply of hydrogen for the turbine can be generated.

The present invention provides improvements in power systems utilizing hydrogen storage alloys.

In accordance with the present invention there is provided an apparatus for generating an electric energy, comprising:

a gas turbine having gas inlet and gas outlet ports and capable of being driven by hydrogen gas flowing from said inlet to outlet ports;

an electric generator operatively connected to said gas turbine and capable of operating, when said gas turbine is driven, to generate an electric energy;

first through sixth heat exchange zones each containing a hydrogen storage alloy capable of absorbing hydrogen upon being cooled and of releasing the absorbed hydrogen upon being heated, and each being adapted to heat or cool the hydrogen storage alloy contained therein by indirect heat exchange with a heating or cooling medium supplied thereto;

connecting conduit means connecting said first through sixth heat exchange zones in loop so that the heating or cooling medium can recirculate successively through said first to sixth heat exchange zones in that order;

a source of the heating medium;

a source of the cooling medium;

first through sixth heating medium feed conduits, extending between said first through sixth heat exchange zones and said source of the heating medium, respectively, for introducing therethrough the heating medium to respective heat exchange zones;

first through sixth cooling medium feed conduits, extending between said first through sixth heat exchange zones and said source of the cooling medium, respectively, for introducing therethrough the cooling medium to respective heat exchange zones;

first valve means provided in said heating medium and cooling medium feed conduits and operable so that the heating medium from said source thereof is fed to selected one of said first through sixth heat exchange zones and the cooling medium from said source thereof is fed to the next but two heat exchange zone located downstream of said selected heat exchange zone;

second valve means provided in said connecting conduit means and operable so that the heating medium introduced into said selected heat exchange zone is passed successively to two succeeding heat exchange zones located downstream from said selected heat exchange zone and the cooling medium introduced into said next but two heat exchange zone is passed successively to two succeeding heat

exchange zones located downstream from said next but two heat exchange zone;

first through sixth hydrogen feed pipes, extending between said first through sixth heat exchange zones and said gas inlet, respectively, for introducing the released hydrogen from respective heat exchange zones into said gas turbine;

first through sixth hydrogen discharge pipes, extending between said first through sixth heat exchange zones and said gas outlet, respectively, for feeding the hydrogen from said gas turbine to respective heat exchange zones;

third valve means provided in said first through sixth hydrogen feed pipes and operable so that the passage of hydrogen through said first through sixth hydrogen feed pipes is prevented except through those feed pipes leading from said selected heat exchange zone and its adjacent downstream heat exchange zone; and

fourth valve means provided in said first through sixth hydrogen discharge pipes and operable so that the passage of hydrogen through said first through sixth hydrogen discharge pipes is prevented except through those feed pipes leading to said next but two heat exchange zone and its adjacent downstream heat exchange zone.

The present invention will now be described in detail below with reference to the accompanying drawings, in which:

Fig. 1 is a flow chart of an apparatus illustrating the principles of generating electricity using hydrogen storage alloys; and

Fig. 2 is a flow chart of a preferred embodiment of the apparatus according to the present invention.

Referring first to Fig. 1, the reference numeral 1 denotes a first heat exchange zone, generally a heat exchanger, accomodating a bed of a hydrogen storage alloy MH which has absorbed hydrogen, 2 denotes a second heat exchange zone, similar to the first heat exchange zone, accomodating a bed of a hydrogen storage alloy M which is generally the same as the alloy in the first heat exchange zone 1 and which has released hydrogen. The first and second heat exchangers 1 and 2 are generally composed of first and second closed containers 24 and 25, respectively, in which first and second heat transfer members, such as heat transfer pipes 5 and 6, respectively, are disposed for heating or cooling the hydrogen storage alloy contained in the first and second containers 24 and 25 by indirect heat exchange with heat transfer media flowing therethrough. The heat transfer media are introduced in the first and second heat transfer pipes 5 and 6 through feed conduits 18 and 19, respectively.

Designated as 3 is a gas turbine to which an electric generator 4 is connected through a transmission shaft 16 so that the generator 4 operates and generates electric energy or power upon driving of the gas turbine 3. The gas turbine 3 has a hydrogen inlet conduit 14 which is connected, via three-way valve 12, both to the first heat exchanger 1 through pipes 8 and 7 and to the second heat exchanger 2 through pipes 10 and 17. The gas turbine 3 also has a hydrogen outlet conduit 15 which is connected, via three-way valve 13, both to the first heat exchanger 1 through pipes 9 and 7 and to the second heat exchanger 2 through pipes 11 and 17.

The apparatus thus constructed operates as follows. The hydrogen storage alloy MH in the first heat exchanger 1 is heated, while maintaining the three-way valves 12 and 13 in closed state, by introducing a heating medium through the line 18 into the first heat transfer pipe 5, so that the hydrogen absorbed in the alloy MH is released therefrom and the first container 24 and the pipes 7, 8 and 9 are filled with hydrogen at a tempeature of T_1 and a pressure of P_1. At the same time, the hydrogen storage alloy M is cooled indirectly be introducing a cooling medium into the second heat transfer pipe 6 through the line 19 so that the inside of the second container 25 has a temperature T_2 and a pressure P_2.

The three-way valves 12 and 13 are then actuated to selectively communicate the inlet conduit 14 with the pipe 8 and to selectively communicate the outlet conduit 15 with the pipe 11. As a result, the high pressure hydrogen is introduced into the gas turbine 3 through lines 7, 8 and 14 and, after driving the gas turbine and the electric generator 4, passed through lines 15, 11 and 17 to the second container 25 of the second heat exchanger 2 where the hydrogen is reabsorbed by the alloy M. In this case, there are maintained relationships of $P_1 > P_2$ and $T_1 > T_2$ while the alloy MH in the first heat exchanger 1 releases the absorbed hydrogen and the alloy M absorbes the released hydrogen. Therefore, the gas turbine 3 continues driving until the system arrives at an equilibrium.

When the desorption of hydrogen from the alloy in the first heat exchanger 1 ceases, the valves 12 and 13 are closed. Then, the heating medium is supplied to the second heat transfer pipe 6 while the cooling medium is introduced into the first heat transfer pipe 5 so that the hydrogen absorbed, in the previous step, in the alloy in the second heat exchanger 2 is desorbed therefrom and fills the lines 10, 11 and 17 and the container 25 at a temperature of T_2' and a pressure of P_2'. The valves 12 and 13 are then opened to communicate the line 10 with the line 14 and the line 9 with the line 15. This results in the introduction of

the hydrogen at T_2' and P_2' into the gas turbine 3, thereby driving the electric generator 4 operatively connected to the gas turbine 3. The hydrogen is then fed, through the lines 15, 9 and 7, to the first heat exchanger 1 and is absorbed by the alloy in the first heat exchanger 1 at a temperature of T_1' and a pressure of P_1'. Since $P_1' < P_2'$ and $T_1' < T_2'$, the gas turbine 3 is driven with the high pressure hydrogen serving as a working gas.

The operations as described above are repeated to continuously obtain electric energy from the generator 4. In this case, since the efficiency in the turbine 3 depends upon the difference in temperature in the incoming hydrogen and the exausted hydrogen, it is effective to provide a heater (not shown) in the hydrogen inlet conduit 14 in improving the operation efficiency of the gas turbine 3.

Fig. 2 depicts one preferred embodiment of the apparatus for the generation of electric energy according to the present invention which is suited for continuously obtaining steady levels of electric power. The apparatus includes a combination of a gas turbine 20 and an electric generator 21 similar to that described previously with reference to Fig. 1. In the embodiment shown, the gas turbine 20 is driven with high pressure hydrogen supplied from a hydrogen releasing and absorbing system as described below.

The hydrogen desorbing and absorbing system includes six, first through sixth,heat exchange zones 201-206, generally heat exchangers, within each of which is provided a bed of hydrogen storage alloy, generally of the same kind. The first through sixth heat exchangers 201-206 are connected to an inlet port of the gas turbine 20 by hydrogen feed pipes 150 via valve means, generally open-close valves 40-45, respectively, and to an outlet port of the gas turbine 20 by hydrogen discharge pipes 140 via valve means, generally open-close valves 50-55, respectively.

The first through sixth heat exchangers 201-206 have first through sixth heat transfer members such as heat transfer pipes 211-216, respectively, for cooling or heating the hydrogen storage alloy contained therein. The first and sixth heat transfer pipes 211-216 are connected to a source of a heating medium via heating medium feed conduits 131 and valve means, generally open-close valves 80, 82, 84, 86, 88 and 90, respectively, and also to a source of a cooling medium via cooling medium feed conduits 121 and valve means, generally open-close valves 100, 102, 104, 106, 108 and 110, respectively. The first through sixth heat transfer pipes 211-216 are connected to heating medium discharge lines 132 via valve means, generally open-close valves 81, 83, 85, 87, 89 and 91, respectively, and to cooling medium discharge lines 122 via valve means, generally open-close valves 101, 103, 105, 107, 109 and 111.

Furthermore, the first through sixth heat transfer pipes 211-216 are connected to form a loop by connecting conduits 76 provided with valve means, generally open-close valves 70-75.

In the thus constructed apparatus, different operations, i.e. preheating, primary hydrogen desorption, secondary hydrogen desorption, pre-cooling, primary hydrogen absorption and secondary hydrogen absorption, are simultaneously performed in the first through sixth heat exchangers 201-206, with each heat exchanger performing successively and cyclically these operations in the following manner:

In an instance where preheating is run in the third heat exchanger 203, the primary hydrogen desorption is run in the second heat exchanger 202, the secondary hydrogen desorption in the first heat exchanger 201, the pre-cooling in the sixth heat exchanger 206, the primary hydrogen absorption in the fifth heat exchanger 205 and the secondary hydrogen absorption in the fourth heat exchanger 204, the open-close valves 40-45, 50-55, 70-75, 80-91 and 100-111 are set in the following conditions:

Opened: 80, 71, 72, 85, 106, 74, 75, 111, 40, 41, 53 and 54

Closed: All valves other than the above

Thus, the heating medium is introduced into the first heat transfer pipe 211 and is passed successively through the second and third heat transfer pipes 212 and 213 to heat the respective hydrogen storage alloys contained in respective heat exchangers 201-203. The temperature of the heating medium becomes gradually lowered as it is passed in the downstream side heat exchangers. Thereafter, the medium is exhaused through the discharge conduit 132. On the other hand, the cooling medium is introduced into the fourth heat transfer pipe 214 and is then fed to the fifth and sixth heat transfer pipes 215 and 216 to cool the respective alloys in respective heat exchangers 214-216. The temperature of the cooling medium becomes gradually increased as it is passed in the down stream side heat exchangers. The cooling medium discharged from the sixth heat transfer piper 216 is exhausted through the line 122.

In the above conditions, hydrogen is released from the hydrogen storage alloys in the first and second heat exchangers 201 and 202 and is fed though valves 40 and 41 and feed pipes 150 to the gas turbine 20. The hydrogen which has been used for the driving of the gas turbine is then fed through the discharge pipes 140 and the valves 53 and 54 to the fourth and fifth heat exchangers 214 and 215 where it is reabsorbed by respective hydrogen storage alloy cooled by indirect heat exchange with the cooling medium flowing in the heat transfer pipes 214 and 215. In the third and sixth heat exchangers, preheating and precooling are effected, respectively.

When the release of hydrogen in the hydrogen storage alloy in the first heat exchanger 201 is substantially finished, the valves are shifted as follows.

Opened: 82, 72, 73, 87, 108, 75, 70, 101, 41, 42, 54 and 55

Closed: all valves other than the above

Thus, the heating medium is first supplied to the second heat transfer pipe 212 in the second heat exchanger 202, which has been subjected to the primary hydrogen desorbing conditions, so that the alloy in the second heat exchanger 202 is heated to a higher temperature than that in the previous primary desorbing step. As a result, the hydrogen which remains unreleased in the primary hydrogen desorbing step is released from the alloy in the second heat exchanger 202. The heating medium is then passed to the third heat transfer pipe 213 to heat the alloy in the third heat exchanger 203, which has been preheated in the preheating step, so that the hydrogen is released from the preheated alloy (primary desorption). The released hydrogen from the second and third heat exchangers 202 and 203 is supplied to the gas turbine 20 through the opened valves 41 and 42 and lines 150.

On the other hand, the cooling medium is first supplied to the fifth heat transfer pipe 215, which has been subjected to the primary hydrogen absorbing conditions, so that the alloy in the fifth heat exchanger 205 is cooled to a lower temperature than that in the previous primary absorbing step. As a result, the alloy in the fifth heat exchanger 205 further absorbs hydrogen supplied from the gas turbine 20 through the line 140 and the opened valve 54. The cooling medium is then passed to the sixth heat transfer pipe 216 to cool the alloy in the sixth heat exchanger 206, which has been pre-cooled in the pre-cooling step, so that the hydrogen supplied from the gas tubine 20 through the opened valve 55 is absorbed by the precooled alloy in the sixth heat exchanger 206 (primary absorbing step).

The heating medium in the third heat transfer pipe 213 is passed to the fourth heat transfer pipe 214 through the opened valve 73 to preheat the alloy in the fourth heat exchanger 204 which has absorbed hydrogen in the previous secondary hydrogen absorbing step. The cooling medium in the sixth heat transfer pipe 216 is passed to the first heat transfer pipe 211 through the opened valve 70 to pre-cool the alloy in the first heat exchanger 201 which has desorbed hydrogen in the previous secondary hydrogen desorbing step.

When the secondary desorption of hydrogen from the alloy in the second heat exchanger 202 is finished, the valves are operated to effect the secondary hydrogen desorption in the next third heat exchanger 203, the primary desorption in the fourth heat exchanger 204, the preheating in the fifth heat exchanger 205, the secondary hydrogen absorption in the sixth heat exchanger 206, the primary absorption in the first heat exchanger 201 and the pre-cooling in the second heat exchanger 202. By operating the valves 40-45, 50-55, 70-75, 80-91 and 100-111 in order in the above manner, the gas turbine 20 is driven continuously since hydrogen is continuously desorbed from at least one of the hydrogen storage alloys in the first through sixth heat exchangers 201-206 and is continuously absorbed in at least one of the heat exchangers 201-206 throughout the process inclusive of during the valve opening and closing operations. Therefore, the above-described apparatus of the present invention can continuously generate a steady level of electric power.

Preferably, the first through sixth heat exchangers 201-206 are connected in parallel with each other by means of connecting pipes 160 through valves 60-65 as shown in Fig. 2. The valves 60-65 are operated so as to intercommunicate the heat exchanger in which the secondary hydrogen desorption was finished and which has disconnected from the gas turbine 20 and the heat exchanger in which the secondary hydrogen absorption was finished and which has disconnected from the gas turbine 20. By this, the hydrogen pressures in the two heat exchangers are equalized. As a consequence, the hydrogen storage alloy which finished its secondary hydrogen desorption can further release the absorbed hydrogen while the alloy which finished its secondary hydrogen absoption can further absorb the released hydrogen, improving the hydrogen desorbing and absorbing efficiency of the alloy. The valve operations for the above hydrogen pressure equalizing procedure will be described more particularly hereinbelow.

Suppose that the secondary hydrogen desorption in the first heat exchanger 201 and the secondary hydrogen absorption in the fourth heat exchanger 204 have just finished. Then, the valves 40 and 53 are closed so that the first and fourth heat exchangers are disconnected from the gas turbine 20. Thereafter, the valves 60 and 63 are opened to selectively communicate the first and fourth heat exchangers 201 and 204 with each other. This causes the high pressure hydrogen remaining in the first heat exchanger 201 to flow into the fourth heat exchanger 204 containing low pressure hydrogen, thereby equalizing the pressure in the first and fourth heat exchangers 201 and 204 to a middle hydrogen pressure. Under this condition, the hydrogen storage alloy in the first heat exchanger 201 further releases hydrogen of the middle pressure while the alloy in the fourth heat exchanger 204 further absorbs the desorbed hydrogen of the middle pressure. Then, the valves 60 and 53 are closed to separate the heat exchangers 201 and 204 from each

other, and the valves 80, 71, 106 and 74 are closed with the simultaneous opening of the valves 70, 101, 73 and 87 to effect pre-cooling in the first heat exchanger 201 and preheating in the fourth heat exchanger 204.

By carrying out the above pressure-equalizing operation before the preheating and pre-cooling, the amount of hydrogen absorbed by the alloy in the first heat exchanger becomes smaller while the amount of hydrogen absorbed by the alloy in the fourth heat exchanger becomes greater. Therefore, the hydrogen available for working the gas turbine 20 per unit weight of the alloy is increased, improving the efficiency of the apparatus.

In Fig. 2, designated as 22 is a super heater for heating the hydrogen gas with a heating medium flowing through a line 30 and 23 is a reheater for heating the hydrogen gas, diverted from the gas turbine 20 through a line 32, with a heating medium flowing through a line 31. Both the superheater 22 and the reheater 23 can serve to improve the electric power generation efficiency of the apparatus. The gas turbine 20 is preferably a multiple stage expansion turbine. The reference numeral 27 designates a pressure detecting controller, 26 a speed and pressure governing mechanism and 29 a speed and pressure governing valve.

In the embodiment illustrated in Fig. 2, each of the first through sixth heat exchange zones 201-206 is constituted from a single heat exchanger. However, it is of course possible to construct each heat exchange zone or each desired heat exchange zone from two or more heat exchangers whose heating or cooling medium inlets and outlets are connected in series and whose hydrogen inlets and outlets are connected in parallel. Thus, for the purpose of the present specification, the term "a heat exchange zone" is intended to refer not only to a single heat exchanger but also to two or more heat exchangers in which a similar operation is performed. For example, the number of the containers in the apparatus shown in Fig. 2 can be increased to 10, three of them being used for primary cooling and another three for primary hydrogen release.

Any known hydrogen storage alloy may be suitably used for the purpose of the present invention. Representative alloys to be used for the present invention may be selected appropriately in consideration of, for example, the temperature of a source of the heating medium to be utilized for heating the alloys. The same hydrogen storage alloy is generally used for the accommodation in the first to sixth heat exchange zones 201-206, though different kinds of hydrogen storage alloys may be used if desired.

Generally, the difference in temperature of the heating medium between the inlet and outlet of the apparatus according to the present invention is less than 50 °C.

In accordance with the present invention, electric energy may be efficiently generated using a source of heat of low levels that could not be used heretofore for electric generation. Unlike conventional techniques, no pump is required for pressure elevation and neither condenser for gases discharged from a turbine nor circulating devices for condensed gases are required, thereby rendering the electric energy generation system simple and economical. The present invention has the great industrial significance because electric energy can be advantageously generated using geothermal heat or exhaust heat of low levels produced by chemical plants or other manufacturing plants.

Example

The apparatus as illustrated in Fig. 2 was operated with a source of a low temperature heat. The main operation conditions were as follows:

Hydrogen storage alloy:	rare earth type
Heat source temperature (hydrogen desorbing temperature):	110-90 °C
Cooling temperature (hydrogen absorbing temperature):	30-45 °C
High pressure hydrogen (in line 150):	10 atm.
Low pressure hydrogen (in line 140):	1 atm.
Superheater temperature (as hydrogen temperature):	140 °C
Reheater temperature (as hydrogen temperature):	135 °C
Amount of hydrogen recirculated:	1 Kg/second
Electric power generated:	2300 KW

Claims

1. An apparatus for generating electric energy, comprising:

a gas turbine (20) having gas inlet and gas outlet ports and capable of being driven by hydrogen gas flowing from said inlet to outlet ports;

an electric generator (21) operatively connected to said gas turbine and capable of operating, when said gas turbine is driven, to generate an electric energy;

first through sixth heat exchange zones (201-206) each containing a hydrogen storage alloy capable of absorbing hydrogen upon being cooled and of releasing the absorbed hydrogen upon being heated, and each being adapted to heat or cool the hydrogen storage alloy contained therein by indirect heat exchange with a heating or cooling medium supplied thereto;

connecting conduit means (76, 211-216) connecting said first through sixth heat exchange zones in loop so that the heating or cooling medium can recirculate successively through said first to sixth heat exchange zones in that order;

a source of the heating medium;

a source of the cooling medium;

first through sixth heating medium feed conduits (211-216), extending between said first through sixth heat exchange zones and said source of the heating medium, respectively, for introducing therethrough the heating medium to respective heat exchange zones;

first through sixth cooling medium feed conduits (211-216), extending between said first through sixth heat exchange zones and said source of the cooling medium, respectively, for introducing therethrough the cooling medium to respective heat exchange zones;

first valve means (80-91, 100-111) provided in said heating medium and cooling medium feed conduits and operable so that the heating medium from said source thereof is fed to selected one of said first through sixth heat exchange zones and the cooling medium from said source thereof is fed to the next but two heat exchange zone located downstream of said selected heat exchange zone;

second valve means (70-75) provided in said connecting conduit means and operable so that the heating medium introduced into said selected heat exchange zone is passed successively to two succeeding heat exchange zones located downstream from said selected heat exchange zone and the cooling medium introduced into said next but two heat exchange zone is passed successively to two succeeding heat exchange zones located downstream from said next but two heat exchange zone;

first through sixth hydrogen feed pipes (150), extending between said first through sixth heat exchange zones and said gas inlet, respectively, for introducing the released hydrogen from respective heat exchange zones into said gas turbine;

first through sixth hydrogen discharge pipes (140), extending between said first through sixth heat exchange zones and said gas outlet, respectively, for feeding the hydrogen from said gas turbine to respective heat exchange zones;

third valve means (40-45) provided in said first through sixth hydrogen feed pipes and operable so that the passage of hydrogen through said first through sixth hydrogen feed pipes is prevented except through those feed pipes leading from said selected heat exchange zone and its adjacent downstream heat exchange zone; and

fourth valve means (50-55) provided in said first through sixth hydrogen discharge pipes and operable so that the passage of hydrogen through said first through sixth hydrogen discharge pipes is prevented except through those feed pipes leading to said next but two heat exchange zone and its adjacent downstream heat exchange zone.

2. An apparatus as claimed in Claim 1, further comprising connecting pipe means (160) for connecting said first through sixth heat exchange zones in parallel, and fifth valve means (60-65) provided in said connecting pipe means and operable so that said selected heat exchange zone and said next but two heat exchange zone are in gas communication with each other when said heat exchange zones are disconnected from said gas turbine (20).

3. An apparatus as claimed in Claim 1 or Claim 2, wherein said first through sixth heat exchange zones are each composed of one or more heat exchangers having heating or cooling medium inlet and outlet ports connected in series and hydrogen inlet and outlet ports connected in parallel with each other.

Patentansprüche

1. Ein Apparat zur Erzeugung elektrischer Energie, dadurch gekennzeichnet, daß er folgende Bestandteile aufweist -

eine Gasturbine (20) mit Gaszuleitungs- und Gasableitungsöffnung, die so gestaltet ist, daß sie durch Wasserstoffgas angetrieben werden kann, der von der genannten Zuleitungs- zur Ableitungsöffnung strömt;

ein betriebsmäßig mit der genannten Gasturbine verbundener Stromerzeuger (21), der, wenn die Gasturbine angetrieben wird, arbeiten kann, um elektrische Energie zu erzeugen;

Wärmeaustauschbereiche eins bis sechs (201-206), die jeweils eine Wasserstoff speichernde Legierung enthalten, die Wasserstoff absorbieren kann, wenn sie abgekühlt wird, und die den so absorbierten Wasserstoff wieder abgeben kann, wenn sie aufgewärmt wird, und die jeweils so ausgelegt sind, daß sie die darin enthaltene Wasserstoffspeichernde Legierung durch indirekten Wärmeaustausch mit einem zugeführten Medium aufwärmen oder abkühlen können;

verbindende Rohrleitungsmittel (76, 211-216), durch die die Wärmeaustauschbereiche eins bis sechs miteinander in einer Schleife verbunden werden, so daß das Heiz- bzw. Kühlmedium die Wärmeaustauschbereiche eins bis sechs in dieser Reihenfolge rezirkulierend durchfließen kann;

eine Quelle des Heizmediums;

eine Quelle des Kühlmediums;

Zuführrohrleitungen eins bis sechs (211-216) für das Heizmedium, die sich von der Quelle des Heizmediums bis zu den dazugehörigen Wärmeaustauschbereichen eins bis sechs erstrecken und die dazu dienen, das Heizmedium an die jeweiligen Wärmeaustauschbereiche heranzuführen;

Zuführrohrleitungen eins bis sechs (211-216) für das Kühlmedium, die sich von der Quelle des Kühlmediums bis zu den dazugehörigen Wärmeaustauschbereichen eins bis sechs erstrecken, und die dazu dienen, das Kühlmedium an die jeweiligen Wärmeaustauschbereiche heranzuführen;

erste Ventilmittel (80-91, 100-111), die in den Zuführleitungen des Heizmediums und des Kühlmediums bereitgestellt sind, und die so arbeiten können, daß das Heizmedium von seiner genannten Quelle an einen gewählten der sechs Wärmeaustauschbereiche eins bis sechs zugeführt wird, und das Kühlmedium an den jeweils von dort gezählten dritten, weiter stromabwärts befindlichen Wärmeaustauschbereich zugeführt wird;

zweite Ventilmittel (70-75), die in den Zuführleitungen bereitgestellt sind, und die so arbeiten können, daß das Heizmedium, welches in den zuvor gewählten Wärmeaustauschbereich zugeführt worden ist, nacheinander an die zwei darauffolgenden, stromabwärts liegenden Wärmeaustauschbereiche geführt wird, und daß das Kühlmedium, welches jeweils von der Einführstelle des Heizmediums aus an den jeweils von dort gezählten dritten, weiter stromabwärts befindlichen Wärmeaustauschbereich zugeführt wird, nacheinander an die zwei darauffolgenden, stromabwärts liegenden Wärmeaustauschbereiche geführt wird;

Wasserstoffzuleitungen (150) eins bis sechs, die sich jeweils zwischen dem ersten und dem sechsten Wärmeaustauschbereich und der genannten Gas-Zuleitungsöffnung erstrecken, und die dazu dienen, den aus dem jeweiligen Wärmeaustauschbereich freiwerdenden Wasserstoff an die Gasturbine zu führen;

Wasserstoffableitungen (140) eins bis sechs, die sich jeweils zwischen dem ersten und dem sechsten Wärmeaustauschbereich und der genannten Gas-Ableitungsöffnung erstrecken, und die dazu dienen, den Wasserstoff aus der Turbine in die jeweiligen Wärmeaustauschbereiche zu führen;

dritte Ventilmittel (40-45), die in den genannten Wasserstoffzuleitungen bereitgestellt sind und die so arbeiten können, daß der Wasserstoffstrom durch die Wasserstoffzuleitungen eins bis sechs verhindert wird, außer durch jene Zuleitungen, die von dem jeweils gewählten Wärmeaustauschbereich an den jeweils benachbarten, stromabwärts befindlichen Wärmeaustauschbereich führen; und

vierte Ventilmittel (50-55), die in den genannten Wasserstoffableitungen bereitgestellt sind und die so arbeiten können, daß der Wasserstoffstrom durch die Wasserstoffableitungen eins bis sechs verhindert wird, außer durch jene Zuleitungen, die von dem der Einführstelle des Heizmediums gezählten dritten, weiter stromabwärts befindlichen Wärmeaustauschbereich aus an den jeweils benachbarten, stromabwärts befindlichen Wärmeaustauschbereich führen.

2. Ein Apparat gemäß Anspruch 1, dadurch gekennzeichnet, daß er ferner Verbindungsleitungsmittel (160) beinhaltet, durch die die genannten Wärmeaustauschbereiche eins bis sechs parallel miteinander verbunden werden, sowie fünfte Ventilmittel (60-65), die in diesen Verbindungsleitungsmitteln bereitgestellt sind und so arbeiten können, daß der gewählte Wärmeaustauschbereich und der von dort

stromabwärts gezählte, dritte Wärmeaustauschbereich gasmäßig miteinander in Verbindung stehen, wenn die genannten Wärmeaustauschbereiche von der genannten Gasturbine (20) getrennt sind.

3. Ein Apparat gemäß den Ansprüchen 1 oder 2, dadurch gekennzeichnet, daß der erste bis sechste Wärmeaustauschbereich jeweils aus einem oder mehreren Wärmeaustauschbereichen besteht, die jeweils seriell miteinander verbundene Heizmittel- bzw. Kältemittel-zu- und -ableitungsöffnungen sowie parallel miteinander verbundene Wasserstoffein- und -auslaßöffnungen enthalten.

Revendications

1. Appareil générateur d'énergie électrique, comportant:

une turbine à gaz (20) ayant des orifices d'entrée et de sortie de gaz, susceptible d'entraînement par l'hydrogène venant desdits orifices d'entrée et de sortie;

un générateur d'électricité (21) en raccord fonctionnel avec ladite turbine et susceptible de fonctionner de façon à assurer la génération d'énergie électrique lorsque la turbine à gaz est entraînée;

une série de la première à la sixième zone d'échange de chaleur (201-206) chacune contenant un alliage accumulateur d'hydrogène apte à absorber l'hydrogène suite à la réfrigération et à dégager l'hydrogène absorbé suite à la chauffe, chacune étant agencée de façon à chauffer ou réfrigérer l'alliage accumulateur d'hydrogène par échange indirect de chaleur suite à l'apport à cet effet d'une matière de chauffe ou de réfrigération;

des moyens de conduit (76, 211-216) raccordant ladite première à ladite sixième zone d'échange de chaleur en boucle de telle façon que la matière de chauffe ou de réfrigération soit recyclée successivement dans l'ordre dans la première à la sixième zone d'échange de chaleur;

une source de matière de chauffe;

une source de matière de réfrigération;

une série du premier au sixième conduit d'apport (211-216), allant respectivement de ladite première à ladite sixième zone d'échange de chaleur jusqu'à ladite source de matière de chauffe, permettant d'y circuler ladite matière de chauffe jusqu'aux zones respectives d'échange de chaleur;

une série du premier au sixième conduit d'apport (211-216), allant respectivement de ladite première à ladite sixième zone d'échange de chaleur jusqu'à ladite source de matière de réfrigération, permettant d'y circuler ladite matière de réfrigération jusqu'aux zones respectives d'échange de chaleur;

des premiers moyens à robinet (80-91, 100-111) sur lesdits conduits d'apport de matière de chauffe et de réfrigération dont la fonction est telle que la matière de chauffe est amenée de ladite source à une zone d'échange de chaleur sélectionnée de la première à la sixième et la matière de réfrigération de ladite source est amenée à la troisième zone d'échange de chaleur dans l'ordre située en aval de ladite zone d'échange de chaleur sélectionnée;

des deuxièmes moyens à robinet (70-75) sur lesdits conduits de raccord exploitables pour que la matière de chauffe introduite dans ladite zone d'échange de chaleur sélectionnée est successivement transférée aux deux zones suivantes d'échange de chaleur situées en aval de ladite zone d'échange de chaleur sélectionnée et la matière de réfrigération introduite dans ladite troisième zone dans l'ordre est transférée successivement aux deux zones suivantes d'échange de chaleur situées en aval de la troisième zone dans l'ordre d'échange de chaleur;

une série de la première à la sixième tubulure d'apport d'hydrogène (150), menant respectivement de ladite première à ladite sixième zone d'échange de chaleur jusqu'à l'entrée du gaz, pour introduire l'hydrogène ainsi dégagé des zones respectives d'échange de chaleur et dans ladite turbine à gaz;

une série de la première à la sixième tubulure de décharge d'hydrogène (140), menant respectivement de ladite première à ladite sixième zone d'échange de chaleur jusqu'à la sortie du gaz, pour amener l'hydrogène de la turbine à gaz jusqu'aux zones respectives d'échange de chaleur;

des troisièmes moyens à robinet (40-45) dans ladite série de la première à la sixième tubulure d'apport d'hydrogène exploitables pour que le passage de l'hydrogène par ladite série de la première à la sixième tubulure d'apport est condamné sauf dans les tubulures d'apport menant de ladite zone d'échange de chaleur sélectionnée et sa zone contiguë d'échange de chaleur en aval; et

des quatrièmes moyens à robinet (50-55) dans ladite série de la première à la sixième tubulure de décharge d'hydrogène exploitables pour que le passage de l'hydrogène par lesdites tubulures d'apport de la première à la sixième soit condamné sauf par les tubulures d'apport menant à ladite troisième zone d'échange de chaleur et à sa zone contiguë d'échange de chaleur en aval.

2. Appareil tel que revendiqué à la revendication 1, comportant en outre des moyens de tubulures de raccord (160) assurant le raccord en parallèle de ladite série de la première à la sixième zone d'échange, et des cinquièmes moyens à robinet (60-65) prévus dans lesdits moyens de tubulure de raccord exploitables pour assurer le passage du gaz de l'une à l'autre entre ladite zone ainsi sélectionnée et ladite troisième zone d'échange de chaleur dans l'ordre quand lesdites zones d'échange de chaleur sont débranchées de ladite turbine à gaz (20).

3. Appareil tel que revendiqué à la revendication 1 ou la à revendication 2, dont chacune de la série de première à la sixième zone d'échange de chaleur consiste d'un seul ou de plusieurs échangeurs de chaleur ayant des orifices d'entrée et de sortie raccordés en série pour la matière de chauffe ou de réfrigération et des orifices d'entrée et de sortie raccordés en parallèle pour l'hydrogène.

FIG. 1

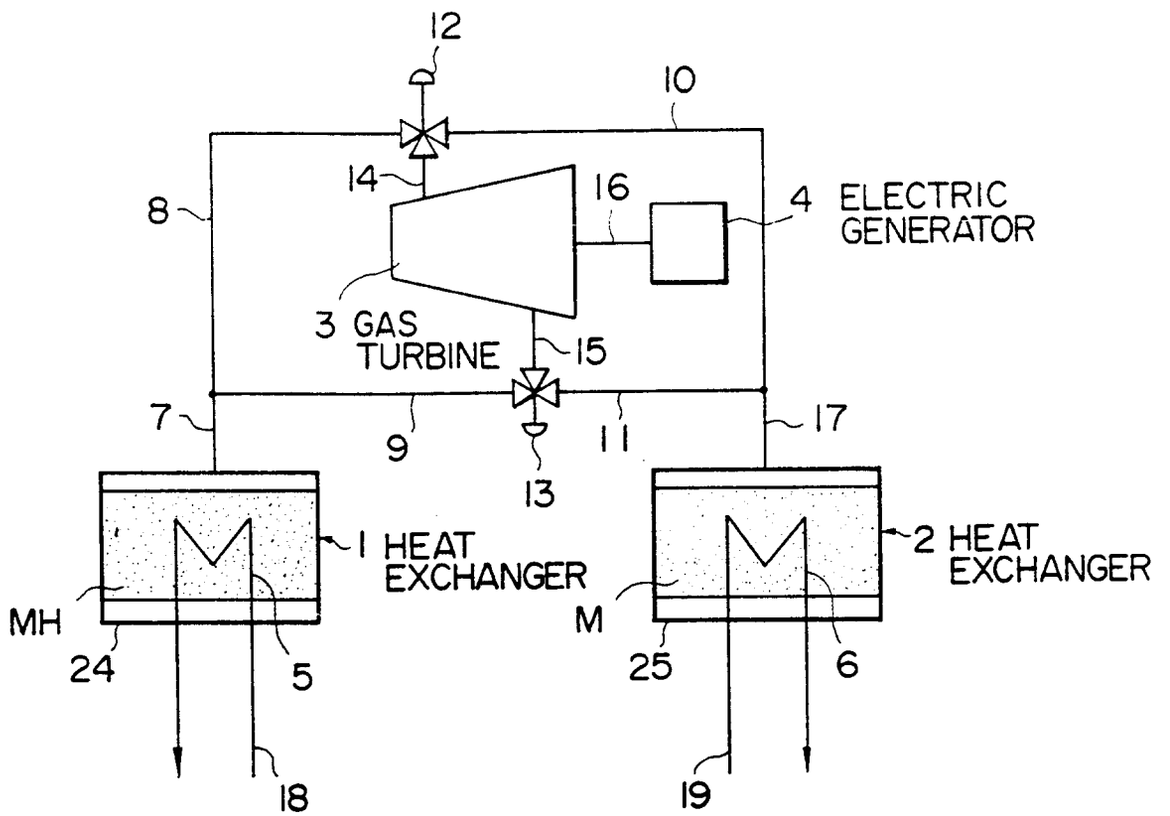
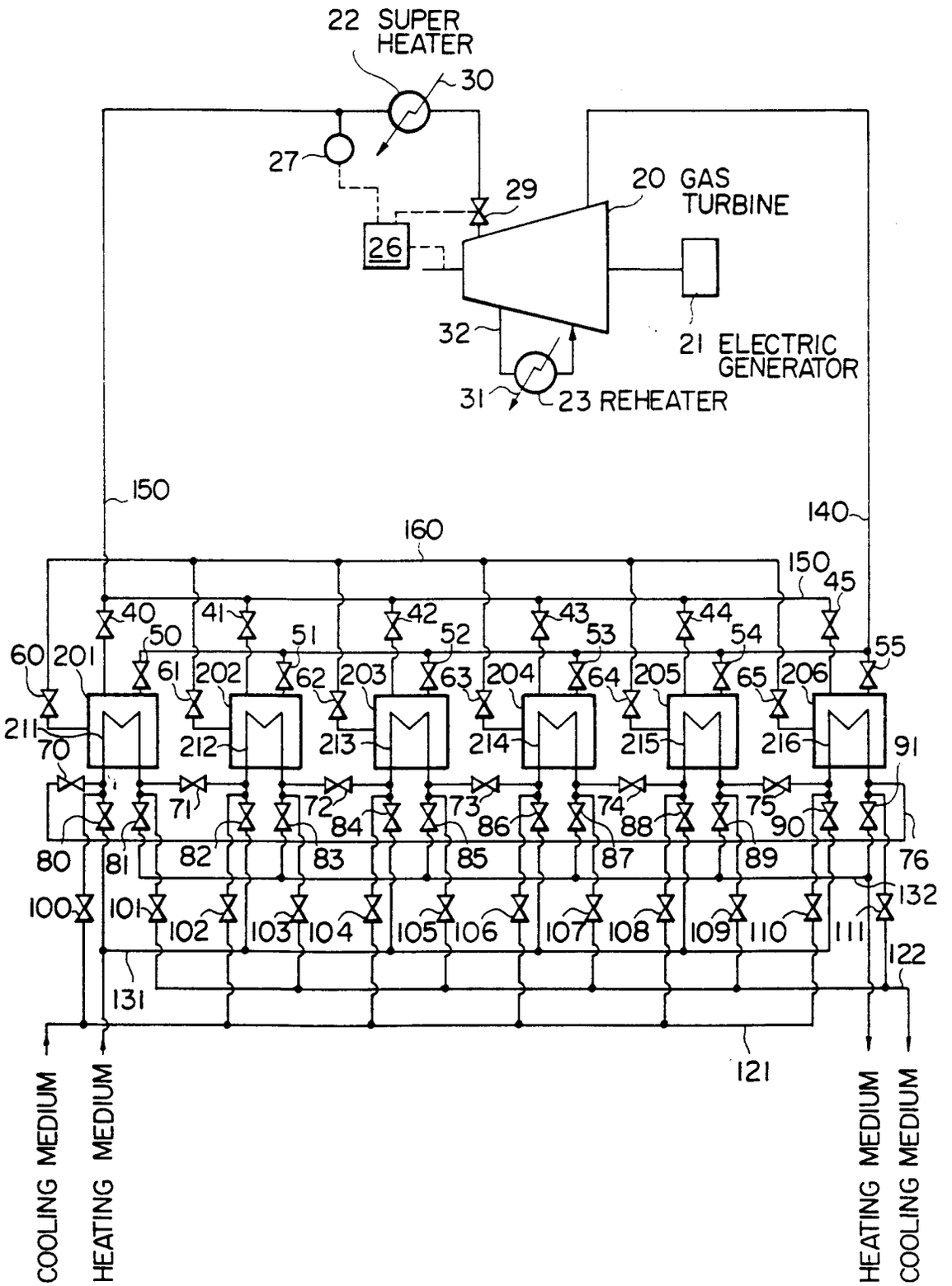

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4 ELECTRIC GENERATOR
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3 GAS TURBINE
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1 HEAT EXCHANGER
2 HEAT EXCHANGER
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FIG. 2


22 SUPER HEATER
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20 GAS TURBINE
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21 ELECTRIC GENERATOR
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23 REHEATER
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COOLING MEDIUM
HEATING MEDIUM
HEATING MEDIUM
COOLING MEDIUM