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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 January 2016 (21.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/009385 A1

(51) International Patent Classification:
F23L 7/00 (2006.01) *F23C 99/00* (2006.01)

(21) International Application Number:
PCT/IB2015/055393

(22) International Filing Date:
16 July 2015 (16.07.2015)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
FI2014A000171 17 July 2014 (17.07.2014) IT

(71) Applicant: **E.HY. ENERGY HYDROGEN S.R.L.S.** [IT/IT]; Via Garzella,183, I-56021 Cascina (Pisa) (IT).

(72) Inventors: **VITELLI, Davide**; Via di Oratoio, 75e, I-56100 Pisa (IT). **BERTELLI, Marco**; Via Bargagna, 48, I-56100 Pisa (IT).

(74) Agents: **BRAZZINI, Silvia** et al.; Società Italiana Brevetti S.p.A., Corso dei Tintori, 25, I-50122 Firenze (IT).

(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, BN, BR, BW, BY, BZ, CA, CH, CL, 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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, 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, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

[Continued on next page]

(54) Title: APPARATUS FOR PRODUCING ELECTRICITY, AND RELATED PROCESS

(57) Abstract: The present invention relates to the field of production of energy from renewable or green resources, and in particular it relates to an apparatus for producing electrical energy and aqueous vapour starting from molecular hydrogen, oxygen, and water that does not generate pollutant emissions and, besides this, is further greatly efficient in producing energy and completely safe in its functioning.

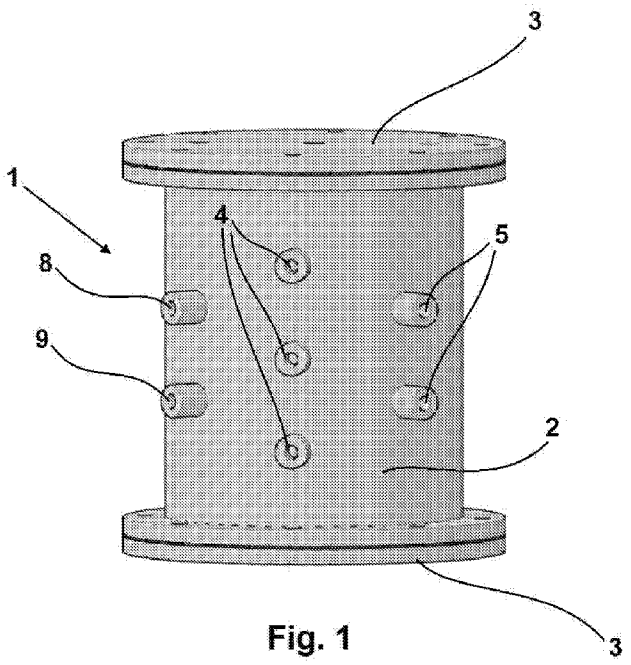


Fig. 1

WO 2016/009385 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

APPARATUS FOR PRODUCING ELECTRICITY, AND RELATED PROCESS

Field of the Invention

The present invention relates to the field of the production of energy from non-polluting renewable sources or green sources, and it refers to an apparatus for producing energy starting from molecular hydrogen, oxygen and water, that can be used for both civil use and industrial applications.

State of the Art

Molecular hydrogen, or dihydrogen, is constituted by a molecule of two hydrogen atoms and its formula is H_2; incorrectly, it is generally referred to simply as "hydrogen". In conditions of room temperature and pressure, it appears as a colourless and odourless gas and it may be obtained by various methods, even on a large scale, on industrial scale, for instance by electrolysis of water or by reforming of natural gas or of other hydrocarbons. The industrial production of this gas is a process widely used and now acquired, also because its uses are many and widespread since long time, and they range from the production of ammonia to the use as an alternative fuel to hydrocarbons.

Molecular hydrogen is in fact a gas which combustion is particularly advantageous from the point of view of emissions, which are much less polluting than those emitted by any other type of fuel: the main product of the combustion of molecular hydrogen with oxygen or air as oxidizing is in fact simply water, or better water vapour. For this reason, in recent years there have been numerous attempts to develop systems to produce "clean" energy from the combustion of molecular hydrogen, alone or in mixture with other fuels, for example with methane. These technological systems that exploit molecular hydrogen as an energy source have been developed both for the application to mobile devices in the transport sector is also for application to stationary devices in the production of energy in industrial and domestic.

Molecular hydrogen is in fact a gas whose combustion is particularly advantageous from the point of view of emissions that are much less polluting than those emitted by any other type of fuel: the main product of the combustion of molecular hydrogen with oxygen or air as combustive agent is in fact simply water, or

better water vapour. For this reason in recent years there have been numerous attempts to develop systems for producing "clean" energy from the combustion of molecular hydrogen, alone or in mixture with other fuels, such as methane. These technological systems that exploit molecular hydrogen as an energy source have been developed both for the application to mobile devices in the transport sector and also for the application to stationary devices in the production of energy in industrial sectors as well as in the domestic sphere.

Up to now, however, such technologies have not had the expected development due to various kinds of problems, among which the main concern relates to storing hydrogen in relatively small volumes and complexity of the technology necessary for processing energy / hydrogen / energy and transport of molecular hydrogen, which makes its practical applications in the production of energy excessively expensive.

Opposite to its positive characteristics in terms of emissions, molecular hydrogen also has an energy density per unit of volume that is much lower than that of any other fuel which, again, makes it inconvenient its practical use as fuel to produce energy.

As far as the Applicant is aware of, these technical disadvantages have not been effectively solved to date, so that the technical problem of developing a system efficient and safe for the production of clean energy by using molecular hydrogen as a fuel remains still unsolved.

Subjects of the Invention

A subject of the present invention is therefore to provide an apparatus and a process for producing electric energy based on the combustion of molecular hydrogen, which is efficient and makes use of a technology having costs relatively low.

A further subject of the present invention is to provide an apparatus and a process for producing energy that only use as main consumable materials renewable materials, such as molecular hydrogen, oxygen and water, without producing polluting emissions.

A further subject of the present invention is to provide an apparatus and a process for producing electric energy for civil and industrial uses, which further allows recovering the water vapour produced for generating sanitary water or for the use in heating systems.

These and further subjects are provided by the apparatus for producing electric energy according to the invention, whose essential characteristics are as defined in the first of the attached claims, and by the related process for producing electric energy according to the invention, whose essential characteristics are as defined in the claim 9 here attached.

Further important characteristics of the apparatus and of the process of the present invention are defined in the related dependent claims here attached.

Brief Description of the Drawings

The features and advantages of the apparatus and of the process for producing energy according to the present invention will be clarified in the following exemplary and non-limiting description of an embodiment thereof, with reference to the attached figure wherein:

- the figure 1 is a front view of a combustion cell comprised in the apparatus of the present invention;
- the figure 2 is an exploded view of the main components of the combustion cell of Figure 1;
- the figure 3 shows a block diagram of the process according to the present invention.

Detailed Description of the Invention

With reference to said figures, and more in particular for the moment with reference to Figures 1 and 2, it is illustrated an apparatus for producing electric energy according to the present invention comprising a combustion cell 1, for the combustion of molecular hydrogen, typically made of steel. The Figures 1 and 2 depict a combustion cell 1 having a hollow body 2 of substantially cylindrical form, but it is meant that different forms of the cell's body, for instance a parallelepiped form with square or rectangular base, are anyway to be considered as comprised in the scope of the present invention. The body 2 of the combustion cell 1 is closed by two blind flanges 3, which close the body 2 on opposite sides by means of a suitable connection system, for instance by fixing with a support ring 3', or by another system that is suitable to be used with materials at high pressure. The present combustion cell 1 further comprises at least a valve 4 for the supply of molecular oxygen and at least a

valve 5 for the supply of water, which allow introducing respectively hydrogen and sprayed water inside the combustion cell, by means of suitable nozzles. At least a further valve, not represented in the figure, has the function to introduce oxygen in the combustion chamber 1. Such supply valves are typically electromechanical valves and are each accompanied, upstream, by a check valve for security against backfiring.

The water supplied to the combustion cell in the present apparatus may be water taken from a dedicated tank or, preferably, recycle water coming from the combustion cell in the form of water vapour, collected downstream of the cell and deposited in a special collection tank from which it is taken when needed.

With reference to the Figure 2 it is further illustrated a micro-holed element 6, comprised in the present apparatus and made of titanium or of a titanium alloy, intended to be placed inside the body 2 of the combustion cell. In the alternative, the present micro-holed element 6 can be made of a core in steel or any other analogous material, completely coated by a surface layer of titanium or of a titanium alloy. By the term "micro-holed element" in the present invention a body is meant that is provided with through holes of dimensions of the order of millimetres, preferably all having the same dimensions, ranging for instance between 0.5 and 2 mm, and positioned at equal distance between each other, for instance at a distance comprised between 1.5 and 2.5 mm, and preferably at a distance equal to about 2.0 mm. The form and dimensions of the micro-holed element according to the invention may be various and depend on the form and dimensions of the combustion cell where the micro-holed element is positioned; it is critical that the micro-holed element 6 is fixed inside the cell in such a position as to be invested by the flow of hydrogen entering parallel to the through holes on its surface, and positioned so that every point of said element is at a distance not exceeding 30 cm from the nozzle of the valve for the supply of hydrogen, preferably at a distance comprised between 5 and 10 cm, and more preferably at a distance comprised between 2 and 5 cm.

According to the present invention the micro-holed element 6 may be fixed at one of the blind flanges 3 closing the cell. In Figure 2 it is illustrated a preferred embodiment of the micro-holed element 6, having the form of a plate, which may be fixed to the cell by one or more fixing means, such as two drilled bolts 7, which can

allow wires and cables to come out from inside the plate towards the outside of the cell.

According to a preferred embodiment of the present invention the holes of the micro-holed element have frustoconical shape, all with their major base on the same surface, intended for being hit by the flow of hydrogen. In other words, in this embodiment, the position of the micro-holed element inside the combustion cell must be such that the flow of hydrogen strikes the micro-holed element on the side on which the major bases of the frustoconical holes is exposed.

As a matter of fact, the micro-holed element, during operation of the combustion apparatus of the present invention, must be heated, for example to be able to assume an operating temperature comprised between about 180°C and about 300°C, and it can be heated to such temperatures thanks to appropriate electrical resistances inside the element itself, supplied from the outside through wires passing in the above mentioned perforated fixing means.

In order to achieve the condition of keeping a distance less than 30 cm between the micro-holed element and the nozzle of the valve for supply of molecular hydrogen, the present apparatus can comprise only one micro-holed element in the form of a plate and, depending on the dimensions of the plate, one or more nozzles for supplying hydrogen, so that each point of the micro-holed plate is at a distance less than 30 cm, preferably at a distance between 5 and 10 cm, and more preferably at a distance between 2 and 5 cm, from at least one of the nozzles. Alternatively, the present combustion apparatus may comprise more micro-holed plates arranged in parallel among each other, so as to achieve the above said conditions for the distance from the nozzles of the valves for supplying hydrogen.

According to a further embodiment, the micro-holed element can have substantially the same form of the combustion cell, but smaller dimensions so as to form inside the hollow body 2 of the cell a kind of interspace with micro-holed portions, each placed at a distance not exceeding 30 cm from a nozzle of a valve for supplying hydrogen.

According to a particular embodiment of the invention, to the fixing means 7 of the micro-holed element are anchored one or more piezoelectric ignition elements that,

at the request of an external battery to which they are connected, can bring the temperature of the micro-holed element to the desired value in case of breakage or malfunction of the main device for the increase of temperature of the micro-holed element.

Combustion cells according to the invention, suitable for domestic use, having, therefore small size, can for example have a body 2 with dimensions of 6-8 cm of thickness and about 30 cm in height, with about 20 cm in diameter in the case of cells having a cylindrical body and 10-20 cm of base side for cells having a body of parallelepiped shape. Also the dimensions of the micro-holed element of titanium will be determined accordingly so as to provide an element of dimensions suitable for the insertion in a cell of the above mentioned dimensions, for example a suitable micro-holed element is a plate that is about 3 cm thick, about 25 cm tall and about 15 cm in width.

Also the number of the supply valves, for supplying molecular hydrogen, oxygen and water, is commensurate with the size of the cell of combustion and it will be greater the larger is the cell. For a cell of the dimensions mentioned above, the valves for supplying hydrogen are for example three in number, and the valves for the supply of water and oxygen are two in number. The apparatus according to the present invention further comprises at least a motorized valve for the controlled discharge of steam and, preferably, also one or more safety valves, such as a static safety valve and a dynamic safety valve, for the discharge of the gas inside the cell in emergency situations, such as when the internal pressure of combustion cell exceeds a certain threshold value, or during the maintenance operations of the apparatus.

According to a preferred embodiment of the invention, on the combustion cell are also placed at least one pressure sensor 8 and at least one temperature sensor 9 in order to constantly check the parameters of temperature and pressure within the cell during its operation. The values of temperature and pressure detected can be read directly on the instrument or, according to a preferred embodiment, the relevant data can be transferred to an external unit able to collect, store and manage such data, for example to a programmable logic controller (or PLC, Programmable Logic Controller) which has also the purpose to control the operation of the apparatus depending on the

values of the above said parameters as detected.

The above external unit, for example a control unit of the PLC type, may also advantageously control the operation of all the various valves present in the apparatus including, for example, the motorized valve for the controlled release of water vapour or the valve for supplying hydrogen or again the dynamic safety valve, on the basis of the pressure values required by the plant and / or pre-set in the program that the PLC unit is running, and the values detected. The PLC unit, again on the basis of the data pre-set in the program that is running, may also control the supplying of the hydrogen flow to supply it at predetermined time intervals.

The process for producing electric energy according to the invention, based on the use of an apparatus as the apparatus described above, comprises the following steps:

a) heating of a micro-holed element (6) up to a temperature ranging from 180°C and 300°C;

b) feeding of molecular hydrogen and feeding of oxygen by spraying inside said combustion cell (1);

c) combustion of hydrogen with increase of temperature inside said combustion cell (1) up to a value comprised between about 650°C and about 1000°C; and preferably to a temperature comprised between about 650°C and about 700°C;

d) feeding of water by spraying inside the combustion cell with formation of water vapour at high temperature and pressure;

e) controlled discharge of the water vapour formed in the step d) for the supply of a steam turbine that generates electric energy;

f) re-carrying out of the steps from b) to e) to create a continuous cycle where the combustion cell is supplied with molecular hydrogen, oxygen and water and electric energy is produced from the water vapour formed.

According to a preferred embodiment of the process of the present invention, the water vapour leaving the turbine is passed through a chiller to bring its temperature to values lower than 90°C. In this way the water vapour produced is not dispersed in the form of vapour, but water is recovered that can be used for re-entry into the

combustion cell for a subsequent cycle. The water recovered, typically at a temperature of 70-80°C, can be moreover used for heating radiant groups or radiators or as sanitary water; in this latter case, a heat exchanger fed by a flow of external water, which does not interfere on the cycle of production of energy in the combustion cell, is introduced into the chiller, thus allowing the passage of water at a higher temperature, which can then be taken for use as sanitary water.

According to the process of the invention in the initial steps from a) to c), the combustion of molecular hydrogen occurs thanks to the presence in the cell of the micro-holed element 6, and more in particular to the fact that it is previously heated and to the fact that the hydrogen sprayed in contact with the micro-holed element generates a friction that, together with the high temperature and the presence of oxygen acting as combustive agent, causes the hydrogen combustion and the rise of temperature inside the cell. This phenomenon is particularly effective when the micro-holed element has holes of frustoconical shape, as described above, being in this case greater the friction generated by the flow of hydrogen entering into the holes.

The rise of temperature inside the cell is preferably controlled so that the temperature does not exceed about 700°C; the inside of the combustion cell can be anyway coated by a ceramic layer having high thermal resistance or by an analogous material having for instance a thickness comprised between 10 and 20 mm approximately.

In the subsequent steps d) and e) the combustion cell is fed with water, thus being charged with water vapour having high pressure, typically about 40-50 atm; the discharge of the so-formed vapour occur under controlled conditions, thanks to a motorized valve, which creates a flow of vapour with a pressure of about 2-6 atm towards the turbine. The combustion cell, emptied of the vapour, typically drops to values of temperature around 550°C, then it is fed again with molecular hydrogen and oxygen that, thanks to the friction with the heated micro-holed element, undergoes a new combustion and raises the temperature in the cell, fed again with water that forms water vapour, which is led to the turbine to generate electric energy, and so on from cycle to cycle.

It should be noted that the amount of molecular hydrogen for feeding the

combustion cell with in the normal operating phases of the present apparatus, is lower than the amount of molecular hydrogen for feeding the same cell in the starting step b). Once triggered the first phase of combustion, the process of the present invention produces energy with even greater efficiency, consuming a smaller amount of molecular hydrogen.

It is easily understood from what said above how the apparatus for the production of energy according to the present invention provides a solution of great practicality and effectiveness, able to fully respond to the predetermined purposes at relatively low cost.

As a matter of fact the present apparatus allows producing electrical energy from renewable sources without emission of any kinds of pollutants. The present apparatus for producing energy finds a privileged application in domestic plants where the small dimensions of the plant helps maintaining low the costs of the technology used and the recovery of the vapour formed is maximized by the immediate recovery for the heating system and for the production of sanitary water.

A further advantage of the apparatus for producing energy according to the present invention is the fact that it may be used not only for domestic and industrial application in new plants, but also in pre-existing plants, for instance for converting hydrocarbons power plants, for haulage, in particular by trains and subway trains.

The present invention was anyway herein described with reference to preferred embodiments. It is to be understood that there may be other embodiments afferent to the same inventive core, as defined by the scope of protection of the claims set out below.

CLAIMS

1. An apparatus for the production of electric energy starting from molecular hydrogen and water, comprising a combustion cell (1) comprising a hollow body (2) of substantially cylindrical or parallelepiped shape, said body (2) having at least one valve for the supply of molecular hydrogen (4), at least one valve for the supply of oxygen and at least one valve for the supply of water (5) for the introduction of said hydrogen, said oxygen and said water in said body (2) by means of suitable nozzles, and also having at least one valve for the emission of water vapour, said apparatus being characterized in that it further comprises at least one micro-holed element (6) made of titanium or of a titanium alloy and provided with a heating system and through holes of dimensions of the order of millimetres, fixed inside said body (2) in such a position as to be invested by the flow of hydrogen entering parallel to the through holes on its surface, and positioned so that every point of said element is at a distance not exceeding 30 cm from the nozzle of said at least one valve for the supply of hydrogen.

2. The apparatus according to claim 1, wherein said micro-holed element (6) consists of a micro-holed plate or of more micro-holed plates placed in parallel amongst each other.

3. The apparatus according to claim 1, wherein said micro-holed element (6) consists of a hollow body having substantially the same shape of said hollow body (2) and smaller dimensions so as to form a sort of interspace between the outer wall of said micro-holed element (6) and the inner walls of said hollow body (2).

4. The apparatus according to any one of the preceding claims, wherein said micro-holed element (6) has holes of frustoconical shape, all with their major base on the same surface of said element intended for being hit by the hydrogen flow.

5. The apparatus according to claim 1, wherein said heating system of the micro-holed element (6) consists of a system of electrical resistors placed inside the element itself, and fed from the outside of said cell combustion.

6. The apparatus according to claim 1, further comprising at least one pressure

sensor (8) for measuring the pressure inside said combustion cell (1).

7. The apparatus according to claim 1, further comprising at least one temperature sensor (9) for measuring the temperature inside said combustion cell (1).

8. The apparatus according to claim 1, further comprising a steam turbine connected to said combustion cell (1) in such a way that the water vapour produced in said combustion cell is conveyed with a controlled flow inside said steam turbine, generating electric energy.

9. The apparatus according to any one of the preceding claims, further comprising a control unit for controlling the operation of said apparatus, said unit being able to collect, store and manage data detected by said sensors, and to control the operation of said valves according to said detected data and/or pre-set data in said control unit.

10. A process for the production of electric energy starting from molecular hydrogen and water in an apparatus as defined in claims 1-9, comprising a combustion cell (1) and a micro-holed element (6) positioned inside said cell, said process comprising the following steps:

a) heating of a micro-holed element (6) up to a temperature ranging from 180°C and 300°C;

b) feeding of molecular hydrogen and feeding of oxygen by spraying inside said combustion cell (1);

c) combustion of hydrogen with increase of temperature inside said combustion cell (1) up to a value comprised between 650°C and 1000°C;

d) feeding of water by spraying inside said combustion cell (1) with formation of water vapour at high temperature and pressure;

e) controlled discharge of the water vapour formed in step d) for the supply of a steam turbine that generates electric energy;

f) re-carrying out of steps from b) to e) to create a continuous cycle where said combustion cell (1) is supplied with molecular hydrogen and water and electric energy is produced from the aqueous vapour formed.

11. The process according to claim 10, wherein the increase of temperature in step

c) brings the temperature to a value comprised between about 650°C and about 700°C.

12. The process according to claim 10, wherein the water vapour leaving said turbine is passed through a chiller to bring its temperature to values lower than 90°C, and the water thus obtained is recovered for re-entry into said combustion cell (1) for a subsequent cycle and/or used for heating radiant groups or radiators and/or for the production of sanitary water.

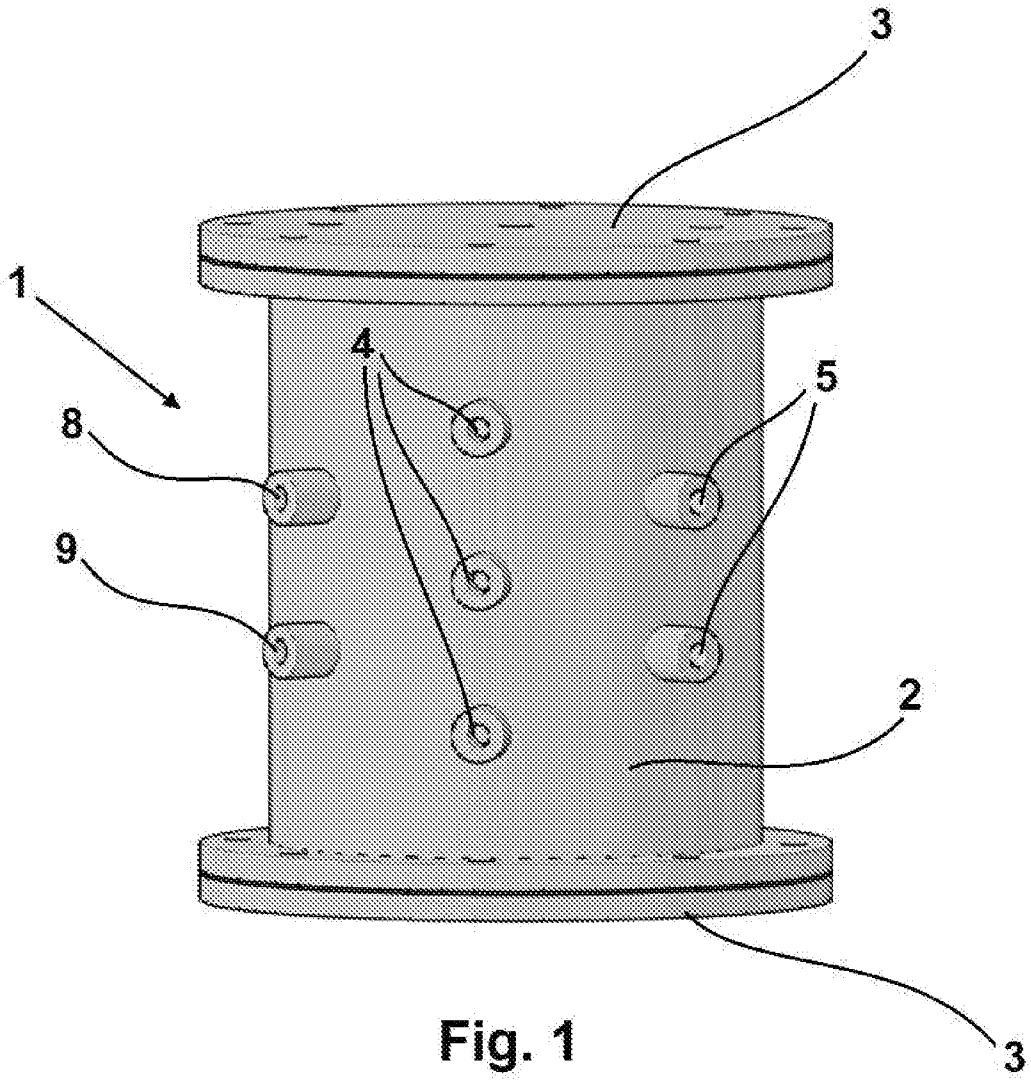


Fig. 1

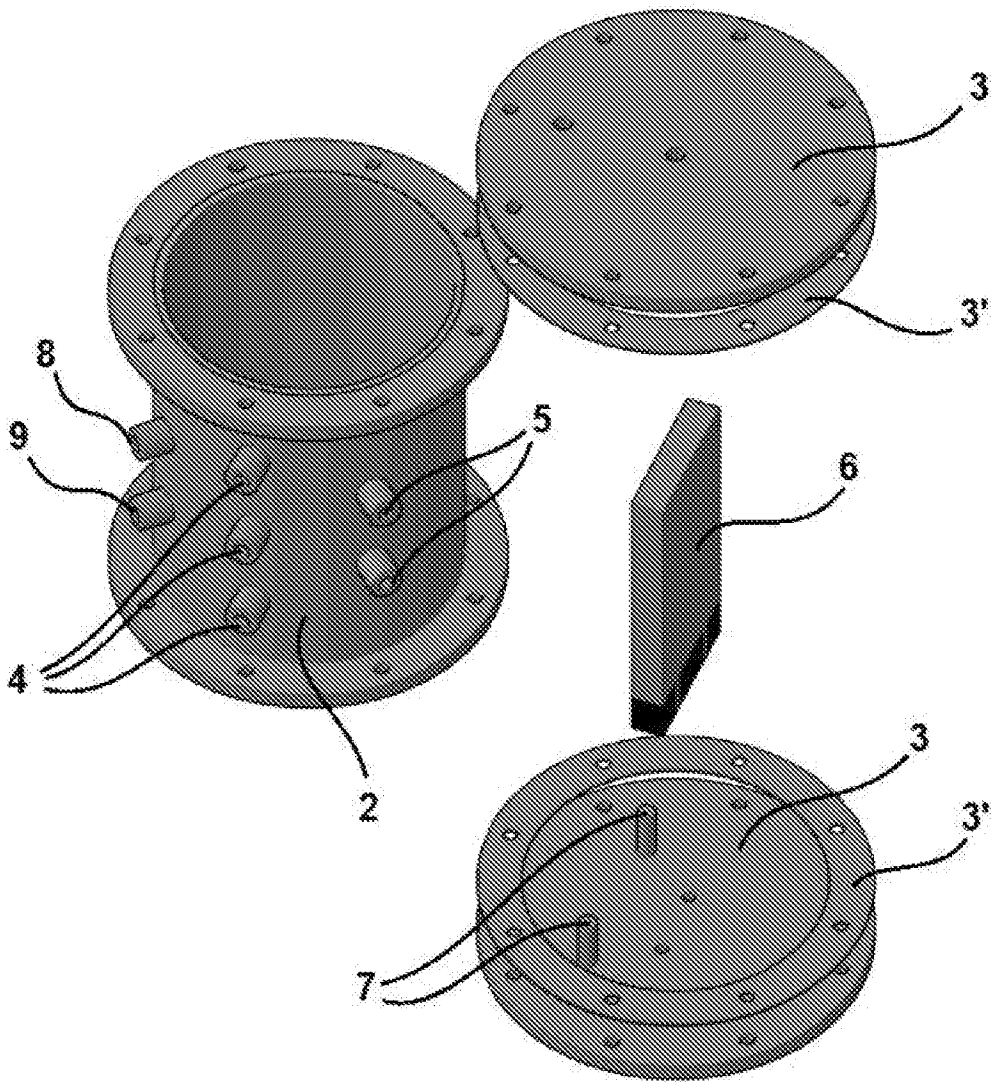
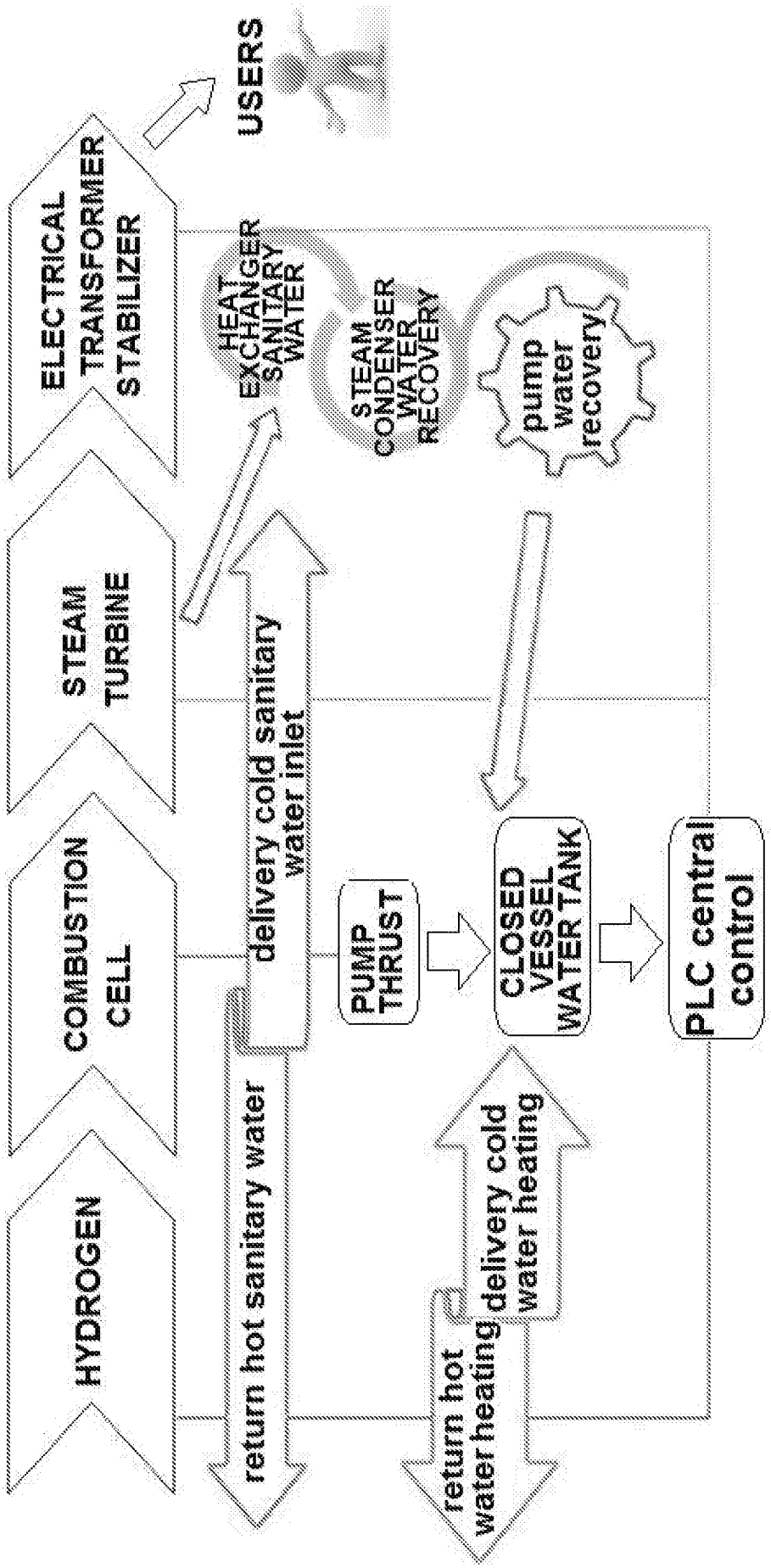


Fig. 2


USERS
ELECTRICAL TRANSFORMER STABILIZER
HEAT EXCHANGER SANITARY WATER
STEAM CONDENSER WATER RECOVERY
pump water recovery
STEAM TURBINE
delivery cold sanitary water inlet
COMBUSTION CELL
PUMP THRUST
CLOSED VESSEL WATER TANK
PLC central control
HYDROGEN
return hot sanitary water
return hot water heating
delivery cold water heating

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/055393

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23L7/00 F23C99/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23L F23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012/013289 A2 (LINDE AG [DE]; BIEGNER ANDRE [DE]; MAASS HANS-JUERGEN [DE]; MOSTERTZ M) 2 February 2012 (2012-02-02) page 8, line 15 - page 9, line 22; figure 1	1-3,5-12
Y	US 2011/027739 A1 (COLIN JEROME [FR] ET AL) 3 February 2011 (2011-02-03) paragraphs [0002], [0003], [0013], [0054] - [0056]	1-3,5-12
Y	US 2010/043433 A1 (KELLY PATRICK J [US]) 25 February 2010 (2010-02-25)	6,7,9
A	paragraphs [0014], [0015], [0033], [0051], [0055], [0057], [0077] - [0079], [0087] - [0093], [0100], [0103]; figures 3-7,15	1,10

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 November 2015	09/11/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Mougey, Maurice

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/055393

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/033963 A1 (BOSCH GMBH ROBERT [DE]; HOENIG GUENTER [DE]; MILLER FRANK [DE]) 22 April 2004 (2004-04-22) page 2, line 13 - line 17 page 8, line 35 - page 9, line 12 figure 1	5
A	US 2007/193537 A1 (MIYASAKA YOSHIO [JP]) 23 August 2007 (2007-08-23) paragraphs [0061], [0062]	1,2,10
A	US 2005/223711 A1 (GOLDMEER JEFFREY S [US] ET AL) 13 October 2005 (2005-10-13) paragraphs [0002], [0013], [0014], [0028] - [0030], [0033] - [0036]; figure 1	1,10,12
A	WO 2005/024301 A1 (GIACOMINI SPA [IT]; GIACOMINI LUCA [IT]) 17 March 2005 (2005-03-17) page 9, line 6 - line 25	1,10
A	US 5 761 896 A (DOWDY THOMAS E [US] ET AL) 9 June 1998 (1998-06-09) figures 1,2 column 2, line 61 - column 3, line 9 column 4, line 17 - line 54 column 5, line 20 - line 29 column 6, line 20 - column 7, line 18	1-12
A	WO 2009/019520 A2 (3R CARBON CAPTURE AND STORAGE [AU]; HARANGI ARPAD [HU]; SIKLOSI EDIT [] 12 February 2009 (2009-02-12) page 2, paragraph 2	1,10
A	GB 1 330 299 A (EXXON RESEARCH ENGINEERING CO) 12 September 1973 (1973-09-12) page 2, line 5 - line 42	1,10
A	EP 1 179 709 A2 (CALSONIC KANSEI CORP [JP]) 13 February 2002 (2002-02-13) paragraphs [0001], [0012], [0013]	1,5

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2015/055393

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012013289 A2	02-02-2012	DE 102010035487 A1	23-02-2012
		WO 2012013289 A2	02-02-2012
US 2011027739 A1	03-02-2011	CA 2675989 A1	16-10-2008
		EP 2129966 A2	09-12-2009
		FR 2913097 A1	29-08-2008
		JP 5331713 B2	30-10-2013
		JP 2010519501 A	03-06-2010
		KR 20090118036 A	17-11-2009
		RU 2009135815 A	10-04-2011
		US 2011027739 A1	03-02-2011
		WO 2008122707 A2	16-10-2008
US 2010043433 A1	25-02-2010	US 2010043433 A1	25-02-2010
		US 2010043435 A1	25-02-2010
		US 2010043640 A1	25-02-2010
		US 2010045034 A1	25-02-2010
		US 2010045042 A1	25-02-2010
		WO 2010021706 A1	25-02-2010
WO 2004033963 A1	22-04-2004	DE 10246231 A1	15-04-2004
		EP 1552219 A1	13-07-2005
		JP 2006501435 A	12-01-2006
		US 2006147859 A1	06-07-2006
		WO 2004033963 A1	22-04-2004
US 2007193537 A1	23-08-2007	CN 1946928 A	11-04-2007
		HK 1099067 A1	30-09-2010
		MY 140431 A	31-12-2009
		TW I257449 B	01-07-2006
		US 2007193537 A1	23-08-2007
		WO 2005121540 A1	22-12-2005
US 2005223711 A1	13-10-2005	NONE	
WO 2005024301 A1	17-03-2005	NONE	
US 5761896 A	09-06-1998	US 5761896 A	09-06-1998
		WO 9607019 A2	07-03-1996
WO 2009019520 A2	12-02-2009	AU 2008285305 A1	12-02-2009
		WO 2009019520 A2	12-02-2009
GB 1330299 A	12-09-1973	NONE	
EP 1179709 A2	13-02-2002	DE 60115785 T2	24-08-2006
		EP 1179709 A2	13-02-2002
		US 2003031971 A1	13-02-2003
		US 2005142507 A1	30-06-2005