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

(11) EP 3 091 204 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.11.2016 Bulletin 2016/45

(51) Int Cl.:
F01K 25/10 *(2006.01)*

(21) Application number: **16168704.1**

(22) Date of filing: **09.05.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **07.05.2015 ES 201530623**

(71) Applicant: **Pujol Latre, Maximo**
08242 Manresa (ES)

(72) Inventor: **Pujol Latre, Maximo**
08242 Manresa (ES)

(74) Representative: **Oficina Ponti, SLP**
C. de Consell de Cent 322
08007 Barcelona (ES)

(54) ELECTRICITY POWER GENERATION SYSTEM

(57) The invention comprises a first thermodynamic working circuit (1) employing carbon dioxide for the obtaining of energy by means of a power generator (8) of the system, characterised by the fact that said thermodynamic working circuit (1) is associated in parallel with a secondary ammonia absorption and evaporation circuit (2) which is sized to condense the carbon dioxide gas coming from the generator (8), said system featuring a device (5a,5b,5c) for the recovery of low-grade thermal energy (E) which is sized to evaporate ammonia from the solution of ammonia in the secondary circuit (2), a fraction of the low-grade thermal energy (E) captured by the device (5a,5b,5c) being susceptible to being used to superheat the carbon dioxide in the working circuit (1).

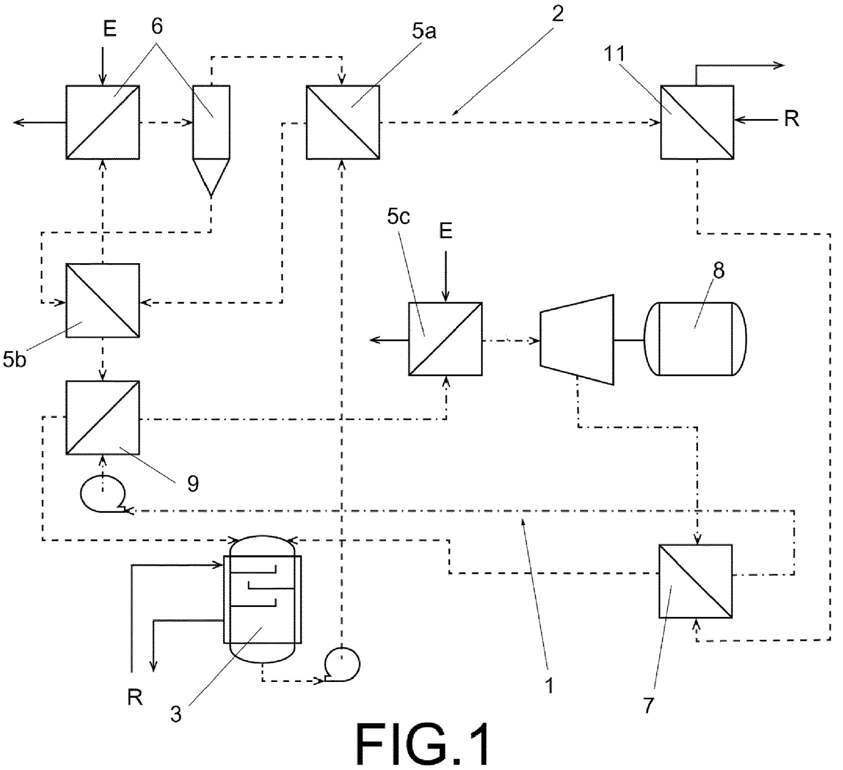

FIG.1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to a system for the production of electrical energy comprising a thermodynamic working circuit employing carbon dioxide to obtain energy by means of a generator.

Background of the invention

[0002] Systems for the production of energy employing carbon dioxide and ammonia as basic transport fluids for the generation of electricity are well known.

[0003] Patent DE19921336 describes a system for the production of energy comprising two thermodynamic circuits which operate together, each with a different transport fluid. One of the circuits operates with carbon dioxide and the other with ammonia gas. Each circuit features a heating means, a condenser and a compressor. The carbon dioxide circuit includes the electricity generating turbine, which is driven by the carbon dioxide itself, which acts as the motive fluid.

[0004] The system described by the aforementioned patent combines the two circuits to obtain electrical energy by means of a fluid (the carbon dioxide) which presents the advantage that it is harmless to the environment. Furthermore, carbon dioxide is a working fluid which condenses at a temperature of approximately 0°C; for this reason it is possible to utilise the cooling capacity of a parallel ammonia evaporation circuit to condense it.

[0005] In the system described, the carbon dioxide gas is heated, prior to its entry into the generator, by means of low-grade thermal energy. However, the energy yield of this system is still very low, as it requires the use of conventional compressors.

Description of the invention

[0006] The aim of the present invention is to provide a high-performance system for the obtaining of electrical energy, presenting the advantages to be described below.

[0007] In accordance with this aim, according to a first aspect, the present invention provides a system for the obtaining of electrical energy comprising a thermodynamic working circuit which employs carbon dioxide to obtain electrical energy by means of a generator, and which is characterised by the fact that the thermodynamic working circuit is associated in parallel with a secondary absorption and evaporation circuit of ammonia sized to condense, by means of a solution of ammonia in said circuit, the carbon dioxide gas arriving from a turbine associated with the generator, said system comprising a low-grade thermal energy recovery device sized to evaporate ammonia from the solution of ammonia in the secondary circuit, a fraction of the low-grade thermal energy captured by the device being susceptible to being used to evaporate the condensed carbon dioxide and to superheat the carbon dioxide gas in the working circuit.

[0008] In accordance with the same aim, according to a second aspect, the present invention provides an electricity generation unit or group comprising the system claimed for the obtaining of electrical energy by means of a generator coupled to the output shaft of a carbon dioxide expansion turbine.

[0009] The system claimed dispenses with conventional compressors and employs a parallel secondary circuit for the absorption and evaporation of ammonia to evaporate and condense the carbon dioxide. Furthermore, the system comprises a device for the recovery of low-grade thermal energy which enables the boosting of the physicochemical reaction which evaporates the ammonia gas from the solution of ammonia in the secondary circuit, significantly increasing the energy yield of the system.

[0010] The source of low-grade thermal energy recovered by the device may come from the residual heat of the exhaust gases of a motor or, for example, from the cooling of thermal power plants, on condition that these sources of heat surpass a temperature of 100°C.

[0011] Additionally, the system claimed presents the advantage of operating under low-risk technical conditions (between 1 bar and 12 bar for the ammonia gas); the possibilities of leaks of this gas are therefore practically non-existent. The carbon dioxide works at higher pressures, of up to 65 bar; however, in this case, being a fluid which is harmless to the environment, accidental leaks do not represent a problem.

[0012] Preferably, the secondary gas absorption and evaporation circuit comprises a first heat exchanger employing a cooling fluid to condense the ammonia gas coming from the solution of ammonia or ammoniacal solution in the second circuit, a second heat exchanger to evaporate the condensed ammonia by means of the thermal energy provided by the carbon dioxide at the outlet of the electrical generator, and an absorption column for the ammonia gas evaporated in the second heat exchanger.

[0013] Specifically, the second heat exchanger is sized to condense the carbon dioxide by means of the solution of ammonia arriving from the first heat exchanger, said second heat exchanger enabling the evaporation of the ammonia condensed in the first heat exchanger, by means of the thermal energy provided by the carbon dioxide at the outlet of the turbine associated with the electrical generator.

[0014] Advantageously, said secondary absorption and evaporation circuit comprises a third heat exchanger sized to evaporate the condensed carbon dioxide by means of the heat recovered by the solution of ammonia in contact with the recovery device. The ammonia solution outlet of the third heat exchanger is connected to an inlet of the ammonia absorption column.

[0015] In this third heat exchanger, the carbon dioxide evaporates while at the same time the solution of ammonia cools, which substantially improves the subsequent absorption of ammonia in the ammoniacal solution column.

[0016] The liquid carbon dioxide outlet from the second heat exchanger is connected to the carbon dioxide inlet of the third heat exchanger, while the ammonia gas outlet from said second heat exchanger is connected to another inlet of the ammonia gas absorption column.

[0017] Preferably, the low-grade thermal energy recovery device comprises heat exchangers associated with a distillation apparatus to evaporate, by means of low-grade thermal energy, a fraction of the ammonia gas from the solution of ammonia in the secondary absorption and evaporation circuit.

[0018] In this way, the energy recovered from low-grade heat sources is exploited to boost the absorption and evaporation cycle of the ammonia which condenses and evaporates the carbon dioxide of the working cycle. Thus, a system is obtained which enables the efficient exploitation of the low-grade thermal energy which to date is being discarded and released into the environment, causing environmental pollution problems.

[0019] Advantageously, the recovery device further comprises a second heat exchanger to use low-grade thermal energy to superheat the carbon dioxide gas at the inlet of the electrical generator or at the inlet of the turbine associated with the electrical generator.

[0020] In the system claimed, the working pressure of the ammonia is between 1 bar and 12 bar, and the working pressure of the carbon dioxide is between 30 bar and 65 bar. The concentration of ammonia gas in the solution of ammonia in the secondary absorption and evaporation circuit is between 35% and 45% by weight. However, if the temperature balance conditions vary, the concentration in the solution of ammonia would change.

[0021] In the present invention, "low-grade thermal energy" shall be understood, preferably, to be the thermal energy E derived from heat sources whose temperature does not surpass 150°C, advantageously industrial vapours and gases. The system claimed enables the exploitation of this thermal energy, which is currently discarded and released into the environment.

Brief description of the drawings

[0022] For a better understanding of that which is described herein, a set of drawings is attached which, schematically and by way of a non-limiting example only, represent a practical case of an embodiment.

Figure 1 is a schematic diagram of the operating principle of the system.

Figure 2 is a schematic diagram of the ammonia absorption column.

Figure 3 is a schematic representation of a high-performance heat exchanger which evaporates or condenses the carbon dioxide by means of the solution of ammonia or ammoniacal solution of the secondary circuit.

Description of a preferred embodiment

[0023] An embodiment of the system, employing a secondary circuit of ammonia diluted in water working at 25°C to operate absorption, and at 100°C to operate evaporation, is described below.

[0024] In the embodiment described, the carbon dioxide circuit 1 reaches a maximum working pressure of 65 bar at 25°C in a gaseous state, and a pressure of 35 bar at 0°C during the expansion phase, in a liquid state.

[0025] As has been mentioned, in order to reach the working conditions of the carbon dioxide, a secondary circuit 2 is employed, with a solution of ammonia and water in an absorption and evaporation cycle working at a pressure of 2.5 bar at a temperature of -15°C, and at 12 bar at a temperature of 100°C.

[0026] The secondary circuit 2 features an absorption column 3 through which the solution of ammonia circulates from an inlet 3a to an outlet 3b. The reaction temperature is maintained by means of a cooling fluid 3c, for example water. The reaction time within the column 3 is that which is sufficient for the solution to reach a concentration of ammonia of 45% by weight at a working pressure of 2.5 bar at a temperature of 25°C, entailing a 10% increase in the concentration of ammonia gas in the solution in the secondary circuit 2.

[0027] Once the solution of ammonia is concentrated, an injector pump sends it at a pressure of 12 bar to a recovery device where this solution of ammonia is heated by means of a fraction of the low-grade thermal energy, enabling the separation of a fraction of the ammonia gas.

[0028] As has been mentioned in the description of the invention, the recovery device includes a number of heat exchangers 5a, 5b, which are associated with an ammonia distillation apparatus 6. In this way, the physicochemical reaction which evaporates the gas from the solution of ammonia in the secondary circuit 2 is boosted. The same device also includes another heat exchanger 5c which heats the carbon dioxide gas to 100°C at the inlet of the generator 8 by means of a fraction of the thermal energy E recovered.

[0029] In addition to the absorption column 3, the secondary circuit 2 includes;

- a first heat exchanger 11 sized to condense the ammonia gas coming from the solution by means of a cooling fluid R (for example, water),
- a second heat exchanger 7, to evaporate the condensed ammonia by means of the thermal energy provided by the carbon dioxide at the outlet of the electrical generator 8, and
- a third heat exchanger 9 to evaporate the condensed carbon dioxide, by means of the heat recovered by the solution of ammonia in contact with the recovery device.

[0030] Then heat exchangers 7, 9 of the secondary circuit 2 which evaporate and condense the carbon dioxide are configured in such a way that they force the carbon dioxide to circulate in the space between two concentric tubes 10a, 10b disposed very close together in order to ensure the heating or cooling the gas throughout its volumetric mass. The liquid ammonia, or solution of ammonia or ammoniacal solution, circulates through the interior of the tubes 10a and the exterior of the tubes 10b.

[0031] At the outlet of the second heat exchanger 7, the condensed carbon dioxide is at a working pressure of 35 bar at a temperature of 0°C, while at the same heat exchanger 7, the evaporated ammonia gas exits at a working pressure of 2.5 bar and at a temperature of-15°C.

[0032] The third heat exchanger 9 receives the liquid carbon dioxide, injected by a second pump, and evaporates it to obtain carbon dioxide gas at a pressure of 65 bar and a temperature of 25°C, while at the same heat exchanger 9, the solution of ammonia is maintained at a pressure of 12 bar, being cooled to 20°C prior to its ingress into the absorption column 3. In this way, the subsequent absorption of ammonia in the absorption column 3 is enhanced.

[0033] In an experimental test of the system, the flowrate of carbon dioxide in the working circuit 1 employed is 150 Kg/h, while the flowrate of the solution of ammonia in the secondary circuit 2 is 30 Kg/h, with a 10% difference in the concentration of ammonia during the cycle, which entails a circulation flowrate of 300 Kg/h of the solution of ammonia.

[0034] With these data;

- The external energy input necessary for the evaporation of the ammonia gas from the solution exiting the distillation apparatus 6, and for the heating of the carbon dioxide at the inlet of the generator 8, is 9,480 Kcal/h and 2,273 Kcal/h respectively, totalling 11,752 Kcal/h.

- The heat input necessary for the condensation of the carbon dioxide gas subsequent to expanding is 6,050 Kcal/h, with an estimated condensation percentage of carbon dioxide gas of 27%, and

- The heat input necessary for the evaporation and heating to 100°C of the carbon dioxide is 11,280 Kcal/h.

[0035] Therefore, the energy necessary to close the cycle of the working circuit 1 is 5,230 Kcal/h, the low-grade thermal energy input being 11,752 Kcal/h, implying a theoretical thermal efficiency of the system estimated at 44.5%.

[0036] In spite of the fact that reference has been made to a specific embodiment of the invention, it is evident to a person skilled in the art that the system described is susceptible to numerous variations and modifications, and that all the details mentioned may be substituted by other technically equivalent details, without departing from the scope of protection defined by the attached claims.

Claims

1. A system for the production of electrical energy, comprising a first thermodynamic working circuit (1) which employs carbon dioxide to obtain energy by means of the system energy generator (8), **<u>characterised</u> in that** said thermodynamic working circuit (1) is associated in parallel with a secondary absorption and evaporation circuit (2) of ammonia sized to condense, by means of a solution of ammonia of the secondary circuit (2), the carbon dioxide gas coming from a turbine associated with the generator (8), said system further comprising a low-grade thermal energy (E) recovery device (5a,5b,5c), sized to evaporate ammonia from the solution of ammonia in the secondary circuit (2), a fraction of the low-grade thermal energy (E) captured by said device (5a,5b,5c) being susceptible to being used to evaporate the condensed carbon dioxide and to superheat the carbon dioxide gas in the working circuit (1).

2. A system as claimed in claim 1, where said secondary circuit (2) of absorption and evaporation of gas comprises a first heat exchanger (11) for the condensation, by means of a cooling fluid (R), of the evaporated ammonia gas coming from the solution of ammonia in the secondary circuit (2), and a second heat exchanger (7) sized to condense the carbon dioxide by means of the solution of ammonia arriving from said first heat exchanger (11), enabling said second heat exchanger (7) to evaporate the ammonia condensed in the first heat exchanger (11) by means of the thermal energy provided by the carbon dioxide at the outlet of the turbine associated with the electrical generator (8), said secondary circuit (2) comprising an absorption column (3) of the ammonia gas evaporated in the second heat exchanger (7).

3. A system as claimed in claim 2, where said absorption and evaporation secondary circuit (2) comprises a third heat exchanger (9) sized to evaporate the condensed carbon dioxide by means of the heat recovered by the solution of ammonia in contact with the device (5a,5b,5c).

4. A system as claimed in claim 3, where the outlet for the solution of ammonia from said third heat exchanger (9) is connected to an inlet of the ammonia gas absorption column (3).

5. A system as claimed in claim 4, where the liquid carbon dioxide outlet of the second heat exchanger (7)

is connected to the carbon dioxide inlet of the third heat exchanger (9), while the ammonia gas outlet of the same second heat exchanger (7) is connected to an inlet of the ammonia gas absorption column (3).

6. A system as claimed in any of the preceding claims, where said low-grade thermal energy (E) recovery device comprises heat exchangers (5a,5b) associated with a distillation apparatus (6) to evaporate, by means of low-grade thermal energy (E), a fraction of the ammonia gas from the solution of ammonia in the secondary absorption and evaporation circuit (2).

7. A system as claimed in claim 6, where said device further comprises a heat exchanger (5c) to superheat, by means of low-grade thermal energy (E), the carbon dioxide gas at the inlet of the turbine associated with the electrical generator (8).

8. A system for the production of energy, as claimed in any of claims 1 to 7, where the working pressure of the ammonia gas is between 1 bar and 12 bar and the working pressure of the carbon dioxide gas is between 30 bar and 65 bar.

9. A system for the production of energy, as claimed in claim 1, where the concentration of ammonia gas in the solution of ammonia in the secondary absorption and evaporation circuit (2) is between 35% and 45% by weight.

10. A system for the production of energy, as claimed in any of the preceding claims, where said low-grade thermal energy (E) comes from heat sources with a temperature not surpassing 150°C.

11. An electricity-generating unit comprising the system as claimed in any of claims 1 to 10 for the obtaining of electrical energy by means of a generator coupled to the output shaft of a carbon dioxide expansion turbine.

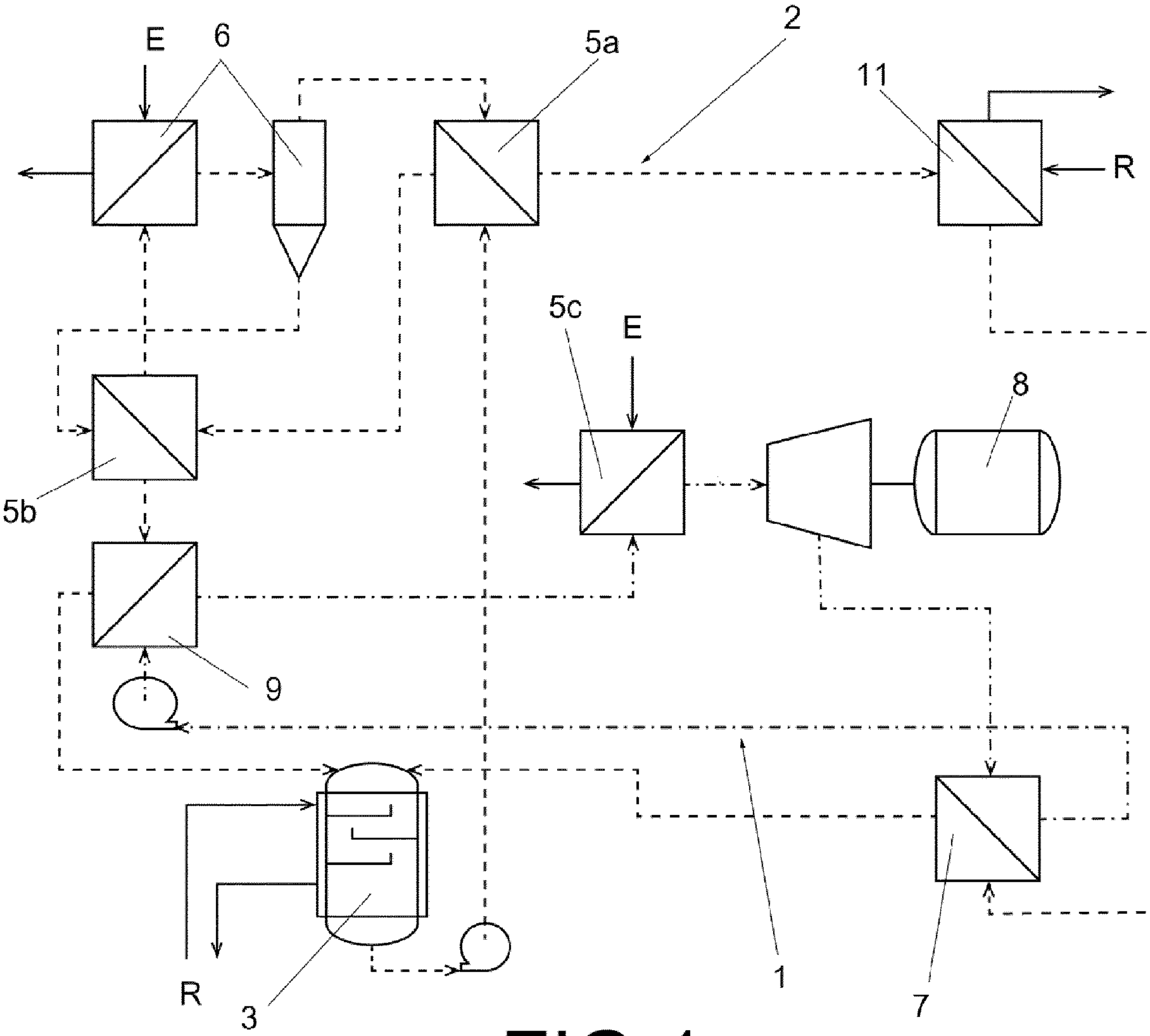

FIG.1

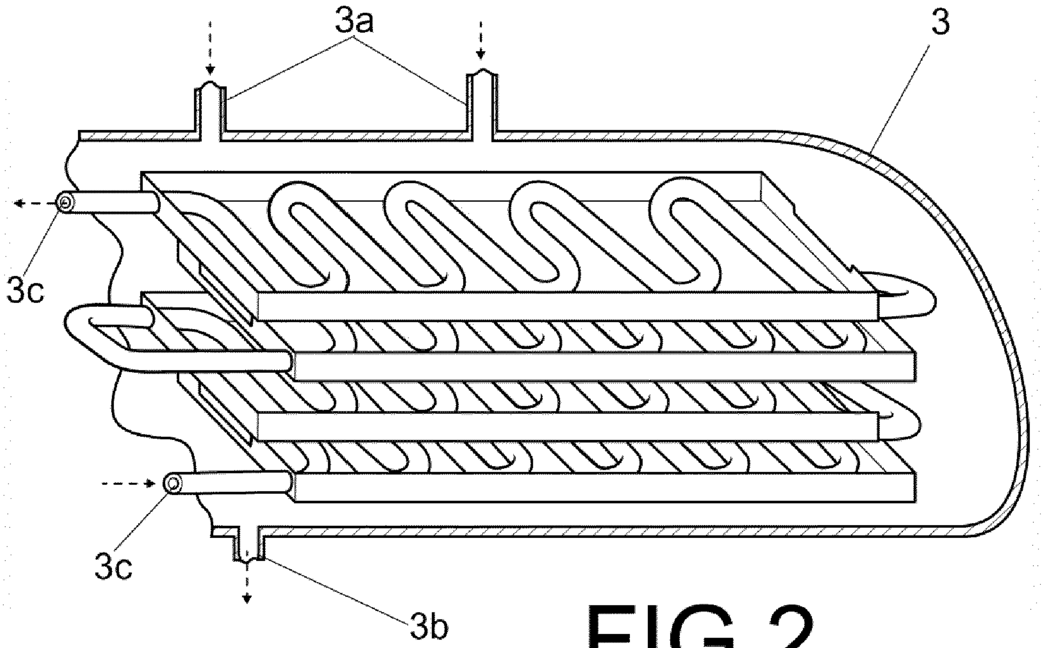

FIG.2

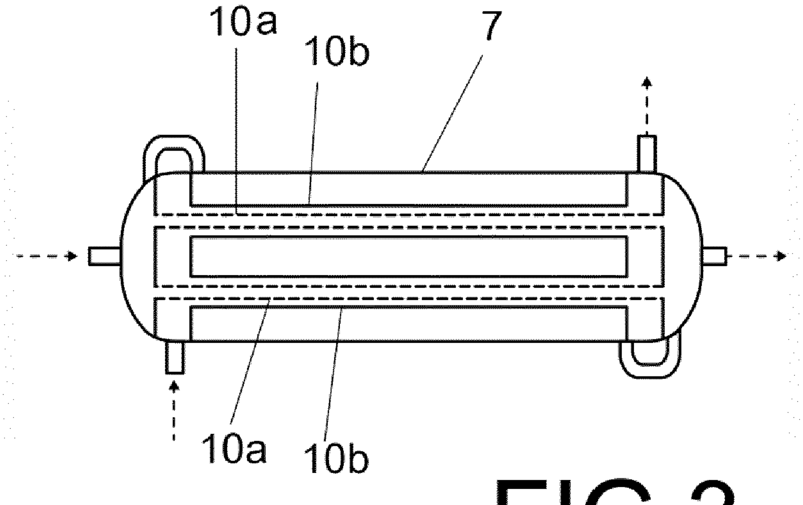

FIG.3

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 16 16 8704

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 447 483 A2 (GEN ELECTRIC [US]) 2 May 2012 (2012-05-02) * paragraph [0015] - paragraph [0051]; claims; figures * * abstract *	1-11	INV. F01K25/10
A,D	DE 199 21 336 A1 (HOLDER K [DE]; BLONDEAU JEAN [DE]) 7 December 2000 (2000-12-07) * column 3, line 12 - column 4, line 10; claims; figure * * abstract *	1-11	
A	FR 2 916 225 A1 (GUERIN BARTHELEMY [FR]) 21 November 2008 (2008-11-21) * page 2, line 7 - page 6, last line; claims; figure * * abstract *	1-11	
A	WO 2014/194400 A1 (HER MAJESTY THE QUEEN IN RIGHT OF CANADA AS REPRESENTED BY THE MINISTE) 11 December 2014 (2014-12-11) * page 7, line 28 - page 12, line 24; claims; figures * * abstract *	1-11	

TECHNICAL FIELDS SEARCHED (IPC)

F01K

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	29 September 2016	Zerf, Georges

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 16 8704

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-09-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2447483 A2	02-05-2012	CA 2755034 A1	29-04-2012
		CN 102454441 A	16-05-2012
		EP 2447483 A2	02-05-2012
		JP 5906058 B2	20-04-2016
		JP 2012097742 A	24-05-2012
		KR 20120047795 A	14-05-2012
		RU 2011143401 A	10-05-2013
		US 2012102996 A1	03-05-2012
DE 19921336 A1	07-12-2000	NONE	
FR 2916225 A1	21-11-2008	NONE	
WO 2014194400 A1	11-12-2014	CA 2885583 A1	11-12-2014
		US 2015267567 A1	24-09-2015
		WO 2014194400 A1	11-12-2014

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- DE 19921336 **[0003]**