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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 February 2016 (04.02.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/018851 Al

(51) International Patent Classification:
F24J1/00 (2006.01)

(21) International Application Number:
PCT/US2015/042353

(22) International Filing Date:
28 July 2015 (28.07.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/999,582 1 August 2014 (01.08.2014) US

(72) Inventor; and
(71) Applicant : ROSSI, Andrea [US/US]; 1331 Lincoln Road, Apt 601, Miami Beach, Florida 33139 (US).

(74) Agent: OCCHIUTI, Frank; Occhiuti & Rohlicek LLP, 321 Summer Street, Boston, Massachusetts 02210 (US).

(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))*

(54) Title: FLUID HEATER

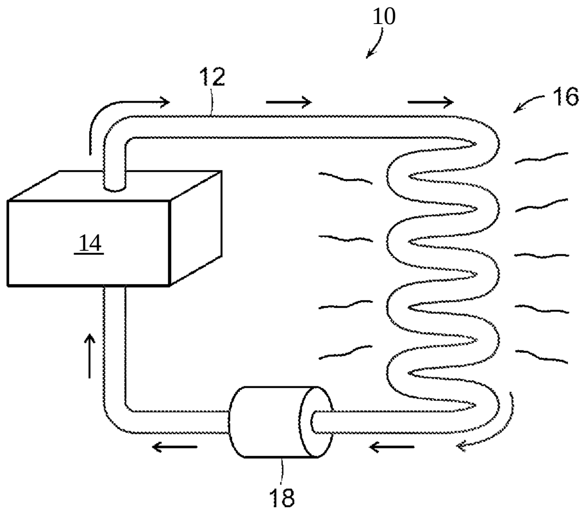

FIG. 1

(57) Abstract: An apparatus for heating fluid includes a tank for holding fluid to be heated, and a fuel wafer in fluid communication with the fluid. The fuel wafer includes a fuel mixture including reagents and a catalyst, and an electrical resistor or other heat source in thermal communication with the fuel mixture and the catalyst.

WO 2016/018851 A1

FLUID HEATER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the August 1, 2014 priority date of U.S. Application No. 61/999,582, the contents of which are incorporated herein by reference.

FIELD OF DISCLOSURE

This disclosure relates to heat transfer systems, and in particular to devices for transferring heat to a fluid.

BACKGROUND

Many heat transfer systems use hot fluids as a heat transfer medium. Such systems include a heat generator for generating heat, a heat transfer medium in thermal communication with the energy source, and a pump to move the heated medium to wherever the heat is needed. Because of its high heat capacity and its abundance, a common heat transfer fluid is water, both in its liquid and gas phase.

A variety of heat generators are in common use. For instance, in nuclear power plants, nuclear fission provides energy for heating water. There also exist solar water heaters that use solar energy. However, most heat transfer sources rely on an exothermal chemical reaction, and in particular, on combustion of some fuel.

SUMMARY

In one aspect, the invention features an apparatus for heating fluid, the apparatus including a tank for holding fluid to be heated, and a fuel wafer in fluid communication with the fluid, the fuel wafer including a fuel mixture including reagents and a catalyst, and a heat source or ignition source in thermal communication with the fuel mixture and the catalyst. The heat source or ignition source can be an electrical resistor, or a heat source that relies on either heat from combustion, such as combustion of natural gas, or a heat source that relies on inductive heating.

Among the embodiments are those in which the fuel mixture includes lithium and lithium aluminum hydride, those in which the catalyst includes a group 10 element, such as nickel in powdered form, or in any combination thereof.

In other embodiments, the catalyst in powdered form, has been treated to enhance its porosity. For example, the catalyst can be nickel powder that has been treated to enhance porosity thereof. The apparatus can also include an electrical energy source, such as a voltage source and/or current source in electrical communication with the heat source.

Among the other embodiments are those in which the fuel wafer includes a multi-layer structure having a layer of the fuel mixture in thermal communication with a layer containing the heat source.

In yet other embodiments, the fuel wafer includes a central heating insert and a pair of fuel inserts disposed on either side of the heating insert.

A variety of tanks can be used. For example, in some embodiments, the tank includes a recess for receiving the fuel wafer therein. Among these are embodiments in which the tank further includes a door for sealing the recess. In yet other embodiments the tank includes a radiation shield.

Also included among the embodiments are those that further include a controller in communication with the voltage source. Among these are controllers that are configured to vary the voltage in response to temperature of the fluid to be heated.

In another aspect, the invention features an apparatus for heating a fluid, the apparatus including means for containing the fluid, and means for holding a fuel mixture containing a catalyst and a reagent, and means for initiating a reaction sequence mediated by the catalyst to cause an exothermic reaction.

Another aspect of the invention is a composition of matter for generating heat, the composition including a mixture of porosity-enhanced nickel powder, lithium powder, and lithium aluminum powder. A heat source in thermal communication with the mixture can be used for initiating a nickel catalyzed exothermic reaction.

Yet another aspect features a for generating heat. The composition includes a fuel mixture and a catalyst. The catalyst comprises a group 10 element.

Embodiments include those in which the catalyst comprises nickel. Among these are embodiments in which the nickel is in the form of nickel powder and those in which the nickel powder has been treated to enhance porosity thereof .

Another aspect of the invention is a method of heating a fluid, the method including placing a mixture of nickel powder, lithium powder, and lithium aluminum hydride in thermal communication with the fluid; and heating the mixture, thereby initiating an exothermic reaction in the mixture .

These and other features of the invention will be apparent from the following detailed description and the accompanying figures, in which:

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 shows a heat transfer system having a heat source ;

FIG. 2 is a cut-away view of the heat source in FIG. 1 ;

FIG. 3 is a cross-section of the wafer for use in the heat source of FIG. 2 ;

FIG. 4 shows an exemplary resistor in the central layer of the wafer shown in FIG. 3 .

FIG. 5 shows the heat source of FIG. 1 operating with a conventional furnace.

FIG. 6 shows plural heat sources like that in FIG. 2 connected in series.

FIG. 7 shows plural heat sources like that in FIG. 2 connected in parallel.

DETAILED DESCRIPTION

Referring to FIG. 1 , a heat transfer system **10** includes a pipe **12** for transporting a heated fluid in a closed loop between a heat source **14** and a thermal load **16**. In most cases, for example where there is hydraulic resistance to be overcome, a pump **18** propels the heated fluid. However, in some cases, such as where the heated fluid is steam, the fluid's own pressure is sufficient to propel the fluid. A typical thermal load **16** includes radiators such as those commonly used for heating interior spaces .

As shown in FIG. 2, the heat source **14** is a tank **20** having a lead composite shield, an inlet **22** and an outlet **24**, both of which are connected to the pipe **12**. The interior of the tank **20** contains fluid to be heated. In many cases, the fluid is water. However, other fluids can be used. In addition, the fluid need not be a liquid fluid but can also be a gas, such as air.

The tank **20** further includes a door **26** that leads to a receptacle **28** protruding into the tank **20**. Radiating fins **30** protrude from walls of the receptacle **28** into the tank **20**. To maximize heat transfer, the receptacle **28** and the fins **30** are typically made of a material having high thermal conductivity, such as metal. A suitable metal is one not subject to corrosion, such as stainless steel.

The receptacle **28** holds a multi-layer wafer **32** for generating heat. A voltage source **33** is connected to the wafer **32**, and a controller **35** for controlling the voltage source **33** in response to temperature of fluid in the tank **12** as sensed by a sensor **37**.

As shown in FIG. 3, the multilayer fuel wafer **32** includes a heating section **34** sandwiched between two fuel sections **36**, **38**. The heating section **34** features a central layer **40** made of an insulating material, such as mica, that supports a resistor **42**.It should be noted that other heating sources can be used, including heat sources that rely on combustion of, for example, natural gas, as well as heat sources that rely on electrical induction. The use of gas thus avoids the need to have a source of electrical energy for initiating the reaction.

FIG. 4 shows an exemplary central layer **40** having holes **44** through which a resistive wire **42** has been wound. This resistive wire **42** is connected to the voltage source **33**. First and second insulating layers **46**, **48**, such as mica layers, encase the central layer **40** to provide electrical insulation from the adjacent fuel sections **36**, **38**.

Each fuel section **36**, **38** features a pair of thermally conductive layers **50**, **52**, such as steel layers. Sandwiched between each pair of conductive layers **50**, **52** is a fuel layer **54** that contains a fuel mixture having nickel, lithium, and lithium aluminum hydride $LiAlH_4$ ("LAH"), all in powdered form. Preferably, the nickel has been treated to increase its porosity, for example by heating the nickel powder to for times and temperatures selected to superheat any water present in micro-cavities that are inherently in each particle of nickel powder. The resulting steam pressure causes explosions that create larger cavities, as well as additional smaller nickel particles.

The entire set of layers is welded together on all sides to form a sealed unit. The size of the wafer **32** is not important to its function. However, the wafer **32** is easier to handle if it is on the order of 1/3 inch thick and 12 inches on each side. The steel layers **50**, **52** are typically 1 mm thick, and the mica layers **40**, **48**, which are covered by a protective polymer coating, are on the order of 0.1 mm thick. However, other thicknesses can also be used .

In operation, a voltage is applied by the voltage source **33** to heat the resistor **42**. Heat from the resistor **42** is then transferred by conduction to the fuel layers **54**, where it initiates a sequence of reactions, the last of which is reversible. These reactions, which are catalyzed by the presence of the nickel powder, are:

$$3LiAlH_4 \rightarrow Li_3AlH_s + 2A1 + 3H_2$$

$$2Li_3AlH_s \rightarrow 6LiH + 2A1 + 3H_2$$

$$2LiH + 2A1 \rightarrow 2LiAl + H_2$$

Once the reaction sequence is initiated, the voltage source **33** can be turned off, as the reaction sequence is self-sustaining. However, the reaction rate may not be constant. Hence, it may be desirable to turn on the voltage source **33** at certain times to reinvigorate the reaction. To determine whether or not the voltage source **33** should be turned on, the temperature sensor **37** provides a signal to the controller **35**, which then determines whether or not to apply a voltage in response to the temperature signal. It has been found that after the reaction has generated approximately 6 kilowatt hours of energy, it is desirable to apply approximately 1 kilowatt hour of electrical energy to reinvigorate the reaction sequence.

Eventually, the efficiency of the wafer **32** will decrease to the point where it is uneconomical to continually reinvigorate the reaction sequence. At this point, the wafer **32** can simply be replaced. Typically, the wafer **32** will sustain approximately 180 days of continuous operation before replacement becomes desirable.

The powder in the fuel mixture consists largely of spherical particles having diameters in the nanometer to micrometer range, for example between 1 nanometer and 100 micrometers. Variations in the ratio of reactants and catalyst tend to govern reaction rate and are not critical. However, it has been found that a suitable mixture would include a starting mixture of 50% nickel, 20% lithium, and 30% LAH. Within this mixture, nickel acts as a catalyst for the reaction, and is not itself a reagent. While nickel is particularly useful because of its relative abundance, its function can also be carried out by other elements in column 10 of the periodic table, such as platinum or palladium.

FIGS. 5-7 show a variety of ways to connect the heat source **14** in FIG. 1.

In FIG. 5, the heat source **14** is placed downstream from a conventional furnace **56**. In this case, the controller **35** is optionally connected to control the conventional furnace. As a result, the conventional furnace **56** will remain off unless the output temperature of the heat source **14** falls below some threshold, at which point the furnace **56** will start. In this configuration, the conventional furnace **56** functions as a back-up unit.

In FIG. 6, first and second heat sources **58**, **60** like that described in FIGS. 1-4 are connected in series. This configuration provides a hotter output temperature than can be provided with only a single heat source **58** by itself. Additional heat sources can be added in series to further increase the temperature.

In FIG. 7, first and second heat sources **62**, **64** like that described in FIGS. 1-4 are connected in parallel. In this configuration, the output volume can be made greater than what could be provided by a single heat transfer unit by itself. Additional heat transfer units can be added in parallel to further increase volume.

In one embodiment, the reagents are placed in the reaction chamber at a pressure of 3-6 bar and a temperature of from 400 C to 600 C. An anode is placed at one side of the reactor and a cathode is placed at the other side of the reactor. This accelerates electrons between them to an extent sufficient to have very high energy, in excess of 100 KeV. Regulation of the electron energy can be carried out by regulating the electric field between the cathode and the anode.

Having described the invention, and a preferred embodiment thereof, what I claim as new and secured by letters patent is:

CLAIMS

1. An apparatus for heating fluid, said apparatus comprising a tank for holding fluid to be heated, and a fuel wafer in fluid communication with said fluid, said fuel wafer including a fuel mixture including reagents and a catalyst, and an ignition source in thermal communication with said fuel mixture and said catalyst, wherein the ignition source is selected from the group consisting of an induction heater, an electrical resistor, a heater that relies on natural gas combustion, and a heater that relies on combustion of fuel.

2. The apparatus of claim 1, wherein said ignition source comprises an electrical resistor.

3. The apparatus of claim 1, wherein said ignition source comprises an induction heater.

4. The apparatus of claim 1, wherein said ignition source obtains heat from combustion of natural gas .

5. The apparatus of claim 1, wherein said fuel mixture comprises lithium and lithium aluminum hydride .

6. The apparatus of claim 1, wherein said catalyst comprises nickel powder.

7. The apparatus of claim 1, wherein said nickel powder has been treated to enhance porosity

thereof.

8. The apparatus of claim **1**, wherein said catalyst comprises a group 10 element.

9. The apparatus of claim **1**, further comprising a voltage source in electrical communication with said ignition source.

10. The apparatus of claim **2**, further comprising a voltage source in electrical communication with said ignition source.

11. The apparatus of claim **1**, wherein said fuel wafer comprises a multi-layer structure having a layer of said fuel mixture in thermal communication with a layer containing said ignition source.

12. The apparatus of claim **2**, wherein said fuel wafer comprises a multi-layer structure having a layer of said fuel mixture in thermal communication with a layer containing said ignition source.

13. The apparatus of claim **1**, wherein said fuel wafer comprises a central heating insert and a pair of fuel inserts disposed on either side of said heating insert.

14. The apparatus of claim **1**, wherein said tank comprises a recess for receiving said fuel wafer therein.

15. The apparatus of claim **14**, wherein said tank further comprises a door for sealing said recess.

16. The apparatus of claim 1, wherein said tank comprises a radiation shield.

17. The apparatus of claim 9, further comprising a controller in communication with said voltage source .

18. The apparatus of claim 17, wherein said controller is configured to cause vary said voltage in response to temperature of said fluid to be heated.

19. The apparatus of claim 2, wherein said tank is configured for holding fluid to be heated, wherein said fuel wafer is configured to be in thermal communication with said fluid, wherein said resistor is configured to be coupled to a voltage source, wherein said apparatus further comprises a controller in communication with said voltage source, and a temperature sensor, wherein said fuel mixture comprises lithium, and lithium aluminum hydride, wherein said catalyst comprises a group 10 element, wherein said controller is configured to monitor a temperature from said temperature sensor, and, based at least in part on said temperature, to reinvigorate a reaction in said fuel mixture, wherein reinvigorating said reaction comprises varying a voltage of said voltage source.

20. The apparatus of claim 19, wherein said catalyst comprises nickel powder.

21. The apparatus of claim 20, wherein said nickel powder has been treated to enhance porosity thereof.

22. The apparatus of claim 19, wherein said fuel wafer comprises a multi-layer structure having a layer of said fuel mixture in thermal communication with a layer containing said electrical resistor.

23. The apparatus of claim 19, wherein said fuel wafer comprises a central heating insert and a pair of fuel inserts disposed on either side of said heating insert.

24. The apparatus of claim 19, wherein said tank comprises a recess for receiving said fuel wafer therein.

25. The apparatus of claim 24, wherein said tank further comprises a door for sealing said recess.

26. The apparatus of claim 19, wherein said tank comprises a radiation shield.

27. The apparatus of claim 19, wherein said reaction in said fuel mixture is at least partially reversible.

28. The apparatus of claim 27, wherein said reaction comprises reacting lithium hydride with aluminum to yield hydrogen gas.

29. An apparatus for heating a fluid, said apparatus comprising means for containing said fluid, and means for holding a fuel mixture containing a catalyst and a reagent, and means for initiating a reaction sequence mediated by said catalyst to cause an exothermic reaction.

30. The apparatus of claim **29**, wherein said catalyst that comprises a group 10 element and a reagent comprises lithium and lithium aluminum hydride, said apparatus further comprising means for periodically reinvigorat ing said reaction sequence .

31. A composition of matter for generating heat, said composition comprising a mixture of porosity-enhanced nickel powder, lithium powder, and lithium aluminum powder.

32. A composition of matter for generating heat, said composition comprising a fuel mixture and a catalyst, said catalyst comprising a group 10 element .

33. The composition of claim **32**, wherein said catalyst comprises nickel.

34. The composition of claim **32**, wherein said catalyst comprises nickel powder.

35. The composition of claim **34**, wherein said nickel powder has been treated to enhance porosity thereof .

36. A method of heating a fluid, said method comprising placing a mixture of nickel powder, lithium powder, and lithium aluminum hydride in thermal communication with said fluid; and heating said mixture, thereby initiating an exothermic reaction in said mixture.

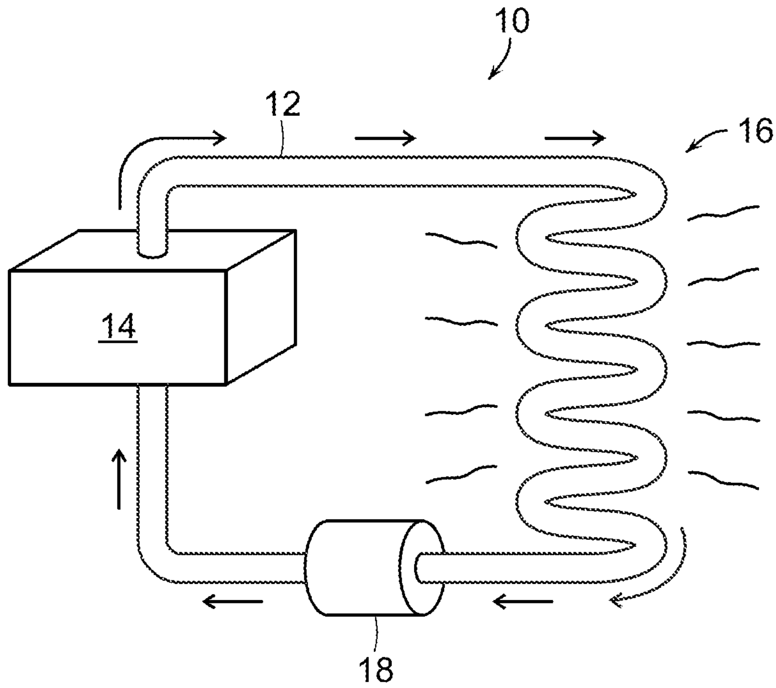

FIG. 1

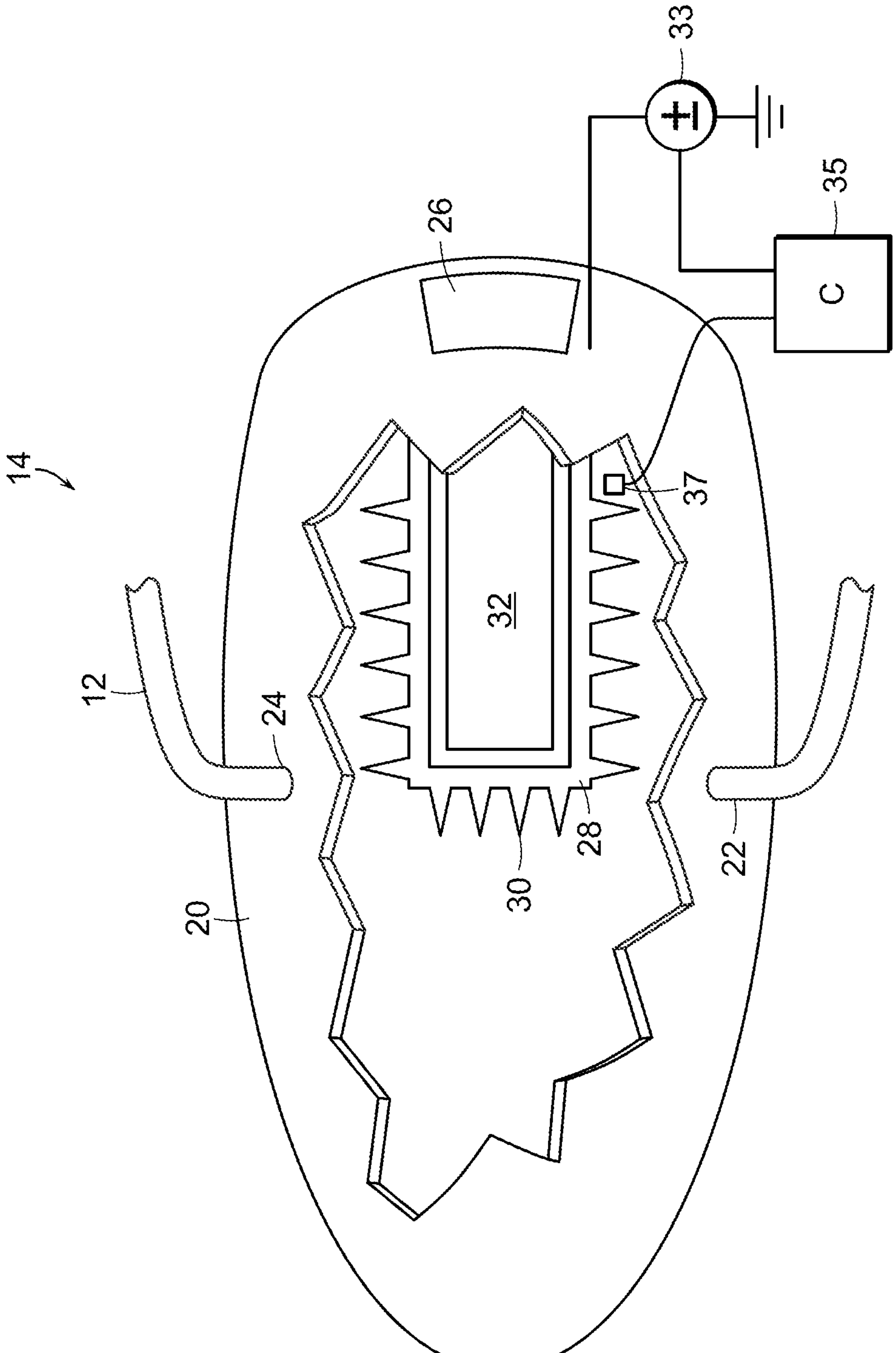

FIG. 2

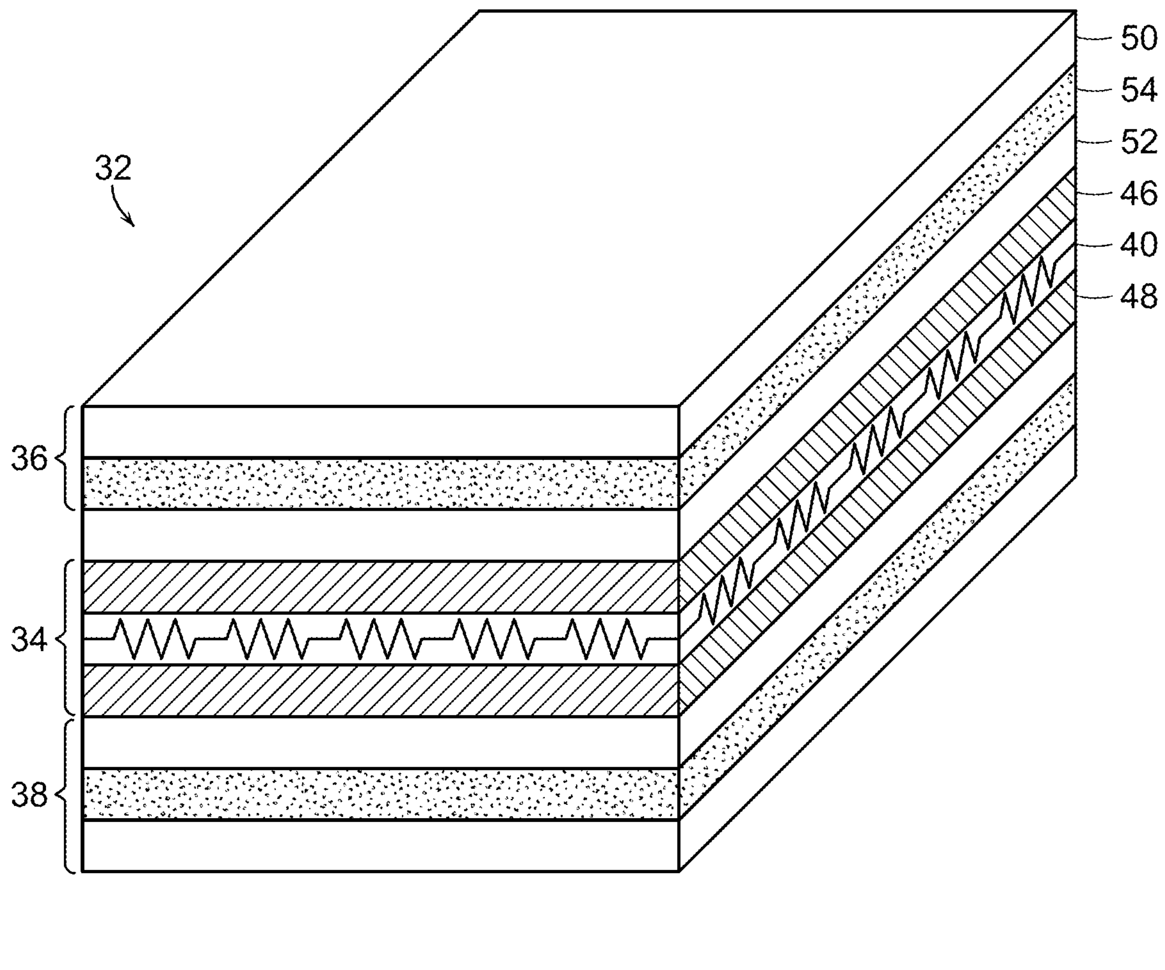

FIG. 3

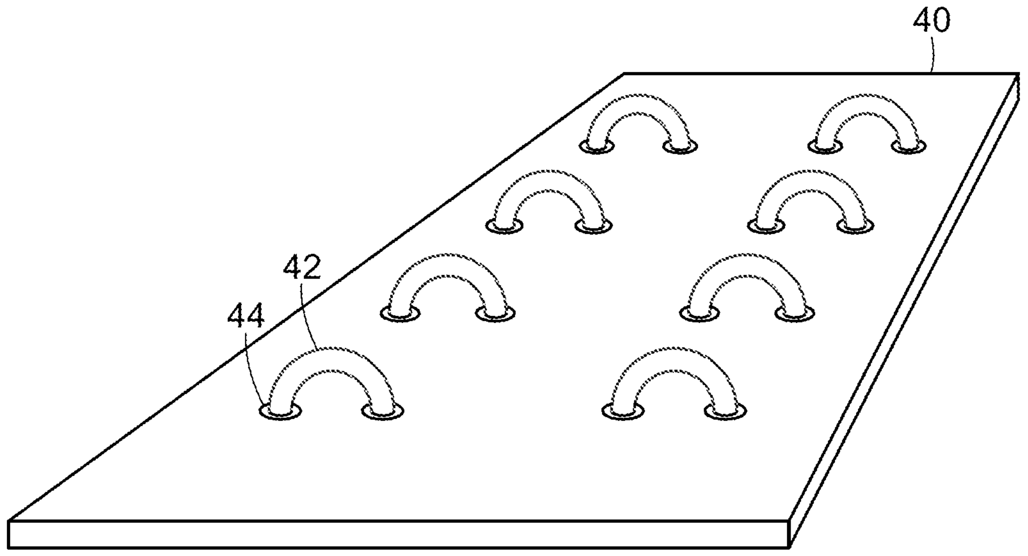

FIG. 4

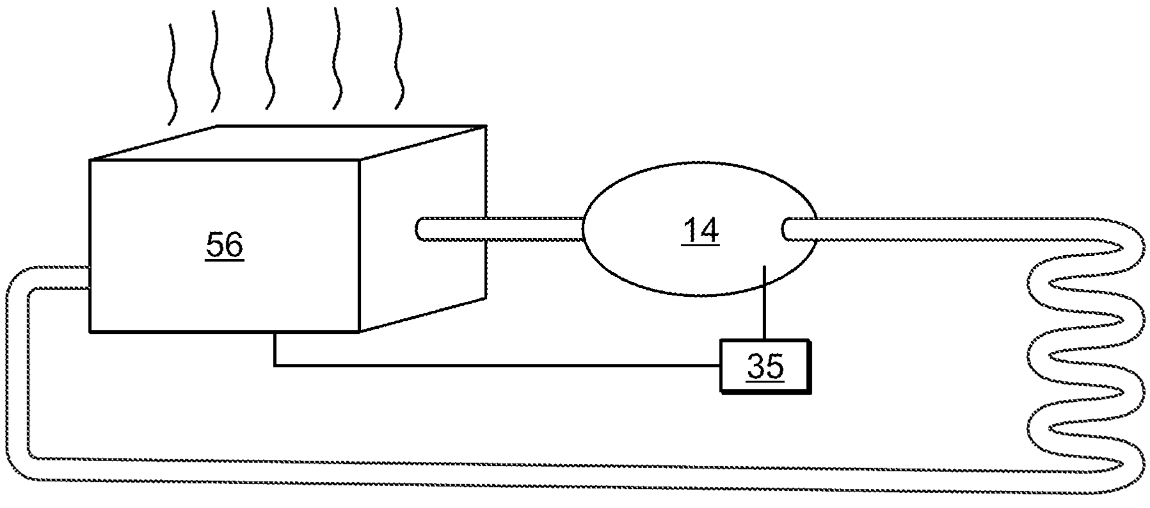

FIG. 5

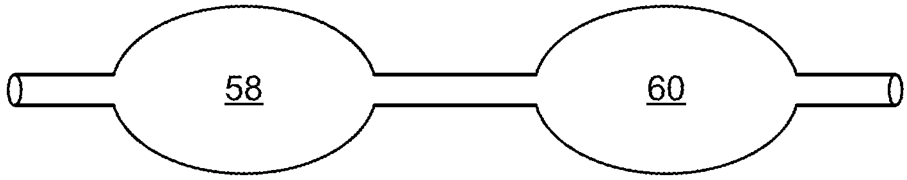

FIG. 6

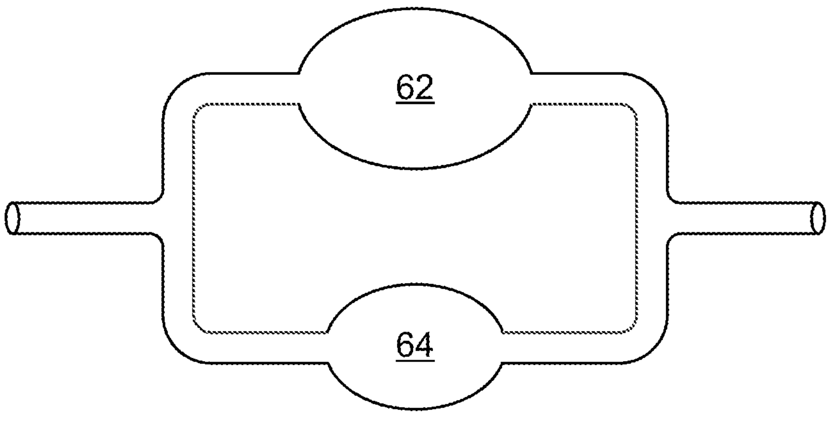

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/042353

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F24J 1/00 (2015.01)
CPC - F24J 1/00 (2015.09)
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)
IPC(8) - F24J 1/00 (2015.01)
CPC - F24J 1/00 (2015.09)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC -122/4D, 16.1, 21, 263.01; IPC(8) - F24J 1/00 (2015.01)
CPC - F24J 1/00 (2015.09) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Scholar
Search terms used: heating, heater, tank, container, vessel, fluid, liquid, water, fuel wafer, catalyst, ignition, induction heater, electrical resistor, natural gas, lithium, lithium aluminum, hydride, nickel, powder, enhanced, porosity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2012/0122017 A1 (MILLS) 17 May 2012 (17.05.2012) entire document	29, 32-35 --- 1-18, 30, 31, 36
Y	US 2010/0252023 A1 (COFFEY et al) 07 October 2010 (07.10.2010) entire document	1-18
Y	US 3,083,526 A (HUDSON) 02 April 1963 (02.04.1963) entire document	5, 30, 31, 36
Y	US 5,770,838 A (ROHRBAUGH et al) 23 June 1998 (23.06.1998) entire document	3
Y	US 2014/0147361 A1 (C-NOX GMBH & CO. KG) 29 May 2014 (29.05.2014) entire document	4
Y	US 2004/0065314 A1 (LAYER et al) 08 April 2004 (08.04.2004) entire document	17, 18
A	US 2011/0005506 A1 (ROSSI) 13 January 2011 (13.01.2011) entire document	1-36

☐ Further documents are listed in the continuation of Box C. ☐ 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
21 September 2015	19 OCT 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774