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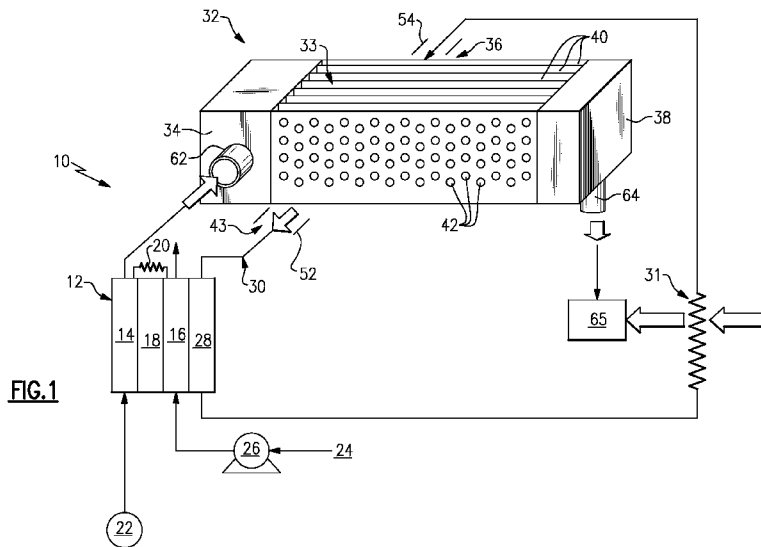
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(54) Title: ACID FUEL CELL CONDENSING HEAT EXCHANGER



(57) Abstract: A fuel cell assembly includes a cell stack assembly having a flow field configured to provide a fluid flow. The fluid flow has an acid and a water content. A condenser heat exchanger is arranged downstream from and fluidly connected to the flow field by a fluid flow passage. The condenser heat exchanger is configured to receive the fluid flow from the flow field through the fluid flow passage. A water supply system including a water source in fluid communication with the flow passage is arranged downstream from the flow field. The water source is configured to provide additional water to the fluid flow at a water inlet and increase the water content. The increased water content is within the condenser heat exchanger.

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## ACID FUEL CELL CONDENSING HEAT EXCHANGER

### BACKGROUND

This disclosure relates to an acid fuel cell, such as a phosphoric acid electrolyte  
5 fuel cell. More particularly, the disclosure relates to a condensing heat exchanger for  
use in an acid fuel cell.

One type of acid fuel cell uses a phosphoric acid electrolyte. Typically, a  
condenser is used in conjunction with the phosphoric acid fuel cell to condense and  
remove water from a gas stream, such as anode or cathode exhaust. One type of  
10 condenser heat exchanger uses multiple tubes supported in multiple fins. A coolant  
flows through the tubes to condense water from the gas stream flowing between the  
fins. The water vapor in the gas stream includes a small amount of phosphoric acid.  
The heat transfer fins at an upstream portion of the condenser heat exchanger have  
exhibited corrosion due to acid condensation on the fins. The fin edge temperature is  
15 much higher than the coolant temperature due to the heat resistance through the fin. As  
a result, the fin edge temperature is typically higher than the water dew point but lower  
than the acid dew point, which causes strong acid condensation on the fin leading to  
corrosion build-up.

Corrosion products must be removed during a maintenance procedure to prevent  
20 the fins from becoming blocked, which could inhibit the gas stream flow through the  
condenser heat exchanger. Corrosion-resistant metals, such as stainless steel and  
HASTELLOY, have been used for the fins and tubes. Use of corrosion-resistant metals  
has not extended the maintenance interval for removing corrosion products from the  
condenser heat exchanger to a desired duration, which may be ten years or more.

25

### SUMMARY

A fuel cell assembly is disclosed that includes a cell stack assembly having a  
flow field configured to provide a fluid flow. The fluid flow has an acid and a water

content. A condenser heat exchanger is arranged downstream from and fluidly connected to the flow field by a fluid flow passage. The condenser heat exchanger is configured to receive the fluid flow from the flow field through the fluid flow passage. A water supply system including a water source in fluid communication with the flow passage is arranged downstream from the flow field. The water source is configured to provide additional water to the fluid flow at a water inlet and increase the water content. The increased water content is within the condenser heat exchanger.

These and other features of the disclosure can be best understood from the following specification and drawings, the following of which is a brief description.

10

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a schematic view of a portion of an acid fuel cell having a condensing heat exchanger, in accordance with an embodiment of the present disclosure.

15 Figure 2 is another schematic view of the condensing heat exchanger shown in Figure 1, in accordance with an embodiment of the present disclosure.

Figure 3 is a schematic view of the water supply system for a condenser heat exchanger and a thermal management system, in accordance with an embodiment of the present disclosure.

20 Figure 4 is a schematic view of a water supply system including a condenser heat exchanger and an ammonia scrubber.

Figure 5 is a schematic view of a water supply system and a condenser heat exchanger including a presaturator, in accordance with an embodiment of the present disclosure.

25 Figure 6 is a schematic view of a condenser heat exchanger similar to Figure 5 and in accordance with an embodiment of the present disclosure.

Figure 7 is a cross-sectional view of the condenser heat exchanger in Figure 6 taken along line 7-7.

Figure 8 is a schematic view of a condenser heat exchanger, in accordance with an embodiment of the present disclosure.

Figure 9 is a schematic view of another condenser heat exchanger, in accordance with an embodiment of the present disclosure.

5 Figure 10 is a cross-sectional view of the condenser heat exchanger shown in Figure 9 taken along line 10-10.

### **DETAILED DESCRIPTION**

A fuel cell 10 is depicted in a highly schematic fashion in Figure 1. Like numerals are used to indicate like components. The fuel cell 10 includes a cell stack assembly 12 having an anode 14 and a cathode 16. In one example, a phosphoric acid electrolyte 18 is arranged between the anode 14 and the cathode 16. The cell stack assembly 12 produces electricity to power a load 20 in response to a chemical reaction. A fuel source 22 supplies hydrogen to a fuel flow field provided by the anode 14. In one example, the fuel source is a natural gas. Components, such as a desulfurizer, a reformer, and a saturator, may be arranged between the fuel source 22 and the anode 14 to provide a clean source of hydrogen. An oxidant source 24, such as air, is supplied to an oxidant flow field provided by the cathode 16 using a blower 26.

The cell stack assembly 12 includes a coolant plate 28, in one example, to cool the cell stack assembly 12 to desired temperature. A coolant loop 30 is in fluid communication with the coolant plate 28 and a condenser heat exchanger 32. A heat exchanger 31 is arranged in the coolant loop 30 to reject heat from the fuel cell 10 to ambient 65. A gaseous stream containing water vapor flows through the condenser heat exchanger 32. In one example, the gaseous stream is provided by anode exhaust from the anode 14. However, it should be understood that a condenser heat exchanger can also be used in connection with the cathode 16.

The condenser heat exchanger 32 includes an inlet manifold 34 providing a fluid inlet receiving the gaseous stream. The gaseous stream flows through a common

housing 36 to a fluid outlet in an outlet manifold 38. A fluid flow passage 33 within the housing 36 receives the gaseous stream. In one example, the condenser heat exchanger 32 is provided by a tube-in-fin type arrangement. The tube-in-fin heat exchanger is constructed from 316L stainless steel that is brazed together with nickel, in one  
5 example.

In one example, the tubes 42 are illustrated in a horizontal orientation. The fins 40 are illustrated in a vertical orientation such that the tubes 42 are perpendicular to the fins 40. The fins 40 are arranged parallel to one another and include holes to accommodate the passage of and provide support to the tubes 42 through the fins 40.  
10 The tube-in-fin arrangements illustrated in Figures 1 and 2 can be oriented differently than shown and still fall within the scope of the claims. The tubes 42 provide a coolant flow passage 43 that extends between a coolant inlet 52 and coolant outlet 54, which are arranged within the coolant loop 30. The coolant inlet and outlet manifolds are not shown for clarity. The fins 40 are spaced apart from and parallel with one another to  
15 provide the fluid flow passage 33, which extends between the inlet manifold 34 and the outlet manifold 38.

In addition to containing water vapor, the gas stream entering the fluid flow passage 33 also contains a small amount of phosphoric acid. Phosphoric acid has a dew point of approximately 160°C, and water vapor has a dew point of approximately 65°C  
20 within the condenser heat exchanger 32. The coolant within the coolant flow passage 43 includes a first temperature, and the fluid, which may be anode exhaust, within the fluid flow passage 33 includes a second temperature that is greater than the first temperature. Coolant flow through the coolant flow passage 43 condenses the phosphoric acid and water vapor within the fluid flow passage 33 onto the exterior of  
25 the tubes 42.

Referring to Figure 2, an acid drip tray 56 collects condensed phosphoric acid and supplies the condensed phosphoric acid to an acid return line 66. In one example, water from the condenser heat exchanger 32 can be supplied to a water return passage

60 that supplies the recovered water to a reformer 63. The exhaust gas from the outlet manifold 38 is exhausted to ambient 65 through gas outlet 64 (Figure 1). The outlet manifold 38 includes a drain 61, for example, that is fluidly connected to the water return passage 60. The phosphoric acid tends to condense upstream from where the  
5 water vapor condenses due to the difference in dew points between phosphoric acid and water. Some water vapor may condense with the acid producing a diluted phosphoric acid. A pump 68 supplies the acid from the acid return line 66 to a sprayer 70. The sprayer 70 sprays the acid into a gas stream 74 that is arranged upstream from a gas inlet 76 to a gas flow field 72 within the cell stack assembly 12. In one example, the  
10 gas flow field 72 is an anode flow field provided by the anode 14.

The fuel cell 10 includes a cell stack assembly 12 having a gas flow field 72 provided by the anode 14 and/or cathode 16. The gas flow field 72 provides a fluid flow that includes an acid and a water content. The condenser heat exchanger 32 is arranged downstream from and fluidly connected to the gas flow field 72 by a fluid  
15 flow passage 33. The condenser heat exchanger 32 is configured to receive the fluid flow from the gas flow field 72 through the fluid flow passage 33. A water supply system 48 includes a water source 44 in fluid communication with the fluid flow passage 33 downstream from the gas flow field 72. The water source 44 is configured to provide additional water to the fluid flow at a water inlet 46 arranged between  
20 portions 33a, 33b of the fluid flow passage, which increases the water content that is within the condenser heat exchanger 32. Adding water to the fluid flow through the condenser heat exchanger 32 dilutes the acid condensing on the fins 40 and tubes 42.

Referring to Figure 3, the water supply system 148 includes a thermal management system 78 as the water source 144. The thermal management system 78  
25 has one or more heat exchangers 80 in a cooling loop. Liquid water from the thermal management system 78 is supplied to the water inlet 46 through a blowdown water passage 82. The water from the thermal management system 78 is typically under pressure so that no additional pumping power is required to atomize the water for

vaporization when introduced to the water inlet 46. The fluid flow includes a temperature whereby introducing the blowdown water to the fluid flow as the water inlet 46 decreases the temperature, for example, to approximately 70°C.

Another water supply system 248 is shown in Figure 4. A wet ammonia scrubber 84 receives fuel from the fuel source 22 before providing the fuel to the anode 14 of the cell stack assembly 12. The water source 244 is provided by a water storage tank 86 that receives excess water from the wet ammonia scrubber 84. Water from the water storage tank 86 is supplied to the condenser heat exchanger 32 by a sprayer 92. A pump 88 pumps and pressurizes the water to the sprayer 92. A controller 90 communicates with the pump 88 to supply the water to the water inlet 46 in response to a predetermined condition, for example, at a desired interval. By using a periodic injection of water sprayed to the water inlet 46, the water dew point of the inlet gas can be lowered to the fin edge surface temperature. As a result, excess acid forms on the fins and falls off. In one example, the wet ammonia scrubber 84 supplies water to the water storage tank 86 at 2 g/s. In the example, the water quantity desired to desuperheat the condenser heat exchanger 32 at the water inlet 46 is approximately 33.3 g/s. As a result, water will be sprayed by the sprayer 6 % of the time, or approximately 5 minutes every 90 minutes of operation. An example, water storage volume for the wet ammonia scrubber 84 is 2.8 gallons, which can be reasonably accommodated in most fuel cell designs.

The condenser heat exchangers 132, 232, 332 shown in Figures 5-8 use a presaturator 98, 198, 298 to provide a compact heat exchanger, such as a plate-fin type heat exchanger. Since the hot fluid flow through the condenser heat exchanger is saturated, the acid and water will condense at the same time, resulting in little or no corrosion on the surface of the fins 40 since the acid is sufficiently diluted. As a result, the risk of plugging the channels or passages between the fins 40, even in a dense fin core, is greatly reduced such that the overall size of a typical condenser heat exchanger can be reduced in volume by  $\frac{1}{4}$  to  $\frac{1}{3}$ .

Referring to Figure 5, the condenser heat exchanger 132 includes an inlet manifold 134 and an outlet manifold 138 that respectively provides a fluid flow inlet 62 and a fluid flow outlet 64. The fluid flow passage 33 (schematically illustrated in Figure 2) extends between the inlet and outlet manifolds 134, 138. The inlet manifold 134 is configured to receive the increased water content. In the example shown, the water supply system 348 also has a burner 93 that provides burner exhaust to the inlet manifold at a burner exhaust passage 94. Water is provided to the burner exhaust passage 94 at another water inlet 146. A coolant flow passage 143 extends between the coolant inlet and outlets 52, 54 and is arranged between the inlet and outlet manifolds 134, 138. A presaturator 98, which includes a packing material in one example, is arranged between the coolant flow passage 143 and the inlet manifold 134. The coolant flow passage 143 is provided by the tubes 42, as illustrated in Figure 1. The packing material of the presaturator 98 provides uniform distribution of the saturated gas. Water droplets form, which fall from the presaturator 198 generally evenly upon the fins 40 supporting the tubes 42 within the heat exchanger portion of the condensing heat exchanger 132. A hydrophilic layer may be provided on the fins 40 to prevent drop formation and to ensure a consistent film of water between the metal fins and the diluted acid drops from the presaturator 98. The temperature of the fluid flow is reduced by evaporating the water into the gas stream and raising the relative humidity to 100 %.

The condensing heat exchanger 232 for a water supply system 348 that is illustrated in Figures 6 and 7 is similar to that shown in Figure 5. The presaturator 198 and coolant flow passage 243 are offset from the flow inlet and outlet 62, 64 such that the flow inlet and outlet 62, 64 are arranged next to but not above or beneath the presaturator 198 and coolant flow passage 243. The presaturator 198 is arranged vertically between the inlet and outlet manifolds 234, 238.

Another condensing heat exchanger 332 for a water supply system 548 is shown in Figure 8. In this example, the flow inlet 62 is arranged beneath the flow outlet 64

such that the inlet manifold 334 is arranged below the outlet manifold 338. The presaturator is arranged beneath the coolant flow passage 343 such that water collects on the presaturator 298 and falls to a drain 161 in the inlet manifold 334.

Another condensing heat exchanger 432 for a water supply system 648 is  
5 illustrated in Figures 9 and 10. The inlet manifold 434 and outlet manifold 438 are arranged side by side and beneath the coolant flow passage 443. A turn manifold 100 is provided above the coolant flow passage 443. The coolant flow passage 443 is effectively separated into two portions 443a, 443b. Fluid flow enters the inlet manifold 434 through the flow inlet 62. This fluid flow and a burner exhaust flow from the  
10 burner exhaust passage 94 flow through one portion 443a of the coolant flow passage 443 before entering turn manifold 100, which directs the fluid flow through the other portion 443b of the coolant flow passage 443 before entering the outlet manifold 438. The first portion 443a of the coolant flow passage 443 creates a partial condensation of water, which flows downward due to the gravity and hydrophilic nature of the tube  
15 and/or fin coatings to ensure that acid corrosion will not occur. The acid condenses in the presence of liquid water in the first portion 443a of the coolant flow passage 443 and is supplied to the acid return line 66 for recycling. A total condensation of water occurs in the second portion of the coolant flow passage 443, which permits full water recovery.

20 Although example embodiments have been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of the claims. For that reason, the following claims should be studied to determine their true scope and content.

## CLAIMS

1. A fuel cell assembly comprising:  
a cell stack assembly including a flow field configured to provide a fluid flow  
5 having an acid and a water content;  
a condenser heat exchanger arranged downstream from and fluidly connected to  
the flow field by a fluid flow passage, the condenser heat exchanger configured to  
receive the fluid flow from the flow field through the fluid flow passage; and  
a water supply system including a water source and in fluid communication with  
10 the fluid flow passage downstream from the flow field, the water source configured to  
provide additional water to the fluid flow at a water inlet and increase the water content  
that is within the condenser heat exchanger.
2. The assembly according to claim 1, comprising a thermal management system  
15 including a heat exchanger in fluid communication with a blowdown water passage  
configured to carry blowdown water, the thermal management system configured to  
transfer heat between the blowdown water and the heat exchanger, and the water source  
and the water respectively include the blowdown water passage and the blowdown  
water.  
20
3. The assembly according to claim 2, wherein the fluid flow includes a  
temperature whereby introducing the blowdown water to the fluid flow at the water  
inlet decreases the temperature.
- 25 4. The assembly according to claim 2, wherein the blowdown water passage within  
the thermal management system is at a pressure greater than an atmospheric pressure.

5. The assembly according to claim 2, wherein the blowdown water at the water inlet is atomized liquid water.

6. The assembly according to claim 1, wherein the water source includes an ammonia scrubber configured to provide the additional water.

7. The assembly according to claim 6, comprising a fuel source in fluid communication with the ammonia scrubber, and the cell stack assembly includes an anode downstream from and in fluid communication with the ammonia scrubber.

10

8. The assembly according to claim 6, wherein the water supply system includes a controller and a water storage tank configured to receive the additional water from the ammonia scrubber, the controller configured to selectively provide the additional water to the water inlet in response to a predetermined condition.

15

9. The assembly according to claim 8, wherein the water supply system includes a pump, the controller in communication with the pump and configured to selectively command the pump to provide the additional water to the water inlet the predetermined condition including an interval.

20

10. The assembly according to claim 9, wherein the water inlet includes a sprayer.

11. The assembly according to claim 1, wherein the condenser heat exchanger includes an inlet manifold and an outlet manifold respectively providing a fluid flow inlet and a fluid flow outlet, and a portion providing a coolant flow passage, the coolant flow passage arranged between the inlet and the outlet manifolds, the fluid flow passage extending between the inlet and the outlet manifolds, and the inlet manifold configured to receive the increased water content.

25

12. The assembly according to claim 11, wherein the condenser heat exchanger includes a material layer arranged adjacent to the coolant flow passage and between the inlet and the outlet manifolds

5

13. The assembly according to claim 12, wherein the material layer separates the fluid flow inlet from the coolant flow passage

14. The assembly according to claim 13, wherein the material layer is arranged  
10 beneath the coolant flow passage, the inlet manifold including a drain configured to collect water falling from the material layer.

15. The assembly according to claim 12, wherein the material layer is arranged  
15 above the coolant flow passage and configured to disperse the increased water content across the coolant flow passage.

16. The assembly according to claim 11, comprising a burner and a burner exhaust  
20 passage fluidly connected between the burner and the inlet manifold, the burner exhaust passage configured to provide burner exhaust to the condenser heat exchanger, and the water inlet associated with the burner exhaust passage.

17. The assembly according to claim 1, wherein the condenser heat exchanger  
25 includes an inlet manifold arranged adjacent to an outlet manifold and a turn manifold arranged fluidly between the inlet and the outlet manifolds.

18. The assembly according to claim 17, wherein the condenser heat exchanger includes a coolant flow passage arranged between the inlet manifold and the turn manifold and between the turn manifold and the outlet manifold.

19. The assembly according to claim 18, wherein inlet manifold includes an acid return line in fluid communication with the cell stack assembly, the acid return line configured to collect the acid in the condenser heat exchanger.

5

20. The assembly according to claim 1, wherein the cell stack assembly includes an anode and a cathode, each of which has a gas inlet, at least one gas inlet in fluid communication with the condenser heat exchanger and configured to receive the acid from the condenser heat exchanger.

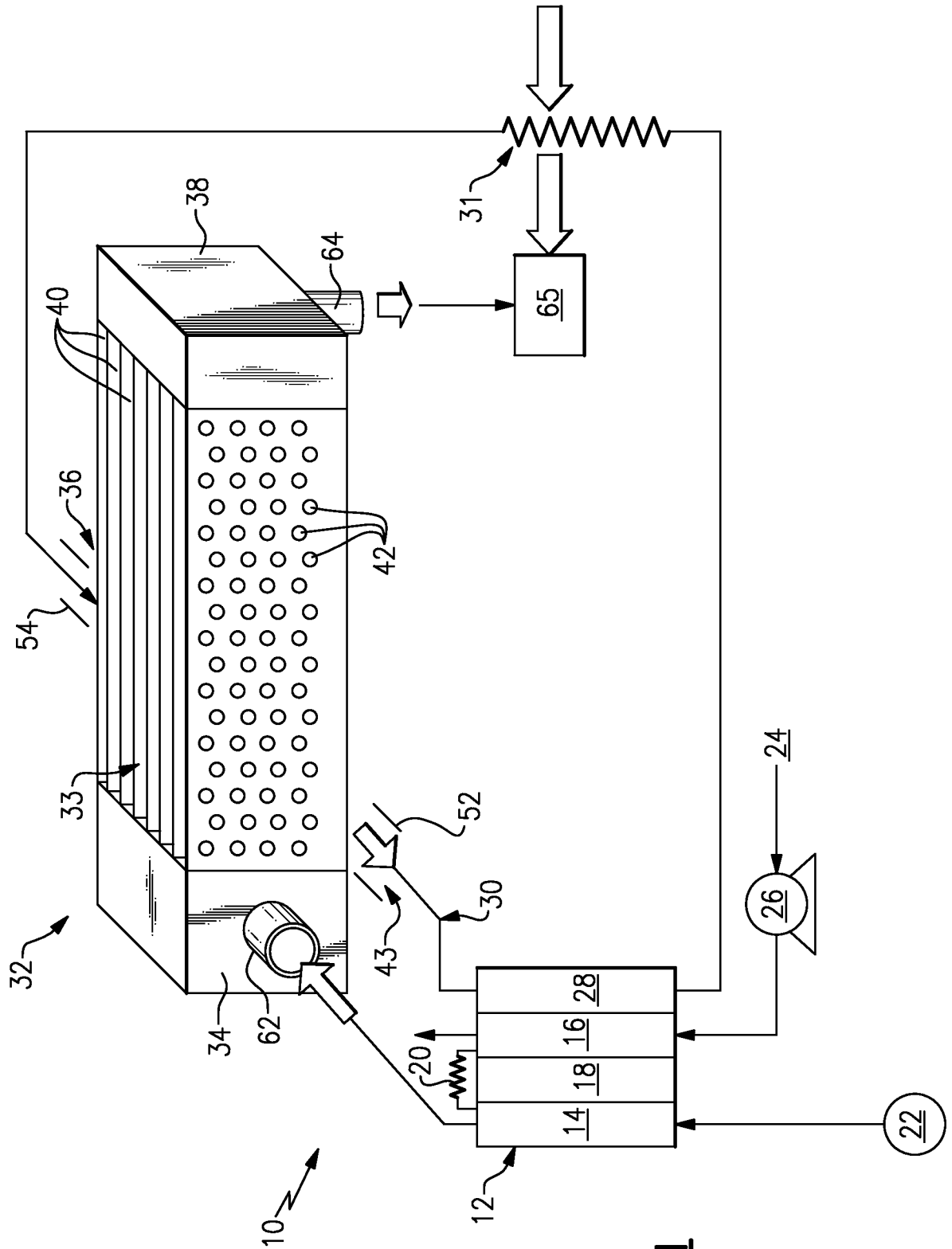
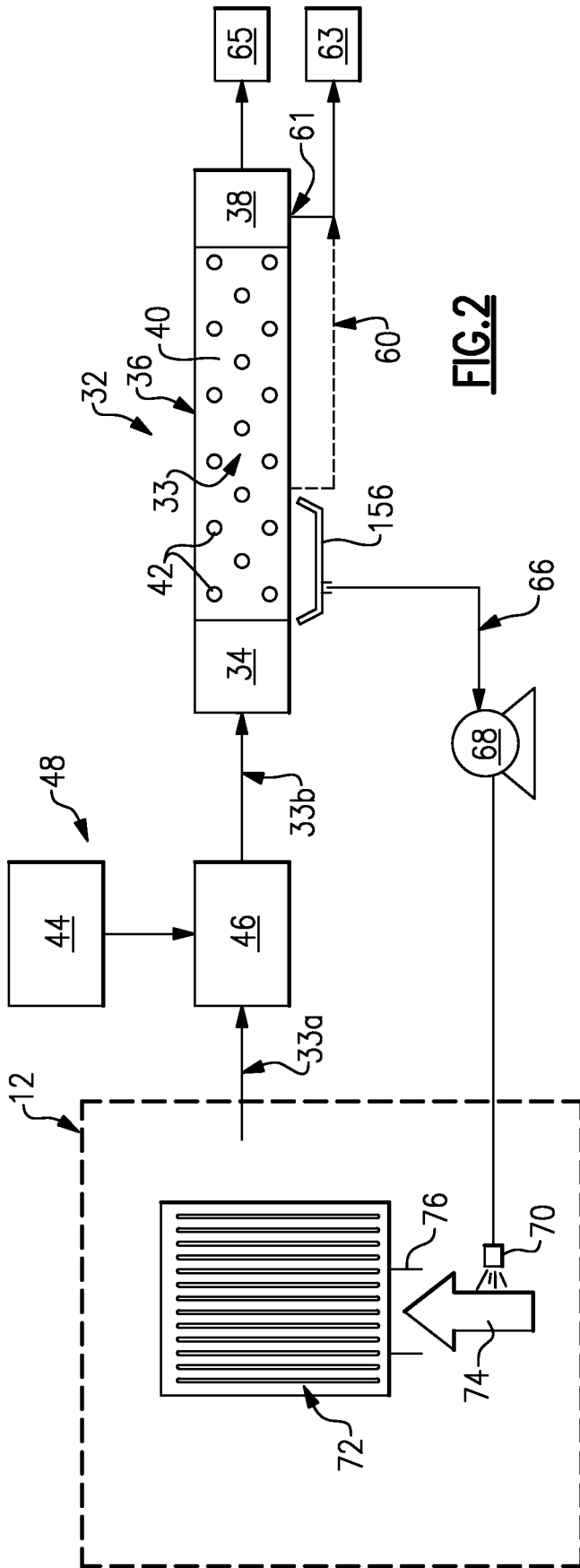
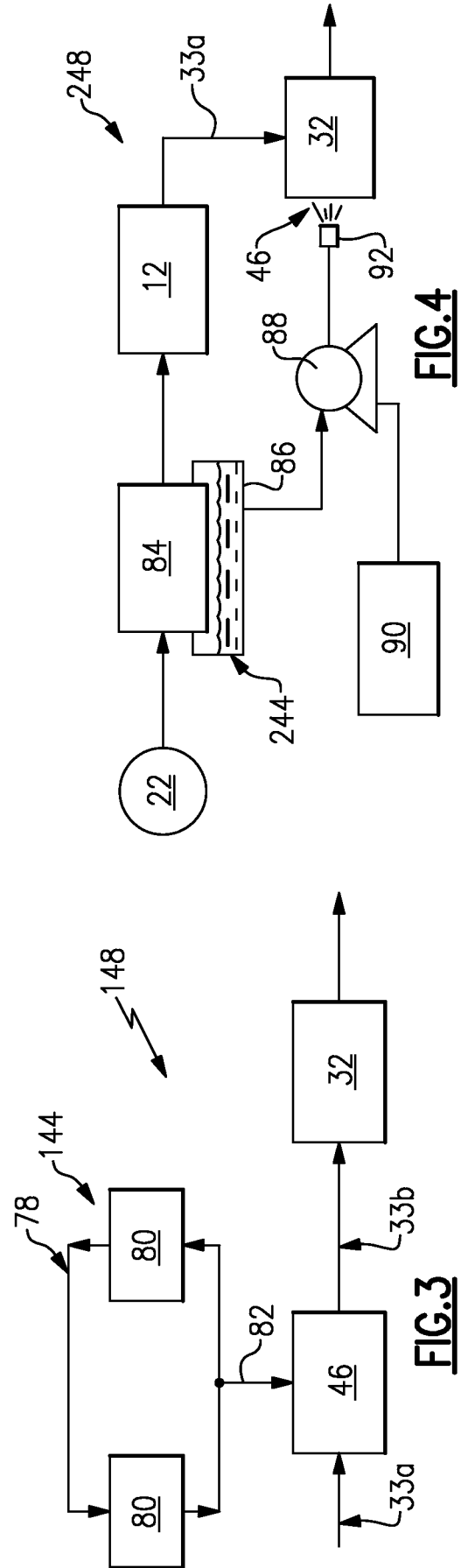


FIG.1

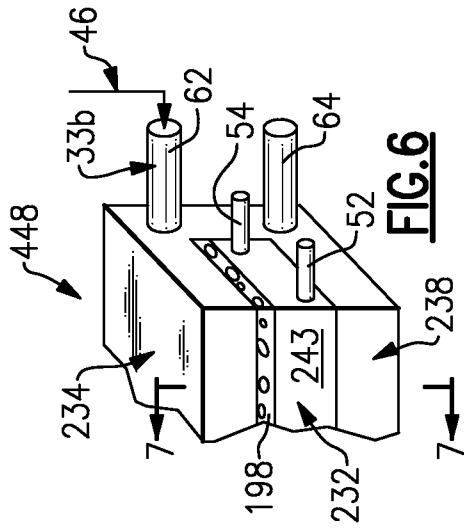


**FIG. 2**

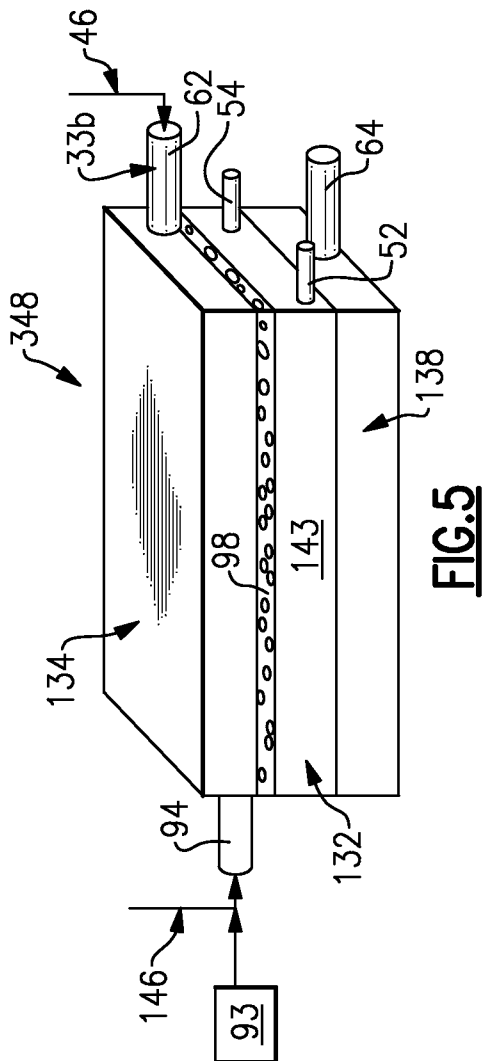


**FIG. 4**

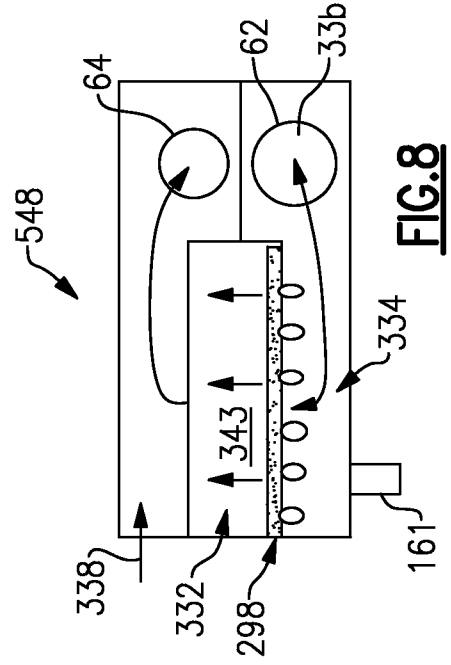
**FIG. 3**



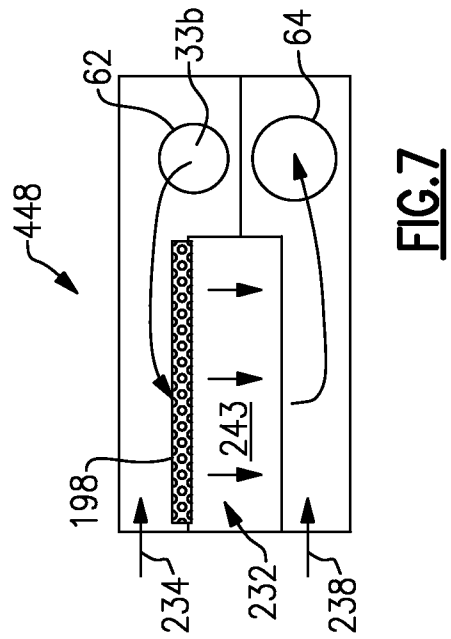
**FIG. 6**



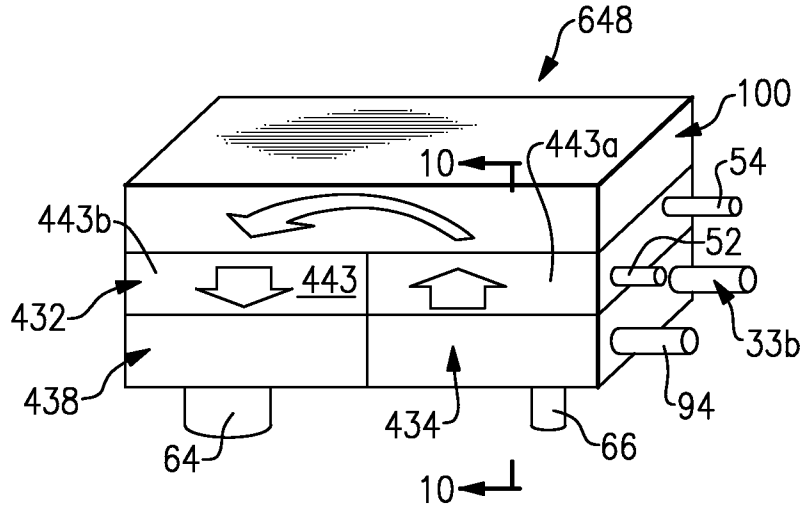
**FIG. 5**



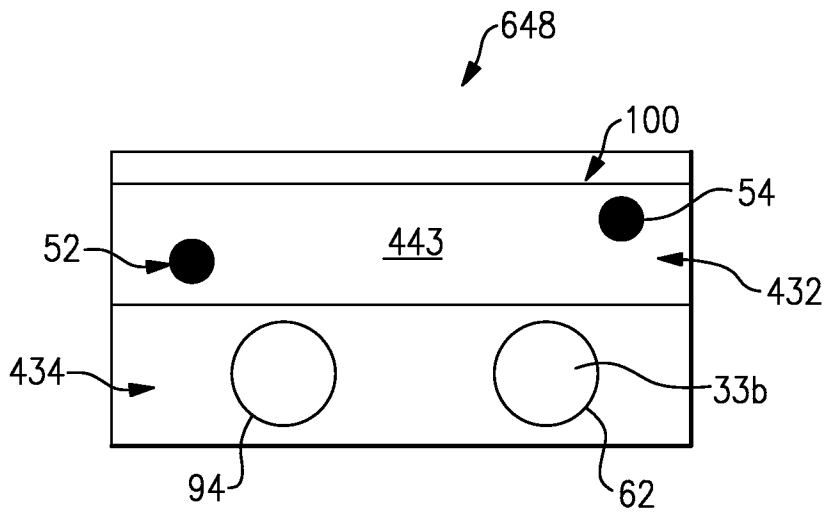
**FIG. 8**



**FIG. 7**





**FIG. 9**



**FIG. 10**

## INTERNATIONAL SEARCH REPORT

International application No.  
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<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
<i>H01M 8/04(2006.01)i, H01M 8/24(2006.01)i</i>		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) IPC 9: H01M, B01D, H02M		
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) eKOMPASS (KIPO internal) and keywords "fuel cell, phosphoric acid, condenser heat exchanger, water supply system, thermal management, ammonia scrubber, controller, and similar terms"		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 10-012259 A ( TOSHIBA CORP ) 16 January 1998 See abstract, Figures 1 and 5-6, paragraphs [0038] to [0040] and [0060] to [0062], claims 1-10	1-20
A	US 4372759 A ( Sederquist et al. ) 08 February 1983 See abstract, Figures 1-2, column 2, lines 11-15 and column 3, lines 20-51, and claims 1-8	1-20
A	US 6274259 B1 ( Grasso et al. ) 14 August 2001 See abstract, Figure 1, column 1, lines 38-44 and column 7, line 56 to column 8, line 9 and column 8, lines 33-46 and column 9, lines 52-55, and claims 1 and 14	1-20
A	JP 10-154522 A ( TOKYO GAS CO LTD ) 09 June 1998 See abstract, Figure 1, paragraphs [0015] and [0017], and claim 1	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search 24 SEPTEMBER 2009 (24.09.2009)		Date of mailing of the international search report <b>25 SEPTEMBER 2009 (25.09.2009)</b>
Name and mailing address of the ISA/KR  Korean Intellectual Property Office Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140		Authorized officer KIM, Kyong Min Telephone No. 82-42-481-8173 

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Information on patent family members

International application No.

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