



- (51) International Patent Classification:
C01B 3/06 (2006.01) *F16K 31/00* (2006.01)
- (21) International Application Number:
PCT/GB2014/050660
- (22) International Filing Date:
6 March 2014 (06.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
1304214.8 8 March 2013 (08.03.2013) GB
- (71) Applicant: **INTELLIGENT ENERGY LIMITED**
[GB/GB]; Charnwood Building, Holywell Park, Ashby
Road, Loughborough, Leicestershire LE11 3GB (GB).
- (72) Inventor: **PAYNE, Simon**; Charnwood Building, Holy-
well Park, Ashby Road, Loughborough, Leicestershire
LE11 3GB (GB).
- (74) Agent: **LINCOLN, Ben James**; Potter Clarkson LLP, The
Belgrave Centre, Talbot Street, Nottingham NG1 5GG
(GB).
- (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, LT, 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, 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,

[Continued on next page]

(54) Title: GAS SUPPLY CARTRIDGE

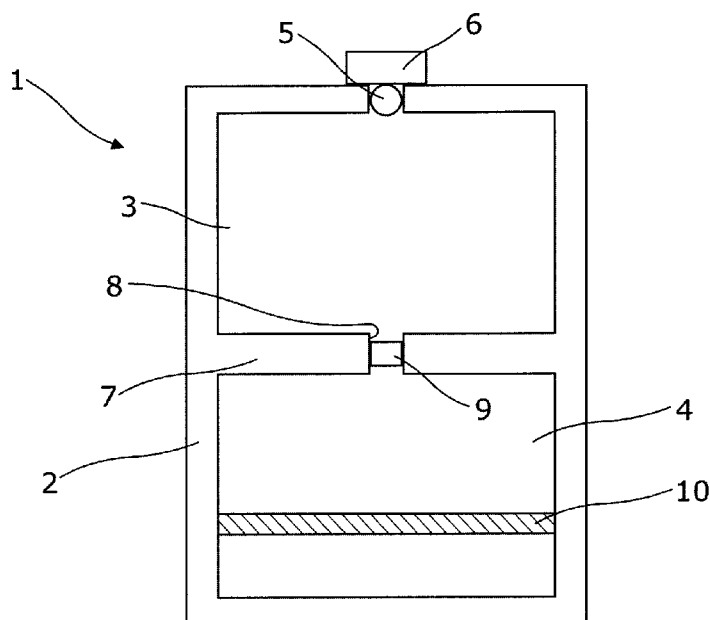


Fig. 1

(57) Abstract: A fuel cartridge (1) for generating gas, comprising: a cartridge housing (2); a reaction chamber (3) containing fuel; a fluid supply chamber (4) within the cartridge housing and containing a fluid reactant, the fluid supply chamber being coupled to the reaction chamber for supplying the fluid reactant to the reaction chamber; and wherein the cartridge includes a temperature sensitive element (9) adapted to control the supply of fluid reactant to the reaction chamber, the temperature sensitive element configured to reversibly restrict the supply when a threshold temperature is exceeded.





TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, —
KM, ML, MR, NE, SN, TD, TG).

*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))*

Published:

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

GAS SUPPLY CARTRIDGE

The present invention relates to a gas supply cartridge which generates gas from a reactant fuel material and a fluid reactant. More particularly, the invention relates to hydrogen gas supply cartridges which rely on displacement of an aqueous solution or water from a fluid supply storage chamber into a reaction chamber to drive a reaction generating the hydrogen.

Gas supply cartridges, such as hydrogen gas supply cartridges, are useful for supplying hydrogen as fuel to hydrogen-consuming devices such as electrochemical fuel cells which use the hydrogen to generate electrical power. For fully portable, fuel cell-based electrical power supplies, it is desirable to have a compact, safe and controllable source of hydrogen.

A known type of hydrogen gas supply cartridge releases hydrogen on demand by the reaction of reactant fuel material, such as a stabilized alkali metal material, contained within a reaction chamber, with an aqueous solution or water supplied from a water chamber. As water is fed into the reaction chamber, hydrogen gas is generated and gas pressure is created in the reactor chamber which stops further input of water, until the hydrogen pressure falls, for example by drawing off the hydrogen from the reaction chamber for consumption by a fuel cell. Examples of such hydrogen gas supply cartridges are provided in US 2010/0247426.

It is important that the generation of hydrogen is controlled over a wide range of temperatures. The temperature of the cartridge can be affected by the ambient temperature of the cartridge and the heat generated by the reaction.

Hydrogen gas supply cartridges are known to include safety shut off valves that prevent the aqueous solution or water from reaching the reactant fuel material if the temperature is too high. Thus, the cartridge is permanently disabled and can no longer be used.

It would be desirable to have a simple, low cost and easily implemented system for controlling the reaction in the cartridge that is responsive to temperature.

According to one aspect, the present invention provides a fuel cartridge for generating a gas, comprising:

a cartridge housing;

a reaction chamber to contain fuel;

a fluid supply chamber within the cartridge housing to contain a fluid reactant, the fluid supply chamber being coupled to the reaction chamber for supplying the fluid reactant to the reaction chamber; and

wherein the cartridge includes a temperature sensitive element adapted to control the supply of fluid reactant to the reaction chamber, the temperature sensitive element configured to reversibly restrict the supply when a threshold temperature is exceeded.

This is advantageous as the cartridge includes a safety temperature control element that ensures reliable operation of the portable fuel cartridge.

Preferably the temperature sensitive element is configured to inhibit the flow of fluid reactant when the threshold temperature is reached or exceeded. This is advantageous as the inhibition of the supply of fluid reactant will, when in use, stop the reaction in the reaction chamber. Thus, the fuel cartridge will be temporarily disabled while the temperature is at or above the threshold temperature. As the temperature sensitive element reversibly restricts the supply, when the temperature falls below the threshold temperature the temperature sensitive element is configured to allow the supply of fluid reactant.

Preferably, the temperature sensitive element comprises a thermo-mechanical actuator, such as a bimetallic strip, wherein movement of the actuator in response to temperature acts to control the supply of reactant fluid to the reaction chamber. This is advantageous as the actuator or bimetallic strip provides a reliable means for controlling the supply in response to changes in temperature and can be independent of any electronics.

Preferably, the temperature sensitive element is located such that it is in thermal contact with the reaction chamber. Thus, the temperature sensitive element, and particularly the bimetallic strip, may be located on the reaction chamber side of a divider that separates the fluid supply chamber and the reaction chamber. It can therefore react more closely to the temperature in the reaction chamber as well as the ambient temperature of the environment surrounding the cartridge. The temperature sensitive element may be physically spaced from the reaction chamber, but in thermal contact by way of a heat pipe, for example.

Preferably the temperature sensitive element comprises a valve and a temperature sensitive valve actuator. This is advantageous as the valve can be used to control the flow of fluid reactant in response to changes in temperature, for example.

- 5 The valve actuator may comprise a bimetallic strip.

The valve may be located between the fluid supply chamber and the reaction chamber. The temperature sensitive valve may be located within a fluid path that extends through a divider that separates the fluid supply chamber and the reaction chamber. Placing the
10 valve in a flow path between the chambers provide a simple tamper-proof design.

Preferably, the valve is configured to open against the flow of fluid reactant, when in use. Thus, in use, the pressure of the fluid reactant acts to close the valve. This is advantageous as failure of the temperature sensitive valve results in the fluid reactant
15 pressure closing the valve.

The valve may include a valve body arranged to be moved with respect to a valve seat by the valve actuator to control the supply of fluid reactant.

20 The valve may include a sealing diaphragm and a sealing plate having an aperture therein, the sealing diaphragm adapted to lie against the sealing plate to close the aperture in a closed position and the sealing diaphragm adapted to be displaced from the sealing plate by the valve actuator in an open position.

25 The valve may include a flexible conduit through which the reaction fluid is arranged to flow and a valve head, the valve head arranged to compress or pinch the flexible conduit to restrict the supply of fluid reactant.

The cartridge may include a moveable part in the fluid supply chamber for driving the
30 reactant fluid into the reaction chamber and the temperature sensitive element may include a movement inhibitor for preventing and allowing the movement of the moveable part in response to changes in temperature. In particular, the movement inhibitor may be moveable to a position which prevents the movement of the moveable part when the threshold temperature is exceeded.

35

The fuel cartridge may include a second temperature sensitive element adapted to control or inhibit the supply of fluid reactant to the reaction chamber, the second temperature sensitive element configured to reversibly restrict the supply when a second threshold temperature is exceeded.

5

The temperature sensitive element may comprise a first valve with an associated first temperature sensitive valve actuator, the second temperature sensitive element may comprise a second valve with an associated second temperature sensitive valve actuator, the first and second valves connected in series. Alternatively, the temperature sensitive element and second temperature sensitive element may comprise first and second valve actuators respectively that act on the same valve.

The valve actuators may act to control the supply of fluid reactant at different rates in response to temperature changes. Thus, the first actuator may act to restrict flow through the valve over a wide range of temperatures above the threshold temperature, while the second actuator may be configured to close abruptly once the second threshold temperature has been reached.

The cartridge may include further temperature sensitive elements. Thus, three, four, five, six or more temperature sensitive elements can be provided acting on the same valve, different valves or grouped to act on the same valve while others act individually or in groups.

The temperature sensitive element may include two or more bimetallic strips, the bimetallic strips connected together and arranged to act together to control the supply of fluid reactant to the reaction chamber. This is advantageous as different types of bimetallic strip (i.e. having different displacement response to temperature and/or different operating temperatures) can be connected in series or act in parallel to control the flow of fluid reactant.

30

According to another aspect, the present invention provides a method for controlling the supply of a fluid reactant to a reaction chamber in a fuel cartridge, the method comprising the steps of;

providing a temperature sensitive element in the cartridge for controlling the supply of a fluid reactant to a reaction chamber; and

35

using the temperature sensitive element to reversibly restrict the supply of fluid reactant to the reaction chamber when a threshold temperature is exceeded.

Embodiments of the present invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1 shows a schematic cross-sectional side view of a fuel cartridge for supplying gaseous fuel;

Figures 2a and 2b show a first exemplary embodiment of a temperature sensitive valve in an open position and a closed position;

Figures 3a and 3b show a second exemplary embodiment of a temperature sensitive valve in an open position and a closed position;

Figures 4a and 4b show a third exemplary embodiment of a temperature sensitive valve in an open position and a closed position;

Figures 5a and 5b show a fourth exemplary embodiment in a closed position and an open position;

Figure 6 shows a fifth exemplary embodiment;

Figures 7a and 7b show a sixth exemplary embodiment of a temperature sensitive element in a first unrestricting position and a second restricting position;

Figures 8a-c show a seventh exemplary embodiment of a temperature sensitive element in combination with a second temperature sensitive element;

Figure 9 shows an eighth exemplary embodiment showing a temperature sensitive element in combination with a second temperature sensitive element; and

Figure 10 shows a ninth exemplary embodiment showing a temperature sensitive element in combination with a second temperature sensitive element.

With reference to figure 1, a fuel cartridge 1 is shown. The fuel cartridge is a hydrogen gas supply cartridge 1 and has a cartridge housing 2 containing a reaction chamber 3 and a fluid supply chamber 4. The reaction chamber 3 is initially charged with any suitable reactant material fuel capable of generating hydrogen gas upon reaction with water or an aqueous solution. Examples of such reactant material fuel include alkali metal materials, including sodium silicide and/or sodium silica gel, sodium borohydride and/or ammonia borane, or more generally chemical hydrides. Any suitable reactant material which generates hydrogen, with or without catalysts, upon reaction with or exposure to an aqueous solution, may be considered.

The fluid supply chamber 4 is initially charged with any suitable aqueous solution or water for reacting with the contents of the reactant material fuel to produce hydrogen.

5 The reaction chamber 3 has an output valve 5 leading to an output port 6 for coupling to any required hydrogen consumption device, such as an electrochemical fuel cell. The reaction chamber 3 and the fluid supply chamber 4 are defined by the cartridge housing 2 and a divider 7, which defines a separating wall between the chambers within the cartridge housing. The reaction chamber 3 and the fluid supply chamber 4 are coupled together by a fluid conduit 8 through the divider 7 so that the aqueous solution or
10 water from fluid supply chamber 4 can be delivered to the reaction chamber 3. The fluid conduit 8 incorporates a temperature sensitive element 9.

The fluid conduit 8 may also include a one-way valve and may also incorporate a flow
15 restrictor.

The fluid supply chamber 4 includes a moveable part 10 to compress the fluid in the chamber 4 to thereby expel water or aqueous solution from the fluid supply chamber 4 into the reaction chamber 3. The moveable part 10 may be driven by a motor or air pressure, for example. It will be appreciated that the moveable part 10 may not be
20 present at all and a pump may be used to drive the aqueous solution from the fluid supply chamber. Alternatively, the aqueous solution may be contained within a bladder and physical and/or air pressure on the bladder may drive the aqueous solution out of the bladder and into the reaction chamber 3.

25 In use, under normal operating conditions, the fluid in the fluid supply chamber 4 is injected into the reaction chamber 3 via the conduit 8. Introducing the fluid into the reaction chamber 3 causes a reaction with the reactant material fuel to thereby generate hydrogen gas.

30 The reaction also generates heat, which can increase the reaction rate and increase the pressure. Ambient heat in the environment can also affect the reaction rate and the pressures within the hydrogen gas supply cartridge 1. For example, if the cartridge 1 was left in sunlight on a hot day, the temperature within the cartridge 1 can be very high. Elevated pressures and high reaction rates can therefore be experienced in the
35 cartridge, which can stress the cartridge and/or lead to unsatisfactory operation. The temperature sensitive element 9 can control the flow of fluid reactant from the fluid

supply chamber 4 to the reaction chamber 3. Thus, if the temperature rises above a threshold value, the element 9 may restrict fluid reactant flow or prevent any further fluid entering the reaction chamber 3. This will prevent any further reaction that may add to the elevated temperatures. Further, once the temperature falls below the threshold value, the temperature sensitive element 9 can open or reopen to allow the supply of reactant fluid to the reaction chamber 3 to recommence.

Figures 2a and 2b show a first embodiment of the temperature sensitive element 9 in the form of a valve located between the fluid supply chamber 4 and reaction chamber 3. The chambers 3, 4 are diagrammatically shown in dashed lines and may be sized and oriented differently. The valve 9 comprises a valve body 20 and a valve seat 21. The valve body 20 can sealingly engage with the valve seat 21 in a closed position (shown in Figure 2b) where fluid flow from the fluid supply chamber 4 is prevented. The valve body 20 can also be lifted from the valve seat 20 to adopt an open position (shown in Figure 2a) where fluid can flow from the fluid supply chamber 4, past the valve body 20 and seat 21 and into the reaction chamber 3. The valve body 20 is urged towards the closed position by the force of the fluid in the fluid supply chamber 4.

The valve body 20 is connected to a distal end of a valve stem 22. The proximal end of the valve stem 22 is connected to a thermo-mechanical valve actuator comprising a bimetallic strip 23. The bimetallic strip 23 comprises two component strips of metal have different coefficients of thermal expansion. Thus, as the strip 23 is heated, the component strips expand at different rates converting the temperature change into a mechanical displacement in a first direction. When the strip 23 cools the component strips contract at different rates converting the temperature change into a mechanical displacement in a second, substantially opposite direction. The bimetallic strip 23 is positioned within the divider 7, adjacent the reaction chamber 3. Locating the bimetallic strip 23 adjacent to or in the reaction chamber 3 is advantageous as it will be more sensitive to changes in temperature that occur due to the reaction between the reactant fluid and the reactant material. Further, locating the valve 9 within the cartridge 2 prevents it being tampered with or dirt ingress affecting its operation.

The bimetallic strip 23 is formed in a U-shape having two legs 23a and 23b. The bimetallic strip 23 is configured to straighten at higher temperatures and fold or bend into a U-shape at lower temperatures. The first leg 23a is fixed to the cartridge housing 2 or divider 7. The second leg 23b is connected to the valve stem 22. Thus, movement of

the bimetallic strip 23 controls the position of valve body 20 relative to the valve seat 21. In particular, straightening of the bimetallic strip 23 draws the valve body 20 towards the valve seat 21. Bending of the bimetallic strip 23 moves the valve body 20 away from the valve seat 21. The thickness of the component strips, the length of the bimetallic strip, the materials that form the strip and the shape of the strip can be selected to ensure that the bimetallic strip 23 provides the required amount of movement to actuate the valve body over the desired operating temperature range.

In use, if the temperature of the cartridge 1 increases, the bimetallic strip 23 straightens and draws the valve body 20 closer to the valve seat 21. This will throttle the flow of the fluid reactant into the reaction chamber 3, slowing the reaction. This, in turn, will reduce the heat generated by the reaction. The bimetallic strip 23 may be configured to move the valve body 20 to the closed position (as shown in figure 2b) when a safety threshold temperature is reached or exceeded. It will be appreciated that the bimetallic strip 23 may be configured, as in this example, to adjust the position of the valve body 20 relative to the valve seat 21 as a function of temperature and close the valve 9 at or above the threshold temperature. However, the bimetallic strip 23 may be constructed or arranged to maintain the valve body 20 in a substantially fixed open position over a range of operating temperatures below a threshold temperature and then, if the threshold temperature is reached or exceeded, move the valve 9 to the closed position. This may be achieved using a catch that retains the strip and only allows movement of the bimetallic strip when a predetermined force is exceeded.

When the temperature of the cartridge 2 decreases, the bimetallic strip 23 bends and urges the valve body 20 away from the valve seat 21. If the safety threshold temperature has been exceeded, once the temperature has dropped below this threshold temperature, the valve body 20 will be lifted from the valve seat 21 so that fluid is able to flow into the reaction chamber 3. The valve 9 therefore provides a reversible temperature safety shut-off function.

Figures 3a and 3b show a second embodiment of the valve 9 in which the valve seat and valve body now comprise a sealing plate 30 and sealing diaphragm 31 to control the supply of fluid from the fluid supply chamber 4 to the reaction chamber 3. The sealing plate 30 comprises a concave plate that extends across the flow path 32 between the fluid supply chamber 4 and the reaction chamber 3. The sealing plate 30 includes a

central aperture 33 therethrough. The central aperture 33 can be opened and closed by movement of the sealing diaphragm 31 relative to the sealing plate 30.

The sealing diaphragm 31 comprises a flexible member, such as of silicone polymer.

- 5 The sealing diaphragm 31 is urged towards the sealing plate 30 by the force of the fluid from the fluid supply chamber 4. Thus, the sealing diaphragm 31 will lie against and seal the flow path 32 by blocking aperture 33.

- 10 The valve 9 further includes a valve head 34 located outside the flow path 32. The flow path 32 includes a flexible wall portion 35, which allows the valve head 34 to interact with the sealing diaphragm 31. The flexible wall portion 35 may comprises a localised reduction in thickness of the flow path wall, or may be of a different, more flexible material than the remainder of the wall.

- 15 The position of the valve head 34 is controlled by a bimetallic strip 36. The bimetallic strip 36 is formed in a U-shape and has two legs 36a and 36b. The first leg 36a is connected to the cartridge housing 2. The valve head 34 is affixed to the second leg 36b. The bimetallic strip 36 is configured to straighten when the temperature decreases and fold or bend when the temperature increases. The bimetallic strip 36 is
20 located adjacent the reaction chamber 3.

- In use, the bimetallic strip 36 is configured and arranged such that at acceptable operating temperatures, it positions the valve head 34 such that it urges the flexible wall portion 35 to contact the sealing diaphragm 31 and displace it from the sealing plate 30
25 (as shown in Figure 3b). Accordingly, the aqueous solution or water can flow from the fluid supply chamber 4, past the sealing diaphragm 31, through the aperture 33 and into the reaction chamber 3. When the temperature increases, the bimetallic strip 36 bends and withdraws the valve head 34 such that the sealing diaphragm 31 moves closer to the sealing plate 30, which restricts the flow through the valve 8. A reduced amount of
30 aqueous solution or water will enter the reaction chamber 3 thereby controlling the reaction. The bimetallic strip 36 is configured to withdraw the valve head 34 sufficiently to allow the sealing diaphragm 31 to lie against the sealing plate 30 to seal the flow path 32 when a safety threshold temperature is reached or exceeded. Thus, aqueous solution is prevented from entering the reaction chamber 3 and further reaction is
35 inhibited. This, in effect, reversibly deactivates the gas supply cartridge 1 when a safety threshold temperature is reached or exceeded. Once the temperature decreases, the

bimetallic strip straightens which drives the valve head towards the sealing diaphragm 31 and displaces it from its sealing engagement with the sealing plate. The flow of aqueous solution from the fluid supply chamber 4 to the reaction chamber 3 is therefore possible once again.

5

Figures 4a and 4b show a third embodiment of the valve 9. The valve 9 comprises a flow path 42 between the fluid supply chamber 4 and the reaction chamber 3. The flow path includes a flexible section 40. In this embodiment, the flexible section comprises a section of flexible pipe located between sections of the flow path 42. The valve 9 further includes a valve head 44 and a valve actuator comprising a bimetallic strip 46, which controls the position of the valve head 44. The valve head 44 is configured to pinch the flexible section 40 to control the flow of aqueous solution therethrough. The bimetallic strip 46 is located within the divider 7 on the side of reaction chamber 3.

15 The bimetallic strip 46 is arranged such that it is substantially straight during acceptable operating temperatures and therefore the valve 9 is in an open position as shown in Figure 4a. The bimetallic strip 46 is configured to bend when its temperature increases to drive the valve head 44 towards the flexible section 40 to pinch it and therefore restrict or inhibit flow therethrough. Figure 4b shows the valve 9 in the closed position.

20

In use, at acceptable operating temperatures, the bimetallic strip 46 positions the valve head 44 such that it does not compress the flexible section 40 and aqueous solution can flow through the flow path 42. As the temperature increases towards a safety threshold temperature, the bimetallic strip 46 bends and drives the valve head 44 to compress the flexible section and thereby restrict the flow through the flow path 42. The bimetallic strip 46 is configured such that once a safety threshold temperature is reached, the valve head 44 is in a position to pinch the flexible section 40 sufficiently to inhibit flow through the flow path 42. As the temperature of the cartridge 1 decreases, the bimetallic strip straightens, withdrawing the valve head 44 and allowing flow through the flow path 42.

30

Figures 5a and 5b show a fourth embodiment. The valve 9 comprises a valve body 50 that is slidably mounted within a valve channel 51. The valve 9 is located within a flow path 52 and the valve body 50 is sized to block the flow path 52 in the closed position (Figure 5a) and slide out of the flow path 52 in the open position (Figure 5b). Thus, in this embodiment, the valve seat comprises the wall of the flow path. The valve body 50 is connected to a first end of a valve stem 53. A second end of the valve stem 53

35

extends into an actuator housing 57 and is connected to a bias plate 54. A biasing element 55, comprising a spring, acts between the cartridge housing 2 and the bias plate 54. The biasing element 55 acts to bias the valve body 50 to the closed position. A bimetallic strip 56 acts on an opposing side of the bias plate 54 to control the position of the valve body 50.

The bimetallic strip 56 is substantially U-shaped and has two legs 56a and 56b. The first leg 56a bears against the bias plate 54. The second leg 56b bears against the actuator housing 57. The bimetallic strip 56 is configured to bend or fold with increasing temperature and straighten with decreasing temperature.

In use, at acceptable operating temperatures, the bimetallic strip 56 positions the valve body 50 such that it extends into the valve channel 51 and aqueous solution can flow through the flow path 52. Thus, the bimetallic strip 56 acts to push the bias plate 54 against the force of bias element 55 to drive the valve body 50 out of the flow path 52, as shown in Figure 5b. As the temperature increases towards a safety threshold temperature, the bimetallic strip 46 bends, reducing the distance between its legs 56a, 56b. This allows the biasing element 55 to drive the bias plate 54 (downwards in Figures 5a and 5b) and therefore move the valve body 50 into or further into the flow path 52. Thus, the valve body 50 restricts the flow through the flow path 52. The bimetallic strip 56 is configured such that once a safety threshold temperature is reached, the valve body 50 is in a position to inhibit flow through the flow path 52 thereby closing the valve 9. As the temperature of the cartridge 1 decreases, the bimetallic strip straightens, driving the valve body 50 out of the flow path 52 which allows flow through the flow path 52.

Figure 6 shows a further embodiment of the temperature sensitive valve 9. In this embodiment, the moveable part is driven by air pressure supplied by a pump (not shown) to a region 61 behind the moveable part 10. The temperature sensitive valve 9 controls the flow of air to that region. By restricting the flow of air to this region, the movement of the moveable part 10 can be controlled as controlling the pressure behind the moveable part 10 will control its movement. It is the movement of the moveable part 10 that drives aqueous fluid or water from the fluid supply chamber 4 to the reaction chamber 3 and therefore the flow can be disabled by hindering movement of the moveable part 10. The valve 9 may be configured and arranged similarly to any of the embodiments discussed

above but will control the flow of air to or from a pump which directs atmospheric air from inlet aperture 60 in the cartridge housing 2 to the region 61 behind the moveable part 10.

5 The valve 9 is located adjacent the reaction chamber 3. The valve 9 is configured to be biased closed by the flow of air through into the region 61. For example, if the valve 9 comprises the valve of the second embodiment, the air from the inlet 60 may be configured to act on the diaphragm 31 to urge it towards the sealing plate 30. A bimetallic strip (not shown) may act to open the valve 9 when the temperature is within acceptable operating limits. If the temperature increases beyond a safety threshold
10 temperature, the bimetallic strip may move to allow the valve to close. The flow of air into the region 61 will be inhibited and movement of the moveable part 10 is restricted thereby preventing the flow of aqueous fluid into the reaction chamber 3. Once the temperature decreases, the bimetallic strip can allow the flow of air into the region 61 to allow the moveable part 10 to move once again. The fluid conduit 8 is shown containing
15 a one-way check valve 62.

In a further embodiment shown in Figures 7a and 7b, a bimetallic strip 70, located adjacent the reaction chamber 3, may be configured to act on an inhibitor bar 71, which extends along a wall of the fluid supply chamber 4. The inhibitor bar 71 is configured to
20 physically act on the moveable part 10 to inhibit its movement. The aqueous solution is contained within a bladder 72 that is acted on by the moveable part 10. Thus, during normal operating temperatures, the bimetallic strip maintains the inhibitor bar 71 out of contact with the moveable part 10 and the moveable part is able to drive aqueous solution or water into the reaction chamber 3 (as shown in Figure 7a). If the temperature
25 rises above a safety threshold temperature, the bimetallic strip 70 is constructed and arranged to move the inhibitor bar 71 into contact with the moveable part 10 to prevent movement of the moveable part 10 (as shown in Figure 7b). This will therefore prevent aqueous solution or water from entering the reaction chamber 3 and therefore temporarily disable the cartridge 1. Once the temperature falls below the safety
30 threshold temperature, the bimetallic strip 70 moves the inhibitor bar 71 out of contact with the moveable part 10 so that flow of aqueous solution or water is once again possible. A check valve 73 is shown in the fluid conduit 8. Although this embodiment discusses the movement of an inhibitor bar 71, any moveable part 10 inhibiting element could be used.

35

Figures 8a to 8c show a further embodiment, similar to Figures 4a and 4b, in which the temperature sensitive element comprises two temperature sensitive actuators 80 and 81 that act on a single valve 82. The first temperature sensitive actuator 80 acts on one side of the valve, while the second temperature sensitive actuator 81 acts on an opposed side of the valve 82. Other arrangements are possible. The first temperature sensitive actuator, like in Figures 4a and 4b comprises a bimetallic strip 83, which controls the position of a valve head 84. Likewise, the second temperature sensitive actuator comprises a bimetallic strip 85, which controls the position of a valve head 86. The valve heads 84, 86 are configured to pinch the flexible section 87.

The first bimetallic strip 83 is configured to move the valve head 84 over a wide temperature range above a first threshold temperature. The second bimetallic strip 85 is of snap-close type and reacts abruptly once a second threshold temperature is reached or exceeded.

Figure 8a shows the configuration at normal operating temperatures with both valve heads 84 and 86 withdrawn from compressing the flexible section 87. In figure 8b, the temperature has risen above the first threshold temperature but not above the second threshold temperature. Accordingly, the first bimetallic strip 83 has moved the valve head 84 to pinch the flexible section 87 and restrict the flow therethrough. Figure 8c shows the configuration at a temperature above both the first and second threshold temperatures. In this figure, the second bimetallic strip 85 has reacted abruptly and moved from its below threshold position to its above threshold position. Accordingly, valve head 86 has been driven to pinch the flexible section 87 and, in combination with the first actuator 80, close the flexible section to flow. When the temperature falls below the second threshold, the valve head 86 is withdrawn, allowing flow of fluid reactant to resume. With further decrease in temperature, below the first threshold, the valve head 83 is withdrawn to increase flow back to 100%.

This arrangement of actuators 84 and 86 is advantageous as specific valve closing profiles in response to temperature can be achieved. For example, in this embodiment, as the temperature nears the high end of the normal operating temperature, the first threshold temperature is exceeded. Accordingly, the first actuator acts to slow the flow of fluid reactant to try and bring the high, but acceptable operating temperature under control. Thus, the first valve head 84 is able to throttle flow between 0% and 50% of normal flow, for example, as the temperature increases. The second threshold

temperature may be set at the maximum normal operating temperature. Thus, when this temperature is reached the second actuator snaps the valve head 86 to close off the flow and temporarily shut down the fuel cartridge.

5 Figure 9 shows a further embodiment. In this embodiment, two temperature sensitive actuators 90 and 91 each act on a separate valve 92a and 92b. As in the previous embodiment, the first temperature sensitive actuator 90 comprises a bimetallic strip 93, which controls the position of a valve head 94. Likewise, the second temperature sensitive actuator comprises a bimetallic strip 95, which controls the position of a valve
10 head 96. The valve heads 94, 96 are configured to pinch flexible sections 97a and 97b to control the flow of fluid reactant.

The first bimetallic strip 93 and second bimetallic strip 95 are both of snap-close type and react abruptly once a first and second threshold temperature is reached or exceeded.
15 However, the first bimetallic strip 93 is configured with a restricted displacement. Thus, the first bimetallic strip 93 can move the valve head 94 between an open position, in which fluid can flow unhindered through the flexible section 97a, and a restricting position in which the flow is restricted but not inhibited. The second bimetallic strip 95 does not have a restricted displacement and is able to pinch the flexible section 97b to close it to
20 flow. The second threshold temperature, at which the second bimetallic strip actuates, is higher than the first threshold temperature at which the first bimetallic strip actuates.

At normal operating temperatures both valve heads 94 and 96 are withdrawn from compressing the flexible sections 97a and 97b. In figure 9, the temperature has risen
25 above the first threshold temperature but not above the second threshold temperature. Accordingly, the first bimetallic strip 93 has moved to the restricting position and the valve head 94 pinches the flexible section 97a to restrict the flow therethrough. When the temperature is above both the first and second threshold temperatures, the second bimetallic strip 95 operates to drive valve head 96 to pinch the flexible section 97b
30 closed. Thus, the valve head 96 and bimetallic strip 95 adopt the position adopted by strip 46 and head 44 in Figure 4b. When the temperature falls below the second threshold, the valve head 96 is withdrawn, allowing flow of fluid reactant to resume. With further decrease in temperature, below the first threshold, the valve head 93 is withdrawn to increase flow back to 100%.

35

Figure 10 shows a further embodiment in which two different bimetallic strips 1000 and 1001 are used. In this embodiment the first bimetallic strip 1000 drives a first valve head 1002 that acts on a flexible section of pipe 1003 as in previous embodiments. Thus, the first bimetallic strip 1000 acts to restrict flow through the conduit. In Figure 10, the first bimetallic strip 1000 is shown in its fully extended position, in which it has pinched the pipe 1003 to about 50% of its width. In this embodiment, the second bimetallic strip 1001 drives a second valve head 1004. The second valve head 1004 acts on the rear face of the first valve head 1002. Thus, the second bimetallic strip 1001 acts in addition to the first bimetallic strip to drive the first valve head, which controls the flow. The threshold temperatures and the response to temperature of the first and second bimetallic strip have been set such that as the temperature rises near to the maximum operating temperature the first bimetallic strip actuates abruptly and drives the valve head 1002 to the position shown in Figure 10. The supply of fluid from the supply chamber to the reaction chamber is therefore restricted. If the temperature rises to the maximum operating temperature the second bimetallic strip is configured to actuate abruptly to drive the second valve head 1004 and therefore the first valve head 1002 to inhibit flow through the pipe 1003. When the temperature falls to the acceptable operating range, the bimetallic strips 1000, 1001 will reopen the pipe 1003 as the threshold temperatures are reached. The use of multiple bimetallic strips to drive a valve head 1002 is advantageous (with the second bimetallic strip acting directly on the valve head 1002 or through the second valve head 1004), as the displacement to temperature profile can be controlled precisely.

It will be appreciated that further actuators (such as 2, 3, 4, 5, 6 or more) operating on the same valve or further valves (with one or more actuators acting on the further valves) could be provided. Further, two or more different bimetallic strips having different threshold temperatures or responses to temperature may be connected together in series. This bimetallic composite strip can then act to control a valve or the like. Thus, a valve closing profile can be achieved using only a single valve head.

It will be appreciated that the above embodiments are described as using a thermo-mechanical actuator comprising a bimetallic strip. However, other thermo-mechanical actuators that translate a change in temperature to a physical displacement can be used. For example, a bimetallic coil or MEMS thermal actuator may be used to react to temperature and actuate the opening or closing of the valve 9 or movement of the inhibitor bar. The form of the gas supply cartridge 1 described above is only an example

and other designs or types of gas supply cartridge can be used. Also, the bimetallic strip is described as being located adjacent to the reaction chamber, however, it could be spaced from the reaction chamber and be able to sense the temperature of the reaction chamber by way of a heat pipe that bridges the gap between the bimetallic strip and the
5 reaction chamber. The heat pipe is able to transfer the heat from the reaction chamber to the bimetallic strip.

Other embodiments are intentionally within the scope of the accompanying claims.

CLAIMS

1. A fuel cartridge for generating gas, comprising:
a cartridge housing;
5 a reaction chamber containing fuel;
a fluid supply chamber within the cartridge housing and containing a fluid reactant, the fluid supply chamber being coupled to the reaction chamber for supplying the fluid reactant to the reaction chamber; and
wherein the cartridge includes a temperature sensitive element adapted to control
10 the supply of fluid reactant to the reaction chamber, the temperature sensitive element configured to reversibly restrict the supply when a threshold temperature is exceeded.
2. The fuel cartridge of claim 1 in which the temperature sensitive element is configured to inhibit the flow of fluid reactant when the threshold temperature is reached
15 or exceeded.
3. The fuel cartridge of claim 1 or claim 2 in which the temperature sensitive element includes a thermo-mechanical actuator, wherein movement of the actuator in response to temperature acts to control the supply of reactant fluid to the reaction
20 chamber.
4. The fuel cartridge of claim 3 in which the thermo-mechanical actuator comprises a bimetallic strip.
- 25 5. The fuel cartridge of any preceding claim in which the temperature sensitive element is located such that it is in thermal contact with the reaction chamber.
6. The fuel cartridge of claim 3 or claim 4 in which the temperature sensitive element includes a valve and the thermo-mechanical actuator is configured to actuate
30 the valve.
7. The fuel cartridge of claim 6 in which the valve is located between the fluid supply chamber and the reaction chamber.
- 35 8. The fuel cartridge of claim 6 or claim 7 in which the valve is configured to open against the flow of fluid reactant, when in use.

9. The fuel cartridge of any one of claims 6 to 8 in which the valve includes a valve body arranged to be moved with respect to a valve seat by the thermo-mechanical actuator to control the supply of fluid reactant.

5

10. The fuel cartridge of any one of claims 6 to 8 in which the valve includes a sealing diaphragm and a sealing plate having an aperture therein, the sealing diaphragm adapted to lie against the sealing plate to close the aperture in a closed position and the sealing diaphragm adapted to be displaced from the sealing plate by the valve actuator in a open position.

10

11. The fuel cartridge of any one of claims 6 to 8 in which the valve includes a flexible conduit through which the fluid reactant is arranged to flow and a valve head, the valve head arranged to compress or pinch the flexible conduit to restrict the supply of fluid reactant.

15

12. The fuel cartridge of any one of claims 1 to 5 in which the cartridge includes a moveable part in the fluid supply chamber for driving the reactant fluid into the reaction chamber and the temperature sensitive element includes a movement inhibitor for preventing and allowing the movement of the moveable part in response to changes in temperature.

20

13. The fuel cartridge of claim 12 in which the movement inhibitor is moveable to a position which prevents the movement of the moveable part when the threshold temperature is exceeded.

25

14. The fuel cartridge of any preceding claim, in which the fuel cartridge includes a second temperature sensitive element adapted to control or inhibit the supply of fluid reactant to the reaction chamber, the second temperature sensitive element configured to reversibly restrict the supply when a second threshold temperature is exceeded.

30

15. The fuel cartridge of claim 14 in which the temperature sensitive element comprises a first valve with an associated first temperature sensitive valve actuator, and the second temperature sensitive element comprises a second valve with an associated second temperature sensitive valve actuator, the first and second valves connected in series.

35

16. The fuel cartridge of claim 14 in which the temperature sensitive element and second temperature sensitive element comprise first and second valve actuators respectively that act on the same valve.

5

17. The fuel cartridge of claim 15 or claim 16 in which the valve actuators act to control the supply of fluid reactant at different rates in response to temperature changes.

10

18. The fuel cartridge of any preceding claim, in which the temperature sensitive element includes two or more bimetallic strips, the bimetallic strips connected together and arranged to act together to control the supply of fluid reactant to the reaction chamber.

15

19. A method for controlling the supply of a fluid reactant to a reaction chamber in a fuel cartridge for generating gas, the method comprising the steps of;

providing a temperature sensitive element in the cartridge for controlling the supply of a fluid reactant to a reaction chamber; and

using the temperature sensitive element to reversibly restrict the supply of fluid reactant to the reaction chamber when a threshold temperature is exceeded.

20

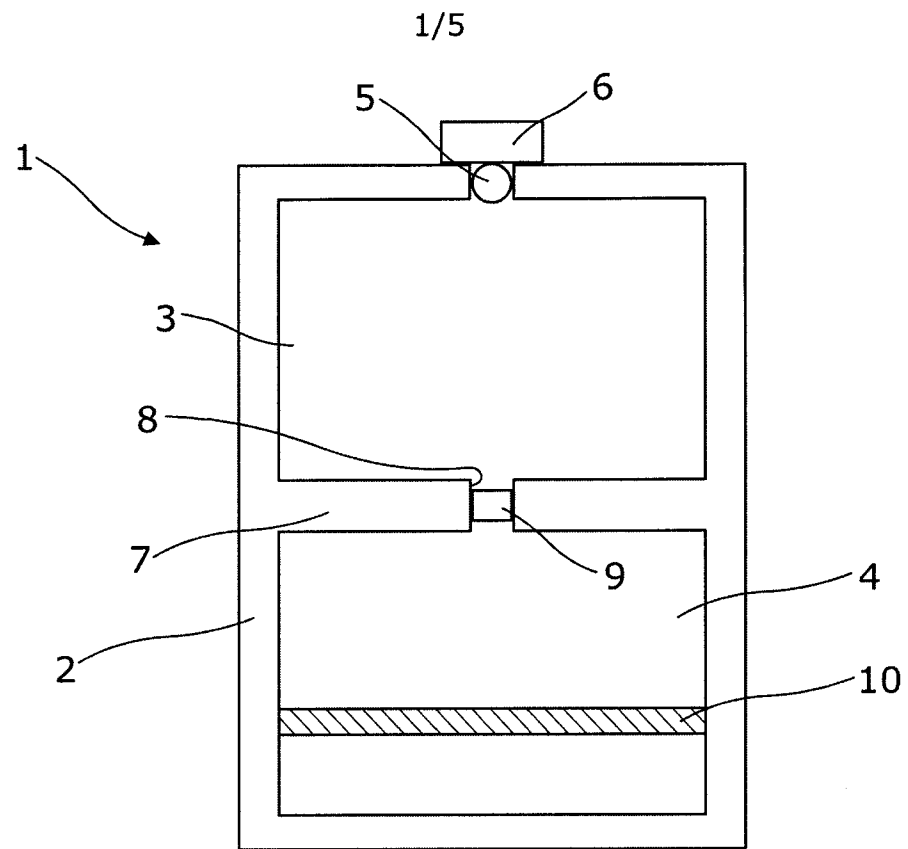


Fig. 1

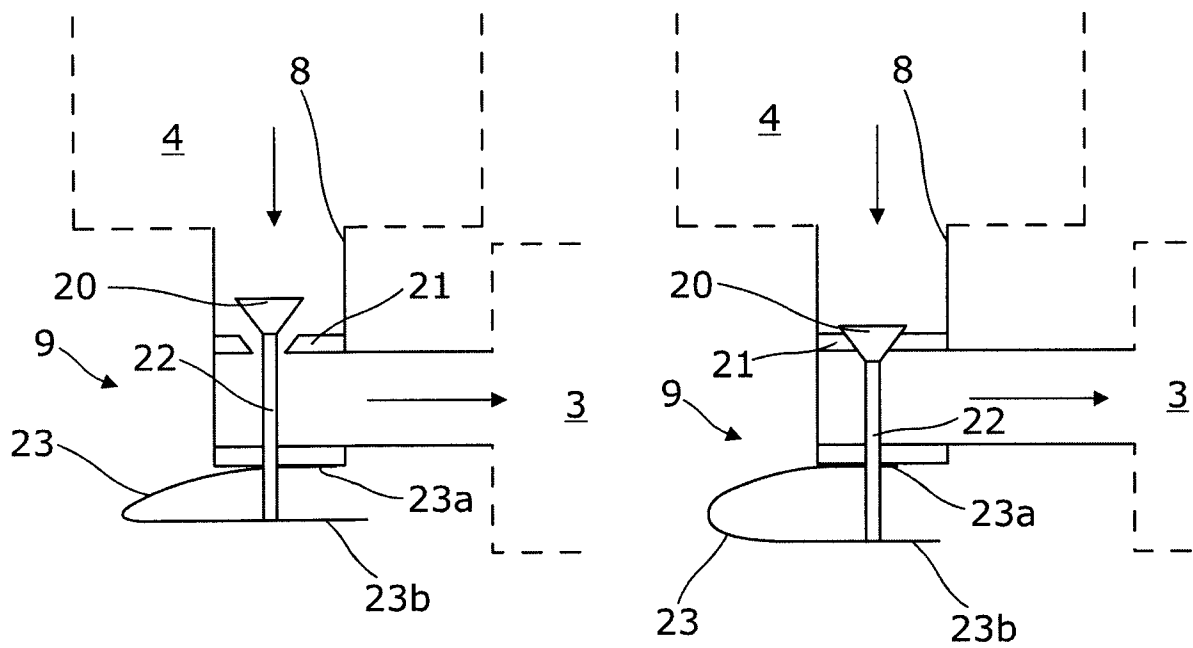


Fig. 2a

Fig. 2b

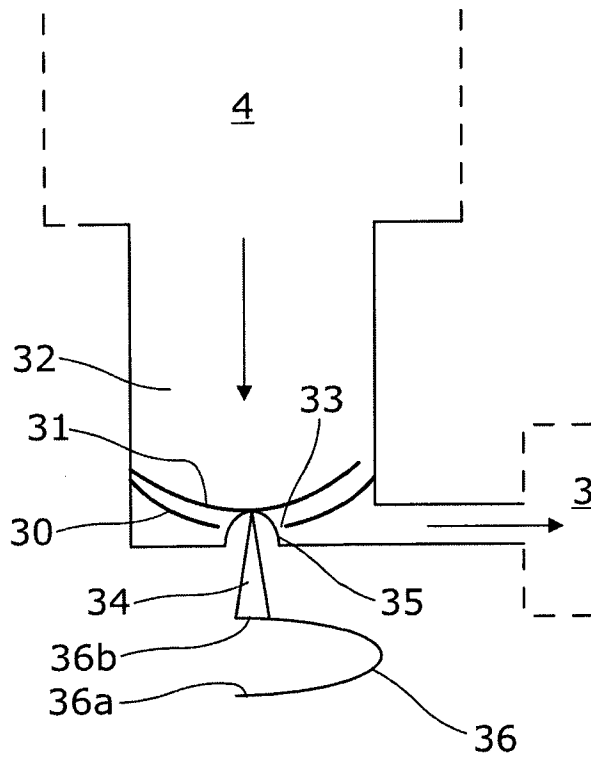


Fig. 3a

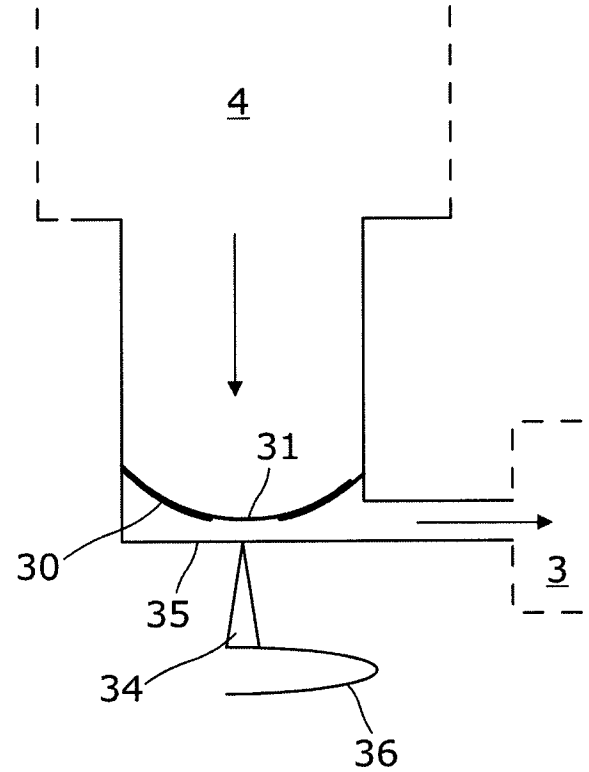


Fig. 3b

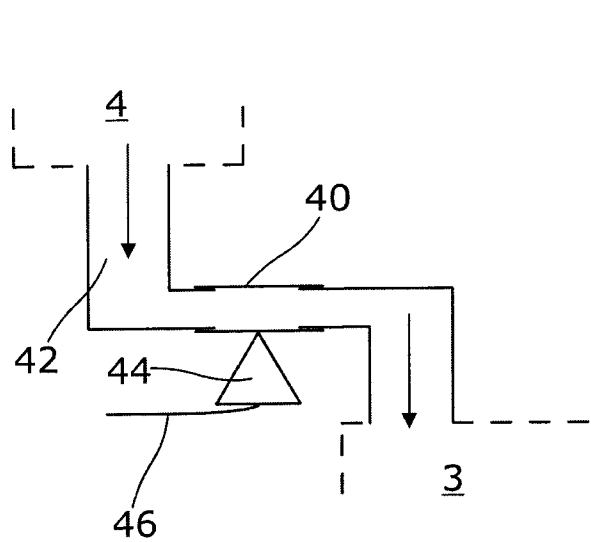


Fig. 4a

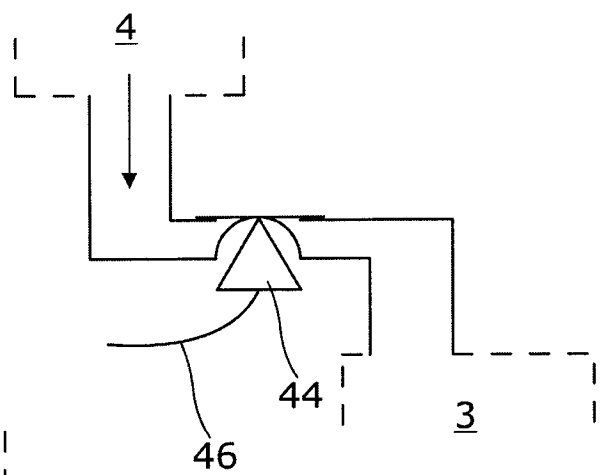


Fig. 4b

3/5

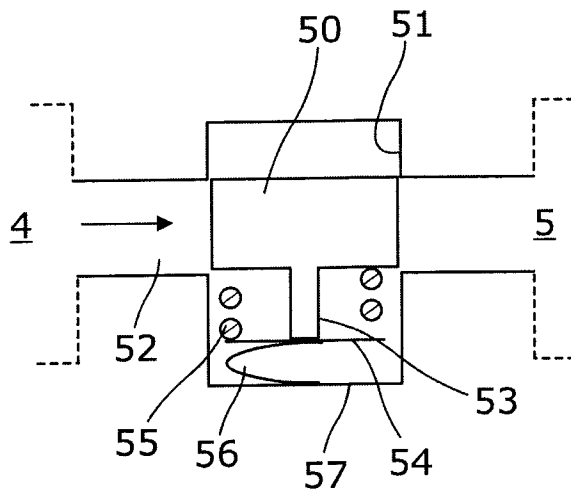


Fig. 5a

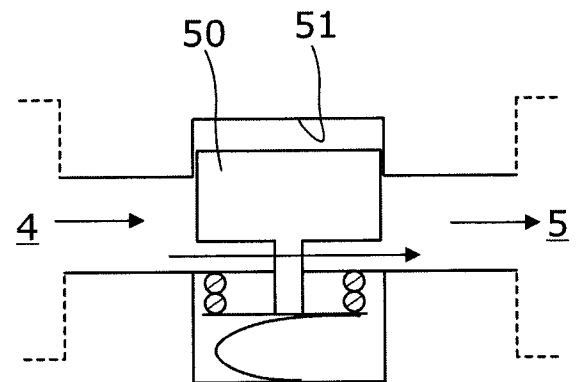


Fig. 5b

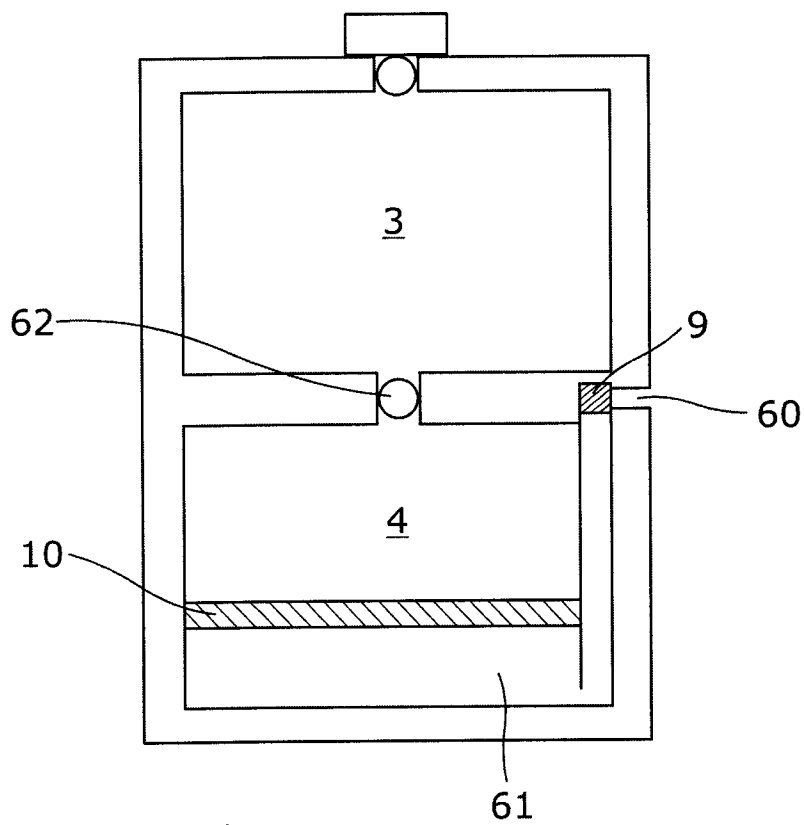


Fig. 6

4/5

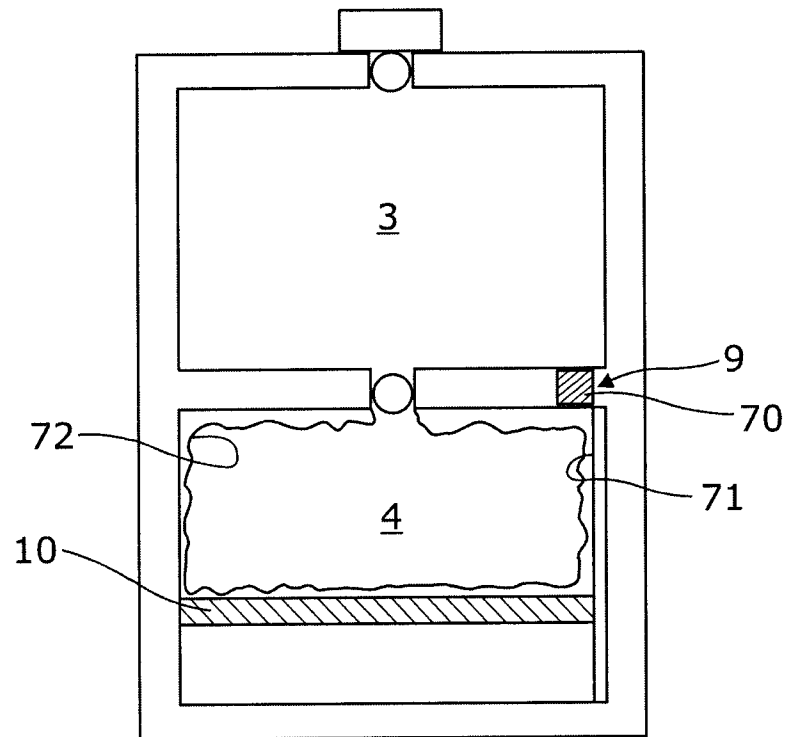


Fig. 7a

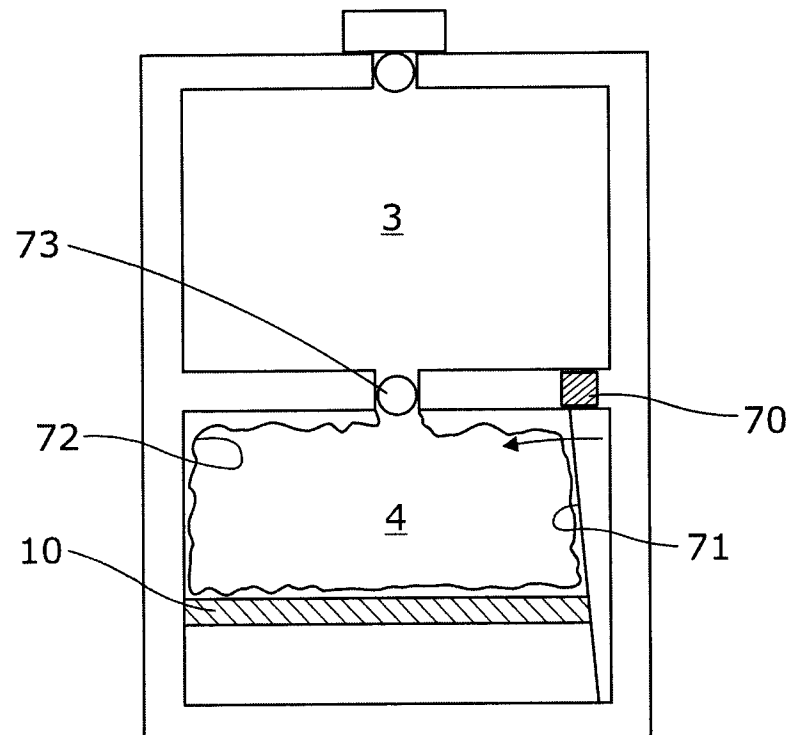


Fig. 7b

5/5

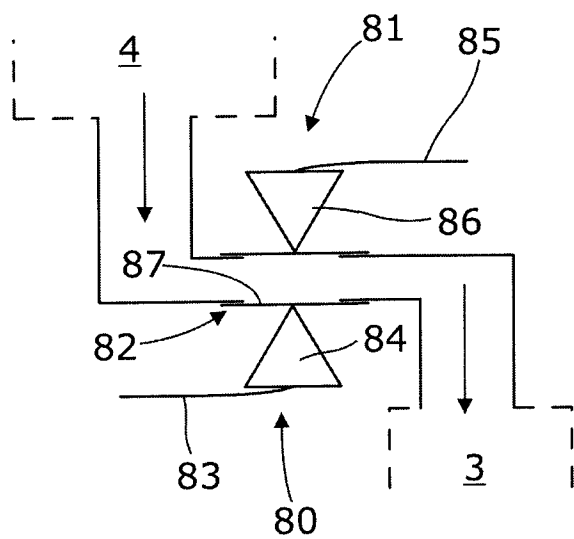


Fig. 8a

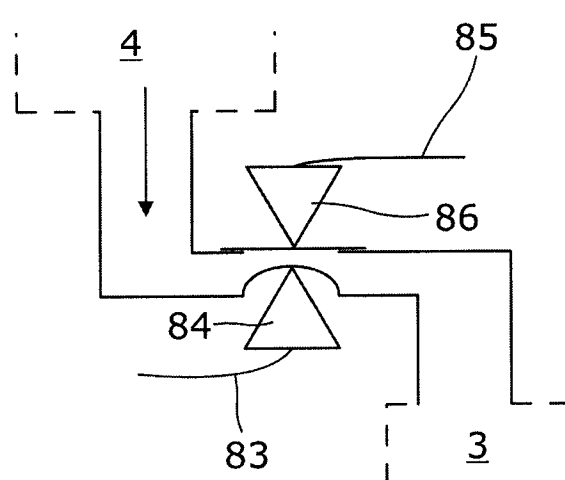


Fig. 8b

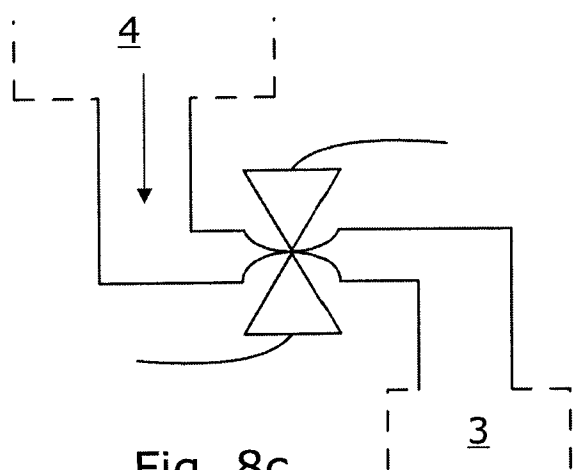


Fig. 8c

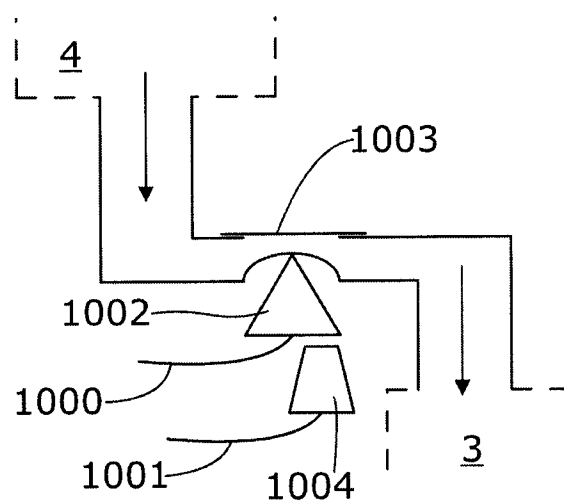


Fig. 10

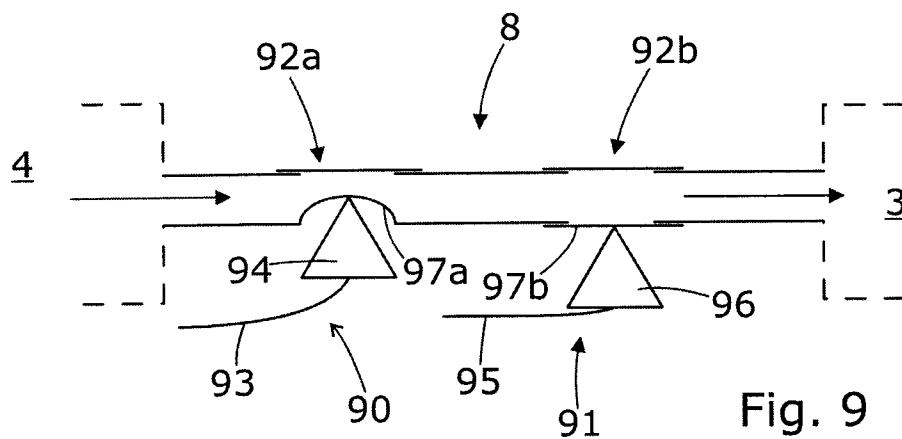


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2014/050660

A. CLASSIFICATION OF SUBJECT MATTER

INV. C01B3/06 F16K31/00
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)

C01B F16K

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/059778 A1 (SHURTLEFF JAMES K [US] ET AL SHURTLEFF JAMES KEVIN [US] ET AL) 23 March 2006 (2006-03-23)	1,2,5,19
Y	paragraphs [0035], [0038], [0040] -----	3,4,6-18
X	US 2010/247426 A1 (WALLACE ANDREW P [US] ET AL) 30 September 2010 (2010-09-30)	1-3,5-7, 19
Y	paragraphs [0035], [0038], [0040]; figures 1,2 -----	4,8-18
Y	DE 10 2008 054222 A1 (FRAUNHOFER GES FORSCHUNG [DE]) 16 September 2010 (2010-09-16)	3,4,6-18
	paragraphs [0001], [0027]; figure 1 ----- -/-	



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

4 July 2014

Date of mailing of the international search report

15/07/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Galleiske, Anke

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/050660

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 10 2004 050510 A1 (SIEMENS AG [DE]) 20 April 2006 (2006-04-20) paragraphs [0026], [0029]; claims 6,8,9,10,12,13; figures 2,3 -----	3,4,6-18
Y	GB 2 064 723 A (GESTRA KSB VERTRIEB GMBH) 17 June 1981 (1981-06-17) page 2, lines 67-100; figures 1,3 -----	4,6-18
A	US 2007/036711 A1 (FISHER TOBIN J [US] ET AL) 15 February 2007 (2007-02-15) paragraphs [0024], [0027], [0038] - [0040] -----	1-19
A	US 6 746 496 B1 (KRAVITZ STANLEY H [US] ET AL) 8 June 2004 (2004-06-08) column 7, lines 30-40; claims 1,5; figure 2 -----	1-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2014/050660

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006059778 A1	23-03-2006	AU 2005304304 A1 EP 1814653 A1 US 2006059778 A1 US 2009053134 A1 WO 2006053236 A1	18-05-2006 08-08-2007 23-03-2006 26-02-2009 18-05-2006
US 2010247426 A1	30-09-2010	AU 2010232775 A1 CA 2757452 A1 CN 102448600 A EP 2414096 A1 JP 2012522716 A KR 20110133615 A SG 174594 A1 US 2010247426 A1 WO 2010114849 A1	13-10-2011 07-10-2010 09-05-2012 08-02-2012 27-09-2012 13-12-2011 28-10-2011 30-09-2010 07-10-2010
DE 102008054222 A1	16-09-2010	DE 102008054222 A1 EP 2340386 A1 WO 2010049092 A1	16-09-2010 06-07-2011 06-05-2010
DE 102004050510 A1	20-04-2006	DE 102004050510 A1 US 2007265439 A1 WO 2006042825 A1	20-04-2006 15-11-2007 27-04-2006
GB 2064723 A	17-06-1981	BE 886473 A1 BR 8007880 A CA 1159030 A1 DE 2948686 A1 ES 8202124 A1 FI 803519 A FR 2470921 A1 GB 2064723 A HU 182246 B IT 1207159 B JP H0150800 B2 JP S5690191 A NL 8006228 A SE 8008488 A US 4347975 A	01-04-1981 16-06-1981 20-12-1983 11-06-1981 01-04-1982 05-06-1981 12-06-1981 17-06-1981 28-12-1983 17-05-1989 31-10-1989 22-07-1981 01-07-1981 05-06-1981 07-09-1982
US 2007036711 A1	15-02-2007	EP 1922285 A2 JP 2009504555 A US 2007036711 A1 US 2009274595 A1 US 2012121996 A1 WO 2007021934 A2	21-05-2008 05-02-2009 15-02-2007 05-11-2009 17-05-2012 22-02-2007
US 6746496 B1	08-06-2004	US 6746496 B1 US 7306780 B1 US 7427302 B1	08-06-2004 11-12-2007 23-09-2008