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(54) **Piezoelectric pump and pressurised circuit provided therewith**

(57) A piezoelectric pump for use in a pressurised circuit is provided, comprising a pump chamber (5) with an inlet (6) provided with a one way inlet valve (7), for connection to a feeding line (8) of the pressurised circuit and an outlet (9) provided with a one way outlet valve (10), for connection to a discharge line (11) of the pressurised circuit and a pump diaphragm (12) closing one end of the pump chamber (5). A pressure chamber (15) is defined at the side of the pump diaphragm (12) facing away from the pump chamber (5), wherein said pressure chamber (15) is connected to a pressure source, which may be the feeding line (8).

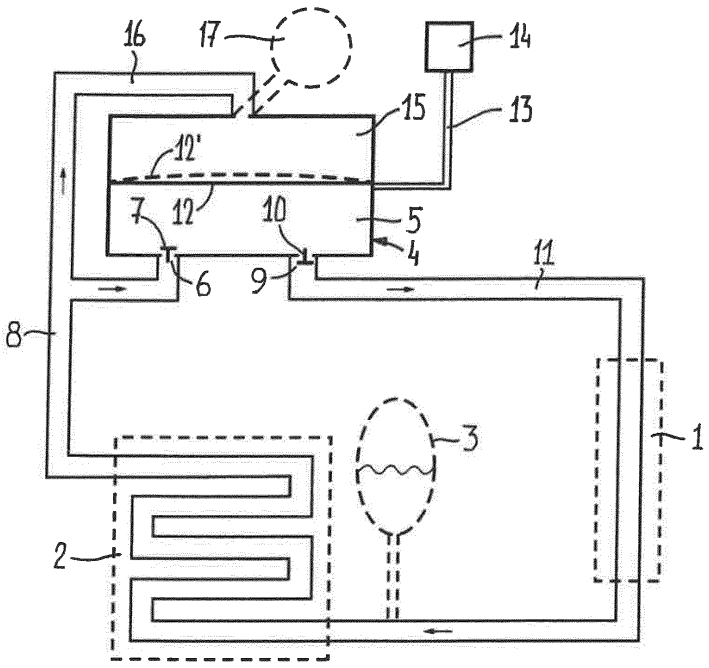

Fig.1

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Description

[0001] The invention relates to the field of piezo pumps for use in a pressurised circuit, comprising a pump chamber with an inlet provided with a one way inlet valve, for connection to a feeding line of the pressurised circuit and an outlet provided with a one way outlet valve, for connection to a discharge line of the pressurised circuit and a piezo pump diaphragm closing one end of the pump chamber.

[0002] In such a piezo pump the piezo pump diaphragm is the driving element which, when connected to an alternate current, vibrates for alternatingly sucking fluid through the one way inlet valve into the pump chamber and forcing the fluid through the one way outlet valve out of the pump chamber. Although such a piezo pump with a very simple design effectively achieves a pump action, the use of such a piezo pump in a pressurised circuit may lead to problems with respect to the seal between the piezo pump diaphragm and a surrounding wall of the pump chamber. Whereas achieving an appropriate seal already is difficult because of the vibrations of the piezo pump diaphragm, the fact that the fluid in the pump chamber is pressurised increases the risk of leakages between the surrounding wall of the pump chamber and the piezo pump diaphragm.

[0003] Thus it is an object of the present invention to provide an improved piezo pump of the type referred to above.

[0004] For achieving this object, the piezo pump in accordance with the present invention is characterized in that a pressure chamber is defined at the side of the piezo pump diaphragm facing away from the pump chamber, wherein said pressure chamber is connected to a pressure source.

[0005] The pressure in the pressure chamber at least partially compensates the pressure in the pump chamber, as a result of which the pressure difference over the piezo pump diaphragm is reduced and, consequently, the forces acting on the piezo pump diaphragm are reduced. This will substantially reduce the risk of leakages.

[0006] In one embodiment of the piezo pump the pressure source is defined by the feeding line which is connected to the pressure chamber via a pressure line. Such an embodiment offers the advantage that the pressure at both sides of the piezo pump diaphragm always will be substantially the same, thus minimising any pressure difference over said piezo pump diaphragm. Moreover such an embodiment only requires a connection between the feeding line and the pressure chamber, but not a separate pressure source, because the feeding line will act as such.

[0007] However, in an alternative embodiment of the piezo pump the pressure source may be defined by a pressurised vessel (or an equivalent pressure source).

[0008] The invention also relates to a piezo pump assembly comprising at least two piezo pumps connected to each other in series, wherein the outlet of a previous piezo pump is connected to the inlet of a following piezo pump. This allows to achieve an increased pressure difference.

[0009] With respect to such a piezo pump assembly an embodiment is conceivable in which the pressure source of at least the first piezo pump is defined by the feeding line and wherein the pressure source of at least the last piezo pump is defined by the discharge line which is connected to the pressure chamber of said last piezo pump via an additional pressure line.

[0010] Thus, in such an embodiment not only the feeding line, but also the discharge line acts as a pressure source for the pressure chamber to which it is connected. One large advantage offered by such an embodiment is, that the risk of an hydraulic short circuit over the series of piezo pumps is substantially reduced compared to a situation in which also the pressure chamber of the last piezo pump is connected to the feeding line. In the latter case a failure of only two members (the one way outlet valve and the piezo pump diaphragm of the last piezo pump) is sufficient to cause a short circuit (a connection between the feeding line and discharge line), whereas in the former case a failure of four elements (both the one way inlet and outlet valves of the last piezo pump and the one way outlet valve with the one way inlet valve or with the piezo pump diaphragm of the first piezo pump) is required to cause a short circuit (for more than two piezo pumps connected in series an equivalent situation applies).

[0011] If there are exactly two piezo pumps connected to each other in series in such an assembly, the pressure chamber of the first piezo pump will be connected to the feeding line and the pressure chamber of the second piezo pump will be connected to the discharge line.

[0012] In embodiments of a piezo pump assembly with more than two piezo pumps connected to each other in series, only the pressure chamber of the last piezo pump may be connected to the discharge line. The pressure chamber of the remaining piezo pumps then all will be connected to the feeding line. Thus the number of pressure chambers connected to the discharge line is kept minimal (one only), which may be advantageous in view of pressure fluctuations which inevitably are present in the discharge line as a result of the operation of the piezo pumps and which could influence the effectiveness of the pressure equalisation over the piezo pump diaphragm (it may be desirable to have a more constant pressure in the pressure chambers and this will be provided by the feeding line in which no or lesser pressure fluctuations occur).

[0013] In a special embodiment of the piezo pump according to the present invention it comprises an additional pump chamber at the side of the piezo pump diaphragm opposite the pump chamber, which additional pump chamber likewise is provided with an inlet provided with a one way inlet valve, for connection to the feeding line of the pressurised circuit and an outlet provided with a one way outlet valve, for connection to the discharge line

of the pressurised circuit, wherein the piezo pump diaphragm is common for both the pump chamber and the additional pump chamber and wherein the additional pump chamber acts as the pressure chamber.

[0014] In such a piezo pump the additional pump chamber not only acts as the pressure chamber, but also helps in pumping the fluid, thus increasing the delivery of the piezo pump. A separate pressure source is not required in such an embodiment, because the feeding line of the additional pump chamber acts as such. It is noted that in such an embodiment the indications pump chamber and additional pump chamber are just a matter of definition and could be switched.

[0015] Also in such an embodiment of the piezo pump a piezo pump assembly is conceivable which comprises at least two of such piezo pumps connected to each other in series, wherein the outlets of a previous piezo pump are connected to the inlets of a following piezo pump. The number of piezo pumps connected in series may vary as desired.

[0016] The invention also relates to a piezo pump device comprising a number of piezo pumps or piezo pump assemblies according to the present invention connected to each other in parallel. Thus the total delivery may be increased.

[0017] For example it is conceivable that in such a piezo pump device each piezo pump or piezo pump assembly has a planar configuration and wherein these piezo pumps or piezo pump assemblies are stacked in a planar fashion to define a pillar like structure.

[0018] Finally the invention also relates to a pressurised circuit comprising a piezo pump, piezo pump assembly or piezo pump device according to the invention.

[0019] Hereinafter the invention will be elucidated while referring to the drawings, in which:

Figure 1 schematically shows a pressurised circuit comprising a first embodiment of the piezo pump according to the invention;
Figure 2 shows an embodiment of a piezo pump assembly comprising two piezo pumps in series;
Figure 3 shows an embodiment of a piezo pump assembly comprising three piezo pumps in series;
Figure 4 shows another embodiment of a piezo pump having two pump chambers;
Figure 5 shows an embodiment of a piezo pump assembly comprising two piezo pumps according to figure 4 in series;
Figure 6 shows an embodiment with two piezo pump assemblies in parallel, and
Figure 7 schematically illustrates an embodiment of a pillar shaped piezo pump device.

[0020] Referring firstly to figure 1 a pressurised circuit for a fluid is illustrated schematically. Such a circuit may, for example, be used as a cooling circuit for electronics 1 in a satellite. The circuit as illustrated further comprises a heat exchanger 2 and possibly an accumulator vessel 3.

[0021] For causing a flow of the fluid through the circuit in accordance with the arrows indicated in figure 1, a piezo pump 4 is provided which comprises a pump chamber 5 with an inlet 6 provided with a one way inlet valve 7, for connection to a feeding line 8 of the pressurised circuit and an outlet 9 provided with a one way outlet valve 10, for connection to a discharge line 11 of the pressurised circuit.

[0022] The piezo pump 4 further is provided with a piezo pump diaphragm 12 that closes one end of the pump chamber 5 and that by control lines 13 is connected to a control unit 14. As a result of electric control signals (for example an alternate current) from the control unit 14 the piezo pump diaphragm 12 will vibrate between two positions (for example 12 and 12') for alternatingly sucking fluid into the pump chamber 5 through the inlet 6 and forcing fluid out of the pump chamber 5 through the outlet 9.

[0023] A pressure chamber 15 is defined at the side of the piezo pump diaphragm 12 facing away from the pump chamber 5 and this pressure chamber 15 is connected to the feeding line 8 via a pressure line 16. As an alternative the pressure chamber 15 may be connected directly to a pressurised vessel 17 or another pressure source. The pressure in the pressure chamber 15 (or pressure vessel 17) at least partially compensates the pressure in the pump chamber 5, as a result of which the pressure difference over the piezo pump diaphragm 12 is reduced and, consequently, the forces acting on the piezo pump diaphragm 12 are reduced. This will substantially reduce the risk of leakages past said diaphragm.

[0024] Figure 2 illustrates a piezo pump assembly comprising two piezo pumps 4' and 4" connected to each other in series, wherein the outlet 9' of the first piezo pump 4' is connected to the inlet 6" of the second piezo pump 4". The pressure chamber 15' of the first piezo pump 4' is connected to the feeding line 8 by a pressure line 16', but the pressure chamber 15" of the second piezo pump 4" is connected to the discharge line 11 via an additional pressure line 18.

[0025] One large advantage offered by such an embodiment is, that the risk of an hydraulic short circuit over the series of piezo pumps 4' and 4" is substantially reduced compared to a situation in which also the pressure chamber 15" of the second piezo pump 4" would be connected to the feeding line 8. In the latter case a failure of only two members (the one way outlet valve 10" and the piezo pump diaphragm 12" of the second piezo pump 4") would be sufficient to cause a short circuit in which the discharge line 11 is directly connected to the feeding line 8. In the illustrated embodiment, however, a failure of four elements (both the one way inlet valve 7" and one way outlet valve 10" of the second piezo pump 4" and the one way outlet valve 10" with the one way inlet valve 7' or with the piezo pump diaphragm 12' of the first piezo pump 4') is required to cause such a short circuit.

[0026] Figure 3 shows an embodiment of a piezo pump assembly with three piezo pumps 4', 4" and 4"', wherein only the pressure chamber 15"' of the last piezo pump 4"' is connected to the discharge line 11. The pressure chambers of the remaining piezo pumps all are connected to the feeding line 8.

[0027] Figure 3 in dotted lines illustrates an alternative possibility according to which the pressure chamber 15" of the second piezo pump 4" is connected to the outlet 9' of the first piezo pump 4' by a connecting line 19 (and is not connected to the feeding line 8). A similar situation may occur for the pressure chamber 15"'.

[0028] Referring to figure 4 a special embodiment of the piezo pump is illustrated which comprises an additional pump chamber 20 (taking the place of the pressure chamber) at the side of the piezo pump diaphragm 12 opposite the pump chamber 5. Said additional pump chamber 20 likewise is provided with an inlet 21 provided with a one way inlet valve 22, for connection to the feeding line 8 of the pressurised circuit and an outlet 23 provided with a one way outlet valve 24, for connection to the discharge line 11 of the pressurised circuit. In this embodiment the piezo pump diaphragm 12 is common for both the pump chamber 5 and the additional pump chamber 20. The additional pump chamber 20 acts as the pressure chamber for the pump chamber 5, and the pump chamber 5 acts as a pressure chamber for the additional pump chamber 20.

[0029] In an embodiment of an piezo pump assembly illustrated in figure 5, two piezo pumps according to figure 4 are connected to each other in series (wherein the outlets of a first piezo pump are connected to the inlets of a second piezo pump). Of course it is possible to connect more than two piezo pumps in series.

[0030] Referring to figure 6 a schematic representation is illustrated of a piezo pump device comprising two piezo pump assemblies (one comprising two piezo pumps 25 and 26 connected in series and the other comprising two piezo pumps 27 and 28 connected in series) connected to each other in parallel. Of course more than two such piezo pump assemblies may be connected in parallel and each such piezo pump assembly may comprise any number of piezo pumps (also only one), wherein those numbers do not have to be the same for all piezo pump assemblies.

[0031] It is possible that each piezo pump or piezo pump assembly as described above has a planar configuration and wherein a number of such piezo pumps or piezo pump assemblies 29 are stacked in a planar fashion to define a pillar like structure 30 as shown in figure 7.

[0032] The invention is not limited to the embodiments described before, which may be varied widely within the scope of the invention as defined by the appending claims.

Claims

1. Piezo pump for use in a pressurised circuit, comprising a pump chamber with an inlet provided with a one way inlet valve, for connection to a feeding line of the pressurised circuit and an outlet provided with a one way outlet valve, for connection to a discharge line of the pressurised circuit and a piezo pump diaphragm closing one end of the pump chamber, **characterized in that** a pressure chamber is defined at the side of the piezo pump diaphragm facing away from the pump chamber, wherein said pressure chamber is connected to a pressure source.

2. Piezo pump according to claim 1, wherein the pressure source is defined by the feeding line which is connected to the pressure chamber via a pressure line.

3. Piezo pump according to claim 1, wherein the pressure source is defined by a pressurised vessel.

3. Piezo pump assembly comprising at least two piezo pumps according to claim 1 or 2 connected to each other in series, wherein the outlet of a previous piezo pump is connected to the inlet of a following piezo pump.

4. Piezo pump assembly according to claim 3, wherein the pressure source of at least the first piezo pump is defined by the feeding line and wherein the pressure source of at least the last piezo pump is defined by the discharge line which is connected to the pressure chamber of said last piezo pump via an additional pressure line.

5. Piezo pump assembly according to claim 4, wherein only the pressure chamber of the last piezo pump is connected to the discharge line.

6. Piezo pump according to claim 1, comprising an additional pump chamber at the side of the piezo pump diaphragm opposite the pump chamber, which additional pump chamber likewise is provided with an inlet provided with a one way inlet valve, for connection to the feeding line of the pressurised circuit and an outlet provided with a one way outlet valve, for connection to the discharge line of the pressurised circuit, wherein the piezo pump diaphragm is common for both the pump chamber and the additional pump chamber and wherein the additional pump chamber acts as the pressure chamber.

7. Piezo pump assembly comprising at least two piezo pumps according to claim 6 connected to each other in series, wherein the outlets of a previous piezo pump are connected to the inlets of a following piezo pump.

8. Piezo pump device comprising a number of piezo pumps or piezo pump assemblies according to a corresponding one of the previous claims connected to each other in parallel.

9. Piezo pump device according to claim 8, wherein each piezo pump or piezo pump assembly has a planar configuration and wherein these piezo pumps or piezo pump assemblies are stacked in a planar fashion to define a pillar like structure.

10. Pressurised circuit comprising a piezo pump, piezo pump assembly or piezo pump device according to a corresponding one of the previous claims.

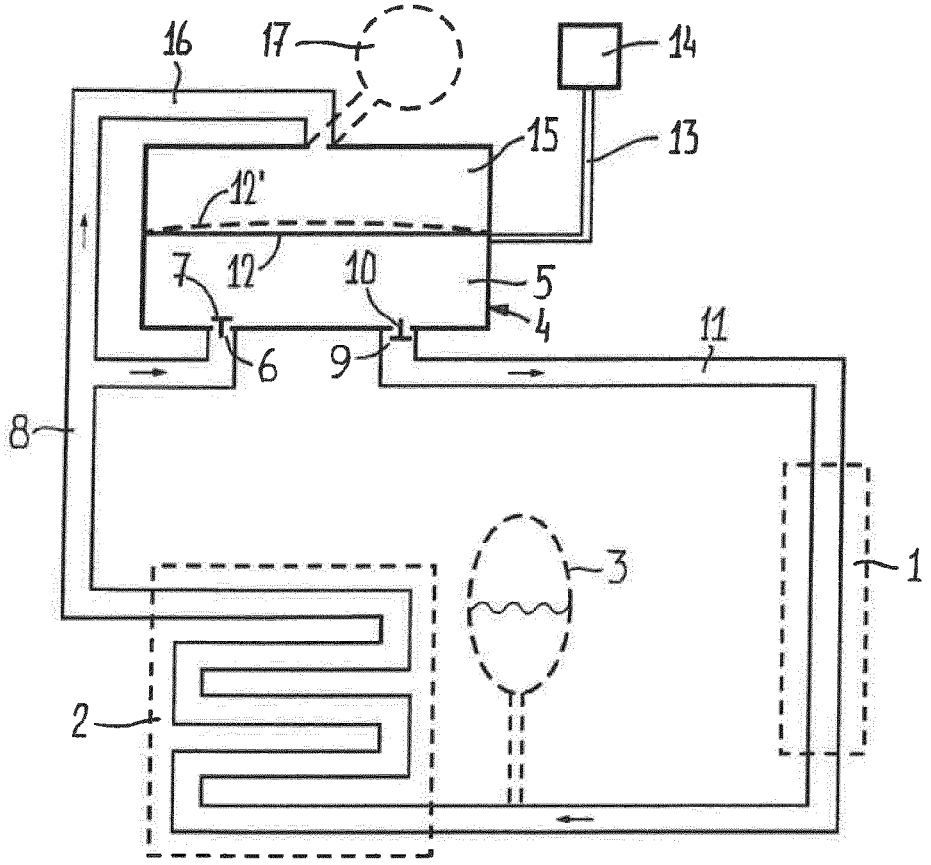
16
17
14
15
13
12'
12
7
10
5
4
11
6
9
8
3
1
2

Fig.1

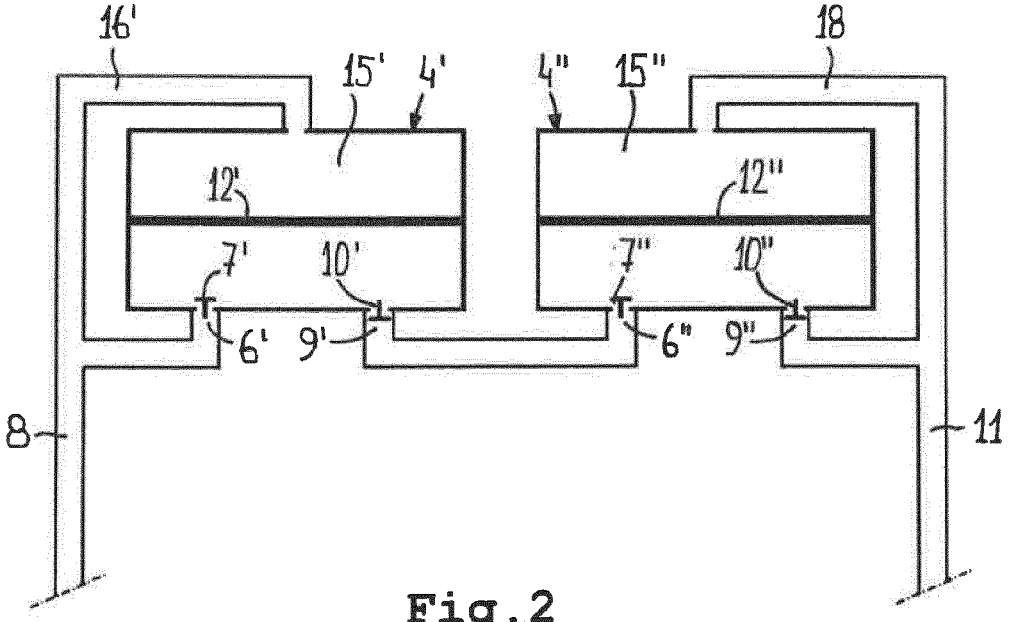
16'
18
15'
4'
4"
15"
12'
12"
7'
10'
7"
10"
6'
9'
6"
9"
8
11

Fig.2

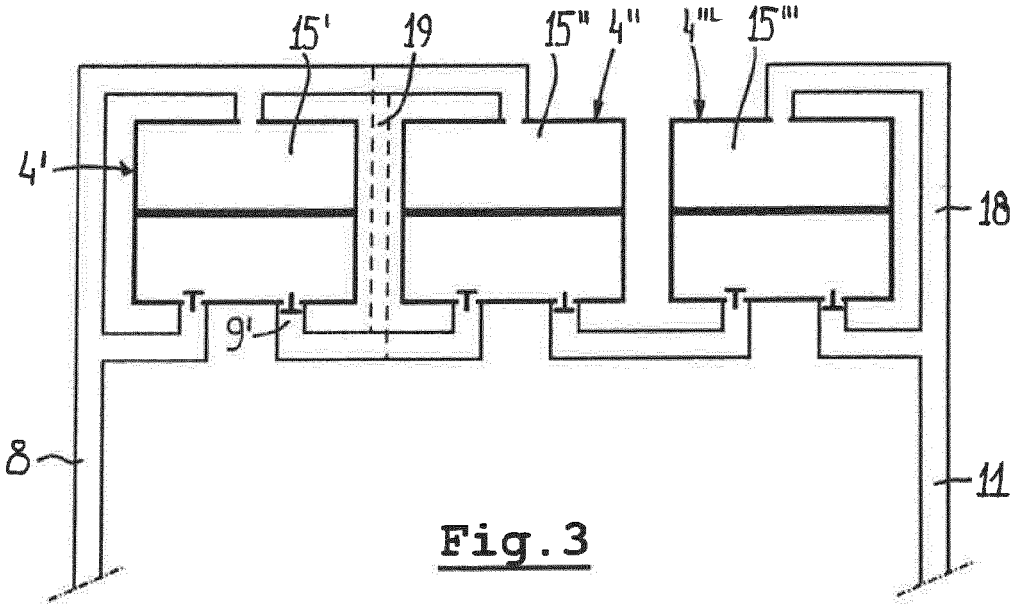

Fig.3

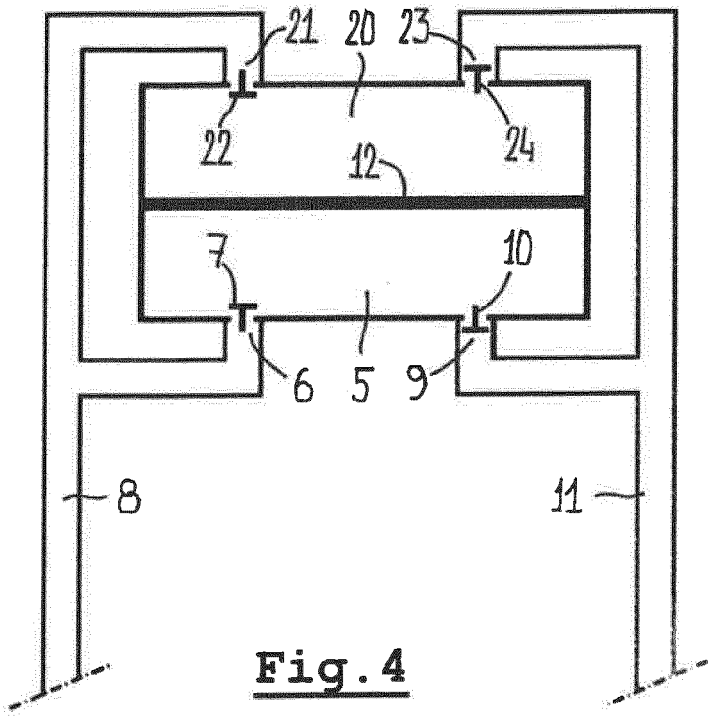

Fig.4

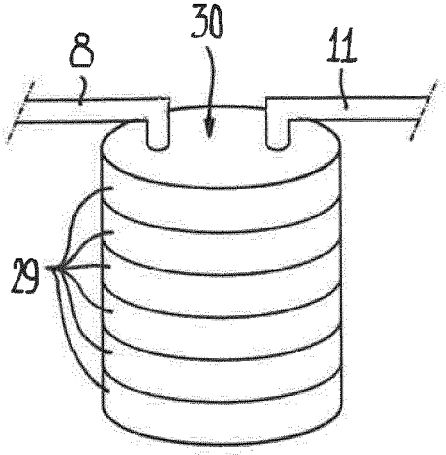

Fig.7

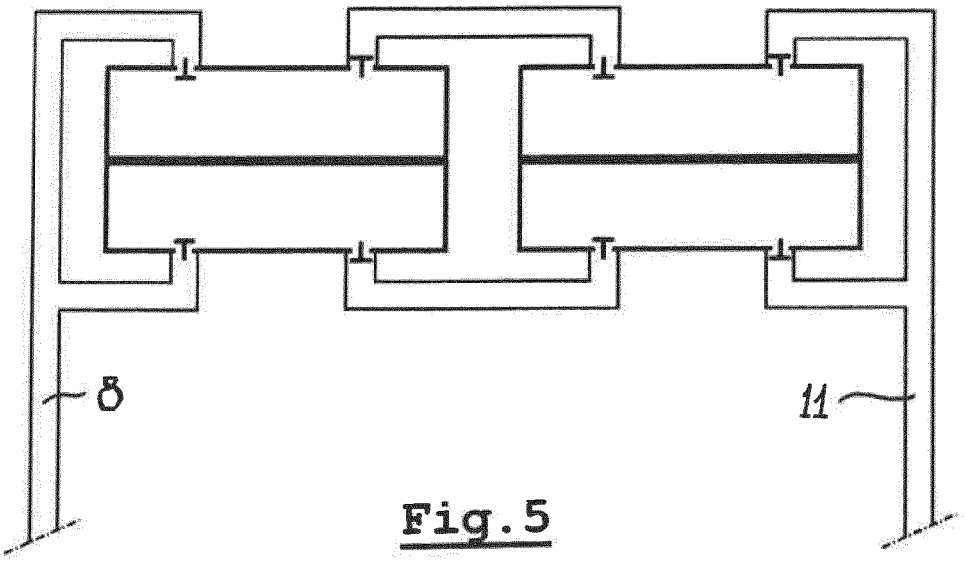

Fig.5

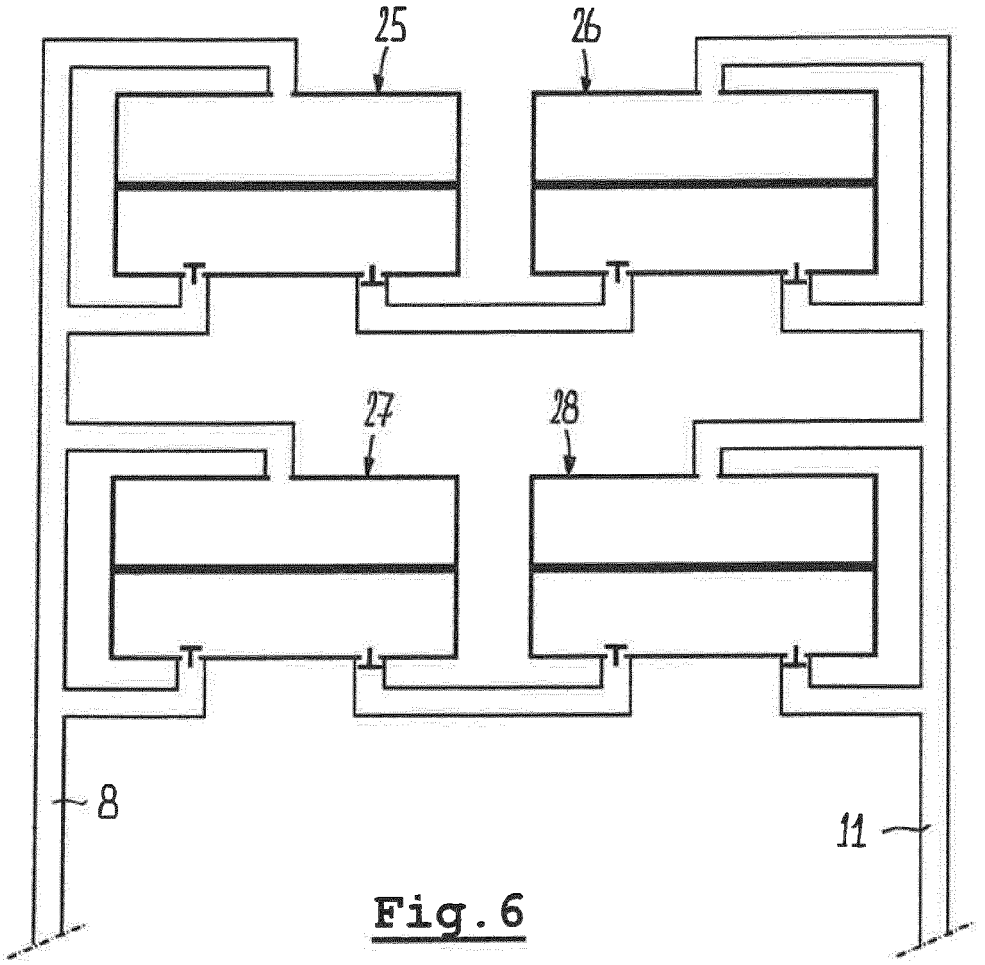

Fig.6

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 4209

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	24 June 2014	Olona Laglera, C

CATEGORY OF CITED DOCUMENTS

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