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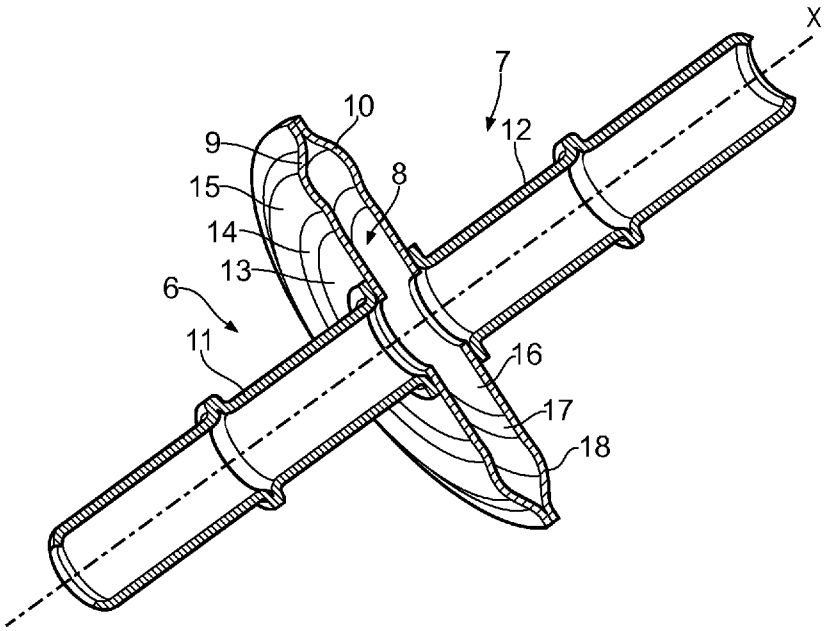

FIG. 2

(57) Abstract: The present disclosure relates to a damping apparatus (1) for damping pressure waves in a conduit (2). The damping apparatus (1) includes a vessel (5) defining a damping chamber (8) having an internal volume. An inlet (6) and an outlet (7) are provided for connecting the damping chamber (8) in series to the conduit (2). The vessel (5) comprises at least one resiliency deformable plate (9, 10) to enable the internal volume of the damping chamber (8) to change. In use, pressure waves transmitted in the conduit (2) can be damped. The present disclosure also relates to a pump system (3) in combination with a damping apparatus (1).

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DAMPING APPARATUS

TECHNICAL FIELD

The present disclosure relates to a damping apparatus; and to a fuel pump system comprising a damping apparatus.

BACKGROUND

Fuel pumps, particularly single plunger pumps, often have problems filling at higher speeds. The fuel pump typically has an inlet valve which opens and closes during the pumping cycle. The change of state of the inlet valve during the pumping cycle can induce a stop-start behaviour in the fluid. The inertia of the fluid resists the pumping action and gives rise to pressure waves along an inlet conduit. These pressure waves are reflected at both ends and can lead to significant variations in the pressure at the inlet of the pump. Low pressure during filling can lead to under filling and cavitation and can mean that the pump does not meet the delivery requirements. These problems can be compounded at higher engine speed when the operating speed of the plunger is higher.

It is known to provide accumulators/dampers to reduce the magnitude of the pressure fluctuations by storing fluid during peak pressures and returning it during the low pressure part of the cycle. One known arrangement for a gasoline pump comprises a plurality of gas-filled containers disposed in a chamber in communication with the pump inlet. An increase in the pressure in the pump inlet compresses the gas-filled containers which then expand when the pressure decreases. However, it is not always possible to fit these types of accumulators/dampers to the pump due to packaging and/or physical design limitations.

It is against this backdrop that the present invention has been conceived. The present invention seeks to overcome or ameliorate at least some of the limitations associated with the prior art systems.

SUMMARY OF THE INVENTION

Aspects of the present invention relate to a damping apparatus; and to a fuel injection system incorporating a damping apparatus.

According to a further aspect of the present invention there is provided a damping apparatus for damping pressure waves, the damping apparatus comprising:

a vessel defining a damping chamber having an internal volume, the damping chamber having an inlet and an outlet for connection in series;

wherein the vessel comprises at least one resiliently deformable plate to enable the internal volume of the damping chamber to change in dependence on pressure variations. In use, the at least one resiliently deformable plate can deflect, thereby changing the internal volume of the damping chamber and damping pressure waves. Each said resiliently deformable plate can function as a diaphragm (and can be referred to as a diaphragm plate). In use, the at least one resiliently deformable plate can deform in dependence on the pressure in the vessel, thereby altering the internal volume of the damping chamber. At least in certain embodiments these variations in the internal volume of the damping chamber can help to reduce fluctuations in the pressure therein. In use, the damping chamber can damp pressure waves and/or pressure spikes. The damping apparatus has particular application as an in-line damping device for connection in series. For example, the inlet and outlet can be connected in series in a conduit to damp pressure waves and/or pressure spikes. When the damping apparatus is used in conjunction with a pump, this can help to damp a pressure wave in the conduit, thereby improving stability of the pump inlet pressure.

The damping apparatus has particular application in damping pressure waves in a liquid. The damping chamber is connected in series such that, in use, the liquid flows there through. The liquid can, for example, be fuel supplied to, or returning from a fuel injection system for an internal combustion engine. The fuel can be gasoline or diesel. When used in conjunction with a fuel pump, the damping apparatus can be connected in a supply conduit to the pump to provide improved stability of the pump inlet pressure. At least in certain embodiments, this can improve metering of the fuel supplied to the fuel injection system, for example using an inlet metering valve. The damping apparatus can be configured to be connected in series in a conduit to damp pressure waves in the conduit.

The vessel can comprise a first plate and a second plate. The first and second plates can be movable relative to each other in dependence on pressure variations to change an internal volume of the damping chamber. The first plate can be the at least one resiliently deformable plate. The second plate can be the at least one resiliently deformable plate. In certain embodiments, the vessel can comprise more than two plates.

One of said inlet and outlet can be disposed in the first plate, and the other of said inlet and outlet disposed in the second plate. Alternatively, both the inlet and the outlet can be disposed in either the first plate or the second plate. In a further alternative, the inlet and/or the outlet can be offset from said first and second plates, for example disposed in a housing or frame member.

The first plate can comprise a first resilient section; and/or the second plate can comprise a second resilient section. The first resilient section can comprise a first concave section formed in said first plate. The first concave section can extend into the damping chamber. The first concave section can be annular. The second resilient section can comprise a second concave section formed in said second plate. The second concave section can extend into the damping chamber. The second concave section can be annular.

The first and second plates can be connected to each other along their outer edges. The first and second plates can be substantially circular.

The first and second plates can be formed from first and second sheet members. The sheet members can, for example, be made of steel. The sheet members can be press formed to provide the desired profile. In alternate arrangements, the first and second plates can be formed from other resilient materials, for example a plastics material. The first and second plates can be moulded from said plastics material, either separately or integrally.

The first and second plates can be arranged in opposition to each other. The damping chamber can be defined between said first and second plates. The first and second plates can be symmetrical about a transverse section of the vessel.

The inlet and outlet are suitable for connection in series to provide a fluid pathway through the vessel. In use, fluid enters the vessel through the inlet and exits the vessel through the outlet. The inlet can be configured to be connected to a first section of a conduit; and the outlet can be configured to be connected to a second section of the conduit. This arrangement provides a series connection in which fluid is supplied from the first section of the conduit and exits through the second section of the conduit.

According to a further aspect of the present invention there is provided a pump system comprising a pump, a supply conduit, and a damping apparatus as described herein. The damping apparatus can be disposed in said supply conduit. The damping apparatus can be connected in series in said supply conduit. The damping apparatus can be disposed in said supply conduit proximal to an inlet to said pump. In certain embodiments, the damping apparatus can be integrated into said pump.

According to a yet further aspect of the present invention there is provided a fuel pump comprising a damping apparatus as described herein connected in series to an inlet to the pump.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the present invention will now be described, by way of example only, with reference to the accompanying Figures, in which:

Figure 1 shows a perspective view of a damping apparatus in accordance with an embodiment of the present invention;

Figure 2 shows a sectional view of the damping apparatus shown in Figure 1;

Figure 3 shows a schematic representation of the damping apparatus in a fuel pump system for an internal combustion engine; and

Figure 4 shows a schematic representation of a damping apparatus in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION

A damping apparatus 1 in accordance with an embodiment of the present invention will now be described with reference to Figures 1, 2 and 3. The damping apparatus 1 is in the form of an in-line damper adapted for connection in series to a conduit 2 for conveying a liquid. In the present embodiment the conduit 2 is a supply line for supplying fuel to a fuel pump 3 for pumping fuel to a fuel injection system 4, as shown schematically in Figure 3. As described herein, the damping apparatus 1 is operative to damp pressure waves generated by the pump 3 and transmitted along the conduit 2.

The damping apparatus 1 comprises a vessel 5 having an inlet 6 and an outlet 7. The vessel 5 defines a damping chamber 8 which is fluidly connected to the inlet 6 and the outlet 7. The vessel 5 comprises opposing first and second plates 9, 10 which function as first and second diaphragms (and can be referred to as diaphragm plates). The first and second plates 9, 10 are circular and have a diameter in the range of 40-50mm. The damping chamber 8 has an internal volume of approximately 6000mm^3. It will be appreciated that the dimensions of the

damping chamber 8 can be changed for different applications. The first and second plates 9, 10 are connected to each other about their outer edges to form the damping chamber 8. In the present embodiment the first and second plates 9, 10 are made of steel and welded around their outer edges. The inlet 6 comprises a first connector 11 mounted to the first plate 9; and the outlet 7 comprises a second connector 12 mounted to the second plate 10. The first and second connectors 11, 12 have a diameter of 9mm for connecting to the conduit 2.

The vessel 5 is resiliently deformable such that an internal volume of the damping chamber 8 can change in dependence on fluctuations in the pressure of the liquid in the conduit 2. The profile of the first and second plates 9, 10 facilitates their resilient deformation. As shown most clearly in Figure 2, the first plate 9 comprises a first circular region 13, a first resilient section in the form of a first concave section 14 and a first convex section 15 arranged concentrically about the central longitudinal axis X of the vessel 5. The first concave section 14 forms an annular recess or groove that projects inwardly into the damping chamber 8; and the first convex section 15 projects outwardly to form an outer ring. The second plate 9 comprises a second circular region 16, a second resilient section in the form of a second concave section 17 and a second convex section 18 arranged concentrically about the central longitudinal axis X of the vessel 5. The second concave section 17 forms an annular recess or groove that projects inwardly into the damping chamber 8; and the second convex section 18 projects outwardly to form an outer ring. In the present embodiment the first and second plates 9, 10 are symmetrical about a transverse section of the vessel 5.

A schematic representation of the damping apparatus 1 to the fuel injection system 4 is provided in Figure 3. The fuel injection system 4 in the present embodiment is operative to inject diesel fuel into the combustion chambers of a compression ignition internal combustion engine. However, it will be appreciated that the damping apparatus 1 could also be used in conjunction with petrol (gasoline) fuel injection systems. The conduit 2 supplies fuel to the pump 3 from a reservoir 19. A first section 2A of the conduit 2 extends from the reservoir 19 to the first connector 11; and a second section 2B of the conduit 2 extends from the second connector 12 to the pump 3. Thus, the damping chamber 8 is connected in series to allow a through flow of fuel.

The pump 3 operates to supply high pressure fuel from the reservoir 19 to the fuel injection system 4. A return line 20 is provided to return fuel from the fuel injection system 4 to the reservoir 19. The operation of the pump 3 can induce pressure fluctuations in the fuel which can manifest as inlet pressure waves which are transmitted along the conduit 2. At least in

certain embodiments of the damping apparatus 1 can help to reduce these inlet pressure waves. The vessel 5 is disposed proximal to the inlet of the pump 3. Any variations in the fuel pressure in the conduit 2 result in a change in the internal volume of the damping chamber 8. When the pressure in the damping chamber 8 increases the first and second plates 9, 10 deflect outwardly, thereby increasing the internal volume of the damping chamber 8. When the pressure in the damping chamber 8 decreases the first and second plates 9, 10 are displaced towards their respective un-deflected states thereby decreasing the internal volume of the damping chamber 8. The first and second concave sections 14, 17 and/or the first and second convex sections 15, 18 function as spring biasing means for biasing the first and second plates 9, 10 towards their respective un-deflected states. The variations in the internal volume of the damping chamber 8 help to reduce fluctuations in the pump inlet pressure. The inlet pressure wave(s) can thereby be damped. The variability in the operation of the pump 3 can be reduced at least in certain embodiments.

A modified arrangement of the damping apparatus 1 will now be described with reference to Figure 4. Like reference numerals will be used for like components. The modified damping apparatus 1 comprises a vessel 5 having an inlet 6 and an outlet 7. The vessel 5 defines a damping chamber 8 which is fluidly connected to the inlet 6 and the outlet 7. The vessel 5 comprises a first plate 9 which is resiliently deformable to function as a first diaphragm. However, the second plate 10 forms a rigid base plate which is not intended to deform. The inlet 6 comprises a first connector 11 and the outlet 7 comprises a second connector 12. The first and second connectors 11, 12 are both fixedly mounted to the second plate 10. This modified arrangement of the damping apparatus 1 helps to reduce relative movement of the first and second sections 2A, 2B of the conduit 2. It will be appreciated that the vessel 5 is again connected in series to provide a through flow. The operation of the damping apparatus 1 is unchanged in this arrangement.

The damping apparatus 1 has been described herein with reference to damping of the inlet pressure wave of the pump. However, the damping apparatus 1 could be used in other applications. For example, the damping apparatus 1 could be disposed in the return line 20 to damp pressure variations (for example pressure waves and/or pressure spikes) in the fuel returned to the reservoir 19. This arrangement can help to reduce vibrations which may otherwise cause unwanted noise and/or damage.

The damping apparatus 1 has been described as being disposed in series in the conduit 2. However, the damping apparatus 1 could be incorporated into the pump 3, for example in the pump inlet.

It will be appreciated that various changes and modifications can be made to the damping apparatus 1 described herein without departing from the scope of the present application. The first connector 11 and/or the second connector 12 could be mounted at an outer edge of the first and second plates 9, 10. For example, the first and second connectors 11, 12 could extend radially outwardly from the central longitudinal axis X of the arrangement shown in Figure 1.

The damping apparatus 1 could be configured to create one or more air trap in the damping chamber 8. For example, the first and second plates 9, 10 and/or the first and second connectors 11, 12 can be configured to form one or more air trap. By establishing an air pocket in the damping chamber 8 the stiffness of the damping apparatus 1 can be varied.

The first and second plates 9, 10 are described as being made of steel, but it will be appreciated that other resilient materials could be used. For example, the vessel 5 could be moulded from a plastics material. The first and second plates 9, 10 could be moulded as separate components and then joined, for example by friction welding. Alternatively, the first and second plates 9, 10 could be integrally moulded, for example using blow moulding or injection moulding techniques.

CLAIMS:

1. Damping apparatus (1) for damping pressure waves, the damping apparatus (1) comprising:

a vessel (5) defining a damping chamber (8) having an internal volume, the damping chamber (8) having an inlet (6) and an outlet (7) for connection in series, said vessel comprising a first resiliently deformable plate (9) and a second resiliently deformable plate (10),

characterised in that

the inlet (6) is disposed in the first plate (9), and the outlet (7) is disposed in the second plate (10) to enable the internal volume of the damping chamber (8) to change in dependence on pressure variations.

2. Damping apparatus (1) as claimed in any one of claim 1, wherein the first plate (9) comprises a first resilient section comprising a first concave section (14) formed in said first plate (9); and wherein the second plate (10) comprises a second resilient section comprising a second concave section (17) formed in said second plate (10).

3. Damping apparatus (1) as claimed in claim 2, wherein the first concave section (14) is annular; and the second concave section (17) is annular.

4. Damping apparatus (1) as claimed in any one of claims 1 to 3, wherein the first and second plates (9, 10) are connected to each other along their outer edges.

5. Damping apparatus (1) as claimed in any one of claims 1 to 4, wherein the first and second plates (9, 10) are substantially circular.

6. Damping apparatus (1) as claimed in any one of claims 1 to 5, wherein the first and second plates (9, 10) are formed from first and second sheet members.

7. Damping apparatus (1) as claimed in any one of claims 1 to 6, wherein the first and second plates (9, 10) are arranged in opposition to each other, the damping chamber (8) being defined between said first and second plates (9, 10).

8. Damping apparatus (1) as claimed in any one of claims 1 to 7, wherein the inlet (6) is configured to be connected to a first section (2A) of a conduit (2); and the outlet (7) is configured to be connected to a second section (2B) of the conduit (2).

9. A pump system comprising a pump (3), a supply conduit (2), and a damping apparatus (1) as claimed in any one of the preceding claims, wherein the damping apparatus (1) is connected in series in said supply conduit (2).

10. A pump system as claimed in claim 9, wherein the damping apparatus (1) is disposed in said supply conduit (2) proximal to an inlet to said pump (3).

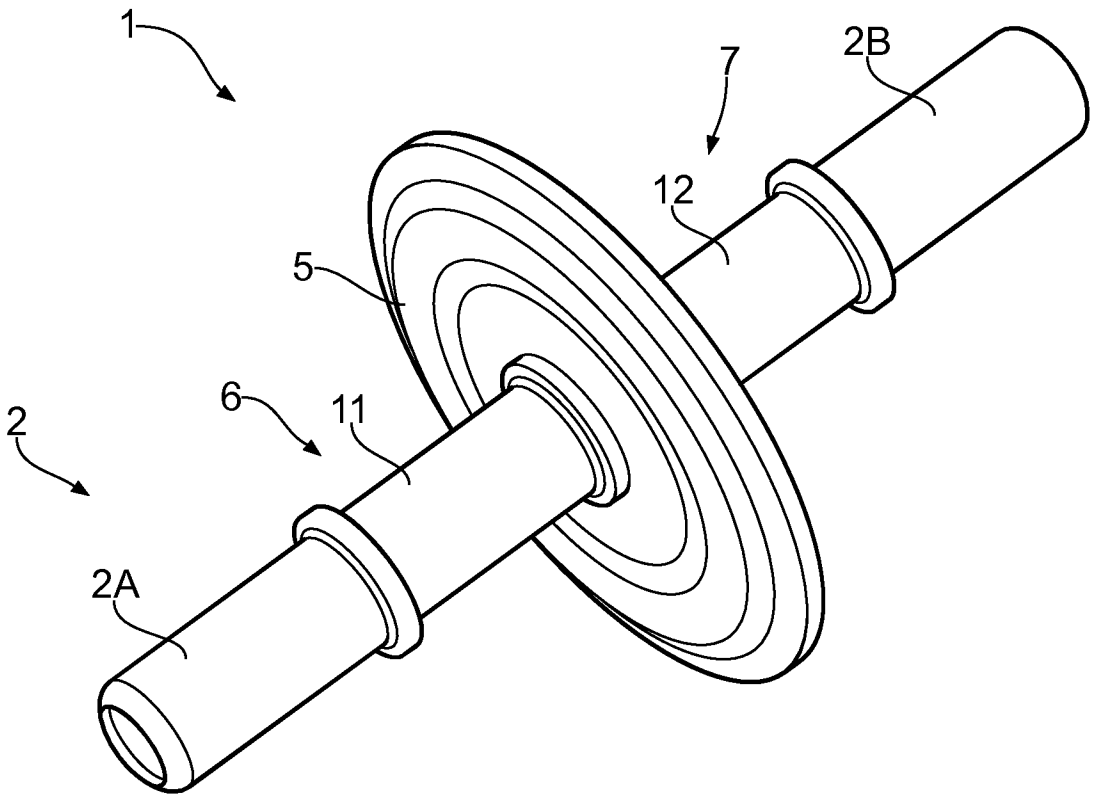

FIG. 1

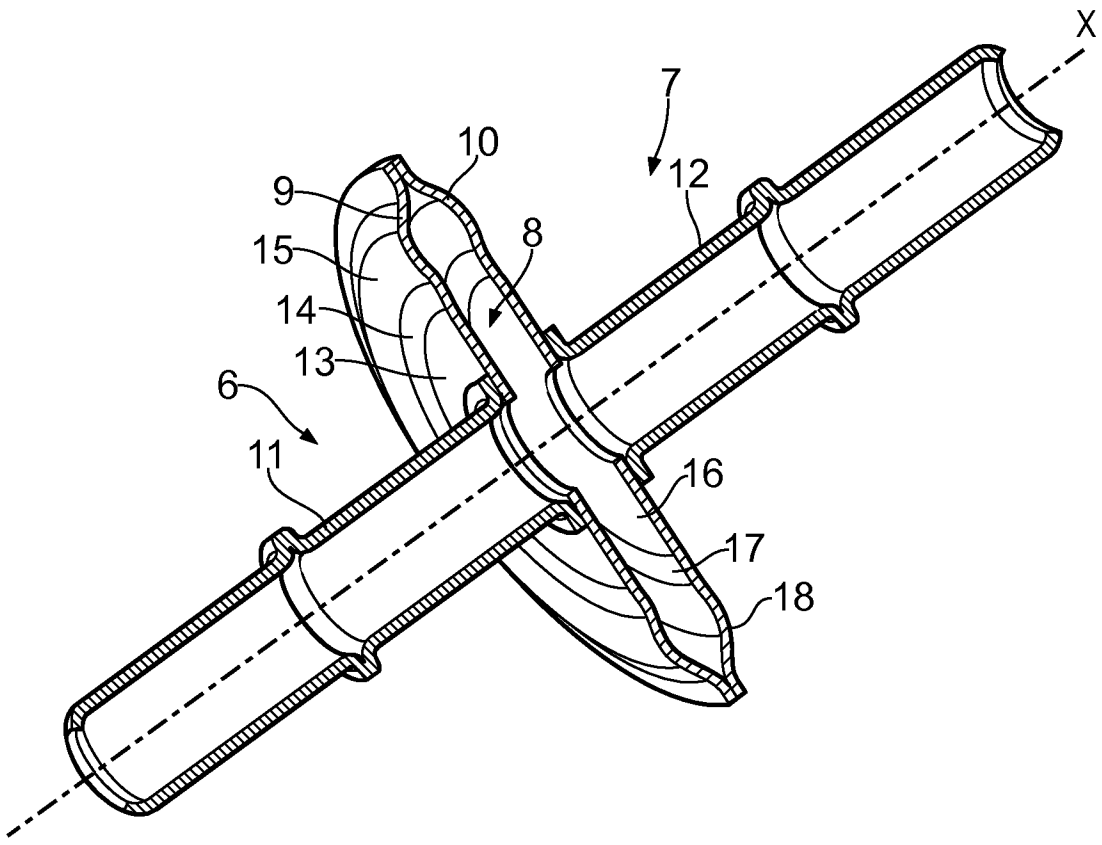

FIG. 2

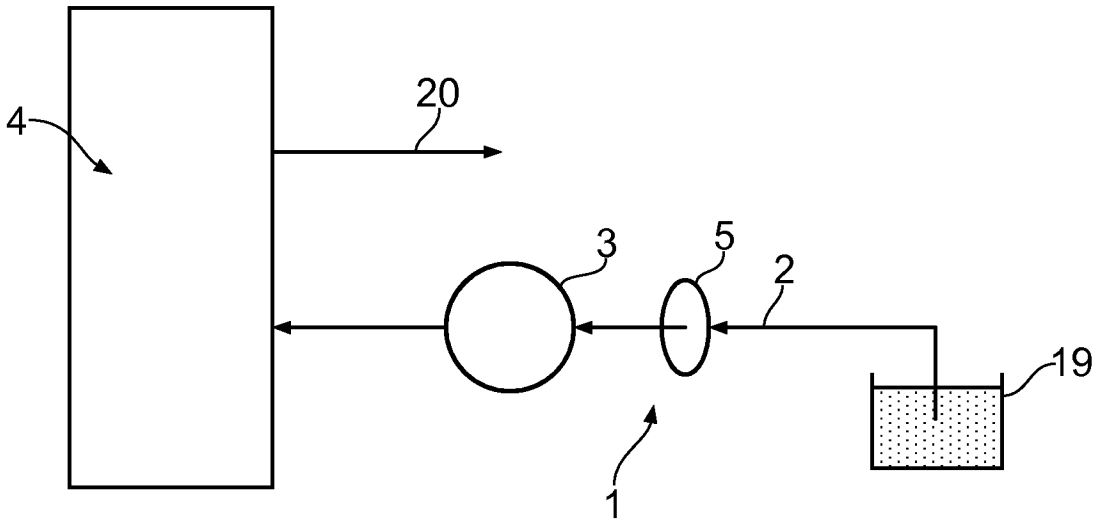

FIG. 3

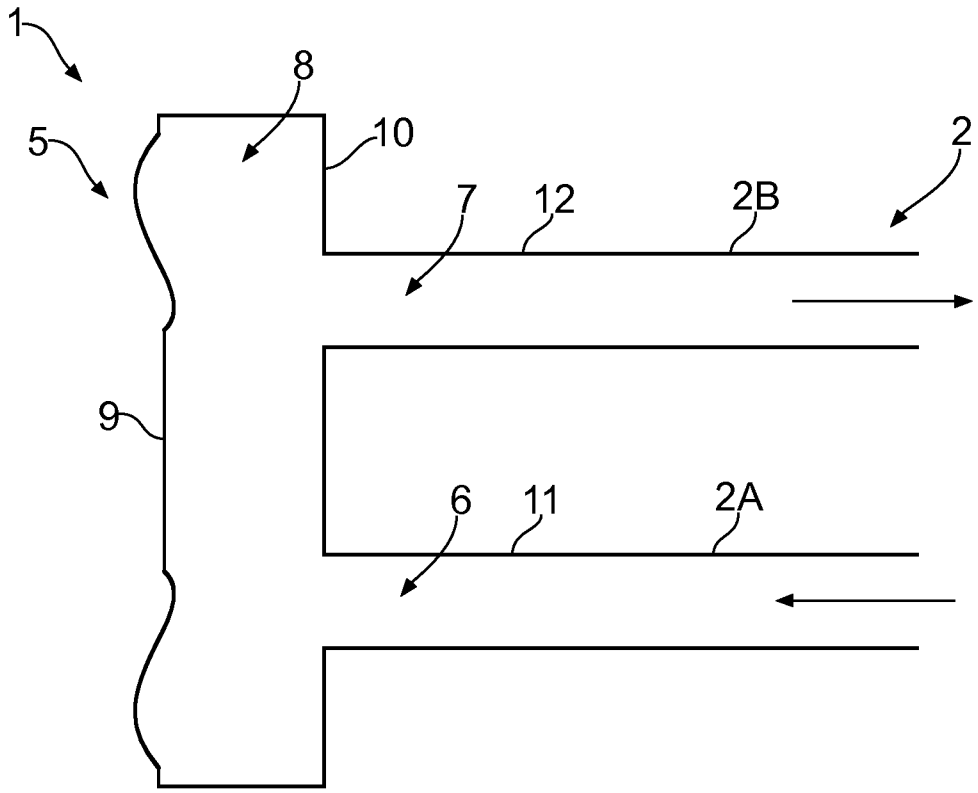

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/052305

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M37/00 F02M55/04 F04B1/00
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)
F02M F01N F04B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	column 2, line 47 - column 3, line 32; figure 1	10

Y	JP 2007 120356 A (TOYOTA MOTOR CORP) 17 May 2007 (2007-05-17)	10
A	the whole document	1-9

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A	US 2009/285626 A1 (CHAHINE PAUL [US] ET AL) 19 November 2009 (2009-11-19) paragraph [0011] - paragraph [0012]; figures 1-1b	1-10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
8 April 2016	19/04/2016

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/052305

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2 113 661 A1 (MAT MISCHANLAGENTECHNIK GMBH [DE]) 4 November 2009 (2009-11-04) paragraph [0016] - paragraph [0017]; figure 1 -----	1-10

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Information on patent family members

International application No
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