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(71) Applicant: **Philip Morris Products S.A.**
2000 Neuchâtel (CH)

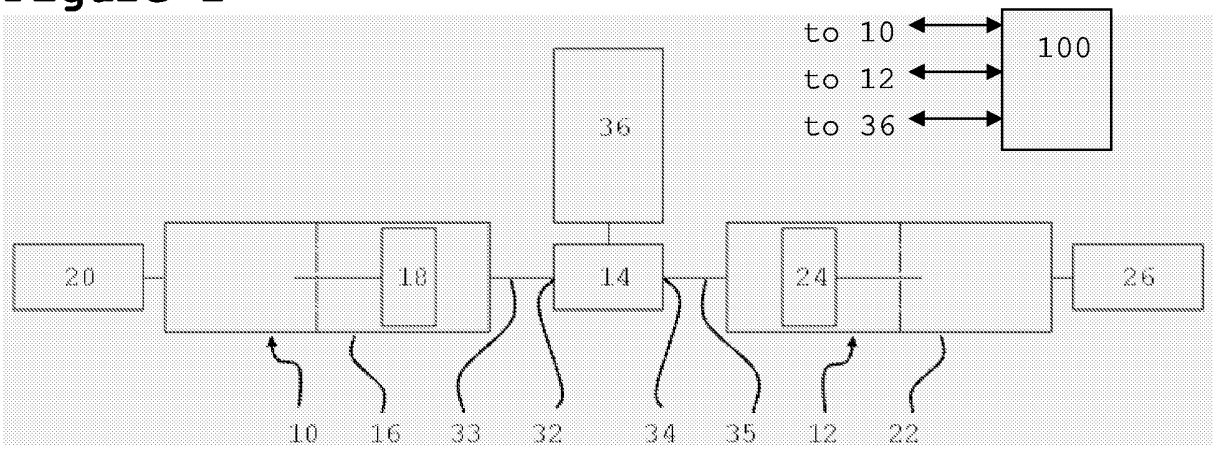
(72) Inventors:
- **RADTKE, Falk**
  53797, Lohmar (DE)
- **SCHMICKLER, Manfred**
  53604, Bad Honnef (DE)
- **OCHEL, Wolfgang**
  50389, Wesseling (DE)
- **SCHAFFERNICHT, Helmut**
  51491, Overath (DE)

(74) Representative: **Gritschneder, Martin et al**
Abitz & Partner
Patentanwälte
Postfach 86 01 09
81628 München (DE)

(54) **Pump system**

(57) The invention concerns a pump system, comprising:
- a first piston pump (10);
- a first motor (20) for driving the first piston pump (10);
- a second piston pump (12);
- a second motor (26) for driving the second piston pump (12);
- a directional control valve (14);
- wherein, in a first position of the valve (14), the valve (14) is connecting the first connector (32) to the outlet (30) and the second connector (34) to the inlet (28) and,
- wherein, in a second position of the valve (14), the valve (14) is connecting the second connector (34) to the outlet (30) and the first connector (32) to the inlet (28); and
- a valve drive (36) for driving the valve (14) from said first position to said second position and vice versa and a smoking machine comprising such a pump system.

Figure 1



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Description

[0001] The present invention relates to a new pump system suitable for gases, liquids and particularly aerosols.

[0002] Known aerosol pump systems are used for example in so called smoking machines allowing reproducible cigarette smoking under standard conditions according to DIN ISO 3308 or DIN ISO 4387. An aerosol is for example the condensed and cooled mixture of gases passing down a cigarette and issuing through the butt end of a cigarette.

[0003] In operation a cigarette smoking machine automatically smokes a cigarette in a series of puffs. During each puff a piston pump first performs a suction stroke according to a suction volume flow profile. The suction stroke draws smoke from the cigarette into the cylinder of the pump. Then the piston pump performs an exhaust stroke according to an exhaust volume flow profile to exhaust the smoke out of the cylinder of the pump. The smoke is then for example transported into an analyzing device to analyze the smoke constituents.

[0004] Such a smoking machine with a one piston pump system is disclosed in the German patent DE3537580. This smoking machine further comprises a programmable drive for the piston pump system which allows the application of different suction or exhaust volume flow profiles during puffs.

[0005] In existing aerosol pump systems, particularly for smoking machines the aerosol is conveyed in a discontinuous stream due to the alternating suction and exhaust strokes of the piston pump. To improve the quality of measurements of smoke constituents it would be desirable if the aerosol could be provided in a continuous stream or volume flow.

[0006] It is the object of the present invention to provide a pump system, particularly a pump system suitable for aerosols, which is capable of providing a substantially continuous stream or volume flow.

[0007] According to the present invention there is provided a pump system, comprising:

- a first piston pump,
- a first motor for driving the first piston pump,
- a second piston pump,
- a second motor for driving the second piston pump,
- a directional control valve comprising an inlet, an outlet, a first connector connected to the first pump, and a second connector connected to the second pump,
- wherein, in a first position of the valve, the valve connects the first connector to the outlet, and the second connector to the inlet, and
- wherein, in a second position of the valve, the valve connects the second connector to the outlet and the first connector to the inlet, and
- a valve drive for driving the valve from said first position to said second position and vice versa.

[0008] The pump system according to the present invention is suitable for pumping any aerosol, gas, liquid, or suspension.

[0009] By alternating the suction strokes of the two pumps as well as the exhaust strokes of the pumps a substantially continuous stream or volume flow can be produced. The volume flow is only interrupted by the switching time of the valve, that is, the time needed to switch between the first position and the second position of the valve. The switching time may advantageously be reduced by appropriately designing the geometry of the valve, for example as described below.

[0010] A substantially continuous volume flow with minimal interruption is particularly advantageous if the pump system is connected at its outlet to the inlet of an aerosol analyzing instrument, for example as part of a smoking machine. Such an aerosol analyzing instrument comprises an aerosol chamber and one or more sensors inside this chamber so that the measuring conditions to measure for example smoke constituents are substantially constant. Examples for such aerosol analyzing instrument are trapping or exposing systems for cigarette smoke which are required for smoke chemistry or toxicology investigations.

[0011] In a preferred embodiment, the pump system of the invention further comprises a control unit connected to the first piston pump, the second piston pump and the valve drive, the control unit controlling the two piston pump motors and the valve drive such that when the valve is in the first position, the first pump performs an exhaust stroke while the second pump simultaneously performs a suction stroke, and, when the valve is in the second position, the second pump performs an exhaust stroke while the first pump simultaneously performs a suction stroke.

[0012] In a further preferred embodiment, the control unit of the pump system is capable of generating various volume flow profiles at the inlet as well as at the outlet. Preferably, the control unit independently drives the two piston pumps such that the resulting volume flow profiles of the piston pumps may be the same or different. More preferably, the settings for the volume flow profiles are configured individually for every piston stroke cycle. The volume flow profiles may be sinusoidal, such as the ISO standard profile, rectangular, trapezoidal, or any individually defined volume flow profiles for example recorded during tobacco smoking.

[0013] In a further preferred embodiment, the control unit of the pump system is configured to vary the operation

parameters of the pump system, such as the shape of the volume flow profiles, pump stroke volume, pump stroke duration, pump stroke period, exhaust pump stroke duration, and number of pump strokes per analysis object. In combination with a smoking machine, a stroke represent the individual puffs generated from for example a cigarette, a cigar or a pipe.

[0014] In a further preferred embodiment, the control unit of the pump system is configured to synchronize the operation of the pump system with external processes. The control unit may be either in the master position, synchronizing external processes or instruments, or operating as a slave, triggered by an external instrument like for example a smoking machine.

[0015] Preferably, the control unit is configured to adapt differently sized cylinders and pistons for the piston pumps. The configuration of the control unit may be performed via an operator console, an on-board web server, or both.

[0016] Preferably, the pump system allows generating reproducible flow profiles at the aerosol generation source, for example the cigarette, independent of additional flow resistances or void volumes of for example trapping or exposing systems.

[0017] In a further preferred embodiment the volume flow profile or profiles of the exhaust stroke of the first pump or the second pump or both pumps is different from the flow profile of the suction stroke of the first pump or the second pump. Preferably the flow profile of the exhaust stroke of the first pump may be the same as the flow profile of the exhaust stroke of the second pump or that the flow profile of the suction stroke of the first pump is the same as the flow profile of the suction stroke of the second pump or both. For example, the exhaust strokes of both pumps may have the same rectangular profile whereas the suction strokes of both pumps may have the same sinus profile according to the ISO requirements for cigarette smoking machines. Alternatively, the suction volume flow profile may mimic any individually defined volume flow profile, for example a profile recorded during tobacco smoking.

[0018] In a further preferred embodiment, the valve comprises channels for the connections of the first connector to the outlet and the second connector to the inlet, when in the first position and channels for the connection of the second position. Furthermore a first line connects the first connector to the first pump, and a second line connects the second connector to the second pump, wherein the channels, the first line, the second line, the inlet and the outlet have a constant cross-sectional area over their whole length.

[0019] The constant cross-sectional area reduces deposition losses of an aerosol on the surfaces of the aerosol conveying ducts in the pump system which would otherwise contaminate the pump system. This advantageously reduces the downtime of the pump system for cleaning. Preferably, the parts of the pump system which may come in contact with the aerosol, are made of suitable inert materials, such as glass, stainless steel, fluorine caoutchouc (FKM) or polyetheretherketone (PEEK) or other, to reduce the chemical interaction of the aerosol with the surfaces of the pump system.

[0020] In a further, preferred embodiment the channels, the first line and the second line have no edges. Thus the suction line of the aerosol from the inlet through the valve to the piston pump and the exhaust line from the piston pump through the valve to the outlet have only smooth surfaces and curves which also contribute to reducing the deposition losses of the aerosol on the surfaces of the pump system.

[0021] In the following, a particularly preferred and advantageous embodiment of the pump system according to the present invention is described in detail with reference to the schematic drawings.

Figure 1 shows a side view and a plan view of the pump system;
Figure 2 shows a longitudinal cross-sectional view of a preferred valve of the pump system;
Figure 3 shows a top view onto the base of said valve;
Figure 4 shows a cross-sectional view along line VI-VI of Figure 2;
Figure 5 shows a time-volume flow graph of the suction flow with a sinusoidal flow profile and the exhaust flow with a rectangular profile in a first operation mode of the pump system;
Figure 6 shows the set-up of the valve and the piston pumps during the first cycle of operation;
Figure 7 shows the set-up of the valve and the piston pump during the second cycle of operation; and
Figure 8 shows a time-volume flow graph of the suction flow with an individually defined flow profile and the exhaust flow with a rectangular flow profile in a second operation mode of the pump system.

[0022] Figure 1 shows schematically a pump system according to the present invention. The pump system comprises a first piston pump 10, a second piston pump 12 and a directional control valve 14.

[0023] The first pump 10 comprises a cylinder 16, a piston 18 inside the cylinder 16, and a first motor 20 for driving the piston 18. The second pump 12 comprises a cylinder 22, a piston 24 inside the cylinder 22, and a second motor 26 for driving the piston 24.

[0024] The valve 14 is a four/two directional control valve comprising an aerosol inlet 28, an aerosol outlet 30, a first connector 32 connected to the first pump 10 via a first line 33, and a second connector 34 connected to the second pump 12 via a second line 35, see also figure 3. The aerosol pump system further comprises a valve drive 36, for example a pneumatic drive connected to the valve 14 for driving it from a first position to a second position and vice versa.

[0025] The pump system also comprises a programmable control unit 100 connected to the first pump 10, the second pump 12 and the drive 36.

[0026] Figure 2 shows a preferred embodiment of valve 14. The valve 14 comprises a housing 38, a base 40, a valve disk 42 and a shaft 44. The housing 38 has two openings at its lower and upper sides, respectively. The base 40 is fixed with its top face to the lower side of the housing 38 and covers the lower opening. The valve disk 42 is located inside the housing 38 on the top face of the base 40 and is pressed with its top face to the lower end of the shaft 44 by a spring 45. The shaft 44 is supported by a bearing 46 inside the housing 38 and extends upwards through the upper opening. The upper end of the shaft is connected to the valve drive 36. Thus, the drive 36 may turn the valve disk 42 via the shaft 44.

[0027] As shown in Figure 3, the valve base 40 has four side faces each having a bore, said four bores being the aerosol inlet 28, the aerosol outlet 30, the first connector 32 and the second connector 34, respectively. Each bore 28, 30, 32, 34 is continued at its inner end by a corresponding channel 48 inclined upwardly towards the top face of the base 40 and ending in a corresponding top opening 50, 52, 54, 56. Thus, each bore 28, 30, 32, 34 is connected via one of the four inclined channels 48 with an assigned top opening 50, 52, 54, 56.

[0028] As shown in Figure 4, the valve disk 42 has two kidney shaped bent channels 66 and 68, so that the bent channel 66 connects the top openings 52 and 54 and the bent channel 68 connects the top openings 50 and 56.

[0029] The four/two direction control valve 14 may adopt two positions as shown in Figure 6 and 7. In the first position of the valve 14, the valve disk 42 is in the position shown in Figure 4 so that the top openings 50, 52, 54, 56 are aligned in pairs 50 with 56 and 52 with 54 and connected with the ends of the channels 68 and 66 respectively. In the second position of the valve 14, the valve disk 42 is in a position turned clockwise by 90 degrees from the position shown in Figure 4 so that now the top openings 50, 52, 54, 56 are aligned in pairs 50 with 54 and 52 with 56 and connected with the ends of the channels 68 and 66 respectively.

[0030] Thus, when the valve is in the first position, for example by the position of the valve disk 42 shown in Figure 4, it connects the first connector 32 to the outlet 30 via the top opening 54, the bent channel 66, and top opening 52. Additionally the valve is connecting the second connector 34 to the inlet 28 via the top opening 56, the bent channel 68, and top opening 50. When the valve 14 is in the second position, for example by the position of the valve disk 42 turned clockwise by 90 degrees from the position shown in Figure 4, it connects the second connector 34 to the outlet 30 via the top opening 56, the bent channel 66, and the top opening 52. Additionally the valve is connecting the first connector 32 to the inlet 28 via the top opening 54, the bent channel 68, and the top opening 50. Thus, in the first position, the first pump 10 is connected to the outlet 30 and the second pump 12 is connected to the aerosol inlet 28, whereas in the second position, the second pump 12 is connected to the outlet 30 and the first pump 10 is connected to the aerosol inlet 28.

[0031] To switch the valve 14 between the first and second position the valve disk 42 is turned either clockwise or counterclockwise by 90 degrees. A pneumatic drive alternates the turning direction of the valve disk 42 with every cycle while an electrical drive stepwise turns the valve disk 42 in the same direction by 90 degrees steps.

[0032] In the following, the operation of the aerosol pump system will be described.

[0033] Figure 5 contains three graphs showing from top to bottom the time dependant status of the external or internal synchronization signal 135, the time dependent suction volume flow profile and the time dependent exhaust volume flow profile in a first operation mode of the aerosol pump system generating the sinusoidal suction volume flow profile. In this exemplary application the pump system is part of a smoking machine (not shown) and the aerosol inlet 28 is connected to a cigarette 70 to be smoked and the aerosol outlet 30 is connected to a smoke analyzing instrument (not shown).

[0034] At the beginning of an operation cycle 130 the drive 36 is actuated by the control unit by the synchronization signal 135 so as to switch the valve 14 into the first position (see Figure 6) in which the first pump 10 is connected to the outlet 30 and the smoke analyzing instrument and the second pump 12 is connected to the aerosol inlet 28 and the cigarette 70. During or at the end of the switching, the first motor 20 is activated by the control unit to push the piston 18 in the cylinder 16 so that the first pump 10 performs an exhaust stroke 115, and the second motor 26 is activated by the control unit to pull the piston 24 in the cylinder 22 so that the second pump 12 performs simultaneously a suction stroke 120. In doing so, smoke is drawn from the cigarette 70 into the cylinder 22 of the second pump 12 and air, gas or aerosol still contained in cylinder 16 is exhausted from the cylinder 16 of the first pump 10 out to the smoke analyzing instrument.

[0035] At the end of the suction stroke 120, the next operation cycle 130 starts and the drive 36 is actuated by the control unit so as to switch the valve 14 into the second position (see Figure 7) in which the second pump 12 is connected to the outlet 30 and the smoke analyzing instrument and the first pump 10 is connected to the aerosol inlet 28 and the cigarette 70. During or at the end of the switching, the first motor 20 is activated by the control unit to pull the piston 18 in the cylinder 16 so that the first pump 10 performs a suction stroke 110, and the second motor 26 is activated by the control unit to push the piston 24 in the cylinder 22 so that the second pump 12 simultaneously performs an exhaust stroke 125. In doing so, new smoke is drawn from the cigarette 70 into the cylinder 16 of the first pump 10 and the previously generated smoke is exhausted from the cylinder 22 of the second pump 12 out to the smoke analyzing instrument.

[0036] At the end of the suction stroke 110, the next operation cycle starts and the valve 14 is switched again into the

first position (see Figure 6), and then the first pump 10 performs again the exhaust stroke 115 to blow the previously generated smoke out to the smoke analyzing instrument, while the second pump 12 simultaneously performs again the suction stroke 120 to draw new smoke from the cigarette 70. As can be seen from the graph in Figure 5 the exhaust aerosol flow is substantially continuous with the exception of the short valve switching time.

[0037] According to the first operation mode of the pump system, the control unit controls the suction strokes of the pumps 10, 12 in such a manner that the suction volume flow profile is a sinusoidal profile according to the ISO requirements (Figure 5). Further, the control unit controls the exhaust strokes of the pumps 10, 12 in such a manner that the exhaust volume flow profile is substantially rectangular profile (Figure 5).

[0038] Figure 8 is similar to Figure 5 but relates to a different configuration mode of the control unit for the pump system which differs from the first operation mode in the suction volume flow profile being an individually defined profile recorded, for example during tobacco smoking, resulting in a more complex shape of suction strokes 140, 150.

LIST OF REFERENCE NUMBERS

[0039]

10	first piston pump
12	second piston pump
14	directional control valve
16	cylinder of 10
18	piston of 10
20	first motor
22	cylinder of 12
24	piston of 12
26	second motor
28	aerosol inlet
30	aerosol outlet
32	first connector
33	first line
34	second connector
35	second line
36	valve drive
38	housing
40	base
42	valve disk
44	shaft
45	spring
46	bearings
48	inclined channels in 40
50	top opening in 40 from aerosol inlet
52	top opening in 40 from aerosol outlet
54	top opening in 40 from first connector
56	top opening in 40 from second connector
66, 68	bent channels in 42
70	cigarette
100	control unit
110, 120, 140, 150	suction stroke
115, 125	exhaust stroke
130	operation cycle
135	synchronization signal

Claims

1. Pump system, comprising:

- a first piston pump (10);
- a first motor (20) for driving the first piston pump (10);

- a second piston pump (12);
- a second motor (26) for driving the second piston pump (12);
- a directional control valve (14);
- wherein, in a first position of the valve (14), the valve (14) connects the first connector (32) to the outlet (30) and the second connector (34) to the inlet (28) and,
- wherein, in a second position of the valve (14), the valve (14) connects the second connector (34) to the outlet (30) and the first connector (32) to the inlet (28); and
- a valve drive (36) for driving the valve (14) from said first position to said second position and vice versa.

2. Pump system according to claim 1,
further comprising a control unit (100) connected to the first piston pump (10), the second piston pump (12) and the valve drive (36); the control unit (100) controlling the two piston pump motors (20, 26) and the valve drive (36) such that, when the valve (14) is in the first position, the first pump (10) performs an exhaust stroke and the second pump (12) performs a suction stroke, and, when the valve (14) is in the second position, the second pump (12) performs an exhaust stroke and the first pump (10) performs a suction stroke.

3. Pump system according to one of the preceding claims,
wherein the flow profile of the exhaust stroke of the first (10) pump, or the second pump (12) or the flow profile of the fist pump (10) and the second pump (12) is different from the flow profile of the suction stroke of the first (10) pump, or the second pump (12) or the flow profile of the suction stroke of the first pump (10) and the second pump (12).

4. Pump system according to claim 3,
wherein the control unit (100) of the pump system is configured to vary at least one of the operation parameters: shape of the volume flow profiles, pump stroke volume, suction pump stroke duration, pump stroke period, exhaust pump stroke duration, number of pump strokes per analysis object.

5. Pump system according to claim 3 or 4,
wherein the definition of the flow profiles is individually settable by the programmable control unit on a cycle to cycle base.

6. Pump system according to one of the preceding claims,
wherein:

- the valve (14) comprises channels (48, 66, 68) for the connections of the first connector (32) to the outlet (30) and the second connector (34) to the inlet (28), when in the first position and for the connections of the second connector (34) to the outlet (30) and the first connector (32) to the inlet (28), when in the second position;
- a first line connects the first connector (32) to the first pump (10), and a second line connects the second connector (34) to the second pump (12);
- the channels (48, 66, 68), the first line and the second line have the same cross-sectional area.

7. Pump system according to claim 6,
wherein the channels (48, 66, 68), the first line and the second line have no edges.

8. Pump system according to one of the preceding claims,
wherein parts of the valve (14) are made of inert materials, such as glass, stainless steel, fluorine caoutchouc or polyetheretherketone.

9. Smoking machine for the reproducible cigarette smoking under standard conditions, comprising a pump system according to one of the preceding claims.

Figure 1

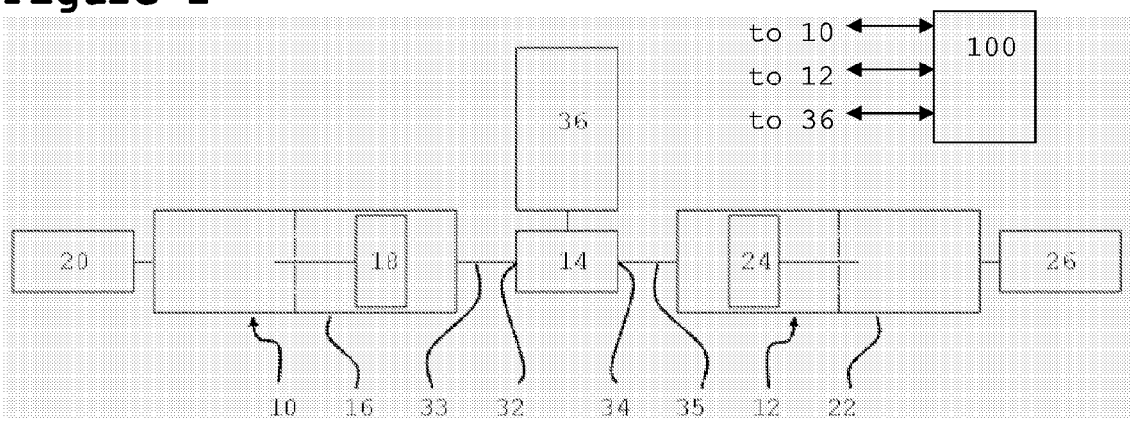


Figure 2

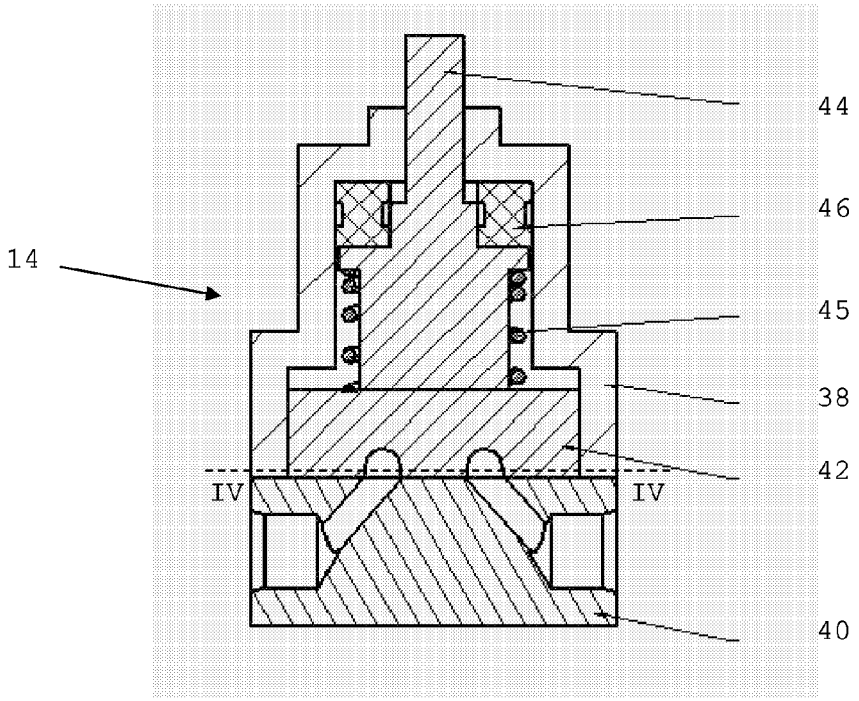


Figure 3

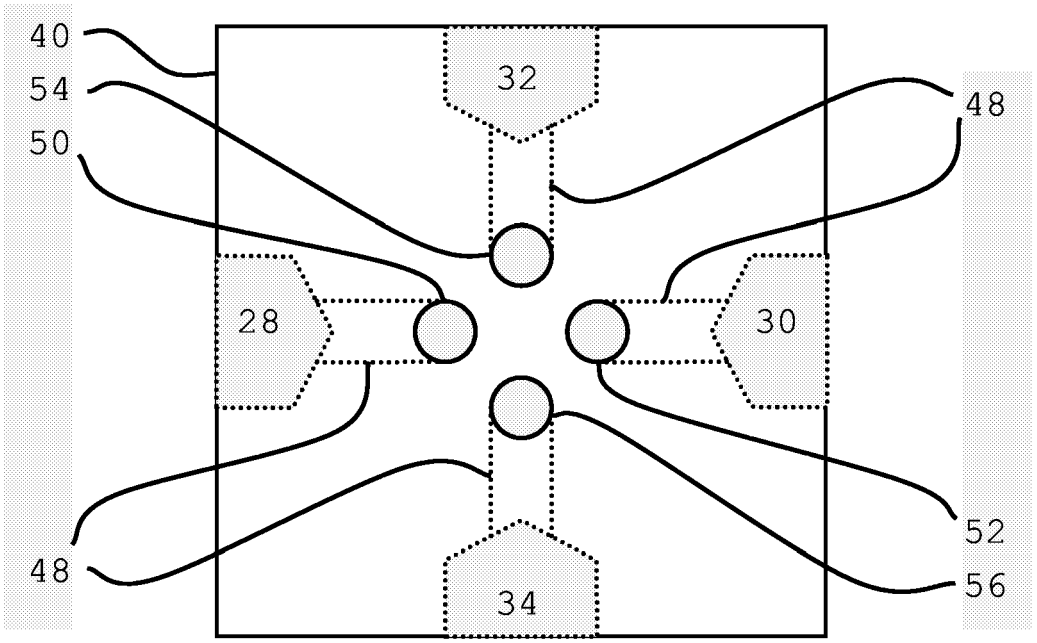


Figure 4

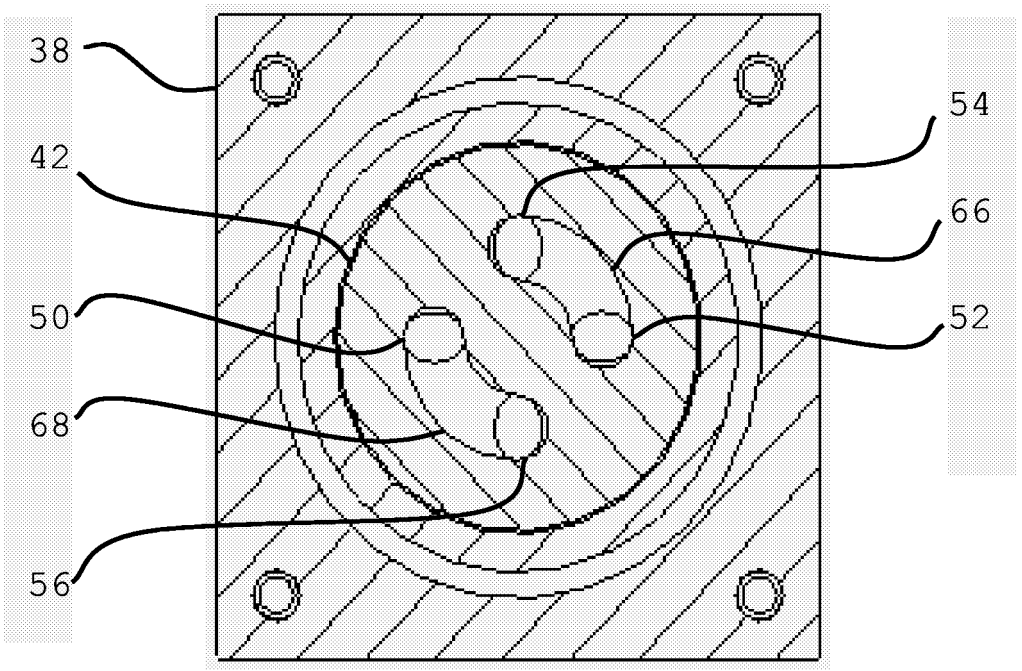


Figure 5

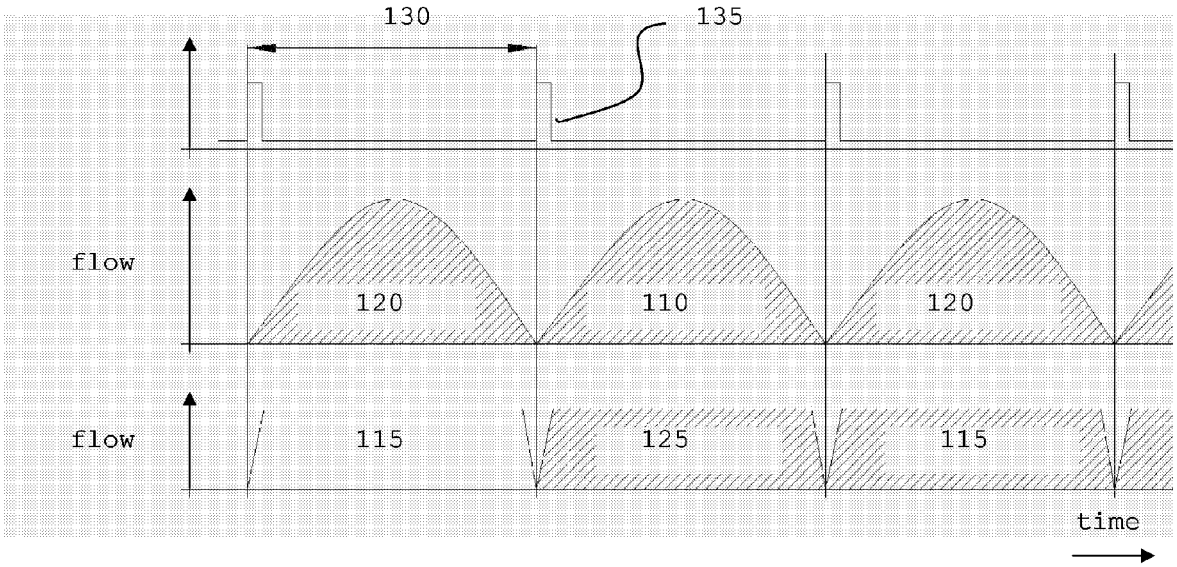


Figure 6

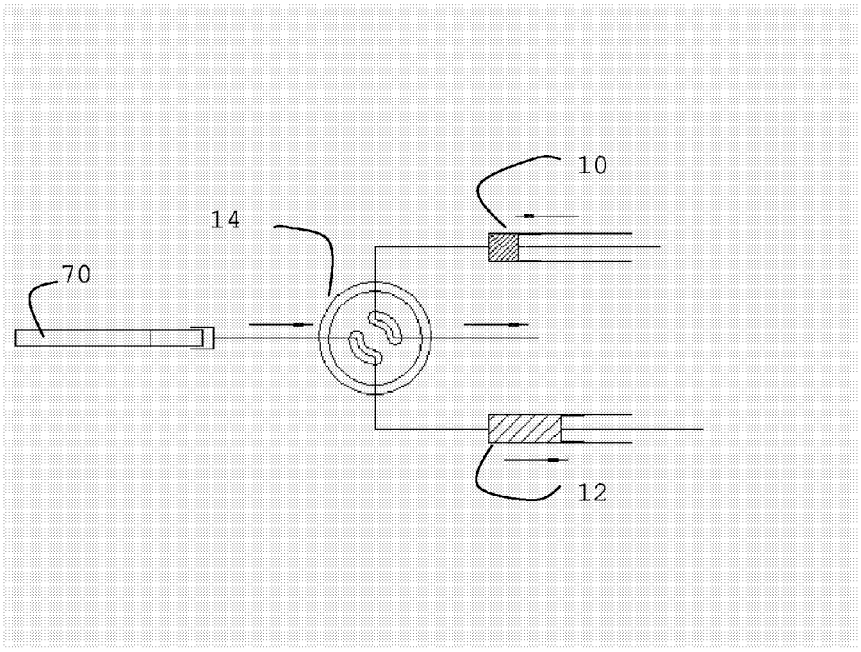


Figure 7

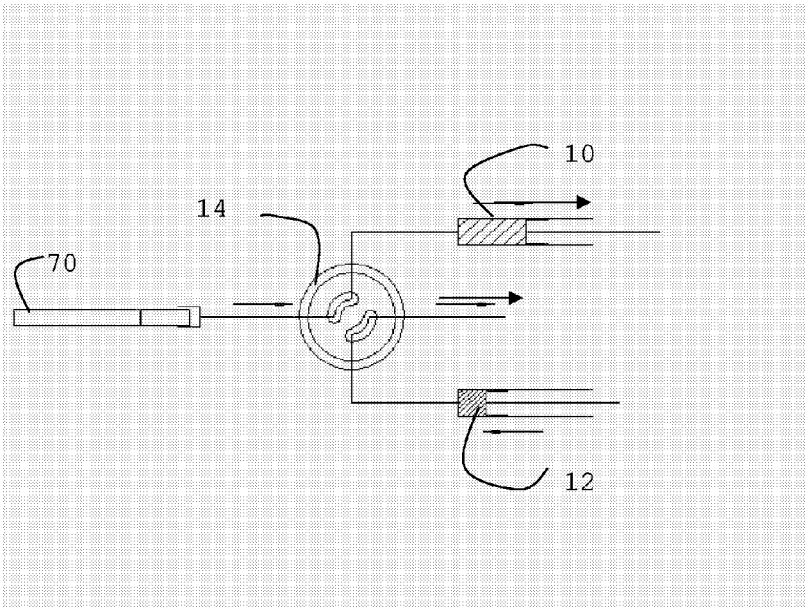
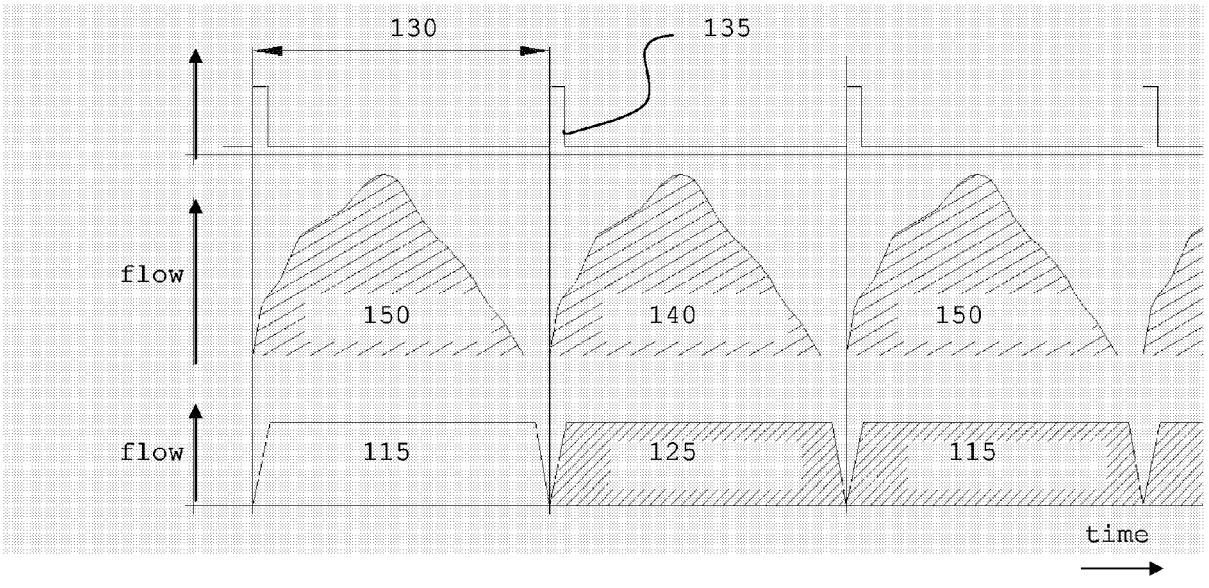


Figure 8



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EUROPEAN SEARCH REPORT

Application Number
EP 06 11 0921

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2005/106246 A (SIEMENS AKTIENGESELLSCHAFT; SCHNEEBERGER, REINHOLD) 10 November 2005 (2005-11-10)	1-8	INV. F04B7/00 F04B11/00
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TECHNICAL FIELDS SEARCHED (IPC)

F04B
A24C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 August 2006	Ingelbrecht, P

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Patent documents cited in the description

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