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- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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[Continued on next page]

(54) Title: AXIAL PISTON MACHINE

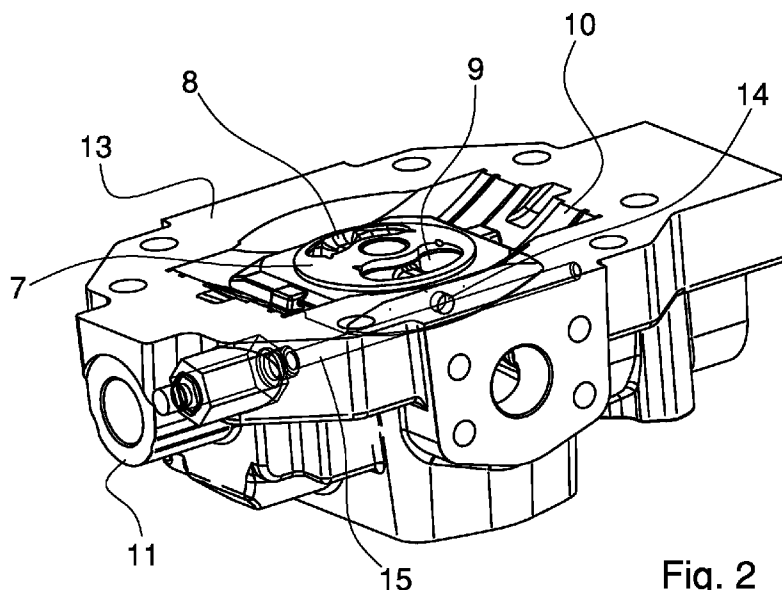


Fig. 2

(57) Abstract: In an axial piston machine with variable displacement with tilted cylinder block, a distributor is coupled with the cylinder block, and a magnetostrictive position sensor has a magnet that is integral with the distributor and a sensor rod that is integral with a fixed body with which the distributor is coupled with the possibility of varying the tilt thereof. The sensor emits a signal that indicates the angular position of the distributor with respect to the fixed body to determine the actual displacement of the machine.



— *with amended claims and statement (Art. 19(1))*

AXIAL PISTON MACHINE**Background of the invention**

[0001] The invention relates to an axial piston machine with variable displacement.

5 [0002] Specifically, but not exclusively, the invention can be used in an axial piston motor/pump with variable displacement of the type with a tilted body, for example of the type with a tilted disc or with a tilted cylinder block.

10 [0003] In particular, the invention relates to a machine comprising a rotating shaft, a rotating cylinder block connected to said shaft, at least one piston slidable with reciprocal movement in said cylinder block, and a tilted body coupled with said cylinder block or with said at least one piston, wherein the displacement of said at least one piston
15 depends on the tilt of said tilted body.

[0004] A machine of this type is already known, for example from patent publication US 2010/0107865.

20 [0005] In machines (for example pumps or motors) with pistons with a tilted body (for example with a tilted disc or cylinder block) with variable displacement, there is the problem of monitoring the displacement that, as known, is a function of the diameter and of the number of pistons, of the gap between the ball joints (which are generally used to couple the shaft and the cylinder block) and of the angle of
25 tilt between the tilted body and the axis of the shaft. Determining the angle of tilt in real time, which may vary during operation of the machine, is thus fundamental for monitoring the machine, in particular for measuring current displacement.

30 [0006] One known system for measuring the angle of tilt of the tilted body comprises a rotating sensor positioned on the plane of the ball joints coupled with the rotating shaft.

[0007] Another known system involves using sensors connected mechanically (typically by levers and/or transmissions) to
35 the actuating piston that moves the tilted body.

[0008] Various aspects of known systems for monitoring

displacement are nevertheless improvable.

[0009] Firstly, it is desirable to improve the precision of displacement monitoring.

[0010] It is further desirable to make available a system
5 that is constructionally cheap and simple to assemble.

[0011] Another improvable aspect is to increase the operating duration of the monitoring system.

Summary of the invention

[0012] One object of the invention is to provide a piston
10 machine with variable displacement that is able to improve one or more of the aspects of the prior art indicated above.

[0013] One advantage is to increase the operating duration of the displacement monitoring system, in particular owing to the fact that there are no reciprocally sliding sensor
15 operating parts, the possibility of wear through sliding being thus avoided. Further, the operating duration can be high because there are no sensor operating parts communicating with relatively high-pressure zones of the machine.

[0014] One advantage is to make a displacement monitoring system available that is easy to assemble. In particular, the system can be easy to assemble if the sensor comprises two parts that communicate with one another at a distance without reciprocal contact, in which a first part is inserted into a
25 first seat obtained on a body with a tilt that is variable with respect to the motor shaft (in which the displacement of the machine depends on the aforesaid tilt), and a second part is inserted into a second seat obtained on a fixed body.

[0015] One advantage is not to modify substantially the
30 inertia of moving masses in the context of the piston machine (for example motor), so it is possible to obtain the same machine response speed during displacement variation. In particular, the monitoring system does not substantially have sensor parts that connected to rotating elements of the
35 machine.

[0016] One advantage is making a particularly precise

monitoring system. In particular, the monitoring system is able to monitor directly and without contact the movement and/or the position of the tilted body (in particular of the distributor operationally associated with the piston/s of the cylinder block). In particular, the monitoring system does not require mechanical connection (for example transmissions or the like) to detect the (angular) position of the tilted body, thus avoiding measuring errors due, for example, to deformation of mechanical parts.

[0017] Such aims and advantages, and also others, are achieved by the axial piston machine according to one or more of the claims set out below.

Brief description of the drawings

[0018] The invention can be better understood and implemented with reference to the attached drawings that illustrate a non-limiting example.

[0019] Figure 1 is a section of a machine made according to the invention.

[0020] Figure 2 is a prospective view of a part of the machine in figure 1, with the position sensor of the tilted body in a first operating configuration.

[0021] Figure 3 is a top view of the aforesaid machine part in the first operating configuration.

[0022] Figure 4 is a prospective view of the aforesaid machine part in a second operating configuration.

[0023] Figure 5 is a top view of the aforesaid machine part in the second operating configuration.

[0024] Figure 6 is a prospective view of the aforesaid machine part in a third operating configuration.

[0025] Figure 7 is a top view of the aforesaid machine part in the third operating configuration.

[0026] Figures 8 to 10 are three side views of the aforesaid machine part, respectively in the first, second and third configuration.

Detailed description

[0027] With reference to the aforesaid figures, with 1 an

axial piston machine has been indicated, in particular a piston motor with variable displacement of the type with a tilted body.

[0028] With 2 there has been indicated a rotating shaft and
5 with 3 a rotated cylinder block connected mechanically to the rotating shaft 2 by a mechanical joint 4 (for example a ball joint). With 5 a sliding piston with reciprocating movement in the cylinder block 3 has been indicated. It is possible to provide a cylinder block containing two or more slidable
10 pistons. Each piston 5 will be connected mechanically to the rotating shaft 2 by a further mechanical joint 6 (for example a ball joint). As known, in the operation of the machine as a motor, the reciprocating motion of the piston 5 will cause the rotating shaft 2 to rotate; vice versa, in the case of
15 operation of the machine as a pump. The rotating cylinder block 3 may have a certain tilt with respect to the rotating shaft 2. On this tilt, which is variable, the displacement of each piston 5 and thus of the machine depends.

[0029] The machine 1 comprises a distributor 7 having a
20 first face coupled with the rotating cylinder block 3. The distributor 7 may have a tilt (with respect to the rotating shaft 2). The tilt of the distributor 7 (with respect to the rotating shaft 2) will be the same as the tilt of the rotating cylinder block 3 (with respect to the rotating shaft
25 2). The first face has a first entry port 8 (supply or aspiration) and a second outlet port 9 (discharge or delivery) for an operating fluid (liquid, for example oil) operationally associated with each slidable piston 5. In use, the cylinder block 3 will rotate on the fixed distributor 7.
30 Through the effect of the rotation of the cylinder block 3, the piston 5 (which rotates with the cylinder block 3) will be placed in communication with the first port 8 and with the second port 9 alternately.

[0030] The cylinder block 3 and the distributor 7 are
35 coupled together in such a manner as to enable the cylinder block 3 to rotate with respect to the distributor 7. Further,

the cylinder block 3 and the distributor 7 are coupled together in such a manner that each tilt variation of the distributor 7 (with respect to the rotating shaft 2) is matched by the same tilt variation of the cylinder block 3 (with respect to the rotating shaft 2).

[0031] The displacement of the slidable piston 5, and thus of the machine will depend on the tilt of the cylinder block 3 and of the distributor 7 (with respect to the rotating shaft 2). The distributor 7 is slidably coupled on a sliding guide 10 that guides the distributor 7 along a circular arch path. The guide 10 is arranged on a fixed machine part. The distributor 7 thus gives rise to a tilted body coupled with a fixed machine part such a manner as to vary the tilt and thus the displacement of the slidable piston 5.

[0032] With 11 there is indicated an actuator for controlling the variation of tilt of the distributor 7. The actuator 11 may comprise, as in the specific case, a linear actuator mechanically coupled with a second face of the distributor 7 opposite the first face. A (linear) movement of the movable element (piston) of the actuator 11 causes a variation in the tilt of the distributor 7 and thus of the cylinder block 3.

[0033] With 12 a containing case of at least one part of the rotating shaft 2 and of at least one part of the cylinder block 3 has been indicated. A connecting end of the rotating shaft 2 protrudes from a side of the case 12 to enable the connection (of known type) to an application (in the case of operation of the machine as a motor). With 13, a closing cover of a further side of the case 12 (opposite the side that has the connecting end of the shaft 2) has been indicated. Substantially, the cover 13 closes the side of the case where the distributor 7 is arranged. The cover 13 bears the guide 10 with which the distributor 7 is slidably coupled. The cover 13 bears internally the linear actuator 11, for example of hydraulic type.

[0034] The machine is provided with a position sensor

configured for detecting the position, and thus the tilt with respect to the axis of the rotating shaft 2, of the tilted body (distributor 7 and/or cylinder block 3 that have the same tilt). The sensor may comprise, as in the specific case, a first part 14 and a second part 15, wherein the first part 14 may be mounted on the distributor 7 and the second part 15 may be mounted on the fixed machine part, i.e. on a machine part the position of which (in particular the tilt or the orientation) is not modified with respect to the axis of the motor shaft 2. The second part 15 of the sensor may be mounted, in particular, on the cover 13. The second part 15 of the sensor may be, as in the specific case, connected to the first part 14 in a contactless mode, with the possibility of detecting the position of the first part 14. The contactless mode may be achieved, for example, with inductive, capacitive, magnetic, ultrasound, optic, etc. position sensors.

[0035] In particular, the position sensor may comprise, as in the specific case, a magnetorestrictive sensor, for example a linear sensor. The first part 14 of sensor may also comprise a magnet and the second part 15 may comprise a sensor rod that is sensitive to the position of the magnet.

[0036] The distributor 7 has at least one side that extends from a side edge of the first face and/or of the second face. In particular, this side of the distributor 7 may be a side of the distributor that joins the first face to the second face. The side of the distributor 7 may be, as in the specific case, substantially parallel to the axis of the linear actuator 11. The aforesaid side will, in particular, be the side of the distributor 7 nearest of the linear actuator 11. This side has a recess in which the magnet of the magnetorestrictive sensor is housed. In particular, the first part 14 of sensor (magnet) may be connected integrally with the distributor 7, for example by means of coupling with interference by means of forcing of the magnet inside the recess.

[0037] The linear actuator 11 may be, as in the specific case, parallel to the sensor rod (second part 15 of sensor). The sensor rod may be, as in the specific case, parallel to the side of the distributor 7 that bears the magnet. The cover 13 may have a hole in which the second part 15 of sensor (sensor rod) is housed.

[0038] The first part 14 and the second part 15 of sensor face one another and are spaced apart by a separating gap filled with a fluid (for example a liquid, like oil). The gap may be, as in the specific case, at a relatively low pressure, in particular with respect to the operating pressures of the piston 5 and of the actuator 11. In particular, the gap may be insulated such as to be fluid-tight with respect to zones communicating with the operating fluid of the piston 5. In particular, the gap may be insulated such as to be fluid-tight with respect to high-pressure zones of the operating fluid of the actuator 11. The two parts, 14 and 15, of sensor may be arranged, for example, at a mutual distance comprised between 1 and 20 mm, for example at about 8 mm. The second part 15 of sensor will be sensitive to the position of the first part 14 of sensor along the entire stroke of the distributor 7 (the ends of the stroke of the distributor 7 correspond to the second and third configuration of the attached figures). In particular, the sensor rod may emit a signal indicating the distance of the magnet from the base of the sensor rod. Once the aforesaid distance has been determined, the angle of tilt of the distributor 7 with respect to the shaft 2 may be calculated, this angle being a known function of this distance.

[0039] In figures 8 to 10 three relative positions are visible that are taken on by the two parts, 14 and 15, of sensor (magnet and sensor rod) in three different operating configurations, that correspond to three different tilts of the distributor 7 (and of the cylinder block 3). The two parts, 14 and 15, of the sensor communicate together (without

contact), such that the second part 15 (sensor rod) is able to detect the position of the first part 14 that is integral with the distributor 7 (and with the cylinder block at least as regards the tilt with respect to the axis of the shaft 2).

- 5 The sensor (in particular the second part 15 of sensor) is thus able to send a signal to a control unit of the machine. This signal will indicate the position of the first part 14 of sensor. The control unit will be programmed in such a manner as to determine the tilt of the distributor 7 as a
- 10 function of the position signal of the first part 14 of sensor (magnet). On the basis of this tilt, the control unit can thus determine, in real time, the actual displacement of the piston 5 and of the machine.

CLAIMS**1.** Axial piston machine, comprising:

- a rotating shaft (2), a rotating cylinder block (3) connected mechanically to said shaft (2), and at least one piston (5) slidable with reciprocal movement in said cylinder block (3); the reciprocal movement of said at least one piston (5) being generated by, or generating the rotation of said shaft (2);
- a tilted body (7) coupled with said cylinder block (3) or with said at least one piston (5), wherein the displacement of said at least one piston (5) depends on the tilt of said tilted body (7); said tilted body (7) being coupled with a fixed part (13) of said machine such as to vary the tilt thereof and thus to vary the displacement of said at least one piston (5);
- a position sensor for detecting the position of said tilted body (7), said sensor having a first part (14) and a second part (15), wherein said first part (14) is mounted on said tilted body (7) and said second part (15) is mounted on said fixed machine part (13), said second part (15) being contactlessly connected to said first part (14) such as to detect the position of said first part (14).

2. Machine according to claim 1, said position sensor comprising a linear magnetostrictive sensor wherein said first part (14) comprises a magnet and said second part (15) comprises a sensor rod that is sensitive to the position of said magnet.**3.** Machine according to claim 1 or 2, said tilted body (7) having a first face coupled with said cylinder block (3) or with said at least one piston (5), said tilted body (7) having a side that extends from a side edge of said first face, said first part (14) being arranged at said side.

4. Machine according to claim 3, said tilted body (7) having a second face coupled with said fixed part (13), said second face being opposite to said first face, said side joining together said first face and said second face.
- 5 5. Machine according to claim 4, said second face being coupled with said fixed part (13) through sliding guide means (10) with an arcuate shape.
6. Machine according to claim 4 or 5, comprising an actuator (11) configured for varying the tilt of said tilted body
10 (7), said actuator (11) being mechanically coupled with said second face.
7. Machine according to claims 6 and 2, said actuator (11) comprising a linear actuator that is parallel to said sensor rod.
- 15 8. Machine according to claim 6 or 7, said actuator (11) comprising a linear actuator that is substantially parallel to said side.
9. Machine according to any one of claims 3 to 8, said first face having at least a first inlet port (8) and a second
20 outlet port (9) for an operating fluid operationally associated with said at least one piston (5).
10. Machine according to any preceding claim, wherein said tilted body (7) is coupled on sliding guide means (10) that guides said tilted body (7) along a circular arch
25 path, said first part being faced to said second part in a direction that is parallel to an axis of the circular arch of said path.
11. Machine according to any preceding claim, comprising a case (12) containing at least a part of said shaft (2) and/or at least a part of said cylinder block (3), and
30 further comprising a closing cover of said case, said fixed part (13) of machine comprising said closing cover.
12. Machine according to claims 11 and 7, wherein said tilted body (7) is slidably coupled with said cover, said cover
35 further having a hole in which said sensor rod is housed, said cover having said linear actuator inside.

13. Machine according to any preceding claim, wherein said first part (14) and said second part (15) face one another and are spaced apart by a separating gap filled with a fluid, said gap being insulated in a fluid-tight manner from zones communicating with an operating fluid that is operationally associated with said at least one piston (5).
14. Machine according to claim 13, comprising an actuator (11) configured for varying the tilt of said tilted body (7), and wherein said gap is insulated in a fluid-tight manner from zones communicating with an operating fluid that is operationally associated with said actuator (11).
15. Machine according to any preceding claim, wherein said tilted body (7) comprises a distributor of an operating fluid.

AMENDED CLAIMS

received by the International Bureau on
10 November 2011 (10.11.2011)

CLAIMS

1. Axial piston machine, comprising:
 - a rotating shaft (2), a rotating cylinder block (3) connected mechanically to said shaft (2), and at least one piston (5) slidable with reciprocal movement in said cylinder block (3); the reciprocal movement of said at least one piston (5) being generated by, or generating the rotation of said shaft (2);
 - a tilted body (7) coupled with said cylinder block (3) or with said at least one piston (5), wherein the displacement of said at least one piston (5) depends on the tilt of said tilted body (7); said tilted body (7) being coupled with a fixed part (13) of said machine such as to vary the tilt thereof and thus to vary the displacement of said at least one piston (5);
 - a position sensor for detecting the position of said tilted body (7), said sensor having a first part (14) and a second part (15), wherein said first part (14) is mounted on said tilted body (7) and said second part (15) is mounted on said fixed machine part (13), said second part (15) being contactlessly connected to said first part (14) such as to detect the position of said first part (14);characterized by said tilted body (7) having a first face coupled with said cylinder block (3) or with said at least one piston (5), said tilted body (7) having a side that extends from a side edge of said first face, said first part (14) being arranged at said side.
2. Machine according to claim 1, said position sensor comprising a linear magnetostrictive sensor wherein said first part (14) comprises a magnet and said second part (15) comprises a sensor rod that is sensitive to the position of said magnet.
3. Machine according to claim 1 or 2, said tilted body (7)

having a second face coupled with said fixed part (13), said second face being opposite to said first face, said side joining together said first face and said second face.

- 5 4. Machine according to claim 3, said second face being coupled with said fixed part (13) through sliding guide means (10) with an arcuate shape.
5. Machine according to claim 3 or 4, comprising an actuator (11) configured for varying the tilt of said tilted body
10 (7), said actuator (11) being mechanically coupled with said second face.
6. Machine according to claims 5 and 2, said actuator (11) comprising a linear actuator that is parallel to said sensor rod.
- 15 7. Machine according to claim 5 or 6, said actuator (11) comprising a linear actuator that is substantially parallel to said side.
8. Machine according to any one of claims 1 to 7, said first face having at least a first inlet port (8) and a second
20 outlet port (9) for an operating fluid operationally associated with said at least one piston (5).
9. Machine according to any preceding claim, wherein said tilted body (7) is coupled on sliding guide means (10) that guides said tilted body (7) along a circular arch
25 path, said first part being faced to said second part in a direction that is parallel to an axis of the circular arch of said path.
10. Machine according to any preceding claim, comprising a case (12) containing at least a part of said shaft (2) and/or at least a part of said cylinder block (3), and
30 further comprising a closing cover of said case, said fixed part (13) of machine comprising said closing cover.
11. Machine according to claims 10 and 6, wherein said tilted body (7) is slidably coupled with said cover, said cover
35 further having a hole in which said sensor rod is housed, said cover having said linear actuator inside.

12. Machine according to any preceding claim, wherein said
first part (14) and said second part (15) face one
another and are spaced apart by a separating gap filled
with a fluid, said gap being insulated in a fluid-tight
manner from zones communicating with an operating fluid
that is operationally associated with said at least one
piston (5).
13. Machine according to claim 12, comprising an actuator
(11) configured for varying the tilt of said tilted body
(7), and wherein said gap is insulated in a fluid-tight
manner from zones communicating with an operating fluid
that is operationally associated with said actuator (11).
14. Machine according to any preceding claim, wherein said
tilted body (7) comprises a distributor of an operating
fluid.

Statement under Art. 19(1) PCT

Claim 1 has been amended in order to better define the invention and to distinguish the invention from the prior art cited in the search report.

Amended claim now states that the first part (14) of the sensor is arranged at a side of the tilted body (7) that extends from a side edge of a first face of the tilted body (7) that is coupled with the cylinder block (3) or with the piston (5).

Each of Documents D1 to D8 cited in the Search Report fails to disclose the aforementioned claimed arrangement of the first part of the sensor.

It is noted that, in the machines described in D1 and D2, the sensor is arranged to operate on the active face of the tilted body. In D3 the sensor is not contactless. The contactless sensors of documents D4 to D8 have at least a part that is arranged on an oscillating/rotating body, whereby they substantially emit a signal at each revolution of the rotating shaft, in a completely different way with respect to the claimed sensor.

In the claimed system the sensor is not integral with a body that rotates or oscillates in connection with the rotating shaft. Thanks to the above claimed arrangement, the inclination of the tilted body can be detected in a very simple, accurate and reliable manner. In particular, in the claimed arrangement, the sensor can move on a wide arc of circumference and therefore the measurement can be more accurate due to the wide operating range.

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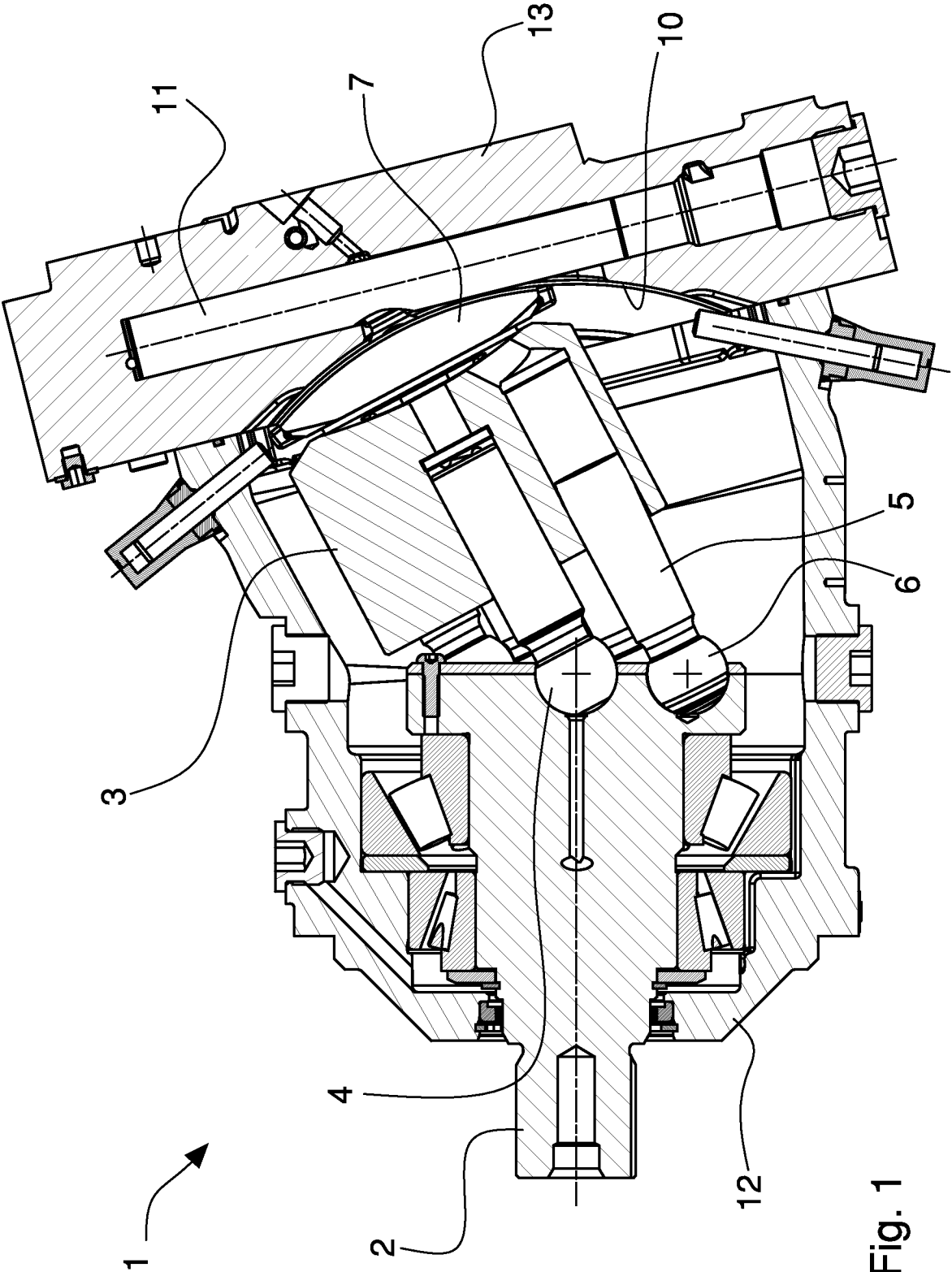
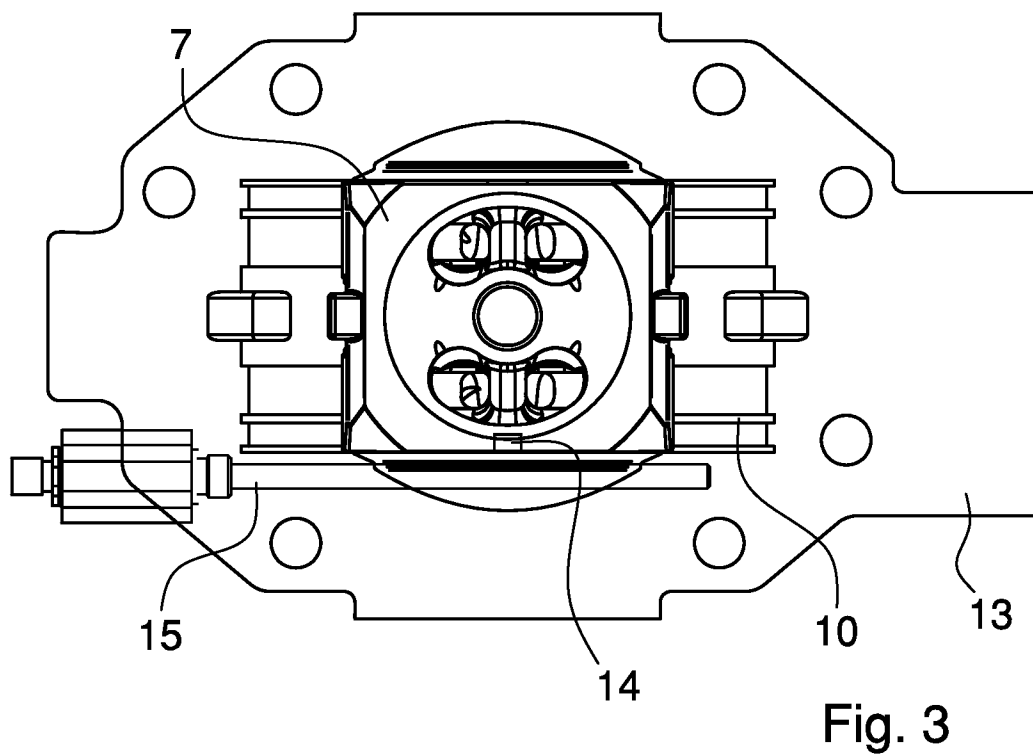
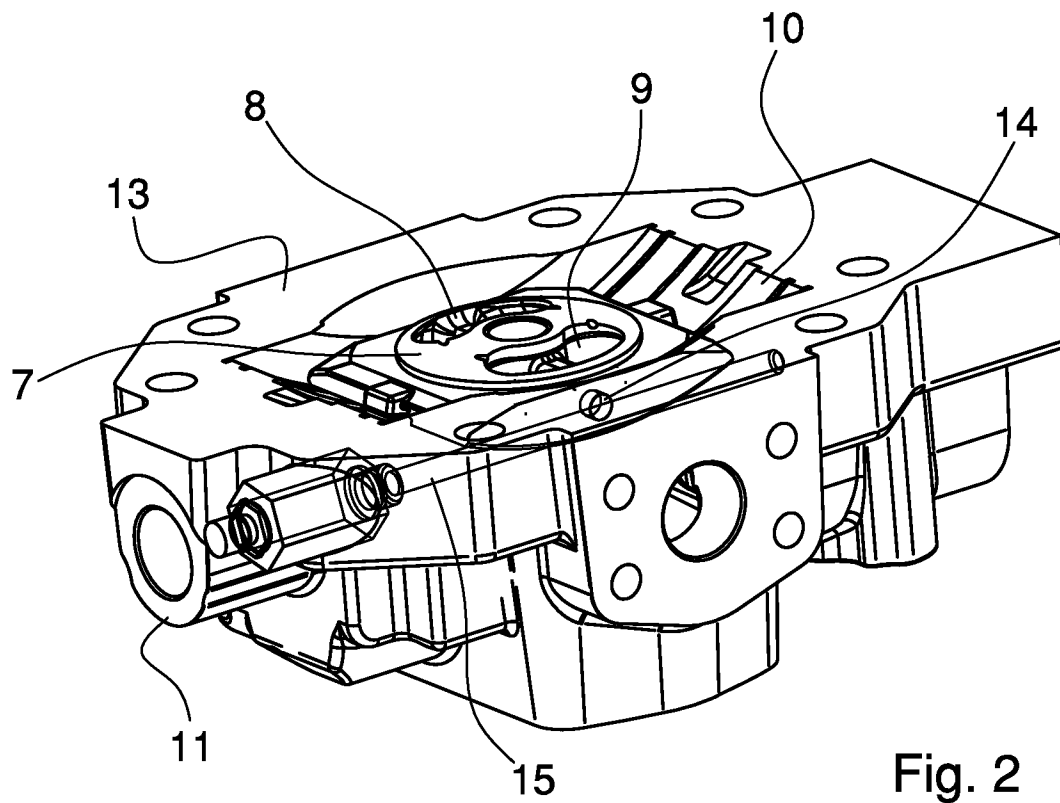
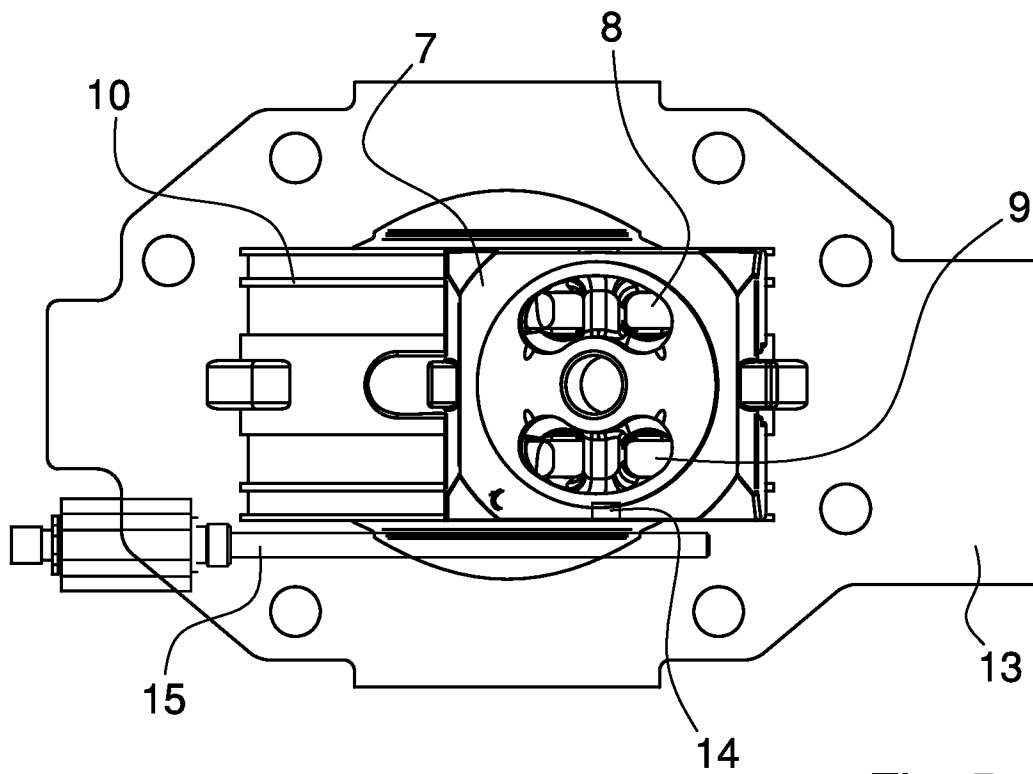
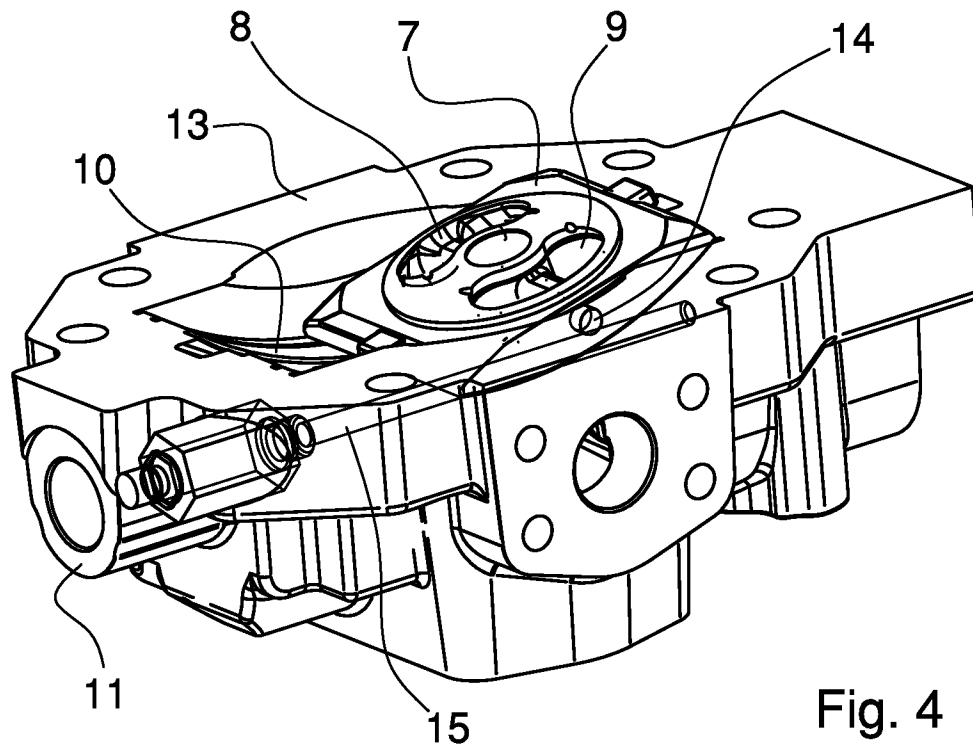


Fig. 1

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3/5



4/5

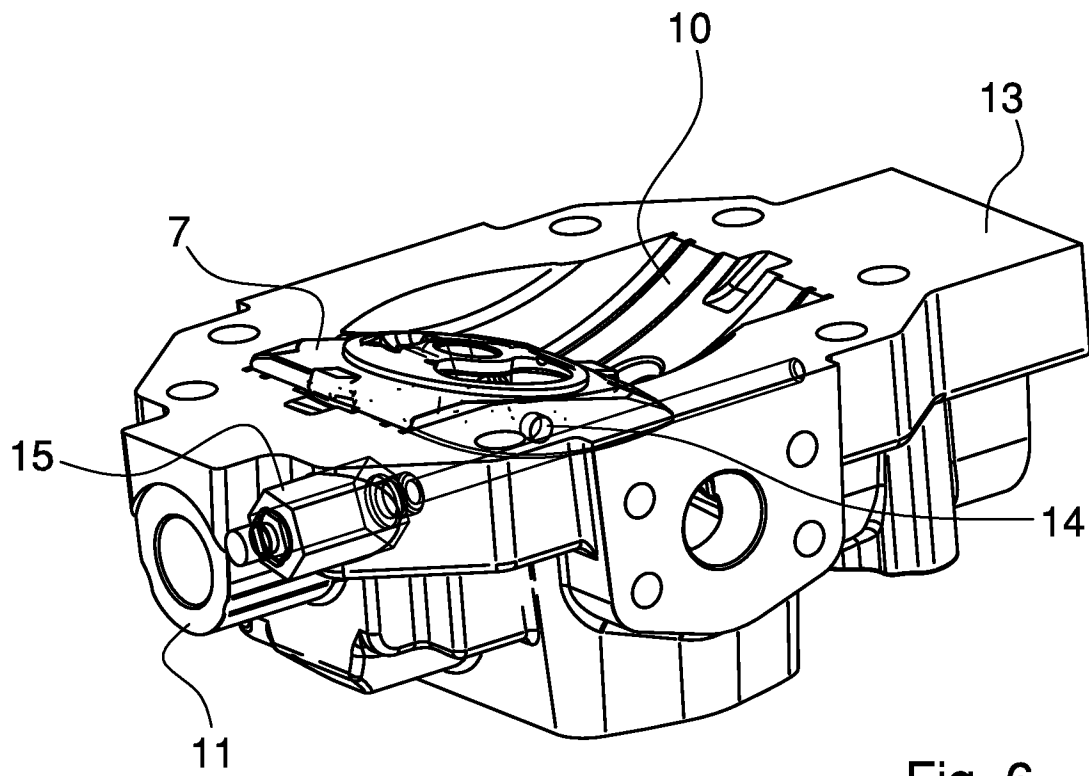


Fig. 6

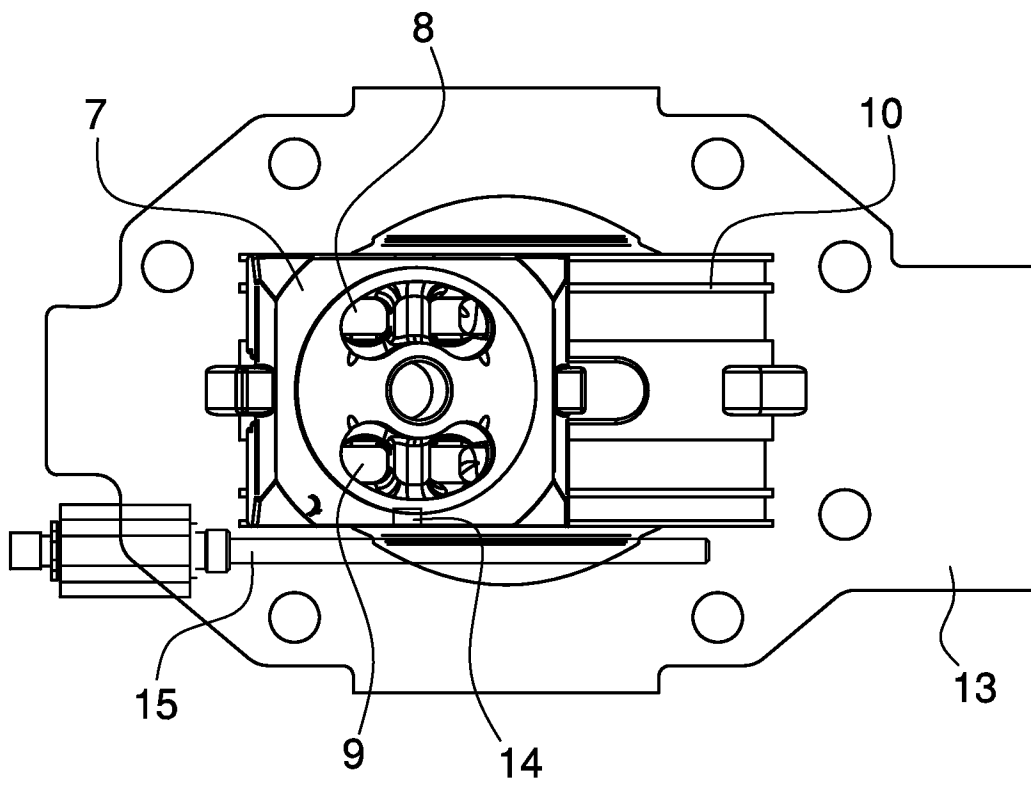


Fig. 7

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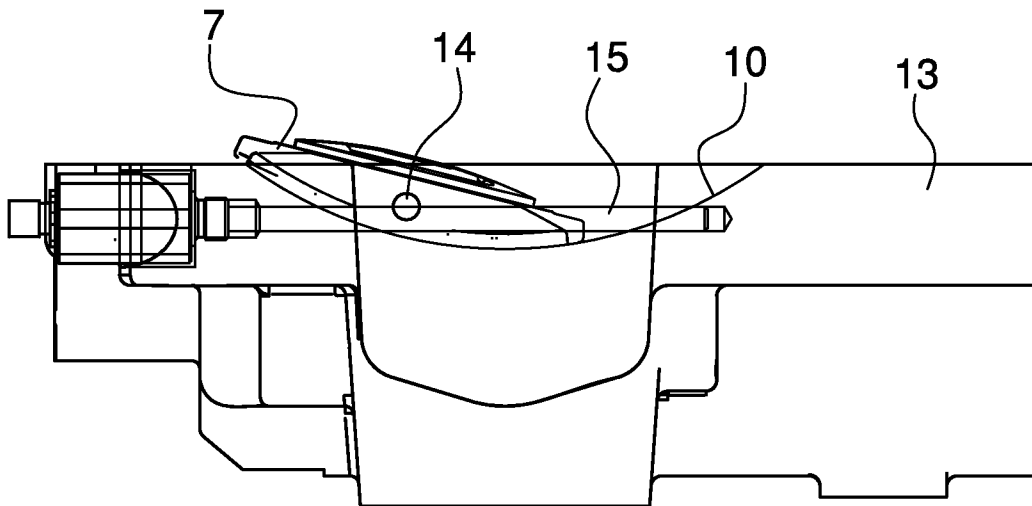


Fig. 10

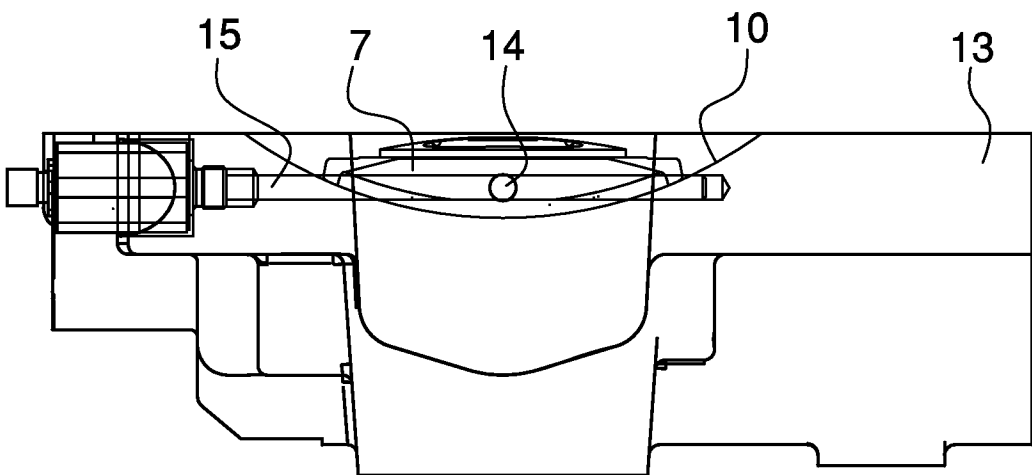


Fig. 8

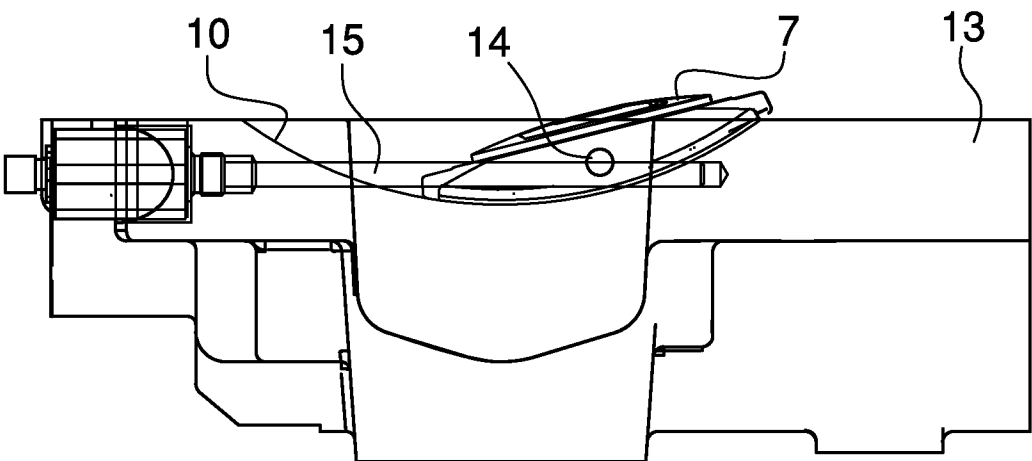


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2011/053249

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03C1/06 F04B1/20 F04B1/24
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)
F04B F03C

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 practical, search terms used)

EP0-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 2005/175442 A1 (KADLICKO GEORGE [US]) 11 August 2005 (2005-08-11)	1,2,10, 11,13,14
Y	paragraph [0066]; claims 1,8-13; figures 4,11,12	1-15
X	WO 2008/138606 A1 (BOSCH GMBH ROBERT [DE]; DREHER HERBERT [DE]; KREBS CLEMENS [DE]) 20 November 2008 (2008-11-20)	1,2,10, 11,13,15
Y	page 8, line 25 - page 25, line 26; figures 1-7	1-15
Y	US 6 283 721 B1 (GOELLNER WILHELM [DE]) 4 September 2001 (2001-09-04) column 4, line 14 - column 5, line 18; claims 1-3; figures 1,3	1-15
	-/--	

☒ 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 document 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)

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"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

22 September 2011

Date of mailing of the international search report

30/09/2011

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