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(54) **A LUBRICATION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE**

(57) A lubrication system (1) for an internal combustion engine comprises an oil pump (2) for circulating oil through the system (1), an oil sump (3) and a suction pipe (6) for drawing oil from the oil sump (3) and transporting the oil to the oil pump (2). The oil sump (3) includes a first compartment (4) and a second compartment (5), which communicate with each other via a closeable first passage (12, 13, 14). The system (1) also comprises a return flow collector (9) for receiving and transporting a return flow of oil towards the first compartment (4), wherein the first compartment (4) is provided with an overflow outlet (11) for transferring overflow oil to the second compartment (5), a closable second passage (12, 13) through which the second compartment (5) communicates with

the suction pipe (6) and a third passage (14) through which the first compartment (4) communicates with the suction pipe (6) and a control device for controlling the system (1), wherein the control device is configured such that during a heating-up period after a cold start of the engine the first passage (12, 13, 14) and the second passage (12, 13) are closed and the suction pipe (6) communicates with the first compartment (4) only and after reaching a predetermined oil temperature in the first compartment (4) at least the second passage (12, 13) is opened such that the suction pipe (6) communicates with at least the second compartment (5). At least the second passage (12, 13) is closeable independent from the oil temperature.

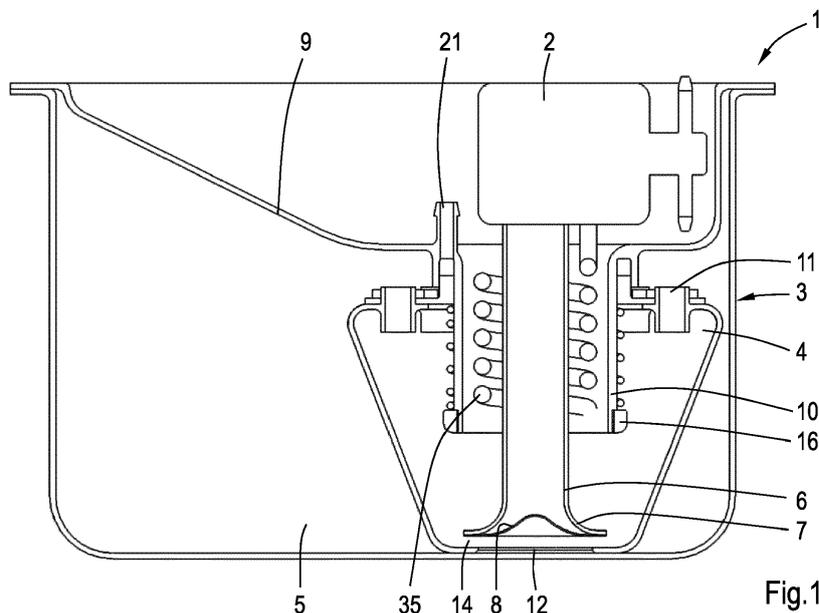


Fig.1

**EP 3 425 178 A1**

## Description

**[0001]** The present invention relates to a lubrication system for an internal combustion engine, comprising an oil pump for circulating oil through the system, an oil sump, a suction pipe for drawing oil from the oil sump and transporting the oil to the oil pump, wherein the oil sump includes a first compartment and a second compartment, which communicate with each other via a closeable first passage, a return flow collector for receiving and transporting a return flow of oil towards the first compartment, wherein the first compartment is provided with an overflow outlet for transferring overflow oil to the second compartment, a closable second passage through which the second compartment communicates with the suction pipe and a third passage through which the first compartment communicates with the suction pipe, a control device for controlling the system, wherein the control device is configured such that during a heating-up period after a cold start of the engine the first passage and the second passage are closed and the suction pipe communicates with the first compartment only and after reaching a predetermined oil temperature in the first compartment at least the second passage is opened such that the suction pipe communicates with at least the second compartment.

**[0002]** During operation of an internal combustion engine, oil circulates within the internal combustion engine to lubricate moving components, to dissipate thermal energy and to protect the internal combustion engine against wear. After lubricating the moving parts of the engine, the oil is collected by the oil sump. To maximize fuel efficiency when an internal combustion engine is warming up, the oil in the oil sump should be heated to an optimum temperature as quickly as possible.

**[0003]** A lubrication system as described above is known from DE 32 35 292. The known lubrication system comprises an oil sump including a first compartment which is accommodated in a second compartment. An oil pump draws oil via a suction pipe. A thermostat is arranged in the suction pipe. The thermostat acts on a bell-shaped valve which, depending on the oil temperature, opens the space within the first compartment to the suction pipe or the space within the second compartment to the suction pipe or the spaces within the first and second compartments to the suction pipe. An oil-catching plate arranged above the first compartment directs the dripping oil always into the first compartment, from which it can overflow into the second compartment. When the engine is cold, the lower base of the bell-shaped valve closes the bottom opening of the first compartment, with the result that the oil is supplied within a small oil circuit to the lubrication points. When this small quantity of oil reaches a certain temperature, the thermostat is activated, the bell-shaped valve thus being displaced downwards in order to connect the suction pipe to the large quantity of oil in the second compartment.

**[0004]** An object of the invention is to provide an im-

proved lubrication system.

**[0005]** This object is accomplished with the lubrication system according to the invention, which is characterized in that at least the second passage is closeable independent from the oil temperature.

**[0006]** Due to this feature the second passage can be opened or closed at any desired moment. For example, under certain engine conditions, such as part-load, it might be advantageous to run the engine at increased oil temperature to improve its efficiency; in such a case the second passage can be closed such that the small oil circuit is used.

**[0007]** In practice the first passage may also be closeable independent from the oil temperature.

**[0008]** Preferably, the control device is configured such that the first passage is immediately closed upon stopping the oil pump and remains closed until at least the next start of the oil pump. The first and second compartment form communicating vessels. Since the return flow of oil is collected in the first compartment the first compartment can be filled up to the overflow outlet, which may have a level above the oil level in the second compartment in practice. Due to immediately closing the first passage the oil in the first compartment does not leak away to the second compartment via the first passage after switching-off the engine. This is advantageous since the oil level in the first compartment remains at the higher level which level can be selected such that the oil volume in the first compartment is sufficient for the small oil circuit during warming-up of the engine, without the risk of emptying the first compartment. During the warming-up period of the engine the oil temperature in the first compartment will rise, whereas the oil in the second compartment will remain at a low temperature. In case of controlling the closeable first passage by means of a thermostat as described in the above-mentioned prior art publication the passage will gradually open during cooling down, leading to levelling of the oil level in the first and second compartments.

**[0009]** Upon starting the engine the second passage may remain closed and the suction pipe may communicate with the first compartment only. Alternatively, the control device may be configured such that the second passage is opened upon or shortly after a cold start of the engine and closed again after a predetermined period of time such that the suction pipe communicates with the second compartment during this period of time. The length of this period is much shorter than the warming-up period and may be inversely related with the oil temperature at the start of the engine. For example, at 0° C the time period may be 5 seconds and at 20° C the time period may be 2 seconds, whereas at a temperature above 20 °C the time period may be zero. A lower oil temperature leads to a higher viscosity which means that it takes more time before the return flow of oil arrives back in the first compartment. In order to have sufficient oil supply for lubrication the first amount of oil may be drawn from the second compartment during the prede-

terminated short time period. After closing the second passage and drawing oil from the first compartment only an oil volume is circulated in the small oil circuit which is larger than the volume of the first compartment. As soon as the viscosity is reduced due to increased oil temperature the return flow of oil will be so much that the first compartment cannot contain the oil which results in overflow from the first compartment to the second compartment.

**[0010]** After the oil temperature in the short oil circuit has reached a desired temperature the second passage is opened and the suction pipe communicates with at least the second compartment. This means that the oil in the second compartment, which had still a relatively low temperature, flows to the suction pipe. In this case the suction pipe may still draw hot oil from the first compartment, as well. This leads to a mixing of hot and cold oil. This intermediate condition may be maintained until the oil temperature reaches a stable temperature of for example 90 °C. Then, the second passage may be fully open and the suction pipe may draw oil from the second compartment only. In practice an engine may have an oil cooler for preventing the oil from overheating.

**[0011]** The second compartment may have a larger volume than the first compartment. For example, the volume of the first compartment may range between 20-30% of the total volume of both compartments.

**[0012]** In a particular embodiment the third passage is also a closable passage; preferably, it is closable independent from the oil temperature.

**[0013]** In practice the three passages may be provided in a three-way valve which is configured such that upon operating the valve the flow area through the second passage becomes larger when the flow area through the third passage becomes smaller and vice versa, whereas the first passage is closed when either the second passage or the third passage is closed and the first passage is open when both the second passage and the third passage are open. This means that the flow areas of the passages can be controlled in dependence from each other.

**[0014]** In a specific embodiment the suction pipe has an inlet portion which is located at the bottom of the first compartment, wherein the first compartment is accommodated within the second compartment, wherein the valve has a closing member which surrounds a through-hole and which is movable with respect to the suction pipe between an upper position in which an upper side of the closing member abuts the inlet portion of the suction pipe such that the first passage and third passage are closed and the second passage is open and formed by a space between the bottom of the second compartment and the closing member and by the through-hole, and a lower position in which a lower side of the closing member abuts the bottom of the second compartment such that the first passage and the second passage are closed and the third passage is open and formed by a space between the inlet portion of the suction pipe and

the closing member. In fact, the inlet portion and the bottom of the second compartment function as valve seats for the closing member.

**[0015]** The first compartment may have a fixed position with respect to the suction pipe, whereas the closing member is guided by a through-hole in the bottom of the first compartment. The closing member is a separate part in this embodiment and may be a ring-shaped element, for example.

**[0016]** In an alternative embodiment the first compartment is movable with respect to the suction pipe and the closing member is formed by at least a portion of the bottom of the first compartment. This means that the through-hole in the closing member is formed by a through-hole in the bottom of the first compartment. In this case the first compartment also functions as a valve element for the three-way valve.

**[0017]** In another alternative embodiment the closing member is formed by at least a portion of the bottom of the first compartment, which portion is movable with respect to the remainder of the first compartment which has a fixed position with respect to the suction pipe. This means that the through-hole in the closing member is formed by a through-hole in the bottom of the first compartment. In this case the bottom portion of the first compartment functions as a valve element for the three-way valve.

**[0018]** The return flow collector may comprise a pipe which protrudes into the first compartment. Preferably, the pipe ends at or close to the inlet portion of the suction pipe, since the heated return flow can be drawn again by the suction pipe so as to supply hot oil to the engine parts as quickly as possible after a cold start of the engine. Besides, if the oil is drawn from the second compartment only, the return flow of oil flows through the first compartment from a low level upwards to the overflow outlet, which prevents the oil from stand still in the first compartment.

**[0019]** The pipe of the return flow collector may be located about the suction pipe whereas the internal diameter of the pipe is larger than the external diameter of the suction pipe. This facilitates assembly of the system, since the pipe can be placed over an existing suction pipe.

**[0020]** Furthermore, the return flow collector may be made of plastic. This is beneficial from manufacturing point of view since there are a lot of different shapes and sizes of oil sumps of engines. Besides, plastic is a thermal insulator which leads to minimal heat loss of the return flow of oil.

**[0021]** It is also beneficial if oil-contacting surfaces of an engine along a path between hot engine parts and the return flow collector are covered by heat insulating material so as to avoid temperature loss of oil during a warming-up period of the engine.

**[0022]** In a preferred embodiment the valve is provided with a spring for moving the valve in one direction by spring force, whereas the valve is operated by oil pres-

sure generated by the oil pump for moving the valve in opposite direction against the spring force. For example, the spring may be applied such that the first passage is automatically immediately closed by the spring when the engine is switched-off due to drop of oil pressure because of stopping the oil pump.

**[0023]** The control device may be configured such that the first passage and the second passage are closed below a predetermined engine load and the suction pipe communicates with the first compartment only. This means that at low engine load the oil flows through the short oil circuit, causing an increased oil temperature, for example higher than 90°C or up to 110°C. Such a high oil temperature is acceptable under part-load conditions and appears to lead to improvement of engine efficiency. If the engine runs on high-load conditions the first and/or second passage can be opened again in order to supply oil of lower temperature and higher viscosity to the engine parts.

**[0024]** In a specific embodiment a heater may be provided at the return flow collector so as to heat the oil before it enters the suction pipe. In case the return flow collector comprises a pipe which protrudes into the first compartment, the heater may be located within that pipe, for example in the form of a heating coil.

**[0025]** The lubrication system can be used for newly developed engines, but also as retrofit system for existing engines.

**[0026]** The invention will hereafter be elucidated with reference to very schematic drawings showing embodiments of the invention by way of example.

Fig. 1 is a cross-sectional view of a first embodiment of a lubrication system for an internal combustion engine according to the invention, showing a condition during warming-up after a cold start of the engine.

Fig. 2 is a similar view as Fig. 1, showing a condition after a warming-period or a condition immediately after switching-off the engine.

Fig. 3 is a similar view as Fig. 1, showing a second embodiment in a condition during warming-up after a cold start of the engine or a condition immediately after switching-off the engine.

Fig. 4 is a similar view as Fig. 2, showing a condition after a warming-period.

Fig. 5 is a perspective view of a third embodiment.

Fig. 6 is a similar view as Fig. 1, but showing a fourth embodiment.

Figs. 7 and 8 are similar views as Figs. 1 and 2, respectively, but showing a fifth embodiment.

Figs. 9 and 10 are similar views as Figs. 1 and 2, respectively, but showing a sixth embodiment.

Fig. 11 is a similar view as Fig. 5, showing a seventh embodiment.

Fig. 12 is a similar view as Fig. 5, showing an eighth embodiment.

Figs. 1 and 2 show a first embodiment of a lubrication

system 1 for an internal combustion engine (not shown) according to the invention. The lubrication system 1 comprises an oil pump 2 for circulating oil through the system 1 and an oil sump 3 which has a first compartment 4 and a second compartment 5. The first compartment 4 is accommodated within the second compartment 5 and has a smaller volume than the second compartment 5.

**[0027]** Furthermore, the lubrication system 1 comprises a suction pipe 6 for drawing oil from the oil sump 3 and transports the oil to the oil pump 2. The suction pipe 6 has an inlet portion 7 which is located at the bottom of the first compartment 4. At the inlet portion 7 the suction pipe 6 broadens in downward direction and forms a substantially flat ring-shaped surface which faces the bottom of the first compartment 4. The inlet portion 7 is provided with a filter 8.

**[0028]** The lubrication system 1 is provided with a return flow collector 9 for receiving and transporting a return flow of oil towards the first compartment 4. After performing its lubrication function the oil returns to the return flow collector 9 as droplets under the influence of gravity. The return flow collector 9 comprises a drip pan which is obliquely angled relative to sidewalls of the second compartment 5. The return flow collector 9 has a pipe 10 which protrudes into the first compartment 4. The pipe 10 surrounds the suction pipe 6 and its internal diameter is larger than the external diameter of the inlet portion 7.

**[0029]** The first compartment 4 is provided with overflow outlets 11 at the upper side of the first compartment 4. Under certain conditions, which will be explained hereinafter, the return flow of oil enters the first compartment 4 through the pipe 10 whereas overflow oil in the first compartment 4 flows into the second compartment 5 through the overflow outlets 11. The first compartment 4 is also provided with a through-hole 12 in its bottom.

**[0030]** The first compartment 4 is movable with respect to the suction pipe 6 in vertical direction between an upper position in which the bottom of the first compartment 4 abuts the inlet portion 7 and a lower position in which the bottom of the first compartment 4 abuts the bottom of the second compartment 5. The upper position is shown in Fig. 2 and the lower position is shown in Fig. 1. The first compartment 4 can also have intermediate positions between its upper and lower positions.

**[0031]** The first compartment 4 forms part of a three-way valve which provides three different situations. If the first compartment 4 is in its upper position a lower valve opening 13 is fully open. The lower valve opening 13 is formed by a space between the bottoms of the first compartment 4 and the second compartment 5. If the first compartment 4 is in its lower position an upper valve opening 14 is fully open. The upper valve opening 14 is formed by a space between the bottom of the first compartment 4 and the inlet portion 7 of the suction pipe 6. If the first compartment 4 is in an intermediate position both the lower valve opening 13 and the upper valve

opening 14 are partly open. In the latter situation the upper and lower valve openings 13, 14 and the through-hole 12 together form a first passage through which the first compartment 4 and second compartment 5 communicate. At the same time the suction pipe 6 communicates with both the first and second compartments 4, 5. In the upper position of the first compartment 4 the lower valve opening 13 and the through-hole 12 together form a second passage in which the suction pipe 6 communicates with the second compartment 5 only. In the lower position of the first compartment 4 the upper valve opening 14 forms a third passage in which the suction pipe 6 communicates with the first compartment 4 only.

**[0032]** In the embodiment as shown in Figs. 1 and 2 a portion of the bottom of the first compartment 4 that surrounds the through-hole 12 forms a closing member whereas the inlet portion 7 of the suction pipe 6 and the bottom of the second compartment 5 form respective valve seats of the three-way valve for receiving the closing member.

**[0033]** The three-way valve is part of a control device for controlling the lubrication system 1. In the embodiment as shown the control device is configured such that during a heating-up period after a cold start of the engine, which is provided with the lubrication system 1, the first compartment 4 is in its lower position. This means that the lower valve opening 13 is closed and the suction pipe 6 draws oil from the first compartment 4 only. The lower position of the first compartment 4 is achieved by means of hydraulic pressure which is supplied in a cavity between the first compartment 4 and the return flow collector 9 via an oil connection 21. In this position the lubrication system 1 forms a small oil circuit.

**[0034]** Since the return flow of oil which is heated by hot engine parts flows into the first compartment 4 and since the first compartment 4 contains only a part of the total oil volume of the engine the oil heats up relative quickly in the small oil circuit. After reaching a predetermined oil temperature in the first compartment 4 the first compartment 4 is moved upwardly to its intermediate position such that the suction pipe 6 also draws oil from the second compartment 5 which has still a relatively low temperature. This condition is reached by lowering the hydraulic pressure at the oil connection 21. Depending on the engine load the first compartment 4 may be moved upwardly further until it reaches its upper position. In the latter case the return flow of oil will flow through the first compartment 4 from the lower end of the pipe 10 in upward direction to the overflow outlets 11. In order to avoid stand still of oil in the first compartment 4 in this situation it is preferred that the lower end of the pipe 10 ends at or close to the bottom of the first compartment 4.

**[0035]** The control device in this embodiment is also configured such that as soon as the engine is switched-off, i.e. when the oil pump 2 is stopped, the first compartment 4 is immediately set in its upper position in order to close the first passage between the first compartment 4 and the second compartment 5 so as to prevent the oil

in the first compartment 4 from flowing into the second compartment 5 before the next engine start. The volume of the first compartment 4 is sufficient for safely running the engine. Since the first compartment 4 remains filled until the next engine start the oil level in the second compartment 5 may be below the overflow outlets 11. In other words, the ratio between required space of the first compartment 4 and the second compartment 5 can be low.

**[0036]** The embodiment as shown in Figs. 1 and 2 comprises a coil spring 15 for keeping the first compartment 4 in its upper position in case of no or low oil pressure at the oil connection 21. The coil spring 15 is mounted around the pipe 10 and rests on a ring 16 which is fixed to the pipe 10, for example by means of screwing the ring 16 onto the pipe 10. The first compartment 4 is moved downwardly by means of oil pressure which is generated by the oil pump 2. When the oil pressure falls due to stopping the oil pump 2 the upper valve opening 14 will automatically be closed such that the suction pipe 6 communicates with the second compartment 5 only. When starting the engine in a cold condition the oil pressure will increase upon starting and oil pressure may be supplied to the oil connection 21 such that the first compartment 4 will be pushed to its lower position in order to create the small oil circuit.

**[0037]** The lubrication system 1 provides the opportunity to set the relative position of the first compartment 4 independent from the oil temperature. For example, it may be desired to use the small oil circuit under part-load conditions of the engine so as to increase the oil temperature in order to improve engine efficiency. In this case the oil pressure at the oil connection 21 must be increased causing the first compartment 4 to be pushed to its lower position. As a consequence, the second passage between the second compartment 5 and the suction pipe 6 is closed.

**[0038]** It is also conceivable that the first passage is not fully closed during stand-still of the engine, resulting in levelling of the oil in the first and second compartments 4, 5. In this case the oil volume in the first compartment 4 may be insufficient for engine lubrication. In order to supply sufficient lubrication oil after a next engine start the first compartment 4 is lifted or remains lifted from the bottom of the second compartment 5 during a short period after a cold start of the engine and pushed to its lower position after a predetermined period of time such that the suction pipe 6 communicates with the second compartment 5 during this period of time.

**[0039]** Figs. 1 and 2 also show an electrical heater 35 which can be switched on to heat the return flow of oil during a warming-up period of the engine. The heater 35 is located inside the pipe 10, which is advantageous since all oil of the small oil circuit flows through the pipe 10. Such a heater 35 may be applied in other embodiments as described hereinafter, as well, but for clarity reasons the heaters will not be shown.

**[0040]** Figs. 3 and 4 show a second embodiment of the lubrication system 1, in which the connection between

the first compartment 4 and the return flow collector 9 is different with respect to the first embodiment. Parts that are similar as the first embodiment are indicated by the same reference numbers. The pipe 10 of the return flow collector 9 is slidably mounted in an outer sleeve 17 that is fixed to the upper side of the first compartment 4. A lower end of the outer sleeve 17 fits in a cylindrical cavity 19 of the ring 16 which is provided with the oil connection 21. The cavity 19 communicates with a hydraulic control line via the oil connection 21 and causes the first compartment 4 to move upwardly upon pressing oil into the cavity 19. The coil spring 15 is accommodated in a coil spring cavity 20 which is located between the pipe 10 and the outer sleeve 17 and bordered at its upper side by the pipe 10 and at its lower side by a flange at the lower end of the outer sleeve 17. In this case, when the oil pressure falls due to stopping the oil pump 2 the lower valve opening 13 will automatically be closed such that the suction pipe communicates with the first compartment 4 only.

**[0041]** Fig. 5 shows a third embodiment which is functionally the same as the first and second embodiments, but shows a different hydraulic control system for moving the first compartment 4. The first compartment 4 is provided with a ring-shaped groove in its bottom, which groove faces the bottom of the second compartment 5. The groove communicates with a hydraulic control line via the oil connection 21. A ring 22 slidably fits in the groove and is provided with protrusions 23 at its lower side which face the bottom of the second compartment 5. The ring is shown separately in Fig. 5. The protrusions 23 rest on the bottom of the second compartment 5 and a flow area is formed between the protrusions 23 such that the second compartment 5 can communicate with the suction pipe 6 only in the upper position of the first compartment 4 or with both the suction pipe 6 and the first compartment 4 in the intermediate position of the first compartment 4.

**[0042]** Fig. 6 shows a fourth embodiment which has some different components with respect to the other embodiments. Parts that are similar as in the other embodiment are indicated by the same reference numbers. The fourth embodiment has an air-filled toroidal spring 24 between the return flow collector 9 and the first compartment 4 for pushing the first compartment 4 against the bottom of the second compartment 5 if no or low hydraulic pressure is supplied to the groove between the first compartment 4 and the ring 22, for example in case of switching-off the engine and during heating-up after a cold start. The toroidal spring 24 forms a seal between the first and second compartments 4, 5. The overflow outlet 11 is located at a higher position than the upper side of the first compartment 4.

**[0043]** Figs. 7 and 8 show a fifth embodiment which is functionally the same as the other embodiments, but has a different structure. In this case the first compartment 4 has a fixed position with respect to the suction pipe 6. The closing member of the three-way valve is formed by

a tubular valve body 25 including an internal flange 26 which cooperates with an external flange 27 on the outer side of the suction pipe 6. The valve body 25 is slidably mounted in the bottom of the first compartment 4. Fig. 8 shows the upper position of the valve body 25 in which the upper valve opening 14 is closed and the lower valve opening 13 is open such that the suction pipe draws oil from the second compartment 5 only. In this case the internal flange 26 of the valve body 25 abuts the external flange 27 of the suction pipe 6. Fig. 7 shows the lower position of the valve body 25 in which the upper valve opening 14 is open and the lower valve opening 13 is closed such that the suction pipe 6 draws oil from the first compartment 4 only. The coil spring 15 is mounted around the valve body 25 and is located between an external flange 28 of the valve body 25 and a ring 29 which is fixed to the first compartment 4, for example by means of screwing the ring 29 onto the first compartment 4.

**[0044]** Figs. 9 and 10 show a sixth embodiment which is functionally the same as the other embodiments, but has a different structure. Similar as in case of the fifth embodiment the first compartment 4 has a fixed position with respect to the suction pipe 6, but in this case the bottom of the first compartment 4 is movable with respect to the remainder of the first compartment 4. The bottom of the first compartment 4 is provided with a resilient portion 30 in the form of a bellow in which the closing member of the three-way valve is formed by a ring-shaped valve body 31 which cooperates with the external flange 27 on the outer side of the suction pipe 6. Fig. 9 shows the lower position of the valve body 31 in which the upper valve opening passage 14 is open and the lower valve opening 13 is closed such that the suction pipe 6 draws oil from the first compartment 4 only. Fig. 10 shows the upper position of the valve body 31 in which the upper valve opening 14 is closed and the lower valve opening 13 between the protrusions 23 of the ring 22 is open such that the suction pipe 6 draws oil from the second compartment 5 only. In the latter case the valve body 31 abuts the external flange 27 of the suction pipe 6. Similar to the third embodiment as shown in Fig. 5 the ring 22 including the protrusions 23 is accommodated in a groove at the bottom of the first compartment 4, but in this case the oil connection 21 for oil supply to the groove is located within the first compartment 4. The first compartment 4 may be made of a plastic which provides the bellow-shaped portion sufficient spring force to properly close the lower valve opening 13 when the oil pressure from the oil pump 2 falls away upon switching-off the engine.

**[0045]** Fig. 11 shows a seventh embodiment which is functionally the same as the other embodiments, but has a different structure. Similar as in case of the fifth embodiment, as illustrated in Figs. 7 and 8, the first compartment 4 has a fixed position with respect to the suction pipe 6, but in this case the first and second compartments 4, 5 are separated by a vertical dividing wall of which the upper edge forms the overflow outlet 11. The closing member of the three-way valve is formed by a cup-

shaped valve body 33 which cooperates with the inlet portion 7 of the suction pipe 6. The valve body 33 is slidably mounted in the bottom of the first compartment 4.

[0046] Fig. 12 shows an eighth embodiment which is distinguished from the embodiments as described above in that the third passage, between the first compartment 4 and the suction pipe 6, is never fully closed. The eighth embodiment is basically the same embodiment as the first one as shown in Figs. 1 and 2, but the bottom of the first compartment 4 is provided with apertures 34. If the first compartment 4 is in its upper position the lower valve opening 13 is fully open such that the second passage, between the second compartment 5 and the suction pipe 6, is open. In this position of the first compartment 4 the first passage, between the first and second compartment 4, 5, is also open such that oil can flow from both the first compartment 4 and the second compartment 5 to the suction pipe 6. Because of the presence of the apertures 34 the third passage, between the first compartment 4 and the suction pipe 6 via the second compartment 2, is also open. If the first compartment 4 is in its lower position the upper valve opening 14 is fully open such that the third passage, between the first compartment 4 and the suction pipe 6, is open. In this position of the first compartment 4 the first passage, between the first and second compartment 4, 5, is closed and the second passage, between the second compartment 5 and the suction pipe 6, is also closed. Hence, the first and second passages can be closed during warming-up the engine and/or during part-load conditions; when the engine is switched-off the oil in the first and second compartment 4, 5 will level. The first compartment 4 can be moved to its lower position after a short period after a cold start of the engine, during which period oil is drawn from the second compartment 5 in order to provide sufficient oil for the small oil circuit during the warming-up when the first compartment 4 is in its lower position.

[0047] The invention is not limited to the embodiments shown in the drawings and described hereinbefore, which may be varied in different manners within the scope of the claims and their technical equivalents. For example, the lubrication system may be provided with separate controllable valve elements instead of a three-way valve.

## Claims

1. A lubrication system (1) for an internal combustion engine, comprising an oil pump (2) for circulating oil through the system (1), an oil sump (3), a suction pipe (6) for drawing oil from the oil sump (3) and transporting the oil to the oil pump (2), wherein the oil sump (3) includes a first compartment (4) and a second compartment (5), which communicate with each other via a closeable first passage (12, 13, 14), a return flow collector (9) for receiving and transporting a return flow of oil towards the first compartment (4), wherein the first compartment (4) is provided with

an overflow outlet (11) for transferring overflow oil to the second compartment (5), a closable second passage (12, 13) through which the second compartment (5) communicates with the suction pipe (6) and a third passage (14) through which the first compartment (4) communicates with the suction pipe (6), a control device for controlling the system (1), wherein the control device is configured such that during a heating-up period after a cold start of the engine the first passage (12, 13, 14) and the second passage (12, 13) are closed and the suction pipe (6) communicates with the first compartment (4) only and after reaching a predetermined oil temperature in the first compartment (4) at least the second passage (12, 13) is opened such that the suction pipe (6) communicates with at least the second compartment (5), **characterized in that** at least the second passage (12, 13) is closeable independent from the oil temperature.

2. A lubrication system (1) according to claim 1, wherein the first passage (12, 13, 14) is also closeable independent from the oil temperature.

3. A lubrication system (1) according to claim 2, wherein the control device is configured such that the first passage (12, 13, 14) is immediately closed upon stopping the oil pump (2) and remains closed until at least the next start of the oil pump (2).

4. A lubrication system (1) according to one of the preceding claims, wherein the third passage is also a closable passage (14).

5. A lubrication system (1) according to claim 4, wherein the third passage (14) is also closeable independent from the oil temperature.

6. A lubrication system (1) according to claim 5, wherein the three passages (12, 13, 14) are provided in a three-way valve which is configured such that upon operating the valve the flow area through the second passage (12, 13) becomes larger when the flow area through the third passage (14) becomes smaller and vice versa, whereas the first passage (12, 13, 14) is closed when either the second passage (12, 13) or the third passage (14) is closed and the first passage (12, 13, 14) is open when both the second passage (12, 13) and the third passage (14) are open.

7. A lubrication system (1) according to claim 6, wherein the suction pipe (6) has an inlet portion (7) which is located at the bottom of the first compartment (4), wherein the first compartment (4) is accommodated within the second compartment (5), wherein the valve has a closing member which surrounds a through-hole (12) and which is movable with respect to the suction pipe (6) between an upper position in

which an upper side of the closing member abuts the inlet portion (7) of the suction pipe (6) such that the first passage (12, 13, 14) and third passage (14) are closed and the second passage (12, 13) is open and formed by a space between the bottom of the second compartment (5) and the closing member and by said through-hole (12), and a lower position in which a lower side of the closing member abuts the bottom of the second compartment (5) such that the first passage (12, 13, 14) and the second passage (12, 13) are closed and the third passage (14) is open and formed by a space between the inlet portion (7) of the suction pipe (6) and the closing member.

8. A lubrication system (1) according to claim 7, wherein the first compartment (4) has a fixed position with respect to the suction pipe (6), whereas the closing member is guided by a through-hole in the bottom of the first compartment (4). 5
9. A lubrication system (1) according to claim 7, wherein the first compartment (4) is movable with respect to the suction pipe (6) and the closing member is formed by at least a portion of the bottom of the first compartment (4). 10
10. A lubrication system (1) according to claim 7, wherein the closing member is formed by at least a portion of the bottom of the first compartment (4), which portion is movable with respect to the remainder of the first compartment (4) which has a fixed position with respect to the suction pipe (6). 15
11. A lubrication system (1) according to one of the claims 7-10, wherein the return flow collector (9) comprises a pipe (10) which protrudes into the first compartment (4), and which preferably ends at or close to the inlet portion (7) of the suction pipe (6). 20
12. A lubrication system (1) according to one of the claims 6-11, wherein the valve is provided with a spring (15, 24) for moving the valve in one direction by spring force, whereas the valve is operated by oil pressure generated by the oil pump (2) for moving the valve in opposite direction against the spring force. 25
13. A lubrication system (1) according to one of the preceding claims and claim 11, wherein the pipe (10) is located about the suction pipe (6) whereas the internal diameter of the pipe (10) is larger than the external diameter of the suction pipe (6). 30
14. A lubrication system (1) according to one of the preceding claims, wherein the control device is configured such that at least the second passage (13) is opened upon or shortly after a cold start of the engine 35

and closed again after a predetermined period of time such that the suction pipe (6) communicates with the second compartment (5) during said period of time.

15. A lubrication system (1) according to one of the preceding claims and claim 2, wherein the control device is configured such that the first passage (12, 13, 14) and the second passage (13) are closed below a predetermined engine load and the suction pipe communicates with the first compartment (4) only. 40

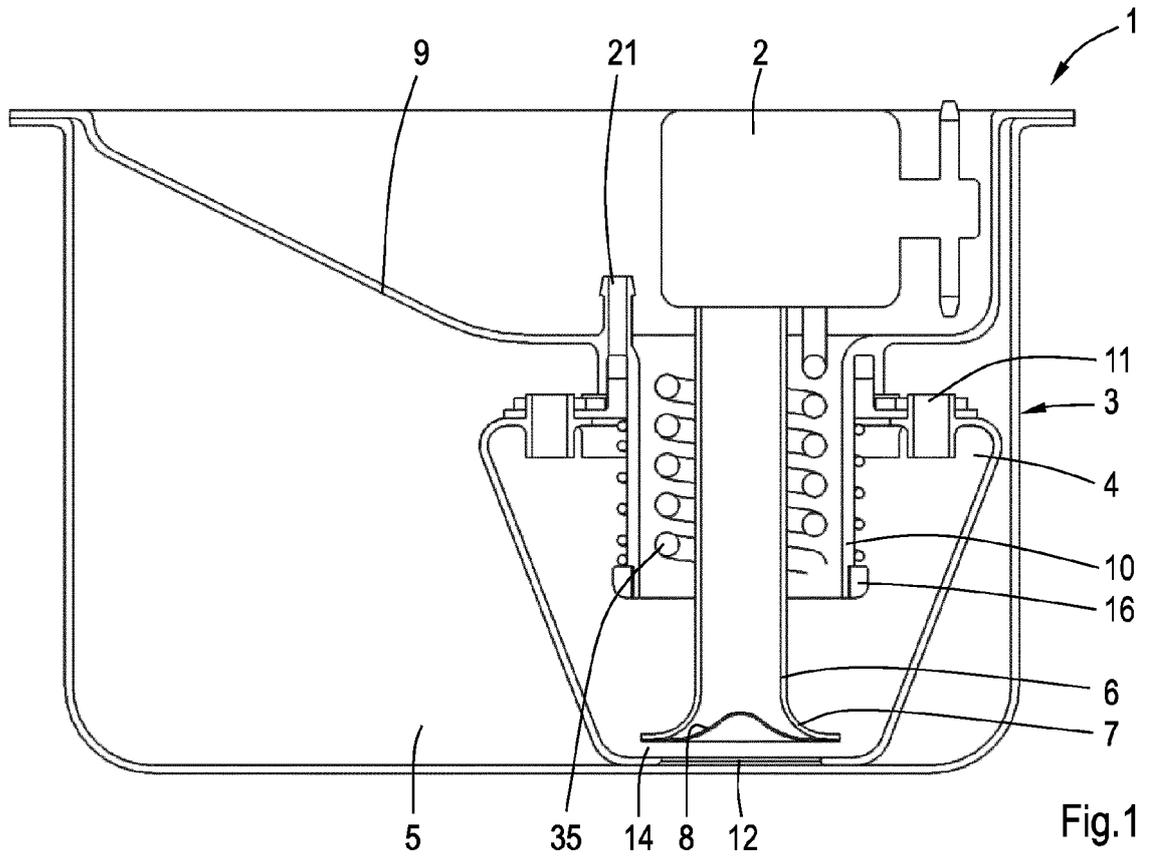


Fig.1

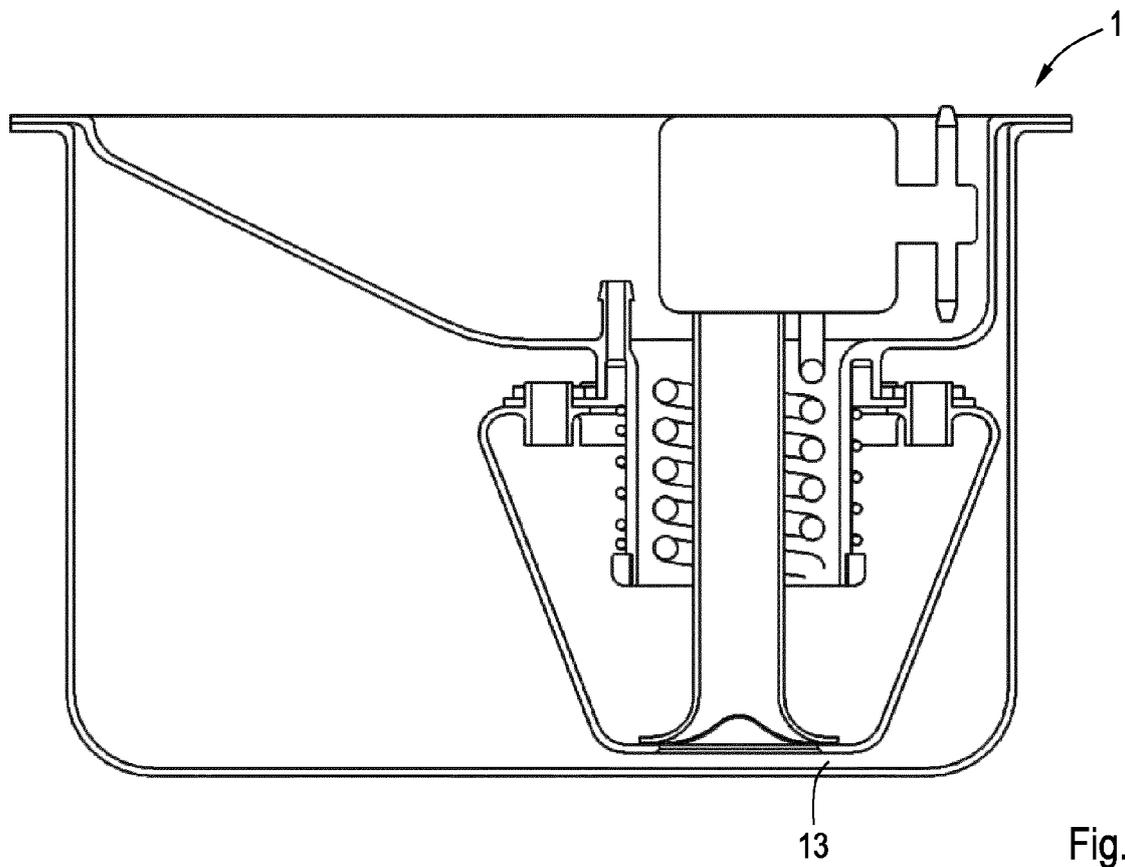


Fig.2

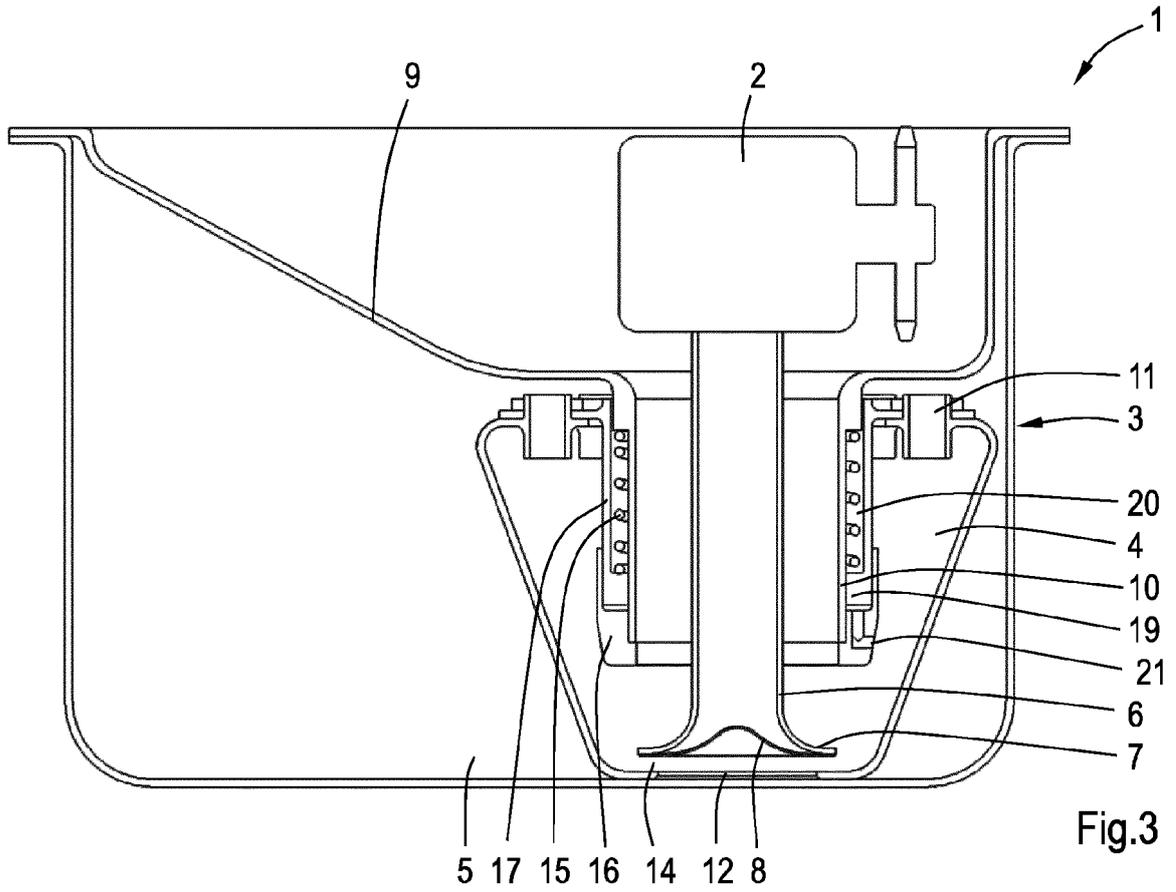


Fig.3

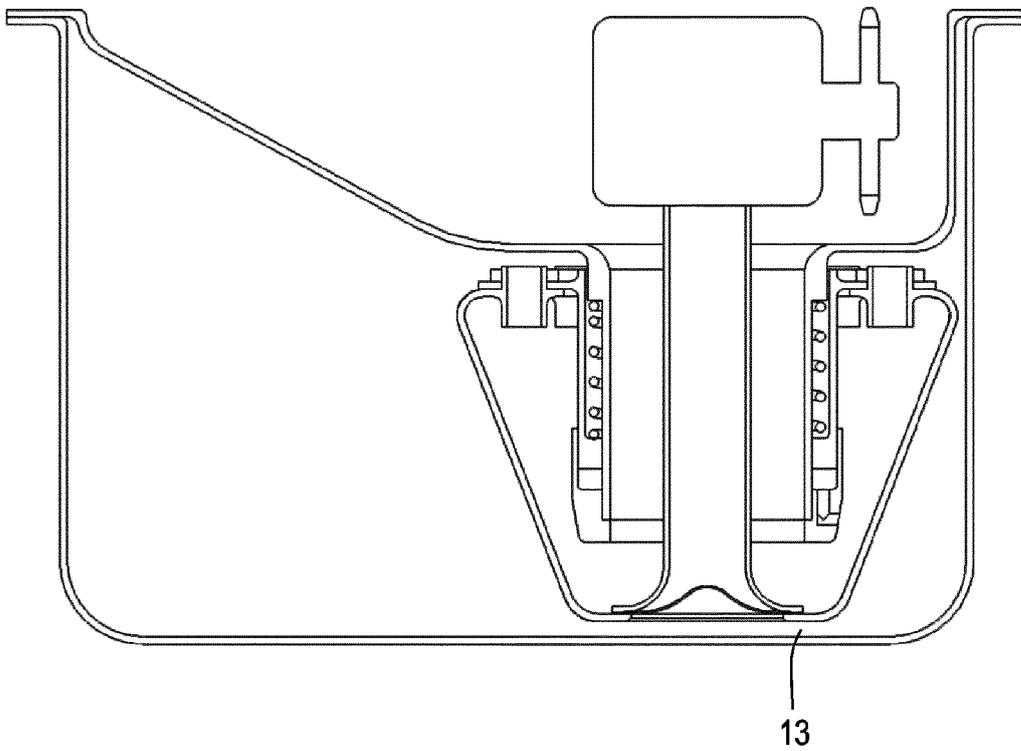


Fig.4

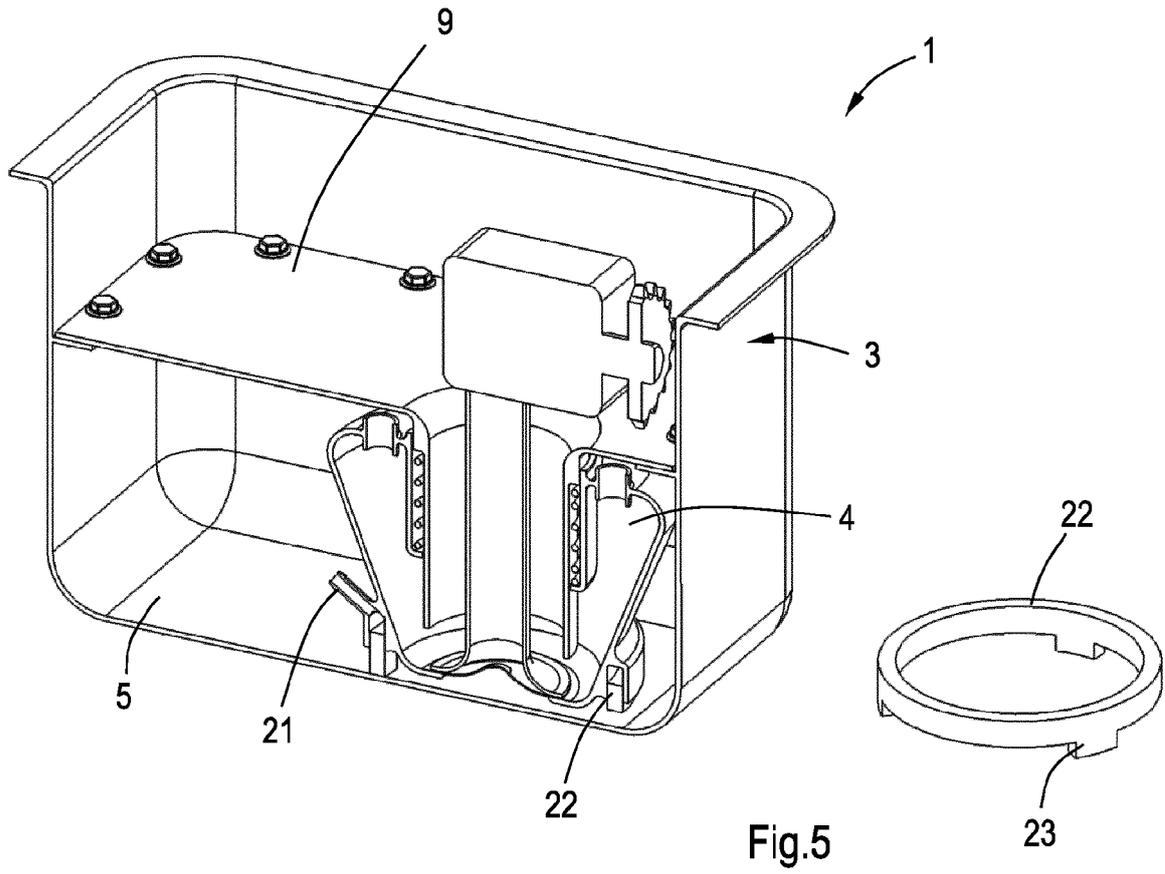


Fig.5

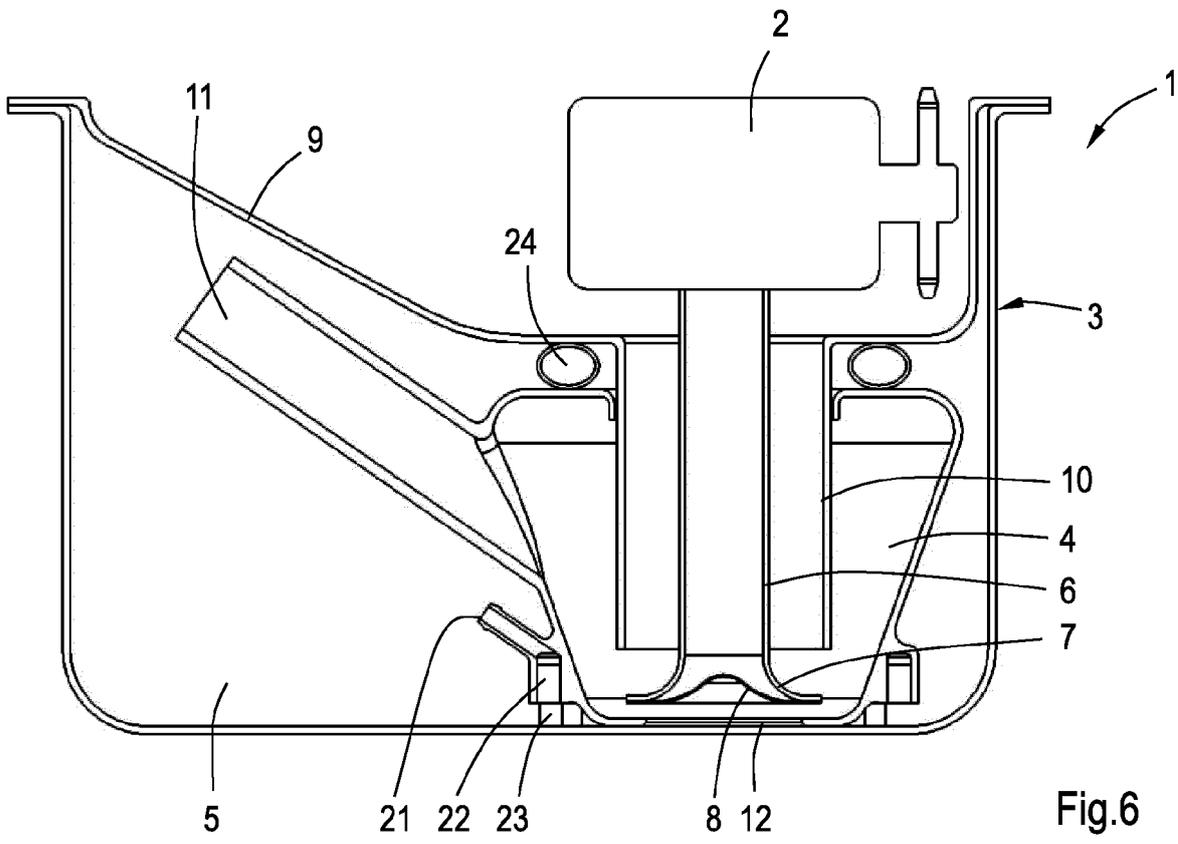


Fig.6

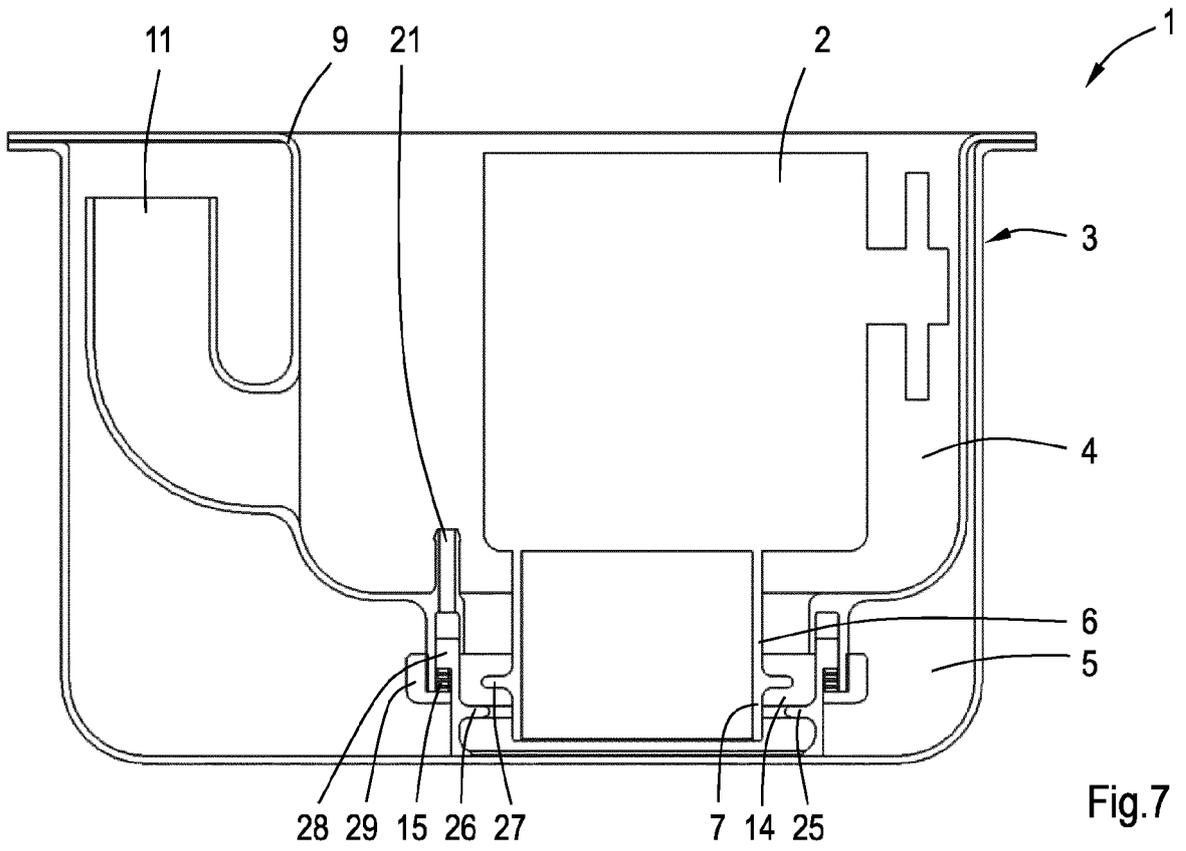


Fig.7

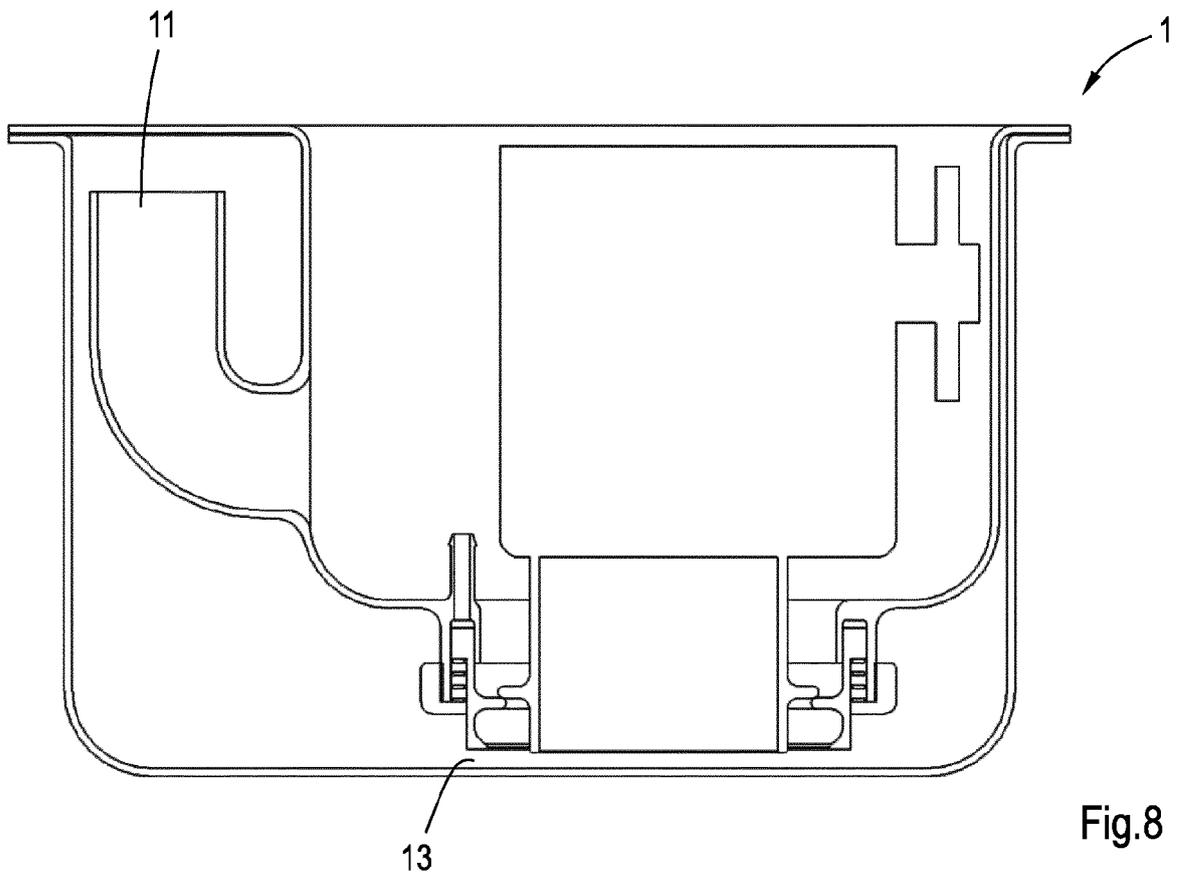


Fig.8

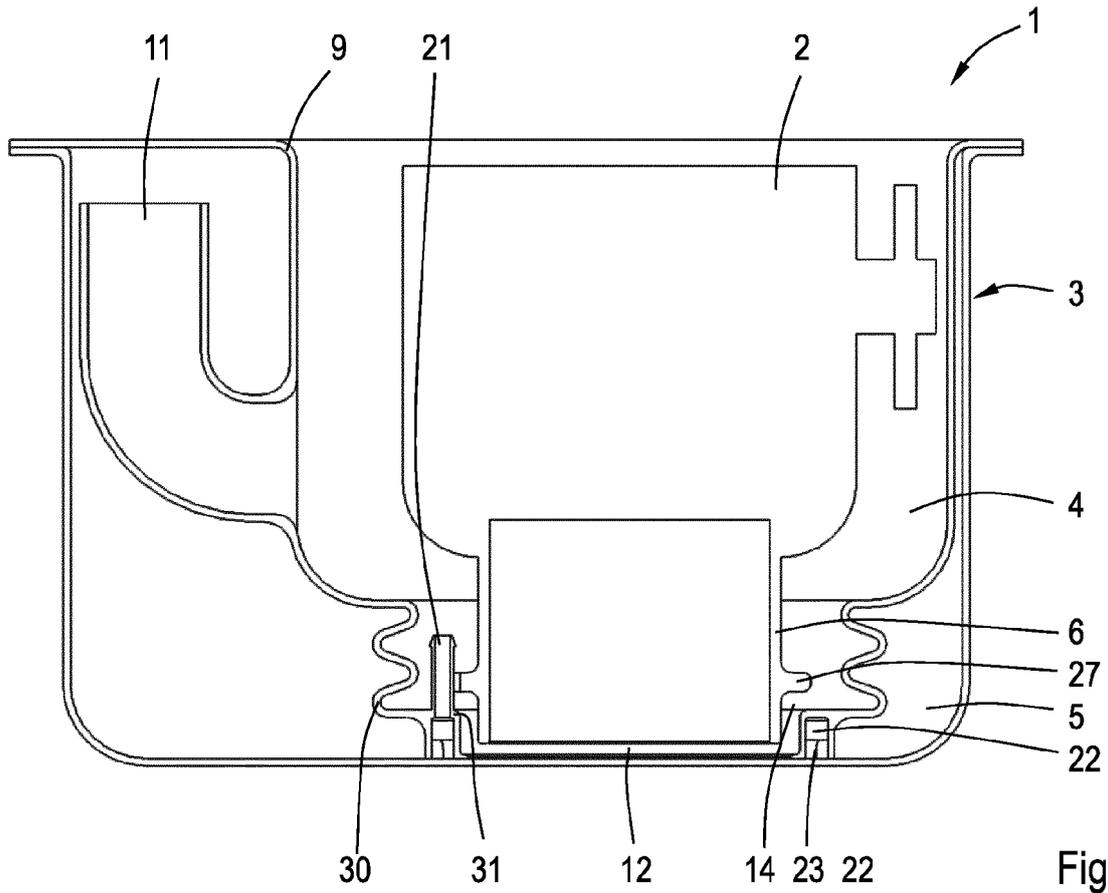


Fig.9

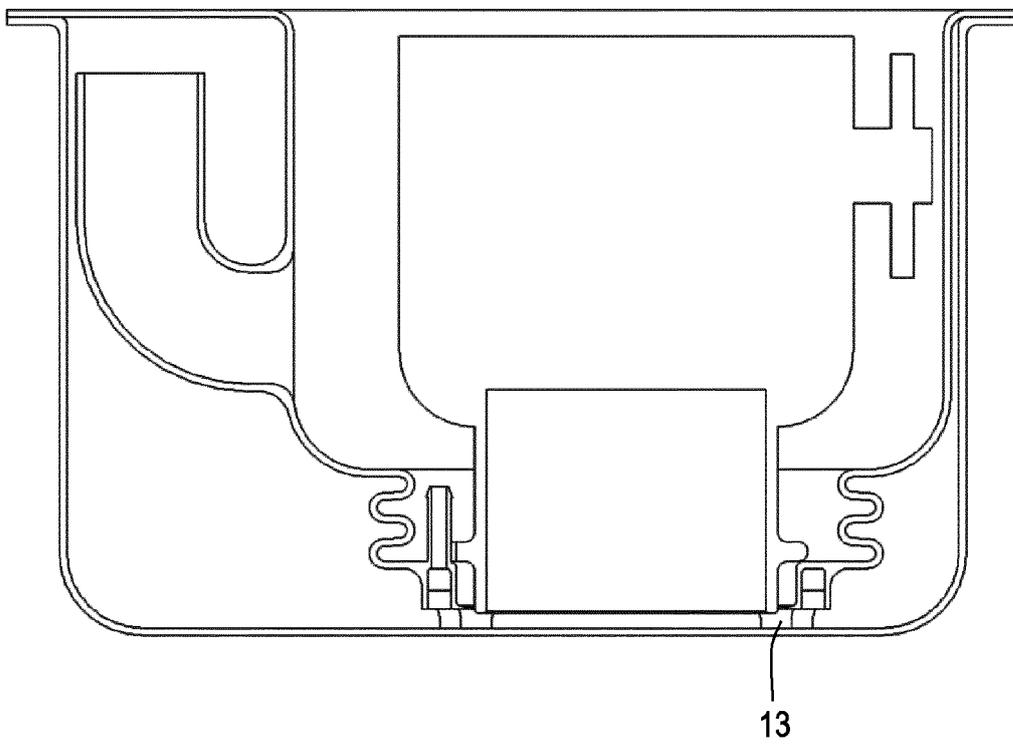


Fig.10

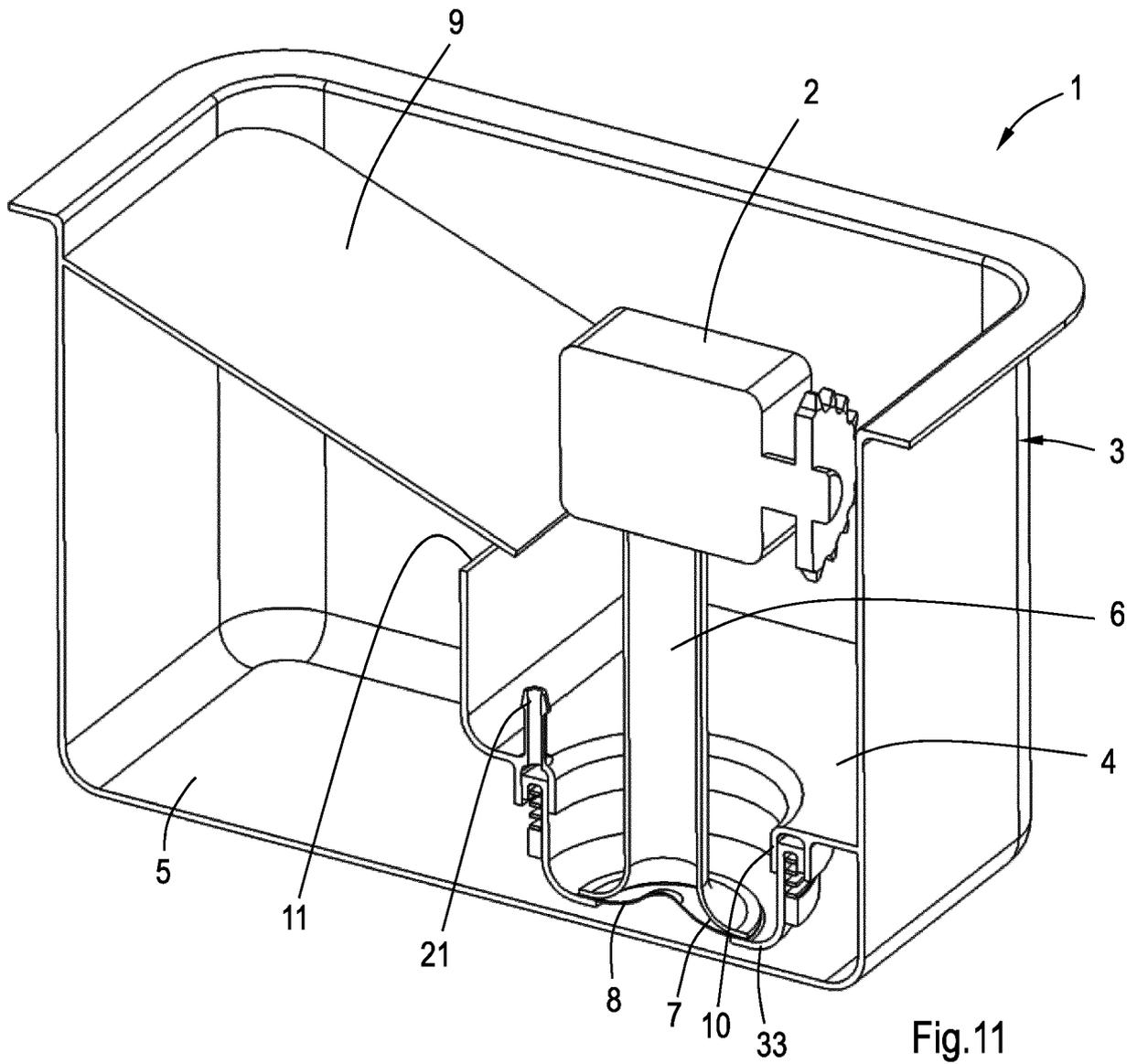


Fig.11

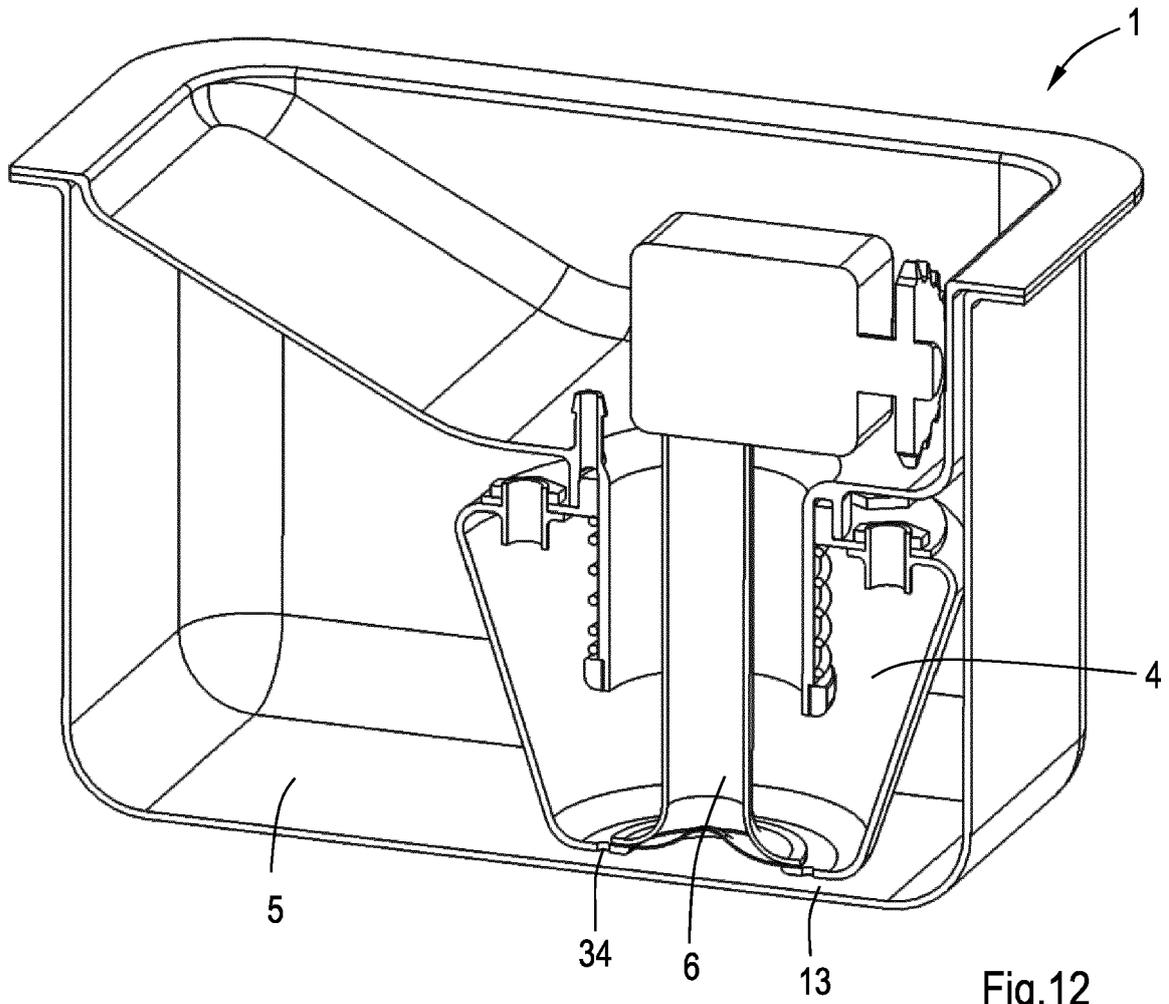


Fig.12



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A	WO 2006/095880 A1 (TOYOTA MOTOR CO LTD [JP]; KOBAYASHI HIDEO [JP]; ARISAWA KATUHIKO [JP];) 14 September 2006 (2006-09-14) * abstract * * page 10, line 17 - page 11, line 36; figure 2 * -----	1	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 January 2018	Examiner Van Zoest, Peter
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