

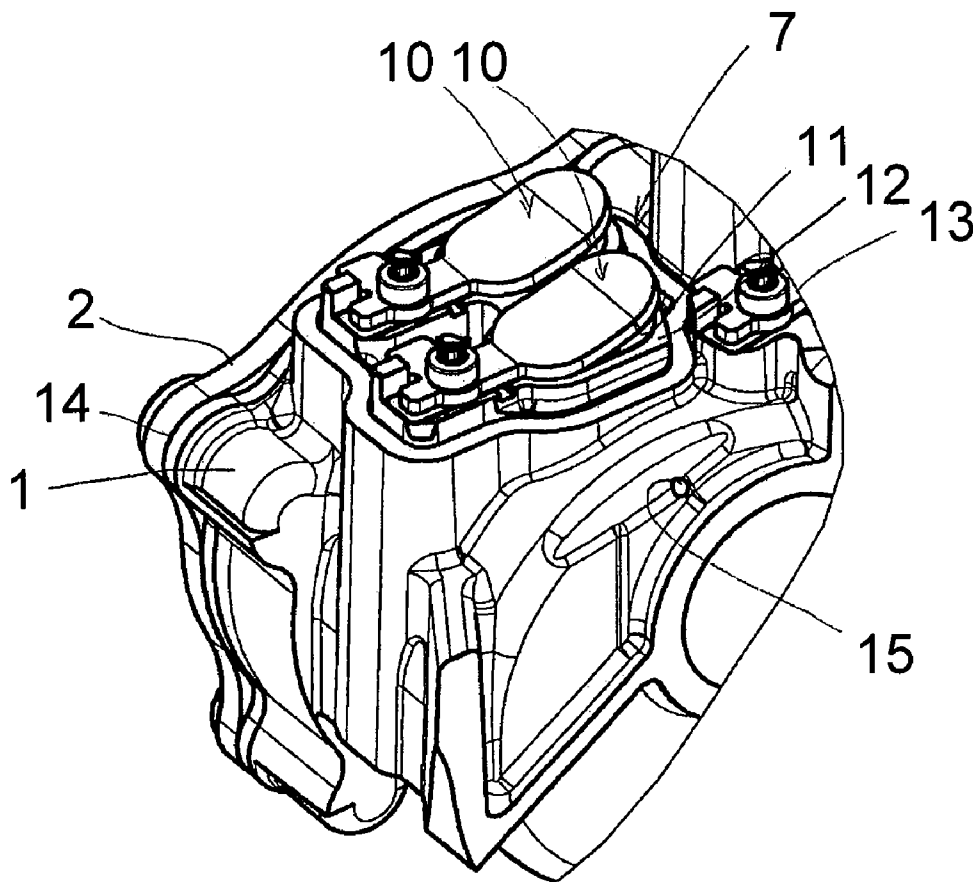


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Peters et al.(10) **Pub. No.: US 2012/0060683 A1**(43) **Pub. Date: Mar. 15, 2012**(54) **VACUUM PUMP WITH VENTILATING
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F04B 53/18 (2006.01)(52) **U.S. Cl. 91/468**(57) **ABSTRACT**(75) **Inventors:** **Sven Peters**, Ummendorf (DE);
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A vacuum pump for supplying a machine assembly with a negative pressure includes a housing and a housing cover surrounding a delivery chamber. The delivery chamber includes a low-pressure region having a working inlet connected to the assembly, and a high-pressure region having a working outlet. A delivery member moveable within the delivery chamber, which, when moved, suctions air into the delivery chamber through the working inlet and expel it at an increased pressure through the working outlet. An outlet valve is arranged at or downstream of the working outlet and at least makes it difficult for air to flow back into the delivery chamber. The delivery chamber is connected to the external environment of the vacuum pump via a ventilating connection in order to establish at least partial pressure equalization with the external environment when the delivery member is stopped and a negative pressure prevails in the delivery chamber.



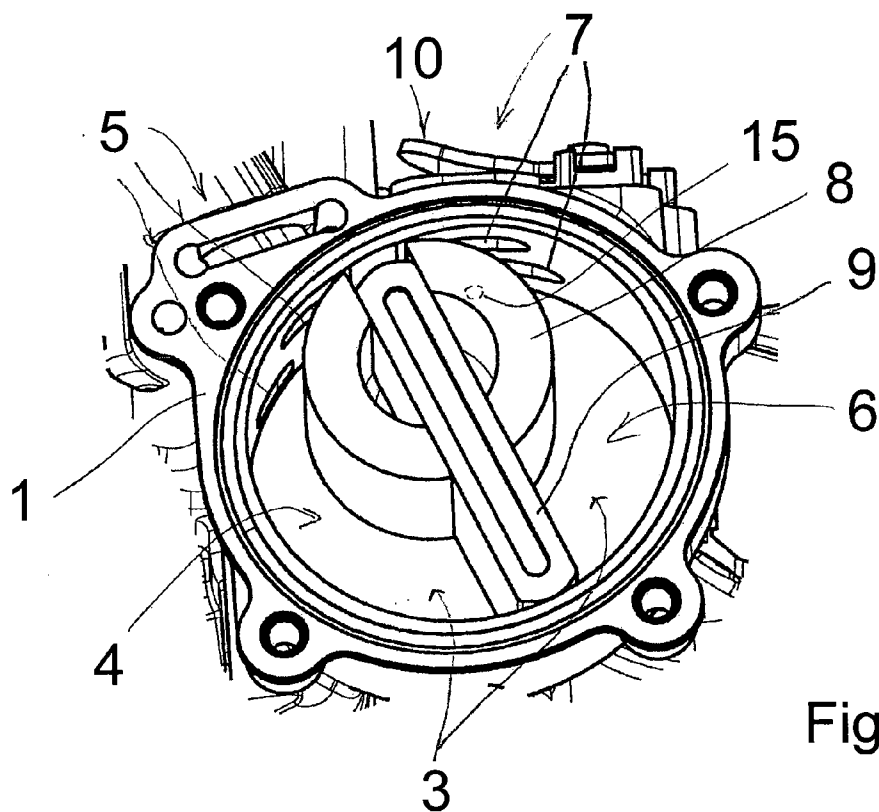


Figure 1

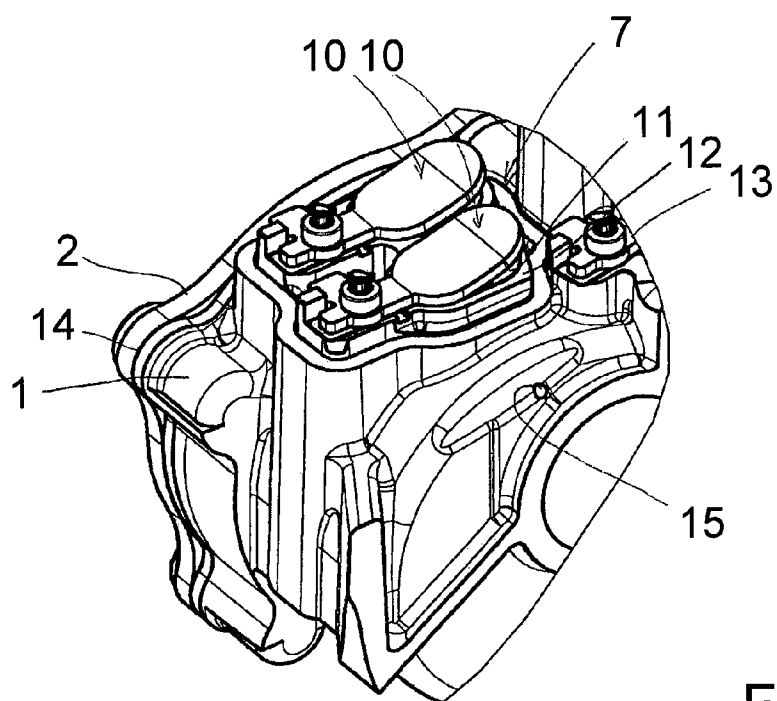


Figure 2

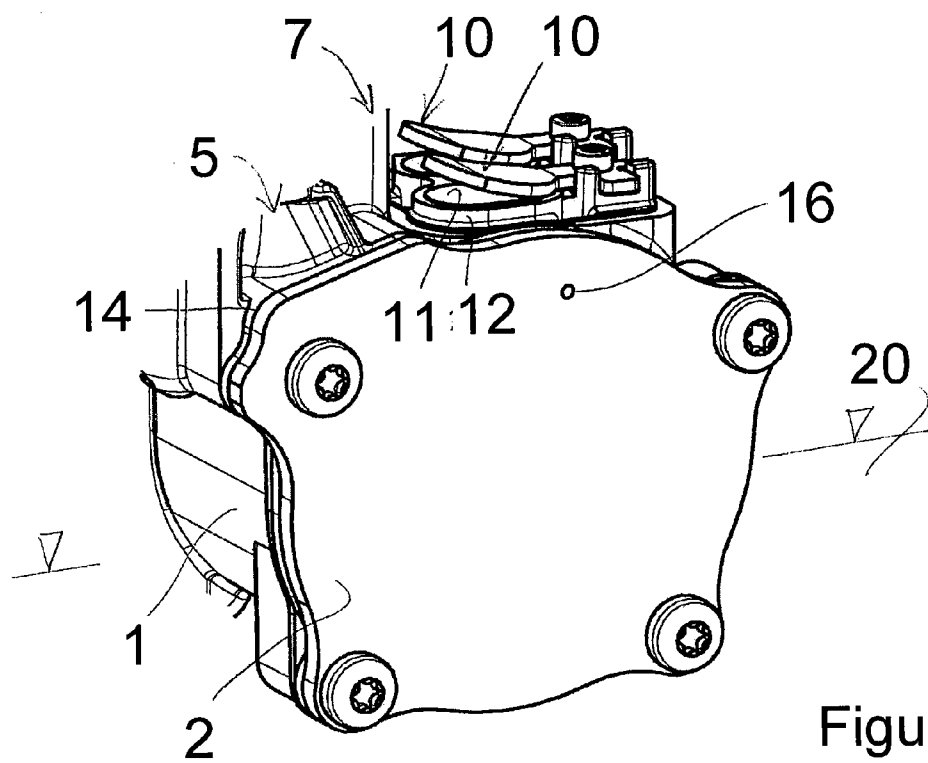


Figure 3

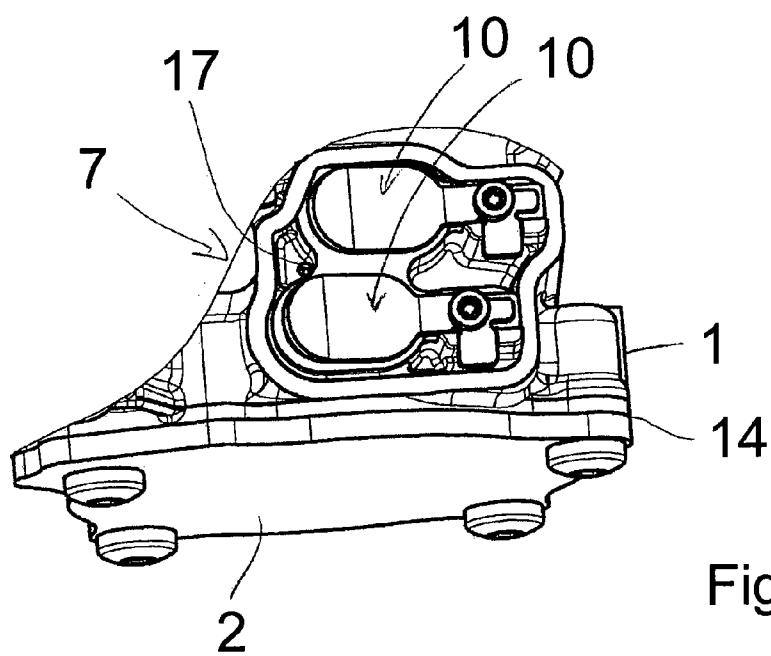


Figure 4

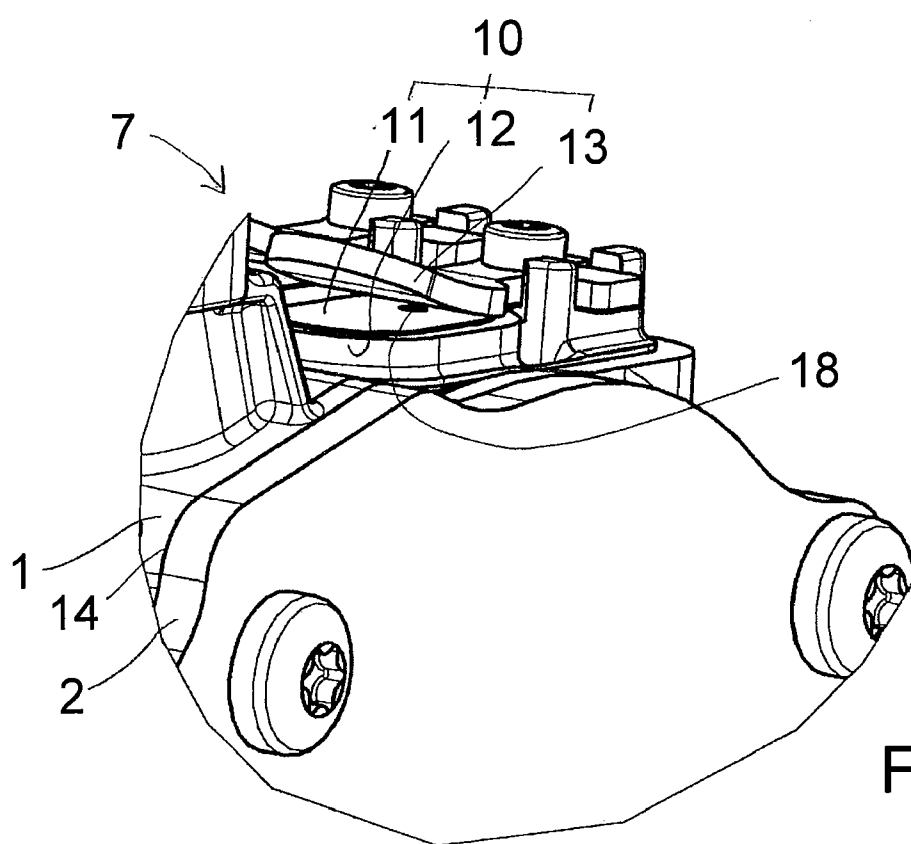
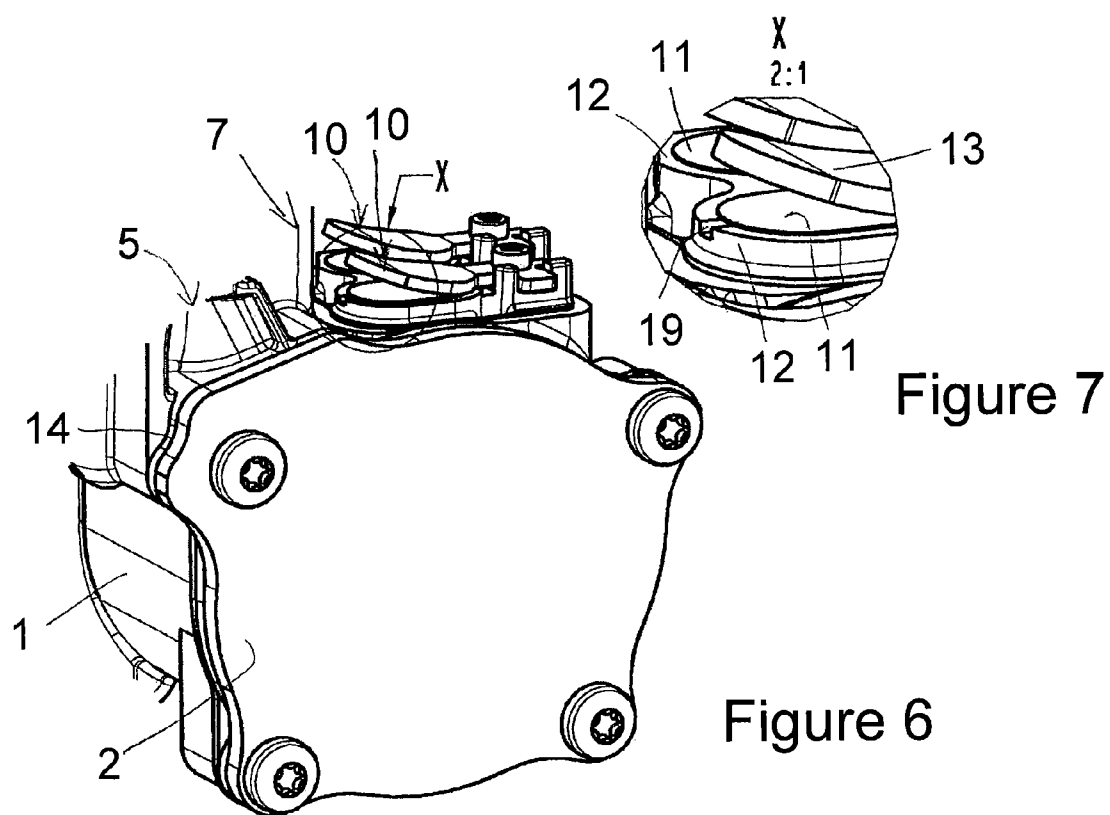


Figure 5



VACUUM PUMP WITH VENTILATING MEANS

RELATED APPLICATION DATA

[0001] This application claims the priority of German patent application No. 10 2010 044 898.2-15, filed on Sep. 9, 2010, which is hereby incorporated in its entirety by reference.

FIELD OF THE INVENTION

[0002] The invention relates to a vacuum pump for supplying a machine assembly with a negative pressure. The assembly is assigned to a machine, preferably an engine and particularly preferably an internal combustion engine. It can be arranged directly on the machine or even within the machine or also retracted from it and can be operated together with the machine, preferably in accordance with the machine. The vacuum pump, when installed, is preferably driven by the machine, for example by a crankshaft or valve control shaft of an internal combustion engine. The invention relates in particular to a vacuum pump which is installed in a motor vehicle or is designed to be installed in a motor vehicle.

BACKGROUND OF THE INVENTION

[0003] Vacuum pumps in motor vehicles, for example for operating brake boosters, are supplied with fluid, usually the lubricating oil which also serves to lubricate the internal combustion engine, for sealing and also for their own lubrication. When the vacuum pump is stopped, the fluid may be suctioned due to the negative pressure which initially still prevails in the delivery chamber. When the vacuum pump is put into operation again, the suctioned fluid has to be displaced. The associated load is enormous and can cause a delivery member of the vacuum pump to break.

SUMMARY OF THE INVENTION

[0004] The invention aims to make vacuum pumps more operationally stable by taking particular account of the described effect of suctioning fluid.

[0005] An aspect of the invention proceeds from a vacuum pump for supplying an assembly which is assigned to a machine which comprises a housing and a housing cover with a delivery chamber and comprises a delivery member which can be moved within the delivery chamber and which, when moved, can suction air into the delivery chamber through a working inlet and expel it at an increased pressure through a working outlet of the delivery chamber. The working inlet is arranged on a low-pressure side of the delivery chamber, and the working outlet is arranged on a high-pressure side of the delivery chamber. The vacuum pump also comprises an outlet valve which is arranged at the working outlet or downstream of the working outlet—in the latter case, preferably near to the working outlet—in order to prevent air from flowing back into the delivery chamber or to at least make it difficult for air to flow back into the delivery chamber. The vacuum pump also comprises a fluid feed through which lubricating or sealing fluid can be fed to the delivery chamber. The fluid can in particular be a lubricating oil which in its main function serves to lubricate the machine. As already mentioned, the machine can be an internal combustion engine such as for example a drive motor for a vehicle.

[0006] In accordance with an aspect of the invention, the vacuum pump comprises a ventilating connection which con-

nects the delivery chamber to the external environment of the vacuum pump, i.e. to the ambient air. The ventilating connection ensures that immediately after the delivery member is stopped, a negative pressure which still prevails in the delivery chamber because of the previous delivery action is relieved via the ventilating connection, and a pressure equalization with the external environment is established. This counteracts the suctioning of fluid and thus filling of the delivery chamber with fluid and the associated negative consequences when the vacuum pump is started up again.

[0007] The ventilating connection is advantageously configured such that as a whole, over its entire flow path between the delivery chamber and the free environment, it counteracts the air flowing through it into the delivery chamber with a flow resistance which on the one hand enables pressure equalization at least substantially within a short enough time to prevent fluid from being suctioned to any appreciable extent, but which on the other hand is still of a magnitude such that it does not impair the effectiveness of the vacuum pump during operation to any practically relevant extent. The function of the outlet valve, namely that of closing the working outlet until a particular minimum positive pressure is reached and opening the working outlet when the minimum positive pressure is reached, is preserved. The ventilating connection is designed such that the minimum positive pressure is still reached in a lower range of the delivery rate of the pump. As mentioned, the ventilating connection is on the other hand designed to equalize the negative pressure which arises in the delivery chamber when the vacuum pump is in operation within a short time, when the delivery member is stopped, using air which flows in from the environment, such that fluid is not suctioned in any significant amount.

[0008] When the vacuum pump is stopped, pressure equalization should be at least 90% complete within a period of a few seconds, preferably within one second. The flow resistance of the ventilating connection is advantageously larger than the flow resistance of the working outlet and preferably also larger than the flow resistance with which an air feed which connects the assembly to the delivery chamber via the working inlet counteracts the air to be suctioned. The flow resistance of the ventilating connection is preferably at least ten times as large as the flow resistance of the working outlet. In preferred embodiments, the flow cross-section of the working outlet is at least ten times as large as the flow cross-section of the ventilating connection. If, when open, the flow cross-section of the working outlet varies from where it ports into the delivery chamber up to the flow cross-section of the valve, then the comparison is based on the smallest flow cross-section of the working outlet on this flow path. If the flow cross-section of the ventilating connection varies between the end of the ventilating connection facing the delivery chamber and where the ventilating connection ports into the free environment, then the comparison for the ventilating connection is also based on the narrowest flow cross-section on this flow path. The flow cross-section of the ventilating connection—in the case of a varying flow cross-section, the narrowest flow cross-section of the ventilating connection—is an area which corresponds to a circular area having a diameter of preferably at least 0.5 mm and preferably at most 2 mm. A flow cross-section corresponding to a circular area having a diameter of between 0.7 and 1.6 mm is advantageous. In advantageous embodiments, the ventilating connection is short. It can in particular be straight over its entire length. Its cross-section

can be shaped as a circle, but can in principle also be shaped otherwise, for example as a square, rectangle, triangle or as a groove.

[0009] The ventilating connection can comprise a passage which leads into the delivery chamber and exhibits a small flow cross-section as compared to the working inlet or in particular the working outlet. The passage can in particular be straight, for example a simple transit bore. A straight passage can already form the ventilating connection as a whole. A straight passage is simple and can be calculated and manufactured exactly in relation to the speed of the desired pressure equalization. A straight passage, in particular in the manner of a calibrated bore, can however also be only part of the ventilating connection. The ventilating connection can for example also be groove-shaped or comprise a groove-shaped portion.

[0010] The ventilating connection can comprise an inlet for the ambient air in the low-pressure region of the delivery chamber. More preferably, it comprises an inlet for the ambient air in the high-pressure region of the delivery chamber, since the effectiveness of the vacuum pump is not impaired, or at least not to any practically relevant extent, by such a connection to the environment. If the minimum positive pressure required for opening the outlet valve has been reached or exceeded in the delivery chamber, the delivery rate of the pump is no longer impaired at all by a ventilating connection which leads into the high-pressure region. The ventilating connection is preferably configured such that it guides air directly from the environment only into the high-pressure region.

[0011] The ventilating connection can connect the delivery chamber to the environment through the working outlet or can lead into the delivery chamber through the housing or the housing cover or also a joining region between the housing and the cover. The word “or” is understood here, as elsewhere, by the invention to mean “inclusive or”, i.e. it includes the meaning of “either . . . or” or also the meaning of “and”, unless only one of these meanings can follow exclusively from the respectively concrete context. With respect to the preferred alternatives, albeit only mentioned by way of example, this means that in a first variant, the ventilating connection leads exclusively through the working outlet which is preferably part of the housing but can alternatively also be part of the housing cover or can be formed only by assembling the housing and housing cover. In a second variant, the ventilating connection only leads through the housing and not through the working outlet if, as is preferred, the latter is formed in the housing. In a third variant, the ventilating connection can lead exclusively through the cover, and likewise not through a working outlet which is for example formed by or together with the cover. In a fourth variant, the ventilating connection can comprise one branch which leads through the working outlet and one or more other branches which bypass the working outlet, for example additionally only one branch which leads through the housing or only one branch which leads through the housing cover or one additional branch through the housing and yet another branch through the housing cover. In yet another variant, the ventilating connection can comprise one branch through the housing cover and another branch through the housing, but no branch through the working outlet. The ventilating connection can also be formed by a cooperation between the housing and the housing cover, for example in the joining region between the housing and the housing cover, such as for example by a recess in the

circumferential edge of a circumferential wall of the housing which surrounds the delivery chamber, against which the housing cover is sealed. If the ventilating connection is formed in the housing, it can for example be a transit bore in the circumferential wall surrounding the delivery chamber or in a front wall of the housing or can comprise such a transit bore or a passage which is formed in a different way. If the ventilating connection as a whole or only one of a plurality of branches of the ventilating connection is formed in the cover, the ventilating connection or branch, respectively, can likewise be a simple transit bore or a passage which is formed in a different way in the cover. The term “transit bore” is understood in a broad sense. In the narrowest sense, it can be a passage which is produced by drilling after originally molding and as applicable subsequently machining the housing or cover. A simple transit bore is however in principle understood to mean any passage which is similar to such a transit bore as understood in the narrow sense and which can for example be formed even as the housing or in particular the cover is originally molded.

[0012] A ventilating connection which leads through the working outlet can be formed as a bypass for the outlet valve. In preferred embodiments, however, the ventilating connection or as applicable only a branch of the ventilating connection leads through the outlet valve. In embodiments in which the outlet valve comprises a valve seating and a valve body which is elastically tensed against the valve seating and can be raised off of the valve seating against an elastic restoring force, the ventilating connection can advantageously lead through the valve body or the valve seating, which as stated above also includes the scenario in which the ventilating connection leads through both the valve body and the valve seating.

[0013] The outlet valve can for example be a leaf spring valve comprising a leaf spring which forms the valve body, is spring-elastically tensed against the valve seating and can for example be a simple single-layer plate spring. The ventilating connection can in particular lead through the leaf spring. It can be formed in the leaf spring as a straight passage. A passage can in particular be punched in such a leaf spring cost-effectively. The passage extends in the thickness direction of the leaf spring. Alternatively or additionally, the ventilating connection can lead through the valve seating, for example in the form of one or more local recesses which are open facing the valve body and through which air can flow past the valve body into the delivery chamber for the purpose of pressure equalization in accordance with the invention.

[0014] In addition to the working outlet in the high-pressure region, the vacuum pump can comprise a second outlet in the region of the delivery chamber which forms the low-pressure region during usual pump operations, in order to be able to expel air and fluid through this second outlet if the delivery direction is reversed. Another outlet valve, if provided, is also arranged at or downstream of the second outlet.

[0015] The vacuum pump is preferably a rotary pump. In such embodiments, the delivery member is a feed wheel which can be rotated in the delivery chamber. A rotary-type vacuum pump can for example be a toothed wheel pump, such as for example an internal toothed wheel pump or an external toothed wheel pump, or a reciprocating piston valve pump. The vacuum pump is preferably embodied as a vane cell pump comprising a rotor and at least one vane. The vacuum pump can in particular be a single-vane vacuum pump and the delivery member can correspondingly be a vane wheel com-

prising only one vane. The vacuum pump can however also be a multi-vaned vacuum pump and the delivery member can correspondingly comprise a rotor and a plurality of vanes. The vacuum pump can be a single-flow or multi-flow pump. It can comprise a plurality of delivery members. In simple and not least for this reason preferred embodiments, the vacuum pump comprises only one delivery member and is preferably also embodied to be only a single-flow pump.

[0016] The problem of fluid being suctioned in immediately after the vacuum pump is stopped, as described at the beginning, can be exacerbated further by the installation situation. The vacuum pump can thus for example be partially or in principle even completely immersed in a reservoir for the lubricating fluid or sealing fluid. In preferred embodiments as a vacuum pump in a motor vehicle, it can for example be partially or completely immersed in a lubricating oil sump of the drive motor. If it is only partially immersed, it is sufficient if the ventilating connection is simply guided through the housing, the housing cover, the joining region or the working outlet only, without any additional attachments. If the vacuum pump is completely immersed, the ventilating connection expediently comprises a sort of snorkel in order to ensure a sufficient distance from the uppermost level of the fluid reservoir with respect to all the operational situations of the internal combustion engine.

[0017] The working outlet can comprise a plurality of openings which port into the delivery chamber in the high-pressure region. If the vacuum pump is embodied as a rotary pump, the openings can be offset with respect to each other in the circumferential direction, i.e. in the rotational direction of the delivery member. Instead, or in addition to a circumferential offset, the openings can be offset with respect to each other in the axial direction of the delivery member.

[0018] In simple embodiments, the vacuum pump comprises only one outlet valve. In further developments, however, a plurality of outlet valves which are separate from each other can also be arranged at the working outlet or downstream of the working outlet. The plurality of outlet valves would be arranged functionally parallel to each other. The working outlet would only be closed when each of the outlet valves assumes its closing state. In embodiments comprising a plurality of outlet openings in the high-pressure region, each one of the plurality of outlet valves can in particular be respectively assigned to one of the plurality of outlet openings, i.e. one outlet valve for each respective outlet opening. Arranging a plurality of outlet valves on the high-pressure side of the pump is advantageous with regard to the response time of the outlet valves, since a plurality of comparatively smaller outlet valves comprising correspondingly smaller valve bodies which exhibit less mass respond more quickly to pressure changes in the delivery chamber than one valve comprising a larger valve body. A vacuum pump which is modified in this way would demonstrate a particularly sensitive response behavior to pressure changes. Dividing the working outlet into a plurality of outlet valves is in particular advantageous when these valves are embodied as leaf spring valves, since smaller-area leaf springs close more reliably than larger-area ones in this type of valve design. Fluttering by the leaf spring can be more reliably avoided. Where features of the ventilating connection relate to an outlet valve, the statements also apply to the modification comprising a plurality of outlet valves and also to modifications comprising a plurality of outlet openings and only one common outlet valve. A ventilating connection can thus for example lead into only one of

the outlet openings, into a plurality of the outlet openings or into each of the plurality of outlet openings. If there are a plurality of outlet valves, a ventilating connection can also lead through only one of the outlet valves or through a plurality of the outlet valves, which also includes the scenario in which a ventilating connection respectively leads through each of the plurality of outlet valves. The Applicant reserves the right to also direct claims to a vacuum pump comprising a plurality of outlet valves in combination with one or more outlet openings, in particular respectively assigned outlet openings, wherein such a vacuum pump preferably comprises, but need not comprise, a ventilating connection in accordance with the invention claimed here. The Applicant also reserves the right to direct claims to a vacuum pump comprising a plurality of outlet openings in the high-pressure region, irrespective of the matter of a ventilating connection in accordance with the invention, wherein if there are a plurality of outlet openings, each of these outlet openings can in particular be respectively assigned an outlet valve of its own or however also one common outlet valve.

[0019] Advantageous features are also described in the sub-claims and combinations of them.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Exemplary embodiments of the invention are described below on the basis of figures. Features disclosed by the exemplary embodiments, each individually and in any combination of features, develop the subjects of the claims and the embodiments described above.

[0021] FIG. 1 shows a vacuum pump of a first exemplary embodiment, comprising a housing through which a ventilating connection leads.

[0022] FIG. 2 shows the vacuum pump of the first exemplary embodiment, in a view onto a rear side.

[0023] FIG. 3 shows a vacuum pump of a second exemplary embodiment, comprising a housing cover through which a ventilating connection leads.

[0024] FIG. 4 shows a vacuum pump of a third exemplary embodiment, comprising a ventilating connection which leads through the housing.

[0025] FIG. 5 shows a vacuum pump of a fourth exemplary embodiment, comprising a ventilating connection which leads through a working outlet.

[0026] FIG. 6 shows a vacuum pump of a fifth exemplary embodiment, comprising a ventilating connection which leads through the working outlet.

[0027] FIG. 7 shows the region of the working outlet comprising the ventilating connection of the fifth exemplary embodiment.

DETAILED DESCRIPTION

[0028] FIG. 1 shows a vacuum pump of a first exemplary embodiment, in a perspective view onto a housing 1 of the vacuum pump. A housing cover is removed, such that a delivery chamber 3 which is surrounded by the housing 1 and the housing cover when they are assembled is exposed. A delivery member comprising a rotor 8 and a vane 9 is movably arranged in the delivery chamber 3. The vacuum pump is for example embodied as a vane cell pump, wherein a single-vane vacuum pump serves as an example. When the delivery member 8, 9 is rotary-driven anti-clockwise, a low-pressure region 4 comprising a working inlet 5 and a high-pressure region 6 comprising a working outlet 7 are formed in the

delivery chamber 3. The vacuum pump is connected to an assembly, for example a brake booster of a motor vehicle, via the working inlet 5 in order to supply the assembly with a negative pressure. When the delivery member 8, 9 is rotary-driven, air is suctioned into the low-pressure region 4 through the working inlet 5 and expelled at an increased pressure through the working outlet 7 in the high-pressure region 6. The working outlet 7 is connected directly to the free environment, i.e. the air which is compressed in the delivery chamber 3 is expelled into the free environment.

[0029] An outlet valve 10 is arranged in the region of the working outlet 7, for example directly at the working outlet 7. The outlet valve 10 seals the working outlet 7, at least when the vacuum pump is stopped, and opens it when a particular minimum positive pressure with respect to the environment is reached in the high-pressure region 6. The outlet valve 10 is advantageously designed such that it is in its closing state until the minimum positive pressure is reached and, when the minimum positive pressure is reached, quickly opens and responds sensitively to this pressure.

[0030] The vacuum pump is supplied with a lubricating and sealing fluid in order to lubricate the components which are moved relative to the housing 1 and in part relative to each other during pump operations, such as in particular the rotor 8 and the vane 9, and simultaneously also to ensure a sufficiently good seal between the high-pressure region 6 and the low-pressure region 4. The lubricating and sealing fluid is fed via a fluid feed. The fluid feed can for example extend through a shaft of the rotor 8 or on the external circumference of such a shaft, in order to guide the fluid into the delivery chamber 3 and in particular into the gap across which relative movements occur, such as for example between the rotor 8 and the opposite-facing front faces of the housing 1 and housing cover, and into the gap between the rotor 8 and the vane 9 which can be moved linearly back and forth relative to it. From there, the lubricating and sealing fluid is distributed and also reaches the gap, to be sealed further outwards, between the delivery member 8, 9 and the housing 1 and reaches the housing cover.

[0031] If the vacuum pump is stopped, a negative pressure still momentarily prevails in the delivery chamber 3 due to the previous pump operations. Due to the negative pressure, there is the danger of lubricating and sealing fluid being suctioned into the delivery chamber 3 via the fluid feed but no longer continuously withdrawn and of the delivery chamber 3 being partially filled with the fluid. This can create problems when the vacuum pump is started up again, since the delivery member 8, 9 initially withdraws this fluid, wherein the vane 9 absorbs enormous moments which can cause destruction or conversely require the delivery member 8, 9 to be dimensioned for this extraordinary load scenario.

[0032] In order to tackle this problem, i.e. to not allow it to arise in the first place, the vacuum pump comprises a ventilating connection 15. The ventilating connection 15 connects the delivery chamber 3 to the free environment. The ventilating connection 15 is indicated in a broken-line layout, since in the representation in FIG. 1, it ports into the delivery chamber 3 at a point which is hidden by the rotor 8. Immediately after the pump is stopped, air therefore flows from the environment into the delivery chamber 3 through the ventilating connection 15 and ensures a pressure equalization between the environment and the delivery chamber 3. The ventilating connection 15 can in particular be dimensioned such that when the delivery member 8, 9 is stopped, pressure equalization is at

least substantially complete within a few seconds, preferably in less than one second, despite the outlet valve 10 being in its closing state. Advantageously, the complete ambient pressure or at least a pressure which still deviates by at most 10% from the ambient pressure already prevails in the delivery chamber 3 after one second at the latest.

[0033] The ventilating connection 15 ports in the high-pressure region 6, such that the effectiveness of the vacuum pump is not impaired or at least not appreciably impaired. The ventilating connection 15 is advantageously arranged such that it ports near to the working outlet 7. In the first example embodiment, the ventilating connection 15 is formed in the housing 1. It ports on the front face which is formed by the housing 1 and which limits the delivery chamber 3 on one of its two axial sides. The ventilating connection 15 can in particular be a straight passage, preferably a short passage, for example an axial passage. The delivery chamber 3 is permanently connected to the free environment via the ventilating connection 15. The ventilating connection 15 is a bypass to the working outlet 7. It can in particular exhibit a flow cross-section which corresponds in terms of its area to a circular area having a diameter of at least 0.5 and at most 2 mm. The flow cross-section can be constant over the entire length of the ventilating connection 15. If the flow cross-section varies, the preferred measurements apply to the smallest flow cross-section.

[0034] FIG. 2 shows a view onto a rear side of the vacuum pump of the first example embodiment, including where the ventilating connection 15 ports into the external environment on the rear side. The housing cover 2 is mounted in FIG. 2. The rear side lies axially opposite the housing cover 2. The housing 1 and the housing cover 2 are connected to each other, in a seal, in a joining region 14 which surrounds the delivery chamber 3. In the joining region 14, a gasket which surrounds the delivery chamber 3 can be arranged between the joining surfaces of the housing 1 and housing cover 2 which face each other across such a gasket, for example an elastomer gasket or alternatively a metal gasket.

[0035] The vacuum pump comprises a working outlet 7 including two outlet openings which port separately from each other into the delivery chamber 3, and assigned outlet valves 10. The two outlet openings and the two outlet valves 10 can be identical. Alternatively, the working outlet 7 can also be formed in one part and comprise only one, correspondingly larger outlet opening and only one outlet valve 10. Dividing it into a plurality of outlet openings, for example two outlet openings, is however advantageous with regard to the design size of the respective outlet valve 10. Two smaller outlet valves 10 more reliably ensure a seal until the minimum positive pressure is reached than one outlet valve comprising a correspondingly larger valve body 11 which can be moved. This is also not least the case in the preferred type of design of the one or more outlet valves 10 which are embodied as leaf spring valves. The valve body 11 is correspondingly a leaf spring which can be formed by an individual plate spring or by a plurality of plate springs stacked on each other. A correspondingly larger-area leaf spring in a larger outlet opening has a greater tendency towards instability in the event of pressure fluctuations than a smaller-area leaf spring.

[0036] The vacuum pump is also equipped with an optional safety valve 10_{SAFE} which seals an outlet in the low-pressure region 4 and only opens it when the delivery member 8, 9 rotates backwards. If the vacuum pump is installed in a motor vehicle, the delivery member 8, 9 can rotate backwards when

the vehicle rolls backwards in gear. In such a scenario, air and in particular lubricating and sealing fluid can be expelled from the delivery chamber 3 by the safety valve 10_{SAFE}. The safety valve 10_{SAFE} corresponds to the outlet valves 10 for regular pump operations. In the example embodiment, a plurality of similar safety valves 10_{SAFE}, for example two, and corresponding outlet openings in the outlet of the low-pressure region 4 (FIG. 1) are also provided. The safety valves 10_{SAFE} are for example identical to the outlet valves 10, i.e. the pump comprises four valves 10 and 10_{SAFE} which are identical to each other as such. In modifications, the safety valves 10_{SAFE} can however also differ from the outlet valves 10 and can in particular be smaller. The pump can also comprise a plurality of outlet valves 10 and only one safety valve 10_{SAFE}, or as applicable even no safety valve.

[0037] FIG. 3 shows a view onto a vacuum pump of a second exemplary embodiment. The vacuum pump differs from that of the first exemplary embodiment only in relation to the ventilating connection which in the second example embodiment is provided with the reference sign 16. Unlike the first exemplary embodiment, the ventilating connection 16 is part of the housing cover 2. The housing cover 2 is mounted on the housing 1 in FIG. 3. The end of the ventilating connection 16 which ports into the free environment can be seen. The ventilating connection 16 is formed in the housing cover 2 as a straight passage, for example an axial passage as is preferred, and is arranged as in the first exemplary embodiment, such that it leads into the delivery chamber 3 in the high-pressure region near to the working outlet 7. Beyond this, the statements made with respect to the ventilating connection 15 also apply to the ventilating connection 16.

[0038] FIG. 4 shows a perspective view onto a vacuum pump of a third exemplary embodiment. In the third exemplary embodiment, a ventilating connection 17 is again formed in the housing 1, but unlike the first exemplary embodiment, not in the region of a front face but rather in the region of a circumferential surface of the housing 1 which surrounds the delivery chamber 3. The ventilating connection 17 leads through a circumferential wall of the housing 1, for example in a radial direction. As is preferred, but only by way of example, it is arranged as near as possible to the outlet 7. In the exemplary embodiment comprising two adjacently arranged outlet openings and/or outlet valves 10, the ventilating connection 17 is arranged between the outlet valves 10 at a circumferential end of the working outlet 7, as viewed axially, where it leads via a short path into the delivery chamber 3. Beyond this, the statements made with respect to the ventilating connection 15 also apply to the ventilating connection 17.

[0039] FIG. 5 shows the outlet region of a vacuum pump of a fourth exemplary embodiment. The vacuum pump features a ventilating connection 18 which is formed in the outlet valve 10. If the vacuum pump comprises a plurality of outlet valves 10, for example two outlet valves 10 as in the exemplary embodiment, then a ventilating connection 18 can be provided at each of the outlet valves 10 or for example only at one of the outlet valves 10. The outlet valve 10 otherwise corresponds to the outlet valve(s) 10 of the other exemplary embodiments. It comprises a movable valve body 11 in the form of a leaf spring, for example a single-layer plate spring, and a valve seating 12 against which the valve body 11 abuts, in a seal, in its closing state. The outlet valve 10 also comprises a rearward abutment 13 for the valve body 11 which the valve body 11 abuts when it is completely open. The valve

body 11 can be moved back and forth—in the example embodiment, elastically flexed back and forth—between the valve seating 12 and the abutment 13. The outlet valves 10 are identical to each other except where differences are described.

[0040] The ventilating connection 18 leads through the valve body 11, for example exclusively through the valve body 11. It is formed as a passage extending linearly in the thickness direction of the valve body 11 and/or leaf spring 11. If the valve body 11 is embodied as a flexurally elastic leaf spring, the ventilating connection 18 can be provided very simply, for example by drilling. Since such valve bodies 11 are in many cases formed from a spring material, for example spring steel, by punching, the ventilating connection 18 can instead also particularly advantageously be punched at the same time as the valve body 11 is punched out. It is in principle also conceivable to punch the ventilating connection 18 in a separate working step of its own. It should also be added with respect to the valve seating 12 that it surrounds the downstream end of the working outlet 7 or—in the example embodiment comprising a plurality of outlet valves 10—one of the plurality of ends of the working outlet 7. As long as the minimum positive pressure mentioned at the beginning has not been reached in the high-pressure region 6, the valve body 11 abuts the valve seating 12 in a seal and seals the working outlet 7 in its region, except for the ventilating connection 18. When the vacuum pump is stopped, the outlet valve 10 closes due to the valve body 11 springing back, but the pressure is equalized with the free environment through the ventilating connection 18. Beyond this, the dimensioning rules described with respect to the first example embodiment apply with respect to the ventilating connection 18.

[0041] FIG. 6 shows a vacuum pump of a fifth example embodiment in a view onto the housing cover 2. FIG. 7 shows a detail X in the outlet region of this vacuum pump. In the fifth example embodiment, a ventilating connection 19 is again formed in one of the outlet valves 10. Unlike the fourth example embodiment, the relevant outlet valve 10 comprises the ventilating connection 19 in its valve seating 12. The valve body 11 is formed as a leaf spring which exhibits a closed spring surface, i.e. it does not comprise a ventilating connection 18. The ventilating connection 19 is a recess which is open towards the valve body 11 and extends through the valve seating 12, such that a passage is created between the flow cross-section enclosed by the valve seating 12 and the external environment, even when the valve body 11 is in its closing state. This creates a bypass, which leads past the valve body 11, for pressure equalization during stoppage. The ventilating connection 19 is for example formed as a straight groove.

[0042] In yet another example embodiment which is not shown, a ventilating connection can also be formed in the joining region 14 between the housing 1 and the housing cover 2. A gasket which circumferentially seals the delivery chamber 3, in particular if embodied as a metal gasket, can then for example provide the ventilating connection, for example by being locally embodied with a smaller thickness than in the remaining gasket region and thus forming the ventilating connection in the region or regions exhibiting the locally smaller thickness. The housing 1 or the housing cover 2 can also for example comprise a small ventilating groove in the manner of the ventilating connection 19 of the fifth example embodiment in their joining region 14. Ventilating connections of the type described can also be realized in combination with each other, for example a ventilating con-

nection **15** or **17** in the housing **1** with a ventilating connection **16** in the housing cover **2**. It is also possible to combine more than two of the different ventilating connections with each other.

[0043] Except for the differences described, the vacuum pumps in all the exemplary embodiments can be identical. They can however also deviate from each other. They are preferably embodied as rotary pumps comprising at least one delivery member which can be rotationally moved in the respective delivery chamber. A single-vane vacuum pump is an advantageous type of pump due to its simple design, low weight and robustness. A vacuum pump which is embodied as a vane cell pump can, as in the exemplary embodiments, comprise one, two, three or in principle even more vanes which can be moved relative to the rotor. Instead of a vane cell pump, a reciprocating piston valve pump or a toothed wheel pump can also be used and ventilated in accordance with the invention.

[0044] The vacuum pump of the exemplary embodiments can in particular be installed in a motor vehicle. It can be at least partially immersed in a reservoir **20** for the lubricating and sealing fluid, as indicated by a reservoir gauge level indicator in FIG. 3. In such installation situations, the working outlet **7** and the respective ventilating connection, for example the ventilating connection **16**, are in particular arranged sufficiently far above the level of the reservoir **20** to ensure a sufficient distance from the fluid in the reservoir **20** in all the operational states of the vehicle. The lubricating and sealing fluid can in particular be the lubricating oil used for lubricating an internal combustion engine or a transmission or other sub-assembly of the vehicle. The fluid reservoir **20** can correspondingly be the oil sump. If the vacuum pump is arranged in the "dry", i.e. outside any fluid reservoir **20**, then the location of the working outlet **7** and the respective ventilating connection is arbitrary, although arranging them in an upper region of the vacuum pump is also preferred for such installation situations.

[0045] In the foregoing description, preferred embodiments of the invention have been presented for the purpose of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described to provide the best illustration of the principles of the invention and its practical application, and to enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth they are fairly, legally, and equitably entitled to.

What is claimed is:

1. A vacuum pump for supplying a machine assembly with a negative pressure, said vacuum pump comprising:

- a) a housing and a housing cover which surround a delivery chamber,
- b) wherein the delivery chamber comprises a low-pressure region comprising a working inlet which can be connected to the assembly, and a high-pressure region comprising a working outlet for air;
- c) a delivery member which can be moved within the delivery chamber and which, when moved, can suction

air into the delivery chamber through the working inlet and expel it at an increased pressure through the working outlet;

- d) an outlet valve which is arranged at the working outlet or downstream of the working outlet and at least makes it difficult for air to flow back into the delivery chamber;
- e) and a fluid feed through which lubricating or sealing fluid can be fed to the delivery chamber,

wherein

- f) the delivery chamber is connected to the external environment of the vacuum pump via a ventilating connection in order to establish an at least partial pressure equalization with the external environment when the delivery member is stopped and a negative pressure prevails in the delivery chamber.

2. The vacuum pump according to claim 1, wherein if the assembly is connected to the vacuum pump, an air feed which connects the assembly to the delivery chamber via the working inlet exhibits, as a whole, a lower flow resistance than the ventilating connection.

3. The vacuum pump according to claim 1, wherein a flow cross-section of the working outlet is at least ten times as large as a flow cross-section of the ventilating connection.

4. The vacuum pump according to claim 1, wherein the ventilating connection is dimensioned such that when the delivery member is stopped, pressure equalization is at least substantially complete within a few seconds.

5. The vacuum pump according to claim 4, wherein pressure equalization is at least substantially complete in at most one second.

6. The vacuum pump according to claim 1, wherein the ventilating connection comprises a passage which leads into the delivery chamber, for example a transit bore which ports into the delivery chamber, and exhibits a small flow cross-section as compared to the working inlet and also as compared to the working outlet.

7. The vacuum pump according to claim 6, wherein the passage is a straight passage.

8. The vacuum pump according to claim 1, wherein the ventilating connection comprises an inlet for ambient air in the high-pressure region of the delivery chamber.

9. The vacuum pump according to claim 1, wherein the inlet for the ambient air is near to the working outlet.

10. The vacuum pump according to claim 1, wherein the ventilating connection connects the delivery chamber to the environment through the working outlet.

11. The vacuum pump according to claim 10, wherein the ventilating connection ports into the working outlet as viewed from the environment.

12. The vacuum pump according to claim 1, wherein the ventilating connection leads through the outlet valve.

13. The vacuum pump according to claim 1, wherein the outlet valve comprises a valve seating and a valve body which is elastically tensed against the valve seating and can be raised off of the valve seating against an elastic restoring force, and wherein the ventilating connection leads through the valve body or the valve seating.

14. The vacuum pump according to claim 13, wherein the outlet valve is a leaf spring valve and the valve body is a leaf spring which is spring-elastically tensed against the valve seating, and wherein the ventilating connection leads through the valve body or the valve seating.

15. The vacuum pump according to claim **14**, wherein the ventilating connection comprises a passage extending through the leaf spring in a thickness direction of the leaf spring.

16. The vacuum pump according to claim **13**, wherein the ventilating connection comprises a recess in the valve seating, through which air can flow from the external environment past the valve body into the delivery chamber, the recess facing the valve body.

17. The vacuum pump according to claim **1**, wherein the ventilating connection leads through the housing or the housing cover or a joining region between the housing and the housing cover.

18. The vacuum pump according to claim **1**, wherein the vacuum pump is arranged in or on a vehicle which is driven by an engine and wherein the assembly is connected at the working inlet or the vacuum pump is designed to be installed in this way.

19. The vacuum pump according to claim **18**, wherein the assembly is a brake booster.

20. The vacuum pump according to claim **1**, wherein the vacuum pump is a rotary pump, and the delivery member is a feed wheel which can be rotated in the delivery chamber.

21. The vacuum pump according to claim **20**, wherein the vacuum pump is a vane cell pump.

22. The vacuum pump according to claim **20**, wherein the delivery member is a vane wheel comprising a rotor and at least one vane which can be moved relative to the rotor.

23. The vacuum pump according to claim **1**, wherein the vacuum pump is at least partially arranged in a reservoir of the lubricating or sealing fluid which serves to lubricate or seal, and wherein at least a lower region of the pump is immersed in the fluid, and wherein the ventilating connection leads into the delivery chamber above an upper level of the fluid or is extended beyond the upper level.

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