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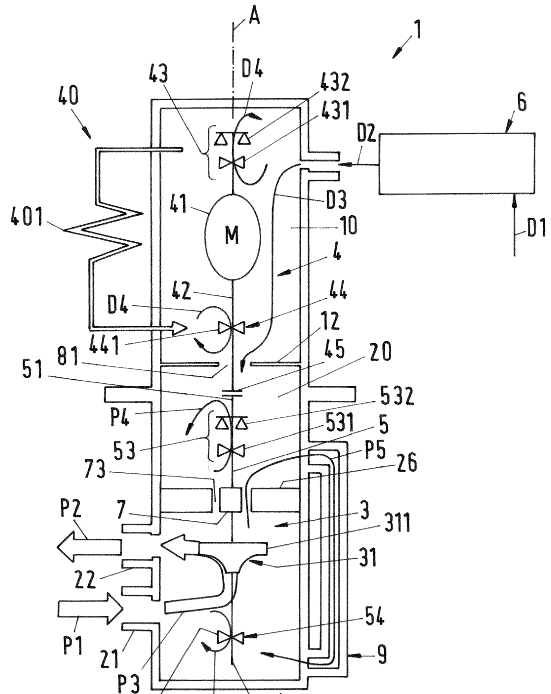
(54) SUBMERSIBLE PUMP

(57) A submersible pump for conveying a process fluid and configured to be completely immersed in an environmental fluid is proposed, the pump comprising a common housing (2) having a first compartment (10) configured to be filled with a dosing fluid, and a second compartment (20) configured to be filled with the process fluid, wherein a first flow passage (81) is provided between the first compartment (10) and the second compartment (20), the pump further comprising, a pump unit (3) arranged in the common housing (2), and a drive unit (4) arranged in the common housing (2), wherein the common housing (2) comprises an inlet (21) and an outlet (22) for the process fluid, wherein the pump unit (3) comprises a pump shaft (5) extending from a drive end (51) to a non-drive end (52) of the pump shaft (5) and configured for rotating about an axial direction (A), the pump unit (3) further comprising a hydraulic unit (31) having at least one impeller (311) fixedly mounted on the pump shaft (5) for conveying the process fluid from the inlet (21) to the outlet (22), wherein the drive unit (4) comprises a drive shaft (42) connected to the drive end (51) of the pump shaft (5) for driving the rotation of the pump shaft (5), and an electric motor (41) configured for rotating the drive shaft (42) about the axial direction (A), wherein the electric motor (41) is arranged inside the first compartment (10) and the hydraulic unit (31) is arranged inside the second compartment (20), and wherein the pump is configured as a seal-less pump without a mechanical seal at the pump shaft (5) and the drive shaft (42). A dosing unit (6) is provided for receiving the environmental fluid, wherein the dosing unit (6) provides the dosing fluid from the environmental fluid, and wherein the dosing unit (6) is configured for dosing a presettable amount of the dosing fluid into the first compartment (10) and through the first flow passage (81) into the second compartment (20).

Fig.1



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Description

[0001] The invention relates to a submersible pump for conveying a process fluid in accordance with the preamble of the independent claim.

[0002] Submersible pumps configured to be completely immersed in an environmental fluid, e.g. water, are used in many different industries, for example in the mining industry, where submersible pumps are used for dewatering, or in the waste water industry, or in the energy industry, where submersible pumps are used e.g. for underwater energy storage systems.

[0003] Another important example is the oil and gas processing industry, where submersible pumps are configured e.g. as multiphase pumps for conveying hydrocarbon fluids, for example for extracting the crude oil from the oil field or for transportation of the oil/gas through pipelines or within refineries. Another application of submersible pumps in the oil and gas industry is the injection of a process fluid, in most cases water and in particular seawater, into an oil reservoir. For such applications, said pumps are designed as water injection pumps supplying seawater at high pressure to a well that leads to a subterranean region of an oil reservoir. A typical value for the pressure increase generated by such a water injection pump is 200-300 bar (20 - 30 MPa) or even more. Water injection into oil reservoirs is a well-known method for increasing the recovery of hydrocarbons from an oil or gas field. The injected water maintains or increases the pressure in the reservoir thereby driving the oil or the hydrocarbons towards and out of the production well.

[0004] Still another application is the reinjection of a lighter CO_2 and CH_4 enriched phase separated from the crude oil into a subterranean region.

[0005] In view of an efficient exploitation of oil and gas fields but also in view of other applications, there is nowadays an increasing demand for pumping equipment such as water injection pumps or multiphase pumps that may be installed directly on the sea ground or in a deep lake, in particular down to a depth of 500 m, down to 1000 m or even down to more than 2000 m beneath the water surface. Needless to say that the design of such pumping equipment is challenging, in particular because such pumps shall operate in a difficult subsea or deep water environment for a long time period with as little as possible maintenance and service work. This requires specific measures to minimize the amount of equipment involved and to optimize the reliability of the pump.

[0006] It goes without saying that for subsea or deep water installations on the sea ground or the ground of other waters the reliability of a pump and the minimization of wear and degradation within the pump are of utmost importance.

[0007] Usually, submersible pumps such as subsea pumps are configured as fully integrated pump-drive devices. A common housing, which is configured to withstand the environmental pressure at the location where the pump is deployed for operation, encloses both the pump unit and the drive unit. For lubrication and cooling of the bearings and the motor in the drive unit a clean barrier fluid is used to avoid that the process fluid enters the critical components in the drive unit. Mechanical seals are an option to separate the process fluid, i.e. the pumped medium, which can contain particles, and the barrier fluid. A mechanical seal is usually used for the sealing of the rotating shaft of a pump and shall prevent the leakage of the process fluid along the pump shaft of the pump. Typically, a mechanical seal comprises a stator and a rotor. The rotor is connected in a torque-proof manner with the shaft of the pump and the stator is fixed with respect to the common housing such that the stator is secured against rotation. During rotation of the shaft the rotor is in sliding contact with the stator with a liquid film in between, thus performing the sealing action.

[0008] The mechanical seals require the barrier fluid pressure to be higher than the process pressure. Maintaining an adequate barrier fluid overpressure requires a system which supplies and relieves barrier fluid. Thus, topside barrier fluid supply units are required, which can have a significant impact on complexity, size and cost of the pumping system. The mechanical seals are considered failure prone and costly components in subsea pumping systems, often resulting in shorter maintenance intervals or unplanned intervention, thus finally reducing the availability of the system.

[0009] In order to reduce the complexity of the pumping equipment, in particular the amount of auxiliaries, it is known in the art to configure subsea pumps as seal-less pumps without a mechanical seal.

[0010] In the framework of this application, the term "seal-less" is used with the meaning that there is no sealing device for sealing a rotating shaft, which is completely tight at standstill of the shaft. Even if other devices such as a throttle bush or a narrow relief passage may be considered as a kind of sealing device during rotation of the shaft, because they allow only a small amount of leakage, such devices are not tight at standstill of the shaft, but allow for a leakage flow trough the device along the shaft even at standstill of the shaft. Thus, "seal-less" means that there is no sealing device for sealing the shaft, which device is completely tight at standstill.

[0011] It is known to configure seal-less pumps as process fluid lubricated pumps, meaning that the process fluid, which is conveyed by the pump, is used for the lubrication and the cooling of components of the pump, e.g. the bearings. A process fluid lubricated pump does not require a specific barrier fluid different from the process fluid to avoid leakage of the process fluid e.g. into the drive unit. In addition, a process fluid lubricated pump does not require a lubricant different from the process fluid for the lubrication of the pump components.

[0012] However, for process fluids containing particles, e.g. sand or the like, bearings have to be provided, which can be lubricated with such a particle containing process fluid without being damaged in an unreasonably short time. In many cases this requires ceramic bearings, i.e. bearings, in which at least one of the mating surfaces of the stationary and the rotating parts is configured as a ceramic surface. Polymer bearings having a polymer such as PEEK (Polyether ether ketone) as one of the mating surfaces are usually not suited for lubrication by a particle containing process fluid, because they are destroyed in quite a short time by the process fluid.

[0013] Furthermore, known seal-less pumps for process fluids with particles rely on motors which have a specific design (e.g. canned motor) and ceramic bearings. The ceramic bearings are prone for catastrophic failure in the drive unit.

[0014] Only for process fluids without particles seal-less pumps equipped with a conventional liquid filled motor and polymer bearings are considered a suitable option.

[0015] Starting from this state of the art, it is therefore an object of the invention to propose an improved or an alternative submersible pump that is also suited for subsea applications and for deployment on the sea ground. The pump shall have a low complexity with regard to the equipment, low wear and a high reliability in operation. In particular, the pump shall also by suited for conveying a process fluid containing particles.

[0016] The subject matter of the invention satisfying this object is characterized by the features of the independent claim.

[0017] Thus, according to the invention, a submersible pump for conveying a process fluid and configured to be completely immersed in an environmental fluid is proposed, the pump comprising a common housing having a first compartment configured to be filled with a dosing fluid, and a second compartment configured to be filled with the process fluid, wherein a first flow passage is provided between the first compartment and the second compartment, the pump further comprising, a pump unit arranged in the common housing, and a drive unit arranged in the common housing, wherein the common housing comprises an inlet and an outlet for the process fluid, wherein the pump unit comprises a pump shaft extending from a drive end to a non-drive end of the pump shaft and configured for rotating about an axial direction, the pump unit further comprising a hydraulic unit having at least one impeller fixedly mounted on the pump shaft for conveying the process fluid from the inlet to the outlet, wherein the drive unit comprises a drive shaft connected to the drive end of the pump shaft for driving the rotation of the pump shaft, and an electric motor configured for rotating the drive shaft about the axial direction, wherein the electric motor is arranged inside the first compartment and the hydraulic unit is arranged inside the second compartment, and wherein the pump is configured as a seal-less pump without a mechanical seal at the pump shaft and the drive shaft. A dosing unit is provided for receiving the environmental fluid, wherein the dosing unit provides the dosing fluid from the environmental fluid, and wherein the dosing unit is configured for dosing a presettable amount of the dosing fluid into the first compartment and through the first flow passage into the second compartment.

[0018] Since the submersible pump according to the invention is configured as a seal-less pump without any mechanical seal at the pump shaft or at the drive shaft, the complexity of the pump is considerably reduced as compared to pumps having mechanical seals.

[0019] The common housing accommodating the pump unit and the drive unit comprises two compartments, wherein the first compartment is filled with the dosing fluid and the second compartment is filled with the process fluid. Usually, the dosing fluid is free of particles. The dosing unit supplies a presettable amount of the dosing fluid to the first compartment and through the first flow passage into the second compartment. Thus, the dosing unit moves a presettable volume per time of the dosing fluid through the first compartment into the second compartment. Therefore, there is a well-defined flow direction of the dosing fluid from the first compartment into the second compartment. This measure ensures that there is no flow of the process fluid from the second compartment into the first compartment, i.e. the process fluid is prevented from entering the first compartment. This is a considerable advantage in particular when the process fluid contains particles. Since the process fluid cannot enter the first compartment, all components arranged in the first compartment can be configured to be cooled and lubricated by a fluid which is free of particles. For example, all bearings arranged in the first compartment can be configured as polymer bearings.

[0020] The volume of the dosing fluid that is moved per time through the first flow passage is typically quite low, namely a few liters per hour, for example 20 liters per hour or up to 50 or 100 liters per hour.

[0021] Another considerable advantage is the fact that the dosing unit provides the dosing fluid from the environmental fluid, which is for example water. In particular, the dosing fluid can be the same fluid as the environmental fluid. It is also possible, that the environmental fluid is filtered or treated in the dosing unit to generate the dosing fluid. The important advantage is the fact that no other fluid than the environmental fluid is required to provide the dosing fluid. Thus, there is no need for any other supply system, for example a topside supply system as it is e.g. required for conventional barrier fluids. The sole fluid required for providing the dosing fluid is the environmental fluid, i.e. the fluid that surrounds the pump. This is a considerable reduction in the complexity of the entire pumping system.

[0022] When the submersible pump according to the invention is configured as a subsea pump, the environmental fluid is usually seawater. The dosing fluid may be the raw seawater, purified seawater, pretreated seawater, filtered seawater, microfiltered seawater or nanofiltered seawater. In other application, the submersible pump may be deployed at the ground of a lake or in a reservoir such as a tank filled with a fluid, in particular with a liquid. The environmental fluid is then the fluid or liquid with which the tank is filled.

[0023] According to a preferred configuration, the first compartment is arranged adjacent to the second compartment with respect to the axial direction, wherein a first partition wall is provided between the first compartment and the second compartment, wherein the first flow passage is arranged in the first partition wall, and wherein the pump shaft or the drive shaft extends through the first flow passage. The first partition wall separates the first compartment from the second compartment. The first flow passage constitutes the sole connection through which the dosing fluid can flow from the first into the second compartment. The first flow passage also constitutes the duct, through which the pump shaft or the drive shaft passes from the first compartment into the second compartment. The first flow passage can be configured for example as a throttle bush surrounding the pump shaft or the drive shaft.

[0024] For balancing or reducing the axial thrust acting on the pump shaft, the submersible pump can comprise a balance drum fixedly connected to the pump shaft between the hydraulic unit and the drive end of the pump shaft, wherein a relief passage is provided between the balance drum and a stationary part configured to be stationary with respect to the common housing, and wherein a balance line is provided for returning the process fluid passing through the relief passage to a low pressure location of the pump unit, for example to the suction side or the inlet for the process fluid.

[0025] In a preferred configuration the submersible pump comprises a first pump bearing unit and a second pump bearing unit for supporting the pump shaft, as well as a first motor bearing unit and an second motor bearing unit for supporting the drive shaft, wherein the first pump bearing unit is arranged between the hydraulic unit and the drive end of the pump shaft, wherein the second pump bearing unit is arranged between the hydraulic unit and the non-drive end of the pump shaft, and wherein the electric motor is arranged between the first motor bearing unit and the second motor bearing unit regarding the axial direction.

[0026] Preferably, the first pump bearing unit, the second pump bearing unit, the first motor bearing unit and the second motor bearing unit are each configured for lubrication by the process fluid or by the dosing fluid. Thus, depending on whether the respective bearing unit is arranged in the first or in the second department, it is either lubricated by the dosing fluid or by the process fluid. All bearing units, which are arranged in the first compartment, are configured to be lubricated by the dosing fluid, and all bearing units, which are arranged in the second compartment, are configured to be lubricated by the process fluid. The dosing fluid or the process fluid, respectively, are also used for the cooling of the bearing units. Preferably, all bearing units arranged in the first compartment are configured as polymer bearing units. Furthermore, it is preferred that all bearing units arranged in the second compartment are configured as ceramic bearings.

[0027] In some embodiments the first pump bearing unit and the second pump bearing unit are arranged in the second compartment.

[0028] In some embodiments the first motor bearing unit and the second motor bearing unit are arranged in the first compartment.

[0029] In some embodiments the first pump bearing unit, the first motor bearing unit and the second motor bearing unit are arranged in the first compartment.

[0030] It is also possible to configure the submersible pump such that the common housing comprises a third compartment, configured to be filled with the dosing fluid, wherein the second compartment is arranged regarding the axial direction between the first compartment and the third compartment, wherein a second flow passage is provided between the third compartment and the second compartment, wherein the dosing unit is configured for dosing an amount of the dosing fluid into the third compartment and through the second flow passage into the second compartment, and wherein the second pump bearing unit is arranged in the third compartment. The dosing unit supplies a presettable amount of the dosing fluid to the third compartment and through the second flow passage into the second compartment. Thus, the dosing unit moves a presettable volume per time of the dosing fluid through the third compartment into the second compartment. Therefore, there is a well-defined flow direction of the dosing fluid from the third compartment into the second compartment. This measure ensures that there is no flow of the process fluid from the second compartment into the third compartment, i.e. the process fluid is prevented from entering the third compartment.

[0031] The volume of the dosing fluid that is moved per time through the second flow connection can be the same or essentially the same as the volume that is moved per time through the first flow connection.

[0032] Regarding the configuration with three compartments in the common housing, it is preferred that a second partition wall is provided between the third compartment and the second compartment, wherein the second flow passage is arranged in the second partition wall, and wherein the pump shaft extends through the second flow passage.

[0033] The second partition wall separates the third compartment from the second compartment. The second flow passage constitutes the sole connection through which the dosing fluid can flow from the third into the second compartment. The second flow passage also constitutes the duct, through which the pump shaft passes from the third compartment into the second compartment. The second flow passage can be configured for example as a throttle bush surrounding the pump shaft.

[0034] Preferably the submersible pump has an external cooling loop for cooling and lubricating the motor unit by means of the dosing fluid, the external cooling loop comprising a heat exchanger for cooling the dosing fluid, wherein the heat exchanger is arranged outside the common housing and configured to receive the dosing fluid from the first compartment and to recirculate the dosing fluid to the first compartment.

[0035] The submersible pump according to the invention can be configured as a vertical pump with the pump shaft extending in the direction of gravity or, alternatively, as a horizontal pump with the pump shaft extending perpendicular to the direction of gravity.

[0036] Regarding embodiment, where the submersible pump is configured as a vertical pump, it is preferred that the drive unit is arranged on top of the pump unit.

[0037] In some embodiments the submersible pump is configured as a subsea pump and preferably configured for installation on a sea ground.

[0038] In particular, the submersible pump according to the invention can be configured as a water injection pump for injecting the process fluid, preferably seawater, into a subterranean region.

[0039] In addition, the submersible pump according to the invention can be configured as a multiphase pump, e.g. for conveying a multiphase process fluid which comprises a mixture of a plurality of phases, such as a liquid phase and a gaseous phase. An important example is the oil and gas processing industry, where multiphase pumps are used for conveying hydrocarbon fluids, for example for extracting the crude oil from the oil field or for transportation of the oil/gas through pipelines or within refineries.

[0040] Furthermore, the submersible pump according to the invention can be configured for conveying a fluid in the dense phase or in the supercritical phase. For example in subsea oil production, the crude oil containing lighter components such as carbon dioxide, methane, ethane can be separated at the sea ground into a heavier liquid enriched phase, which is delivered to a topside location, and into a lighter CO_2 and CH_4 enriched phase, which is reinjected into a subterranean region, e.g. the oil reservoir. Due to the hydrostatic pressure at the sea ground the separation will take place for many applications at a pressure and temperature where carbon dioxide is in the supercritical state or in the dense phase.

[0041] Further advantageous measures and embodiments of the invention will become apparent from the dependent claims.

[0042] The invention will be explained in more detail hereinafter with reference to embodiments of the invention and with reference to the drawings. There are shown in a schematic representation:

Fig. 1: a schematic cross-sectional view of a first embodiment of a submersible pump according to the invention,

Fig. 2: a schematic cross-sectional view of a second embodiment of a submersible pump according to the invention,

Fig. 3: a schematic cross-sectional view of a third embodiment of a submersible pump according to the invention, and

Fig. 4: a schematic cross-sectional view of a fourth embodiment of a submersible pump according to the invention.

[0043] Fig. 1 shows a schematic cross-sectional view of a first embodiment of a submersible pump according to the invention, which is designated in its entity with reference numeral 1. The pump 1 is configured as a centrifugal pump for conveying a process fluid and has a common housing 2, a pump unit 3 and a drive unit 4. Both the pump unit 3 and the drive unit 4 are arranged within the common housing 2. The common housing 2 is designed as a pressure housing, which is able to withstand the pressure generated by the pump 1 as well as the pressure exerted on the pump 1 by the environment. The common housing 2 may comprise several housing parts, e.g. a pump housing and a drive housing, which are connected to each other to form the common housing 2 surrounding the pump unit 3 and the drive unit 4.

[0044] The submersible pump 1 is configured to be completely immersed in an environmental fluid, for example water or any other liquid. The submersible pump 1 can be configured for deployment in a reservoir filled with the environmental fluid such as a tank, a basin or the like. Furthermore, the pump 1 can be configured for deployment in a natural or artificial water reservoir, e.g. a dammed lake, a river, a natural lake or a sea.

[0045] In the following description reference is made by way of example to the important application that the submersible pump 1 is configured and adapted for being used as a subsea pump 1 in the oil and gas industry. The pump 1 can be configured as a multiphase pump deployed on the sea ground for conveying the crude oil or the hydrocarbon fluid from the well to a topside location on or above the water surface or ashore. The process fluid is then the crude oil or the hydrocarbon fluid and the environmental fluid is the seawater. It is also possible that the pump 1 is configured as a subsea pump 1 for injecting water into a subterranean oil and/or gas reservoir to increase recovery of hydrocarbons from the subterranean region. By injecting the water into the reservoir the hydrocarbons are forced to flow towards and out of the production well. In these applications the process fluid that is conveyed by the pump 1 is water and especially seawater. The environmental fluid is seawater. The submersible pump 1 is in particular configured for installation on the sea ground, i.e. for use beneath the water surface, in particular down to a depth of 500 m, down to 1000 m or even down to more than 2000 m beneath the water surface of the sea.

[0046] The term seawater comprises raw seawater, purified seawater, pretreated seawater, filtered seawater, in particular microfiltered seawater and nanofiltered seawater.

[0047] It goes without saying that the invention is not restricted to these specific examples but is related to submersible pumps in general. The pump 1 according to the invention may also be used for applications outside the oil and gas industry.

[0048] By way of example reference is now made to the configuration of the submersible pump 1 as a water injection pump for deployment on the sea ground.

[0049] The common housing 2 of the pump 1 comprises an inlet 21, through which the process fluid enters the pump 1, and an outlet 22 for discharging the process fluid with an increased pressure as compared to the pressure of the process fluid at the inlet 21. Typically, the outlet 22 is connected to a pipe (not shown) for delivering the pressurized process fluid to a well, in which the process fluid is injected. The pressure of the process fluid at the outlet 22 is referred to as 'high pressure' whereas the pressure of the process fluid at the inlet 21 is referred to as 'low pressure'. A typical value for the difference between the high pressure and the low pressure is for example 100 to 200 bar (10 - 20 MPa).

[0050] The pump unit 3 comprises a pump shaft 5 extending from a drive end 51 to a non-drive end 52 of the pump shaft 5. The pump shaft 5 is configured for rotating about an axial direction A, which is defined by the longitudinal axis of the pump shaft 5.

[0051] The pump unit 3 further comprises a hydraulic unit 31 for acting on the process fluid. The hydraulic unit 31 comprises at least one impeller 311 fixedly mounted on the pump shaft 5 in a torque proof manner. The hydraulic unit 31 is configured for increasing the pressure of the process fluid from the low pressure to the high pressure. The specific configuration of the hydraulic unit 5 is not relevant for the invention, i.e. the hydraulic unit 31 can be configured in any manner known in the art. The hydraulic unit 31 can comprise only one impeller (single stage pump) 311 or a plurality of impellers 311 (multistage pump), each of which is fixedly mounted on the pump shaft 5. The plurality of impellers 311 may comprise up to twelve impellers 31, or even more, arranged one after the other regarding the axial direction A on the pump shaft 5. The plurality of impellers 311 can be arranged in a back-to-back configuration or in an inline configuration.

[0052] The submersible pump 1 is configured as a vertical pump 1, meaning that during operation the pump shaft 5 is extending in the vertical direction, which is the direction of gravity. Thus, the axial direction A coincides with the vertical direction.

[0053] A direction perpendicular to the axial direction is referred to as radial direction. The term 'axial' or 'axially' is used with the common meaning 'in axial direction' or 'with respect to the axial direction'. In an analogous manner the term 'radial' or 'radially' is used with the common meaning 'in radial direction' or 'with respect to the radial direction'. Hereinafter relative terms regarding the location like "above" or "below" or "upper" or "lower" or "top" or "bottom" refer to the usual operating position of the pump 1. Each of Fig. 1 - Fig. 4 shows different embodiments of the pump 1 in their respective usual operating position.

[0054] The drive unit 4 is configured to exert a torque on the drive end 51 of the pump shaft 5 for driving the rotation of the pump shaft 5 and the impeller(s) 311 about the axial direction A. As shown in Fig. 1 the drive unit 4 is located above the pump unit 3. However, in other embodiments (see e.g. Fig. 3) the pump unit 3 may be located on top of the drive unit 4. The drive unit 4 comprises an electric motor 41, a drive shaft 42 extending in the axial direction A, a first motor bearing unit 43 arranged above the electric motor 41 with respect to the axial direction A, and a second motor bearing unit 44 arranged below the electric motor 41. The electric motor 41, which is arranged between the first motor bearing unit 43 and the second motor bearing unit 44, is configured for rotating the drive shaft 42 about the axial direction A. The drive shaft 42 is connected to the drive end 51 of the pump shaft 5 by means of a coupling 45 for transferring a torque to the pump shaft 5. Preferably the coupling 45 is configured as a flexible coupling 45, which connects the drive shaft 42 to the pump shaft 5 in a torque proof manner, but allows for a relative movement between the drive shaft 42 and the pump shaft 5, e.g. lateral movements. Thus, the flexible coupling 45 transfers the torque but no or nearly no lateral vibrations. The flexible coupling 45 may be configured as a mechanical coupling, a magnetic coupling, a hydrodynamic coupling or any other coupling that is suited to transfer a torque from the drive shaft 42 to the pump shaft 5.

[0055] The first motor bearing unit 43 and the second motor bearing unit 44 are configured to support the drive shaft 42 both in radial direction and in the axial direction A. The first motor bearing unit 43 comprises both an upper radial bearing 431 for supporting the drive shaft 42 with respect to the radial direction, and an axial bearing 432 for supporting the drive shaft 42 with respect to the axial direction A. The upper radial bearing 431 and the axial bearing 432 are arranged such that the upper radial bearing 431 is arranged between the axial bearing 432 and the electric motor 41. Of course, it is also possible, to exchange the position of the upper radial bearing 431 and the axial bearing 432.

[0056] The upper radial bearing 431 and the axial bearing 432 may be configured as separate bearings, but it is also possible that the upper radial bearing 431 and the axial bearing 432 are configured as a single combined radial and axial bearing supporting the drive shaft 42 both in radial and in axial direction A.

[0057] The second motor bearing unit 44 comprises a lower radial bearing 441 for supporting the drive shaft 42 in radial direction. In the embodiment shown in Fig. 1, the second motor bearing unit 44 comprises no axial or thrust bearing. Of course, it is also possible that the second motor bearing unit 44 comprises an axial bearing for the drive shaft 42.

[0058] The pump 1 comprises a first pump bearing unit 53 and a second pump bearing unit 54 for supporting the pump shaft 5. The first pump bearing unit 53, which is the upper one, is arranged adjacent to the drive end 51 of the pump shaft 5 between the hydraulic unit 31 and the drive unit 4. The second pump bearing unit 54, which is the lower one, is arranged between the hydraulic unit 31 and the non-drive end 52 of the pump shaft 5 or at the non-drive end 52. The pump bearing units 53, 54 are configured to support the pump shaft 5 both in axial and radial direction. In the embodiment shown in Fig. 1 the first pump bearing unit 53 comprises both an upper radial bearing 531 for supporting the pump shaft 5 with respect to the radial direction, and an axial bearing 532 for supporting the pump shaft 5 with respect to the axial direction A. The upper radial bearing 531 and the axial bearing 532 are arranged such that the axial bearing 532 is facing the drive unit 4 and the upper radial bearing 531 is facing the hydraulic unit 31, i.e. the axial bearing 532 is arranged between the upper radial bearing 531 and the drive unit 4. Of course, it is also possible, to exchange the position of the upper radial bearing 531 and the axial bearing 532, i.e. to arrange the upper radial bearing 531 between the axial bearing 532 and the drive unit 4.

[0059] A radial bearing, such as the upper radial bearing 531 is also referred to as a "journal bearing" and an axial bearing, such as the axial bearing 532, is also referred to as an "thrust bearing". The upper radial bearing 531 and the axial bearing 532 may be configured as separate bearings, but it is also possible that the upper radial bearing 531 and the axial bearing 532 are configured as a single combined radial and axial bearing supporting the pump shaft 5 both in radial and in axial direction.

[0060] The second pump bearing unit 54 comprises a lower radial bearing 541 for supporting the pump shaft 5 in radial direction. In the embodiment shown in Fig. 1, the second pump bearing unit 54 comprises no axial or thrust bearing. Of course, it is also possible that the second pump bearing unit 54 comprises an axial bearing for the pump shaft 5.

[0061] The pump 1 further comprises a balance drum 7 for at least partially balancing the axial thrust that is generated by the impeller(s) 311 during operation of the pump 1. The balance drum 7 is fixedly connected to the pump shaft 5 and arranged above the impeller(s) 311, namely between the impeller(s) 311 and the drive end 51 of the pump shaft 5, more precisely between the impeller(s) 311 and the first pump bearing unit 53. The balance drum 7 defines a front side and a back side. The front side is the side facing the hydraulic unit 31 and the back side is the side facing the first pump bearing unit 53 and the drive unit 4. The balance drum 7 is surrounded by a stationary part 26, so that a relief passage 73 is formed between the radially outer surface of the balance drum 7 and the stationary part 26. The stationary part 26 is configured to be stationary with respect to the common housing 2. The relief passage 73 forms an annular gap between the outer surface of the balance drum 7 and the stationary part 26 and extends from the front side to the back side. The front side is in fluid communication with the outlet 22, so that the axial surface of the balance drum 7 facing the front side is exposed essentially to the high pressure prevailing at the outlet 22 during operation of the pump 1. At the back side of the balance drum 7 a balance line 9 is provided for returning the process fluid passing through the relief passage 73 to a low pressure location of the pump unit 3. For example, the balance line 9 is in fluid communication with the inlet 21, such that the pressure prevailing at the back side of the balance drum 7 is essentially the same as the low pressure prevailing at the inlet 21.

[0062] Thus, a pressure drop takes place over the balance drum 7. Since the front side is exposed essentially to the high pressure at the outlet 22 and the back side is exposed essentially to the low pressure, the pressure drop over the balance drum 7 corresponds essentially to the difference between the high pressure and the low pressure. The pressure drop along the balance drum 7 results in a force that is directed upwardly in the axial direction A and therewith counteracts the downwardly directed axial thrust generated by the impeller(s) 311 during operation of the pump 1.

[0063] The common housing 2 comprises a first compartment 10 and a second compartment 20. The first compartment 10 is configured to be completely filled with a dosing fluid, and the second compartment 20 is configured to be completely filled with the process fluid. The first compartment 10 is arranged adjacent to the second compartment 20 with respect to the axial direction A. As shown in Fig. 1, in the first embodiment of the pump 1 the first compartment 10 is arranged above the second compartment 20. The first compartment 10 and the second compartment 20 are separated from each other by a first partition wall 12. A first flow passage 81 is provided between the first compartment 10 and the second compartment 20, so that the dosing fluid can flow from the first compartment 10 through the first flow passage 81 into the second compartment 20. The first flow passage 81 is the sole flow connection between the first 10 and the second compartment 20. There is no other fluid communication between the first compartment 10 and the second compartment 20 allowing for a flow from the first compartment 10 to the second compartment 20 or vice versa.

[0064] The first flow passage 81 is arranged centrally in the first partition wall 12, so that the drive shaft 42 extends through the first flow passage 81. The first flow passage 81 can be configured for example as a throttle device, such as a throttle bush arranged around the drive shaft 42.

[0065] In the first embodiment shown in Fig. 1 the drive unit 4 with the electric motor 41 and the motor bearing units 43, 44 is arranged in the first compartment 10, which is filled with the dosing fluid during operation of the pump 1. The hydraulic unit 31, the balance drum 7, the pump bearing units 53, 54 and the flexible coupling 45 are arranged in the second compartment 20, which is filled with the process fluid during operation of the pump.

[0066] Since the electric motor 41 is arranged in the first compartment 10, which is filled with the dosing fluid during operation, the electric motor 41 is preferably configured as a cable wound motor or wet-wound motor. In a cable wound motor the individual wires of the motor stator which form the coils for generating the electromagnetic field(s), are each insulated, so that the motor stator may be flooded even with an electrically conducting fluid, e.g. raw seawater. The cable wound motor does not require a dielectric fluid for cooling the motor stator. Alternatively, the electric motor 41 may be configured as a canned motor. When the electric motor 41 is configured as a canned motor, a can is provided between the motor stator and the motor rotor that seals the motor stator hermetically with respect to the rotor. Thus, the dosing fluid flowing through the gap between the motor stator and the motor rotor cannot enter the motor stator.
as a hydrodynamic bearing and for lubrication and cooling by the fluid, in which the respective bearing 531, 532, 541, 441, 431, 432 is immersed. Thus, the pump bearings 531, 532, 541 of the pump bearing units 53, 54 are configured as process fluid lubricated bearings 531, 532, 541, which are lubricated and cooled only by the process fluid, i.e. there is no other lubricant different from the process fluid. In an analogous manner, the motor bearings 431, 432, 441 of the motor bearing units 43, 44 are configured for lubrication by the dosing fluid, which are lubricated and cooled only by the dosing fluid, i.e. there is no other lubricant different from the dosing fluid.

[0067] In some embodiments each of the bearings 531, 532, 541, 441, 431, 432 is configured as a tilting pad bearing. In other embodiments each of the bearings 531, 532, 541, 441, 431, 432 is configured as a friction bearing or as an anti-friction bearing. In still other embodiments the bearings are not all of the same type, for example, some of the bearings 531, 532, 541, 441, 431, 432 may be configured as tilting pad bearings, and some of the bearings 531, 532, 541, 441, 431, 432 may be configured as friction bearings.

[0068] The process fluid, e.g. water or a multiphase fluid such as a hydrocarbon fluid or crude oil, can contain particles such as solids, e.g. sand. Therefore, the components arranged in the second compartment 20 are configured to interact with particle containing process fluids. For example, the process fluid lubricated bearings 531, 532, 541 of the pump bearing units 53, 54, are configured with a very hard surface at least on one of the mating surfaces of the stationary and the rotating parts of the respective bearing 531, 532. 541. Said surfaces are for example configured as a ceramic surface. Such bearings are referred to as ceramic bearing.

[0069] Particularly preferred, the dosing fluid does not contain particles or solids or at most in a negligible amount. This has the advantage, that the bearings 441, 431, 432 can be configured with "softer" surfaces at least on one of the mating surfaces of the stationary and the rotary parts of the respective bearing 441, 431, 432. For example, at least one of the mating surfaces of the stationary and the rotating parts is configured as a polymer surface consisting or containing a polymer such as PEEK (Polyether ether ketone). Such bearings are referred to as polymer bearing.

[0070] The submersible pump 1 is configured as a seal-less pump 1. A seal-less pump 1 is a pump that has no mechanical seals for the sealing of the rotating pump shaft 5 or the rotating drive shaft 42. A mechanical seal is a seal for a rotating shaft comprising a rotor fixed to the shaft and rotating with the shaft as well as a stationary stator fixed with respect to the housing. During operation the rotor and the stator are sliding along each other - usually with a liquid there between - for providing a sealing action to prevent the process fluid from escaping to the environment or entering the drive of the pump. The seal-less pump 1 shown in Fig. 1 has no such mechanical seals. The process fluid is prevented from entering the first compartment 10, in which the electric motor 41 is arranged, by means of the dosing fluid flowing from the first compartment 10 through the first flow passage 81 into the second compartment 20, as will be explained in more detail hereinafter.

[0071] As has been stated before, the term "seal-less" is used with the meaning that there is no sealing device neither for sealing the rotating pump shaft 5 nor for sealing the rotating drive shaft 42, which is completely tight at standstill of the respective shaft 5, 42. Even if other devices such as a throttle bush may be considered as a kind of sealing device during rotation of the shaft, because they allow only a small amount of leakage, such devices are not tight at standstill of the shaft, but allow for a leakage flow through the device along the shaft even at standstill of the shaft.

[0072] The configuration as a seal-less pump has several advantages. In particular, the complexity of the entire pump system is considerably reduced, because all the auxiliary systems required for the operation of mechanical seals are not necessary.

[0073] The submersible pump 1 further comprises a dosing unit 6 for providing the dosing fluid and supplying the dosing fluid to the first compartment 10 of the common housing 2. The dosing unit 6 receives the environmental fluid from the environment surrounding the dosing unit 6, as indicated by the arrow with the reference numeral D1. The dosing unit 6 supplies the dosing fluid to the first compartment 10 in the common housing 2, as indicated by the arrow with the reference numeral D2. In many applications the dosing fluid is the same fluid as the environmental fluid. However, it is also possible that there is a treatment of the environmental fluid in the dosing unit 6 to generate the dosing fluid. For example, since it is preferred that the dosing fluid is free of particles or solids, it is possible that the environmental fluid is filtered or otherwise treated, e.g. by sedimentation, to remove solids from the environmental fluid and therewith generating the dosing fluid. If the environmental fluid is e.g. seawater, it may contain sand or other solids. These solids are preferably removed to generate the dosing fluid, which is free of solids.

[0074] Thus, because there may be some treatment of the environmental fluid in or at the dosing unit 6, such as filtering or similar treatments, a linguistic differentiation is made between the environmental fluid entering the dosing unit 6 and the dosing fluid entering the first compartment 10 in the common housing 2.

[0075] The dosing unit 6 is configured to dose the dosing fluid supplied to the first compartment 10 i.e. the dosing unit 6 provides a metered volume of the dosing fluid per time to the first compartment, e.g. a few liters per minute, such as 20 liters per minute or thirty liters per minute.

[0076] For dosing the dosing fluid the dosing unit 6 may comprise a positive displacement pump, such as a diaphragm pump, a piston pump or a peristaltic pump (roller pump).

[0077] The dosing unit 6 is configured to generate a volumetric flow rate of the dosing fluid. Said dosing fluid enters the first compartment 10 in the common housing 2 and is discharged through the first flow passage 81 into the second compartment 20 of the common housing. By moving a volumetric flow of the dosing fluid through the first flow passage 81 into the second compartment 20 it is ensured that the process fluid cannot enter the first compartment 10 through the first flow passage 81.

[0078] To generate the volumetric flow of the dosing fluid through the first flow passage 81, it is necessary that the dosing fluid has a pressure at the entrance into the first flow passage 81, which is at least slightly larger as the pressure prevailing at the exit of the first flow passage 81 to the second compartment 20. Due to the balance line 9 the pressure prevailing at the exit of the first flow passage 81 to the second compartment 20 is essentially the same as the low pressure, i.e. the suction pressure prevailing at the inlet 21.

[0079] If the suction pressure is the same as the ambient pressure of the environmental fluid, the suction pressure at the inlet 21 is essentially the same as the pressure of the environmental fluid entering the dosing unit 6. Therefore, for generating the volumetric flow of the dosing fluid, the dosing unit 6 has to generate only a small pressure increase.

[0080] An example for such a configuration is a submersible pump 1, which is configured as a subsea water injection pump 1 and deployed at the sea ground. The environmental fluid is the seawater and the ambient pressure is the hydrostatic pressure of the seawater at the location where the pump 1 is installed. When the pump 1 receives the seawater from the environment , the suction pressure at the inlet 21 is essentially the same as the pressure of the environmental fluid entering the dosing unit.

[0081] In other subsea applications, the suction pressure can be considerably lower than the ambient pressure of the environmental fluid. For example, when the submersible pump 1 is configured as a multiphase pump for conveying crude oil or a hydrocarbon fluid from a well to a topside location, e.g. at or above the water surface, the suction pressure at the inlet 21 of the pump 1 is typically significantly lower than the ambient pressure of the environmental fluid. In such cases the pressure of the environmental fluid entering the dosing unit 6 is considerably higher that the suction pressure at the inlet 21 of the pump. The dosing unit 6 comprises then a pressure reducing device and/or a flow restriction device for supplying the dosing fluid to the first compartment.

[0082] Depending on the application it may be advantageous to provide the dosing unit 6 with a non-return valve or a similar device, which prevents a backflow from the dosing unit into the environment.

[0083] The additional arrows in Fig. 1 indicate the flow of the process fluid and the dosing fluid during operation of the submersible pump. The arrow P1 indicates the flow of process fluid entering the pump 1 through the inlet 21. The arrow P2 indicates the flow of process fluid discharged from the pump 1 through the outlet 22. The arrow P3 indicates the flow of the process fluid through the hydraulic unit 5 increasing the pressure of the process fluid. The arrows P4 indicate the flow of the process fluid through the pump bearing units 53 and 54 for the lubrication and the cooling of the pump bearing units 53, 54. The arrow P5 indicates the flow of the process fluid through the relief passage 73 along the balance drum 7 and the recirculation through the balance line 9.

[0084] The arrow D3 indicates the flow of the dosing fluid through the first compartment 10 to the first flow passage 81. The arrows D4 indicate the flow of the dosing fluid through the motor bearing units 43 and 44 for the lubrication and the cooling of the motor bearing units 43, 44.

[0085] The submersible pump 1 further comprises an external cooling loop 40 for cooling and lubricating the drive unit 4 by means of the dosing fluid. The external cooling loop 40 comprises a heat exchanger 401 for cooling the dosing fluid, wherein the heat exchanger 401 is arranged outside the common housing 2 and configured to receive the dosing fluid from the first compartment 10 and to recirculate the dosing fluid to the first compartment 10.

[0086] Thus, during operation, the first compartment 10 and the components arranged therein are cooled and lubricated by means of the dosing fluid, e.g. seawater. The external cooling loop 40 is provided to enhance the cooling in particular of the drive unit 4 of the pump 1. In the heat exchanger 401 the dosing fluid as the heat carrier is cooled, for example by the environmental fluid, in which the pump 1 is immersed. A circulation impeller (not shown) can be provided for circulating the dosing fluid through the external cooling loop 40. The circulation impeller is driven by the electric motor 41 and preferably by the drive shaft 42. The circulation impeller may be arranged for example on top the electric motor 41, but other location are also possible.

[0087] The heat exchanger 401 is located outside the common housing 2. Preferably, the heat exchanger 401 is designed as a coil or a spiral that surrounds the common casing 2. In a subsea application, the seawater around the pump 1, i.e. the environmental fluid, extracts heat from the coil-shaped heat exchanger 401 at the outside of the common housing 2 and therewith cools the dosing liquid in the external cooling loop 40. The cooled dosing fluid is then recirculated into the first compartment 10 of the common housing 2.

[0088] The common housing 2 comprises a first compartment 10 and a second compartment 20. The first compartment is configured to be completely filled with a dosing fluid, and the second compartment and

[0089] Fig. 2 shows a schematic cross-sectional view of a second embodiment of a submersible pump 1 according to the invention.

[0090] In the following description of the second embodiment of the process fluid lubricated pump 1 only the differences to the first embodiment are explained in more detail. The explanations with respect to the first embodiment are also valid in the same way or in analogously the same way for the second embodiment. Same reference numerals designate the same features that have been explained with reference to the first embodiment or functionally equivalent features.

[0091] In the second embodiment of the submersible pump 1 the common housing 2 comprises a third compartment 30 configured to be filled with the dosing fluid. The third compartment 30 is arranged below the second compartment 20, i.e. the second compartment 20 is arranged regarding the axial direction A between the first compartment 10 and the third compartment 30. A second flow passage 82 is provided between the third compartment 30 and the second compartment 20. The dosing unit 6 is configured for dosing an amount of the dosing fluid into the third compartment 30 and through the second flow passage 82 into the second compartment 20. The second pump bearing unit 54 is arranged in the third compartment 30. The supply of the dosing fluid from the dosing unit 6 to the third compartment 30 is indicated in Fig. 2 by the arrow with the reference numeral D5. The supply of the dosing fluid to the third compartment 30 and the flow of the dosing fluid through the third compartment 30 and through the second flow passage 82 into the second compartment 20 is realized in an analogous manner as it has been described with respect of the flow of the dosing fluid through the first compartment 10.

[0092] Furthermore, the second embodiment of the submersible pump 1 comprises a second partition wall 32 between the third compartment 30 and the second compartment 20, wherein the second flow passage 82 is arranged in the second partition wall 32. The third compartment 30 and the second compartment 20 are separated from each other by the second partition wall 32. The second flow passage 82 is the sole flow connection between the third 30 and the second compartment 20. There is no other fluid communication between the third compartment 30 and the second compartment 20 allowing for a flow from the third compartment 30 to the second compartment 20 or vice versa.

[0093] The second flow passage 82 is arranged centrally in the second partition wall 32, so that the pump shaft 5 extends through the second flow passage 82. The second flow passage 82 can be configured for example as a throttle device, such as a throttle bush arranged around the pump shaft 5.

[0094] The dosing unit 6 is configured to generate a volumetric flow rate of the dosing fluid through the second flow passage 82 in an analogous manner as it has been described for the first flow passage. The dosing fluid enters the third compartment 30 in the common housing 2 and is discharged through the second flow passage 82 into the second compartment 20 of the common housing 2. By moving a volumetric flow of the dosing fluid through the second flow passage 82 into the second compartment 20 it is ensured that the process fluid cannot enter the third compartment 30 through the second flow passage 82.

[0095] A further difference to the first embodiment is the separation between the first compartment 10 and the second compartment 20. In the second embodiment of the submersible pump 1 the first partition wall 12 is arranged regarding the axial direction A between the balance drum 7 and the first pump bearing unit 53. Thus, the first pump bearing unit 53 and the coupling 45 are also arranged within the first compartment 10. Consequently, in the second embodiment of the pump it is the pump shaft 5, which passes through the first flow passage 81.

[0096] It has to be understood, that the location of the first partition wall 12 separating the first compartment 10 from the second compartment 20, as it has been described with respect to the first embodiment and the second embodiment of the pump 1, is exemplary. The separation between the first compartment 10 and the second compartment 20 can also be located at other locations, for example between the upper radial bearing 531 and the axial bearing 532, or between the first pump bearing unit 53 and the coupling 45.

[0097] Fig. 3 shows a schematic cross-sectional view of a third embodiment of a submersible pump 1 according to the invention.

[0098] In the following description of the third embodiment of the process fluid lubricated pump 1 only the differences to the first and the second embodiment are explained in more detail. The explanations with respect to the first and the second embodiment are also valid in the same way or in analogously the same way for the third embodiment. Same reference numerals designate the same features that have been explained with reference to the first or second embodiment or functionally equivalent features.

[0099] In the third embodiment of the submersible pump the pump unit 3 is located above the drive unit 4. Thus, the second compartment 20 is arranged on top of the first compartment 10.

[0100] The third embodiment of the pump 1 can be configured with the three compartment 10, 20, 30 in the common housing 2 as shown in Fig. 3. It is also possible, that the third embodiment of the pump 1 is configured with only the first compartment 10 and the second compartment 20, but without the third compartment 30, i.e. in an analogous manner as it has been described with respect to the first embodiment of the pump 1.

[0101] Fig. 4 shows a schematic cross-sectional view of a fourth embodiment of a submersible pump 1 according to the invention.

[0102] In the following description of the fourth embodiment of the process fluid lubricated pump 1 only the differences to the first, second and third embodiment are explained in more detail. The explanations with respect to the first, second and third embodiment are also valid in the same way or in analogously the same way for the fourth embodiment. Same reference numerals designate the same features that have been explained with reference to the first, second or third embodiment or functionally equivalent features.

[0103] The fourth embodiment of the submersible pump is configured as a horizontal pump 1, i.e. the pump shaft 5 extends perpendicular to the direction of gravity.

[0104] The fourth embodiment of the pump1 can be configured with the three compartment 10, 20, 30 in the common housing 2 as it is shown in Fig. 3. It is also possible, that the fourth embodiment of the pump 1 is configured with only the first compartment 10 and the second compartment 20, but without the third compartment 30, i.e. in an analogous manner as it has been described with respect to the first embodiment of the pump 1.

[0105] The submersible pump 1 according to the invention combines the advantage of a seal-less configuration with a dosing fluid that is taken from the environmental fluid, in which the pump 1 is immersed. This renders possible a very simple design, because there are no mechanical seals and consequently no auxiliary systems, which would be necessary for the operation of mechanical seals. Furthermore, the umbilical connecting the pump 1 to a location above the surface of the environmental fluid can be configured as a pure electrical umbilical and does not require any fluid lines for supplying the pump 1 e.g. with a buffer fluid or any other fluid.

[0106] The different components of the pump 1 are configured to be compatible with the process fluid or with the dosing fluid, respectively, depending on whether the respective component is arranged in the first compartment 10, in the second compartment 20 or in the third compartment 30. For example, each of the bearings 531, 532, 541, 441, 431, 432 which is arranged in the second compartment 20, is configured to be compatible with the process fluid, and each of the bearings 531, 532, 541, 441, 431, 432, which is arranged in the first compartment 10 or in the third compartment 30, is configured to be compatible with the dosing fluid.

Claims

1. A submersible pump for conveying a process fluid and configured to be completely immersed in an environmental fluid, the pump comprising a common housing (2) having a first compartment (10) configured to be filled with a dosing fluid, and a second compartment (20) configured to be filled with the process fluid, wherein a first flow passage (81) is provided between the first compartment (10) and the second compartment (20), the pump further comprising, a pump unit (3) arranged in the common housing (2), and a drive unit (4) arranged in the common housing (2), wherein the common housing (2) comprises an inlet (21) and an outlet (22) for the process fluid, wherein the pump unit (3) comprises a pump shaft (5) extending from a drive end (51) to a non-drive end (52) of the pump shaft (5) and configured for rotating about an axial direction (A), the pump unit (3) further comprising a hydraulic unit (31) having at least one impeller (311) fixedly mounted on the pump shaft (5) for conveying the process fluid from the inlet (21) to the outlet (22), wherein the drive unit (4) comprises a drive shaft (42) connected to the drive end (51) of the pump shaft (5) for driving the rotation of the pump shaft (5), and an electric motor (41) configured for rotating the drive shaft (42) about the axial direction (A), wherein the electric motor (41) is arranged inside the first compartment (10) and the hydraulic unit (31) is arranged inside the second compartment (20), and wherein the pump is configured as a seal-less pump without a mechanical seal at the pump shaft (5) and the drive shaft (42), **characterized in that** a dosing unit (6) is provided for receiving the environmental fluid, wherein the dosing unit (6) provides the dosing fluid from the environmental fluid, and wherein the dosing unit (6) is configured for dosing a presettable amount of the dosing fluid into the first compartment (10) and through the first flow passage (81) into the second compartment (20).

2. A submersible pump in accordance with claim 1, wherein the first compartment (10) is arranged adjacent to the second compartment (20) with respect to the axial direction (A), wherein a first partition wall (12) is provided between the first compartment (10) and the second compartment (20), wherein the first flow passage (81) is arranged in the first partition wall (12), and wherein the pump shaft (5) or the drive shaft (42) extends through the first flow passage (81).

3. A submersible pump in accordance with anyone of the preceding claims, comprising a balance drum (7) fixedly connected to the pump shaft (5) between the hydraulic unit (31) and the drive end (51) of the pump shaft (5), wherein a relief passage (73) is provided

between the balance drum (7) and a stationary part (26) configured to be stationary with respect to the common housing (2), and wherein a balance line (9) is provided for returning the process fluid passing through the relief passage (73) to a low pressure location of the pump unit.

4. A submersible pump in accordance with anyone of the preceding claims, comprising a first pump bearing unit (53) and a second pump bearing unit (54 for supporting the pump shaft (5), as well as a first motor bearing unit (43) and an second motor bearing unit (44) for supporting the drive shaft (5), wherein the first pump bearing unit (53) is arranged between the hydraulic unit (31) and the drive end (51) of the pump shaft (5), wherein the second pump bearing unit (54) is arranged between the hydraulic unit (31) and the non-drive end (52) of the pump shaft (5), and wherein the electric motor (41) is arranged between the first motor bearing unit (43) and the second motor bearing unit (44) regarding the axial direction (A).

5. A submersible pump in accordance with claim 4, wherein the first pump bearing unit (53), the second pump bearing unit (54), the first motor bearing unit (43) and the second motor bearing unit (44) are each configured for lubrication by the process fluid or by the dosing fluid.

6. A submersible pump in accordance with claim 4 or claim 5, wherein the first pump bearing unit (53) and the second pump bearing unit (54) are arranged in the second compartment (20).

7. A submersible pump in accordance with anyone of claims 4-6, wherein the first motor bearing unit (43) and the second motor bearing unit (44) are arranged in the first compartment (10).

8. A submersible pump in accordance with claim 4 or claim 5, wherein the first pump bearing unit (53), the first motor bearing unit (43) and the second motor bearing unit (44) are arranged in the first compartment (10).

9. A submersible pump in accordance with anyone of claims 4-8, wherein the common housing (2) comprises a third compartment (30), configured to be filled with the dosing fluid, wherein the second compartment (20) is arranged regarding the axial direction (A) between the first compartment (10) and the third compartment (30), wherein a second flow passage (82) is provided between the third compartment (30) and the second compartment (20), wherein the dosing unit (6) is configured for dosing an amount of the dosing fluid into the third compartment (30) and through the second flow passage (82) into the second compartment (20), and wherein the second pump bearing unit (54) is arranged in the third compartment.

10. A submersible pump in accordance with claim 9, wherein a second partition wall (32) is provided between the third compartment (30) and the second compartment (20), wherein the second flow passage (82) is arranged in the second partition wall (32), and wherein the pump shaft (5) extends through the second flow passage (82).

11. A submersible pump in accordance with anyone of the preceding claims, having an external cooling loop (40) for cooling and lubricating the drive unit (4) by means of the dosing fluid, the external cooling loop (40) comprising a heat exchanger (401) for cooling the dosing fluid, wherein the heat exchanger (401) is arranged outside the common housing (2) and configured to receive the dosing fluid from the first compartment (10) and to recirculate the dosing fluid to the first compartment (10).

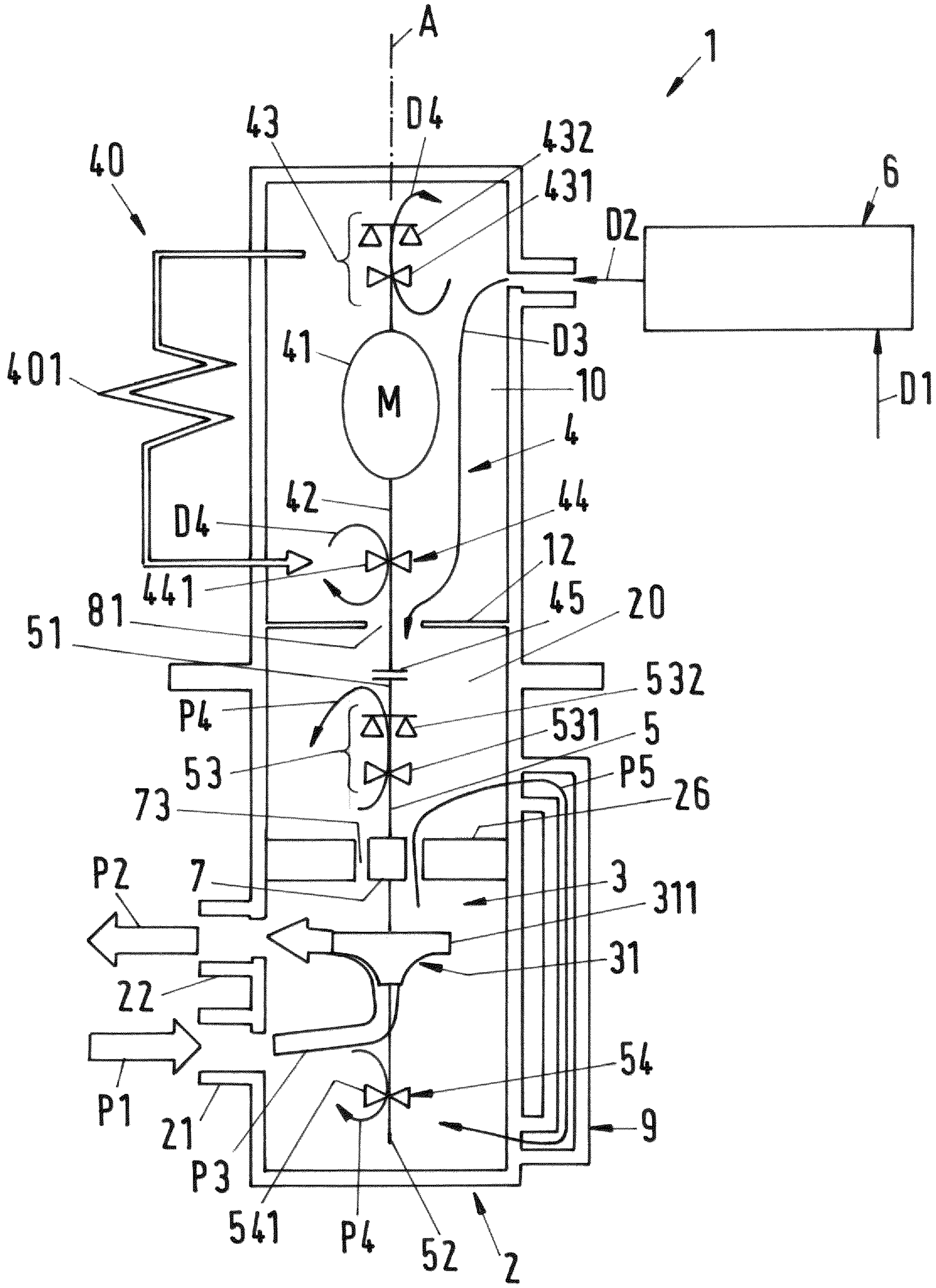
12. A submersible pump in accordance with anyone of the preceding claims, configured as a vertical pump with the pump shaft (5) extending in the direction of gravity.

13. A submersible pump in accordance with claim 12, wherein the drive unit (4) is arranged on top of the pump unit (3).

14. A submersible pump in accordance with anyone of the preceding claims, configured as a subsea pump and preferably configured for installation on a sea ground.

15. A submersible pump in accordance with anyone of the preceding claims, configured as a water injection pump for injecting the process fluid, preferably seawater, into a subterranean region.

Fig.1


A
1
43
D4
432
431
40
6
D2
D3
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M
10
D1
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44
D4
12
441
45
20
81
51
532
P4
531
5
53
P5
26
73
3
P2
7
311
31
22
54
P1
21
9
P3
541
P4
52
2

Fig.2

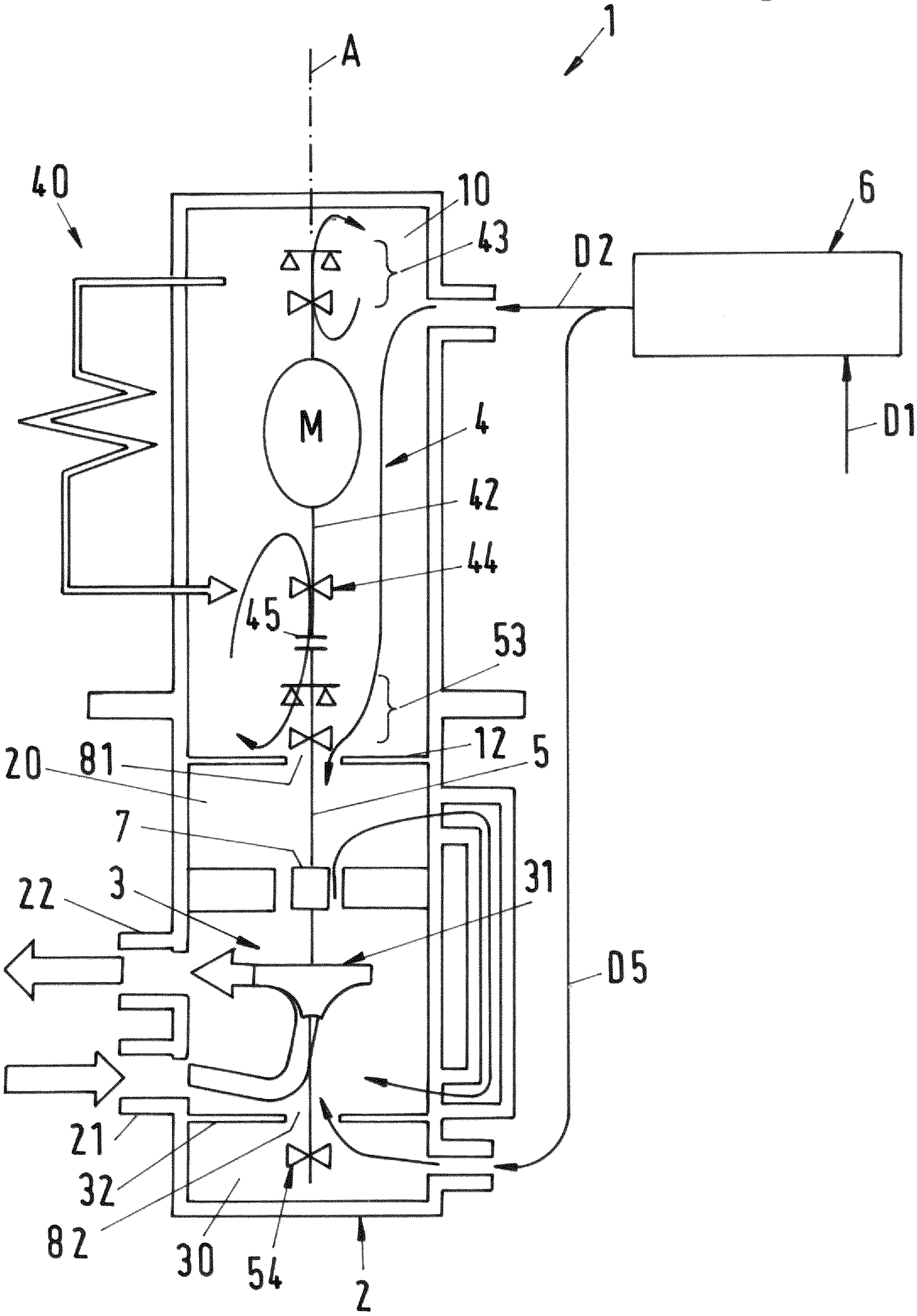


Fig. 3

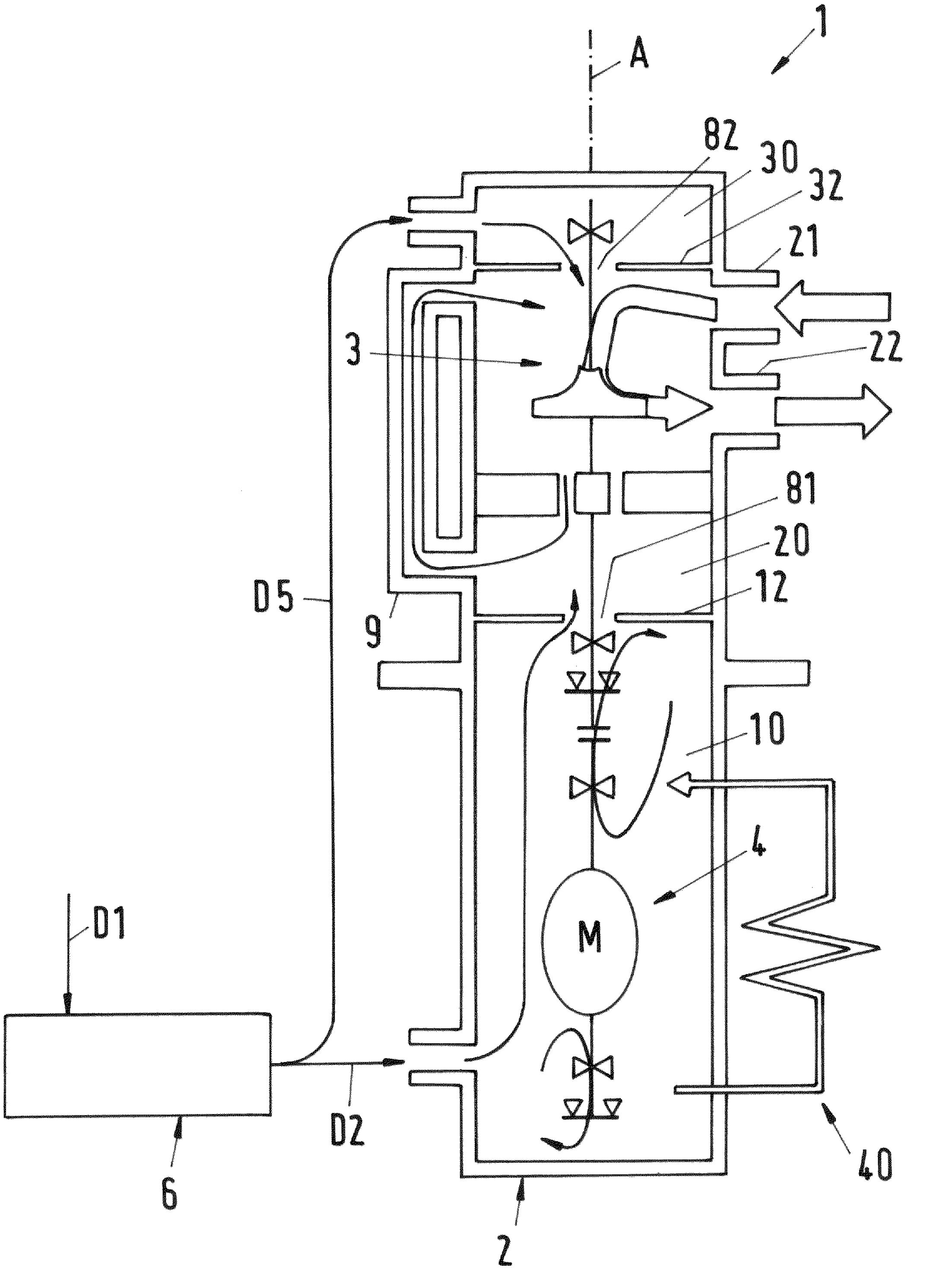
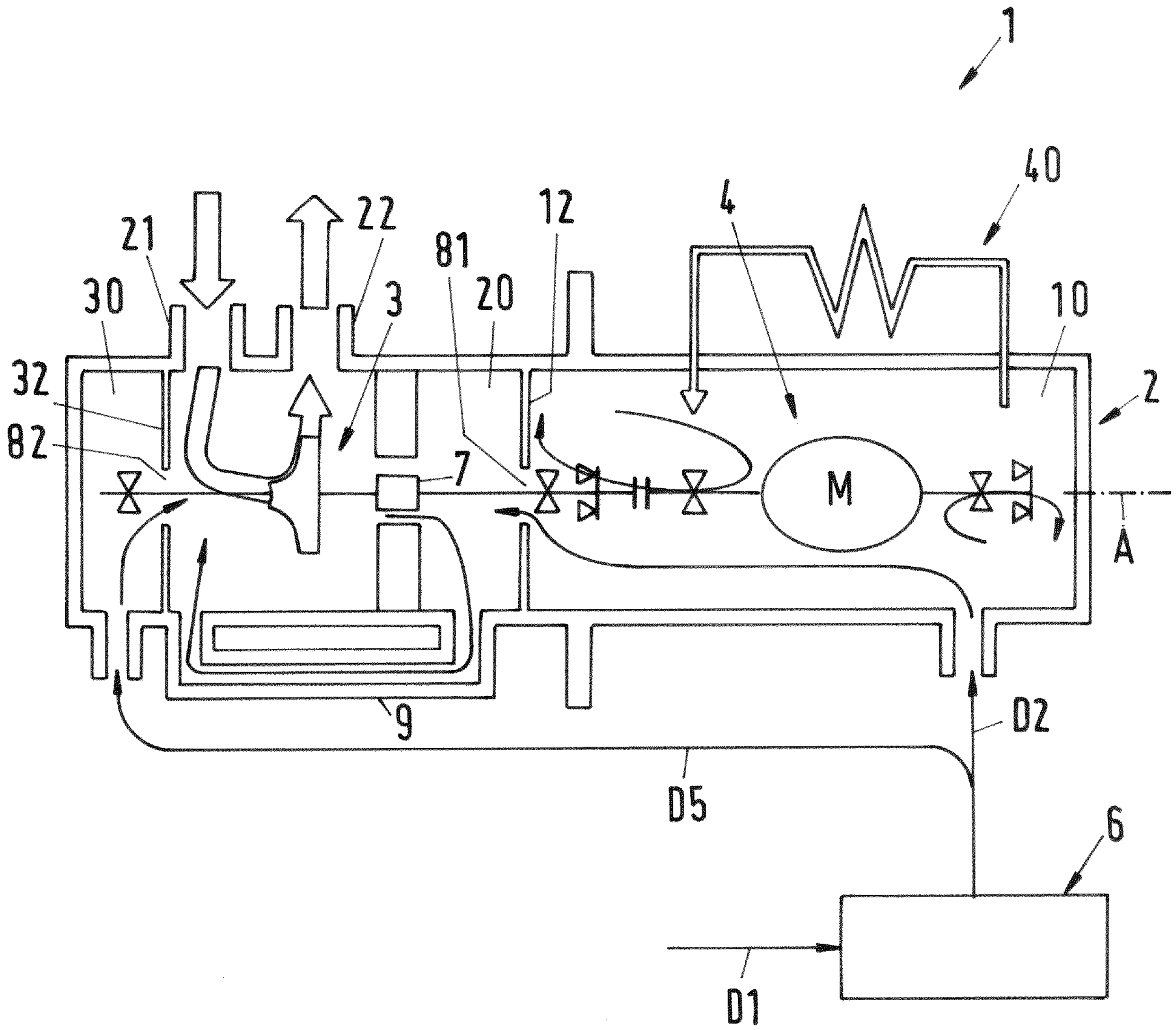


Fig.4



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EUROPEAN SEARCH REPORT

Application Number
EP 24 17 9940

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2016/341209 A1 (LANDI GIACOMO [NO] ET AL) 24 November 2016 (2016-11-24) * figures 1-3 * * paragraphs [0003], [0008], [0009] * * paragraphs [0039] - [0042] * * claim 12 *	1-8, 11-15 9,10	INV. F04D7/02 F04D13/08 F04D29/10
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A	US 8 556 600 B2 (GRYNNING AUDUN [NO]; LARSEN STEIN VEGAR [NO] ET AL.) 15 October 2013 (2013-10-15) * figure 2 * * column 2, line 26 - column 3, line 24 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

F04D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	8 October 2024	Ingelbrecht, Peter

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 24 17 9940

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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