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(71) Applicant: **Vetco Gray Scandinavia AS**
1302 Sandvika (NO)

(72) Inventor: **Tomter, Ole Petter**
N-1397 Nesøya (NO)

(54) **A priming liquid supply system for a sub-sea pump or compressor**

(57) A priming liquid supply system for a sub-sea pump or compressor is disclosed, the pump or compressor having at least one externally threaded rotor that is driven and journalled for rotation in a pump or compressor chamber. An external and constantly pressurized volume of liquid is arranged in flow communication with the pump or compressor chamber (7') via a feed line (19) through which priming liquid is instantly available for injection into the pump or compressor chamber by control of an on/off switching mechanism (20), arranged on the feed line. A barrier fluid system (18) may be installed at the pump or compressor, and the priming liquid feed line (19) may be arranged to connect the pump or compressor chamber with the barrier fluid system from which priming liquid is extracted and supplied to the pump or compressor chamber, driven by a pressure prevailing in the barrier fluid system (18).

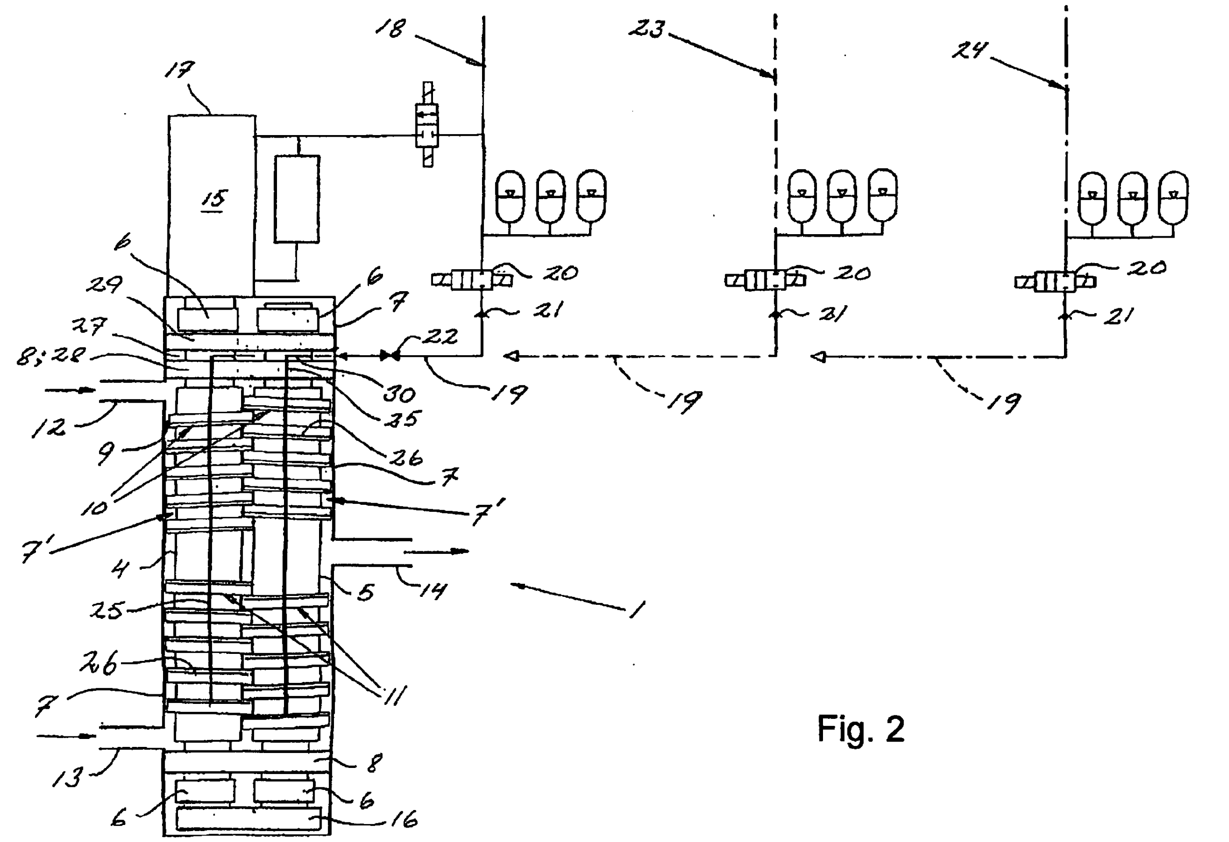

Fig. 2

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention refers to arrangements in a pump or compressor which is operated in sub-sea processes for transport and pressure increase of process fluids, and more specifically to a system by which liquid can be supplied to the sub-sea pump or compressor for priming and/or for rotor cooling purposes.

BACKGROUND AND PRIOR ART

[0002] Pumps and compressors are commonly used in extraction of oil and gas from sub-sea wells to effect transportation or pressure increase in a production fluid. The production fluid is in many cases a multiphase fluid containing varying fractions of liquid and gas. Pumps and compressors may also be used sub-sea for transport and pressure increase of other process fluid than production fluid, or sea-water.

[0003] In this connection, twin screw pumps are widely used. The twin screw pump is a rotary machine comprising two rotors having intermeshing threads which are driven in rotation by a motor to transfer, by positive displacement, fluid or fluid mixtures in the axial directions of the pump. The rotors are housed in a pump chamber defined through a rotor liner or rotor housing, which encases the rotors with a radial clearance between the rotors and the rotor housing. The radial width of the clearance is a compromise between sufficient spacing to accommodate for thermal expansion in the rotors without undue loss of efficiency and pressure caused by slippage of gas or liquid at the clearance.

[0004] In transient operation of a twin screw pump, such as at start-up and shut-down, as well as in operation at high gas volume fractions (GVF) of a pumped multiphase fluid, the pump may suffer from slippage and over-heating caused by dry running.

[0005] Similar problems of gas slippage and over-heating can be encountered in the operation of a compressor that is used for boosting the pressure of gas or wet gas through the driven rotation of one or more rotors housed in a rotor housing which encases the rotor(s) with the required radial clearance between the rotor housing and the rotor(s).

[0006] In order to avoid gas slippage, dry running and over-heating it is previously suggested intermittently to supply liquid for priming and rotor cooling purposes to the clearance between the rotor and the rotor housing.

[0007] In US 5,624,249 (Rohlfing) it is proposed that a partial liquid volume flow be separated on the pressure side of the pump and returned in metered quantities into the intake regions and thus kept in circulation by a rotating rotor.

[0008] In US 5,738,505 (Mezzedimi et al.) it is proposed that liquid be supplied to the perimeter of the rotor via axial supply channel in the rotor central body and radial branches opening in the ends of the rotor threads. Liquid is drawn from a liquid trap which collects a volume of the liquid phase of a pumped fluid. The liquid is introduced in the rotor via the pump's delivery or discharge chamber and is thus kept in circulation by a rotating rotor.

[0009] Both solutions suffer from the fact that priming liquid pressure and flow is dependent on operation of the pump, i.e. dependent on rotation of pump rotors, which may lead to insufficient lubrication during start-up and shut-down. Also, both solutions suffer from a limited volume of priming liquid which may lead to insufficient lubrication and cooling of motor and pump components during high GVF operation for a longer time.

SUMMARY OF THE INVENTION

[0010] The present invention aims at avoiding the drawbacks associated with the prior art solutions.

[0011] The object is met in a priming liquid supply system for a sub-sea pump or compressor having at least one externally threaded rotor that is driven and journalled for rotation in a pump or compressor chamber, wherein an external and pressurized volume of liquid is arranged in flow communication with the pump or compressor chamber via a feed line through which liquid is instantly available for injection into the pump or compressor chamber for priming and/or cooling purposes by control of an on/off switching mechanism arranged on the feed line.

[0012] The invention thus teaches injection of priming liquid from an external source which is maintained under pressure independently of the operational status of a pump or compressor. Instead of being the result of rotor rotation as proposed in the prior art, priming liquid flow is instantly available by operation of an on/off switching mechanism. Switching may be accomplished through an electrically controlled one-way valve, optionally connected in series with a non-return valve. By this solution it is ensured that sufficient volume of priming liquid is available at all times and can be supplied at any stage of operation of a pump or compressor.

[0013] In one embodiment of the invention, the priming liquid feed line connects the pump or compressor chamber with a barrier fluid system that is installed at the pump or compressor, and from which priming liquid is extracted and supplied to the pump or compressor chamber, driven by a pressure prevailing in the barrier fluid system.

[0014] In another embodiment, priming liquid is supplied to the pump or compressor chamber from a dedicated volume of priming liquid, driven by a pressure applied from a sea- or land-based platform.

[0015] In yet another embodiment the priming liquid volume is a volume of hydrate prevention fluid included in a hydrate formation prevention system from which priming liquid is extracted and supplied to the pump or compressor chamber, driven by a pressure prevailing in the hydrate formation prevention system.

[0016] In all embodiments, priming liquid may be injected into the pump or compressor chamber by a drive pressure which at all times is higher than a detected pumped fluid pressure at the inlet or at the outlet of the pump or compressor.

[0017] Each embodiment of the invention can be configured for recharge, from a sea- or land-based platform, of the volume of liquid that is utilized for priming or cooling purposes.

[0018] Priming liquid can be distributed in the pump or compressor chamber via a system of axial and/or radial channels internally in the pump or compressor rotor(s).

[0019] Priming liquid can be introduced in the internal rotor channel system via a priming liquid feed chamber that is defined between axially spaced fluid seals sealing about the rotor periphery.

[0020] Priming liquid can alternatively be introduced in the internal rotor channel system via a slip ring that is journalled on the rotor for relative rotation and stationary and non-rotationally connected to the pump or compressor structure.

[0021] The internal channel system in the rotor(s) may be configured to include one or more axial supply channels in the rotor body and radial branches in the threads of the rotor(s). At least some of the radial branches may be arranged to mouth in the periphery of the rotor threads, while at least some of the radial branches may be arranged to mouth in one or in both side flanks of the rotor threads. Alternatively, at least some of the radial branches are arranged to mouth in the periphery of the rotor threads and in one or in both side flanks of the rotor threads.

[0022] Non-return valves and/or fixed flow restrictions may be arranged in the internal channel system in the rotor(s).

[0023] The axial supply channels may be arranged with pressure regulators.

[0024] Details and embodiments of the invention will be further explained below with reference to the accompanying, schematic drawings.

SHORT DESCRIPTION OF THE DRAWINGS

[0025] In the drawings:

Fig. 1 is an overview of an installation for recovery of hydrocarbon fluid from a sub-sea well;

Fig. 2 is a longitudinal section through a twin screw pump in a pump system useful in a process for recovery of hydrocarbon fluid; Fig. 2 is also a diagrammatic representation of preferred embodiments of the invention;

Fig. 3 is a diagrammatic representation of an alternative embodiment of the invention;

Figs. 4A-4B are detail views illustrating the downstream end of a priming liquid supply circuitry.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0026] In the following disclosure, embodiments of the invention will be explained with reference made to a twin screw fixed displacement pump used in a sub-sea hydrocarbon production system. It should be pointed out however that the invention is likewise applicable to a single rotor pump or to a compressor with one or more rotors used in a sub-sea hydrocarbon production system.

[0027] In this connection it shall also be pointed out that the expression "priming liquid" is used in the specification and claims to simplify language and shall not be narrowly interpreted, and refers to a liquid that is supplied for any or for the combined purposes of priming, cooling or lubrication of a pump or compressor.

[0028] It shall likewise be pointed out that the expression "barrier fluid" is used in the specification and claims to simplify language and shall not be narrowly interpreted, and refers to a fluid, typically a liquid, which is supplied for any or for the combined purposes of providing pressure barrier, cooling or lubrication of a pump or compressor.

[0029] In Fig. 1, reference number 1 depicts a pump situated on the sea floor. The pump 1 may be driven and operative for pumping hydrocarbon fluid from a sub-sea well to a floating platform 2, or to a land based platform, via a conduit 3. The pump may also be used for injecting sea water or process liquid, such as the liquid phase of a multiphase fluid extracted from the sub-sea well, into the sub-sea well for reducing back pressure and assisting in the recovery of hydrocarbon products. In case of long distance conduits, additional pumps or compressors may be required at other locations along the conduit to assist in transportation of hydrocarbon fluid from the sub-sea well to the platform.

[0030] The pump 1 may be a fixed displacement pump of the twin screw type as depicted in sectional view in Fig. 2. The twin screw pump comprises two rotors 4, 5 which are journalled in bearings 6 for rotation inside a rotor liner or rotor housing 7, the rotor housing radially defining a pump chamber 7' that is axially defined between seals 8. In order to accommodate for thermal expansion of the rotors the rotors are journalled with a radial clearance 9 between the rotors and the housing. Each rotor 4, 5 is formed with two sections of threads 10 and 11 in intermeshing relation with corresponding threaded sections of the opposite rotor. In synchronized rotation the intermeshing threads of rotors 4, 5 effect transportation of discrete volumes of a pumped medium in axial directions of the pump, from pump inlets 12, 13 towards a longitudinal center of the pump from where the pumped fluid is discharged via a pump outlet 14. Reverse flow may be accomplished by reverse rotation of the pump rotors.

[0031] The rotors 4, 5 are driven by a motor 15 which is drivingly connected to one of the rotors 4 or 5. Synchronization of the rotors is accomplished by means of a timing gear unit 16 which interconnects the rotors in the ends remote from the motor 15. The motor 15 is encased in a motor housing 17. In order to prevent intrusion of sea water and intrusion of pumped fluid into the motor casing and into rotor bearings and seals which separate the motor casing from the pump, barrier fluid may be supplied to the motor casing, to bearings and seals, at a pressure which exceeds the pressure in sea water and in the pumped fluid. Likewise in order to prevent intrusion of sea water and pumped fluid, barrier fluid may be supplied from the barrier fluid system 18 to bearings, seals and timing gears of the pump. The barrier fluid is typically a water/glycol mixture or a water-based control fluid that is supplied from the platform or from an intermediate supply of barrier fluid, delivered to the pump via pipes included in a barrier fluid system 18.

[0032] In a sub-sea motor and pump assembly, barrier fluid may also fulfill the purpose of cooling and/or lubrication of components which are exposed to mechanical and thermal wear. As used in this specification and appended claims, the expressions "barrier fluid" and "barrier fluid system" shall be understood to include a liquid or a system providing pressure barrier and/or lubrication and/or cooling of components in a sub-sea motor and pump or compressor assembly.

[0033] Pressure and flow in a barrier fluid system may be controlled by means of flow control valves, pressure sensors and pressure control devices which are known in the art and typically included in a sub-sea barrier fluid system. Since a skilled person would be familiar with the structure and functionality of sub-sea barrier fluid systems in general and since the art and function of the priming liquid supply system of the present invention is not dependent on a specific layout of the barrier fluid system, a detailed description of barrier fluid systems is not required to explain and understand the present invention.

[0034] Through pressure detection in the pumped fluid at the pump inlet or outlet, the pressure in the barrier fluid system 18 may be related to variations in pressure in the production fluid, and is at all times maintained at a pressure which exceeds the pressure in the pump chamber. Loss of barrier fluid caused by leakage via seals and bearings is compensated for by filling up the barrier fluid system 18 from a supply of barrier fluid on the platform or from a dedicated supply of barrier fluid at the pump location sub-sea.

[0035] According to a first preferred embodiment of the present invention priming liquid is extracted and supplied from the barrier fluid system 18 for injection into the pump chamber.

[0036] According to a preferred alternative embodiment of the present invention, priming liquid is supplied from a dedicated volume of priming liquid that is set under pressure from the platform.

[0037] According to a preferred second alternative embodiment of the present invention, priming liquid is extracted and supplied from a volume of hydrate formation prevention fluid, such as methanol or glycol that is set under pressure from the platform.

[0038] Priming liquid is routed to the pump via a priming liquid feed line 19 connecting the pump with the priming liquid volume over an on/off valve 20. The on/off valve 20 may be an electromagnetically actuated one-way flow control valve which is controlled from the platform. A non-return valve 21 in the priming liquid supply line 19 may be arranged to prevent back flow of priming liquid. A throttle valve 22 may optionally be inserted in the priming liquid feed line 19 for flow regulation.

[0039] In the said first preferred embodiment the priming liquid feed line 19 connects the pump with the barrier fluid system 18, as illustrated by continuous lines in Fig. 2. Opening the on/off valve 20 provides instant flow of priming liquid driven by a pressure prevailing in the barrier fluid system 18, which can be controlled from the platform and which may optionally be balanced with a detected pumped fluid pressure at the pump inlet or outlet.

[0040] In the alternative embodiment the priming liquid feed line 19 connects the pump with a dedicated volume 23 of priming liquid, as illustrated by broken lines in Fig. 2. Opening the on/off valve 20 provides instant flow of priming liquid driven by a pressure prevailing in the priming liquid volume 23, which can be controlled from the platform.

[0041] In the second alternative embodiment the priming liquid feed line 19 connects the pump with a volume of hydrate prevention fluid in a hydrate formation prevention system 24, as illustrated by dash-dot lines in Fig. 2. Opening the on/off valve 20 provides instant flow of priming liquid driven by the pressure prevailing in the hydrate formation prevention system, which can be controlled from the platform.

[0042] Thus, in all embodiments, the feed of priming liquid to the pump is controlled by operation of an on/ off switching mechanism by which the pump chamber can be set in flow communication with a volume of priming liquid that is maintained under pressure. Likewise in all embodiments, injection of priming liquid can be driven by a pressure that is higher than a detected pumped fluid pressure at the inlet or at the outlet of the pump. Flow of priming liquid is this way instantly available for injection into the pump chamber.

[0043] In the pump chamber, priming liquid can be distributed in various ways. For example, priming liquid may advantageously be routed to the clearance 9 via the pump rotor(s). To this purpose, the rotors may be designed with an internal channel system that opens in the ends/periphery of the rotor threads, in a way that is known in the art. The internal channel system in the rotor(s) then comprises one or more axial supply channels 25 in the rotor body from which channels or branches 26 extend in radial directions to the periphery of the rotor threads.

[0044] In one preferred embodiment of the present invention priming liquid is distributed to the internal channel system 25, 26 of the rotor(s) via a priming liquid feed chamber 27, depicted in Fig. 2. The priming liquid feed chamber 27 is defmed between radial fluid seals 28 and

29 which effect sealing about the rotor axis. The fluid seals 28 and 29 are arranged in axially spaced relation in a region between rotor bearings 6 and the nearest threaded section 10 of the rotor(s). Priming liquid supplied via the priming liquid feed line 19 enters the priming liquid feed chamber 27 via an opening in the wall of the rotor housing 7. From the priming liquid feed chamber 27, priming liquid is distributed to the one or more axial supply channels 25 in the rotor body via one or more radial feed channels 30 mouthing in the rotor periphery.

[0045] In another preferred embodiment of the present invention, depicted in Fig. 3, priming liquid is distributed to the internal channel system 25, 26 of a rotor via a slip ring 31. The slip ring 31 is journalled on the rotor for relative rotation but is stationary/non-rotationally connected to the pump structure, such as to the rotor housing 7. The slip ring 31 is situated on the rotor axis between the rotor bearings 6 and the nearest threaded section 10 of the rotor. The slip ring 31 is located in a position where a circumferential recess 32 in the inner periphery of the slip ring is aligned with the mouth or mouths of the one or more radial feed channels 30. Ring seals 33 on each side of the recess may be arranged to effect sealing about the rotor axis. Priming liquid supplied via the priming liquid feed line 19 enters the circumferential recess 32 via a feed line connection 34 arranged on the exterior of the slip ring. In pumps having more than one rotor, each rotor may be associated with a slip ring 31, respectively. In such case, the flow of priming liquid supplied via the priming liquid feed line 19 is divided, inside or outside the rotor housing, into partial flows feeding the slip rings.

[0046] The priming liquid feed chamber 27, as well as the slip ring 31, may optionally be located at either end of the pump. In all cases priming liquid is supplied to the pump rotor(s) via a priming liquid feed chamber or via a slip ring that is positioned axially outside the pump chamber which is delimited axially between the seals 8. The priming liquid supply system components do not interfere with the flow paths of production fluid through the pump.

[0047] Figs. 4A-4B depicts different designs at the downstream end of the priming liquid supply circuitry. In the embodiment shown in Fig. 4A at least some of the radial branches 26 of the internal channel system in the rotor open axially in one or in both side flanks of the rotor threads. Priming liquid can this way be supplied axially into the spaces between the rotor threads and successively into the clearance 9. If desired, priming liquid may be supplied at large volumes from an external volume of priming liquid which can be recharged from the platform. This option may be desirable at start-up of the pump, e.g., in order to arrive at normal operating conditions for the pump, motor and bearings.

[0048] In the embodiment shown in Fig. 4B at least some of the radial branches 26 of the internal channel system in the rotor open radially in the periphery of the rotor threads. This option may be desirable during operation at high gas volume fractions of the pumped fluid in order to avoid gas slippage, pressure loss and over-heating of the rotor(s).

POSSIBLE MODIFICATIONS

[0049] A combined radial/axial supply of priming liquid is available if some of the radial branches 26 are arranged to mouth in the periphery of the rotor threads and other radial branches 26 are arranged to mouth in the side flanks of the rotor threads. In a modified embodiment, the radial branches 26 may be split in the downstream end into a radial channel length opening in the periphery of the rotor threads and an axial channel length opening in a side flank of the rotor threads.

[0050] An optional radial and/or axial supply of priming liquid is available if those radial branches 26, which open in the periphery, and those radial branches 26 which open in the side flanks, are connected to separate axial supply channels 25 in the rotor body. Priming liquid is then supplied to each one of at least two axial supply channels 25 via two separate priming liquid feed chambers 27, or via two separate slip rings 31. The two feed chambers 27, or the two slip rings 31, may each be arranged to feed priming liquid into a group of axial supply channels 25 which supply priming liquid to the radially mouthing or to the axially mouthing branches 26. The two feed chambers 27 or slip rings 31 may be located in the same one end of the rotor(s), or in separate ends of the rotor(s).

[0051] It can also be foreseen that in a modified embodiment priming liquid may be supplied to the pump chamber via nozzle holes through the rotor housing wall. In such embodiment, the nozzle holes may be connected to the priming liquid feed line 19 outside the pump chamber via a manifold pipe. The nozzle holes may be evenly spaced along the length of the pump chamber, and several axial rows of nozzle holes may be spaced about the circumference of the pump chamber.

[0052] Other possible modifications include, e.g., the provision of back-flow preventing means (such as indicated by reference number 35 in Fig. 4B) at the very downstream ends of the priming liquid supply circuitry. These measures may include non-return valves or flap valves which close automatically when supply of priming liquid is stopped, and serve to prevent intrusion of pumped fluid and particles which could otherwise cause clogging of the radial branches of the rotor channels, or clogging of nozzle holes through the rotor housing wall.

[0053] Still other possible modifications include the provision of fixed or adjustable orifices/flow restrictions or pressure regulators in the axial supply channel(s) 25, and/or at the downstream end of the priming liquid supply circuitry 25, 26 (such as indicated by reference number 36 in Fig. 4A) aiming for flow regulation and compensation for pressure drops in the priming liquid supply system that could otherwise cause uneven distribution of priming liquid at different locations in the pump chamber.

[0054] These and other possible modifications, all of which can be derived from the teachings presented hereinabove, are encompassed in the scope of invention and embodiments thereof as defined by the appended claims.

Claims

1. A priming liquid supply system for a sub-sea pump or compressor having at least one externally threaded rotor (4; 5) that is driven and journalled for rotation in a pump or compressor chamber (7'), the system **characterized in that** an external and pressurized volume of liquid is arranged in flow communication with the pump or compressor chamber via a feed line (19) through which liquid is instantly available for injection into the pump or compressor chamber for priming and/or cooling purposes by control of an on/off switching mechanism (20) arranged on the feed line.

2. The system of claim 1, wherein a barrier fluid system (18) is installed at the pump or compressor, and the feed line (19) connects the pump or compressor chamber with the barrier fluid system from which priming liquid is extracted and supplied, driven by a pressure prevailing in the barrier fluid system (18).

3. The system of claim 1, wherein priming liquid is supplied from a dedicated priming liquid volume (23), driven by a pressure applied from a sea- or land-based platform.

4. The system of claim 1 or 3, wherein the priming liquid is a hydrate prevention fluid included in a hydrate formation prevention system (24) from which priming liquid is extracted and supplied, driven by a pressure prevailing in the hydrate formation prevention system.

5. The system of any of claims 1-4, wherein priming liquid is injectable into the pump or compressor chamber by a drive pressure which at all times is higher than a detected pumped fluid pressure at the inlet or at the outlet of the pump or compressor.

6. The system of any previous claim, wherein the volume of liquid that is used for priming and/or cooling purposes is rechargeable from a sea- or land-based platform.

7. The system of any previous claim, wherein the switching mechanism (20) is an electrically controlled one-way valve (20).

8. The system of any previous claim, wherein priming liquid is distributed in the pump or compressor chamber via an internal system of channels (25, 26) in the pump or compressor rotor(s) (4; 5).

9. The system of claim 8, wherein priming liquid is introduced in the internal rotor channel system (25, 26) via a priming liquid feed chamber (27) that is defined between axially spaced fluid seals (28, 29), sealing about the rotor periphery.

10. The system of claim 8, wherein priming liquid is introduced in the internal rotor channel system (25, 26) via a slip ring (31) that is journalled on the rotor for relative rotation and stationary and non-rotationally connected to the pump or compressor structure.

11. The system of any of claims 8-10, wherein the internal channel system in the rotor(s) comprises one or more axial supply channels (25) in the rotor body and radial branches (26) in the threads (10; 11) of the rotor(s).

12. The system of claim 11, wherein at least some of the radial branches (26) mouth in the periphery of the rotor threads.

13. The system of claim 11 or 12, wherein at least some of the radial branches (26) mouth in one or in both side flanks of the rotor threads.

14. The system of any of claims 8-13, wherein non-return valves (35) are arranged in the internal channel system (25, 26) in the rotor(s).

15. The system of any of claims 8-14, wherein fixed flow restrictions (36) or pressure regulators are arranged in the internal channel system (25, 26) in the rotor(s).

16. The priming liquid supply system of claim 11, wherein the axial supply channels (25) are arranged with pressure regulators.

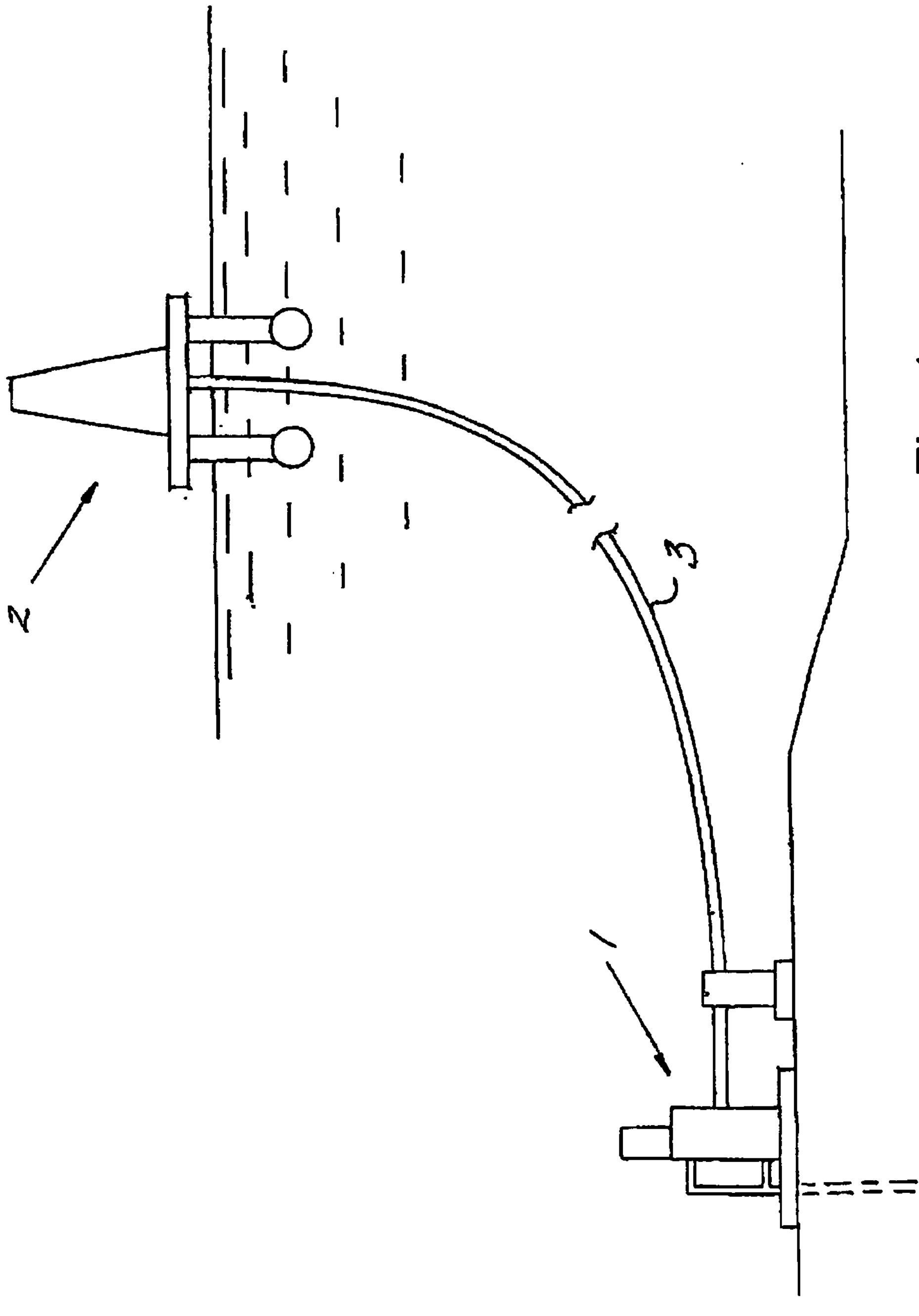

Fig. 1

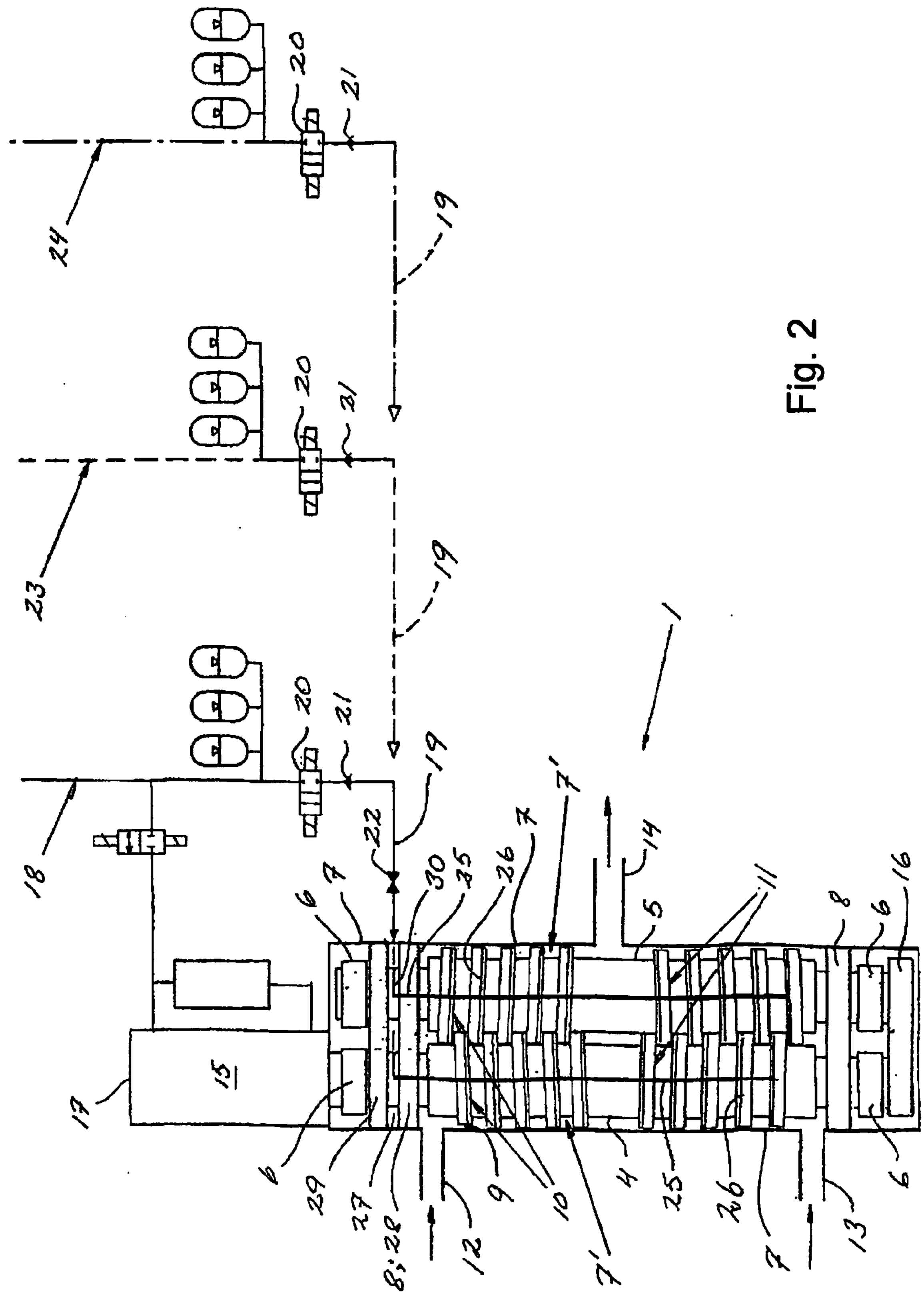

Fig. 2

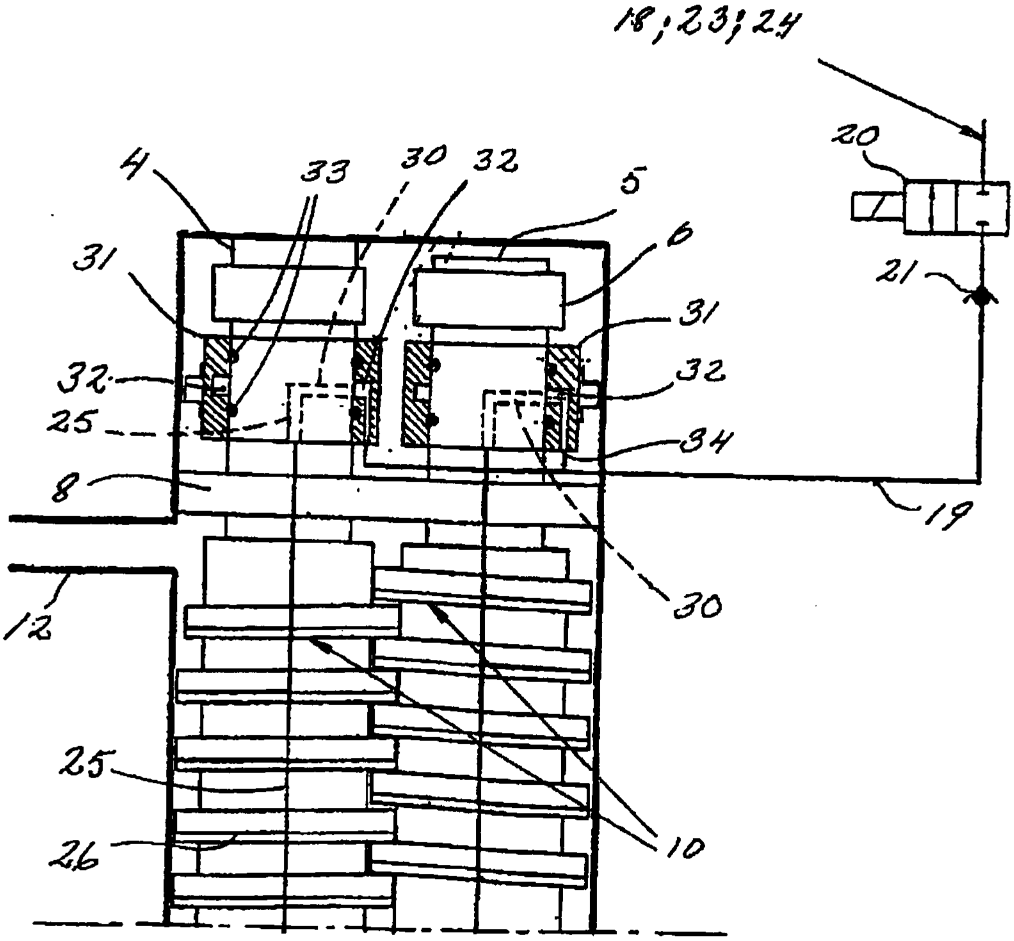

Fig. 3

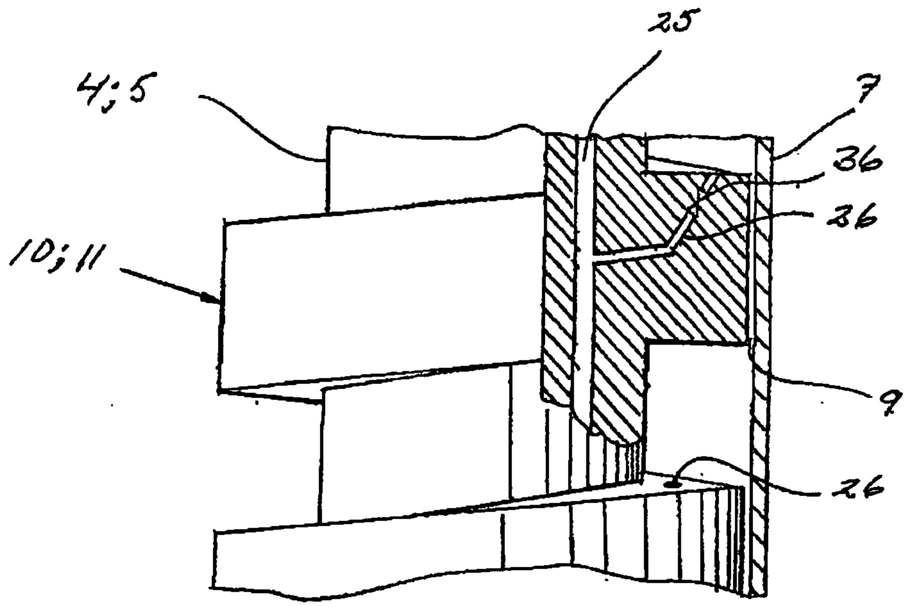

Fig. 4a

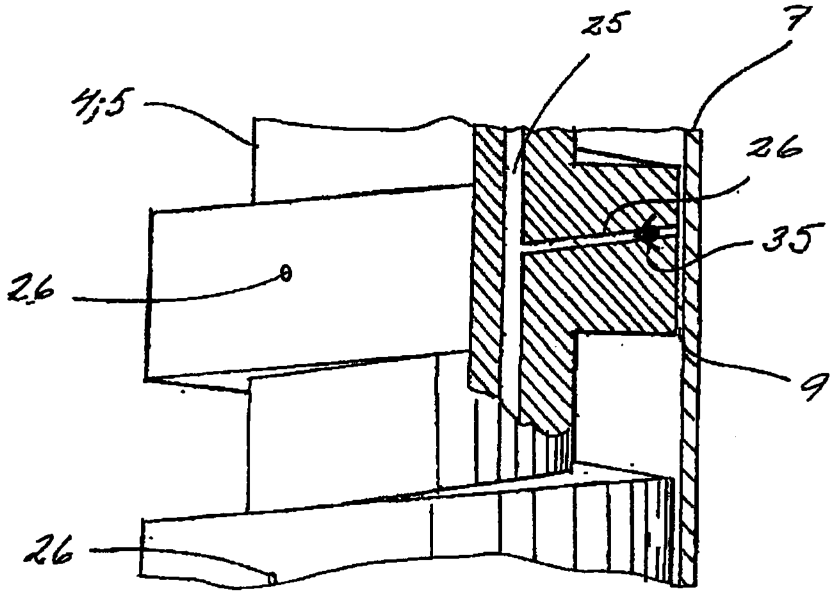

Fig. 4b

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EUROPEAN SEARCH REPORT

Application Number
EP 11 00 7995

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TECHNICAL FIELDS SEARCHED (IPC)
F04C
F17D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	2 February 2012	Sbresny, Heiko

1

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 00 7995

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