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(54) Title: HIGH FLOW AND LOW NPSHR HORIZONTAL PUMP WITH PRIMING MODULE

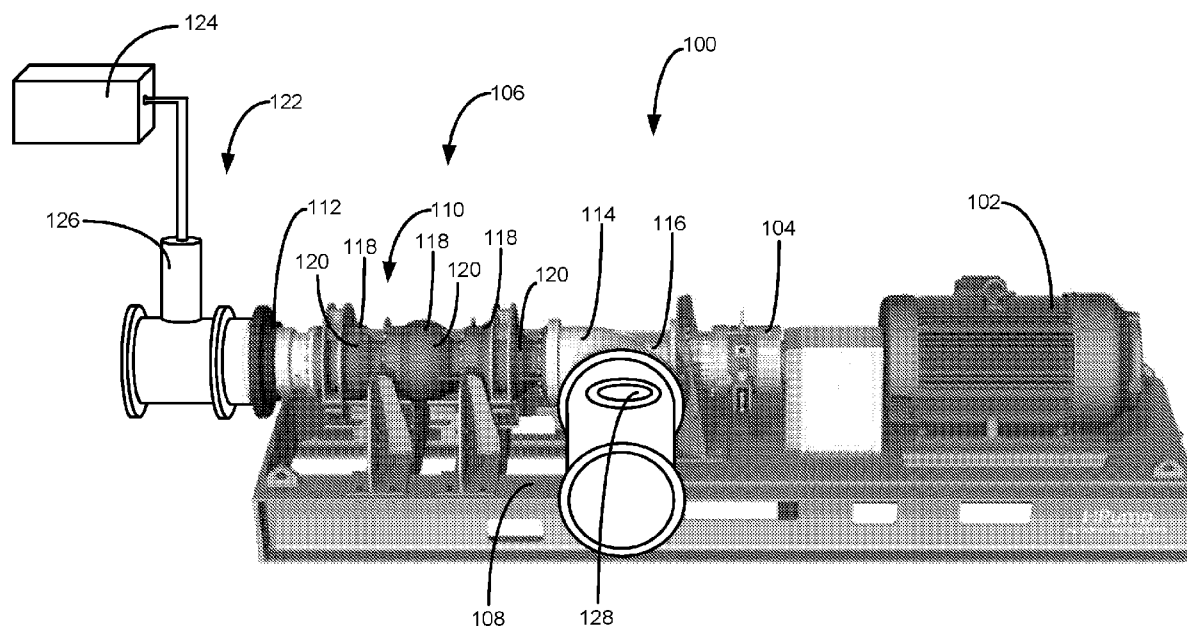


FIG. 2

(57) Abstract: A horizontal pumping system has a motor, a pump driven by the motor and a priming module. The pump has a discharge on a first end of the pump, a suction end on a second end of the pump, and a plurality of stages between the suction end and the discharge. Each of the plurality of stages includes an impeller and a diffuser that encases the impeller. Each diffuser is an independent pressure vessel. The priming module may be a wet priming module or a dry priming module. The priming module permits the use of the horizontal pumping system in many applications in which the liquid is not naturally present at the pump intake.



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High Flow and Low NPSHr Horizontal Pump with Priming Module

Related Applications

[001] This application claims the benefit of United States Provisional Patent Application Serial No. 62/824,782 entitled “High Flow and Low NPSHr Horizontal Pump with Priming Module” filed March 27, 2019, the disclosure of which is herein incorporated by reference.

Field of the Invention

[002] This invention relates generally to the field of pumping systems, and more particularly, but not by way of limitation, to an improved horizontal pump design for use in low net positive suction head (NPSH) applications.

Background

[003] Horizontal pumping systems are used in various industries for a variety of purposes. Large split-casing pumps are often used to move fluids between surface-based storage facilities. For example, in the oil and gas industry horizontal pumping systems are used to pump fluids, such as water separated from oil, to a remote destination, such as a tank, retention pond or disposal well. Many split casing pumps used in this industry are designed to meet or exceed the standards set forth in API 610. Although generally effective, split casing pumps are expensive, difficult to manufacture and often create large lead times to delivery and installation.

[004] As an alternative to split casing pumps, manufacturers have turned to multistage pumps designed for use in a downhole environment. These multistage pumps are placed on a skid-supported frame and used in a horizontal orientation. Typically these horizontal pumping systems include a pump, a motor, and a suction housing positioned

between the pump and the motor. A thrust chamber is also included between the motor and the suction housing. The pump includes a discharge assembly that is connected to downstream piping.

[005] Although widely adopted for use in submersible applications, conventional multistage centrifugal pumps have design requirements that frustrate use in many surface-based, horizontal applications. In downhole pumping applications, the pressure of the fluid at the pump inlet is created by the column of fluid in the wellbore above the pump. In surface-based pumping systems, however, the net positive suction head available (NPSH_A) may be much lower. To match the NPSH_A to the suction pressure required by the pump (NPSH_R), designers have attempted to incorporate a separate “boost pump” that charges the fluid to a NPSH_A that matches or exceeds the NPSH_R required by the horizontal pump. The use of a separate boost pump is expensive and requires additional space that may not be available in certain applications.

[006] In some applications, the pump may be positioned above the intake liquid level, thereby creating a suction lift configuration. Pumps that are positioned on berms above retaining ponds must accommodate suction lift conditions to move fluids out of the below-grade reservoir. In the past, single-stage centrifugal pumps have been paired with dry-prime assist mechanisms that evacuate air from the suction line so that only liquid is available at the pump. Although these systems work well for single-stage conventional pumps that are designed to operate in lower NPSH_A conditions, there remains a need for specialized surface pumping systems that are capable of providing high flow rates in low NPSH_A and suction lift conditions. It is to these and other deficiencies in the prior art that the present invention is directed.

Summary of the Invention

[007] In one aspect, the present invention includes a horizontal pumping system that has a motor, a pump driven by the motor and a priming module. The pump has a discharge on a first end of the pump, a suction end on a second end of the pump, and a plurality of stages between the suction end and the discharge. Each of the plurality of stages includes an impeller and a diffuser that encases the impeller. Each diffuser is an independent pressure vessel. The priming module may be a wet priming module or a dry priming module. The priming module permits the use of the horizontal pumping system in applications in which a suction lift configuration is present at the pump.

[008] In another aspect, the present invention provides a horizontal pumping system that has a motor, a pump driven by the motor and a priming module. The pump includes a discharge on a first end of the pump and a suction end on a second end of the pump, where the discharge is between the suction end and the motor. The pump further includes a shaft seal module connected to the discharge and a plurality of stages between the suction end and the discharge. The priming module is configured to supply liquid to the suction end of the pump.

[009] In yet another embodiment, the present invention includes a horizontal pumping system that has a motor, a pump driven by the motor and a priming module. The pump has a discharge on a first end of the pump, a suction end on a second end of the pump, and a plurality of stages between the suction end and the discharge. The discharge is between the suction end and the motor. Each of the plurality of stages includes a diffuser and an impeller, where each diffuser is an independent pressure vessel. The priming module is configured to supply liquid to the suction end of the pump.

Brief Description of the Drawings

[010] FIG. 1 is a side view of a surface pumping system constructed in accordance with an exemplary embodiment of the present invention, where the pumping system is positioned above a retaining pond.

[011] FIG. 2 is a side perspective of the surface pumping system of FIG. 1 with a dry prime module.

[012] FIG. 3 is a side perspective of the surface pumping system of FIG. 1 with a wet prime module.

Written Description

[013] In accordance with an exemplary embodiment, FIG. 1 shows a side perspective view of a horizontal pumping system 100 deployed above a liquid source 200. The liquid source 200 can be a retaining pond, tank, well, reservoir, or other body of liquid in a natural basin or man-made vessel. An intake line 202 connects the liquid source 200 to the horizontal pumping system 100. A discharge line 204 conveys the pressurized fluid from the horizontal pumping system 100 to downstream locations. In some applications, the liquid source 200 is a man-made retaining pond that holds a volume of liquid intended for use in downstream hydraulic fracturing operations. In those applications, the horizontal pumping system 100 is configured to move fluid from the retaining pond 200 to the pumps and other hydraulic fracturing equipment located at the well site. As explained below, the horizontal pumping system 100 includes a priming module 206 that permits the use of the horizontal pumping system 100 to lift fluids from the liquid source 200 under suction lift conditions. As used herein, the term “priming module” refers to both wet and dry priming mechanisms. As used herein, “suction lift” refers to the

pressure (negative pressure) on the suction side of the horizontal pumping system 100, as measured from the center line of the horizontal pumping system 100 down to the surface of the liquid within the liquid source 200 on the suction side of the horizontal pumping system 100.

[014] Turning to FIG. 2, shown therein is a depiction of the horizontal pumping system 100 constructed in accordance with a first embodiment. The horizontal pumping system 100 includes a motor 102, a thrust chamber 104, and a pump 106. The thrust chamber 104 is connected between the pump 106 and the motor 102. The various components within the horizontal pumping system 100 are supported by a frame 108 that may be configured as a skid suitable for placement on a pad, trailer or any other stable surface capable of supporting the horizontal pumping system 100. In the embodiment depicted in FIG. 2, the various components of the horizontal pumping system 100 are secured to the frame 108 such that the horizontal pumping system 100 can be lifted, moved and set as a unitary element without the need to realign the individual components of the horizontal pumping system 100.

[015] As used herein, the terms “upstream” and “downstream” provide relative positional references to components within the horizontal pumping system 100 based. Upstream components will be understood to be positioned closer to the suction end 112, while downstream components are positioned at a greater distance from the suction end 112 in the direction of fluid flow away from the suction end 112. Although the preferred embodiments are depicted in connection with a horizontal pumping system 100, it will be appreciated that the preferred embodiments may also find utility in other pumping systems, including surface-mounted vertical pumping systems.

[016] The pump 106 includes one or more turbomachinery stages 110, a suction end 112 and a discharge 114. As depicted, the pump 106 is configured as an “end-suction” pump in which the suction end 112 is positioned on the opposite end of the pump 106 from the thrust chamber 104. The discharge 114 is positioned between the stages 110 and the thrust chamber 104. Generally, the motor 102 drives the pump 106 through one or more shafts (not visible) that extend through the thrust chamber 104 and discharge 114 to the stages 110. The motor 102 can be configured as a 4-pole motor that operates at half the rotational speed of a conventional 2-pole motor with an equivalent electrical input frequency. In one embodiment, the motor 102 is configured to rotate at no more than about 1,750 revolutions per minute (RPM). In other embodiments, the motor 102 is an internal combustion engine that produces torque to drive the pump 106. In certain embodiments, it may be desirable to deploy gearboxes, torque converters, clutches, or additional transmission components between the motor 102 and the pump 106. In yet other embodiments, the motor 102 is configured as a 2-pole electric motor.

[017] The discharge 114 includes a shaft seal module 116 that supports and seals the shaft as it enters the discharge 114. The shaft seal module 116 includes one or more shaft seals (not shown) that prevent high pressure fluid from being released from the discharge 114 through the shaft seal module 116.

[018] Pumped fluids are provided to the suction end 112 from the intake line 202 and pressurized by the pump stages 110. Each of the pump stages 110 includes a diffuser 118 and an impeller 120 contained within the diffuser 118. Unlike conventional multistage surface pumping systems, the diffusers 118 are not contained within a separate external housing. In this way, the diffusers 118 are each configured as an independent pressure

vessel that can be sized without restriction to a common external housing found in conventional multistage pumps. This permits the diffuser 118 and the impeller 120 to be enlarged (e.g., a larger outer diameter) and configured for optimal operation under low net positive suction head (NPSH) conditions while also providing high flow rate operation. Additionally, this permits each stage 110 to be sized differently from the other stages 110 in the pump 106. For example, it may be desirable to use a larger diffuser 118 and impeller 120 on the stage 110 closest to the suction end 112 to manage lower NPSH at the suction end. In higher pressure applications, the pump 106 may optionally include an external housing (not depicted) that reinforces the various components of the pump 106 against elevated internal pressures. In some embodiments, the pump 106 includes a plurality of pump stages 110 and each diffuser 118 within the plurality of pump stages 110 is a different size than the other diffusers 118 within the pump 106.

[019] In some embodiments, the stages 110 are configured as large, mixed flow stages. Suitable stages 110 are found in vertical turbine pump applications often used in steam-based power generation facilities. The impellers 120 are designed to provide an increase in the pressure of the pumped fluid while minimizing cavitation. In other embodiments, the stages 110 are configured as radial flow stages or axial flow stages. In yet other embodiments, the pump 106 includes a combination of mixed flow stages 110, radial flow stages 110 and axial flow stages 110. In these embodiments, the diffusers 118 and impellers 120 within the stages 110 may be different sizes, and in particular, may have outer diameters that are different sizes.

[020] For example, a pump 106 might include a large radial flow “inducer” stage 110 adjacent the suction end 112, a small radial flow stage 110 downstream from the large

radial flow stage 110, a large mixed flow stage 110 downstream from the small radial flow stage 110, and a small mixed flow stage 110 downstream from the large mixed flow stage 110. In a modification of this embodiment, the pump 106 may further include one or more axial flow stages 110 downstream from the mixed flow stages 110

[021] In the embodiment depicted in FIG. 2, the priming module 206 of the horizontal pumping system 100 is a dry prime module 122. The dry prime module 122 is generally configured to evacuate air and other gases out of the intake line 202 so that the NPSHa at the suction end 112 matches the NPSHr for the initial stages 110. In exemplary embodiments, the dry prime module 122 includes a vacuum generator 124, a priming valve 126 positioned at or near the suction end 112, and a check valve 128 positioned at or near the discharge 114. The vacuum generator 124 may include a vacuum pump (shown in FIG. 2) or a compressor-driven venturi system (not shown in FIG. 2).

[022] The check valve 128 may be a conventional flapper-style valve that closes the discharge 114 when fluid is not being pumped through the horizontal pumping system 100, or when sufficient suction is applied by the vacuum generator 124 through the horizontal pumping system 100. When the vacuum generator 124 is activated, air in the horizontal pumping system 100 and intake line 202 is evacuated and vented to the atmosphere or storage tank. Once a sufficient negative pressure has been applied through the horizontal pumping system 100, liquid is drawn from the liquid source 200 to the suction end 112 through the intake line 202. When the liquid reaches the priming valve 126, a buoyant float within the priming valve 126 is lifted by the rising liquid level. The priming valve 126 can be configured to automatically throttle or turn off the vacuum generator 124, or to power on the motor 102 of the horizontal pumping system 100 to

initiate the pumping operation. In this way, the dry prime module 122 is well-suited to extend the operating range of the horizontal pumping system 100 to situations in which a suction lift condition is present at the suction end 112.

[023] Referring to FIG. 3, shown therein is an alternate embodiment in which the horizontal pumping system 100 includes a wet prime module 130 in place of, or in addition to, the dry prime module 122. The wet prime module 130 includes a priming reservoir 132 located at or above the suction end 112 that includes a volume of liquid sufficient to prime the horizontal pumping system 100. The priming reservoir 132 is connected to the suction end 112 with a priming line 134. A valve 136 on the priming line 134 controls the flow of fluid from the priming reservoir 132 to the suction end 112. The valve 136 can be manually or automatically controlled. In some embodiments, the wet prime module 130 includes a check valve (not shown) in the intake line 202 or suction end 112 that prevents priming fluid from draining out of the system. The priming reservoir 132 can be filled through a fill line 138 that is connected to the discharge 114 of the horizontal pumping system 100, or provided with priming fluid from an external source. Prior to startup, the valve 136 can be opened to flood the suction end 112 and the intake line 202. Once the system has been primed, the motor 102 can be energized to initiate the pumping operation. Once the horizontal pumping system 100 has been activated, the valve 136 can be closed to prevent further drainage from the wet prime module 130.

[024] In other embodiments, the wet prime module 130 may include an independent wet prime trash pump that feeds the suction end 112 of the horizontal pumping system directly from the liquid source 200.

[025] Thus, the surface pumping system 100 is well suited to pump large volumes of fluid between surface facilities under negative suction lift conditions. Suitable applications include the movement of fluids between storage containers, retention ponds and naturally occurring bodies of water. Because the surface pumping system 100 is configured for high volume operation, the surface pumping system 100 can also be used to provide the fluid feed on hydraulic fracturing operations from a sub-grade liquid source 200. In these applications, the surface pumping system 100 can be used to transfer “frac” fluid from a storage facility to the high pressure triplex pumps commonly used in hydraulic fracturing operations.

[026] It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and functions of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. It will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other systems without departing from the scope and spirit of the present invention.

What is claimed is:

1. A horizontal pumping system comprising:
a motor;
a pump driven by the motor, wherein the pump comprises:
a discharge on a first end of the pump;
a suction end on a second end of the pump, wherein the discharge is
between the suction end and the motor; and
a plurality of stages between the suction end and the discharge; and
a priming module.
2. The horizontal pumping system of claim 1, wherein the priming module comprises a dry priming module.
3. The horizontal pumping system of claim 2, wherein the dry priming module comprises:
a priming valve positioned at or near the suction end;
a vacuum generator connected to the priming valve; and
a check valve positioned at or near the discharge end.
4. The horizontal pumping system of claim 3, wherein the vacuum generator comprises a vacuum pump.
5. The horizontal pumping system of claim 3, wherein the vacuum generator comprises a compressed air driven venturi.

6. The horizontal pumping system of claim 1, wherein the priming module comprises a wet priming module.

7. The horizontal pumping system of claim 6, wherein the wet priming module comprises:

a priming reservoir; and

a priming line connected between the priming reservoir and the suction end.

8. The horizontal pumping system of claim 7, wherein the wet priming module further comprises a fill line connected between the priming reservoir and the discharge.

9. The horizontal pumping system of claim 1, wherein each of the plurality of stages comprises:

an impeller; and

a diffuser that encases the impeller, wherein each diffuser is an independent pressure vessel.

10. The horizontal pumping system of claim 1, wherein the horizontal pumping system further comprises a shaft assembly and wherein the shaft assembly is driven by the motor and wherein each impeller of the plurality of stages is connected to the shaft assembly.

11. A horizontal pumping system comprising:

a motor;

a pump driven by the motor, wherein the pump comprises:

a discharge on a first end of the pump;
a suction end on a second end of the pump, wherein the discharge is
between the suction end and the motor; and
a plurality of stages between the suction end and the discharge, wherein
each of the plurality of stages comprises:
a diffuser, wherein each diffuser is an independent pressure vessel;
and
an impeller within the diffuser; and
a priming module, wherein the priming module is configured to supply liquid to
the suction end of the pump.

12. The horizontal pumping system of claim 11, wherein the plurality of stages comprise:

one or more radial flow stages; and
one or more mixed flow stages.

13. The horizontal pumping system of claim 12, wherein the plurality of stages further comprises one or more axial flow stages.

14. The horizontal pumping system of claim 11, wherein a first one of the plurality of stages comprises a first impeller and a second one of the plurality of stages comprises a second impeller that has a smaller outer diameter than the first impeller.

15. The horizontal pumping system of claim 11, wherein the priming module comprises a dry priming module.

16. The horizontal pumping system of claim 15, wherein the dry priming module comprises:

- a priming valve positioned at or near the suction end;
- a vacuum generator connected to the priming valve; and
- a check valve positioned at or near the discharge end.

17. The horizontal pumping system of claim 11, wherein the priming module comprises a wet priming module.

18. The horizontal pumping system of claim 11, wherein the horizontal pumping system further comprises a shaft assembly and wherein the shaft assembly is driven by the motor and wherein each impeller of the plurality of stages is connected to the shaft assembly.

19. The horizontal pumping system of claim 18, wherein the horizontal pumping system further comprises a shaft seal module, wherein the shaft seal module is connected to the discharge of the pump and wherein the shaft assembly passes through the shaft seal module.

20. A horizontal pumping system comprising:
a motor;
a pump driven by the motor, wherein the pump comprises:

- a discharge on a first end of the pump;
- a suction end on a second end of the pump, wherein the discharge is
between the suction end and the motor;

a shaft seal module connected to the discharge, wherein the shaft seal module is between the discharge and the motor; and

a plurality of stages between the suction end and the discharge; and

a priming module, wherein the priming module is configured to supply liquid to the suction end of the pump.

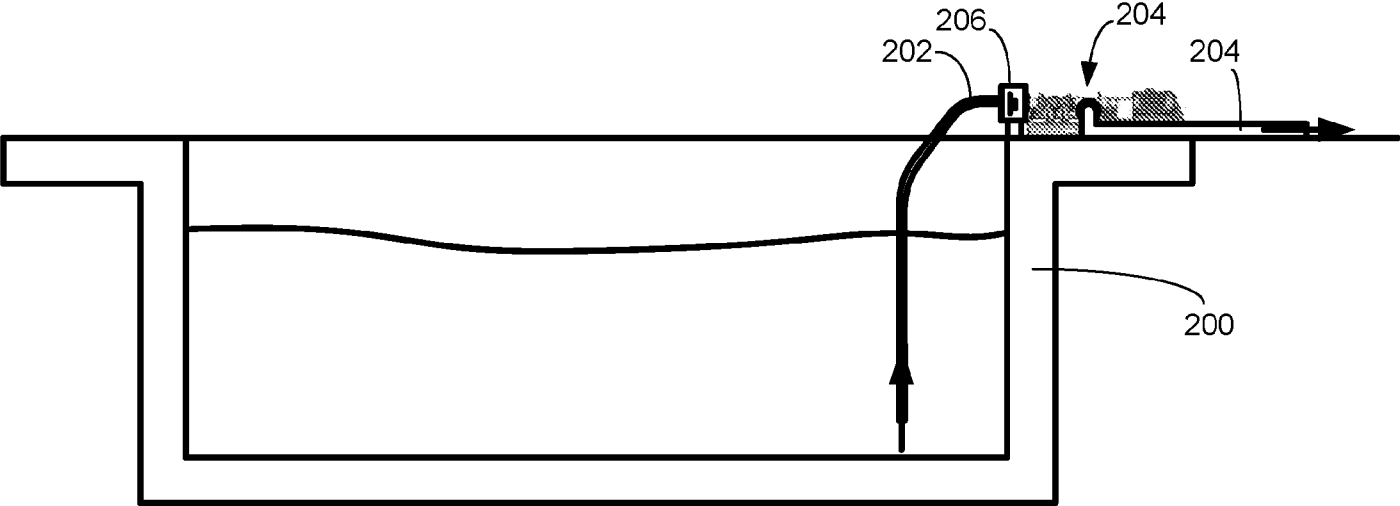


FIG. 1

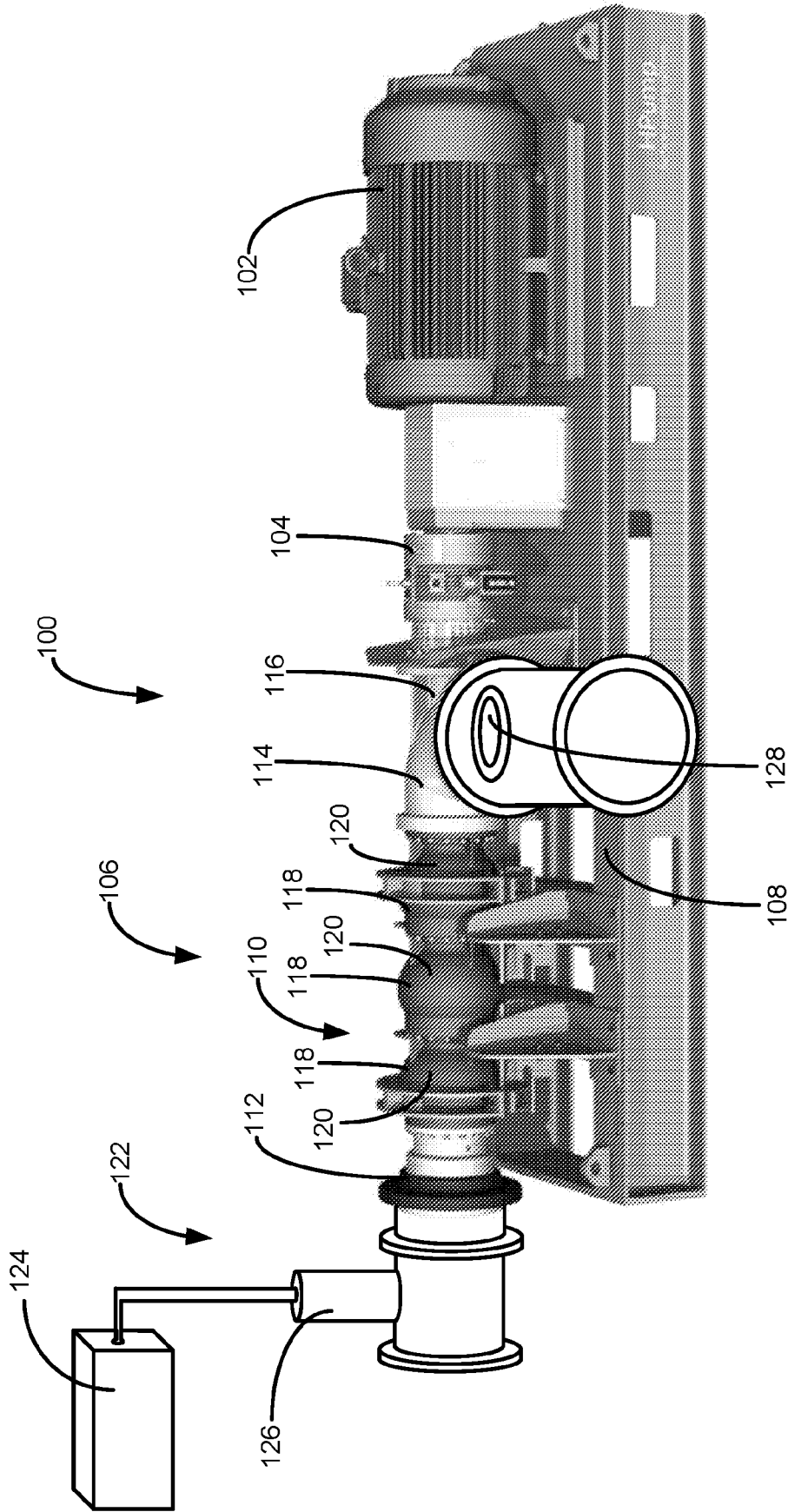


FIG. 2

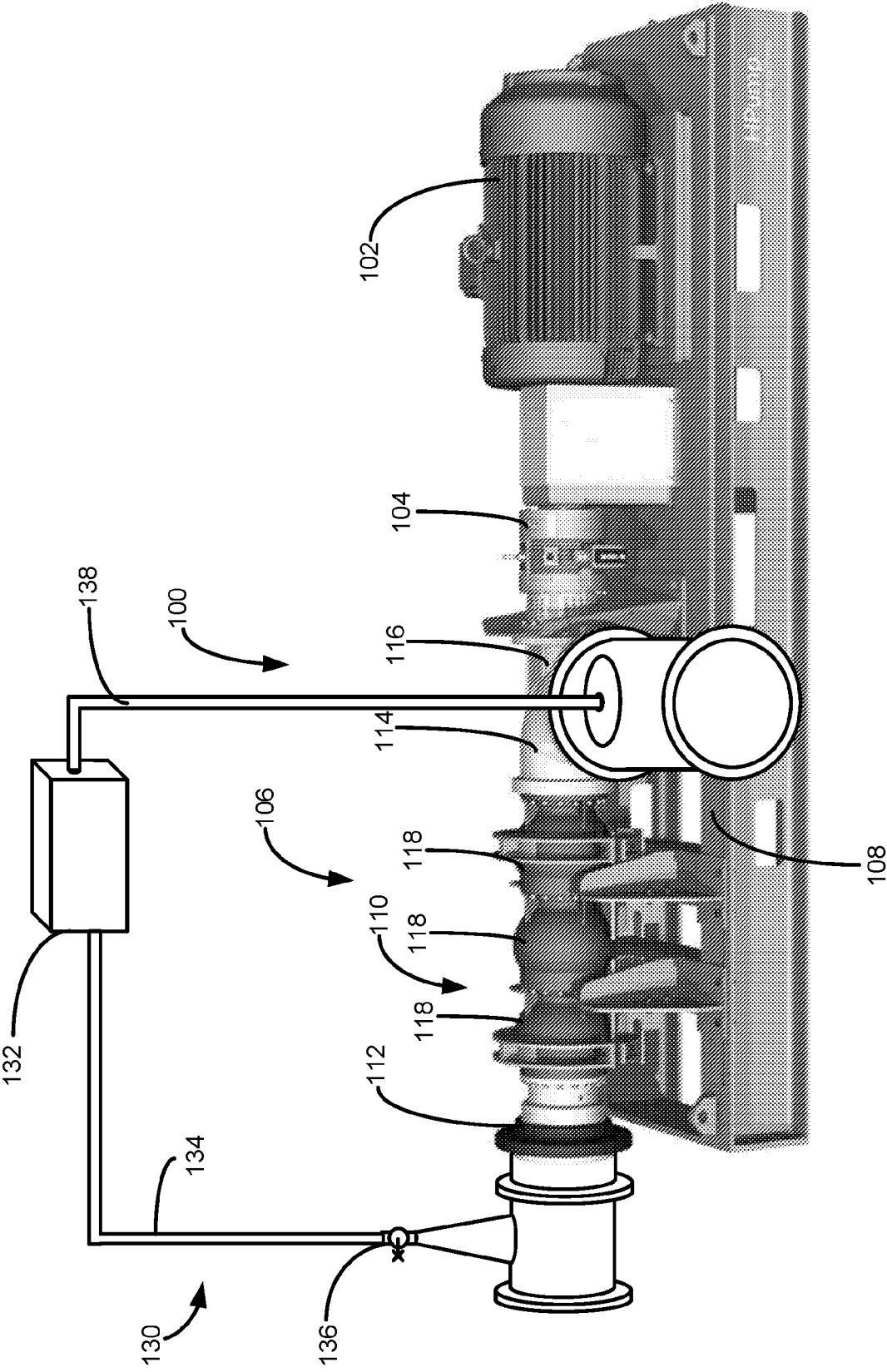


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US20/24821

A. CLASSIFICATION OF SUBJECT MATTER

IPC - F04C 15/00, 29/00, 2/00, 14/00, 14/10 (2020.01)

CPC - F04C 15/00, 29/00, 2/00, 14/00, 14/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	WO 2012/169904 A2 (TECHNIPUMP LIMITED) 13 December 2012; Figure 10; Page 10 Line 280-283	1, 6-7, 9-11, 14, 17-20
Y		2-5, 8, 12-13, 15, 16
Y	US 5,660,533 A (CARTWRIGHT, J) 26 August 1997; Figure 3	2-5, 8, 15, 16
Y	US 2012/0057965 A1 (BERGAMINI, L et al.) 08 March 2012; Figure 7; Paragraph [0038]	12, 13
A	US 8,998,586 B2 (MUHS, D) 07 April 2015; Entire Document	1-20

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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20 May 2020 (20.05.2020)

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