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- (54) Benævnelse: **FREMANGSMÅDE OG SYSTEM TIL INDSTILLING AF EN TURBINE VED ANVENDELSE AF EN HYDRAULISK VENTIL**
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DESCRIPTION

TECHNICAL FIELD

[0001] The present invention relates generally to turbines, and, more specifically, to a method and system for controlling an amount of fluid in a control cavity using a hydraulically controlled secondary valve.

BACKGROUND

[0002] A Turbocharger according to the preamble of claim 1 is generally known from EP 0 086 466 A.

[0003] Furthermore, FR 1 337 654 A describes a turbocharger having a turbine impeller in a housing. Said housing has an inlet in fluid communication with the impeller as well as a bypass channel fluidly connecting the inlet with an outlet of said turbine housing. Said bypass channel is selectively opened and closed by means of a membrane actuated bypass valve on the basis of the pressure in the air suction channel of said turbocharger. Turbochargers are used for many applications. A turbocharger includes a pump portion and a turbine portion. Turbochargers are used for recovering energy from a pressurized stream of fluid. Excessive pressure in the turbine portion is used to drive the pump portion. One use for a turbocharger is recovering energy from a brine outlet of a reverse osmosis membrane assembly.

[0004] Reverse osmosis systems operate in a wide range of operating conditions for any given flow while seeking to maintain a high level of performance. Various turbine configurations are known for improving levels of performance for the turbine.

[0005] In one known turbine, single volute nozzle volute systems use a valve stem to allow bypass fluid from the turbine inlet to the impeller. Some improvement in performance is achieved. A valve is used to control the amount of fluid in the bypass. Manually controlled valves require a person to physically move the control wheel using high torque. This is not practical especially in systems with multiple stages. Electrically controlled valves can be automated. However, due to the high torque involved in turning the valves, the systems for rotating the valves are expensive.

SUMMARY

[0006] The present invention provides a turbine comprising the features of claim 1 as well as a method of operating a turbine comprising the features of claim 5.

[0007] The design of the turbine allows for controlling an amount of fluid entering a control volume using a hydraulically controlled valve in a bypass path.

[0008] In one aspect of the invention a turbine includes a housing having an inlet, a volute and an outlet. The inlet is coupled to the volute through a primary fluid path and a secondary fluid path. The turbine further includes an impeller rotatably coupled to the housing, and a hydraulically actuated valve assembly disposed within the secondary fluid path selectively communicating fluid from the inlet to the volute. The turbine includes a hydraulic actuator coupled to the valve assembly moving the valve assembly from a first position communicating fluid from the inlet into the volute to a second position blocking flow from the inlet to the volute.

[0009] In another aspect of the invention method of operating a turbine includes communicating fluid from an inlet of the turbine to a volute through a primary fluid path and selectively communicating fluid from the inlet of the turbine to the volute through a secondary path fluid path through a hydraulically controlled valve assembly. The hydraulically controlled valve assembly comprises a housing and a piston head defining a control cavity and a valve stem having a valve head thereon. The method further comprises communicating fluid to the control cavity, moving the valve head relative to a valve seat, and changing an amount of fluid flowing through the primary fluid path to the volute in response to communicating fluid to the control cavity.

[0010] Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present invention.

DRAWINGS

[0011] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present invention in any way.

FIG. 1A is a block diagrammatic view of a reverse osmosis system that includes a turbocharger.

FIG. 1B is a block diagrammatic view of the turbocharger of Figure 1A.

FIG. 1C is a block diagrammatic view of a turbocharger and motor assembly referred to as a HEMI.

FIG. 2A is a perspective view of the hydraulic valve assembly on a turbocharger according to the present invention.

FIG. 2B is an exploded view of the of the hydraulic valve assembly of the turbocharger according to the present invention.

FIG. 3 is a cutaway perspective view of the turbocharger and valve assembly.

FIG. 4 is a cutaway view of the hydraulic valve assembly according to the present invention.

FIG. 5A is a schematic view of a control circuit for control of the hydraulically actuated valve assembly in a closed position.

FIG. 5B is a schematic view of a control circuit for control of the hydraulically actuated valve assembly in an open position.

DETAILED DESCRIPTION

[0012] The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical or. It should be understood that steps within a method may be executed in different order without altering the principles of the present disclosure.

[0013] The present invention improves the hydraulic range of a turbine by allowing a variable amount of fluid to be communicated to the volute. The turbine has a primary fluid path and a secondary fluid path for communicating fluid from the inlet to the volute. The primary path is always open. As will be described below, a hydraulically actuated valve is attached to the turbine housing and opens and closes (including positions therebetween) a secondary fluid path from the inlet to the volute

[0014] The turbocharger described below may be used for various types of systems, including a reverse osmosis system. Non-hydraulic applications such as natural gas processing are also possible. Further, the valves used in the turbocharger may be controlled based upon various process parameters.

[0015] Referring now to Figure 1A, a reverse osmosis system 10 that includes a turbocharger 12 is set forth. In this example, feed fluid from an input manifold 14 is communicated through a high pressure pump 16 which in turn is communicated to a membrane housing 18 through the turbocharger 12. The membrane housing 18 includes a reverse osmosis membrane 20 that is used to generate fresh water from sea water. Fresh water is generated at the permeate output 22 of the membrane housing. A brine stream from the membrane housing is directed to an inlet 24 of the turbocharger 12 through a brine control valve 25 selectively communicates the fluid from the turbocharger 12 to the membrane housing 18. The turbocharger 12 uses the energy from the high pressure brine stream to increase feed fluid pressure. The pressurized feed fluid from the high pressure pump 16 is received through a pump input 26. The turbocharger 12 increases the pressure of the feed fluid and increases the pressure of the feed fluid at the pump output 28. Waste from the turbocharger 12 is discharged at a lower

pressure through the turbocharger outlet 30. Although one specific example of a reverse osmosis system 10 is illustrated, various examples for reverse osmosis systems will be evident to those skilled in the art. By providing the turbocharger 12, the required pressure from the high pressure pump is reduced and the overall energy consumed by the system is also reduced as compared to a system without the turbocharger 12.

[0016] Referring now to Figure 1B, the turbocharger 12 is illustrated in further detail. The turbocharger 12 includes a turbine portion 40 and a pump portion 42. The turbine portion 40 recovers energy from the high pressure stream by rotating and ultimately rotating the components within the pump portion 42. The pump is used to increase the pressure of fluid to the input of the membrane housing 18.

[0017] Referring now to Figure 1C, the turbocharger 12 may also be incorporated into a system that includes a common shaft 50 that extends not only through the pump and turbine portion illustrated in Figure 1B but extends to a motor 52. The motor 52 includes a controller 54 the addition of the motor 52 allows the turbocharger to act as a pump when desired. The controller 54 may be used to drive the motor 52. The controller 54 may be referred to as a variable frequency device. The motor 52 may also act as a generator to recover the excess power generated.

[0018] Referring now to Figures 2A and 2B, an assembled view and an exploded view of a turbocharger 12 is illustrated. In this example, the turbine portion 40 and a pump portion 42 having a common shaft 50 therebetween (as denoted by the dotted line). The turbine portion 40 includes a turbine housing assembly 202 and a hydraulically controlled valve assembly 204. The turbine housing assembly 202 includes the brine stream the inlet 24. The turbine outlet 30 is not illustrated in the perspective of Figure 2A.

[0019] The hydraulically controlled valve assembly 204 has a piston housing 206 coupled to the turbine housing assembly 202 and an end cap 208. Fasteners 209 may be used to secure the end cap 208 to the piston housing 206.

[0020] The hydraulically controlled valve assembly 204 has a linear guide 210 that is in physical communication with a position sensor 212 and which extends through the end cap 208. The linear guide 210 is movable in a direction parallel with the direction of movement of a piston head 216 and valve stem 218 that is coupled thereto. The linear guide 210 may extend into the hydraulically controlled valve assembly 204 a varying amount.

[0021] The position sensor 212 may be coupled to the housing 202 with a holder 214. The position sensor 212 may be various types of sensors used to determine the relative position of the linear guide 210. The position sensor 212 generates a position signal corresponding to the linear position. The position sensor 212 may, for example, be formed of a linear potentiometer that changes an output signal or voltage based upon the position of the linear guide 210. The position sensor 212 may also be a linear encoder that provides the relative position of the linear guide 210 to a controller as described below. The position sensor 212 may also be

comprised of a limit switch if exact positions of the system are not required. Details of the movement of the linear guide 210 and the position sensor 212 will be described in more detail below.

[0022] The valve stem 218 is coupled to the piston head 216 and moves together therewith during use. The housing comprises a valve guide 220. The valve guide 220 may be integrally formed with the piston housing 206. The valve guide 220 positions the valve stem 218 so that the valve head 222 is positioned in the desired position relative to a valve seat as is described below.

[0023] Referring now to Figure 3, an end view of the turbine assembly 200 illustrating the turbine housing assembly 202, the volute 232, the hydraulically controlled valve assembly 204 and the inlet 24 are set forth in an assembled manner. The hydraulically controlled valve assembly 204 is set forth without the position sensor 212, guide 210 and the holder 214 for simplicity.

[0024] The shaft 50 is coupled to and rotates with a turbine impeller 228. The shaft 50 represents the axis of rotation of the impeller 228. The shaft 50 may extend out of the turbine housing 202 into the pump portion 42 of the turbocharger as described above. The impeller 228 has impeller vanes 234 that are used to receive pressurized fluid and rotate the shaft 50.

[0025] The housing 202 has a primary fluid path 240 from the turbine inlet 24 to the volute 232. The primary fluid path 240 has a fixed width to allow fluid to pass therethrough. The primary fluid path 240 does not change. That is, fluid is always communicating therethrough during operation. A secondary fluid path 242 also communicates fluid from the inlet 24 to the volute 232. The secondary fluid path 242 has the hydraulic actuated valve assembly 204 disposed therein. The hydraulically controlled valve assembly 204 is used to selectively move between an opened and closed position in the secondary fluid path 242. Thus, the valve assembly 204 may be partially opened or closed. The hydraulically controlled valve assembly 204 is illustrated in an open position. However, as the valve stem 218 moves, the valve head 222 contacts the valve seat 252. The valve seat 252 may be formed as part of the housing 202.

[0026] Referring now to Figure 4, details of the hydraulically controlled valve assembly 204 is set forth. In this example, the piston head 216 and the valve stem 218 moves in the direction indicated by the arrows 410, which corresponds to the longitudinal axis of the valve assembly 204. The linear guide 210 that moves the position sensor 212 also moves in the direction indicated by the arrows 410. The linear guide 210 may have seals 412 that seal a control cavity 414 from the external environment to prevent leakage. The piston head 216 may also include seals 416. The seals 416 may be referred to as piston rings. The seals 416 prevent fluid from within the control cavity 414 from leaking outside of the control cavity 414.

[0027] The piston head 216 divides the piston housing 206 into the control cavity 414 and a movement area 418 that allows the piston to travel back and forth and expand and contract the

control cavity 414.

[0028] An inlet port 420 is used to provide a control fluid to the control cavity 414. By providing a high pressure fluid to the control cavity 414, the control cavity 414 is expanded and the piston head 216 is moved toward the valve seat 252. When a low pressure fluid is provided to the control cavity 414, the piston head 216 moves toward the inlet port 420. This, in turn, moves the valve stem 218 and the valve head 222 away from the valve seat 252.

[0029] An exit port 422 is in fluid communication with the movement area 418. The inlet port 420 allows any air to escape the volume between the piston head 216 and the other part of the piston housing 206.

[0030] In an alternative embodiment, the exit port 422 may be used to provide high pressure into the movement area 418 while the inlet portion 420 is used as an inlet port for the control cavity 414 which is exposed to a low pressure. In this manner, the piston head 216 may be forced toward the inlet 420.

[0031] A plurality of seals 424 may be used to seal the valve stem 218 within the valve guide 220. The valve guide 220 may be sealed within the housing 202 with seals 426.

[0032] A control circuit 440 may be coupled to the inlet port 420. As mentioned briefly above, the control circuit 440 may also be coupled to the exit port 420. The control circuit 440 may be combination of valves that are electrically controlled to provide fluid paths to the control cavity 414 to control the movement of the piston head 216 and the valve stem 218 attached thereto. By controlling the movement of the valve stem 218, the opening and closing of the hydraulically controlled valve assembly 204 is controlled.

[0033] The valve head 222 may include an angular seal surface 426 that is used for engaging the seal seat 252 to form a seal therebetween. The seal prevents fluid flow through the secondary fluid path 242. An angular surface 428 may couple the valve stem 218 to the seal surface. The valve head 222 may also include a flat surface 430. In this example, the flat surface 430 is perpendicular to the longitudinal axis of the valve stem 218.

[0034] Referring now to Figure 5A, a simplified hydraulic control diagram is illustrated in which the control circuit 440 provides high pressure fluid to the control cavity 414. In this example, the valve head 222 is shown in a closed position. That is, the fluid from the inlet 24 does not travel through secondary fluid path 242 to the volute 232. In this example, valve 510 is in an open position to allow high pressure fluid from the high pressure source 508 into the control cavity 414 through the inlet port 420. The low pressure valve 512 is in a closed position. The high pressure valve or the low pressure valve may be a normally open valve for failsafe operation. When the high pressure valve is a normally open valve, the system will close the valve assembly 204 upon loss of power or control. If the low pressure valve 512 is replaced with a normally open valve, the system will open the secondary fluid path 242 upon loss of system power or shutdown. The choice between which valve is normally open is based on

design considerations.

[0035] A controller 514 controls the operation of the valves 510, 512. During operation, typically either the high pressure valve 510 or the low pressure valve 512 is open to allow a varying amount of fluid to pass through the valve assembly 204 and through the fluid path 242. However, during a cleaning process or other type of process, both valves 510 and 512 may be opened. The controller 514 is in communication with a plurality of process sensors 520. The process sensors 520 may include the position sensor illustrated above. Other types of sensors such as temperature sensors, flow sensors, flow rate sensors, or the like may be used by the controller 514 to determine whether to open or close the high pressure valve 510 or the low pressure valve 512 to change the amount of fluid passing through the fluid path 242. It should be noted that both valves 510 and 512 may be closed when no change is desired in the position of the valve head 222 relative to the valve seat 252. From an at-rest position, the piston head 216, the valve stem 218 and valve head 222 may be moved by introducing high pressure fluid into the inlet port 420. To move the piston head 216 and valve head 222 toward the valve seat 252, low pressure may be exposed to the control cavity 414 through the low pressure valve 512.

[0036] Feedback control is achieved by periodically monitoring the process variables using the process sensors 520. The controller 514, in response to the process sensors 520, open and close the appropriate valves 510, 512 to change the opening between the valve head 222 and the valve seat 252. The process variables are described below:

P - Process variable, measured value.

S - Set point for process.

E - Current error (percent).

K - Proportional gain (~1, tunable value).

D - Deadband in percent (typically 1%).

T - Update time period (typically 5 seconds).

TO - Valve open time period.

TC - Valve close time period.

Loop Forever

$E = (P - S) / S$	Calculate error percentage
If $E > 1$ then $E = 1$	Limit error to range [-1..1]
If $E < -1$ then $E = -1$	
$TO = K E T$	Compute valve open time
$TC = T - TO$	Compute valve closed time
If $E > D$	Check for outside of deadband

Open V1 for time TO	Open V1 to close primary fluid path
Close V1 for time TC	
If $E < -D$,	Check for outside of deadband
Open V2 for time TO	Open V2 to open primary fluid path
Close V2 for time TC	

[0037] In the above algorithm the error percentage is calculated between a range of -1 and +1. The valve open time and the valve close time may be calculated using a proportional gain, a current error and an update. A deadband D may be compared to the current error. When the current error is outside of the deadband, the valve may be opened or closed. That is, when the error is greater than the deadband, valve 510 is opened to close the amount of the opening of valve assembly 204. When the error is less than the negative deadband, then the valve 512 is opened so that the piston moves toward the control port.

[0038] Referring now to Figure 5B, the piston 216 is illustrated toward the inlet port 420. To move the piston 216 toward the inlet port 420 as compared to that in Figure 5A, the high pressure valve is 510 is closed and the low pressure valve 512 is opened. This causes the valve head 222 to be in an open position to allow flow through the valve. A plurality of valve head positions may be achievable between the valve head positions illustrated in FIGS. 5A and 5B so that the flow through the fluid path 242 may be varied.

[0039] In both Figures 5A and 5B high pressure source 508 and the low pressure source 516 may be hydraulically coupled to the turbine portion. That is, the high pressure source 508 may be in fluidic communication with the turbine inlet 24 which is a high pressure source. The low pressure source 516 may be coupled to the turbine outlet 30 or even to the atmosphere.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- [EP0086466A \[0002\]](#)
- [FR1337654A \[0003\]](#)

Patentkrav

1. Turbine (40) i forbindelse med en højtryksskilde (508) og en lavtryksskilde (516)
5 omfattende:
et hus (202) med et indløb (24), en volut (232) og et udløb (30), hvor indløbet (24) er
sammenkoblet med volutten (232) gennem en primær fluidbane (240) og en sekundær
fluidbane (242); og
et skovlhjul (228), der er drejbart sammenkoblet med huset (202);
10 kendetegnet ved
en hydraulisk aktiveret ventilenhed (204) placeret inde i den sekundære fluidbane (242), der
selektivt forbinder fluid fra indløbet (24) med volutten (232), hvor ventilenheden (204)
omfatter et ventilhoved (222) placeret i forhold til et ventilsæde (252), der omfatter en flerhed
af ventilhovedpositioner mellem den første position og den anden position; og
15 en hydraulisk aktuator, der er sammenkoblet med højtryksskilden (508) og lavtryksskilden (516),
hvilken hydraulisk aktuator, der er sammenkoblet med den hydraulisk aktiverede ventilenhed
(204), bevæger den hydraulisk aktiverede ventilenhed (204) fra en første position, hvor fluid
forbindes fra indløbet (24) ind i volutten (232), til en anden position, hvor strømning blokeres
fra indløbet (24) til volutten (232) som reaktion på selektiv sammenkobling af højtryksskilden
20 (508) og lavtryksskilden (516) med den hydrauliske aktuator; hvor ventilenheden (204) omfatter
en ventilstamme (218), der er sammenkoblet med et stempel (216) inde i et stempelhus (206),
hvilket stempel (216) og stempelhus (206) definerer en styrekavitet (414) inde i stempelhuset
(206);
hvor styrekaviteten (414) er fluidmæssigt sammenkoblet med en port (420) gennem
25 stempelhuset (206);
hvor porten (420) er selektivt sammenkoblet via en første ventil (510) med en højtryksskilde
(508) og via en anden ventil (512) med en lavtryksskilde (516) for at bevæge stemplet (216)
inde i stempelhuset (206) og for at bevæge ventilstammen (218) i forhold til ventilsædet (252);
og
30 hvor turbinen (40) endvidere omfatter en positionssensor (212), der er sammenkoblet med
stemplet (216), og som genererer et positionssignal, og en styreenhed (514), der er
sammenkoblet med positionssensoren (212), hvilken styreenhed (514) styrer den første ventil
(510) og den anden ventil (512) som reaktion på positionssignalet.

2. Turbine ifølge krav 1, hvori den første ventil (510) omfatter en første normalt åben ventil og den anden ventil (512) omfatter en normalt åben ventil.

3. System, der omfatter:

5 turbinen (40) ifølge krav 1, der omfatter en aksel (50) og en pumpe (42), der er sammenkoblet med akslen (50).

4. System ifølge krav 3, der endvidere omfatter et omvendt osmosehus (18) i forbindelse med turbinen (40) og pumpen (42).

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5. Fremgangsmåde til anvendelse af en turbine (40) med et hus (202), hvilken fremgangsmåde omfatter:

at forbinde fluid fra et indløb (24) til turbinen (40) med en volut (232) gennem en primær fluidbane (240);

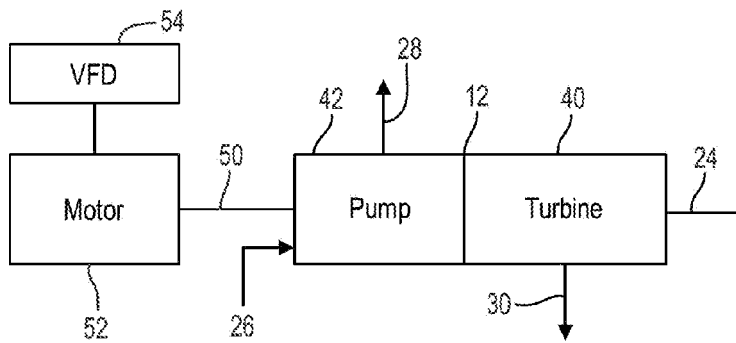
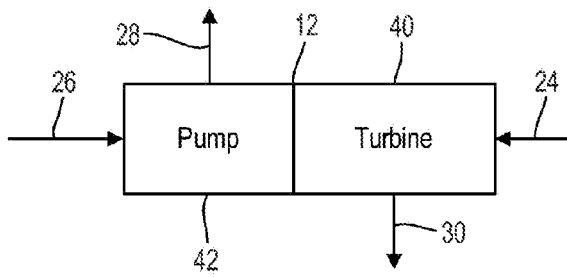
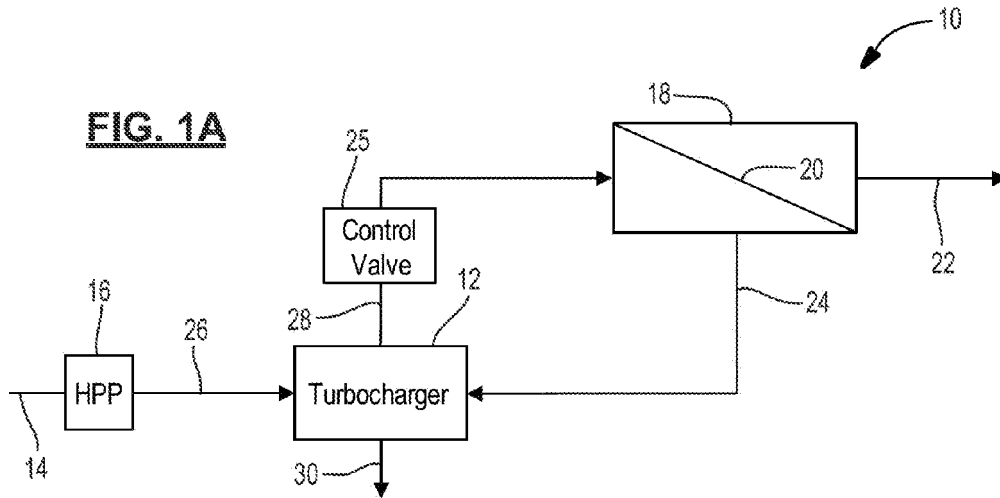
15 selektivt at forbinde fluid fra turbinens (40) indløb med volutten (232) gennem en sekundær fluidbane (242) gennem en hydraulisk styret ventilenhed (204), hvilken hydraulisk styret ventilenhed (204) omfatter et hus (206) og et stempelhoved (216), der definerer en styrekavitet (414), og en ventilstamme (218) med et ventilhoved (222) derpå, hvor styrekaviteten (414) er fluidmæssigt sammenkoblet med en port (420) gennem stempelhuset (206);

20 selektivt at forbinde fluid fra en højtrykskilde (508) via en højtryksventil (510) og porten (420) med styrekaviteten (414) og fra en lavtrykskilde (516) via en lavtryksventil (512) og porten (420) med styrekaviteten (414), hvorved ventilhovedet (222) bevæges i forhold til et ventilsæde (252);

25 generering af et positionssignal ved hjælp af en positionssensor (212), der sammenkoblet med stemplet (216); og

ændring af en mængde fluid, der strømmer gennem den anden fluidbane (242) til volutten (232) som reaktion på at forbinde fluid med styrekaviteten (414) ved styring af højtryksventilen (510) og lavtryksventilen (512) som reaktion på positionssignalet.

DRAWINGS



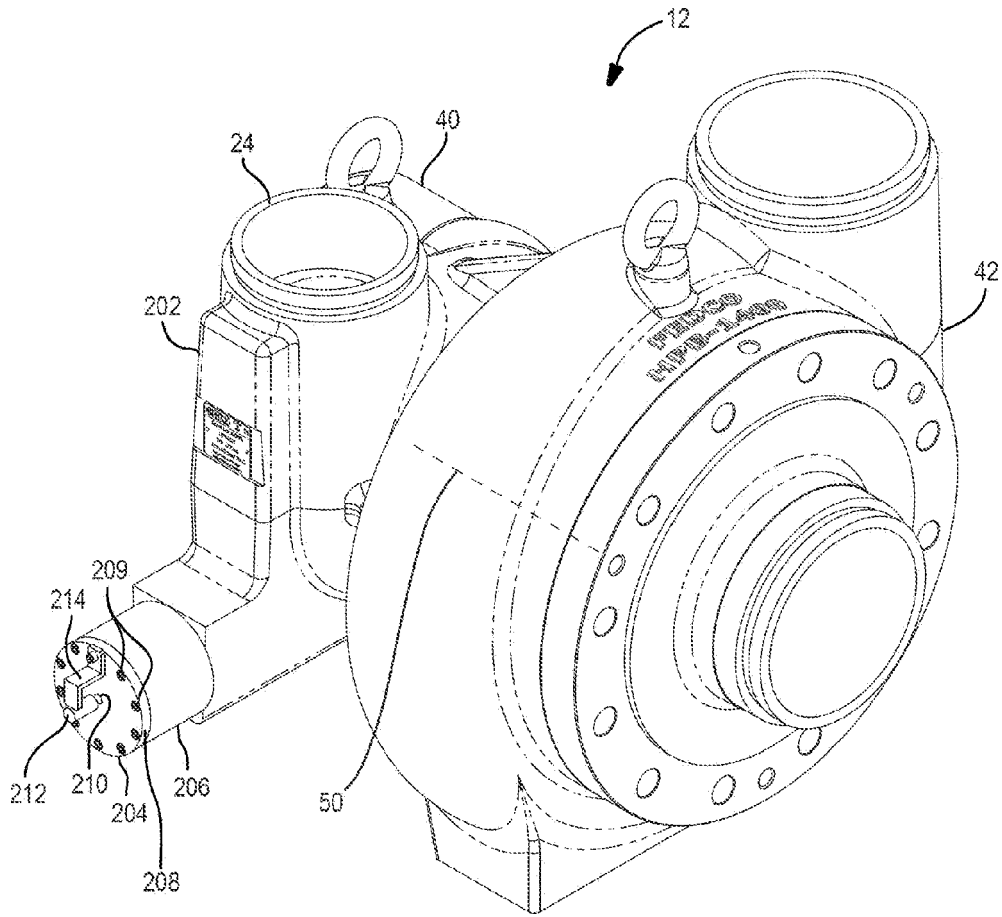


FIG.2A

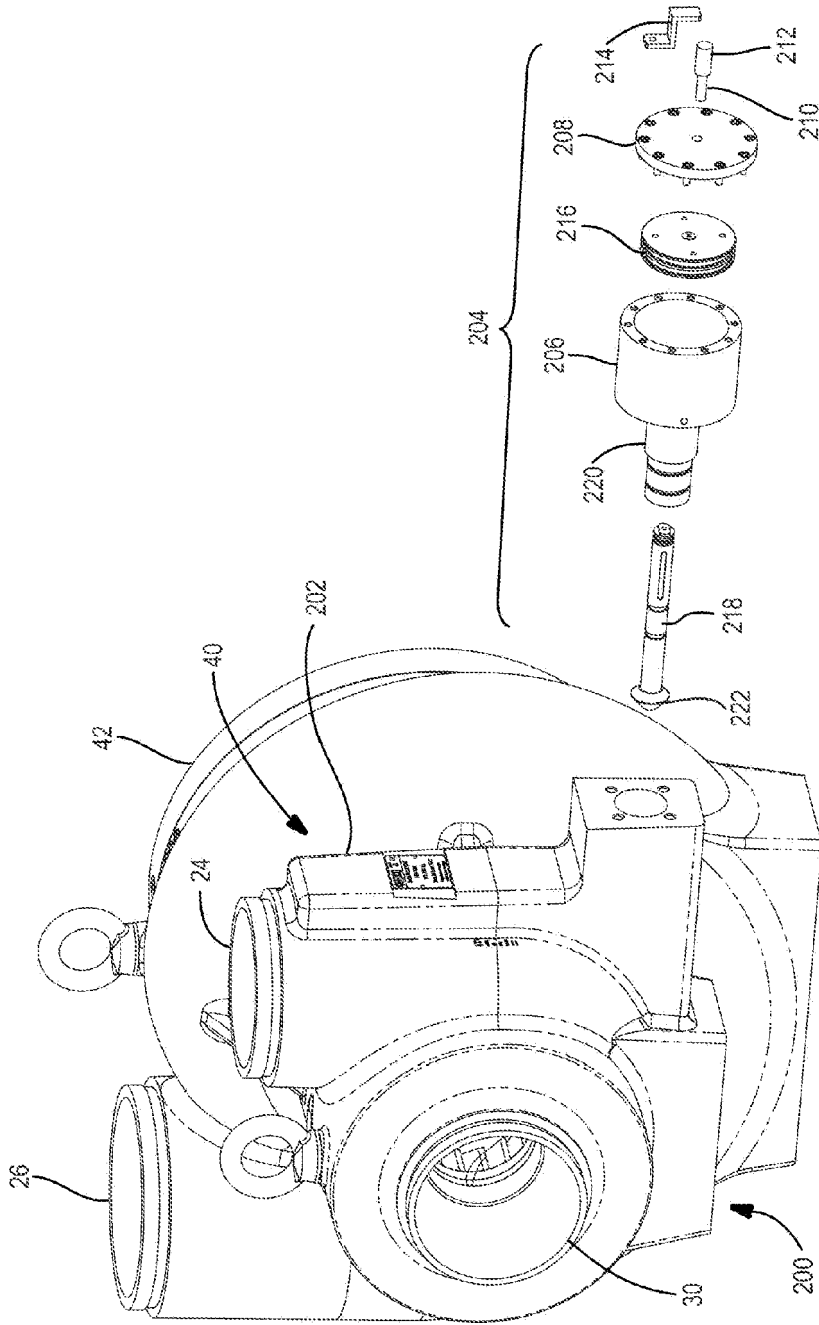


FIG. 2B

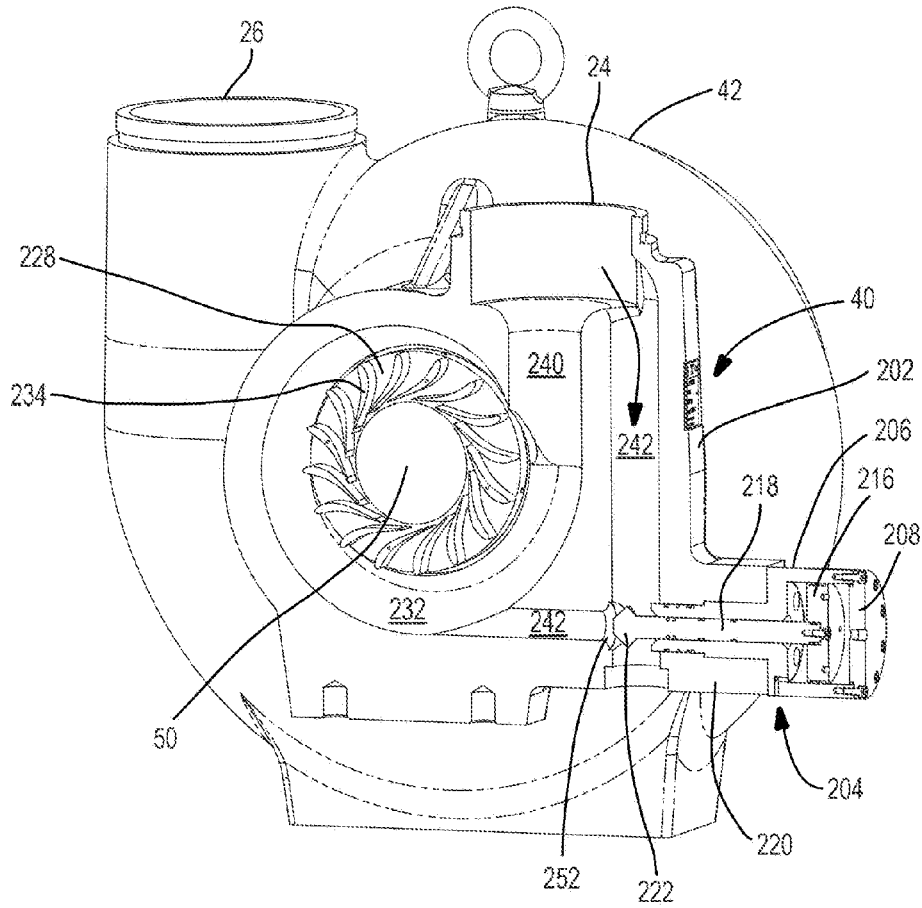


FIG. 3

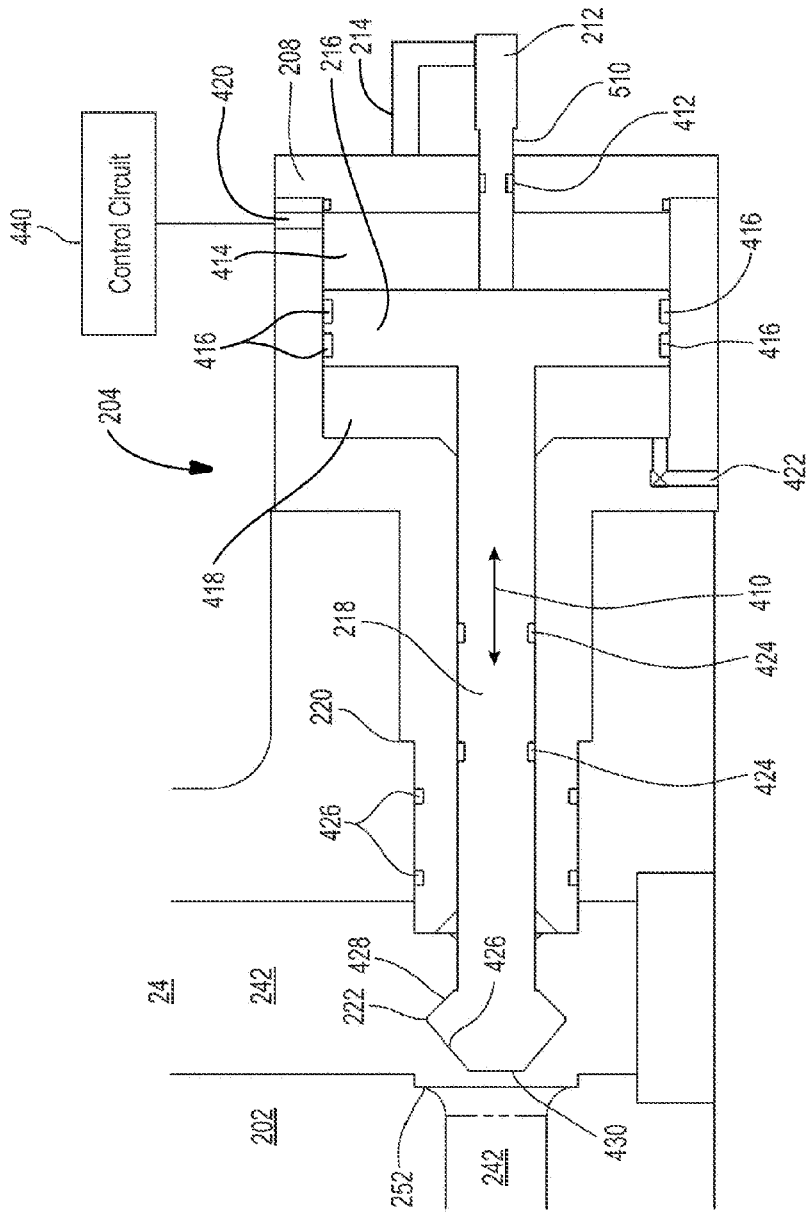


FIG. 4

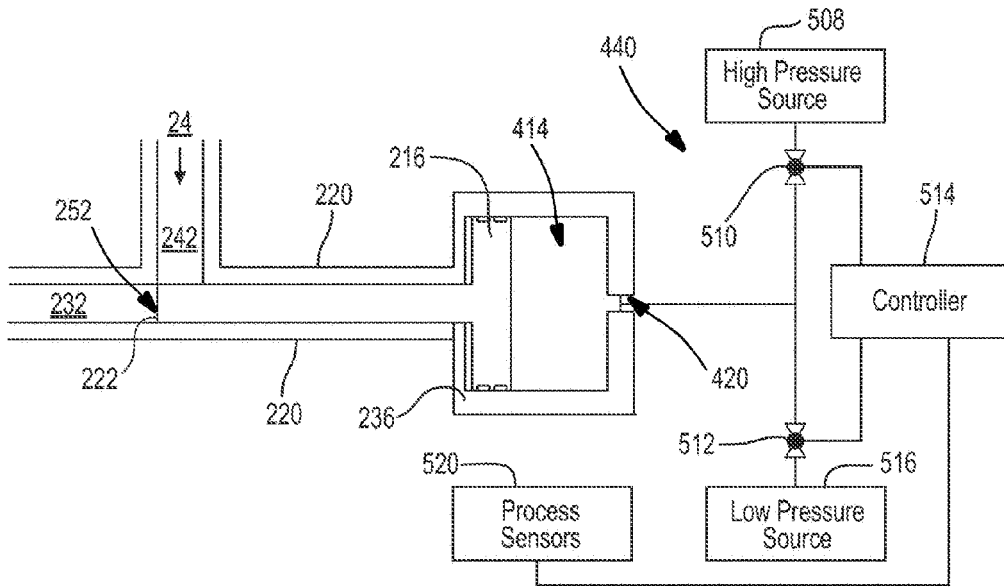


FIG. 5A

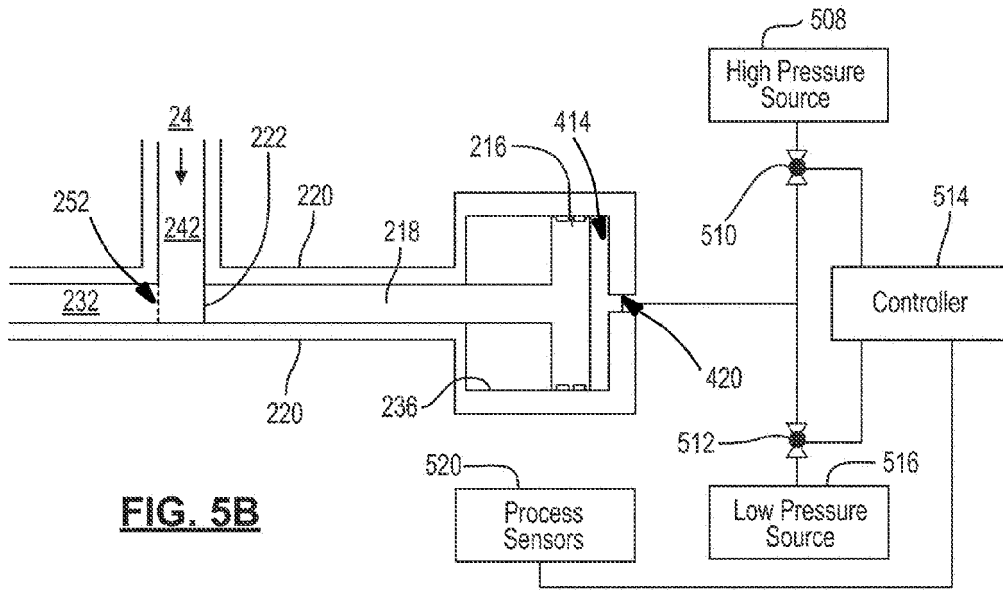


FIG. 5B