(12) **PATENT**

(11) **348925** (13) **B1**

NORWAY

(19) NO

(51) Int Cl.

E21B 34/02 (2006.01)
E21B 34/16 (2006.01)
F16K 31/04 (2006.01)
F16K 37/00 (2006.01)

Norwegian Industrial Property Office

(21)	Application nr.	20200975	(86)	International Filing Date and Application Number	
(22)	Date of Filing	2020.09.07	(85)	Date of Entry into National Phase	
(24)	Date of Effect	2020.09.07	(30)	Priority	
(41)	Publicly Available	2022.03.08			
(45)	Granted	2025.07.21			

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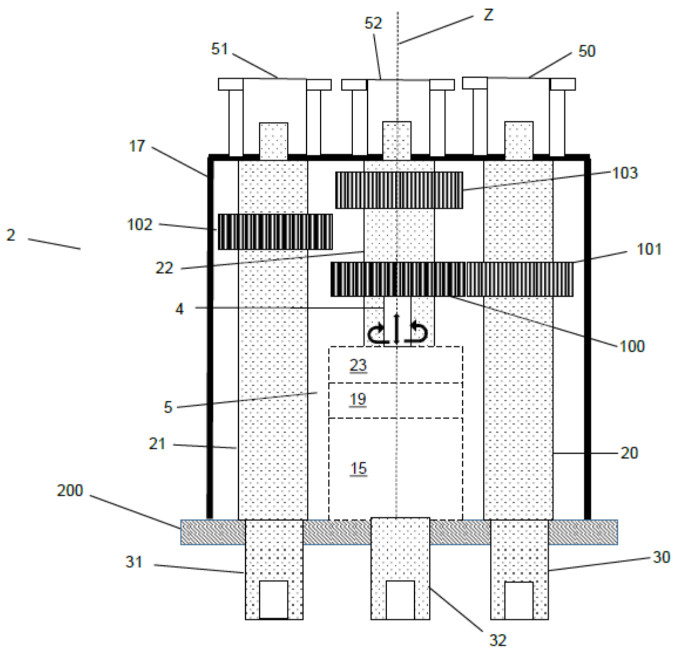
(54)	Title	**A hydrocarbon production manifold valve actuator and methods for installing or operating such a manifold actuator**
(56)	References Cited:	WO 2018/078397 A1, US 2004/0134665 A1, EP 2886916 A1, US 2010/0025610 A1, WO 2005/111484 A2, US 2009/0230338 A1, WO 2013/041842 A2
(57)	Abstract	

The present invention relates to a subsea manifold valve actuator 2, with a rotary actuator 19 rotating a drive gear 100 and a linear actuator 23 shifting the drive gear 100 linearly between different positions in mesh with different driven gears 101, 102, 103, each operating a valve 20, 21, 22 of a subsea manifold for oil and gas. A valve actuator controller 15 is connected to the rotary actuator 19 and the linear actuator 23. Furthermore methods for operating and installing the subsea manifold valve actuator 2 are disclosed.



Manifolds for hydrocarbon wells are used to merge and control the flow of hydrocarbons from multiple wells and to inject fluids. The manifolds can be located subsea, topside or onshore.

The manifolds can utilize valves, such as branch valves and flowline header valves, to control fluid paths. Subsea manifold valves are typically operated individually by ROVs if not required to be remotely operated. Remote operated valves are traditionally hydraulically operated, and the hydraulic operated valves require hydraulic supply from host surface facilities through an umbilical and a nearby control module to distribute hydraulic supply to the different valves.

WO 2018/078397 A1 describes an actuator for adjusting a pilot valve in a gas supply regulator. The actuator comprises a drive electric motor configured to provide rotational movement to a first drive shaft, an emergency electric motor configured to provide rotational movement to a second drive shaft, a differential gear arrangement coupled to the first drive shaft and coupled to the second drive shaft and configured to generate rotational movement of an actuator drive shaft from the rotational movement provided by one of the first drive shaft and the second drive shaft, and a rotary to linear device coupled to the actuator drive shaft and configured to convert rotational movement of the actuator drive shaft into a linear movement for adjusting the pressure valve. The differential gear arrangement is configured to drive the actuator drive shaft when one of the drive electric motor or the emergency electric motor is powered to provide a drive torque to one of the first drive shaft or the second drive shaft and the other of the drive electric motor and the emergency electric motor unpowered. By configuring a back drive torque of each of the drive electric motor and the emergency electric motor with respect to a resistive torque of the actuator drive shaft and the drive torques provided by the drive electric motor and the emergency electric motor, where the drive electric motor and the emergency electric motor can be permanently connected to the actuator drive shaft through the differential gear arrangement, which obviates a requirement for a latching or braking arrangement.

US 2004/0134665 A1 teaches an electrical actuator particularly suited for driving a wellhead valve for regulating the flow of natural gas from a production well. The electrical actuator can be driven using the existing local power supply in wellhead valve systems, typically a solar panel and a battery. The electrical actuator may include a gear reduction train, a brake and a manual input override with clutch protection. The electrical actuator can be configured in three different operational modes that provides a predetermined position upon power loss including: fail-bias fixed, fail open and fail bias closed.

EP 2 886 916 A1 concerns a valve having a balancing function for a fluid distribution system. A valve closing member is movable between a closed position and a fully opened position. An actuation device is provided for changing the position of the valve closing member. A control unit is provided and comprises an electronic memory adapted to receive and store an opening limitation value, said opening limitation value being representative of a selected intermediate position between said closed position and said fully opened position of the valve closing member, wherein the control unit controls the actuation device to limit the movement of the valve closing member to positions from said closed position to said selected intermediate position. The invention also relates to a valve system and to a method of operating a valve.

It is an object of the present invention to provide a remotely controlled actuator located on the manifold to operate multiple valves and to avoid ROV operation or hydraulically operated valves that require hydraulic supply and a nearby control module.

The main features of the present invention are given in the independent claims. Additional features of the invention are given in the dependent claims.

The invention relates to a hydrocarbon production manifold valve actuator including a rotary actuator in driving relationship with a drive gear, a linear actuator adapted to shift the drive gear linearly along an axis of rotation of the drive gear between a first position in mesh with a first driven gear connected to a first valve operating shaft operating a first valve, and at least a second position in mesh with a second driven gear connected to a second valve operating shaft operating a second valve, and a valve actuator controller connected to the rotary actuator and the linear actuator.

The invention further relates to said valve actuator, wherein the linear actuator further is adapted to shift the drive gear linearly along the axis of rotation of the drive gear to a third position in mesh with a third driven gear connected to a third valve operating shaft operating a third valve.

The invention further relates to said valve actuator, wherein each valve operating shaft is connected to a valve socket adapted to fit onto and engage each of the valves to be operated.

The invention further relates to said valve actuator, wherein each valve operating shaft is connected to a auxiliary coupling adapted to be operated by an override tool.

The invention further relates to said valve actuator, wherein the number of valves each being in driving relationship with a driven gear corresponds to a number of positions of the drive gear linearly along the axis of rotation.

The invention further relates to said valve actuator, wherein a drive gear shaft extends between the rotary actuator and the drive gear, and wherein the linear actuator is adapted to move the drive gear along a rotational axis of the drive gear shaft.

The invention further relates to said valve actuator, wherein a drive gear shaft extends between the rotary actuator and the drive gear, and wherein the linear actuator is adapted to move the drive gear shaft and the drive gear along an axis of rotation of the drive gear shaft.

The invention further relates to said valve actuator, wherein the valve actuator further includes an actuator base and a housing fixed to the actuator base providing a watertight room which may be filled with a liquid.

The invention further relates to said valve actuator further including a controller, a force sensor and a position sensor monitoring the linear actuator, adapted to feed input to the controller, and a torque sensor and a rotation sensor monitoring the rotary actuator, adapted to feed input to the controller.

The invention further relates to a method of operating said valve actuator including the steps of identifying a need for actuating one of the at least two valves, actuating the linear actuator to shift the drive gear linearly along the axis of rotation of the drive gear in mesh with the driven gear of the identified valve, and actuating the rotary actuator to operate the identified valve.

The invention further relates to said method of operating said valve actuator, wherein the step of actuating the rotary actuator to operate the identified valve is replaced with the step of actuating an auxiliary coupling to operate the identified valve.

The invention further relates to said method of operating said valve actuator, wherein the step of actuating the linear actuator to position the drive gear in mesh with the driven gear of the identified valve includes feeding a signal from a force and a position sensor to a controller.

The invention also relates to a method of installing said valve actuator including the steps of landing the valve actuator and engaging at least two valves on a subsea hydrocarbon production manifold, identifying a need for actuating one of the at least two valves, positioning the drive gear in mesh with the driven gear of the identified valve and operating the valves.

The mentioned valve actuator may also be used on a subsea hydrocarbon fluid recovery manifold.

Brief description of the drawings:

Fig. 1 is an exploded perspective view of a manifold according to prior art;

Fig. 2 is a top elevation of the manifold of Fig. 1 in an assembled state;

Fig. 3 is a schematic representation of an embodiment of the invention in a top elevation;

Fig. 4 is a schematic representation of an embodiment of the invention in a side view where a drive gear is engaged with a first driven gear;

Fig. 5 is a schematic representation of an alternative embodiment of the invention from a side view where a drive gear is engaged with a second driven gear;

Fig. 6 is a schematic representation of an alternative embodiment of the invention in a side view where a drive gear is engaged with a third driven gear;

Fig. 7 is a schematic representation of an alternative embodiment of the invention in a side view landed on three manifold valve torque interfaces;

Fig. 8 is a schematic representation of an actuator system of the invention.

Detailed description of embodiments of the invention with reference to the drawings:

Fig. 1 is an exploded perspective view of a subsea hydrocarbon production manifold 1 according to prior art. The subsea hydrocarbon production manifold 1 includes four header configuration blocks. Each header configuration block comprises a group three parallel branch valves: a first branch valve of a production header 10, a second branch valve of a production header 11 and a branch valve of a service header 12. These branch valves are located in a proximity of each other in a triangle formation.

Fig. 1 serves as an example of a subsea hydrocarbon production manifold 1 having at least one group of valves. The valves in the group are located in proximity to each other.

Fig. 2 is a top elevation of the manifold of Fig. 1 as assembled.

Fig. 3 is a schematic representation of a gear configuration of the invention comprising, a first valve operating shaft 20, a second valve operating shaft 21, and a third valve operating shaft 22 located in a proximity to each other in a triangle formation. Fig. 3 further shows three driven gears operating the valve operating shafts. A first driven gear 101 operates the first valve operating shaft 20, a second driven gear 102 operates the second valve operating shaft 21, and a third driven gear 103 operates the third valve operating shaft 22. A drive gear 100 of a drive assembly (not shown) is located between the three driven gears. The drive gear 100 is positioned to engage each of the driven gears individually. When engaged, the drive gear 100 is rotated, to rotate each of the driven gears and thereby rotating the valve operating shafts. The driven gears are preferably engaged individually, but the drive gear 100 may be designed to engage more than one driven gear at a time. The driven gears may have different diameters. The teeth of the drive gear 100 are sized to mesh with the teeth of the driven gears, although the schematic representation may deviate from this perception.

Fig. 4 is a side view of the valve actuator 2 of the invention. A drive assembly 5 is located between a first valve operating shaft 20, a second valve operating shaft 21 and a third valve operating shaft 22. A gear shaft 4 is connected to a drive gear 100 and to the drive assembly 5. A first driven gear 101 connected to the first valve operating shaft 20 is located below a second driven gear 102 connected to the second valve operating shaft 21 which is located below a third driven gear 103 connected to a third valve operating shaft 22. The thickness of the driven gears do not overlap along a vertical axis Z extending along the gear shaft 4. The drive assembly 5 includes a linear actuator 23 moving the gear shaft 4 to a specific position to allow the drive gear 100 to engage any of the driven gears. The gear shaft 4 is oriented in parallel with the valve operating shafts 20, 21 and 22. The drive assembly 5 further includes a rotary actuator 19 to rotate the gear shaft 4 to rotate any of the driven gears via the drive gear 100. The drive assembly 5 also includes an actuator controller 15 which is connected to the rotary actuator 19 and the linear actuator 23. The diameter of the drive gear 100 is dimensioned to allow the drive gear 100 to mesh with and thereby operate any of the driven gears. Figure 4 shows an embodiment where the drive gear 100 is engaged with the first driven gear 101. The ends of teeth of the gears may be tapered to facilitate axial movement between the gears and to ensure that the driven gears not prevent the axial movement of the drive gear 100.

The valve operating shafts are connected to auxiliary couplings adapted to be engaged by an override tool in order to override the valve actuator 2. The first valve operating shaft 20 is connected to a first auxiliary coupling 50, the second valve operating shaft 21 is connected to a second auxiliary coupling 51 and the third valve operating shaft 22 is connected to a third auxiliary coupling 52. An ROV may operate the valve actuator 2 by engaging and rotating any of the auxiliary couplings. The auxiliary couplings may be a bucket type coupling adapted to receive a corresponding socket of an ROV override tool.

The valve operating shafts are connected to valve sockets adapted to engage valves. The first valve operating shaft 20 is connected to a first valve socket 30, the second valve operating shaft 21 is connected to a second valve socket 31 and the third valve operating shaft 22 is connected to a third valve socket 32. The valve actuator 2 may be permanently installed on valves on a manifold, in order to operate the valves. The valve actuator 2 may also be retrofitted to the valves on the manifold. The valve actuator 2 may also be removed from the valves on the manifold. Each valve socket is adapted to fit onto and engage a valve stem. Each valve (40, 41, 42) is equipped with a coupling fixed to the end of a valve stem of the valve (see Fig. 7). Each coupling is adapted to connect to the valve sockets (30, 31, 32). The couplings may be bucket type couplings (400, 410, 420) adapted to receive a valve socket (30, 31, 32) of the valve actuator 2 (see Fig. 7). When a valve socket is fitted onto and engaged with a valve by means of its coupling, the motor gear 100 is rotated, to rotate a valve operating shaft, rotating the valve socket connected to the valve operating shaft, and thereby rotating the engaged valve. The valve actuator 2 is adapted to engage the at least two valves. The valves may be any conventional valve type, and the valves may be branch valves with valve housings extending from the manifold as shown in Fig. 1. Each valve controls fluid flow in the manifold.

The valve actuator 2 may be enclosed by a housing 17 and an actuator base 200, providing a room for components of the valve actuator 2. This room may be watertight and filled with a liquid to prevent the housing from collapsing due to hydrostatic pressure in deep sea. A pressure regulating bladder (not shown) may be installed on the housing 17 wall.

Fig. 5 shows an embodiment of the invention with the same components as the embodiment of Fig. 4 where the drive gear 100 is engaged with the second driven gear 102.

Fig. 6 shows an embodiment of the invention with the same components as the embodiment of Fig. 4 where the drive gear 100 is engaged with the third driven gear 103.

Fig. 7 shows an embodiment of the invention with the same components as the embodiment of Fig. 4, wherein the valve actuator 2 is landed on a valve assembly on a manifold (not shown). The first valve socket 30 is engaged with a first valve 40, the second valve socket 31 is engaged with a second valve 41 and a third valve socket 32 is engaged with a third valve 42. In this embodiment, the valves (40, 41, 42) include bucket type couplings (400, 410, 420), receiving the valve sockets (30, 31, 32).

Fig. 8 is a schematic representation of the components of the valve actuator. The controller is shown outside the drive assembly. A user interface manually or automatically receive input and monitor the status of the operational valves on the manifold from an operator topside. The valve actuator may be operated remotely by means of the user interface by an operator. The valve actuator is connected to a power supply through a controller providing electric power and/or pressurized fluid to the valve actuator. The drive assembly includes a linear actuator, a rotary actuator and the controller (shown externally of the valve actuator box). The controller is connected to the linear and the rotary actuators. The linear actuator drives the drive gear up or down as indicated by the arrows in the lower right corner from a retracted starting position to an extended end position. A position and/or force sensor monitor(s) the force and position of the drive gear and provide(s) position feedback to the controller. The linear actuator is preferably electric, but could also be hydraulic. The controller starts and stops the linear actuator, positioning the gear shaft in a desired position for engaging a driven gear in order to open or close a valve. The rotary actuator provides rotational movement to the drive gear. The rotary actuator may be any type of rotary actuator and may include a stepping motor or an induction motor. A torque and/or a rotation sensor provides torque and rotation feedback to the controller. The torque sensor may indicate that a driven gear is stuck or that the valve is fully open or fully closed. The rotation sensor may count the number of turns in order to indicate whether the valves are open or closed. The torque sensor can indicate if the driven gear is prevented from rotating and something is wrong. The drive gear selectively engages one of the three driven gears operating the three valves to open or close the valves. The controller may control the power supply to start or stop the linear actuator and/or the rotary actuator based on the signals received from the sensors so that the correct driven gear is properly aligned and in mesh with the drive gear. The torque and force sensors prevent the valve actuator from exceeding force and torque limits thus preventing damaging the gears or other components.

This description mentions the operation of manifold valves, and the interaction between valve sockets and valves. The mentioned valves include valve stems with couplings attached to the end of the valve stems. The valve stem forms a part of the valve itself, and the term “valve” is meant to also cover the valve stem of the valve. The term valve torque interface may also be used for the valve stem. The mentioned valve actuator may also be used on a subsea hydrocarbon fluid recovery manifold.

CLAIMS

1. A hydrocarbon production manifold valve actuator (2) comprising:

a rotary actuator (19) in driving relationship with a drive gear (100);

a linear actuator (23) adapted to shift the drive gear (100) linearly along an axis of rotation of the drive gear (100) between a first position in mesh with a first driven gear (101) connected to a first valve operating shaft (20) operating a first valve (40), and at least a second position in mesh with a second driven gear (102) connected to a second valve operating shaft (21) operating a second valve (41);

a valve actuator controller (15) connected to the rotary actuator (19) and the linear actuator (23), and

a position sensor monitoring the linear actuator (23), adapted to feed input to the controller (15).

2. The valve actuator (2) of claim 1, wherein the linear actuator (23) further is adapted to shift the drive gear (100) linearly along the axis of rotation of the drive gear (100) to a third position in mesh with a third driven gear (103) connected to a third valve operating shaft (22) operating a third valve (42).

3. The valve actuator (2) of claim 2, wherein each valve operating shaft (20, 21, 22) is connected to a valve socket (30, 31, 32) adapted to fit onto and engage each of the valves (40, 41, 42) to be operated.

4. The valve actuator (2) of claim 2, wherein each valve operating shaft (20, 21, 22) is connected to a auxiliary coupling (50, 51, 52) adapted to be operated by an override tool.

5. The valve actuator (2) of claim 1 or 2, wherein the number of valves (40, 41, 42) each being in driving relationship with a driven gear (101, 102, 103) corresponds to a number of positions of the drive gear (100) linearly along the axis of rotation.

6. The valve actuator (2) of any one of claims 1-3, wherein a drive gear shaft (4) extends between the rotary actuator (19) and the drive gear (100), and wherein the linear actuator (23) is adapted to move the drive gear (100) along a rotational axis of the drive gear shaft (4).

7. The valve actuator (2) of any one of claims 1-3, wherein a drive gear shaft (4) extends between the rotary actuator and the drive gear (100), and wherein the linear actuator (23) is adapted to move the drive gear shaft (4) and the drive gear (100) along an axis of rotation of the drive gear shaft.

8. The valve actuator (2) of any one of the claims 1-5, wherein the valve actuator (2) further includes an actuator base (200) and a housing (17) fixed to the actuator base (200) providing a watertight room which may be filled with a liquid.

9. The valve actuator (2) of any one of the claims 1-5, further including:

a force sensor monitoring the linear actuator (23), adapted to feed input to the controller (15); and

a torque sensor and a rotation sensor monitoring the rotary actuator (19), adapted to feed input to the controller (15).

10. A method of operating a valve actuator (2) according to any one of the preceding claims, comprising the steps of:

identifying a need for actuating one of the at least two valves (40, 41, 42);

actuating the linear actuator (23) to shift the drive gear (100) linearly along the axis of rotation of the drive gear (100) in mesh with the driven gear of the identified valve; and

actuating the rotary actuator (19) to operate the identified valve.

11. The method of operating the valve actuator (2) of claim 10, wherein the step of actuating the rotary actuator (19) to operate the identified valve is replaced with the step of actuating an auxiliary coupling (50, 51, 52) to operate the identified valve.

12. The method of operating the valve actuator (2) of any one of the claims 10-11, wherein the step of actuating the linear actuator to position the drive gear (100) in mesh with the driven gear of the identified valve includes feeding a signal from a force and a position sensor to a controller (15).

13. A method of installing a valve actuator (2) according to any one of the preceding claims 1-9, comprising the steps of:

landing the valve actuator (2) and engaging at least two valves (40, 41, 42) on a subsea hydrocarbon production manifold (1);

identifying a need for actuating one of the at least two valves (40, 41, 42);

positioning the drive gear (100) in mesh with the driven gear of the identified valve; and

operating the valves (40, 41, 42).

PATENTKRAV

1. En hydrokarbonproduksjonsmanifoldventilaktuator (2) som omfatter:

en roterende aktuator (19) som er i drivforhold med et drivhjul eller -gir (100);

en lineær aktuator (23) som er tilpasset til å forskyve eller veksle drivhjulet (100) lineært langs en rotasjonsakse for drivhjulet (100) mellom en første posisjon i inngrep med et første drevet tannhjul (101) som er koblet til en første ventildriftsaksel (20) som betjener eller driver en første ventil (40), og i det minste en andre posisjon i inngrep med et andre drevet tannhjul (102) som er koblet til en andre ventildriftsaksel (102) som betjener eller driver en andre ventil (41);

en ventilaktuatorkontroller (15) som er koblet til den roterende aktuatoren (19) og den lineære aktuatoren (23), og

en posisjonssensor som overvåker den lineære aktuatoren (23) og som er tilpasset til å mate input eller inndata til kontrolleren (15).

2. Ventilaktuatoren (2) i henhold til krav 1, hvor den lineære aktuatoren (23) videre er tilpasset til å forskyve eller veksle drivhjulet (100) lineært langs rotasjons-aksen for drivhjulet (100) til en tredje posisjon i inngrep med et tredje drevet tannhjul (103) som er koblet til en tredje ventildriftsaksel (22) som betjener eller driver en tredje ventil (42a).

3. Ventilaktuatoren (2) i henhold til krav 2, hvor hver ventildriftsaksel (20, 21, 22) er koblet til en ventilsokkel (30, 31, 32) som er tilpasset til å passe på og koble inn hver av ventilene (40, 41, 42) som skal betjenes.

4. Ventilaktuatoren (2) i henhold til krav 2, hvor hver ventildriftsaksel (20, 21, 22) er koblet til en hjelpekobling (50, 51, 52) som er tilpasset til å betjenes av et over-styringsverktøy.

5. Ventilaktuatoren (2) i henhold til krav 1 eller 2, hvor hver av antallet av ventiler (40, 41, 42) som er i drivforhold med et drevet tannhjul (101, 102, 103), tilsvarer til et antall av posisjoner av drivhjulet (100) lineært langs rotasjonsaksen.

6. Ventilaktuatoren (2) i henhold til et hvilket som helst av krav 1-3, hvor en drivhjulaksel (4) strekker seg mellom den roterende aktuatoren (19) og drivhjulet (100), og hvor den lineære aktuatoren (23) er tilpasset til å bevege drivhjulet (100) langs en rotasjonsakse til drivhjulakselen (4).

7. Ventilaktuatoren (2) i henhold til et hvilket som helst av krav 1-3, hvor en drivhjulaksel (4) strekker seg mellom den roterende aktuatoren og drivhjulet (100), og hvor den lineære aktuatoren (23) er tilpasset til å bevege drivhjulakselen (4) og drivhjulet (100) langs en rotasjonsakse til drivhjulakselen.

8. Ventilaktuatoren (2) i henhold til et hvilket som helst av kravene 1-5, hvor ventilaktuatoren (2) videre innbefatter en aktuatorbase (200) og et hus (17) som er festet til aktuatorbasen (200) som gir et vanntett rom som kan fylles med en væske.

9. Ventilaktuatoren (2) i henhold til et hvilket som helst av kravene 1-5, som videre innbefatter:

en kraftsensor som overvåker den lineære aktuatoren (23) og som er tilpasset til å mate input eller inndata til kontrolleren (15); og

en dreiemomentsensor og en rotasjonssensor som overvåker den roterende aktuatoren (19) og som er tilpasset til å mate input eller inndata til kontrolleren (15).

10. En fremgangsmåte for å betjene en ventilaktuator (2) i henhold til et hvilket som helst av de foregående kravene, omfattende trinnene med:

å identifisere et behov for å aktivere én av de minst to ventilene (40, 41, 42);

å aktivere den lineære aktuatoren (23) for å forskyve eller veksle drivhjulet (100) lineært langs rotasjonsaksen for drivhjulet (100) i inngrep med det drevne tann-hjulet til den identifiserte ventilen; og

å aktivere den roterende aktuatoren (19) for å betjene den identifiserte ventilen.

11. Fremgangsmåten for å betjene ventilaktuatoren (2) i henhold til krav 10, hvor trinnet med å aktivere den roterende aktuatoren (19) for å betjene den identifiserte

ventilen blir erstattet med trinnet med å aktivere en hjelpekobling (50, 51, 52) for å betjene den identifiserte ventilen.

12. Fremgangsmåten for å betjene ventilaktuatoren (2) i henhold til et hvilket som helst av kravene 10-11, hvor trinnet med å aktivere den lineære aktuatoren for å posisjonere drivhjulet (100) i inngrep med det drevne tannhjulet til den identifiserte ventilen innbefatter mating av et signal fra en kraft- og en posisjonssensor til en kontroller (15).

13. En fremgangsmåte for å installere en ventilaktuator (2) i henhold til et hvilket som helst av de foregående kravene 1-9, omfattende trinnene med:

å lande ventilaktuatoren (2) og å koble inn minst to ventiler (40, 41, 42) på en undervannshydrokarbonproduksjonsmanifold (1);

å identifisere et behov for å aktivere én av de minst to ventilene (40, 41, 42);

å plassere drivhjulet (100) i inngrep med det drevne tannhjulet til den identifiserte ventilen; og

å betjene ventilene (40, 41, 42).

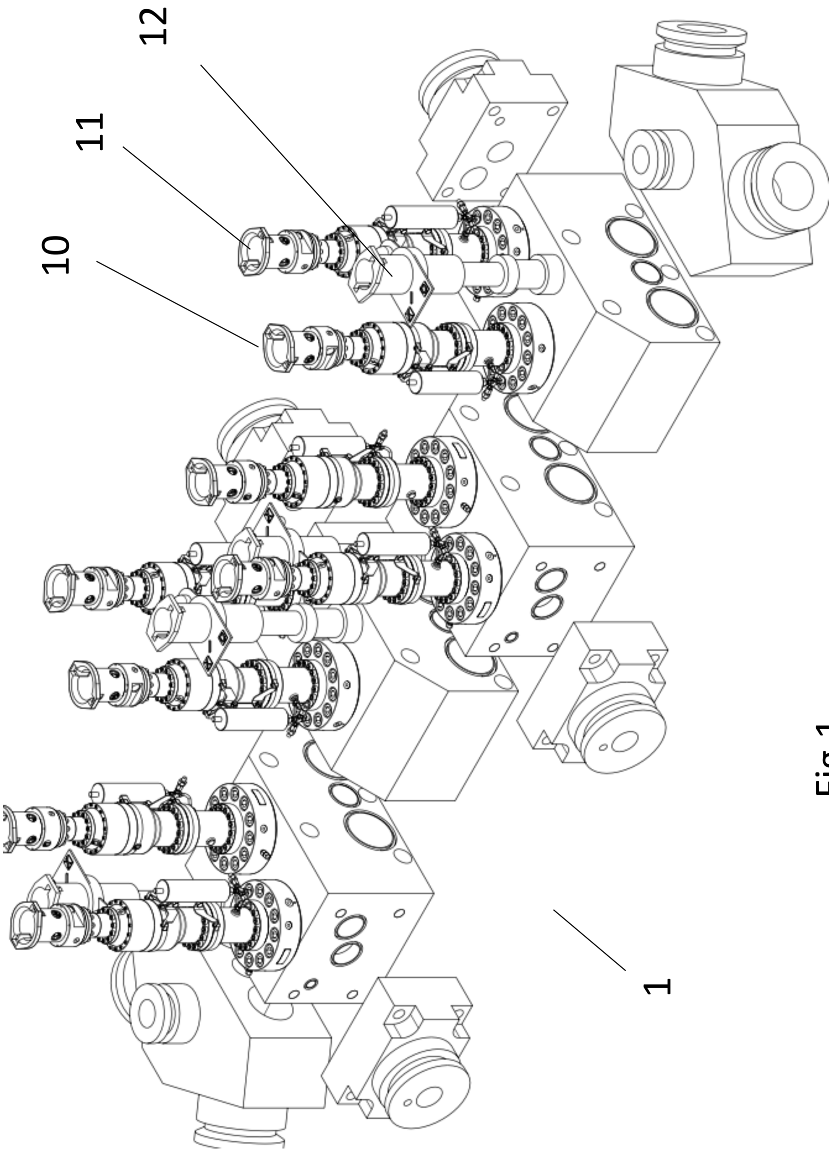


Fig.1

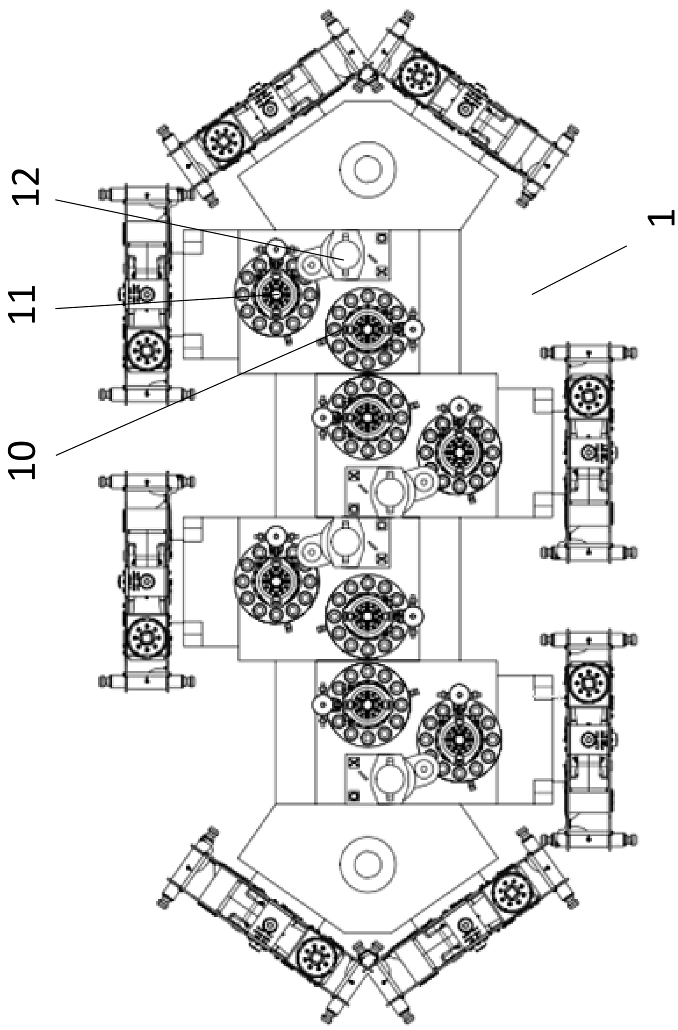


Fig.2

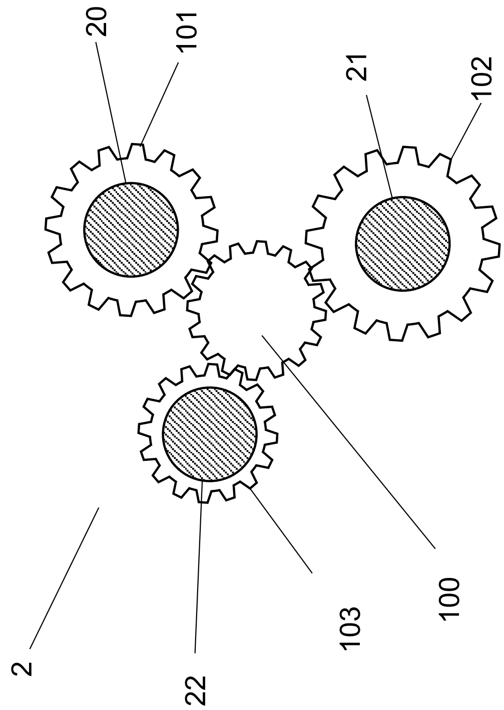


Fig.3

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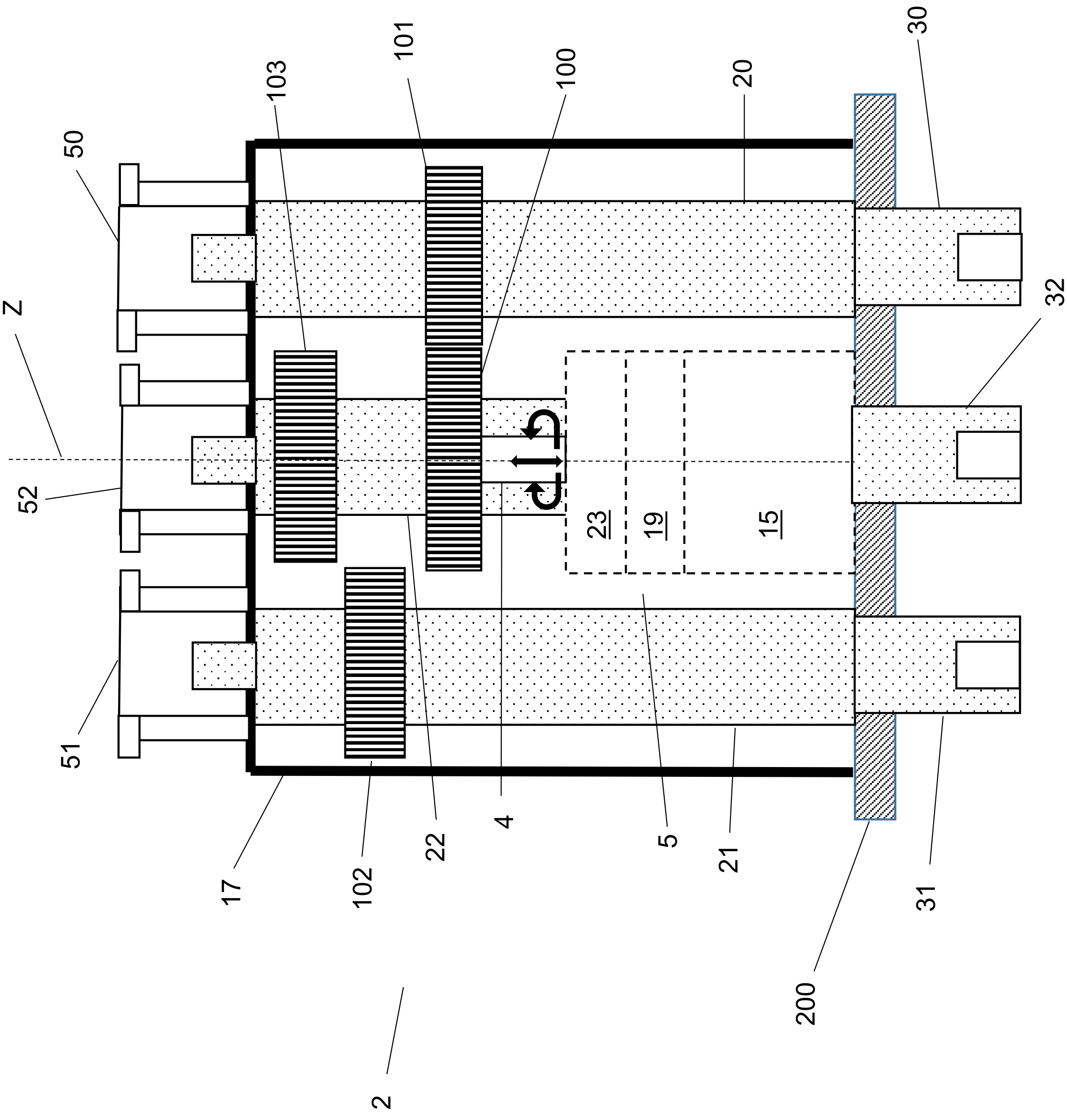

Fig.4

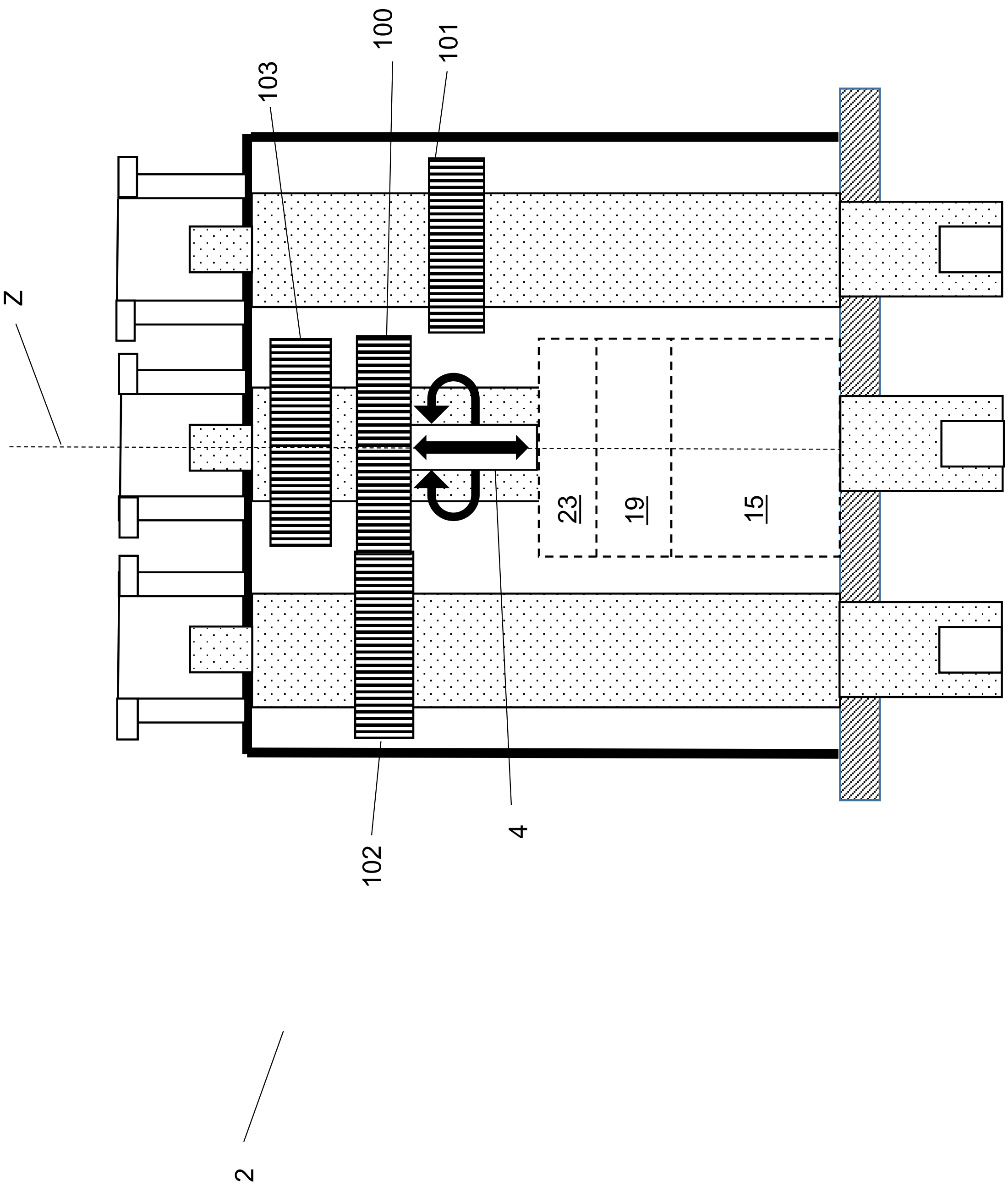

Fig.5

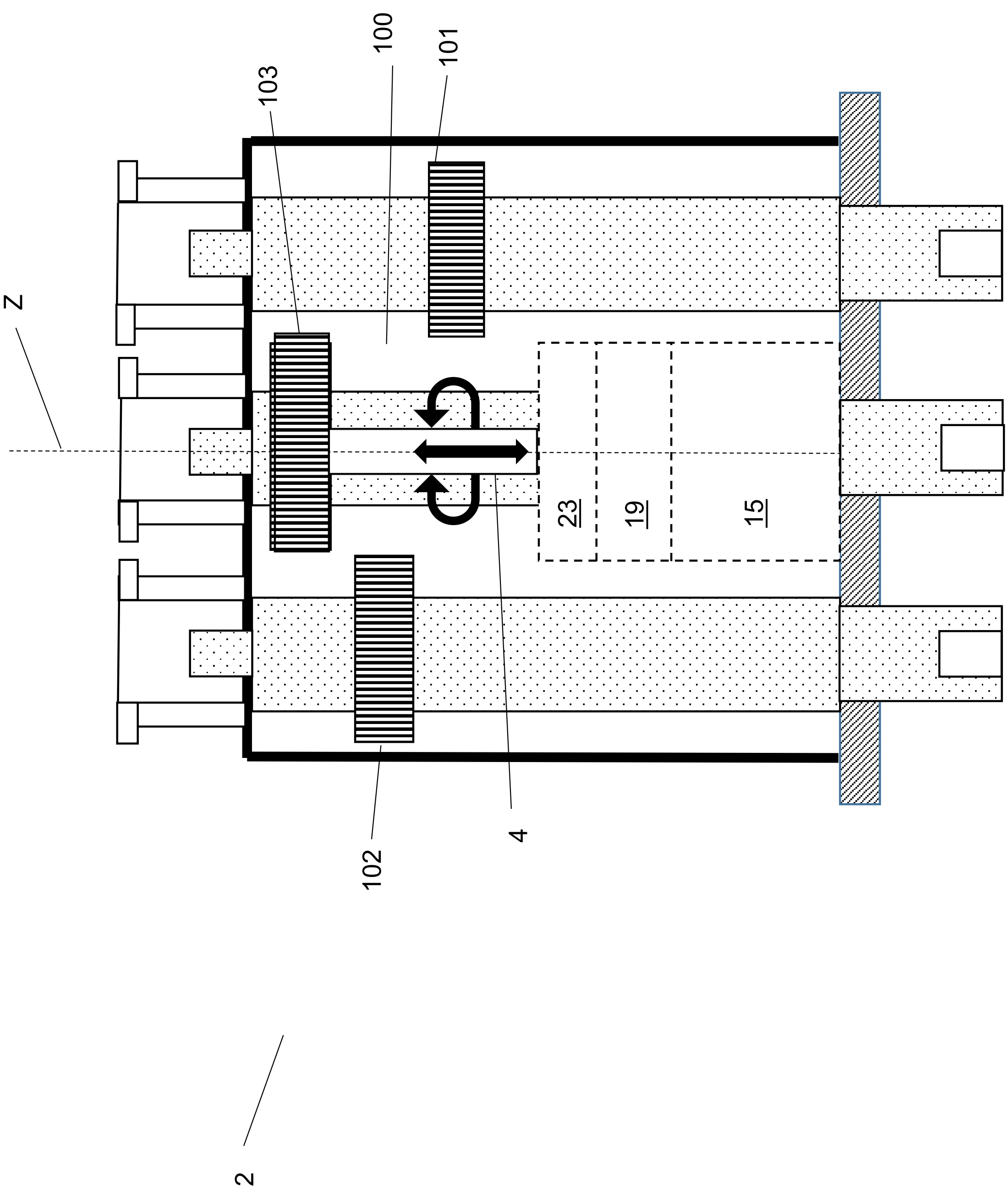

Fig.6

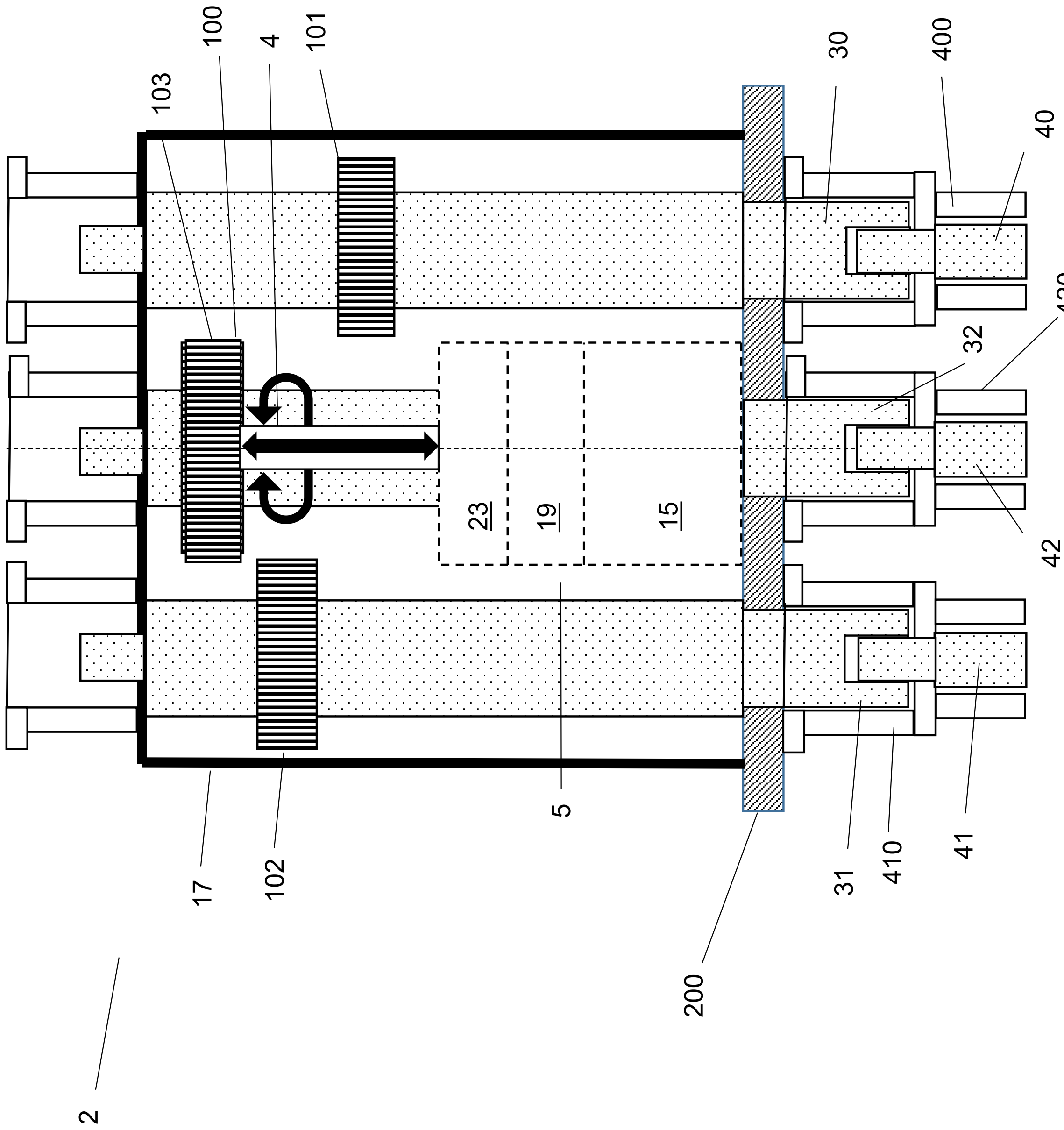

Fig.7

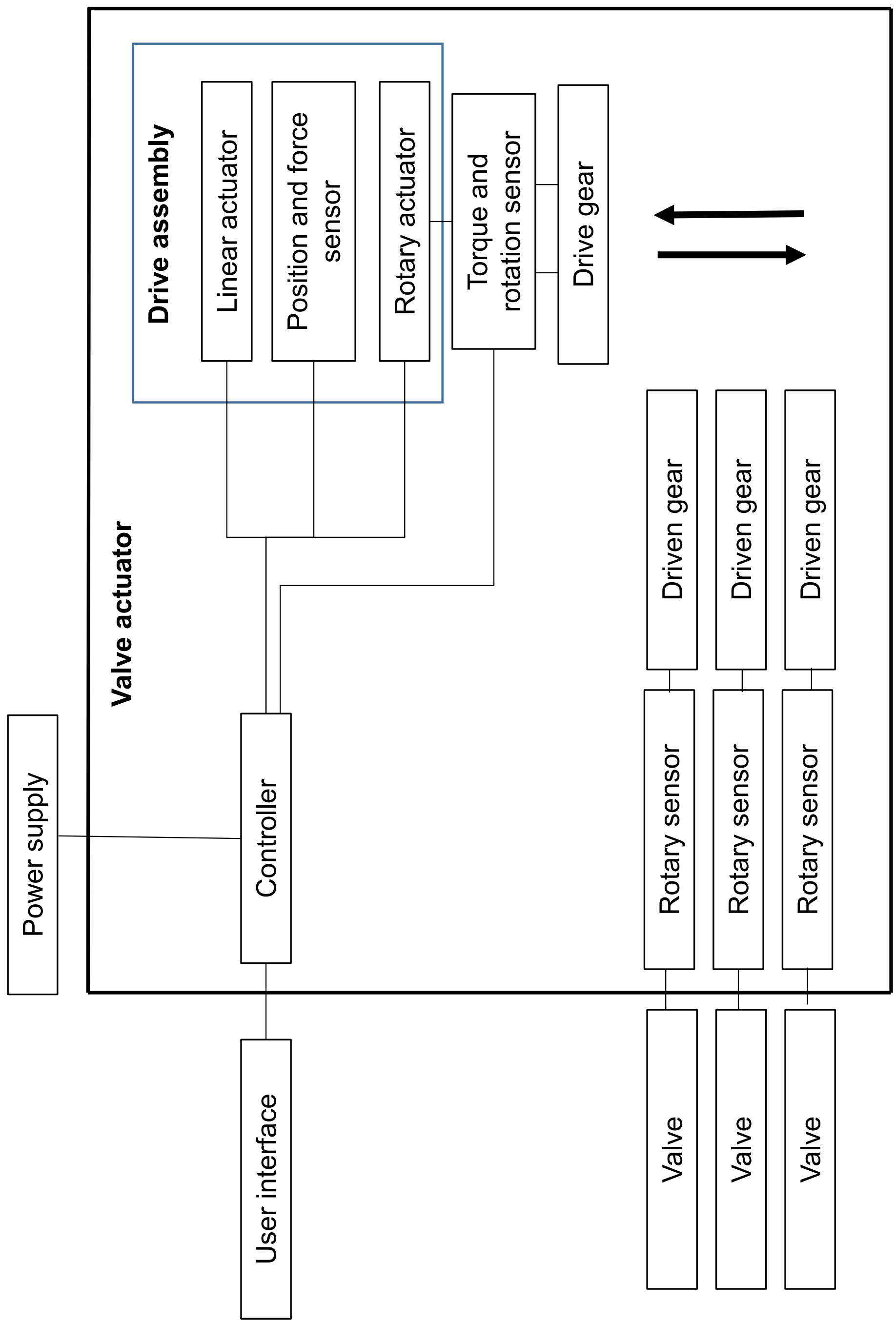
Valve actuator
Drive assembly
Linear actuator
Position and force sensor
Rotary actuator
Torque and rotation sensor
Drive gear
Driven gear
Driven gear
Driven gear
Rotary sensor
Rotary sensor
Rotary sensor
Controller
Power supply
User interface
Valve
Valve
Valve

Fig. 8