

# **Small Combined Construction Equipment for Soft Foundation**

## **Treatment**

### **FIELD OF THE INVENTION**

The invention relates to a construction technology for soft foundation treatment, and particularly to a small combined construction equipment for soft foundation treatment.

### **BACKGROUND OF THE INVENTION**

In the reinforcement construction of a soft soil foundation, most of moisture and gas in the soft soil foundation are required to be pumped such that its compactness can meet the use requirements. In the existing reinforcement construction of a soft soil foundation, three types of construction equipment are widely used currently: I. a jet pump, wherein such construction equipment has the following features: 1. the equipment can pump moisture and gas, or even solids of fine particles from a soft soil foundation and can meet a higher vacuum degree requirement ( $-0.096$  Mpa); 2. the equipment is lightweight and has a very short pipeline, thus the pressure loss is small; and 3. the equipment has lower working efficiency, and especially its gas extraction efficiency is only 30% of that of an equipower vacuum pump, thus the energy consumption is relatively high; II. a vacuum pump, wherein for such construction mode, a vacuum pump with larger power is generally selected to perform the reinforcement construction on a larger area of a soft soil foundation, and

such equipment has the following features: 1. the equipment has higher gas extraction efficiency, can perform reinforcement operation on a larger range of a soft soil foundation, and has less power consumption and higher efficiency per unit area of construction when compared with a jet pump used alone; 2. the equipment has higher requirements on a sucked medium, or sucked liquid is not allowed to be sucked in, or the sucked liquid is required to be filtered for many times, even so, the sucked liquid may corrode a pump ring, which is also unacceptable for such equipment, and meanwhile such vacuum pump has greatly reduced efficiency which is substantially the same as that of a jet pump when used for sucking liquid; and 3. the vacuum pump has requirements on the gas pressure at a suction inlet, i.e. when the gas vacuum degree at a suction inlet is  $-0.090$  Mpa or higher, such vacuum pump has greatly reduced working efficiency, or even the vacuum degree of a sucked space cannot be further increased; and III. a large construction device for soft soil foundation treatment which has been on trial, wherein the device has the advantages of performing construction by a vacuum pump, and has less power consumption and higher efficiency per unit area of construction when compared with a jet pump used alone. However, the device is too bulky and heavy to be mounted on a loose soft soil foundation. Moreover, the device has a long and complicated connecting pipeline to cause greater pressure loss in the pipeline, more leakage accidents, and a lower actual

vacuum degree in a construction area, thus providing poorer construction effects.

## SUMMARY OF THE INVENTION

For the disadvantages of the prior art, a technical problem to be solved by the invention is to provide a small and lightweight combined construction equipment for soft foundation treatment, which is mounted nearby on a covering membrane as a complete set, has an extremely short connecting pipeline and can also greatly reduce energy consumption.

The technical problem to be solved by the invention is achieved by the following technical solution: a small combined construction equipment for soft foundation treatment comprises several membrane outlets for pumping gas and water arranged on a soft soil foundation covering membrane, and is characterized by being provided with a combined gas-water pumping device engaged to the membrane outlets, wherein the combined gas-water pumping device at least comprises one gas-water separation tank and one water ring vacuum pump which are mounted nearby on the soft soil foundation covering membrane in the vicinity of the membrane outlets, the membrane outlets are respectively connected with interfaces arranged around the gas-water separation tank, and a set of a check valve and a cut-off valve are arranged on each interface pipeline; and the gas-water separation tank is internally equipped with one submersible pump, a drain outlet of the submersible pump is arranged

outside the gas-water separation tank, one gas pumping port is arranged at an upper part of the gas-water separation tank, and the gas pumping port is connected with a gas suction port of the water ring vacuum pump via a pipeline.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: one floating cut-off valve is arranged at the gas pumping port at the upper part of the gas-water separation tank, and the gas pumping port at the upper part of the gas-water separation tank is connected with the gas suction port of the water ring vacuum pump by an automatic air pressure distributor; one check valve is arranged on a connecting pipeline between the gas suction port of the water ring vacuum pump and the automatic air pressure distributor; the automatic air pressure distributor comprises a pressure control valve and an atmospheric jet pump which are connected in parallel, and the pressure control valve and the atmospheric jet pump are controlled by the pressure in the gas-water separation tank; when a negative pressure value in the gas-water separation tank is greater than a set negative pressure value, the pressure control valve is in an opened state, the atmospheric jet pump is in a closed state, the pressure of the gas-water separation tank is in a low vacuum state, and then the gas-water separation tank is vacuumized by the opened pressure control valve; and when a negative pressure value in the gas-water separation tank reaches a

set negative pressure value, the pressure control valve is closed, the atmospheric jet pump is opened, and the gas-water separation tank continues to be vacuumized by the atmospheric jet pump such that the pressure in the gas-water separation tank reaches a high vacuum state.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the water ring vacuum pump is an air-cooled water ring vacuum pump operating in the atmosphere.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the water ring vacuum pump is a submersible water ring vacuum pump arranged in a water tank; and one water tank is arranged beside the gas-water separation tank, the submersible water ring vacuum pump is arranged in the water tank, and the drain outlet of the submersible pump is connected with the water tank by a drainage pipeline and a check valve.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the water ring vacuum pump has a power of not greater than 7.5 KW.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the pressure control valve and the atmospheric jet pump are solenoid-operated opening and closing valves, the gas-water separation tank is provided with a negative pressure

sensor, and a control signal outputted by the negative pressure sensor is connected with the pressure control valve and the atmospheric jet pump by a control system.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the pressure control valve is an air pressure membrane box I, a gas pumping port of the air pressure membrane box I and a gas pumping port of the atmospheric jet pump are connected in parallel and then connected with the gas suction port of the submersible water ring vacuum pump by a gas pumping pipeline, a gas suction port of the air pressure membrane box I and a gas suction port of the atmospheric jet pump are connected in parallel and then connected with the gas pumping port of the gas-water separation tank by a gas suction pipeline, an air inlet pipeline of the atmospheric jet pump is connected with the gas pumping pipeline by an air pressure membrane box II, the air inlet pipeline of the atmospheric jet pump is connected with an air outlet of the air pressure membrane box II, and the air outlet of the air pressure membrane box II is communicated with an outer cavity of a diaphragm of the air pressure membrane box I via a branch.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the submersible water ring vacuum pump consists of a supporting seat, a submersible motor, a sealed oil chamber and a water ring vacuum pump head, the sealed oil chamber

has two layers of oil cavities, each of which is internally provided with a set of mechanical seals, the water ring pump head is internally provided with a set of mechanical seals, and the three sets of mechanical seals together ensure the sealing performance in the driving of a pump shaft.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the low vacuum state refers to a negative pressure value of 0 to -0.09 Mpa in the gas-water separation tank.

The technical problem to be solved by the invention may also be further achieved by the following technical solution: the high vacuum state refers to a negative pressure value of -0.09 to -0.096 Mpa in the gas-water separation tank.

Compared with the prior art, the invention has the following advantages. The submersible pump in the gas-water separation tank discharges the accumulated water sucked into the tank from a soft soil foundation to the outside of the tank. The construction equipment is small and lightweight, is mounted nearby on the covering membrane as a complete set, has an extremely short connecting pipeline and can also greatly reduce energy consumption. The discharged underground water is discharged nearby via a pipeline onto the membrane and into a membrane ballasting channel for ballasting, or may also be discharged into the water tank for use as the working fluid of the submersible water ring vacuum pump and for

cooling the submersible motor. The automatic air pressure distributor allows the vacuum degree in the gas-water separation tank to gradually reach high vacuum.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic structural view of the invention;

Fig. 2 is a schematic structural view of a floating cut-off valve;

Fig. 3 is a schematic view of an air-controlled automatic air pressure distributor;

Fig. 4 is a schematic view of an electrically controlled automatic air pressure distributor; and

Fig. 5 is a schematic structural view of a submersible water ring vacuum pump.

#### DETAILED DESCRIPTION OF THE INVENTION

A small combined construction equipment for soft foundation treatment comprises several membrane outlets for pumping gas and water arranged on a soft soil foundation covering membrane, and is provided with a combined gas-water pumping device engaged to the membrane outlets, wherein the combined gas-water pumping device at least comprises one gas-water separation tank and one water ring vacuum pump which are mounted nearby on the soft soil foundation covering membrane in the vicinity of the membrane outlets, the membrane outlets are respectively connected with interfaces arranged around the gas-water separation tank,

and a set of a check valve and a cut-off valve are arranged on each interface pipeline; and the gas-water separation tank is internally equipped with one submersible pump, a drain outlet of the submersible pump is arranged outside the gas-water separation tank, one gas pumping port is arranged at an upper part of the gas-water separation tank, and the gas pumping port is connected with a gas suction port of the water ring vacuum pump via a pipeline.

One floating cut-off valve is arranged at the gas pumping port at the upper part of the gas-water separation tank, and the gas pumping port at the upper part of the gas-water separation tank is connected with the gas suction port of the water ring vacuum pump by an automatic air pressure distributor; one check valve is arranged on a connecting pipeline between the gas suction port of the water ring vacuum pump and the automatic air pressure distributor; the automatic air pressure distributor comprises a pressure control valve and an atmospheric jet pump which are connected in parallel, and the pressure control valve and the atmospheric jet pump are controlled by the pressure in the gas-water separation tank; when a negative pressure value in the gas-water separation tank is greater than a set negative pressure value, the pressure control valve is in an opened state, the atmospheric jet pump is in a closed state, the pressure of the gas-water separation tank is in a low vacuum state, and then the gas-water separation tank is vacuumized by the opened pressure control valve; and

when a negative pressure value in the gas-water separation tank reaches a set negative pressure value, the pressure control valve is closed, the atmospheric jet pump is opened, and the gas-water separation tank continues to be vacuumized by the atmospheric jet pump such that the pressure in the gas-water separation tank reaches a high vacuum state.

The water ring vacuum pump is an air-cooled water ring vacuum pump operating in the atmosphere.

Alternatively, the water ring vacuum pump is a submersible water ring vacuum pump arranged in a water tank; and one water tank is arranged beside the gas-water separation tank, the submersible water ring vacuum pump is arranged in the water tank, and the drain outlet of the submersible pump is connected with the water tank by a drainage pipeline and a check valve. The submersible water ring vacuum pump consists of a supporting seat, a submersible motor, a sealed oil chamber and a water ring vacuum pump head, the sealed oil chamber has two layers of oil cavities, each of which is internally provided with a set of mechanical seals, the water ring pump head is internally provided with a set of mechanical seals, and the three sets of mechanical seals together ensure the sealing performance in the driving of a pump shaft.

The water ring vacuum pump has a power of not greater than 7.5 KW.

The pressure control valve and the atmospheric jet pump are solenoid-operated opening and closing valves, the gas-water separation

tank is provided with a negative pressure sensor, and a control signal outputted by the negative pressure sensor is connected with the pressure control valve and the atmospheric jet pump by a control system.

The pressure control valve is an air pressure membrane box I, a gas pumping port of the air pressure membrane box I and a gas pumping port of the atmospheric jet pump are connected in parallel and then connected with the gas suction port of the submersible water ring vacuum pump by a gas pumping pipeline, a gas suction port of the air pressure membrane box I and a gas suction port of the atmospheric jet pump are connected in parallel and then connected with the gas pumping port of the gas-water separation tank by a gas suction pipeline, an air inlet pipeline of the atmospheric jet pump is connected with the gas pumping pipeline by an air pressure membrane box II, the air inlet pipeline of the atmospheric jet pump is connected with an air outlet of the air pressure membrane box II, and the air outlet of the air pressure membrane box II is communicated with an outer cavity of a diaphragm of the air pressure membrane box I via a branch.

The low vacuum state refers to a negative pressure value of 0 to -0.09 Mpa in the gas-water separation tank. The high vacuum state refers to a negative pressure value of -0.09 to -0.096 Mpa in the gas-water separation tank.

Referring to Fig. 1, the construction equipment comprises several

membrane outlets 2 for pumping gas and water arranged on a soft soil foundation covering membrane, wherein each of the membrane outlets is connected to a set of a check valve and a cut-off valve 3 and connected with each of interfaces disposed around a gas-water separation tank 5 on the covering membrane; the gas-water separation tank 5 is internally equipped with a submersible pump 4 and a liquid level sensor 6, and a vacuum gauge with a negative pressure sensor 8 and a gas pumping port with a floating cut-off valve 7 are mounted at the top of the gas-water separation tank 5; the gas pumping port with the floating cut-off valve 7 is connected with an automatic air pressure distributor 10; a gas pumping port of the automatic air pressure distributor 10 is then connected with a gas suction port of a submersible water ring vacuum pump 15, and their connecting pipeline is connected in series with one check valve 12; a drain outlet of the submersible pump 4 discharges the discharged water into a water tank 16 by a pipeline 11 and a check valve 12; and a distribution box 9 is mounted at the top of the gas-water separation tank 5, and the distribution box 9 is connected with the negative pressure sensor 8, the liquid level sensor 6, the submersible pump 4, the vacuum pump 15, and solenoid valves 23 and 26 in an (electrically controlled) automatic air pressure distributor via a circuit, and supplies power to the outside of a soft soil foundation via one cable.

One floating cut-off valve 7 is arranged at the gas pumping port at the top

of the gas-water separation tank 5, as shown in Fig. 2. When the accumulated water in the gas-water separation tank rises to the top of the tank, a ball float 20 floats to block an inlet of a reducing flange 17. The reducing flange 17 is connected with an outlet of the gas-water separation tank 5 by a sealing gasket 19 and a screw 18. The ball float 20 is confined in a certain space by a grid 21 mounted on the reducing flange 17.

An implementation of an electrical control scheme of the automatic air pressure distributor 10 is as shown in Fig. 4. An (electrically controlled) automatic air pressure distributor connected in series between the gas suction port of the submersible water ring vacuum pump 15 and the gas pumping port of the gas-water separation tank 5 is branched to a gas pumping port of the solenoid valve 23 and a gas pumping port of the atmospheric jet pump 25 via a pipeline 22; a gas suction port of the solenoid valve 23 and a gas suction port of the atmospheric jet pump 25 are connected in parallel via a pipeline 24 and then connected with the reducing flange 17 at the gas pumping port of the gas-water separation tank 5; and the solenoid valve 26 is connected in series in an air inlet pipeline 27 of the atmospheric jet pump 25, and the solenoid valve 23 and the solenoid valve 26 are connected to the distribution box 9 by an air passage. When the vacuum pump 15 works to suck the gas in the gas-water separation tank 5, the vacuum degree in the gas-water separation tank 5 is 0 to -0.09 Mpa, the solenoid valve 23 is “on” and the

solenoid valve 26 is “off”. The vacuum pump 15 then directly sucks the gas in the gas-water separation tank 5 via the pipeline 22 and the pipeline 24. When the gas vacuum degree in the gas-water separation tank 5 reaches  $-0.09$  Mpa, the negative pressure sensor 8 outputs a control signal, the solenoid valve 23 is closed and the solenoid valve 26 is opened. The vacuum pump 15 then can only suck the air incoming from the pipeline 27 by the pipeline 22 and the atmospheric jet pump 25, and then sucks the gas in the gas-water separation tank 5 through a mixing chamber of the atmospheric jet pump 25 via the pipeline 24, thus the vacuum degree in the gas-water separation tank 5 reaches  $-0.096$  Mpa.

An implementation of an air control scheme of the automatic air pressure distributor 10 is as shown in Fig. 3. An (air-controlled) automatic air pressure distributor connected in series between the gas suction port of the submersible water ring vacuum pump 15 and the gas pumping port of the gas-water separation tank 5 is branched to a gas pumping port of an air pressure membrane box I 28B and a gas pumping port of the atmospheric jet pump 25 via a pipeline 22; a gas suction port of the air pressure membrane box I 28B and a gas suction port of the atmospheric jet pump 25 are connected in parallel via a pipeline 24 and then connected with the reducing flange 17 at the gas pumping port of the gas-water separation tank 5; and the pipeline 22 is also branched into a working cavity of an air pressure membrane box II 28A. An air inlet pipeline 27 of

the atmospheric jet pump 25 is closed by a spring valve stem 32 at an end of the air pressure membrane box II 28A. When the vacuum pump 15 starts to suck the gas in the gas-water separation tank 5, the gas vacuum degree in the tank is 0 to -0.09 Mpa. The negative pressure in an inner cavity of the air pressure membrane box II 28A increases gradually, a diaphragm 31 compresses a valve stem 29 to move under the atmospheric pressure outside, and the valve stem 29 can only move stepwise under the resistance from a spring 30; and then the diaphragm 31 of the air pressure membrane box I 28B is still at equivalent negative pressure in the pipeline 27, thus the valve stem 29 does not move. Accordingly, the vacuum pump 15 still directly sucks the gas in the gas-water separation tank 5 by the pipeline 22, an inner cavity of the air pressure membrane box I 28B and the pipeline 24. According to the setting, when the vacuum degree in the gas-water separation tank reaches -0.090 Mpa, the valve stem 29 in the air pressure membrane box II 28A pushes away the spring valve stem 32, and the air inlet pipeline 27 is opened. The atmospheric pressure outside enters an outer cavity of the diaphragm 31 of the air pressure membrane box I 28B via the pipeline 27. The valve stem 29 in its inner cavity then rapidly moves to close a channel through which the pipeline 22 and the pipeline 24 pass through its inner cavity; and meanwhile the atmospheric pressure outside is introduced to an atmospheric inlet of the atmospheric jet pump via the pipeline 27. The

vacuum pump 15 then can only suck the atmospheric jet pump 25 via the pipeline 22, and the atmospheric jet pump 25 sucks the gas in the gas-water separation tank 5 through its mixing chamber via the pipeline 24, thus the vacuum degree in the gas-water separation tank 5 gradually reaches -0.096 Mpa.

As shown in Fig. 5, the submersible water ring vacuum pump 15 consists of a supporting seat 33, a submersible motor 35, a sealed oil chamber 36 and a water ring vacuum pump head 38. A sealing device 34 for a lead-out cable of the submersible motor 35 comprises a cover plate and a cable conductor which are hermetically connected with a pump body, wherein the cover plate is provided with an inner cavity, a cable conductor outlet is arranged on a wall of the inner cavity, each phase of the cable conductor located in the inner cavity of the cover plate is provided with a segment of a bare wire, and the inner cavity of the cover plate is filled with an insulating sealing material. Refer to “Sealing Device for Lead-out Cable Conductor Joint in Pump” (ZL20092003861.5) owned by the applicant, the patent technology of which achieves the underwater sealing performance. The sealed oil chamber 36 has two layers of oil cavities, each of which is internally provided with a set of mechanical seals 37, the water ring pump head 38 is internally provided with a set of mechanical seals 37, and the three sets of mechanical seals 37 together ensure the sealing performance in the

driving of a pump shaft.

## CLAIMS

1. A small combined construction equipment for soft foundation treatment, comprising several membrane outlets for pumping gas and water arranged on a soft soil foundation covering membrane, characterized in that: the construction equipment is provided with a combined gas-water pumping device engaged to the membrane outlets, the combined gas-water pumping device at least comprises one gas-water separation tank and one water ring vacuum pump which are mounted nearby on the soft soil foundation covering membrane in the vicinity of the membrane outlets, the membrane outlets are respectively connected with interfaces arranged around the gas-water separation tank, and a set of a check valve and a cut-off valve are arranged on each interface pipeline; and the gas-water separation tank is internally equipped with one submersible pump, a drain outlet of the submersible pump is arranged outside the gas-water separation tank, one gas pumping port is arranged at an upper part of the gas-water separation tank, and the gas pumping port is connected with a gas suction port of the water ring vacuum pump via a pipeline.

2. The small combined construction equipment for soft foundation treatment according to claim 1, characterized in that: one floating cut-off valve is arranged at the gas pumping port at the upper part of the gas-water separation tank, and the gas pumping port at the upper part of

the gas-water separation tank is connected with the gas suction port of the water ring vacuum pump by an automatic air pressure distributor; one check valve is arranged on a connecting pipeline between the gas suction port of the water ring vacuum pump and the automatic air pressure distributor; the automatic air pressure distributor comprises a pressure control valve and an atmospheric jet pump which are connected in parallel, and the pressure control valve and the atmospheric jet pump are controlled by the pressure in the gas-water separation tank; when a negative pressure value in the gas-water separation tank is greater than a set negative pressure value, the pressure control valve is in an opened state, the atmospheric jet pump is in a closed state, the pressure of the gas-water separation tank is in a low vacuum state, and then the gas-water separation tank is vacuumized by the opened pressure control valve; and when a negative pressure value in the gas-water separation tank reaches a set negative pressure value, the pressure control valve is closed, the atmospheric jet pump is opened, and the gas-water separation tank continues to be vacuumized by the atmospheric jet pump such that the pressure in the gas-water separation tank reaches a high vacuum state.

3. The small combined construction equipment for soft foundation treatment according to claim 1 or 2, characterized in that: the water ring vacuum pump is a submersible water ring vacuum pump arranged in a water tank; and one water tank is arranged beside the gas-water

separation tank, the submersible water ring vacuum pump is arranged in the water tank, and the drain outlet of the submersible pump is connected with the water tank by a drainage pipeline and a check valve.

4. The small combined construction equipment for soft foundation treatment according to claim 2, characterized in that: the pressure control valve and the atmospheric jet pump are solenoid-operated opening and closing valves, the gas-water separation tank is provided with a negative pressure sensor, and a control signal outputted by the negative pressure sensor is connected with the pressure control valve and the atmospheric jet pump by a control system.

5. The small combined construction equipment for soft foundation treatment according to claim 2, characterized in that: the pressure control valve is an air pressure membrane box I, a gas pumping port of the air pressure membrane box I and a gas pumping port of the atmospheric jet pump are connected in parallel and then connected with the gas suction port of the water ring vacuum pump by a gas pumping pipeline, a gas suction port of the air pressure membrane box I and a gas suction port of the atmospheric jet pump are connected in parallel and then connected with the gas pumping port of the gas-water separation tank by a gas suction pipeline, an air inlet pipeline of the atmospheric jet pump is connected with the gas pumping pipeline by an air pressure membrane box II, the air inlet pipeline of the atmospheric jet pump is connected with

an air outlet of the air pressure membrane box II, and the air outlet of the air pressure membrane box II is communicated with an outer cavity of a diaphragm of the air pressure membrane box I via a branch.

6. The small combined construction equipment for soft foundation treatment according to claim 2, characterized in that: the low vacuum state refers to a negative pressure value of 0 to -0.09 Mpa in the gas-water separation tank.

7. The small combined construction equipment for soft foundation treatment according to claim 2, characterized in that: the high vacuum state refers to a negative pressure value of -0.09 to -0.096 Mpa in the gas-water separation tank.

8. The small combined construction equipment for soft foundation treatment according to claim 3, characterized in that: the submersible water ring vacuum pump consists of a supporting seat, a submersible motor, a sealed oil chamber and a water ring vacuum pump head, the sealed oil chamber has two layers of oil cavities, each of which is internally provided with a set of mechanical seals, the water ring pump head is internally provided with a set of mechanical seals, and the three sets of mechanical seals together ensure the sealing performance in the driving of a pump shaft.

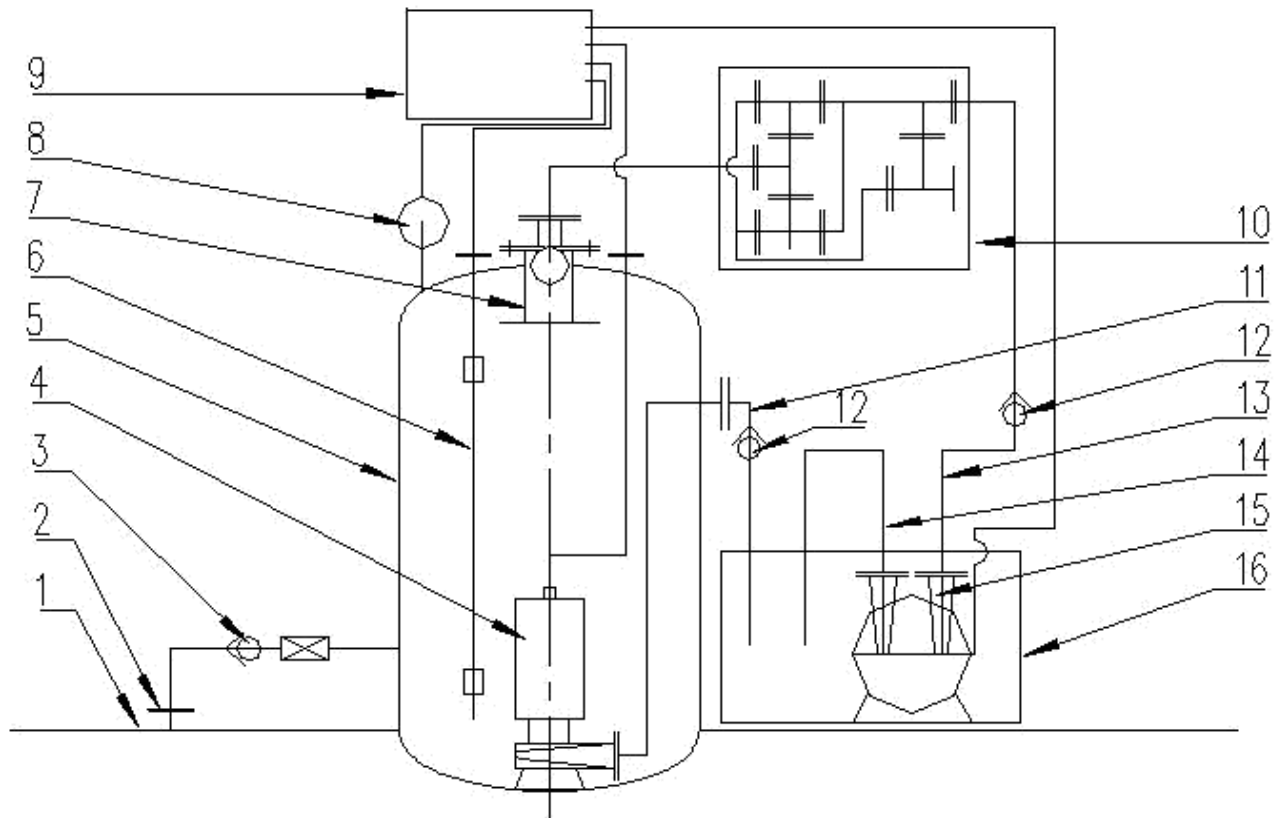


Fig1

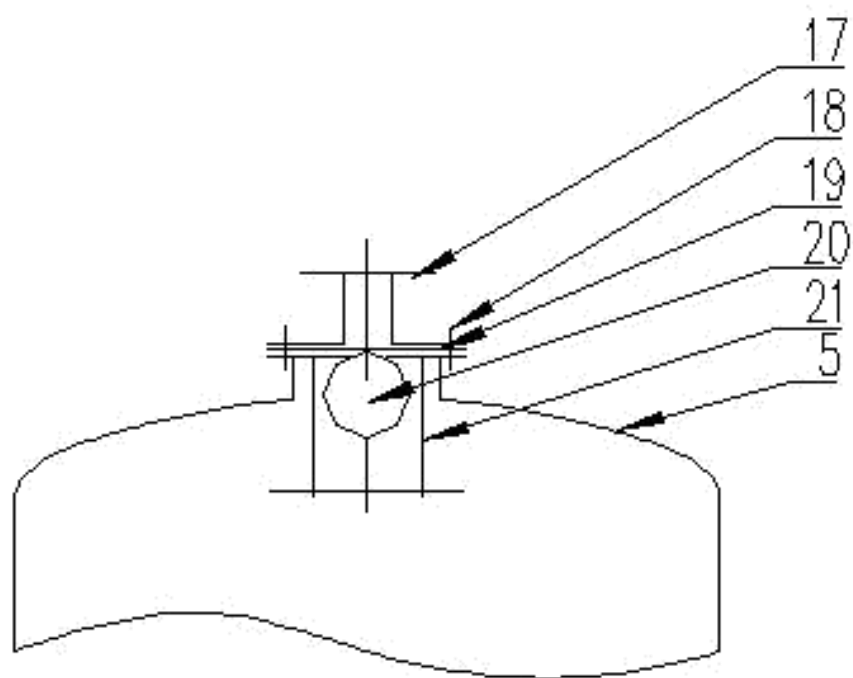


Fig2

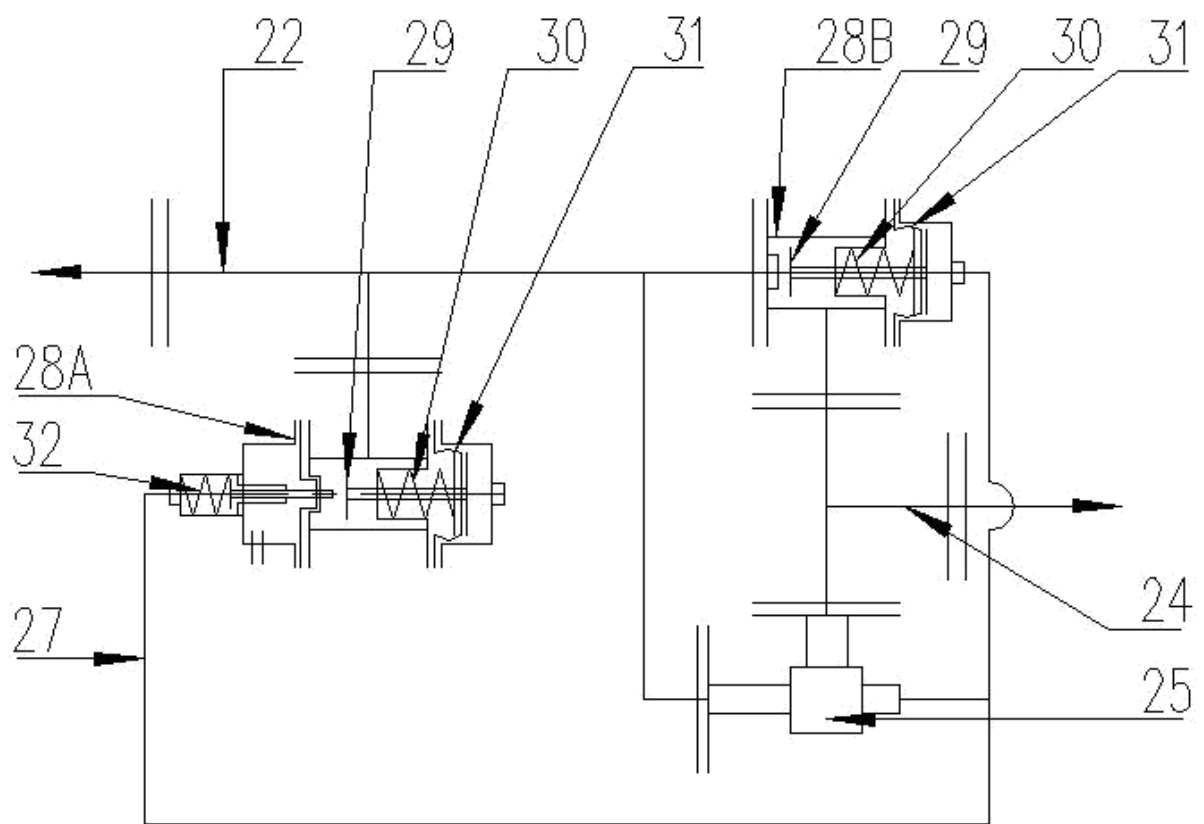


Fig3

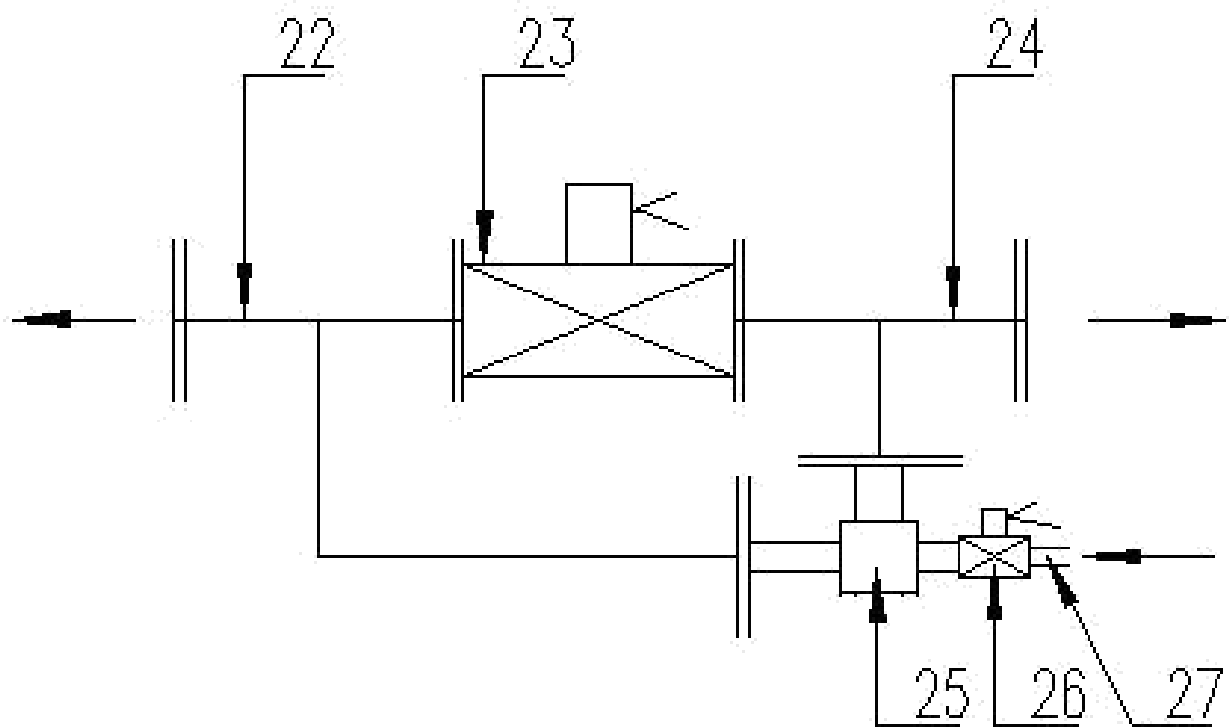


Fig4

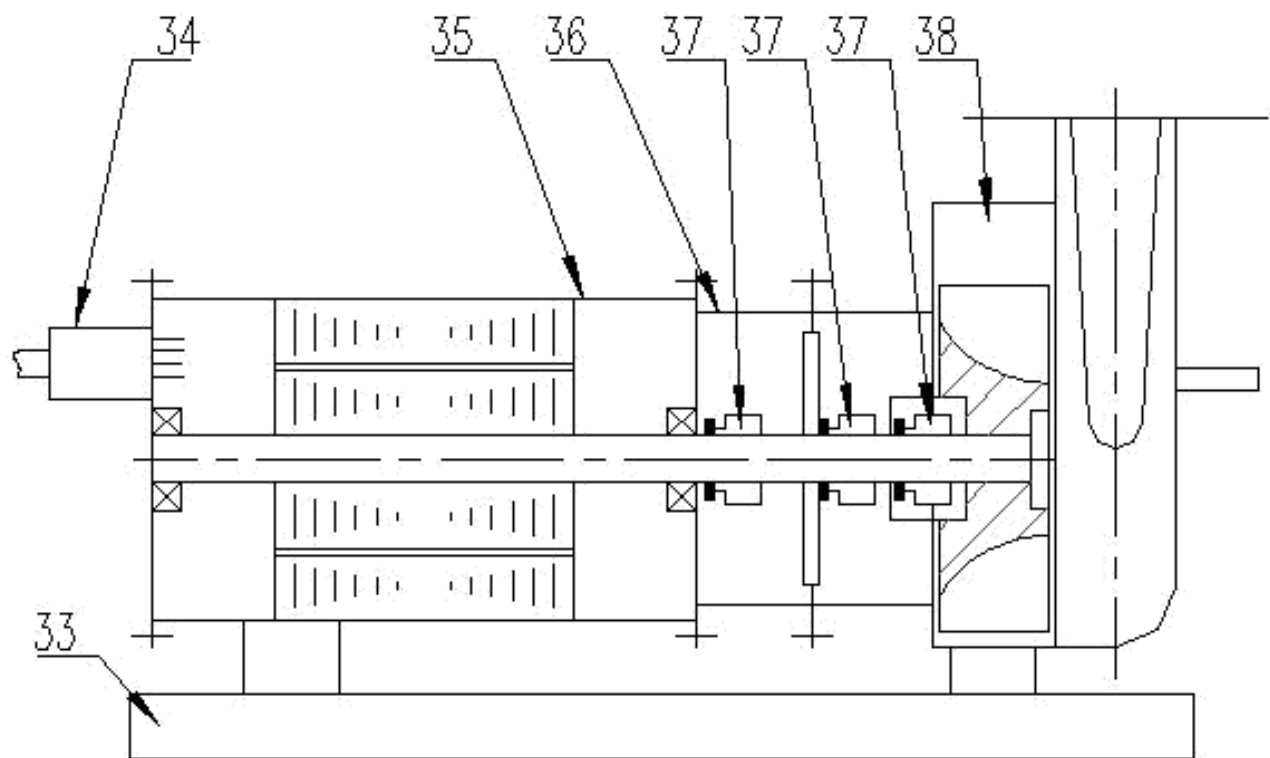


Fig5