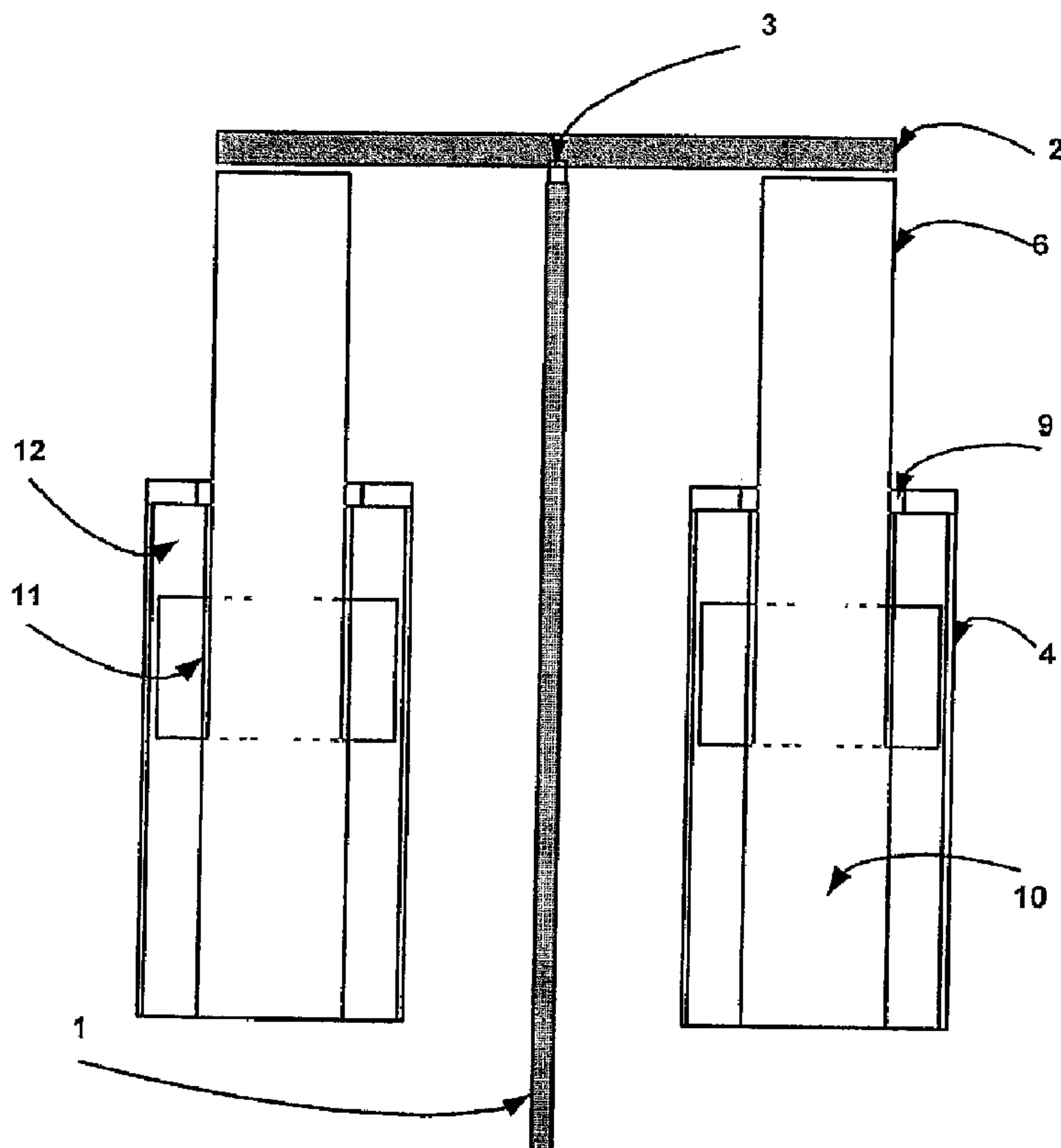




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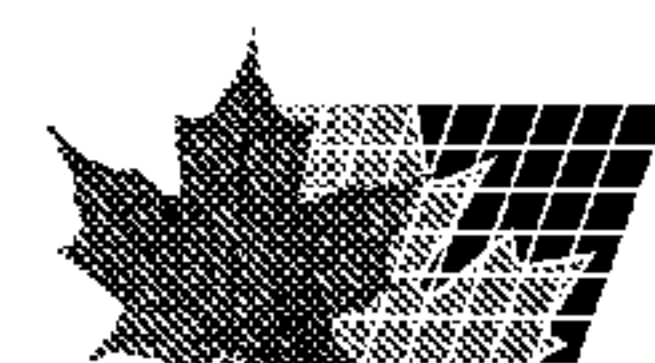
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(57) Abrégé/Abstract:

The invention relates to electric linear motors and gas springs in reciprocating pumps for oil wells. By the use of this invention a simple, silent, compact and adaptable mechanism can be constructed to drive a wide range of such pumps. The mechanism will sense a variety of pumping conditions and react automatically thereto.



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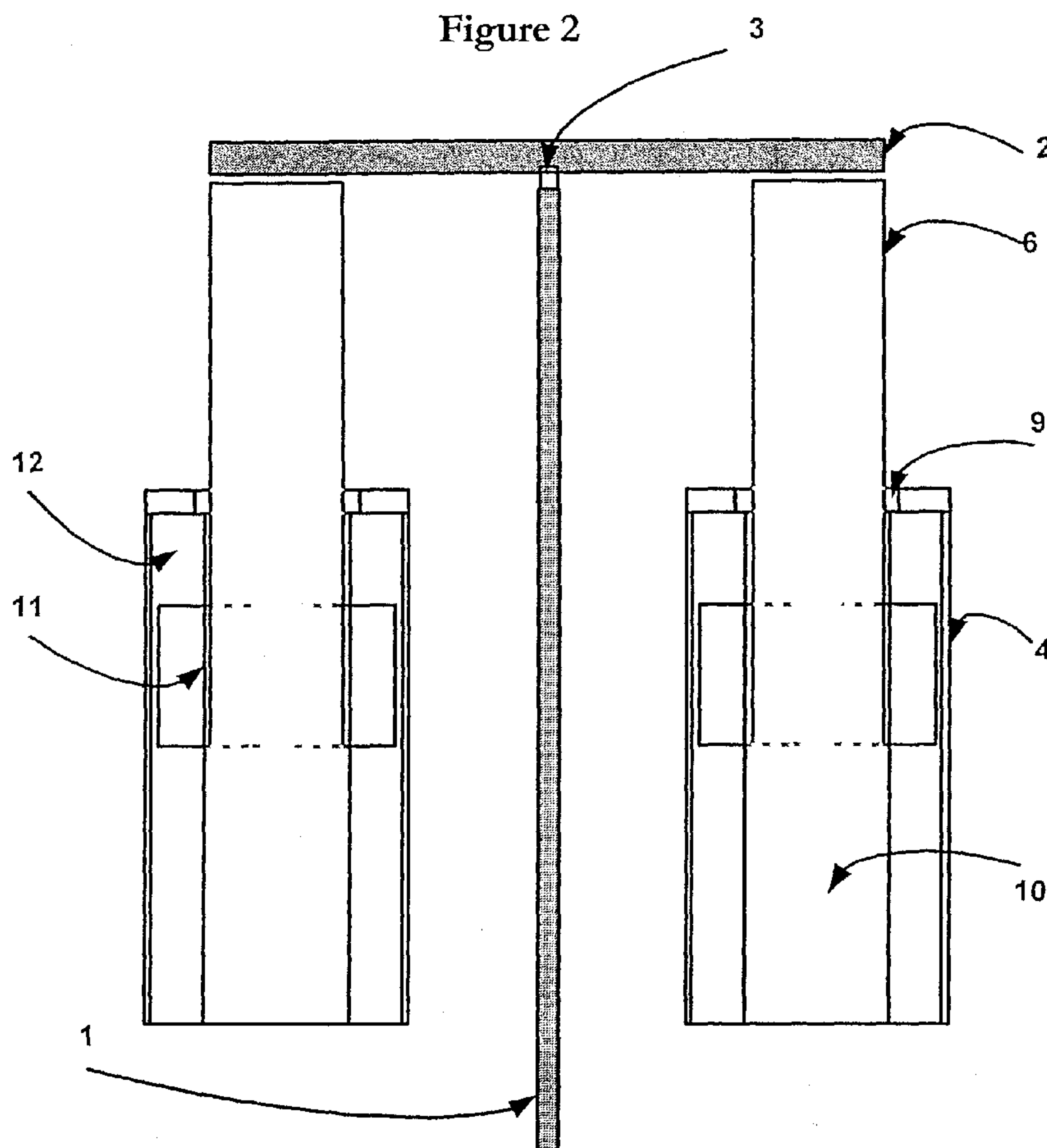
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(54) Title: ARTIFICIAL LIFT MECHANISMS

Figure 2



(57) Abstract: The invention relates to electric linear motors and gas springs in reciprocating pumps for oil wells. By the use of this invention a simple, silent, compact and adaptable mechanism can be constructed to drive a wide range of such pumps. The mechanism will sense a variety of pumping conditions and react automatically thereto.

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ARTIFICIAL LIFT MECHANISMS

TECHNICAL FIELD

- 5 The present invention relates to a form of mechanism intended to drive a reciprocating pump to lift liquids from a deep well or borehole.

BACKGROUND ART

10 In a “jack pump” mechanism, a piston and non-return-valve unit at the base of the well or borehole (which may be several thousand metres deep) is generally connected to the drive mechanism at the surface by means of a long steel rod that, being assembled in sections and screwed together, is known as a rod string. The topmost section of that string — the section that emerges from the well through a pressure seal — necessarily has a higher surface finish and is known as the polished (or polish) rod.

- 15 The polished rod is directly connected to the reciprocating mechanism that forms the invention described herein.

It has long been known to construct such mechanisms in the form of an oscillating horizontal beam having a hammer-shaped end, over which is wrapped a chain or cable from which the pumping string is suspended. Other, more complex, mechanisms exist
20 in which, for example, the polished rod is suspended from a pulley or belt and in which the pulley or belt is raised and lowered by the rotation and contra-rotation of a winch mechanism. Nevertheless, the reciprocating beam or “nodding donkey” has remained the most popular device for moving a rod string. Reciprocating beams have been in use since the eighteenth century for pumping water from mines.

- 25 The powered end of the reciprocating beam unit has either been driven by a linear actuator, similar to an early steam engine design (the Atmospheric or Newcomen engine) or by a crank mechanism, driven in turn by a rotary engine, such as an electric, petrol, gas or diesel engine. These engines have a low output torque and a heavy duty gearbox must be interposed to reduce the rotary speed and to increase the
30 torque of the crank that moves the beam.

It will also be understood that the long steel string that connects the drive mechanism at the top of the well with the pump itself at the base of the well has a weight of several tonnes, which must also be supported by the beam. To increase the efficiency of the mechanism, the weight has to be counterbalanced. Although some recent
5 mechanisms have used a gas spring (in the form of a pneumatic cylinder as a “prop” beneath the loaded end of the beam) it is more common for the counterbalance to be in the form of eccentric weights, attached to the shaft of the crank mechanism that drives the oscillating beam.

From earliest times the pumping stroke has traditionally been about ten feet (two or
10 three metres) and the pumping frequency has been around 5 (between 1 and 10) strokes a minute. It will be understood that the traditional choices have been determined by the large masses involved and by the asymmetric action of the device, which places high stress on the parts and causes significant wear on the bearings of the “nodding donkey” mechanism.

15 The traditional machine has many moving parts and it is required to operate for 24 hrs. a day, 365 days a year for several years, so it will be understood that it needs regular inspection, lubrication, maintenance and repair.

It will be further understood that pumping mechanisms in the past have been designed with regard to their mechanical function alone. The process of their design has been
20 entirely focussed on providing a reliable method of raising and lowering a long rod string within a shaft through which the liquid is itself raised on the upstroke of the pump. In the design of that mechanism no significant thought was given to means of sensing the efficacy of the pumping operation or of reacting to special conditions that may strongly affect the loads on the pumping apparatus. For example, the
25 mechanisms of the prior art do not generally incorporate within themselves the ability to sense and to react appropriately to conditions such as a dry well, a broken rod string or a stuck valve. Such conditions could only be discovered or diagnosed as a result of routine inspection and maintenance and before that discovery the untreated condition will not only have lost output, but may have been the cause of considerable
30 damage to the pumping mechanism.

In recent years a variety of alternative systems have been devised, some using directly-applied hydraulic power to raise and lower the polished rod. Other alternatives have proposed the use of direct-acting linear electric motors, although none of them has been commercially successful.

- 5 Exemplary is that of these proposals which is disclosed in United States Patent No. 5,960,875, issued October 5, 1999, to Elf Exploration Production. The document describes a mechanism by which the piston of an oil pump (placed deep within the borehole and close to the base of the well) is so constructed as to be combined with the cylindrical armature of a linear electric induction motor. It will be understood that,
10 to be lowered into the bore of the well, the outer diameter of that armature has to be restricted to just a few centimetres. United States Patent No. 5,960,875, proposes that the combined piston and armature shall be driven vertically upwards and downwards by forces induced in the said armature by a surrounding set of cylindrical coils and since they must also be lowered into the borehole, the said cylindrical powered coils
15 must also have an outer diameter not significantly greater than that of the piston.

Unfortunately, the proposed design of linear motor is beyond any known technology. The weight of oil that must be raised by every upward stroke of the pump is a few tonne force, so that the force that must be produced by the small diameter electromagnetic piston has to be several thousands of kilograms. But at this time no
20 such small-diameter motor of reasonable length, efficiency and cost can be constructed to meet the requirements of the artificial lift mechanism and to satisfy the safety requirements of the oil business. The invention is therefore impractical of commercial realization.

United States Patent No. 5,196,770, issued March 23, 1993, to Marine Petroleum
25 Equipment, also describes a cylindrical linear electric actuator. In this case it is placed at the head of a well and drives the heavy rod string to move the submerged pump. The proposed linear electric motor is much larger, heavier, more complex and more expensive than that proposed in United States 5,960,875. It is described as being of inductive design, or in the alternative as being of synchronous, asynchronous or
30 variable reluctance design. Unfortunately, all of these are known to be inefficient at the velocities and reciprocation rates that are typical of jack pumping operations. It is also costly to make such linear electric motors to a standard that would allow them to

pass the safety regulations for electrical power devices in a flammable gas environment.

There is the further disadvantage that both the moving part or armature and the fixed part or stator must be continuously supplied with many kilowatts of electrical power.

5 Thus there are cooling difficulties (resulting from the motor inefficiencies and the need to conduct heat away from a moving body) and other problems relating to the incessant flexing of the power cable to the moving part. No reliable electric linear actuator can be constructed to meet the demands of the invention while having a reasonable price, size and weight.

10 It is to be noted especially that the proposed machine has a fixed (predetermined) counterbalance in the form of a large mechanical weight at the far end of a cable that turns 180 degrees around a sheave, so that both the cable and the sheave bearing are highly stressed and will need frequent replacement. In the alternative there are described arrangements by which the armature is effectively hung from a pneumatic
15 cylinder (or a pair of such cylinders) forming part of a gas spring that is pressurized to provide a (predetermined) counterbalance force.

Canadian Patent No. 2,250,739, issued May 30, 2006, to Raos, provides for a machine in which the prime mover is a simple linear motor that is conceived to have a short rectangular armature that runs between two rectangular stators. It is very difficult, if
20 not impossible, to design such a motor that is capable of producing the large forces required to drive the machine while remaining efficient at the slow speeds demanded by the application and meeting the statutory requirements for safety in an oil field environment.

The form of the preferred counterbalance is said to be that of a very large steel spring,
25 compressed between the base of the machine and the electrical armature, so as to support the armature against the deadload of the rod string. (It will be understood that the weight of the rod string may approach 10 tonnes). As is known, the force exerted by a spring is directly proportional to its compression or extension. A common requirement for such a counterbalance is that the force shall remain within ten percent
30 of its set value while the armature travels through a stroke distance of plus or minus

1.25 metres (total displacement 2.5 metres or 100 inches). That means that the length of the spring when compressed to support the rod string must be about 12.5 metres or 40 feet — and that its uncompressed length has to be about 50 feet. Such a massive spring would probably have an outer diameter of several metres. Although alternative
5 counterbalancing systems using pneumatic or hydraulic cylinders are mentioned, they are not described and no related invention is claimed. A further alternative type of counterbalance is mentioned, being a mechanical counterweight connected via a cable and sheave, which would have the same disadvantages described in relation to United States Patent 5,196,770, *supra*.

10 Although Canadian Patent No. 2,250,739, teaches the critical importance of the value of the counterbalance force, the invention as described has a counterbalance force that is not only predetermined but is non-adjustable, so that it cannot be altered in response to changing conditions.

The type of linear motor described in Canadian Patent No. 2,250,739, would appear to
15 be a switched variable-reluctance machine with individual parts of the stator being commutated under microprocessor control. The design of such a motor would be very complex and no such motor is known that would be capable of meeting the exacting demands of this application.

Further, although Canadian Patent No. 2,250,739, teaches the advantages of an
20 electric linear motor with respect to its ability to change its stroke and speed under remote control and in automatic response to local emergency conditions, it does not describe any method by which those conditions might be detected - and the ability of the machine to detect and to respond to emergency conditions is not therefore claimed.

25 **INDUSTRIAL APPLICABILITY**

The invention has applicability in all forms of liquid recovery from deep shafts and boreholes.

The prior art inventions in which it is proposed that a vertically-disposed linear electric motor will be used to drive the motion of a jack pump by direct connection to its rod string have limitations in four critical areas:

1. No proposed type of linear electric motor has been capable of producing the required mechanical forces while being of acceptable size, weight, efficiency and cost;
2. No proposed counterbalance system has been continually adaptive to changes in pumping conditions, so as to minimize dynamic loads on the linear electric motor;
3. No proposed gas spring counterbalance has been continually optimized for the storage and recycling of energy in the reciprocating mechanism; and
4. No proposed type of linear motor has been inherently capable of load-sensing, so that its current demand signals might be used for the control of the mechanism as a whole.

DISCLOSURE OF THE INVENTION

15

One object of the present invention is to construct a thoroughly-practical reciprocating pumping (or "artificial lift") mechanism using a very powerful and highly efficient type of electric linear motor in combination with an adaptive inert gas spring counterbalance, the apparatus being especially suitable for use in association with oil wells and those for de-watering underground gas reservoirs.

20

It is a further object of this invention that the novel artificial lift mechanism, in combination with an electronic drive unit of conventional design and standard specification, will be capable of sensing a variety of pumping conditions, of reporting them to a distant monitoring centre, of responding to remote commands and/or of reacting immediately and automatically in a predetermined way to several emergency conditions.

25

It is a further object of this invention that the novel artificial lift mechanism shall be compact, fully enclosed, relatively light in weight and lower in cost than mechanisms of the prior art, while meeting all statutory regulations for such equipment in oilfield conditions.

30

It is a further objective of this invention that the machine shall be so constructed as to allow energy to be stored during one part of the pump cycle in such a manner that it can be recovered during a later part of the cycle, so as to improve the efficiency of the reciprocating mechanism.

- 5 It is a further objective of this invention that the machine shall be so constructed that each standard marc or model can be so controlled as to suit a wide range of wells, thus reducing the number of different models that are necessary to satisfy the market, minimizing stock inventory, manufacturing cost and training for field work.

The principal advantages of the invention include:

- 10 i. The mechanisms of the prior art have employed many stressed moving parts, on whose continuing and satisfactory operation the reliability of the whole depends. In this instant technology, the sole moving part is the extendible member, so that the mechanism is inherently reliable and needs little maintenance;
- ii. Because the machine is generally placed vertically above the shaft from
15 which the polished rod exits the well, the mechanical stress is orthogonal to the bearing surfaces and bearing wear is minimized;
- iii. Power consumption is also minimized because the gas counterbalancing mechanism is continually tuned to that parameter;
- iv. The inert gas that is used for the counterbalancing function is pressurized
20 within the body of the electrical system, so that it thereby acts also to prevent any flammable gases or liquid aerosols from coming into contact with the electrical apparatus, removing the risk of a fire or an explosion;
- v. The use of the machine in association with an electronic drive unit having drive current output signals and subsidiary computing facilities allows the apparatus
25 to be self-monitoring, self-adjusting and self-protecting so as to maximise productivity and minimize service time;
- vi. The machine consumes little inert gas in normal operation because it is fitted with an economising chamber by which the diurnal temperature variations (which would normally lead to significant consumption of the inert gas) are
30 accommodated without loss;

vii. The machine is entirely enclosed and safe from accidental contact by humans or animals, so that protective arrangements surrounding the well head are simplified;

5 viii. The machine is completely silent and may be used in ecologically-sensitive areas;

ix. The parameters of the reciprocating motion (stroke length, cycling frequency, waveform, etc.) can be automatically controlled according to predetermined strategies and in response to any type of pumping condition that may arise, thus conserving the life of the machine while maximizing productivity; and

10 x. Because the parameters of the counterbalance system are automatically adjusted to an individual load, and because the stroke, stroke frequency and waveform of the reciprocating cycle are independently, remotely and automatically variable over a wide range, physically identical ("standard") machines can be applied to many different pump specifications. Thus the necessary product range is minimized,
15 manufacturing costs are reduced, stockholding is simplified and the time for product training and site work is shortened.

In this invention the machine is comprised of at least one cylindrical electromagnetic linear actuator placed above and adjacent the well-head, the electromagnetic linear actuator being fully enclosed and having a sliding gas seal through which an
20 extendible member emerges from the body of the actuator, the pumping string being connected to the extendible member by means of a polished rod or equivalent component, the deadload of the pumping string being supported by the pressure of an inert gas within the body of the sealed electromagnetic actuator, the reciprocating motion of the pumping string being driven by the electromagnetic forces on the
25 extendible member, the inert gas pressure being automatically adjusted so as to minimize power consumption, there being an intermediate pressure chamber and valves arranged to reduce gas consumption that would otherwise be caused by diurnal temperature cycles, the actuator being controlled by an electronic drive unit and having means incorporated therein or communicable thereto for measuring the
30 instantaneous current required to drive the said actuator, the said current measurements being analyzed according to predetermined algorithms, the inert gas counterbalancing pressure and the modes of action of the pumping mechanism being

arranged to respond automatically according to the said algorithms, the relevant data being also transmitted to a remote monitoring station.

It will be understood that until very recently it has been neither practical nor expedient to employ an electromagnetic linear actuator to drive an artificial lift pump for an oil
5 or gas well. That is principally because no electromagnetic linear actuator of sufficient thrust and power has been available at an acceptable cost. The recent invention of wireless motors has transformed the situation and what was previously impossible is now practical. Generally, the linear motor components used in the instant invention will be constructed according to one of the wireless motor patents.
10 Nevertheless, it will be understood that, in principle and subject to the demands of the application being met by improvements in such machines, the electromagnetic actuator or actuators may be constructed in any practical and convenient form without changing the fundamental nature of the invention.

Generally the position of the extendible member will be measured by means of an
15 appropriate transducer and the electromagnetic actuator forming part of that extendible member will be supplied with electric current via a standard type of electronic drive unit, originally designed for use with rotary motors and commonly available for factory automation purposes. Such a standard drive unit has a number of very useful features, whereby both the current supplied to the motor and the drive
20 voltage across the motor terminals are sampled at frequent intervals. (The current is a direct measure of the force produced by the motor and the voltage is a measure of the speed with which it is moving.) Further, an electronic drive unit will commonly have spare power supply outputs and spare computing power available, sometimes on separate plug-in modules.

25 The extendible member is commanded to follow a sinusoidal waveform of predetermined amplitude and frequency, the drive current demanded by the motor being sampled, as an example, 100 times per cycle. The current measurements are divided into two groups - those in which the movement is upwards and those in which the movement is downwards — and the root mean square of the motor drive current is
30 computed for each group. The rms values are repeated for, as an example, ten

complete cycles and the values added. If, for example, the difference between the two values exceeds a tolerance value in such a way that the power required to raise the extendible member is significantly greater than that required to lower it, the mass of gas in the spring is increased by opening a control valve for a total time proportional
5 to the excess. Conversely, if it requires more energy to compress the gas spring on the down stroke than it does to raise it on the upstroke, the opposite action is taken and the mass of gas in the spring is reduced. It can be demonstrated that the power consumption of the system is minimized by the above algorithm.

If the pumping action should suddenly cease (perhaps by reason of a string breakage,
10 for example) the same algorithm will immediately detect the difference in force required to move the string and cause the pressure in the gas spring to be quickly reduced to protect the machine. The pumping action might then be stopped completely, or the motion reduced to a small amplitude only. The difference in gas pressure before and after the break will provide an immediate estimate of the position
15 of the breakage, so that estimate might be automatically computed and transmitted to a central monitoring facility.

It will be understood that an air lock or a valve failure will also have an immediate effect on the pattern of current values recorded throughout each pumping cycle. Thus, independently of the algorithm used to adjust the gas spring pressures, a number of
20 entirely separate computing algorithms might be arranged to process the very same cyclic data to detect such other anomalies.

The pattern of current values (*i.e.* the measurements of instantaneous power taken by the motor) contains detailed information about the quantity of liquid in the rising column and the rate at which it is being pumped. Further automatic analysis of that
25 data might therefore be used to prepare regular monitoring reports for telemetry to a central monitoring station.

Generally the actuator or actuators will be cylindrical with an extendible member of cylindrical cross section and they will incorporate the gas spring within the actuator casing. It will be understood that in the alternative the gas spring or springs might be
30 conveniently constructed and disposed separately from the electromagnetic actuators.

Generally the polished rod of the pumping string will pass through an open cylindrical channel on the central axis of a single actuator, the cylindrical channel being arranged to separate the polished rod from the pressurized body of the machine, leaving the polished rod "outside" the actuator itself. It will be understood that in the alternative

- 5 the machine may be constructed from a plurality of actuators symmetrically disposed athwart the polished rod and connected thereto by means of a crosshead.

In the conventional form of this apparatus the electrical system is the stator and the magnet array is the armature, but in an alternative arrangement of this invention the electrical system may be the armature and the magnet array may be the stator.

Thus, in one aspect, there is provided a mechanism for driving a reciprocating pump or an artificial lift device, having one or more linear electric motor and at least one gas spring, characterized in that the mass of gas in said at least one spring is continually controlled in accordance with the current demands of the one or more linear motor, integrated over a plurality of complete operating cycles of said reciprocating pump or artificial lift mechanism and at least one of the one or more electric linear motor is arranged to raise and lower an extendible member, said extendible member being arranged to pass through a sliding gas seal in an upper part of a chamber, said chamber containing or forming part of the structure of said at least one electric linear motor, said chamber being filled with an inert gas under pressure so as to form a combined electric linear motor and gas spring.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross section of a basic cylindrical mechanism;

Figure 2 is a schematic illustration of an alternative arrangement to that shown in Figure 1;

Figure 3 is a schematic illustration of a further alternative arrangement to that shown in Figure 1; and

Figure 4 is a schematic illustration of an arrangement by which gas may be conserved that would otherwise be lost by reason of diurnal temperature changes

Similar numerals denote similar elements.

-11A-

MODES FOR CARRYING OUT THE INVENTION

With reference to Figure 1, shown is a diagrammatic vertical cross section of a basic cylindrical mechanism in which the polished rod of the pump string 1 is suspended from a disc 2 by means of a shackle or flexible coupling 3. The flexible coupling is necessary to accommodate the small tolerances in alignment that may exist or that may momentarily occur between the axis of the machine and the direction of the applied force. The rod 1 passes through a cylindrical channel or cavity in the body of the mechanism, the channel or cavity being bounded by the upper tube 7 and the lower tube 5. The interior of the mechanism is made gas-tight by means of the seal and bearing unit 8 between the coaxial tubes 5 and 7.

The rod string 1 is raised and lowered by means of the extendible cylinder 6 to which the disc 2 is affixed on its uppermost outer surface. The cylinder 6 extends variably from the body of the machine 4 through a second bearing and seal unit 9. The position of the cylinder 6 is controlled by the force produced by the interaction of electrical
5 currents in the conductor vanes 12 with magnetic fields produced by the permanent magnet and pole piece array 11. The deadload of the pump rod string 1 is counterbalanced by the force on the effective area of the extendible cylinder 6, produced by the pressure of inert gas within the internal volume of the machine 10.

It will be understood that the gas pressure in the volume 10 will vary adiabatically
10 according to the position of the extendible member 6 during pumping cycle. Thus the electromagnetic actuator 12, 11 will cause energy to be stored within and drawn from the gas spring in such a manner that the electrical power consumption is minimized and the peak electrical power demand is greatly reduced.

The actuator 11, 12 is also fitted with a vented upper casing or cap 13, (the vents not
15 being shown in this Figure) whose purpose is to protect the surface of the extendible member 6 and that of the upper seal 9 from the effects of weather, salt, grit and other aspects of the external environment that might be detrimental to the life of the machine. It is another function of the cap 13 to complete the enclosure of the mechanism so that no animal or person can be harmed by accidental contact
20 therewith.

Referring now to Figure 2, shown is an alternative arrangement in which a plurality of electromagnetic linear actuators may be connected to the polished rod by means of a cross-head piece. In this Figure, shown for clarity are two such electromagnetic linear actuators, being symmetrically disposed athwart the polished rod and constructed to
25 contain pressurized extendible members forming gas springs, thus providing both a counterbalancing force and an energy storage device in association with the masses of the rod string and of the liquid column. Similar numerals depict the same elements as those employed in Figure 1.

Figure 3 shows a further diagrammatic alternative arrangement in which at least one
30 unit has a pure pneumatic function and does not contain an electromagnetic actuator,

so that it acts only as a gas spring. Shown are two such gas spring units 14, having drive piston rods or thrust tubes 15 symmetrically disposed athwart the well head, and two electromagnetic actuators of the form shown in Figure 2 equivalently disposed. It will be understood that in practice the crosshead joining the gas spring units 14 might
5 be orthogonal to the crosshead joining the linear motors. It will be understood that any arrangement of a plurality of gas spring components and a plurality of linear electric motor components, whether or not the functions of those components are combined, will perform the required function without changing the nature of the invention.

Figure 4 shows a diagrammatic arrangement of the intermediate or economizing pressure chamber 16 and electrically-operated valves 17, 18 and 19. It will be
10 understood that the valves may actually be mounted within the sealed chamber 16 and thus immersed in an inert gas environment. It should first be recognized that the pressure of the gas in the counterbalancing mechanism 10 is not constant, but varies during the pumping cycle, reaching a minimum when the extendible member 6 is
15 raised to its uppermost point and being at a maximum when the pumping string is at its lowest point. Consider first that the pressure of gas in the economizing chamber 16 is approximately the same as the median pressure of gas in the gas spring chamber 10. Now if it should be required that the mass of the gas within the counterbalancing mechanism shall be increased, the valve 17 is opened, for a short period only, while
20 the gas spring pressure in 10 is at or near its lowest point. Gas will then pass from the economy chamber into the gas spring volume. Conversely, if it is necessary to reduce the mass of gas within the spring 10, the valve 17 is opened, for a short period only, while the spring pressure is at its maximum value.

The chief use of the economy chamber is related to the diurnal temperature cycle. It
25 will be understood, for example, that in the heat of the day both the gas in the spring and the gas in the economy chamber will increase in pressure, but that it will still be possible by the method described above to reduce the mass of gas in the spring when required - and thus to optimise the electrical power consumption of the artificial lift mechanism — by moving the surplus gas into the economy chamber without actually
30 disposing of it. In the evening of the same day the temperature of the mechanism will fall and it will be necessary to move gas back into the spring 10 from the economy chamber 16 in order to maintain its pressure at that temperature so as to produce the

correct counterbalancing force. The reverse flow is accomplished by timing the operation of valve 17 in the manner previously described — but in this case the valve is opened for a short time when the extendible member is at the top of its stroke and the pressure in the gas spring chamber is at a minimum.

5 Valve 19 connects the economy chamber to the primary source of gas supply 20; valve 18 allows the economy chamber to be vented to atmosphere if required. Pressure transducer 21 measures the difference in pressure between the gas spring and the economy chamber at all times. If, during the short interval when valve 17 is
10 opened to allow gas from the economy chamber 16 to flow into the gas spring chamber 10, the differential pressure between them is less than, for example, 0.5 Bar, valve 19 is also opened for a predetermined interval so as to increase the pressure in the economy chamber 16. Conversely, if, during the short interval when valve 17 is opened to allow gas to flow from the gas spring into the economy chamber, the
15 reverse differential pressure is less than, for example, 0.5 Bar, valve 18 is also opened for a predetermined interval so as to reduce the pressure in the economy chamber. It will be understood that this feature of our invention corrects the gas spring settings for gradual temperature changes and for any slow gas leakage that might occur.

It will be understood that the principles of this invention are not limited to permanent magnet motors but may be extended to include electrical actuators of any other type,
20 including those that use electromagnets, or electrical machines that employ the induction principle, such as those described in various co-pending patent applications relating to wireless motors, wherein the array of permanent magnets is replaced by a passive arrangement of patterned conductive laminations. When a travelling magnetic field is produced by phased alternating currents in the powered conductors, eddy
25 currents are deliberately arranged to flow in the passive conductor array and the interaction of the induced currents and the controlled alternating currents creates an axial force. Although the resulting axial force is smaller than that produced by a machine using permanent magnetic fields or by a machine that uses fields produced by electromagnets, that form of construction is even lower in cost and lighter in
30 weight. The cost and weight advantages may, in some circumstances, offset the lower efficiency of the induction motor.

CLAIMS:

1. A mechanism for driving a reciprocating pump or an artificial lift device, having one or more linear electric motor and at least one gas spring, characterized in that the mass of gas in said at least one spring is continually controlled in accordance with the current demands of the one or more linear motor, integrated over a plurality of complete operating cycles of said reciprocating pump or artificial lift mechanism and at least one of the one or more electric linear motor is arranged to raise and lower an extendible member, said extendible member being arranged to pass through a sliding gas seal in an upper part of a chamber, said chamber containing or forming part of the structure of said at least one electric linear motor, said chamber being filled with an inert gas under pressure so as to form a combined electric linear motor and gas spring.
2. The mechanism in accordance with claim 1, in which at least a part of the deadweight of a rod or rod string connecting said at least one linear electric motor to said reciprocating pump is supported by the controlled gas spring.
3. The mechanism in accordance with claim 2, in which the controlled gas spring is arranged to store energy during part of its motion, such that later release of said energy assists the motion of the reciprocating mechanism to reduce electrical power demand.
4. The mechanism in accordance with any one of claims 1 to 3, in which the gas in said at least one gas spring is an inert gas.
5. The mechanism in accordance with claim 1, a topmost part of the combined electric linear motor and gas spring being fitted with a protective cover for protecting the surface of said extendible member where it emerges from the pressurized enclosure containing said at least one electric linear motor.

6. The mechanism in accordance with claims 5, including an intermediate chamber associated with said gas spring and connected thereto with an electrically-operated valve.
7. The mechanism in accordance with claim 6, further including a transducer arranged to measure the differential pressure across said valve, said intermediate chamber being connected via the electrically-operated valve to a source of pressurized inert gas and via a second valve to the outside atmosphere.
8. The mechanism in accordance with claim 7, the valve of said intermediate chamber being operated in accordance with algorithms related to current demands of said linear motor, the motion of said reciprocating thrust tube and the differential pressures measured by said transducer, to utilize and to conserve the inert gas supply.
9. The mechanism in accordance with any one of claims 1 to 8, in which measured values of instantaneous current demands of said one or more linear electric motors are mathematically processed to calculate at least key parameters of the pumping operation, detect faults and anomalies, initiate appropriate automatic responses, prepare information for transmission to a remote site and combinations thereof.
10. An apparatus for pumping a liquid from a deep shaft or borehole characterized in that said apparatus comprises in combination:
 - one or more electric linear motor; and
 - a gas spring counter balanced for cooperation with said one more electric linear motor, said spring acting to remove all deadload forces from the electric motor and for storing and recycling energy to minimise dynamic power consumption, wherein at least one of the one or more electric linear motors is arranged to raise and lower an extendible member, said extendible member being arranged to pass through a sliding gas seal in an upper part of a chamber, said chamber containing or forming part of the structure of said at least one electric linear motor, said chamber being filled with an inert gas under pressure so as to form a combined electric linear motor and gas spring.
11. The apparatus in accordance with claim 10, characterized in that the mass of gas in the spring is varied in accordance with the integrated electric current consumption of the at least one electric linear motor.

12. The apparatus in accordance with claim 10, characterized in that said apparatus is arranged to be both fully autonomous and remotely controllable.

13. A method for pumping a liquid from a deep shaft or borehole characterized in that said method comprises the steps of:

providing the apparatus as defined in claim 10;

connecting said apparatus via a rod string to a pump positioned within said well;

supplying controlled electric power to the apparatus; and

recovering said liquid.

Figure 1

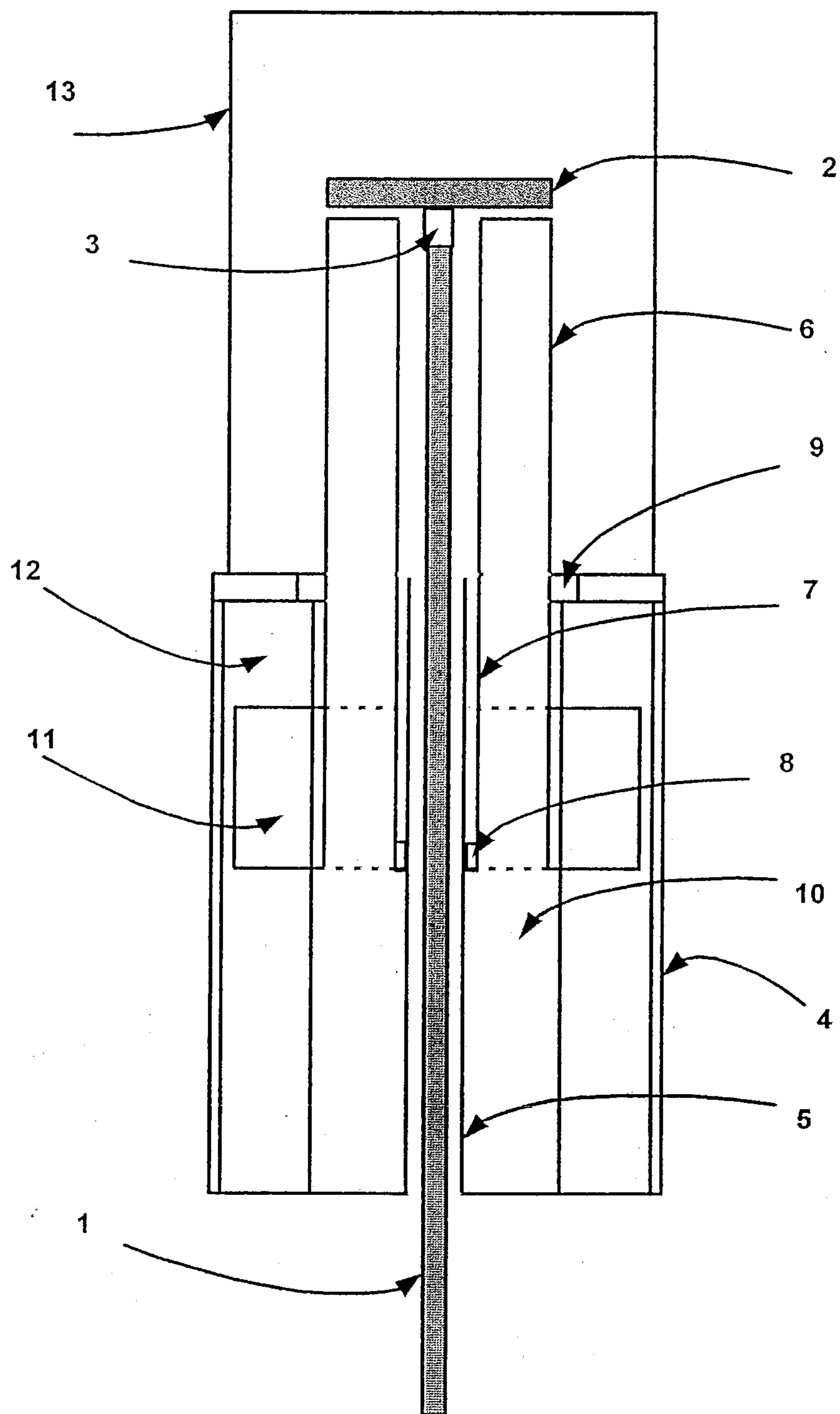


Figure 2

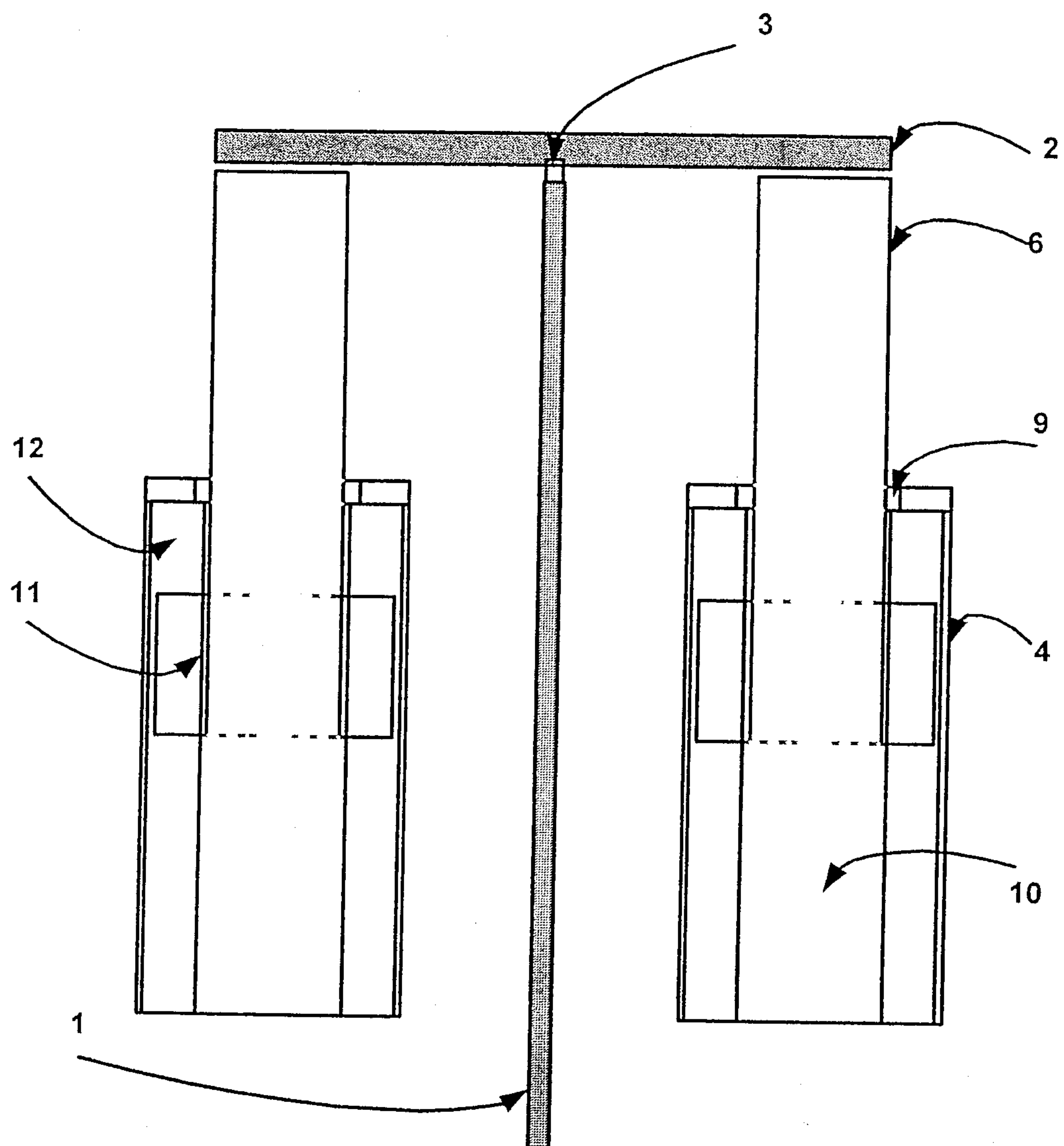


Figure 3

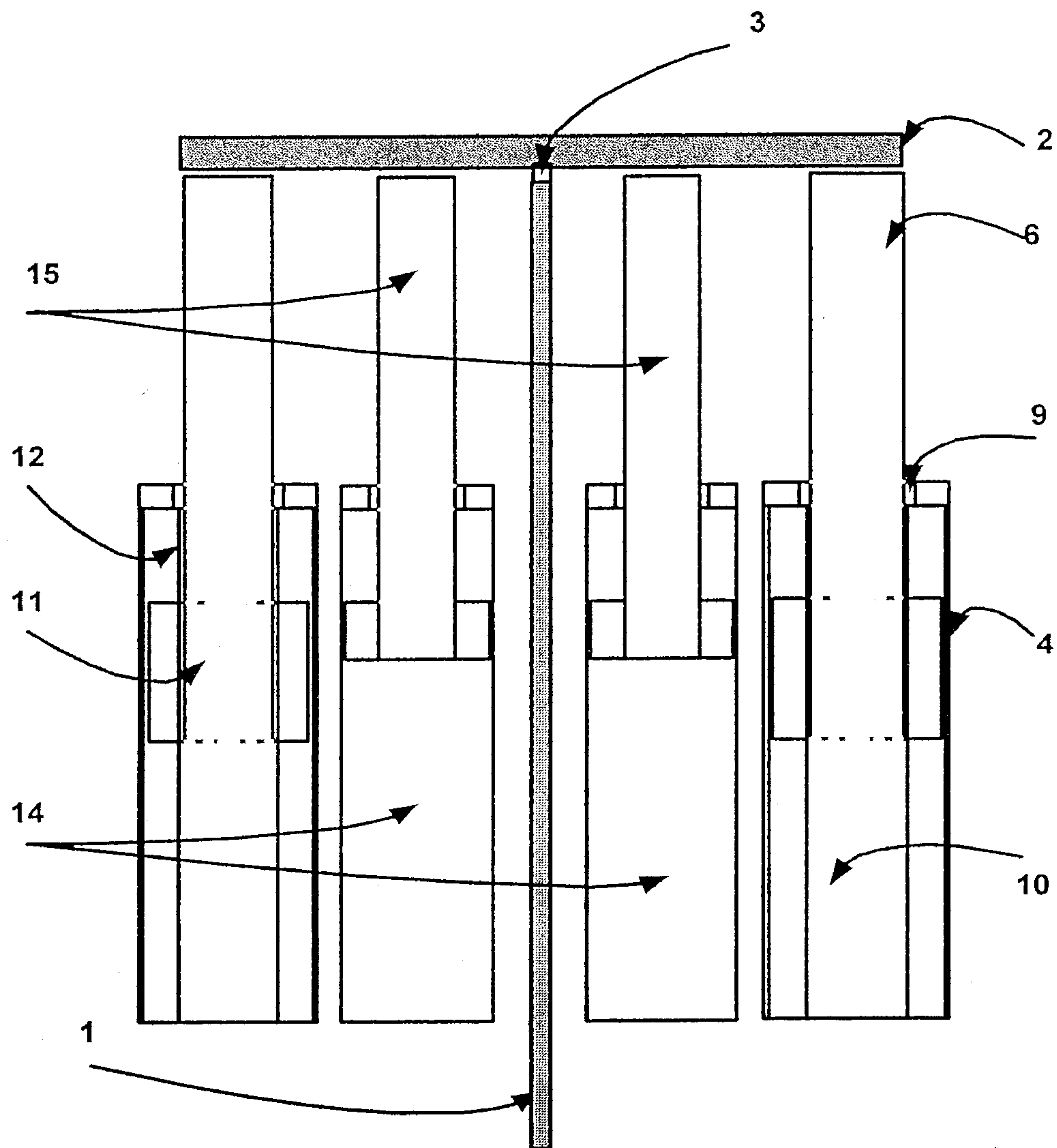


Figure 4

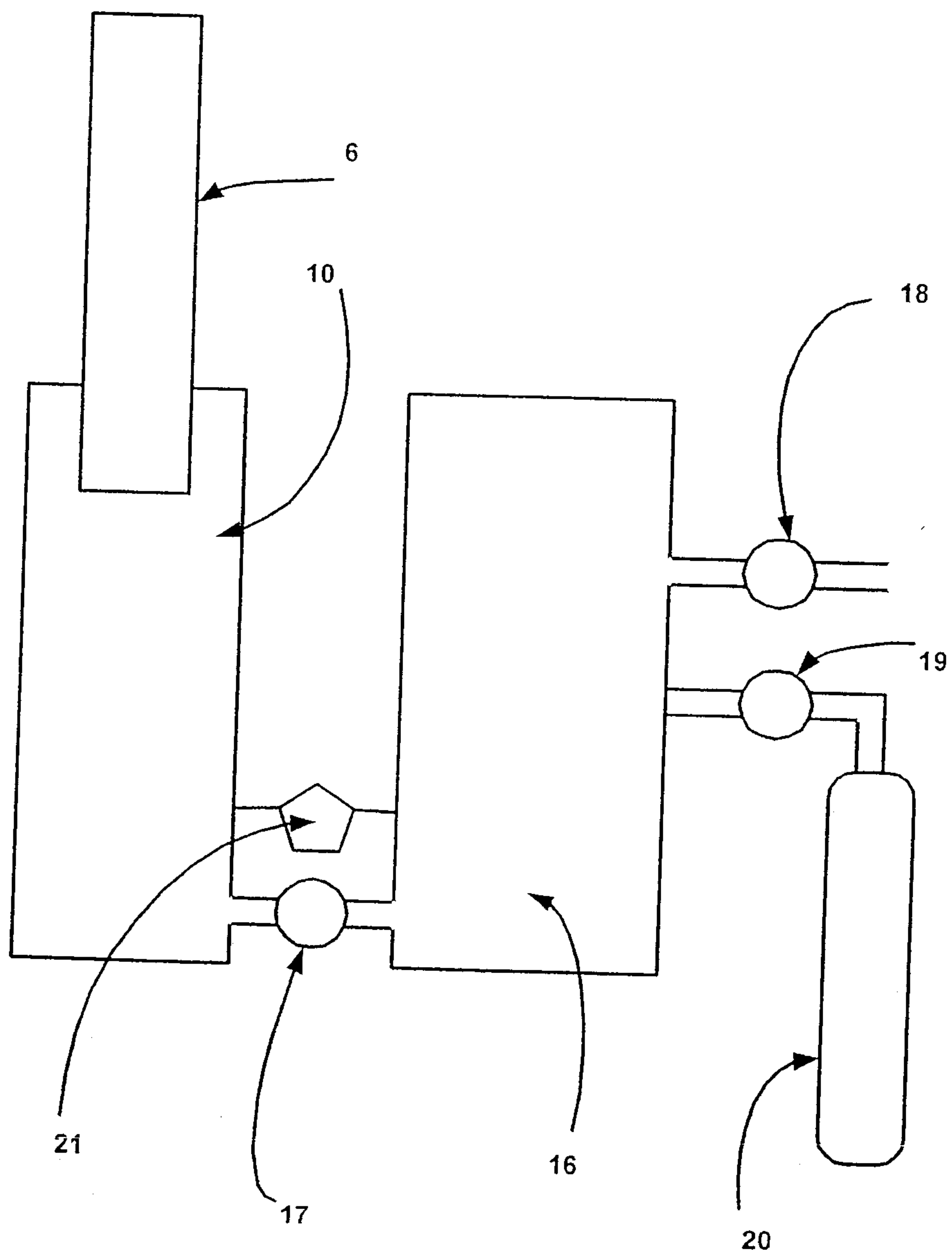


Figure 2

