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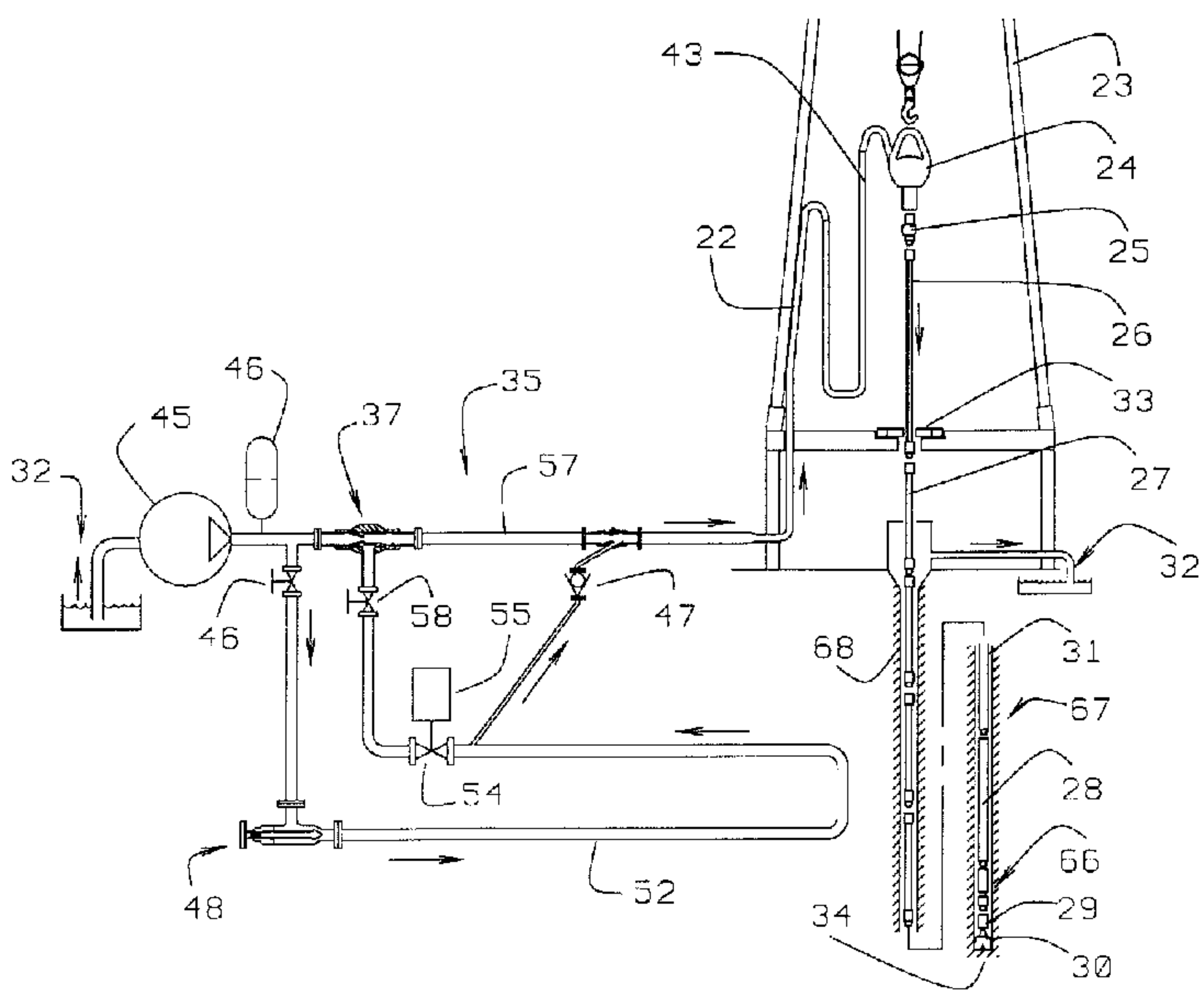
(71) Demandeur/Applicant:
WALTER, BRUNO H., CA

(72) Inventeur/Inventor:
WALTER, BRUNO H., CA

(54) Titre : METHODE ET APPAREIL POUR PRODUIRE DES IMPULSIONS ACOUSTIQUES SUR LA SURFACE ET TRANSMETTRE CES IMPULSIONS PAR LE TRAIN DE TIGES AU TREPAN POUR AUGMENTER LA VITESSE D'AVANCEMENT DU FORAGE

(54) Title: METHOD AND APPARATUS FOR GENERATING ACOUSTIC PULSES ON THE SURFACE AND CONVEYING THESE PULSES THROUGH THE DRILL STRING TO THE DRILL BIT TO INCREASE RATE OF DRILLING



(57) Abrégé/Abstract:

A method and apparatus are disclosed for generating intense acoustic pulses by means of water hammer effect on the surface and conveying these pulses through the drill pipe and drill collars down to the drill bit. Intensity of the acoustic pulses is increased in the bit nozzles. Vigorous pulsing of the fluid exiting the bit nozzles results in better cleaning of the hole bottom and faster drilling. By adding a down hole telescopic tool with multiple pistons arranged in series acoustic pulses are converted into a strong mechanical vibration which increases the efficiency of the drill bit and the whole drilling process. Vibration of the drill string reduces the friction between the drill string and the hole resulting in lower torque requirements. By adding a multiple piston telescopic tool above the drill bit and one or few drill collars acoustic pulse is converted into a strong mechanical upward pulse which causes the bottom end of the drill string to vibrate. Rate of drilling is increased while torque required for the drilling process is reduced.

ABSTRACT

A method and apparatus are disclosed for generating intense acoustic pulses by means of water hammer effect on the surface and conveying these pulses through the drill pipe and drill collars down to the drill bit. Intensity of the acoustic pulses is increased in the bit nozzles. Vigorous pulsing of the fluid exiting the bit nozzles results in better cleaning of the hole bottom and faster drilling. By adding a down hole telescopic tool with multiple pistons arranged in series acoustic pulses are converted into a strong mechanical vibration which increases the efficiency of the drill bit and the whole drilling process. Vibration of the drill string reduces the friction between the drill string and the hole resulting in lower torque requirements. By adding a multiple piston telescopic tool above the drill bit and one or few drill collars acoustic pulse is converted into a strong mechanical upward pulse which causes the bottom end of the drill string to vibrate. Rate of drilling is increased while torque required for the drilling process is reduced.

METHOD AND APPARATUS FOR GENERATING ACOUSTIC PULSES ON THE SURFACE AND CONVEYING THESE PULSES THROUGH THE DRILL STRING TO THE DRILL BIT TO INCREASE RATE OF DRILLING.

FIELD OF THE INVENTION

This invention relates to a method and apparatus for the generation of high intensity acoustic waves in a drilling fluid, conveying these acoustic waves/pulses down through the fluid contained in the drill string, converting them into a mechanical vibration to increase the efficiency of the drilling process.

BACKGROUND OF THE INVENTION

As previously disclosed in my US patent 4,979,577 in the drilling of deep wells such as oil and gas wells it is common practice to drill utilizing the rotary drilling method. A suitably constructed derrick suspends the block and hook arrangement, together with a swivel, kelly, drill pipe, drill collars, other suitable drilling tools, for example reamers, etc with a drill bit being located at the extreme bottom end of this assembly which is commonly called the drill string.

The drill string is rotated from the surface by the kelly which is rotated by a rotary table. During the course of the drilling operation, drilling fluid, often called drilling mud, is pumped downwardly through the hollow drill string. This drilling mud is pumped by relatively large capacity and high pressure mud pumps. At the drill bit this mud cleans the rolling cones of the drill bit or the teeth of the PCD (polycrystalline diamond) drag bit, removes or clears away the rock chips from the cutting surface and lifts and carries such rock chips upwardly along the well bore to the surface.

In more recent years, around 1948, the openings in the drill bit allowing escape of drilling mud were equipped with nozzles to provide high velocity jets near the bit. The result of this was that the penetration or effectiveness of the drilling increased dramatically. As a result of this almost all drill bits presently used are equipped with high velocity nozzles to take advantage of this increased efficiency. It is worthwhile to note that between 45 - 65% of all hydraulic power output from the mud pump is being used to accelerate the drilling fluid or mud in the drill bit nozzle. High velocity jet exiting the bit nozzle is partially converted into pressure on the bottom and chips are lifted upwardly from the bottom of the hole and carried to the surface as previously described.

As is well known in the art, a rock bit drills by forming successive small craters in the rock face as it is contacted by the individual bit teeth. Once the bit tooth has formed a crater, the next problem is the removal of the chips from the crater. As is well known in the art, depending upon the type of formation being drilled, and the shape of the crater thus produced, certain crater types require much more assistance from the drilling fluid to effect proper chip removal than do other types of craters.

The effect of weight on the drill bit on penetration rate is also well known. If adequate cleaning of the rock chips from the rock face is effected, doubling of the bit weight on bit will double the penetration rate, i.e. the penetration rate will be directly proportional to the weight on bit. However, if inadequate cleaning takes place, further increases in the bit weight will not cause corresponding increases in drilling rate owing to the fact that formation chips which are not cleared away are being reground thus wasting energy. If this situation occurs, one solution is to increase the pressure and the flow of the drilling fluid thereby hopefully to clear away the formation chips in which event a further increase in weight on bit will cause a corresponding increase in drilling rate.

For a further discussion of the effect of rotary drilling hydraulic on penetration rate may be had to standard texts on the subject. One recommended text is Drilling Practices Manual by Preston L. Moore published by PennWell Publishing Company from Tulsa Oklahoma.

In an effort to increase the drilling rate, the prior art has provided vibrating devices known as mud hammers which cause a striker hammer to repeatedly apply sharp blows to an anvil, which sharp blows are transmitted through the drill bit to the teeth of the drill bit. This has been found to increase rate of drilling , however these devices havebeen found to be extremely expensive to operate, while practical life was very short.

The prior art has also provided various devices for effecting pulsation's in the flow of drilling fluid to enhance the hydraulic action of the drilling fluid and to induce vibrations in the drill string by virtue of water hammer effect. Examples are my US patents 4, 819, 745; 4, 979, 577; 5, 190, 114 and 5, 009, 272.

While tools manufactured according to the mentioned US patents did provide increase of the drilling rate their operation was not always reliable due to the constantly changing properties of the drilling mud and the constantly changing hydrostatic pressure.

Due to the extremely confined space available in the down hole tool any design is compromised. The operating parts could not withstand operating conditions for long time. In addition it was sometime difficult to ascertain the rate of performance since every well even when exactly the same drilling parameters are implemented is drilled at the different rate. Frequency and magnitude of the generated pulses were directly related to the mud flow and were set on the surface. Therefore, there was no ability to change operating parameters and optimize performance of the down hole mud pulsing tool once the toll was in the hole.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an improved flow pulsing method and an apparatus incorporating a surface acoustic pulse generating circuit and a method to introduce acoustic pulses into the stream of the drilling fluid to be conveyed down through the drill string bore to the bit. Another aspect of the new method and apparatus is the ability to regulate intensity of the acoustic pulses by regulating the flow into the pulse generating circuit and regulating frequency of the acoustic pulses by operating the closure of the interrupter valve at different frequency.

In one form of the invention a partial flow from the mud pump is diverted into a pulse generating circuit which consist of an entry flow regulating valve, length of a drilling mud conduit, flow interrupter valve and means to operate this valve on a periodic basis, drilling mud conduit connecting the down stream port of the interrupter valve and return flow of the drilling mud or into the mud tank. Upstream from the interrupter valve is an outlet that connects this area with the main stream of the mud flow that is entering stand pipe, rubber hose, swivel, kelly, drill pipe and the rest of the drill string. To prevent higher pressure that is in the main flow of the drilling fluid from entering interrupter valve there is a check valve which opens only under high water hammer pressure caused by the closing of the interrupter valve. High pressure acoustic pulse that is generated during the closure of the interrupter valve is conveyed into the main stream of the drilling mud and all the way down to the drill bit where oscillating pressure helps to improve the cleaning of the hole bottom.

Another, more preferred form of the invention is basically as described above with the difference that the down stream of the interrupter valve is connected directly into the main stream of the drilling mud flow. The actual connection is into the low pressure area of a venturi arrangement which provides for a differential of pressure between entry of the mud into the acoustic pulse generating circuit and the main flow of the drilling mud.

In another form of the invention the acoustic pulse generating circuit is incorporated into the tool that is located below the swivel and above kelly or kelly cock to provide sharper pulses that are not dampened by a rubber hose which connects the stand pipe and the swivel. In this arrangement the outflow from the interrupter valve is connected into the venturi arrangement in the main flow of the drilling mud. Interrupter valve can be constructed as shown in my US patent 5, 549, 252 Fig 8 and Fig 9.

To increase intensity of the mechanical vibration, reduce friction of the drill string with the bore hole and increase the effectiveness of drilling harder formations a method using the telescopic tool with multiple pistons in series is placed above the drill bit. Acoustic pulses that are generated on the surface as mentioned earlier are converted into a strong mechanical pulses that will cause the drill bit to drill percusively. Since no mowing parts required to interrupt the flow of drilling mud to cause repeated water hammer effect are incorporated into the down hole tool a long life of the down hole tool can be expected. At the same time new method allows for the change of amplitude and frequency during operation which will assist in the optimization of the rate of drilling.

The invention further provides for incorporating a method where the bottom part of the drill string can be forced to oscillate at high amplitude and frequency thus converting the whole bottom part of the drill string into a percussive striking tool that can in some instances eliminate requirement for the drill bit entirely. This can be achieved by coupling the surface generation of the acoustic pulses with the placement of a telescopic tool that is equipped with multiple pistons mounted in series and a strong spring member that will aid in the oscillation of the one or few drill collars and the percussive drill bit that are mounted bellow.

Further features of the invention and the advantages associated with same will be apparent to those skilled in the art from the following description of preferred embodiments of the invention when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE VIEWS OF DRAWINGS

FIG 1 is a schematic view of the surface acoustic generator and the method of conveying the acoustic pulse to the drill bit. Outflow of the drilling mud from the interrupter valve is into the return stream of the drilling mud;

FIG 2 is schematic view as described above with the difference that the outflow of the drilling mud from the interrupter valve is conveyed into the venturi arrangement in the main stream of the drilling mud;

FIG 3 is schematic view of the method when the acoustic generating circuit is incorporated into a tool that is located below the swivel/ swivel cock and above the kelly;

FIG 4 is schematic view of the acoustic pulse generating circuit where the flow of the drilling mud is conveyed into the return stream of the drilling mud;

FIG 5 is schematic view of the acoustic pulse generating circuit as described above with the difference that the outflow of the drilling mud exiting the interrupter valve is connected into a venturi arrangement in the main flow of the drilling mud;

FIG 6 is a schematic view of the acoustic generating circuit that is incorporated into a tool that is placed below the swivel and above the kelly;

FIG 7 is a schematics view of the method where the acoustic pulse generator sends pulses down into a multiple piston telescopic tool that is place above the drill bit;

FIG 8 is a longitudinal sectional view of the down hole telescopic tool with multiple pistons in series that is placed above the drill bit shown in the position where pressure pulse is at its minimum;

FIG 9 is a longitudinal sectional view of the down hole multiple piston telescopic tool when pressure pulse forces the tool to open;

FIG 10 is a sectional view showing the x-section through the splined part of the multiple piston telescopic tool;

FIG 11 is a schematic view showing surface acoustic pulse generating arrangement with the multiple piston telescopic (MPT) tool that is placed above one or few drill collars;

FIG 12 is a longitudinal sectional view of the MPT tool that is placed above one or more drill collars when the weight bellow is supported by a set of springs and pressure pulse is at its minimum;

FIG 13 is a longitudinal sectional view of the MPT tool shown when the pressure pulse is lifting the assembly bellow the telescopic tool up;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG 1 is a schematic view of the surface acoustic pulse generator (SAP generator) 20 and the method of conveying the acoustic pressure pulse to the drill bit 30. Main flow of the drilling mud 21 enters into the stand pipe 22 which is fastened to the derrick 23, rubber hose 43 and enters swivel 24, Kelly cock 25 and kelly 26. Drilling mud is further conveyed through the drill pipe 27 and drill collars 28, bit sub 29 and the drill bit 30. Drilling mud returns to the surface through the well bore annulus 31 and into the mud tank 32. Kelly 26 is rotated by the rotary table 33. Acoustic pressure pulses cause oscillation of the drilling mud flow exiting the drill bit 30 thus facilitating better cleaning of the bottom of the well bore 34.

FIG 2 is a schematic view of the SAP generator 35. Return flow of the drilling mud from the SAP generating circuit 35 is entering venturi arrangement 37 which supplies differential of the pressure between entry into the SAP generator 28 and exit 45into the venturi arrangement 37. This embodiment will allow for better monitoring of the mud flow and mud loss in the well bore. Acoustic pulse generated in the SAP generator enters main flow of the drilling mud at point 40. This entry of the acoustic pulse can be also incorporated down stream into the venturi arrangement 37.

Fig.. 3 shows schematic view of the apparatus and method where the SAP generating circuit 41 is incorporated into a tool 42 which is placed below the swivel 24 and above the kelly cock 25. This arrangement produces pulses of higher amplitude because the pulse does not travel through the rubber hose 43 as shown in the pervious arrangement.

FIG 4 is schematic view of the SAP generating circuit 20 where the flow of the drilling mud exiting interrupter valve 54 returns to the mud tank 32. The SAP generating circuit 20 comprises of a mud pump 45, pulsation dampener 46 which is usually located upstream of the mud pump 45. Main drilling mud flow 21 continues to flow into the stand pipe 22 while portion of the mud flow entersSAP generating circuit 20 at 45. Shut off valve 46 and check valve 47 will allow for disconnecting the SAP generating circuit from the main flow during operation. This feature can be extremely useful when establishing performance and efficiency of the invention. By disconnecting the SAP generator 20 we can compare rate of drilling with the and without the utilization of the novel method. Ability to disconnect SAP generator 20 during operation of the drilling process can be also useful to perform replacement of the worn working parts.

Partial flow exiting shut off valve 46 enters flow regulator 48 which is usually a needle valve which is controlled by the screwedly rotating needle valve stem 49. Needle valve stem 49 is rotated by the knob 50. Threaded engagement 51 will allow axial movement of the valve stem 49 to restrict or open passage into the conduit 52. This conduit is preferably made from the heavy wall pipe.

Intensity of the acoustic pulse is directly proportional to the velocity of the mud flow in the conduit 52.

dp = @ * Vs * V

dp= pressure increase due to the water hammer

@= specific mass

Vs= velocity of the speed of sound in the conduit 52

V = velocity of the mud flow in the conduit 52

Operation of the system: partial mud flow 53 flows through the flow control valve 48 into the conduit 52 into the interrupter valve 54 which is forced to open and close by a servo mechanism unit 55. When the interrupter valve 54 is open flow of the drilling mud is diverted into the mud tank 32.

During sudden closure of the interrupter valve 54 kinetic energy in the fast flowing mud is converted into a pressure pulse generally described as a water hammer. The matematic and physical effect of the water hammer are discussed in various texts on fluid mechanics including Fluid Mechanics (7th edition) Victor L Streeter and E. Benjamin Wylie, Mc Graw Hill Book Company, 1979.

Water hammer pressure pulse travels upstream from the closed valve 54 at the velocity of the speed of sound in the mud inside conduit 52. This pressure pulse also travels into the conduit 56. When this pressure pulse reaches check valve 47 this check valve will open and pressure pulse will be introduced into the main flow conduit 57. Pressure pulse will continue to travel at the speed of sound in mud into the stand pipe 22 and further through the drill string as discussed before.

FIG 5 is an enlarged schematic diagram of the SAP generating circuit 35. In this circuit mud flow exiting from the interrupter valve 54 enters through the open shut off valve 58 into the venturi arrangement 37. Pressure at point 59 is reduced by the suction action of the jet pump/venturi arrangement 37 which allows pressure at 60 to force flow of the drilling mud through the SAP generating circuit 35. Valve needle 49 is sealed from the outside environment by a shaft seal 61. The rest of the operation is as described above.

FIG 6 is a schematic view of the SAP generating circuit 62 that is incorporated into a tool 63 that is placed below the swivel 24 and above the kelly 26. Venturi arrangement 37 is incorporated into the lower tool body 64. Top tool sub 65 has a conduit that allows exit of the drilling mud into the acoustic pulse generating circuit 62. Interrupter valve 54 can be for example self regulating valve that is operated by the water hammer itself as is shown in my US patent 5, 549, 255 FIG 8 and FIG 9. The rest of the circuit and its operation is the same as discussed above.

Main advantage of this embodiment is that generated acoustis pulse does not travel through the rubber hose 43 which might somewhat reduce maximum intensity of the pulse.

FIG 7 is a schematic view of the method where the acoustic pulses generated by SAP generator are conveyed down into a multiple piston telescopic tools that is mounted above the drill bit 30. This embodiment provides for significant vibrations of the entire drill string 67. Thus reducing friction between the drill string 67 and well bore 68. This vibration will also enhance percussive action of the bit 30 on the bottom of the hole 34 resulting in faster drilling and lower torque requirement.

FIG 8 is a longitudinal sectional view of the multiple piston telescopic tool 66. In the bottom end of the male spline member 69 is a threaded connection 70 that is used to screwedly connect drill bit 30. On the top end of the male spline 69 is fastened piston 72 via threaded connection 71. On top of the piston 72 is fastened by threaded connection 73 piston 74. Surface area 75 is actually a piston area. Cavities 76, 77 and 84 are connected to the inside bore 79 via holes 80, 81 and 82. Cavities 83 and 84 are connected with the outside well bore 31 via holes 85 and 86. Cavities that are connected to the outside well bore 31 and cavities that are connected to the inside bore 79 are sealed by a set of shaft seals 87 and a set of piston seals 88.

Male spline 69 is inserted into the female spline 89. This female spline 89 is screwedly connected to the first piston housing 90. Second piston 72 is also inserted into the first piston housing 90. Second piston housing 91 is srewedly connected by thread 92 with the first piston housing 90. Top sub 93 is screwedly connected by the thread 94 into the second piston housing 91. Multiple piston telescopic tool is connected to the bottom end of the drill collar section 28 by athread 95.

Torsional load between the female spline 89 and male spline 69 is secured by a longitudinal spline 96. This arrangement is more readily described in FIG 10 which shows a cross section along line 10-10 on the FIG 8.

FIG 8 shows multiple piston telescopic tool 66 when acoustic pressure pulse is at it's minimum and tool 66 is in it's closed position. When acoustic pulse reaches area 97 as shown on FIG 9 this pulse is introduced into the cavities 78, 84 and 76 via holes 80, 81 and 82. Some of the projected piston areas multiplied by pressure pulse will produce axial force that will push male spline 69 and drill bit 30 into the bottom of the hole surface 34.

For example, a pressure pulse of 1,500 psi acting on total area of 80 si will produce axial force of 120, 000 lbs.

This axial force will cause drill bit 30 to be buried into the bottom of the hole 34 while reaction of this axial force will lift part of the drill string that is above multiple piston telescopic tool. Relative telescopic movement is indicated "E" on FIG 9.

When the intensity of the acoustic pulse reaches 0, weight of the drill string above the multiple piston telescopic tool will close the gap "E" and additional impact force will be applied on the bit 30.

FIG 11 is a schematic diagram showing a drilling method where SAP generator 35 is generating and sending acoustic pulses through the inside of the drill string into the multiple piston telescopic tool 98 under which is mounted 1 or more drill collars 99, bit sub 29 and in most cases drill bit 30. This arrangement will assure vigorous axial vibration of the bottom part of the drill string allowing in some instances to drill percussively even without the classical drill bit.

FIG 12 is a longitudinal sectional view of the multiple piston telescopic tool as described above. The bottom part of the tool as indicated by "L" is identical to the multiple piston telescopic tool shown on FIG 8 and FIG 9 except that the bottom connection is a male thread 100 which is screwedly connected into the top on the drill collar section 99 and that the cavities 76, 77 and 84 are connected with the outside well bore 31 via holes 101. Internal bore 102 is connected with cavities 83 and 78 via holes 103. Spring housing 104 is screwedly connected with the third piston housing 114 with threaded connection 105. Third piston mandrel 106 is inserted into a stack of disk springs 107.

The weight of the assembly below the multiple piston telescopic tool is being supported by the safety nut 108 over washers 109. Screw 110 keeps safety nut 108 securely on the piston mandrel 106. Top sub 111 is connected with the spring housing 104 by the threaded connection 112. Multiple piston telescopic tool is connected above by a threaded connection 113 to the top end of the drill string.

FIG 12 shows multiple piston telescopic tool 98 during the phase that the acoustic pulse is at its low or zero value and all the weight below is mostly supported by a disk spring stack 107.

FIG 13 shows multiple piston telescopic tool 98 when the acoustic pulse is at it's maximum value and this pressure pulse is introduced into cavities 83 and 78. Projected area of the energized piston multiplied by the pressure pulse will result in substantial axial lifting force that can easily lift one or few drill collars that are suspended below the multiple piston telescopic tool 98.

For example, acoustic pressure pulse 1,500 psi multiplied by the combined piston area 60 si will produce axial lifting force of 90,000 lbs. Expected weight of the drill collar section below the multiple piston telescopic tool is approximately 3,000 - 6,000 lbs.

Vibrating the bottom end of the drill string with such a force will produce extreme percussive blows to the bottom hole 34 resulting in considerable penetration rates in the hard formation.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be concsrewed in accordance with the substance defined by the following claims.

What is claimed is:

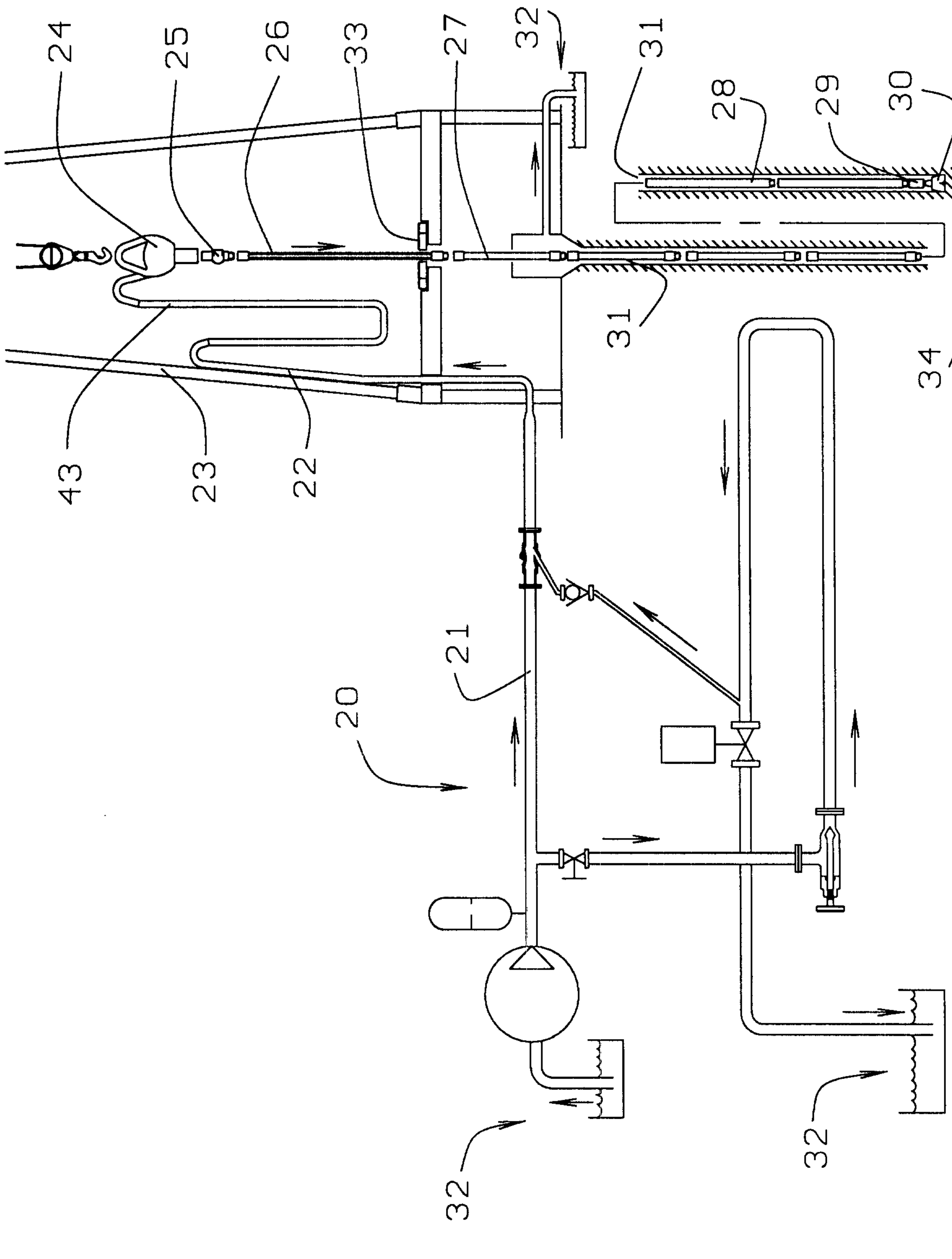


FIG 1

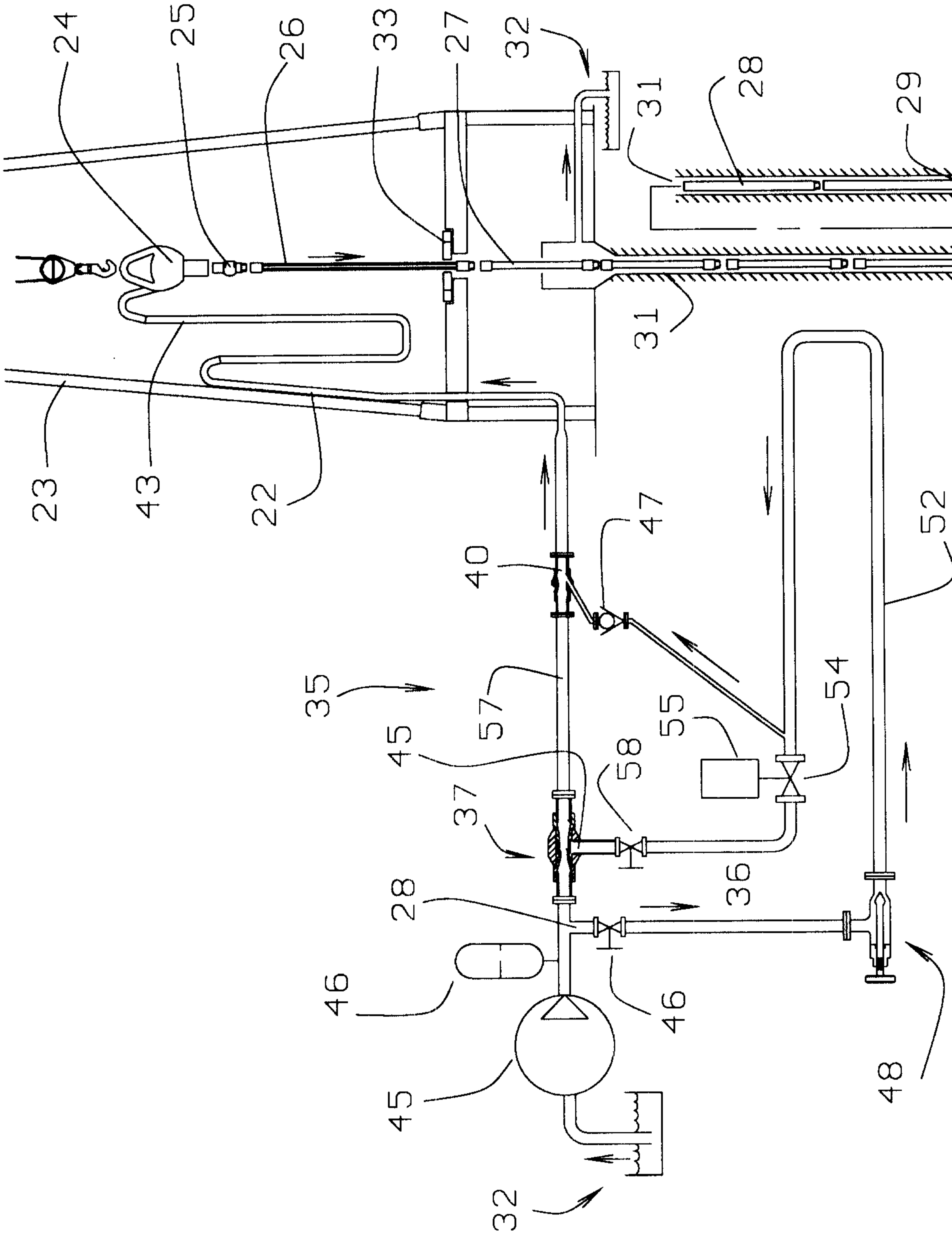

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FIG 2

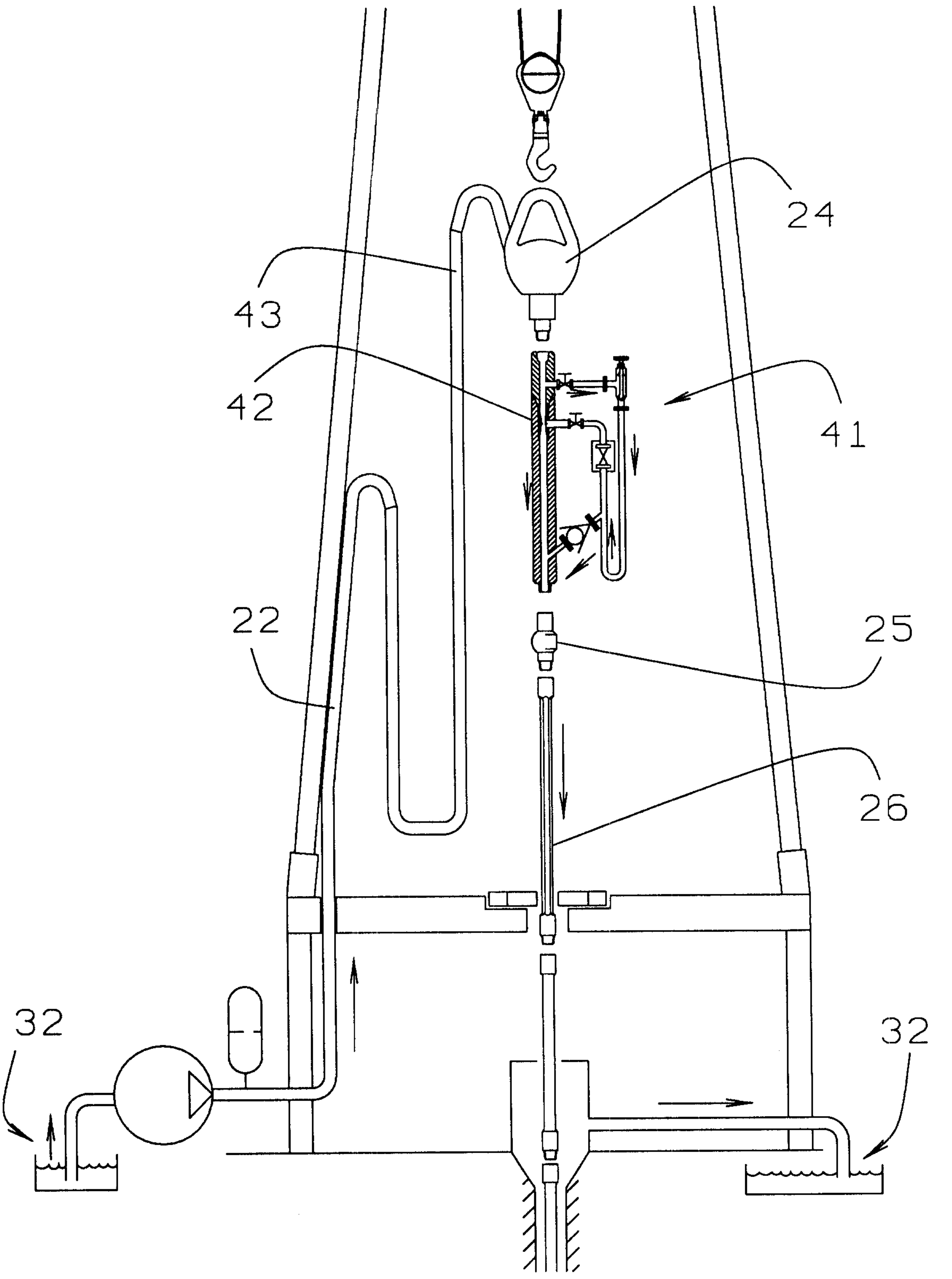
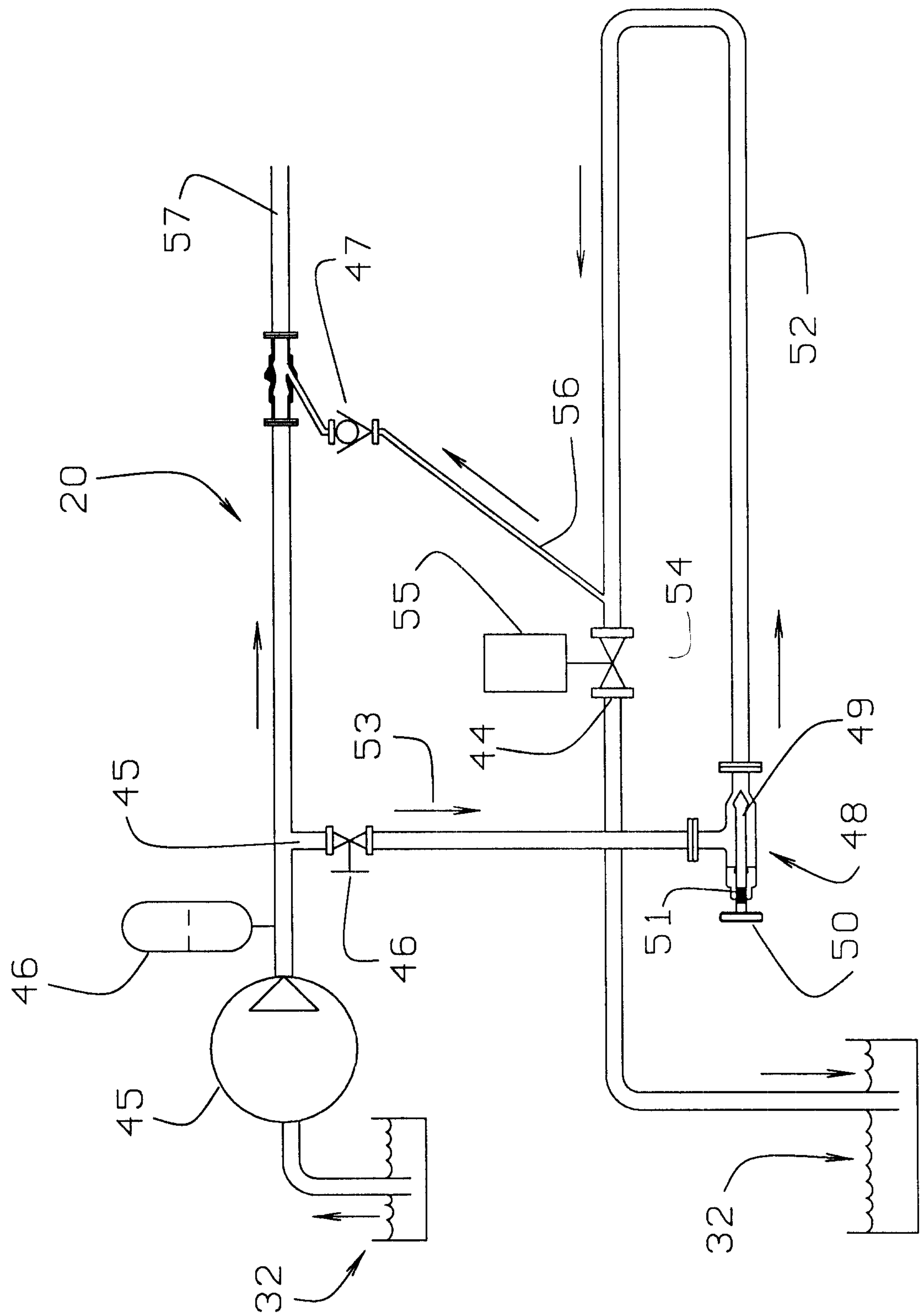


FIG. 3



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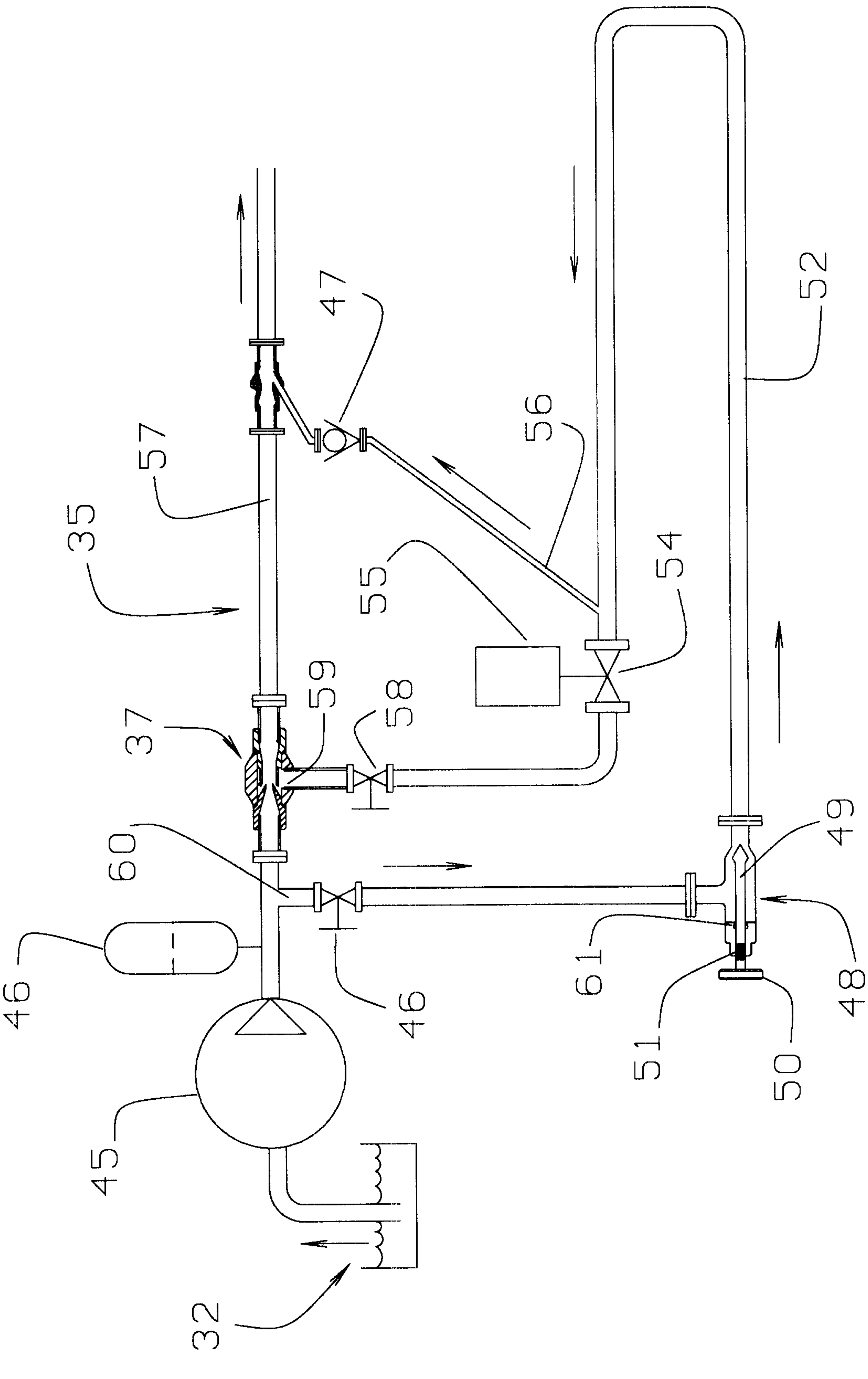

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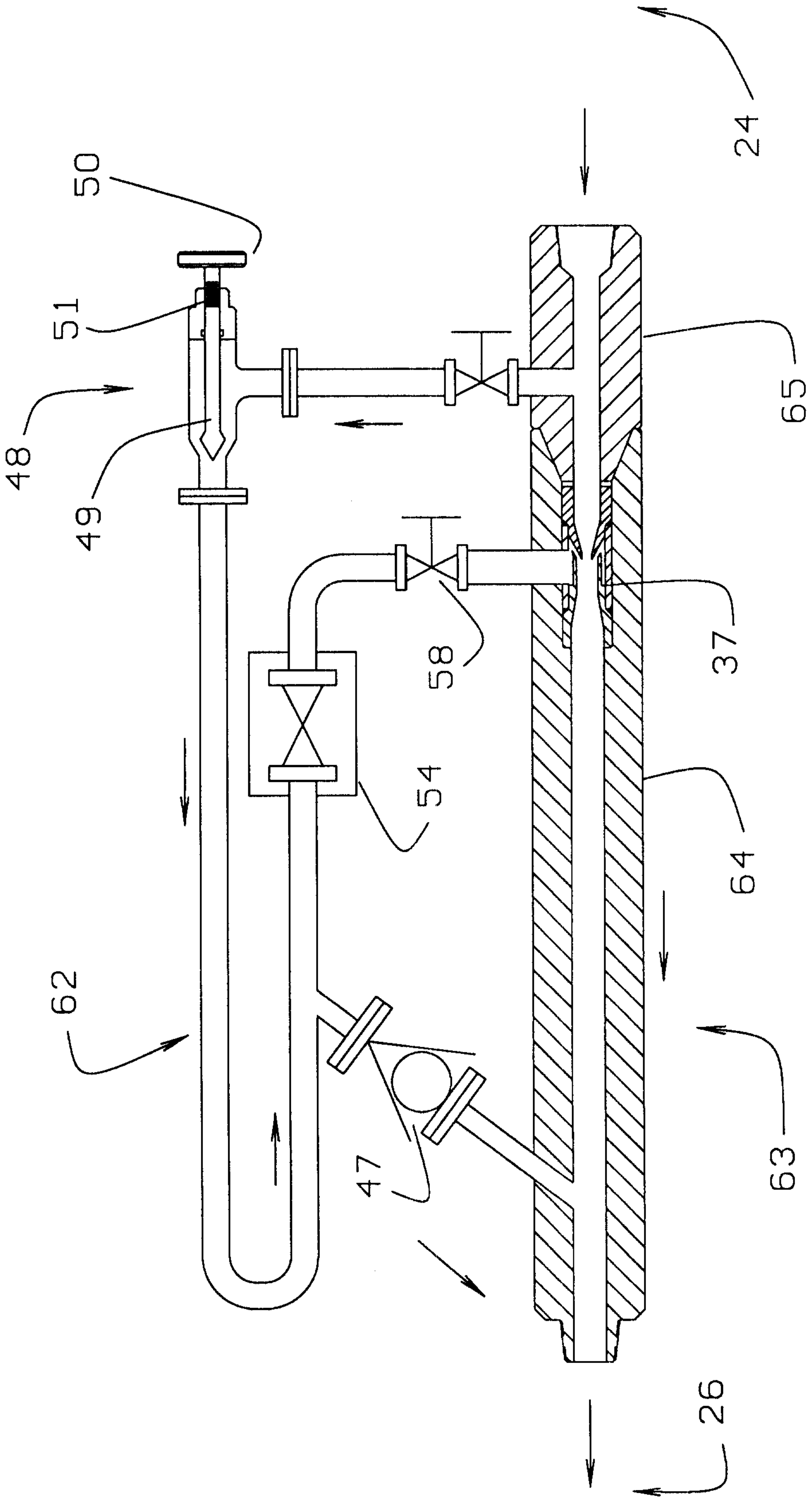

FIG. 6

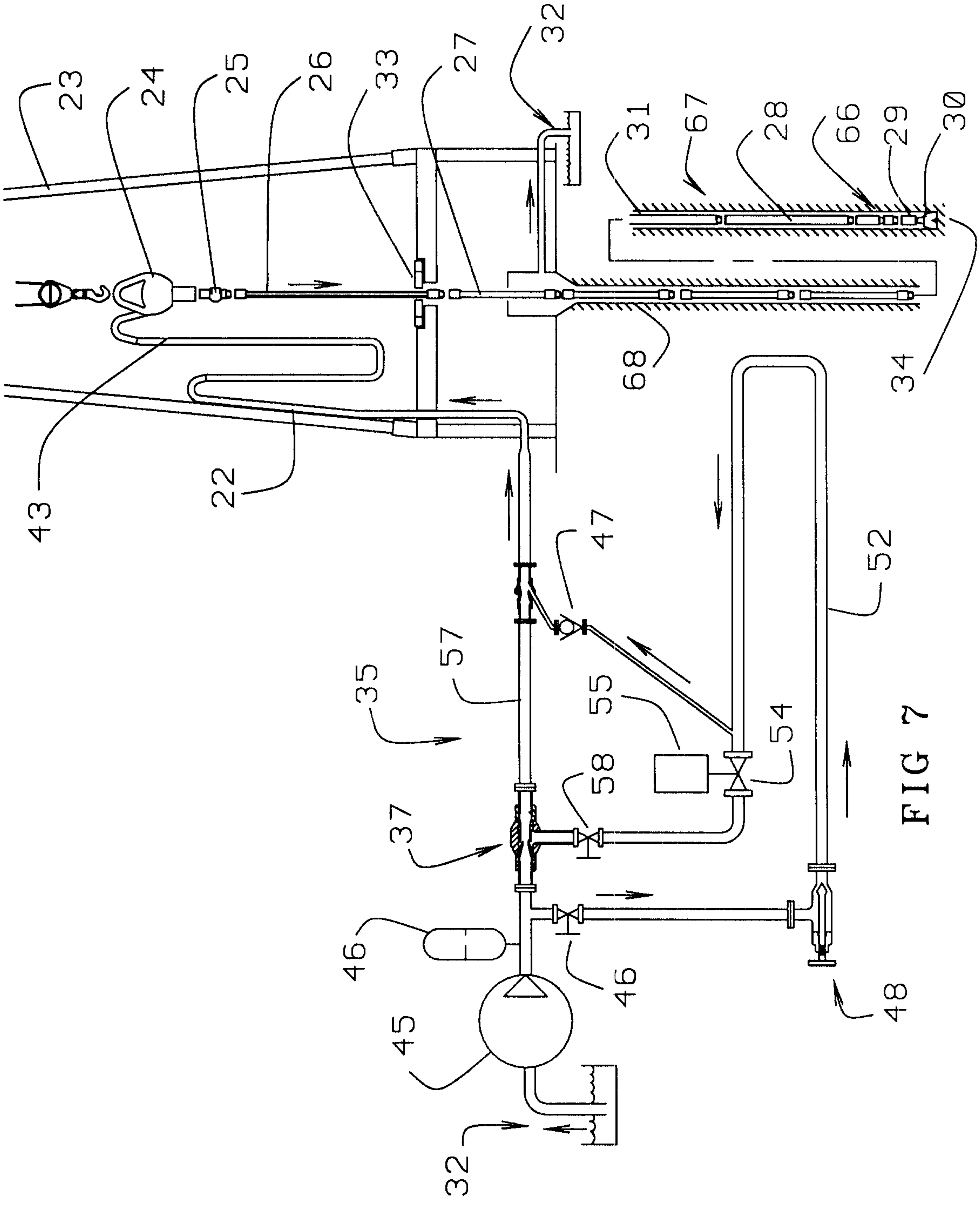
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FIG 7

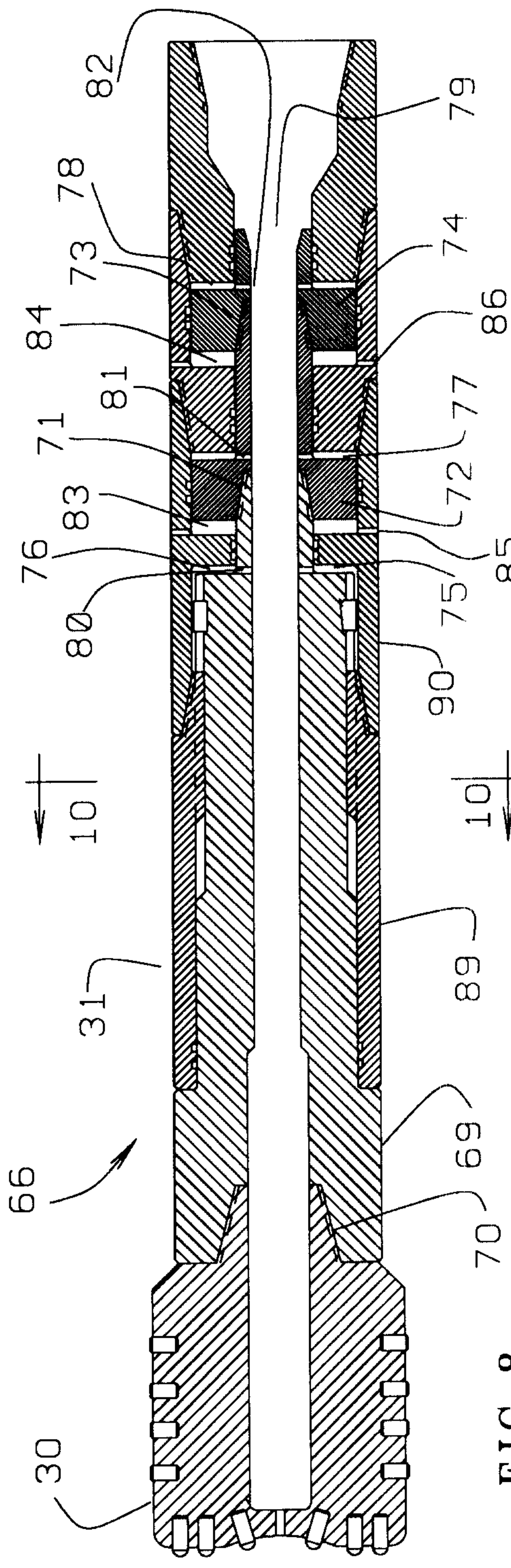
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FIG 8

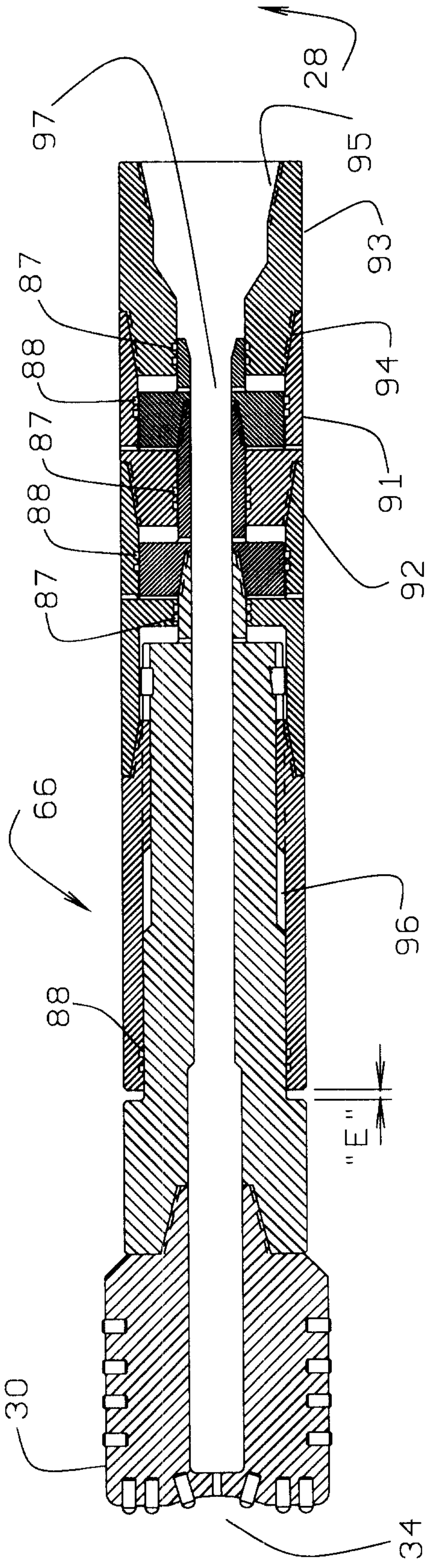
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FIG 9

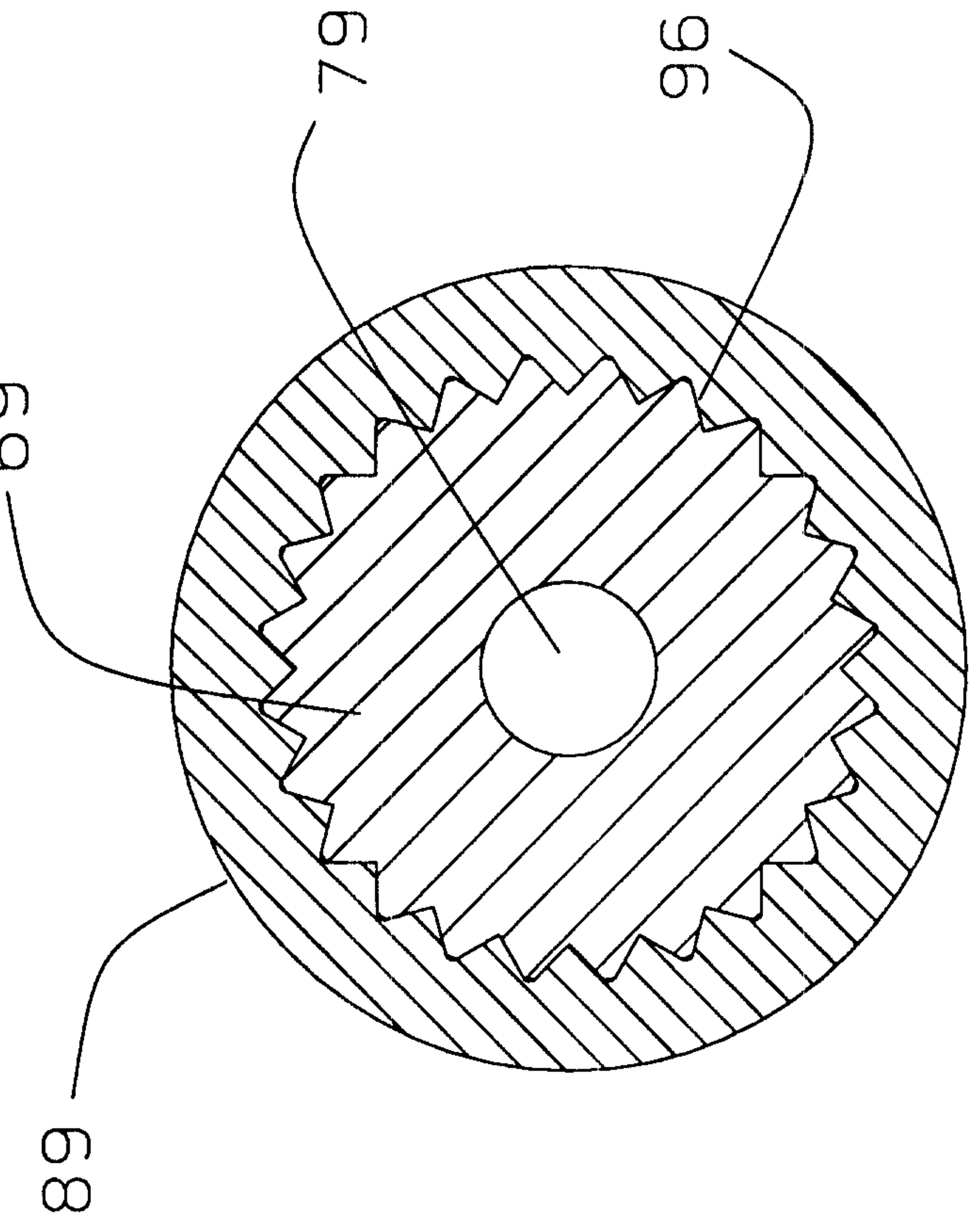

FIG 10

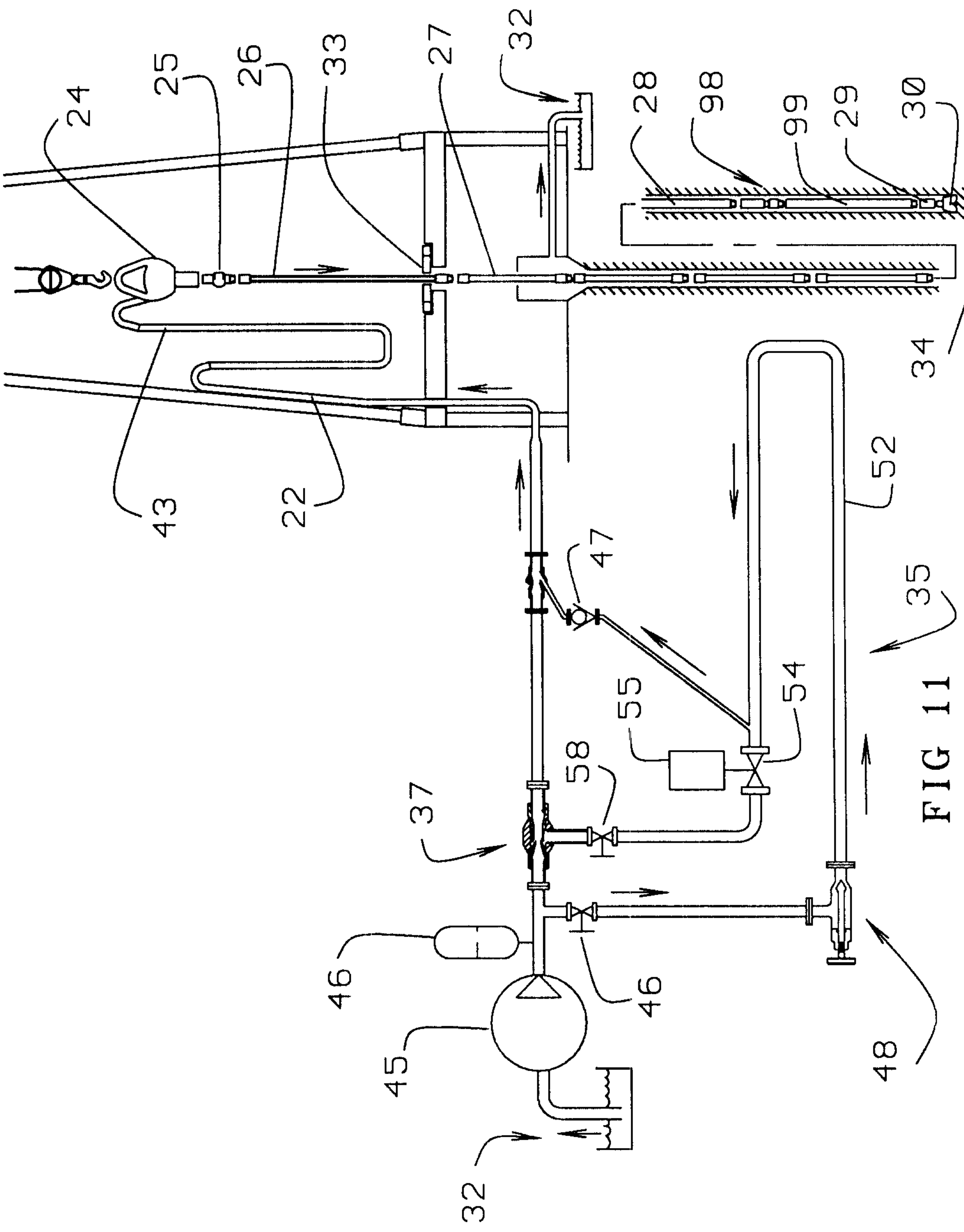
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FIG 11

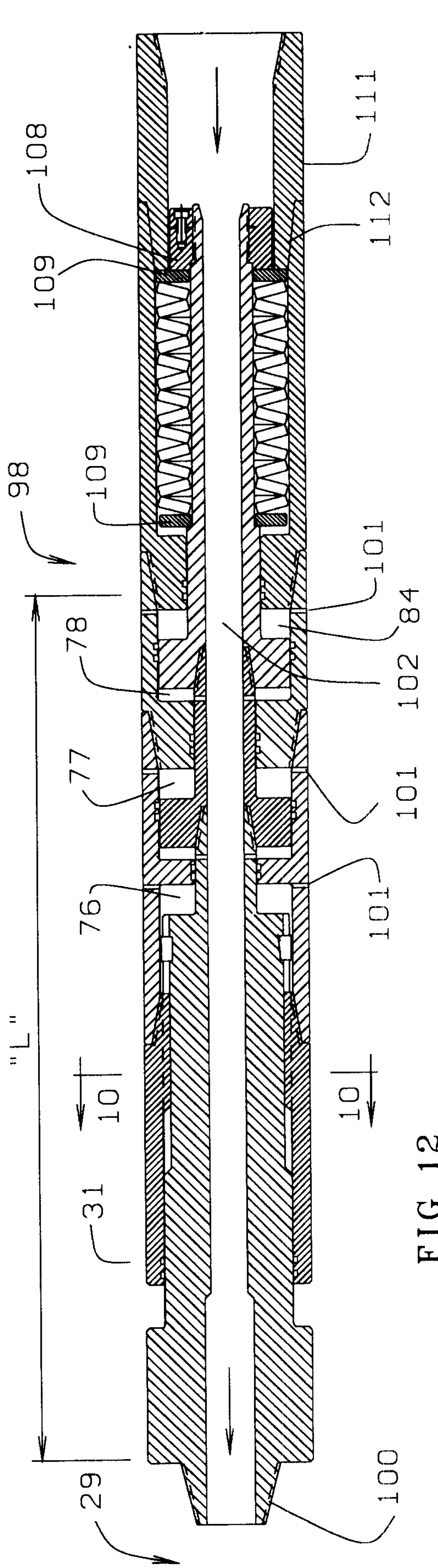
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FIG 12

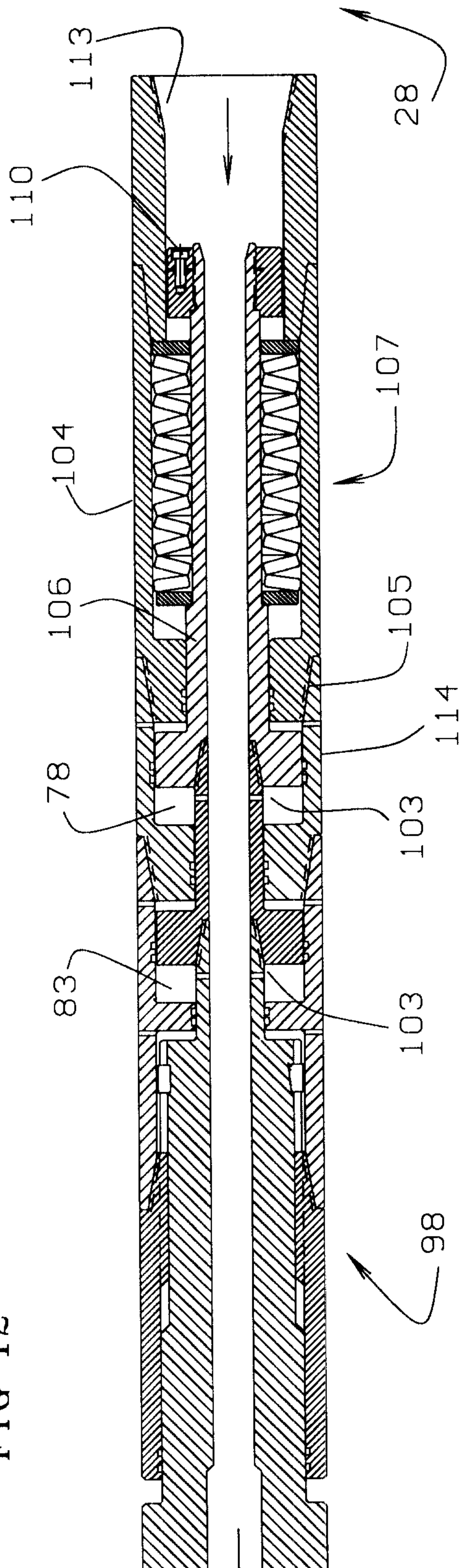
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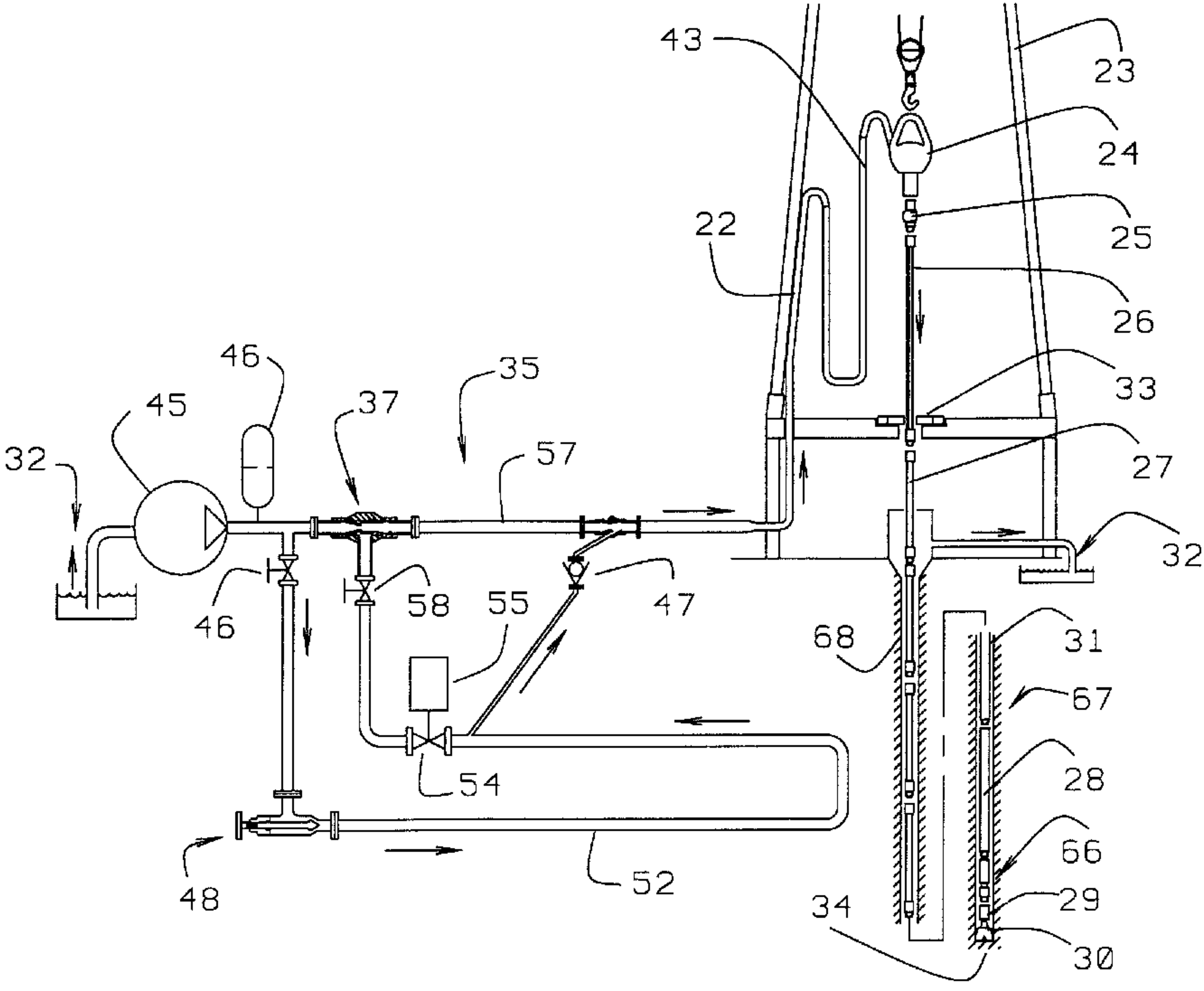
FIG 13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