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(54) A method and plant for consolidating soil by injecting liquid in the soil

(57) To form columns of consolidating material having a non-circular section in the soil, the method comprises the steps of:
- introducing into the soil a rotatable rod (55) having, near an end thereof, a radial nozzle for injecting pressurized consolidating liquid;
- translating and rotating the rod (55) at controlled speed while injecting pressurized consolidating liquid.

During rotation of the rod (55) its speed of rotation is varied between a minimum value, at which the penetration distance of the liquid into the soil is maximum, to a maximum value, at which the penetration distance of the liquid into the soil is minimal.

EP 1 862 596 A1

Description

[0001] The present invention relates to a method and a plant for consolidating soils through injection into the subsurface of suitable materials in liquid form, such as, for example, liquid mortar.

[0002] Methods and plants have been long known for consolidating soils through injection of liquids.

[0003] Italian patent No. 1 083 340 discloses a plant which comprises a preferably self-propelled structure intended to be located at the surface, which carries a drill in the form of a rotating rod consisting of more sections which are screwed one following the other, and means to cause the same to rotate and penetrate the soil to the desired depth. The rod consists of several sections, which are gradually added to the rod as it descends into the soil. The first rod section comprises mill-shaped means adapted to bore the hole into the soil in which the rod is caused to penetrate in a gradual manner. The rod, or more precisely the various sections thereof, comprises at least two concentric tubes that are suitable to generate a gap around a central duct. Both the central tube and the gap directly communicate with the outside, limited to the first rod section.

[0004] Consolidating liquid is fed through the central duct, at a pressure ranging between 150 and 400 kg/cm^2, while pressurised air is fed through the gap at a pressure ranging between 5 and 10 kg/cm^2.

[0005] After the desired depth has been reached, the rod is withdrawn while being rotated, and the liquid and air injection is started. Thereby a sort of solid column is created which has a substantially circular, but irregular, section, since the penetration distance of the liquid from the rod axis depends upon the characteristics of the soil in which it is inserted, which characteristics are quite variable. In crumbly soils, the penetration distance is clearly higher than in more compact soils.

[0006] The rotation is imparted to the rod by a hydraulic motor, and the rod is outputted from a rotating head that is supported by a saddle vertically moving along an injection tower. The axial movement is imparted to the saddle by means well known to those skilled in the art, the description of which is omitted.

[0007] Through the known plants, waterproofing, *inter alia,* or strengthening walls are built, which are obtained by creating a series of adjacent and partially interpenetrating columns. This operative mode finds a major limitation in the fact that, in order to create a continuous wall, a large number of columns requires to be created.

[0008] The object of the present invention is to overcome the aforementioned drawback by providing a simple, inexpensive, and reliable solution.

[0009] Said object is achieved, according to the invention, by a method and a plant which allow forming columns of injected material having an elongated, or in any case shaped, section in which the distance between the perimeter and the injection tube axis is determined by the speed at which the rod bearing the liquid injection nozzle rotates around its own axis. The higher the speed, the lower the distance from the axis.

[0010] The method and the plant which achieve the objects of the invention are as defined by the features set forth in the independent claims.

[0011] The advantages and constructive and functional features of the invention will be clearly understood from the detailed description below, which illustrates, with the drawings in the annexed tables, one preferred embodiment thereof, which is given by way of non-limiting example.

Fig. 1 shows the schematic side view of an injection unit.

Fig. 2 schematically shows the top portion of the vertical drilling tower, with the hydraulic layout of the invention.

Fig. 3 shows section III-III of Fig. 2.

Fig. 4 shows, in cross section, the end portion of the drilling and injection rod, and the adjacent rod section.

Fig. 5 shows the cross section of a column built according to the invention.

[0012] In the figures, a self-propelled means 1 is seen which is provided with a drilling tower 2, on which a saddle 3 slides, which is connected to the tower 2 by a cylinder-hydraulic piston assembly 4. The saddle 3 supports a rotatable head 5 which is fastened to the saddle by means of two brackets 31 which hold a central flange 57 of the head 5.

[0013] The head 5 is connected to a hydraulic motor 6, also supported by the saddle 3, which causes it to rotate through the hydraulic fluid fed by a pump 7. The head 5 comprises an outer tube 56 bearing a co-axial tube 51 therein, which is adapted to define a gap 52.

[0014] The gap 52 and the tube 51 are communicated, through a known rotating joint 50, respectively with a feeding duct 510 of consolidating liquid and a pressurized air feeding duct 520. The head 5 is shaped as the drilling rod 55 sections being connected thereto.

[0015] Secured to the rotating head 5 through a bush 54 are two wings 53 which are individually shaped in the form of a circular sector. Said wings 53 face a proximity sensor 8 supported by the brackets 31. The sensor 8 is intended to perform the functions which will be defined below.

[0016] The hydraulic motor 6 is fed through pressurized fluid from the pump 7 by means of a three-way switching valve 71 which intercepts two different ducts 72, 73 for the feeding and return of fluid to the motor 6.

[0017] The valve 71 is manually driven by the operator in three operative positions. In the first position, illustrated in Fig. 2, the motor 6 is connected to the pump 7 via the first duct 72, and to the exhaust pipe via the second duct 73. In the second position, the pump 7 is directly connected to the exhaust pipe. In the third position, the motor

6 is connected to the pump 7 via the second duct 73, and to the exhaust pipe via the first duct 72.

[0018] Thereby, the pressurized fluid can be induced to flow through the motor 6 in opposite directions, with corresponding opposite directions of rotation of the drilling rod 55.

[0019] From the first duct 72 an auxiliary branch of the exhaust pipe 74 branches off, along which a shut-off valve 75 and a flow adjusting device 76 are located in series. The valve 75 is driven in a usual manner by the pulse emitted by the proximity sensor 8 which through a common control circuit 81 causes it to snap from the closed (in Figure) to the open position. The adjusting device 76 schematically comprises a throttling valve and a by-pass branch of the same throttling valve, which is, in turn, intercepted by a check valve. Said adjusting device 76 is manually calibrated and driven, so as to establish the pressurized fluid flow rate which flows within the exhaust pipe branch 74 when the shut-off valve 75 is opened.

[0020] With reference to Fig. 4, the lower part of the drilling rod is seen to comprise a centrally hollow mill 550 the cavity of which communicates with a chamber 551 via a valve 552. The valve 552 communicates, in turn, with the central duct 553 defined within a bush 554. The central duct 553 communicates with the outside through two nozzles 555 which pass through the outer tube 556, while between the bush 554 and outer tube 556 a gap is defined from which two nozzles 557 start, also leading to the outside. The outer duct 556 and the bush 554 are screwed on two different concentric diameters of a joint 558 which is centrally hollow and axially passed through by a series of ducts 559 which open in the gap between bush 554 and outer duct 556. The top end of the joint 558 has a threaded hold which screws on the central tube 51 of the next rod section, while the outer tube 56 of the next rod sealingly couples within a cylindrical seat of the joint 558 located outside the hold.

[0021] Thereby, the gap 52 between outer tube 56 and inner tube 51 of the next rod section is in communication with the gap between bush 554 and duct 556, while the tube 51 is in communication with the central duct of the bush 554.

[0022] The aforementioned configuration of central tube 51 and outer tube 56 and joint 558 is repeated in all the sections of the drilling rod 55 and in the header 5 lower part.

[0023] The operation of the above described device is as follows. After the machine has been positioned in the desired site, the first rod section is introduced into the soil. The first rod section has a diameter of 105 mm and a length ranging between 800 and 1500 mm, while the next sections have equal diameter and a length ranging between 1000 and 3000 mm.

[0024] The rod is rotated according to a preset direction of rotation at 60 rpm with the simultaneous feeding of drilling liquid, usually water, at a flow rate of 90 lit/min and a pressure of 30 bars. Simultaneously, 3000 lit/min of air are fed under 8 bar pressure. In this condition, the switching valve 71 is located in the first operative position illustrated in Fig. 2.

[0025] Upon reaching the desired depth with the coupling of the required number of sequential rod sections, the rod is withdrawn out of the soil while being rotated. Extraction occurs with the simultaneous injection of air and consolidating liquid. During extraction, the rotation speed of rod 55 can be as high as 120 rpm, the air flow rate can be as high as 25000 lit/min with a pressure up to 25 bars, while the consolidating liquid flow rate can range between 10 and 1000 lit/min with a pressure ranging between 50 and 600 bars.

[0026] The consolidating liquid can consist of a mixture of water and cement, or a mixture of water, cement and bentonite; both mixtures may provide the addition of optional additives. Alternatively, the consolidating liquid can consist of suitable epoxy, phenolic, or acrylic resins, optionally diluted.

[0027] In the example, the rotation speed is 12 rpm, air is introduced with a flow rate of 8000 lit/min at a pressure of 12 bars, while consolidating liquid is introduced with a flow rate of 350 lit/min at a pressure of 400 bars. The consolidating liquid consists of a 1:1 mixture of water and cement.

[0028] The result of this operation is the injection of about 300 litres of mixture per meter of column being built, and the creation of a column having an average diameter ranging between 800 and 1000 mm.

[0029] If a column which does not have a circular irregular section, but instead an elliptic irregular section is desired to be created, the proximity sensor 8 is actuated, which for all the time in which it faces the wings 53, causes the shut-off valve 75 to switch to the open position.

[0030] Thereby, part of the pressurized fluid which runs in the first duct 72 is directly discharged to the auxiliary branch 74, thereby reducing the operative liquid flow rate which passes through the motor 6. The rotational speed of rod 55 proportionally decreases while the period of time for which the soil is exposed to the consolidating liquid jet increases, and so does also the penetration distance of the liquid into the soil.

[0031] Thereby, in the angular sector of the column corresponding to the reduced rotation speed, the liquid jet reaches a much greater distance than in the previous one, and a column is created having an elliptic section with its minor diameter equal to that of the cylindrical column, and its major diameter up to about twice. In particular, the speed reduction of rod 55, and hence the distance reached by the consolidating liquid jet, can be adjusted by a manual calibration of the adjusting device 76.

[0032] It is understood that, wishing to create a wall consisting of columns being in a side-by-side relationship and suitably oriented, the columns number is reduced to about half, thus greatly saving time and material.

[0033] By increasing the number of the wings 53 to three equidistant wings, and by proportionally reducing the circumferential extension, an approximately triangular section column is achieved. By adding a further wing 53, an approximately squared section is achieved, etc.

[0034] Although the example described and illustrated herein refers to a method and plant for air and liquid with dual rods and coaxial nozzles for injecting air and consolidating liquid, those skilled in the art will recognize that the principle underlying the invention is equally applicable to systems different from the cited one. For example, the invention is applicable to consolidating systems so-called "single-fluid", i.e. with rods intended to inject only one consolidating liquid but without the addition of air, and to other "two-fluid" combinations and to so-called "three-fluid" systems, where rods with coaxial nozzles for injecting air and water are used, with separate nozzles for injecting the consolidating fluid.

[0035] The principle of the invention remaining the same, the details of construction and forms of embodiment may be varied widely with respect to those described and illustrated, without thereby departing from the scope of the present invention as identified by the following claims. Particularly, the means for controlling the speed variation may differ from the on-off type of system that controls the flow rate of the fluid fed to the hydraulic motor. According to requirements, a proportional system for controlling the flow rate may be adopted, or a variable amplitude or frequency pulse system. Or, a still different proportional system may be used, operating at a fixed flow rate but with at least one variable displacement motor, or a system consisting of at least two motors connected in series or parallel, or controlling the feed pump directly, or having at least two pumping elements. The means imparting the signal modifying the rotational speed may furthermore be provided with several systems, for example an electronic system comprised of a PLC controlling directly or indirectly the speed variation as a function of the angle of rotation detected by suitable apparatus (rotation and translation encoders, proximity sensors with a toothed wheel secured to the rotating part, etc.). The means providing flow rate control may also differ from those previously described. For example the components designated at 75 and 76 may be replaced by a single integrated valve with an on-off or proportional control and acting directly on the distributor controlling the rotational function, or finally creating an extra-pressure on the exhaust branch pipe opposite to the delivery branch pipe.

Claims

1. A method for forming columns of consolidating material having a non-circular section in the soil, comprising the steps of:

   - introducing into the soil a rotatable rod (55) having, near an end thereof, at least one substantially radial nozzle for injecting pressurized consolidating liquid;
   - translating and rotating the rod (55) at controlled speed while injecting pressurized consolidating liquid;

   characterized in that during rotation of the rod (55) its speed of rotation is varied between a minimum value, at which the penetration distance of the liquid into the soil is maximum, to a maximum value, at which the penetration distance of the liquid into the soil is minimal.

2. The method according to claim 1, **characterized in that** the consolidating liquid is selected from the following: mixture of water and cement, or mixture of water, cement and bentonite, or resins.

3. The method according to claim 1 or 2, **characterized in that** the rod (55) has at least one nozzle for the injection of pressurized air, and that the rod (55) is withdrawn while being rotated and simultaneously injecting pressurized air and consolidating liquid.

4. The method according to claim 1, **characterized in that** it provides the formation of adjacent and partially interpenetrating columns in order to create a barrier.

5. The method according to claim 1, **characterized in that** the injection occurs during the step of withdrawing the rods.

6. The method according to claim 1, **characterized in that** the injection occurs during the step of making the rods penetrate into the soil.

7. A plant for forming columns of consolidating material having a non-circular section in the soil, comprising a vertically translatable head (5) connected to means for rotating it, at least one rod section (55) being outputted from the head, the rod section comprising at least one substantially radial nozzle for the injection of pressurized consolidating liquid,
   characterized by comprising means for controlling the rotation speed between a lowest speed and a highest speed.

8. The plant according to claim 7, **characterized in that** the means for rotating the head comprise at least one hydraulic motor (6).

9. The plant according to claim 8, **characterized in that** the means for varying the speed of the perforating rods comprise means (74, 75, 76) for varying the feeding flow rate of the hydraulic motor.

10. The plant according to claim 9, **characterized in that** the means for varying the flow rate comprise a discharge pipe branch (74) which branches off a feeding duct (72) of the hydraulic motor (6), the dis-

charge pipe branch (74) being intercepted by a valve (75) controlled so as to reach two positions, open or closed.

11. The plant according to claim 10, **characterized in that** the valve (75) control means comprise at least one horizontal surface (53) with a limited circumferential extension, secured to the rotating head (5), which rotates with the latter in front of a proximity sensor (8) which, when it faces the surface (53), sends a signal which drives the valve (75) opening.

12. The plant according to claim 10, **characterized in that** said auxiliary branch (74) is intercepted by an adjusting device (76) for the stream flowing therein, which is located in series to said valve (75).

13. The plant according to claim 8, **characterized in that** the means for varying the rotational speed of the perforating rods act directly on a distributor for controlling the rotation function.

14. The plant according to claim 10, **characterized in that** the means for varying the rotational speed of the perforating rods act on the discharge pipe branch (74) by means of a counter-pressure.

15. The plant according to claim 8, **characterized in that** the means for varying the rotational speed of the perforating rods comprise means for varying the displacement of the hydraulic motor (6).

16. The plant according to claim 8, **characterized in that** the means for varying the rotational speed of the perforating rods comprise at least two hydraulic motors (6) and means for feeding either or both motors, the feeding means effecting series-parallel switching.

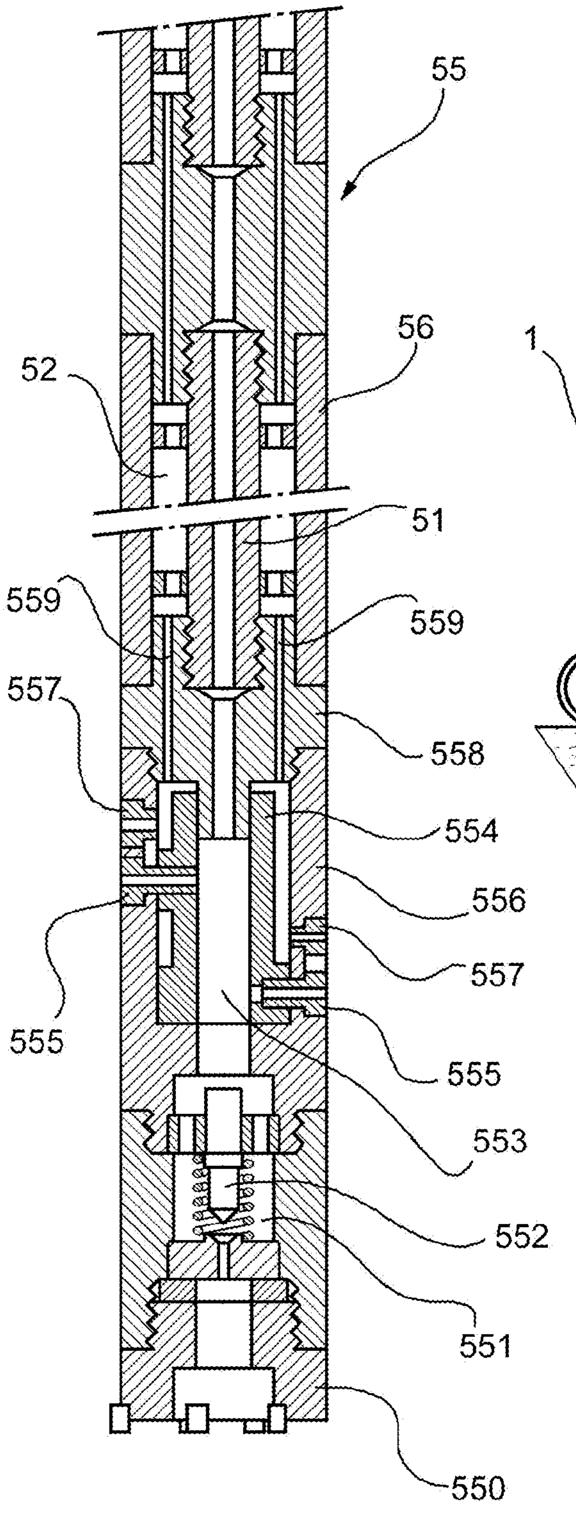
17. The plant according to claim 8, **characterized in that** the means for varying the rotational speed of the perforating rods comprise means for controlling a feed pump (7).

18. The plant according to claim 8, **characterized in that** the means for varying the rotational speed of the perforating rods comprise at least two independent feed pumps (7) and relevant distributors for the combination thereof.

19. The plant according to claim 7, **characterized in that** the means for varying the rotational speed of the perforating rods comprise at least one electric motor with a speed control device.

20. The plant according to claim 7, **characterized in that** the means for varying the rotational speed of the perforating rods are comprised of a PLC electronic control device with speeds programmable as a function of the angular position of the nozzle detected through suitable sensors.

FIG. 4



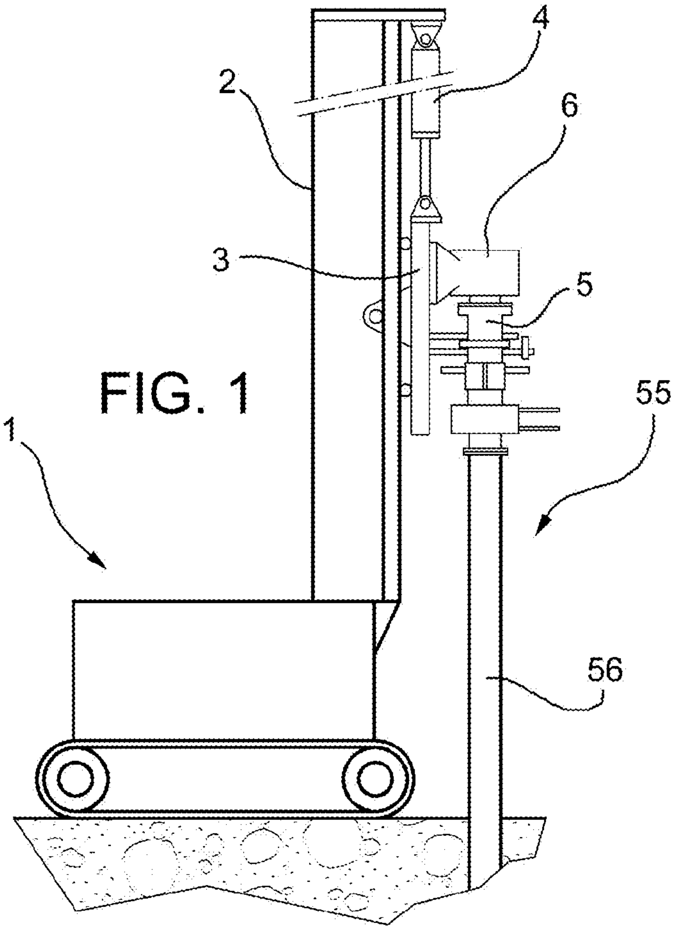


FIG. 1

FIG. 3

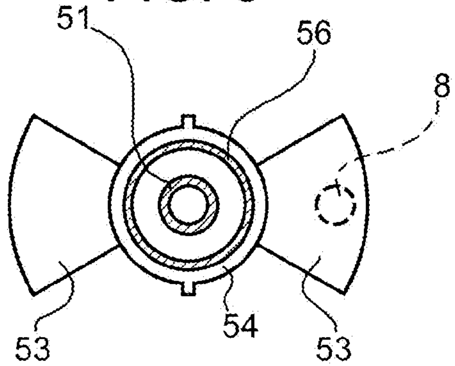


FIG. 5

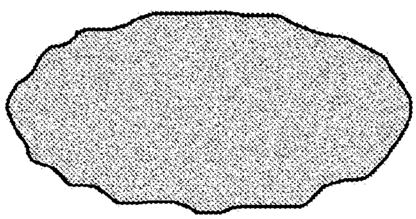
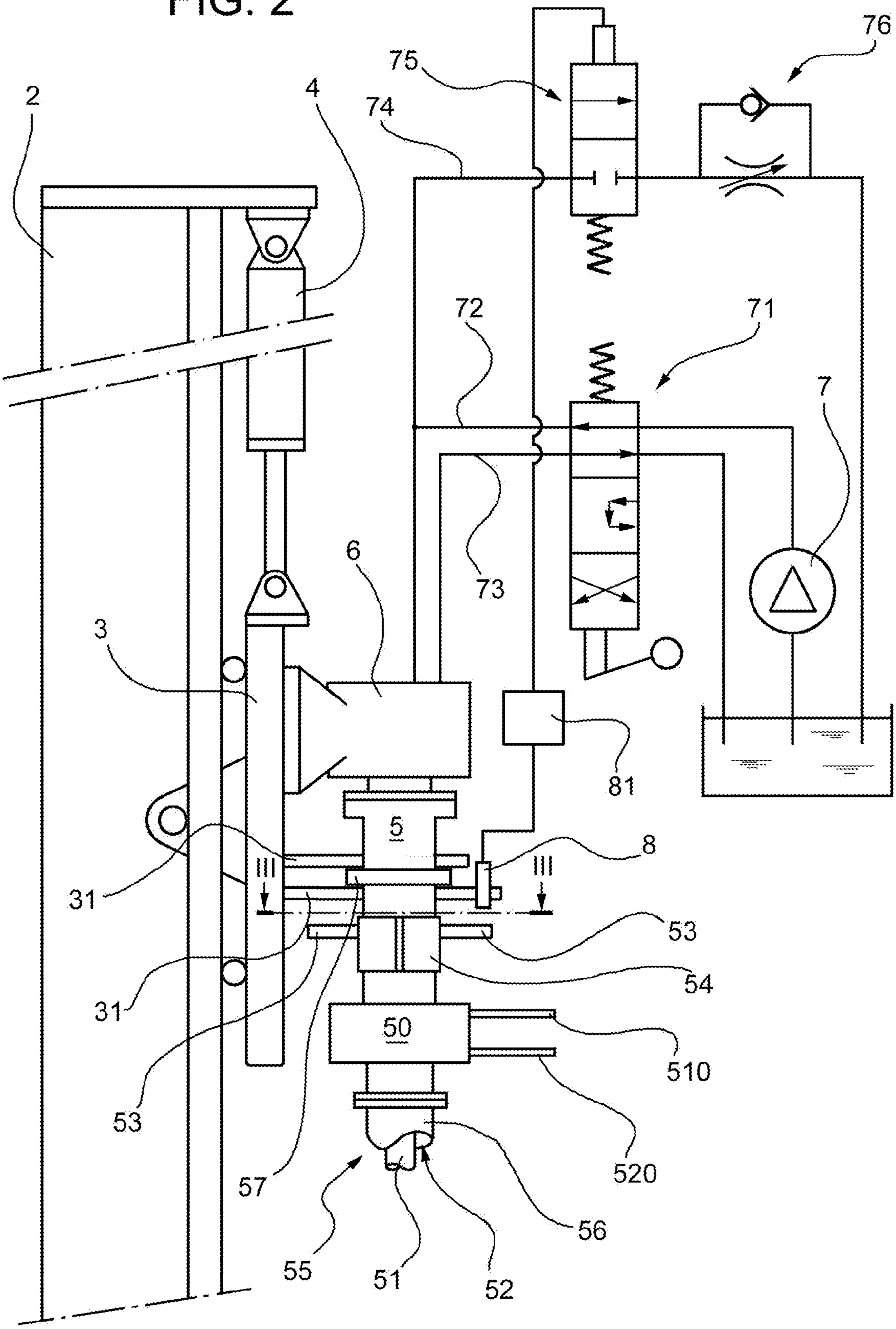


FIG. 2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EUROPEAN SEARCH REPORT

Application Number
EP 07 10 6212

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TECHNICAL FIELDS SEARCHED (IPC)
E02D

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	23 October 2007	Nilsson, Lars

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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