United States Patent [19]

Le Peuvedic et al.

[11] **3,737,843**

[45] **June 5, 1973**

[54] **HYDRAULICALLY CONTROLLED DEVICE FOR MODULATING THE MUD**

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[22] Filed: **Dec. 9, 1971**

[21] Appl. No.: **206,367**

[52] **U.S. Cl.** .....**340/18 NC,** 340/18 LD, 175/45

[51] **Int. Cl.** **G01v 1/40**

[58] **Field of Search** .....340/18 NC, 18 LD; 175/50, 40, 45

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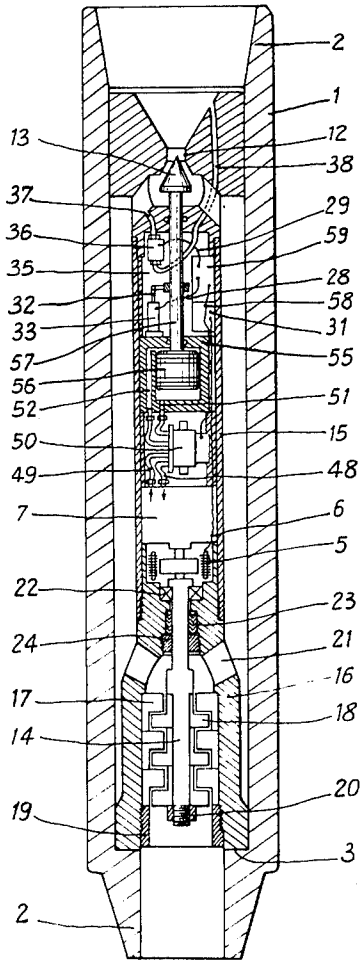
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[57] **ABSTRACT**

A hydraulically controlled device to transmit measurements taken at the bottom of a well to the surface, in the form of pressure modulations created by periodical restrictions on the passage of the drilling fluid, characterized by the use of a servovalve which operates the drilling fluid flow-restriction system, and the hydraulic control fluid of which is uniformly related, in quantity and direction, to the electric intensity passing through its coil.

5 Claims, 3 Drawing Figures



Patented June 5, 1973 3,737,843

Fig. 1

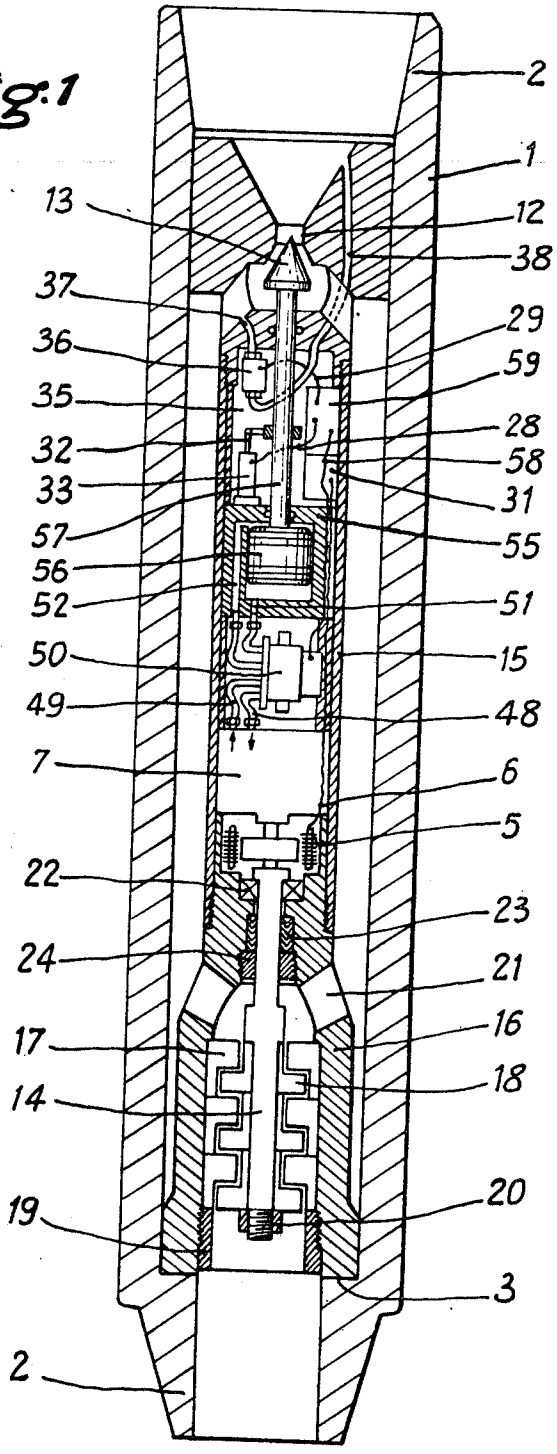


Fig: 2

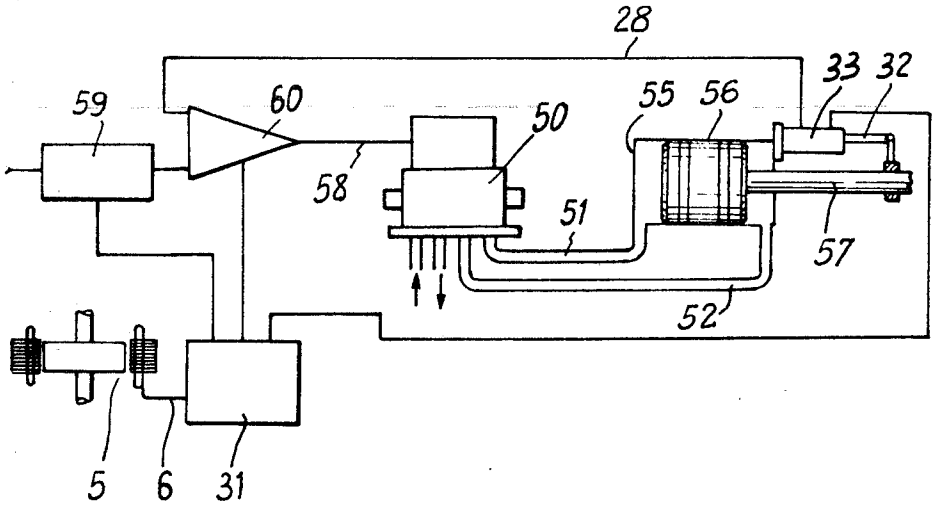
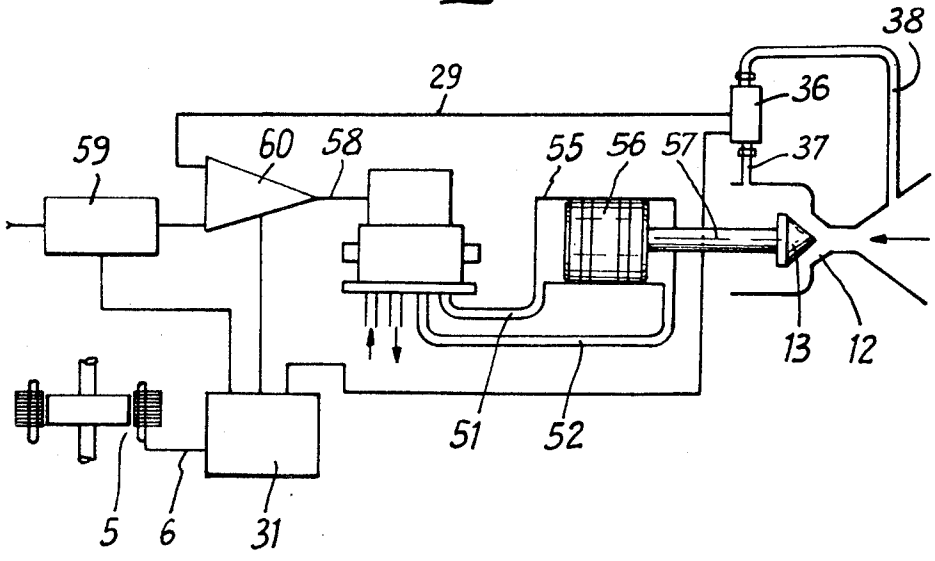

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Fig: 3


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HYDRAULICALLY CONTROLLED DEVICE FOR MODULATING THE MUD

This invention concerns a hydraulic system for transmitting signals, representing measurements taken at the bottom of a well, to the surface.

When drilling a well, it is very useful to know a number of parameters concerning the ground being drilled and the working conditions of the tool. Such information is generally used to define and adjust drilling conditions. It is usually transmitted from the bottom of the well to the surface by means of series of hydraulic impulses produced in the drilling fluid at the base of the well, and transmitted to the surface without disturbing the normal drilling operations.

Many inventors have tried to design simple devices for producing reliable, high-level hydraulic impulses, despite the unfavourable conditions prevailing at the bottoms of wells. Hydraulically controlled devices have attracted particular attention because of their functional reliability and high power-to-weight ratio. The applicant, for instance, has designed a device with independent hydraulic control, in which the hydraulic fluid circuit contains a pump discharging fluid under pressure, through a control device such as a slide distributor or electrovalve, on one side or other of the piston of a double-action hydraulic jack, connected mechanically to a mechanism which restricts the passage of the drilling fluid.

This device, like other existing systems involving hydraulic circuits with separate control fluid, uses a control component operated by electric impulses related to the measurement signals, and which may be a slide distributor controlled by one or two coils or a combination of electro-valves.

This method of controlling the mechanism for restricting the flow of drilling fluid has many drawbacks, however. The equipment involved is often too bulky for the confined space available inside drilling rods. The small flow of fluid produced for a given exciting power means that the fluid restricting mechanism operates at reduced speed, limiting the number of signals that can be sent in one unit of time. Another drawback of existing control systems is that the amplitude of the pressure impulses obtained by operating the restricting mechanism varies with the flow and density of the mud passing through it, which means that when impulses of uniform level are required, in wells being drilling with varying mud flows and densities, a correction system has to be used every time the composition of the drilling fluid is changed.

The aim of this invention is to offer a hydraulic system for rapid operation of the restriction mechanism. Another aim is to provide a hydraulic servo-device which can operate the restriction mechanism at pre-set amplitudes, and which can be regulated independently of drilling fluid circulating conditions. The invention also concerns a method of producing modulations in the total mud flow, at selected frequencies ranging from several tenths of a Hertz to several tens of Hertzes. The system according to this invention allows a considerable amount of data to be transmitted easily, using modulation frequencies that are quite distinct from the unwanted ones often produced by drilling mud pumps.

The present invention concerns a hydraulically controlled system to transmit signals representing measurements taken at the bottom of a well to the surface, in the form of pressure modulations created by periodical restrictions on the flow of the drilling fluid, and consists of a mechanism for restricting this flow, a device for controlling the mechanism, operated by electrical signals related to the measurement signals, a hydraulic fluid circuit by means of which the controlling device operates the flow-restriction device, a turbine driven by the drilling fluid and a hydraulic fluid pressure pump on the same shaft, being characterized by the fact that the device to control the periodical restrictions on the flow of drilling fluid consists of a servovalve controlling a hydraulic fluid, the flow of which is uniformly related, in quantity and direction, to the electrical intensity passing through its coil.

The restriction mechanism used to impart impulses to the drilling fluid and transmit signals to the surface in the form of pressure modulations may be a shutter or needle-valve connected mechanically to a hydraulic sink such as a jack, hydraulic gear or piston motor receiving a continuous flow of control fluid.

According to one embodiment, the servo-valve acts through a control fluid circuit to operate a double-action hydraulic jack, linked mechanically to a needle-valve attached to its piston, which acts with a fixed seat. In this embodiment, the movement of the piston is confined between two positions marked by mechanical stops, corresponding to minimum and maximum openings of the drilling fluid flow-restriction mechanism, maximum opening being obtained by passing an electric current, corresponding to fast displacement of the jack in the direction of opening of the passage, through the servovalve coil, while minimum opening is obtained by reversing the direction of the electric current.

The advantage of this method is the speed with which the restriction mechanism is operated. When used at the base of a well, during drilling, to transmit information to the surface, it allows signals to be sent in the form of rapid pressure variations, ranging from 5 to 30 bars, and succeeding one another at intervals of between 1 and 30 seconds, each such signal being obtained by reversing the electric current passing through the servovalve coil.

According to another embodiment of the invention, the servovalve is the device by which a functional characteristic of the restriction mechanism is controlled by an electrical signal which varies according to a pre-set pattern. A current representing the difference between two signals, one from the detector of a controlled characteristic of the restriction mechanism, and the other from a generator of electrical signals related to the measurement signals, is applied to the servovalve coil.

The functional characteristics of the restriction mechanism may be its position, or the pressure-drop it creates in the drilling fluid passing through it.

Instantaneous command of the position of the restriction mechanism by control signals, preferably related to the measurement signals, allows its functioning to vary in terms of time on the same pattern as the control signal variations.

Instantaneous command of the pressure-drop in the restriction mechanism by control signals, preferably related to the measurement signals, allows it to function, notably as regards the amplitude of the signals transmitted in the form of pressure modulations, without being affected by the flow, nature and density of the drilling fluid used, or the control fluid pressure.

Use of a servovalve to control the functioning of the restriction mechanism allows the use of a wide range of frequencies, from several tenths to several tens of Hertz, with a different set of frequencies for each speed of movement of the mechanism. This range of frequencies allows a considerable amount of information to be transmitted easily, using modulation frequencies quite distinct from the unwanted ones usually produced by drilling pumps.

The controlled hydraulic system according to this invention allows information to be transmitted by the drilling fluid current, by means of signals consisting of continuous or intermittent modulations of the drilling fluid pressure, in the form of sinusoidal pressure variations at frequencies of from 0.1 to 100 cycles per second. The electrical control voltage, which may be nil at rest, is formed during transmission of the signals, by superimposing a sinusoidal alternating voltage with a frequency of between 0.1 and 100 cycles per second on a direct voltage, making it possible, by controlling the position of the restriction mechanism or the pressure-drop it creates, to obtain an average pressure-drop of between 5 and 15 bars, in the flow of drilling fluid passing through the mechanism.

The figures described below illustrate some embodiments of the present invention.

FIG. 1 shows a special drill collar containing the controlled hydraulic system for modulation of the mud flow. Externally it resembles components commonly used in drilling operations. In particular, it has standard API threads at each end, so that it can be incorporated at any point in the drilling line, preferably near the tool.

FIG. 2 shows the electrical circuit by which the position of the hydraulic jack is controlled by any type of electrical signal.

FIG. 3 shows the electrical circuit by which the pressure-drop in the restriction mechanism is controlled by any type of electrical signal.

The special drill collar (1) containing the controlled hydraulic system, in FIG. 1, has standard threaded sections string wide bore on the female side, compatible with the threads and housing the internal equipment, which rests on a shoulder (3).

This internal equipment consists of a modulation valve which occupies the whole upper end of the wide bore, forcing all the drilling fluid to circulate between the fixed seat (12) and mobile needle (13). The invention is not confined to use of this type of valve, and other restriction mechanisms, such as a dome valve or balanced multi-seat valves, may also be used to modulate the mud flow.

Beneath the modulating valve is a watertight cylinder (15), containing the hydraulic valve-control system, electrical control circuits, measurement-sensing devices (not shown) and an independent electricity supply system.

The lower end of this cylinder is connected to a turbine (16) supplying energy from the mud flow. The drilling fluid can pass from the modulating valve (11) to the turbine (16), along the annular space between the bore of the drill collar (1) and the cylinder (15). The fixed (17) and mobile (18) blades of this turbine, which is of standard type, are held by nuts (19 and 20) against shoulders provided inside the turbine casing and on the shaft (14). The drilling fluid penetrates into the fixed blading through a series of apertures (21) at the top of the turbine casing, and leaves the turbine through the bottom, round the shaft, going on to irrigate the drilling tool in the usual way. The shaft (14), with the mobile blades (18), is suspended from a bearing (22) inside the watertight cylinder (15). The shaft passes from the turbine casing into the cylinder through a sealing system (23), which may be a conventional stuffing-box held in position by a nut (24). The role of the bearing (22) is also to absorb the axial hydraulic thrust on the mobile blades. The advantage of having this bearing inside the cylinder is the ease with which it can be lubricated by the fluid with which the watertight cylinder is filled; this may be a mineral oil, which can withstand the pressures and temperatures encountered at the bottoms of drilling wells.

A device not shown in the figure allows the static pressure of the drilling fluid to be applied to the filling and control fluids inside the cylinder (15).

Pressure differences on each side of the sealing system (23) thus remain slight, making it easier to design and maintain in good condition.

The shaft (14) drives an alternator (5), which supplies electricity, and a regulated hydraulic pressure generator (7), not shown in detail in the figure.

The type of regulated pressure generator chosen is of little importance. It may consist of a fixed-cylinder pump, regulator and tank accumulating oil under pressure, or of a self-regulating variable-cylinder pump and pressure tank.

The invention is in no way confined to use of these types of pressure generator: any other regulated pump and tank containing oil under pressure, providing sufficient instant flow at uniform pressure to operate the restriction mechanism energetically may be used, without departing from the context of the present invention, provided that their size is compatible with the space available inside the watertight cylinder (15).

Above the pressure generator (7) is the servovalve (50), the function of which is to modulate the control fluid delivered at uniform pressure by the generator. It does this by receiving the fluid under pressure through an intake pipe (49) and returning it without pressure to the generator, through a discharge pipe (48). On the other side, the servovalve (50) is connected with the two sides of a piston (56), by pipes (51 and 52). This piston forms the main part of a double-acting jack connected mechanically with the restriction mechanism. It moves inside a cylindrical space (55), operating a rod (57) connected to the mobile valve-pin (13), which acts with the fixed seat (12) to modulate the flow of drilling fluid. The piston (56) can move upwards or downwards, depending on whether the fluid under pressure is directed to the upward side along one pipe (51), or to the downward side along the other pipe (52).

The control sensors and electronic circuits regulating the electricity and controlling the servovalve (50) are placed in a compartment (35) in the upper part of the watertight cylinder (15), round the rod (57).

In some cases, measurement sensors supplying signals representing drilling parameters may also be housed in this compartment. Passages separate from the hydraulic circuit are provided in the cylindrical space (55) and generator (7), for electrical conductors (58 and 6), which link the servovalve (50) and alternator (5) with the circuits inside the special compartment (35).

The servovalve contains a control coil or winding through which passes an electric current supplied by these circuits.

When there is no exciting current, no hydraulic communication exists, and the piston (56) cannot move. The special peculiarity of the servovalve is that it can produce any degree of such communication, from complete closure to direct communication between the oil under pressure and one side of the jack piston (56), when an electric current of appropriate direction and intensity is applied to its control coil. In other words, the flow of fluid controlled by a servovalve is uniformly related, in direction and quantity, to the electric intensity passing through its control coil.

The control sensors are instruments detecting some functional characteristic of the restriction mechanism. Their applications are illustrated in FIGS. 2 and 3.

The method of control by position illustrated in FIG. 2 involves a position sensor (33), the rod (32) of which is connected with the rod (57) between the jack piston (56), and the valve-needle. The position of this rod (57) is controlled by an electrical signal, which is fixed or variable in time, so that a restriction, fixed or varying in time, is produced.

FIG. 2 provides a diagrammatical illustration of how this principle is applied.

A position sensor (33), connected mechanically with the jack rod (57), supplies an electrical signal representing the position of the valve-needle (13), in accordance with a continuous, uniform pattern. The coder (59) supplies a reference or control signal, fixed or varying according to a pattern preferably related to measurements taken at the bottom of the well, and designed to produce a pressure variation of predetermined form in the drilling fluid. These two signals are compared in an error detector (60), which is also an amplifier. The difference between the two signals is applied to the servovalve coil by conductors (58). Because of the operating principle of the servovalve, the piston (56) will move in the direction which tends to reduce the difference. When the reference signal is fixed, the piston (56) comes to rest in a position dictated solely by the value of the reference signal, and unaffected by oil pressure, drilling fluid, speed and flow, etc. If the reference signal varies in time, the piston position will also vary in accordance with the same pattern. In this way, position of the needle of the valve modulating the flow of drilling fluid is controlled by a reference signal, which may, for instance, represent successive measurements, coded or uncoded, taken at the bottom of a well during drilling.

The electric power needed to operate the measurement and control sensors and the electronic circuits (59 and 60) is supplied from the alternator (5), by a power-supply unit (31), which is also housed in the compartment (35).

FIG. 3 shows one interesting possibility offered by the controlled hydraulic device. FIG. 2 illustrated how the position of the modulating valve needle (13) could be controlled by a fixed or variable reference signal. When the flow or density of the drilling fluid vary, however, a fixed position of the modulating valve needle will not ensure a pre-determined difference in pressure on each side of the restriction point. For a given restriction, the pressure-drop varies depending on the density, and is proportional to the square of the flow. The system illustrated diagrammatically in FIG. 3 overcomes this drawback, offering a way of controlling the restriction so as to ensure, within a certain range of flows, a pressure-difference that either remains uniform or varies in accordance with a predetermind pattern, without being affected by the flow.

This is done by a pressure differential sensor (36), which detects the pressure above the valve by means of one pipe (38), and the pressure below it by means of another pipe (37), and supplies an electrical signal representing the difference in pressure, in other words the pressure-drop created by the modulating valve.

This signal is compared with a reference signal supplied by a coder (59), in an error-detector amplifier (60).

The difference between the two signals is applied, in the form of an electrical error signal, to the servovalve (50) coil, by conductors (58). When the reference signal is fixed, the pressure-drop will also remain steady, at a level determined solely by this reference signal; the signal representing the difference in pressures above and below the restriction point will then correspond exactly to the reference signal.

In this way, the pressure-difference created by the modulating valve depends on a given reference signal, regardless of the viscosity, density or flow of the drilling fluid. If the reference signal is made to vary in time, according to a pattern related to the drilling parameter measurements to be transmitted, pressure variations can also be created easily in the column of drilling fluid, matching the same time pattern, and thus providing transmission signals. In particular, the process can be used to obtain variable-frequency modulations related to the parameter being measured at the bottom of the well, with a high information-transmission capacity.

What claimed is :

1. In a hydraulically controlled device for transmitting signals representing measurements taken within a well to the surface in the form of pressure modulations created by periodical restrictions on the flow of the drilling fluid, which device comprises

a mechanism for restricting said flow,

means for controlling said mechanism operated by electrical signals indicative of said measurements,

a hydraulic fluid circuit by means of which said control means operates the flow-restricting mechanism, and

a turbine driven by the drilling fluid,

the improvement according to which:

said device comprises a hydraulic fluid pressure pump to supply pressure fluid to said hydraulic circuit and an electrical generator, both driven by said turbine, and

said control means comprises electrically operated servo valve means supplied from said generator for controlling the flow of hydraulic fluid in said circuit in dependence on the quantity and direction of the electrical signal delivered to the servo valve and means for regulating the electrical signal to said servo valve at least in part in dependence on said measurements.

2. A device according to claim 1 in which said flow restriction mechanism comprises a mobile valve-needle cooperating with a fixed seat and attached to a double-action hydraulic jack piston mounted for movement between two positions, one of which corresponds to maximum opening of the flow-restricting mechanism and is obtained by passing an electric current in one di-

rection through the servo valve coil, and the other of which corresponds to minimum opening of the flow-restricting mechanism and is obtained by passing current through said coil in the opposite direction.

3. A device according to claim **1** in which said control means comprises a sensor which emits an electrical signal indicative of a controlled functional characteristic of said restriction mechanism, a generator of signals related to said measurement signals, and an error detector delivering a signal equal to the difference between the signals emitted by said sensor and generator, and said servo valve comprises a control coil to which said difference signal is applied to control said functional characteristic.

4. A device according to claim **3** in which said sensor is responsive to the position of said flow-restricting mechanism.

5. A device according to claim **3** in which said sensor is a pressure difference sensor which measures the difference in pressure above and below said flow-restricting mechanism.

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