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HYDRAULIC TURBINE WITH BY-PASS VALVE

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3 Sheets-Sheet 1

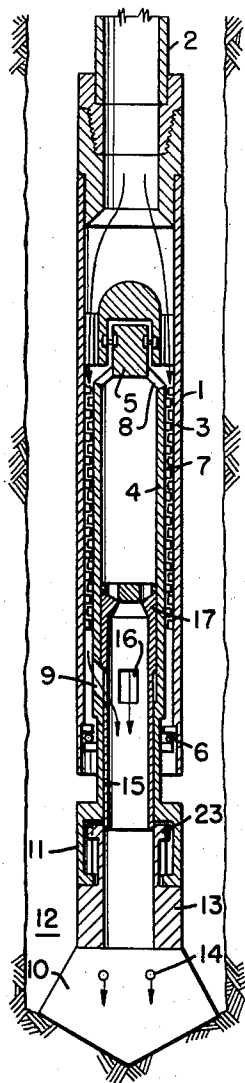


FIG. 1

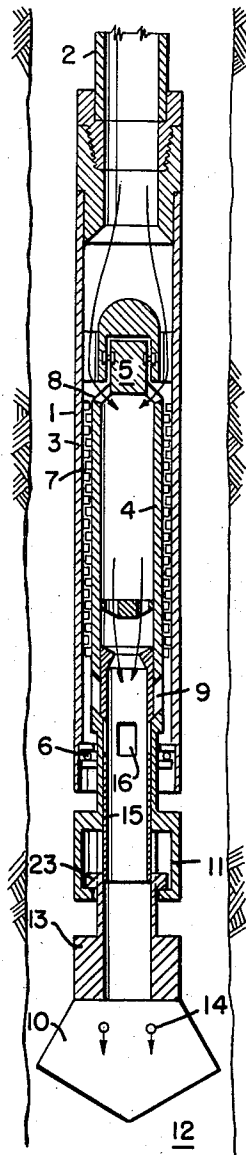


FIG. 2

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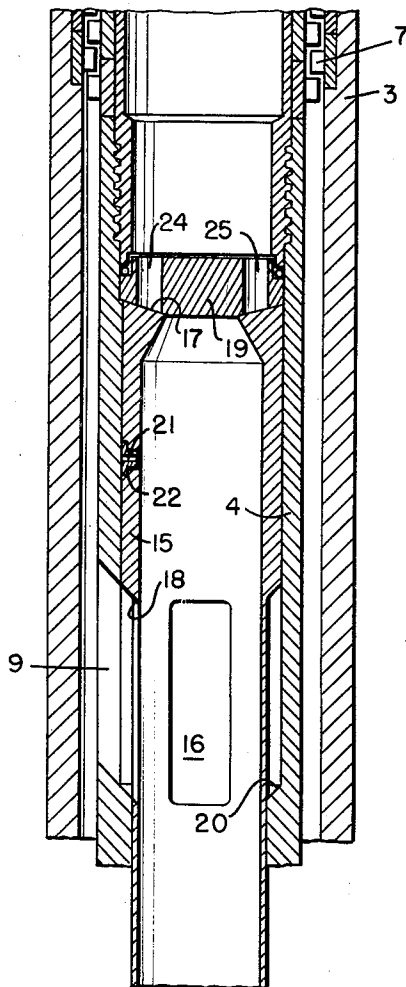


FIG. 3

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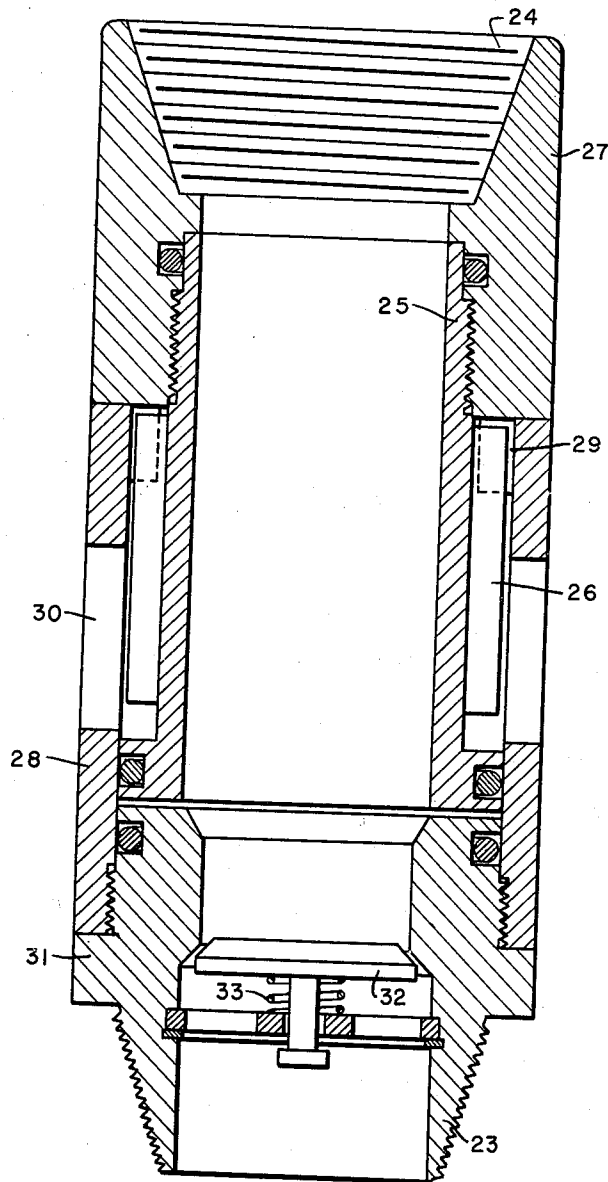


FIG. 4

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HYDRAULIC TURBINE WITH BY-PASS VALVE

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5 Claims. (Cl. 255—4)

The present invention relates to well drilling systems for boring deep wells in the surface of the earth, and pertains more particularly to a well drilling system comprising a hydraulic turbine, which is located near the lower end of a drill string and is arranged to drive a rotary drill bit. The drill string is kept stationary or may be rotated only very slowly so as to prevent it sticking in the borehole.

The hydraulic turbine is driven by a drilling fluid or mud flush which is pumped down through the drill string, and which, after having passed through the turbine blading, is ejected through jet openings provided in the rotary drill bit and directed onto the cutting edges of the rotary drill bit to cool them and to remove the cuttings. The mud flush then circulates back up the borehole outside the drill string to the surface.

When operating such a turbine-driven drill bit at the bottom of a borehole, attention has to be paid to the speed of the turbine as the bit passes through formations of varying hardness, as on the one hand, if the speed drops below a certain value, the turbine may stop, and on the other hand if the speed is too high, the bit as well as the turbine bearings are liable to excessive wear. In addition, it has to be borne in mind that excessive deviations from the design speed of a turbine result in a very low efficiency of operation.

It is also obvious that very high speeds are reached if, while maintaining the mud flush circulation, the bit is lifted from the bottom of the borehole. The turbine then tends to race, with resultant rapid erosion of the turbine blading and excessive wear of the bearings.

Further, in the event of the bit becoming stuck, a substantial loss of circulation pressure in the turbine is experienced when an attempt is made to free the bit by washing action, as in this case the whole mud flush circulation has to be pumped through the immovable turbine which acts as a restriction in the line.

Finally, when it is required to pump lost circulation material through the drill string in order to seal the walls of the borehole, such lost circulation material has to pass through the turbine blading and as it is of a sealing nature, there is the risk that it will block the turbine blading and consequently necessitate withdrawal of the turbine from the borehole to free its fluid passages.

Accordingly, it is a principal object of the present invention to provide a well drilling assembly comprising a hydraulic turbine, for location near the lower end of a drill string, and a rotary drill bit, the turbine being arranged to drive the rotary drill bit and itself being capable of being driven by mud flush or other fluid which is pumped down through a drill string, in which assembly means is provided for automatically directing the flow of mud flush through a channel by-passing the turbine blading, when there is no load on the rotary drill bit.

Another object of the present invention is to provide a hydraulic turbine capable of being mounted near the lower end of a drill string to drive a rotary drill bit, which turbine includes an axially movable member ar-

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ranged to be fixed in relation to a rotary drill bit and to influence the flow of liquid through the turbine in such a way that the turbine blading is by-passed when there is no load on the rotary drill bit.

A further object of the present invention is to provide a rotary drill bit adapted to be connected to a hydraulic turbine in such a manner that it is driven by the turbine rotor, but is capable of axial movement in relation to it.

In one arrangement, the axially movable member of the turbine may be made as part of an assembled unit comprising also the rotary drill bit. In such a case, it is an object of the present invention to provide a hydraulic turbine capable of being mounted near the lower end of a drill string to drive a rotary drill bit, in which turbine means, including a hollow rotor shaft, are provided to direct hydraulic flow through the turbine blading, or alternatively to by-pass the blading.

Furthermore, it is an object of the present invention to provide an assembly comprising primarily a rotary drill bit and an axially extending member fixed to it, the said member being adapted to cooperate with the above-mentioned hollow rotor shaft in such a manner that, when, during operation, the load on the drill bit is reduced or withdrawn, the hydraulic fluid is caused to by-pass the turbine blading.

The bit may be mounted telescopically on the turbine rotor shaft, a valve system being provided, which is adapted to be operated by axial movement of the bit relative to the rotor shaft, so that in the position taken up by the bit when there is no load on it, the flow of mud flush passes through a channel by-passing the turbine blading.

In one assembly in accordance with the invention, the turbine rotor shaft is hollow, the interior thereof communicating with the turbine inlet, and is provided with ports connecting the turbine outlet and the interior, and a valve seating located in the interior between the ports and the point or points of communication with the turbine inlet, and the rotary drill bit is adapted to be mounted on the rotor shaft and to slide telescopically with respect to it and is provided with a hollow sleeve which slides axially inside the rotor shaft, the sleeve being provided with ports in the walls thereof and a valve member on the side of the ports remote from the bit, the arrangement being such that when the bit is loaded and the sleeve is pushed into its inner position within the interior of the rotor shaft, the ports in the rotor shaft and the sleeve are in the register and the valve member and valve seating cooperate to close the interior of the rotor shaft at the valve seating, while, when the load is removed and the sleeve is pulled out to its outer position relative to the rotor shaft, the ports in the rotor shaft are closed by the sleeve and the valve member and seating are apart leaving open the passage through the interior of the rotor shaft. In order to improve the sealing of the ports in the rotor shaft by the sleeve when the latter is in its outer position relative to the rotor shaft, the rotor shaft may be provided with an additional valve seating against which a valve member in the form of a step or projection on the outer surface of the sleeve bears when the sleeve is pulled out to the said other extreme position.

When, under certain conditions solid particles may settle out from the mud flush present in the turbine when the flow by-passes the turbine, a number of small openings may be provided in the sleeve, which openings cooperate with the ports in the rotor shaft in the outer position of the sleeve, so as to permit a slight circulation of fluid through the passages of the turbine.

According to a further aspect of the invention the hydraulic turbine is telescopically arranged with respect to the drill string, a valve system being provided which is adapted to be operated by axial movement of the

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hydraulic turbine and the bit relative to the drill string, such that in the one extreme position passage of mud flush from the drill string to the hydraulic turbine is substantially blocked and direct passage of mud flush from the drill string to the bore hole is possible, whereas in the other extreme position passage of mud flush from the drill string to the hydraulic turbine is possible and direct passage of mud flush from the drill string to the bore hole is substantially blocked. Such a device may comprise telescopically operated ports which control the direct communication between the drill string and the bore hole and a string-actuated valve which controls the communication between the drill string and the hydraulic turbine.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawing in which,

Fig. 1 is a longitudinal sectional view of the hydraulic turbine and the drill bit, when the bit is loaded,

Fig. 2 is a longitudinal sectional view of the hydraulic turbine and the drill bit, shown in Fig. 1, when the bit is not loaded, and,

Fig. 3 shows a part of Fig. 1 in greater detail.

Fig. 4 is a longitudinal section of a sub with a valve system.

A hydraulic turbine 1, as shown in the Figs. 1 and 2, is connected to the drill string or drill collar 2, and comprises a stator casing 3 and a rotor shaft 4 which is supported at its upper end by a bearing 5 and near its lower end by a bearing 6, which bearing is provided with suitable sealing means (not shown). The turbine blading 7, consisting of rotor and stator blades, is located in the space left between the casing 3 and the shaft 4.

The rotor shaft 4 is hollow and is provided with openings 8 at its upper end interconnecting its interior and the fluid space at the turbine inlet. The rotor shaft 4 is also provided with ports 9 located near its lower end through the wall thereof, interconnecting the turbine outlet, i. e., the lower end of the space between the shaft 4 and casing 3, and the interior of the shaft 4.

The bit 10 (shown only diagrammatically) is connected to an extension of the lower end of the rotor shaft 4 by means of a telescopic arrangement 11 having spline means 23 incorporated in it to prevent any rotational movement between the bit 10 and the rotor shaft 4. The spline means 23 are adapted to move upwardly with a telescoping movement a distance equal to the height of the telescopic arrangement or housing 11 which forms the lower end of the rotor shaft 4. The hollow bit stem 13 has bit jet openings 14 in it, through which mud flush is ejected onto the cutting edges of the bit 10, before finally passing back up the borehole 12 to the surface.

In addition, a sleeve 15 is provided, the lower end of which is rigidly connected to the bit stem 13. The sleeve 15 is provided with ports 16 through the wall thereof (Fig. 3), and valve members 17 and 18 located above said ports. The valve member 17 is formed as an enlarged portion at the upper end of the sleeve 15 and, if desired, may be provided with a steel ring seal or the like as additional sealing means. The valve member 17 cooperates with a valve seating 19, installed in the shaft 4, and provided with passages 24 and 25 which are closed by valve 17.

As shown in Fig. 3, the sleeve 15 is in its raised position, and the ports 16 are in full register with the ports 9 in the shaft 4, while the upper valve member 17 closes the passages 24 and 25 through the valve seating 19, which may comprise a spider-like perforate plate fixedly located in the interior of the hollow shaft 4. The lower valve member 18 of the valve sleeve 15, which is formed as a tapered portion of said sleeve 15, is adapted to cooperate with the valve seating 20 provided in the interior of the hollow shaft 4 below the ports 9, to assist in sealing the ports 9 when the sleeve 15 is in its lower position.

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A limited number of small openings 21 (only one of which is shown in the drawing) may be preferably provided in the wall of the sleeve 15, which are arranged to communicate with the ports 9 when the sleeve is in its lower extreme position. These openings 21 may be provided in hard metal inserts 22 to prevent or minimize wear by any mud flush which passes through in operation.

Figure 3 also shows in greater detail how the turbine blading 7 may be recessed into the stator housing 3 and rotor shaft 4, respectively, with the rotor shaft being formed, if desired, in two portions threaded together.

As shown in Fig. 1, the bit 10 is in contact with the bottom of the borehole 12, and is loaded, so that in consequence the bit stem 13 is brought up against abutments 11 provided on the lower end of the hollow shaft 4, by the weight of the turbine and by part of the weight of the drill string and drill collars. In this case the sleeve 15, which is connected to the bit 10, is pushed in to its upper position (see also Fig. 3). Now the mud flush, which is pumped down through the drill string 2, passes through the turbine blading 7 and is ejected from the turbine outlet through the ports 9 and 16 to the interior of the sleeve 15, whence it passes through the hollow drill stem 13 and is ejected through the bit jet openings 14 of the drill bit 10.

On lifting the drill string 2 off the bottom of a well borehole, the weight on the bit may decrease to zero, and the telescopic arrangement 11 operates so that the sleeve 15 is pulled out to its lower position (Fig. 2) by the combined action of the gravity and the pressure drop prevailing across the bit jet openings 14. In this position, the ports 9 and 16 are no longer in register while at the same time the valve member 17 is drawn away from the valve seating 19. An additional sealing is obtained by the valve member 18, virtually a projection or step on the external surface of the sleeve 15, seating on to the valve seating 20. Now, the mud flush flowing through the drill string 2, passes down through the openings 8, the passages 24 and 25 through the valve seating plate 19 and further through the interior of sleeve 15 to the hollow bit stem 13, thus by-passing the turbine blading 7, and is ejected into the borehole 12 through the bit jet openings 14. Thus, the turbine stops rotating.

In the position of the sleeve, as shown in Fig. 2, the small openings 21 (only one of which is shown in Fig. 3) come into communication with the ports 9. This results in a very small flow of mud flush through the turbine, thus preventing settling out of solid particles from the mud flush remaining in the turbine when it is not in action. The circulation rate through the turbine is now determined by the total area of the openings 21, which may be so designed that the said rate is insufficient or only just sufficient to rotate the turbine.

Figure 4 shows a sub with a screw thread 23 for connection with a hydraulic turbine and a screw thread 24 for connection with the drill string. An inner sleeve 25 with splines 26 is connected to the upper part 27 of the sub, and an outer sleeve 28 with splines 29 and ports 30 is connected to the lower part 31 of the sub. In the lower part of the sub a valve mechanism 32 is provided, with a closing spring 33.

During normal drilling operation the sub is positioned as shown in Figure 4, with valve 32 open, permitting the flow of liquid from the drill string to the hydraulic turbine. When it is desired not to direct fluid through the turbine, the driller raises the drill string, permitting the inner splines 26 to move up relative to the outer splines 29, whereby the ports 30 are uncovered and the fluid can escape directly to the bore hole. Leaking of fluid to the turbine is prevented by valve 32, which is closed by the spring 33.

It is also possible to form the apparatus according to Figure 4 or a similar device as an integral part of the hydraulic turbine (in which case screw thread 23 is omitted).

As compared with the system according to Figures 1-3,

the device according to Figure 4 has the advantage that the hydraulic turbine can have a solid rotor shaft. The device according to Figures 1-3 has the advantage that the mud will pass the bit under all circumstances.

I claim as my invention:

1. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is pumped through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor being provided with a hollow shaft mounted within said rotor and having the lower end extending downwardly from said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit fixedly mounted against radial movement and telescopically mounted for axial movement on the downwardly-extending end of said rotor shaft, port means near the upper end of said rotor shaft interconnecting the interior of said shaft and the interior of the pipe string, port means through the wall of said hollow rotor shaft below said turbine blading for admitting fluid discharged from said blading into the lower portion of said shaft above the bit, first valve means operatively secured to said telescoping bit for opening said port means when the bit is on the bottom of the well, and second valve means operatively secured to said telescoping bit and within said hollow rotor shaft for directing the flow of drilling fluid through said hollow shaft and around said turbine blading as the drill bit is raised off the bottom of the well.

2. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is pumped through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor being provided with a hollow shaft mounted within said rotor and having the lower end extending downwardly from said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a splined section formed on the downwardly-extending end of said shaft, a drill bit fixedly mounted against radial movement and telescopically mounted for axial movement on the splined downwardly-extending end of said rotor shaft, port means near the upper end of said rotor shaft interconnecting the interior of said shaft and the interior of the pipe string, port means through the wall of said hollow rotor shaft below said turbine blading for admitting fluid discharged from said blading into the lower portion of said shaft above the bit, first valve means operatively secured to said telescoping bit for opening said port means when the bit is on the bottom of the well, and sleeve valve means operatively secured to said telescoping bit and within said hollow rotor shaft for directing the flow of drilling fluid through said hollow shaft and around said turbine blading as the drill bit is raised off the bottom of the well.

3. A turbine unit adapted to be connected between a drill string and a drill bit to rotate said bit, said unit comprising a tubular stator attachable to the drill string, a tubular rotor coaxially supported for rotation within said stator, an annular space being formed between the inner wall of the stator and the outer wall of the rotor, stator

and rotor blades attached in said annular space to said two walls respectively, telescoping spline means attaching the rotor to the drill bit, a sleeve mounted within the rotor coaxially therewith and attached to the drill bit for telescoping motion with regard to said sleeve, radial port means through the rotor and the sleeve, a valve seat provided with axial port means mounted within the rotor, valve means carried by the sleeve to close said axial port means at the end of the upward telescoping motion of the sleeve, the radial port means through the rotor and the sleeve being axially spaced to register with each other at the end of the downward stroke of the sleeve.

4. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is pumped through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor being provided with a shaft mounted within said rotor and having the lower end extending downwardly from said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit fixedly mounted against radial movement and telescopically mounted for axial movement on the downwardly-extending end of said rotor shaft, longitudinal conduit means through said rotor shaft bypassing said turbine blading, passage means above and below said turbine blading for circulating the fluid there-through and through the conduit means in said rotor shaft, and valve means operatively secured to said telescoping bit for directing the flow of drilling fluid through said conduit means and around said turbine blading as the drill bit is raised off the bottom of the well.

5. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is pumped through said pipe string and turbine, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor being provided with a hollow shaft mounted within said rotor and having the lower end extending downwardly from said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, passage means above and below said turbine blading for circulating the fluid there-through, a drill bit fixedly mounted on the downwardly extending end of said rotor shaft for rotation therewith, port means in said hollow shaft interconnecting its interior and the fluid space at the inlet to the turbine blading, thereby bypassing the latter, and valve means in said hollow shaft and secured to said bit for directing the flow of drilling fluid through said hollow shaft and the drill bit, and thereby bypassing said turbine blading when the drill bit is raised off the bottom of the well.

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